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Environmental Degradation and Inclusive Human Development in Sub-Saharan Africa

Simplice A. Asongu[2] and Nicholas M. Odhiambo[3]

Abstract

In the light of challenges to sustainable development in the post-2015 development agenda, this study assesses how increasing carbon dioxide (CO_2) emissions affect inclusive human development in 44 countries in sub-Saharan Africa for the period 2000-2012. The following findings are established from Fixed Effects and Tobit regressions. First, unconditional effects and conditional impacts are respectively positive and negative from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a Kuznets shaped curve because of consistent decreasing returns. Second, the corresponding net effects are consistently positive. The following findings are apparent from Generalised Method of Moments (GMM) regressions. First, unconditional effects and conditional impacts are respectively negative and positive from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a U-shaped curve because of consistent increasing returns. Second, the corresponding net effects are overwhelmingly negative. Based on the robust findings and choice of best estimator, the net effect of increasing CO_2 emissions on inclusive human development is negative. Policy implications are discussed.

Key words: CO_2 emissions; Sustainable development; Inclusiveness; Environmental policy; Africa

JEL Classification Code: C52; O38; O40; O55; P37

1. Introduction

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Three contemporary trends in academic and policy circles motivate the positioning of this inquiry, namely: growing exclusive development in sub-Saharan Africa (SSA); poor energy and environmental management in the sub-region and gaps in the literature. We discuss the points in chronological order.

First, in the transition from the Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs), extreme poverty has been decreasing in all regions of the world with the exception of SSA (World Bank, 2015; Asongu & le Roux, 2017). According to the narrative, the fact that close of half of nations in the sub-region were considerably off-course from achieving the MDG extreme poverty target is an indication that the fruits of economic prosperity accruing from the recent growth resurgence have not been trickling down to the poorest factions of the population. Obviously, this substantial and consistent trend of economic growth logically has a positive effect on the emission of green house gases which represent a veritable challenge to environmental sustainability.

Second, whereas a key theme in the post-2015 development agenda is environmental sustainability (Mbah & Nzeadibe, 2016; Asongu *et al*., 2016a; Akpan *et al*., 2015), the consequences of climate change and global warming are projected to be most nefarious in Africa for at least three main reasons, notably: evolving energy crises; ramifications of climate change and mismanagement of energy and pollution crises. The points are expanded in chronological order. (i) The consumption of energy per capita in SSA is about one-sixth of the global average. Moreover, access to energy in the sub-region (which is limited about 5% of the population) is equivalent to the energy consumed in the single state in the United States, such as New York (Shurig, 2015). According to Akinyemi *et al*. (2015), energy crisis represent one of the most challenging policy syndromes in the post-2015 sustainable development era. (ii) Carbon dioxide (CO_2) emissions constitute about 75% of global greenhouse gas emissions (Akpan, 2012) and according to projections, the corresponding negative ramifications of climate change will be largely felt in Africa (Kifle, 2008). Such climate change is the direct consequence of growing and unsustainable consumption of fossil fuels, globally (Huxster *et al*., 2015). (iii) Issues have been raised on the ability of decision makers to effectively manage energy crisis and challenges to environmental sustainability in most countries in the sub-region (Anyangwe, 2014). A good example is Nigeria which addresses energy shortage by subsidizing petroleum fuels instead of using alternative sources of energy that are renewable (Apkan, 2012).

Third, this study engages how the concerns in the second strand affect the issue discussed in the first strand by investigating how CO_2 emissions affect inequality adjusted human development. Such a positioning steers clear of recent CO_2 literature which has fundamentally been articulated along the relationships between energy consumption, CO_2 emissions and economic growth. Two main strands make-up the corresponding literature: (i) the first strand documents the nexus between environmental pollution and economic prosperity with particular emphasis on the Environmental Kuznets Curve (EKC)[4] hypothesis (see Akbostanci *et al*., 2009; Diao *et al*., 2009; He & Richard, 2010), whereas the second strand engages two sub-strands. On the one hand, we find studies on the relationship between energy consumption, pollution and economic growth (Mehrara, 2007; Olusegun, 2008; Akinlo, 2009; Esso, 2010) and on the other hand, the nexus between energy consumption and economic growth (Jumbe, 2004; Ang, 2007; Odhiambo, 2009a, 2009b; Apergis & Payne, 2009; Menyah & Wolde-Rufael, 2010; Ozturk & Acaravci, 2010; Begum *et al*., 2015; Bölük & Mehmet, 2015).

Noticeably, the literature on the EKC has largely focused on the relationship between environmental degradation and per capita income. We complement the literature by assessing the reversed EKC hypothesis within the framework of inclusive human development. In essence, whereas in a standard EKC, per capita income explains environmental degradation, in this inquiry, environmental degradation explains inclusive human development. Accordingly, we argue that environmental degradation affects the three components of the inequality adjusted human development index (IHDI), namely: education, health and long life and income levels or living standards. First, from intuition, environmental degradation can directly affect the ability of parents to send their children to school, especially in the absence of good transport facilities and presence of atmospheric pollution (Currie *et al*., 2009). Moreover, such atmospheric pollution can also affect the ability of pupils to study effectively in class (Clark *et al*., 2012; Sunyer *et al*., 2015). Second, from a logical standpoint, environmental degradation or pollution also has a direct effect on the health and life expectancy of citizens (Rich, 2017; Boogaard *et al*., 2017). Third, intuitively, environmental degradation can influence a family's income by affecting the ability of workers in a household to search for work and/or work effectively even when work is found (Zivin, 2011; Neidell, 2012).

In the light of the above, the intuition motivating this study falls within the framework of theory-building because we intend to provide practical implications based on the results. In essence, we join a strand of recent empirical literature (e.g. Narayan *et al*., 2011) in arguing that applied econometrics should not be exclusively based on the acceptance or rejection of existing

[4] The EKC hypothesis postulates that in the long term, there is an inverted U-shaped relationship between per capita income and environmental degradation.

theories. This is essentially because an empirical exercise based on sound intuition may lead to theory-building, especially for a new phenomenon like the interaction between CO_2 emissions and inclusive development in the sustainable development era.

The above positioning departs from recent studies on environmental sustainability which has focused on, among others: linkages between development, environmental sustainability and conflicts (Fisher & Rucki, 2017); the relevance of normative beliefs on attitudes towards the environment (Wang & Lin, 2017); sustainable economic planning (Radovanovic & Lior, 2017), the encouragement of sustainability in the work place (Saifulina & Carballo-Penela, 2017) and comparative environmental sustainability (Asongu, 2018). It is important to note that the concepts of inclusive development and sustainability are linked in the view that for sustained development to be sustainable it must be inclusive and in order for inclusive development to be sustainable, it should be sustained (Amavilah *et al*., 2017).

There are two main contending theoretical underpinnings on the role "massive production and over-use of environmental resources" on human wellbeing, namely the neoliberal and hegemony schools (Tsai, 2006). With regard to the second school, environmental destruction and depletion of natural resources is a hegemonic project from industrialized countries and multinational financial institutions. According to Petras and Veltmeyer (2001), "a world-wide crisis of living standards for labor" is expected from the process of globalization which emphasizes capital accumulation and pays little attention to more ethnical concerns such as environmental degradation. Such environmental degradation negatively affects human well being and promotes exclusive development, both at national and human levels. These theoretical insights are consistent with this study because we have seen in the previous paragraphs that the environmental degradation affects all dimensions of the inequality adjusted human development index used in this study, notably: education (Currie *et al*., 2009; Clark *et al*., 2012; Sunyer *et al*., 2015), health and life expectancy (Rich, 2017; Boogaard *et al*., 2017) and income (Zivin, 2011& Neidell, 2012).

Conversely, the neoliberal school or contending theoretical underpinning maintains that globalization and associated negative externalities such as environmental degradation are a force of "creative destruction" in the perspective that, they enable technological innovation and advancement in science with which such negative effects on human well being can be mitigated to produce overall positive effects on the economic development of nations (Grennes, 2003; Asongu, 2014).

The rest of the study is structured as follows. Section 2 discusses the data and methodology while the empirical results are covered in Section 3. We conclude in Section 4 with implications and future research directions.

2. Data and methodology

2.1 Data

This study investigates a panel of forty-four Sub-Saharan African (SSA) countries with data from: (i) the African Development Indicators (ADI) of the World Bank; (ii) the United Nations Development Program (UNDP) and (iii) World Governance Indicators of the World Bank, for the period 2000-2012[5]. The adopted periodicity is based on constraints in data availability and the motivation discussed in the introduction. Consistent with recent inclusive development literature on Africa (Asongu *et al*., 2015), the inequality adjusted human development index (IHDI) is used as a proxy for inclusive human development. The human development index (HDI) denotes a national mean of results in three principal dimensions, notably: health and long life, knowledge and basic living standards. The IHDI goes a step further by adjusting the HDI to prevalent levels of inequality in the aforementioned three dimensions. In other words, the IHDI also takes into consideration the manner in which the three underlying achievements are distributed within the population.

Four main CO_2 emission variables are used, namely: CO_2 emissions per capita; CO_2 emissions from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity. In order to avoid variable omission bias, four control variables are employed, namely: education quality, private domestic credit, foreign aid and foreign direct investment. With the exception of development assistance, we anticipate the variables in the conditioning information set to positively impact on inclusive human development. The quality of primary school enrolment is anticipated to positively affect the outcome variable because relative to other forms of education, social returns from primary education are higher when countries are at a tender stage of industrialisation (Asiedu, 2014; Petrakis & Stamakis, 2002). The positive association between education and inclusive development has been established in recent literature (Dunlap-Hinkler *et al*., 2010). Moreover, education is a component of the IHDI. However, it is important to balance the narrative with the fact that in spite of an appealing pupil-

[5] The 44 countries are: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Democratic. Republic., Congo Republic, Cote d'Ivoire, Djibouti, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda and Zambia.

teacher ratio, the quality of education may also be compromised by the lack of academic infrastructure. In the light of the construction of the pupil-teacher ratio, we expect a negative effect from primary education. This is essentially because an increasing ratio denotes decreasing quality in primary education.

Recent literature has also concluded that foreign aid decreases the inequality adjusted human development (Asongu & le Roux, 2017). Furthermore, private domestic credit and foreign direct investment have been established by a broad stream of literature to positively impact on inclusive development partly because they create favourable conditions for unemployment reduction and social mobility (Mishra *et al*., 2011; Anand *et al*., 2012; Seneviratne & Sun, 2013; Mlachila *et al*., 2017).

In the light of the above clarifications, the choice of control variables is motivated by both the available inclusive development literature and intuition on the constituents of the IHDI. For instance, whereas education as a constituent of the IHDI is justified by both the literature and intuition, the other control variables are justified by the engaged literature. Further details on the definitions of variables and sources can be found in Appendix 1. Appendix 2 provides the summary statistics. The correlation matrix is presented in Appendix 3.

2.2 Methodology

Three empirical strategies are adopted to control for specific characteristics. First, Fixed Effects (FE) regressions are used to control for the unobserved heterogeneity. Then, the bite on endogeneity is increased with control for persistence in the dependent variable by employing the Generalised Method of Moments (GMM) which accounts both for simultaneity using instruments and further controls for the unobserved heterogeneity using time invariant omitted variables. Last, the Tobit model is employed to control for the limited range in the dependent variable.

The panel FE model is presented as follows:

$$IHD_{i,t} = \partial_0 + \partial_1 CO_{i,t} + \partial_2 COCO_{i,t} + \sum_{h=1}^{4} \omega_h W_{h,i,t-\tau} + \eta_i + \varepsilon_{i,t} \quad , \qquad (1)$$

where, $IHD_{i,t}$ is inclusive human development for country i at period t; ∂_0 is a constant; CO is a CO_2 emissions variable; $COCO$, is an interaction term representing the multiplication of two identical CO_2 emissions variables; W is the vector of control variables (education quality, private domestic credit, foreign aid and foreign direct investment); η_i is the country-specific effect and $\varepsilon_{i,t}$ the error term.

Since we are employing an estimation technique that deals with interactive regressions, it is relevant to briefly discuss some pitfalls associated with interactive specifications. In accordance with Brambor *et al*. (2006), all constitutive variables should be involved in the specifications. Moreover, in order for the estimated interactive parameters to make economic sense, they should be interpreted as conditional or marginal effects.

A plethora of reasons motivate the choice of an alternative *system* GMM estimation strategy, notably, it: (i) does not eliminate cross-country variations; (ii) controls for potential endogeniety in all regressors through instrumentation and accounts for the unobserved heterogeneity and (iii) mitigates potential small sample biases from the *difference* estimator (Asongu, 2013; Tchamyou *et al*., 2018). Moreover, basic conditions for the use of the GMM strategy are also fulfilled, notably: (i) the condition for persistence is apparent because the correlation coefficient between the outcome variable and its first lag is higher than 0.800 which is the rule of thumb for establishing persistence in an outcome variable and (ii) the number of cross sections (or 44 countries) is higher than the number of periods in each cross section (or 13 years).

In this study, we adopt the Roodman (2009a, 2009b) extension of Arellano and Bover (1995) which has been established to restrict over-identification and limit the proliferation of instruments (Love & Zicchino, 2006; Baltagi, 2008; Tchamyou, 2018). Hence, the corresponding specification is a *two-step* GMM with forward orthogonal deviations instead of differencing. We prefer the *two-step* to the *one-step* procedure because the latter is homoscedasticity-consistent while the former controls for heteroscedasticity.

The following equations in levels (2) and first difference (3) summarize the standard *system* GMM estimation procedure.

$$IHD_{i,t} = \sigma_0 + \sigma_1 IHD_{i,t-\tau} + \sigma_2 CO_{i,t} + \sigma_3 COCO_{i,t} + \sum_{h=1}^{4} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad , \tag{2}$$

$$\begin{aligned} IHD_{i,t} - IHD_{i,t-\tau} &= \sigma_1 (IHD_{i,t-\tau} - IHD_{i,t-2\tau}) + \sigma_2 (CO_{i,t} - CO_{i,t-\tau}) + \sigma_3 (COCO_{i,t} - COCO_{i,t-\tau}) \\ &+ \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + \varepsilon_{i,t-\tau} \quad , \end{aligned} \tag{3}$$

where, τ represents the coefficient of autoregression which is one in our case and ξ_t is the time-specific constant.

It is relevant to briefly engage properties related to identification and exclusion restrictions because these are critical for sound GMM specifications. In accordance with recent literature, all explanatory variables are acknowledged as predetermined or suspected endogenous whereas only time-invariant variables are considered to be strictly exogenous. This identification strategy has been recently adopted in the literature (Boateng *et al*., 2018; Asongu & Nwachukwu, 2016a; Tchamyou & Asongu, 2017). It is important to note that Roodman (2009b) has argued that it is not very likely for time-invariant variables to reflect endogeneity after first difference[6].

As concerns exclusion restrictions corresponding to the identification process, time invariant indicators affect the IHDI exclusively via the suspected endogenous variables. Furthermore, the statistical validity of the underlying exclusion restriction is examined with the Difference in Hansen Test (DHT) for instrument exogeneity. Within this framework, the null hypothesis of the DHT should not be rejected for the exclusion restriction hypothesis to hold, notably: that the time invariant variables affect the IHDI exclusively through suspected endogenous variables. Hence, in the findings that are reported in the empirical results section, the exclusion restriction assumption is confirmed if the null hypothesis of the DHT connected to instrumental variables (IV) (year, eq(diff)) is not rejected. This process of assessing the validity of exclusion restriction is similar to the standard IV procedure whereby, the failure to reject the null hypothesis of the Sargan Overidentifying Restrictions (OIR) test is an indication that strictly exogenous variables affect inclusive development exclusively via the suspected endogenous variable channels (Beck *et al*., 2003; Asongu & Nwachukwu, 2016b).

Since the IHDI theoretically falls between 0 and 1, estimation by Ordinary Least Squares (OLS) is not appropriate. A double-censored Tobit model is employed to control for the limited range in the dependent indicator (Kumbhakar & Lovell, 2000; Koetter *et al*., 2008; McDonald, 2009; Coccorese & Pellecchia, 2010; Ariss, 2010). This is the case with the IHDI because it has minimum and maximum values of 0.129 and 0.768 respectively.

The standard Tobit model (Tobin, 1958; Carsun & Sun, 2007) is as follows:

$$y^{*}_{i,t} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t} \ , \qquad (4)$$

where $y^{*}_{i,t}$ is a latent response variable, $X_{i,t}$ is an observed $1\times k$ vector of explanatory variables and $\varepsilon_{i,t} \approx$ i.i.d. N(0, σ^2) and is independent variable of $X_{i,t}$. Instead of observing $y^{*}_{i,t}$, we observe $y_{i,t}$:

$$y_{i,t} = \begin{cases} y^{*}_{i,t}, \ if \ y^{*}_{i,t} > \gamma \\ 0, \ if \ y^{*}_{i,t} \leq \gamma, \end{cases} \qquad (5)$$

where γ is a non stochastic constant. In other words, the value of $y^{*}_{i,t}$ is missing when it is less than or equal to γ.

[6] Hence, the procedure for treating *ivstyle* (years) is 'iv (years, eq(diff))' whereas the *gmmstyle* is employed for predetermined variables.

3. Empirical results

Table 1 and Table 2 present the empirical results. While Table 1 focuses on Fixed Effects and Tobit regressions, Table 2 presents GMM findings. Evidence of the net effect of environmental degradation on inclusive development is assessed with two information criteria, namely: the marginal impact and the net effect. Whereas a marginal effect is the estimated coefficient corresponding to the interaction between CO_2 emissions variables, a net effect is computed to assess the overall effect of increasing CO_2 emissions. For instance in the second column of Table 1, the net impact from increasing CO_2 emissions per capita in Fixed Effects regressions is 0.0477 ($2\times[-0.004\times 0.901] + [0.055]$). In the computation, the mean value of CO_2 emissions per capita is 0.901, the unconditional effect of CO_2 emissions per capita is 0.055 while the conditional effect from the interaction of CO_2 emissions per capita variables is -0.004.

The following findings can be established from Table 1 from Fixed Effects and Tobit regressions. First, unconditional effects and conditional impacts are respectively positive and negative from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a Kuznets shaped curve because of consistent evidence of decreasing returns. Second, the corresponding net effects are consistently positive. Most of the significant control variables have expected signs.

Table 1: Fixed Effects and Tobit Regressions

	Dependent variable: Inequality Adjusted Human Development (IHDI)							
	CO2 emissions per capita (CO2mtpc)		CO_2 emissions from electricity and heat production(CO2elehepro)		CO_2 emissions from liquid fuel consumption (CO2lfcon)		CO_2 intensity (CO2inten)	
	FE	Tobit	FE	Tobit	FE	Tobit	FE	Tobit
Constant	**0.411*** (0.000)**	**0.419*** (0.000)**	**0.426*** (0.000)**	**0.583*** (0.000)**	**0.465*** (0.000)**	**0.452*** (0.000)**	**0.431*** (0.000)**	**0.498*** (0.000)**
CO2mtpc	**0.055*** (0.007)**	**0.121*** (0.000)**	---	---	---	---	---	---
CO2elehepro	---	---	0.001 (0.219)	**-0.003** (0.028)**	---	---	---	---
CO2lfcon	---	---	---	---	0.0008 (0.146)	**0.002*** (0.007)**	---	---
CO2inten	---	---	---	---	---	---	0.006 (0.562)	**0.006* (0.090)**
CO2mtpc× CO2mtpc	**-0.004*** (0.007)**	**-0.011*** (0.000)**	---	---	---	---	---	---
CO2elehepro ×CO2elehepro	---	---	-0.00002 (0.108)	0.00005 (0.100)	---	---	---	---

CO2lfcon ×CO2lfcon	---	---	---	---	**-0.00001*** (0.001)**	**-0.00001*** (0.006)**	---	---
CO2inten× CO2inten	---	---	---	---	---	---	-0.00005 (0.569)	**-0.00008* (0.079)**
Education	**-0.0005* (0.090)**	**-0.0006** (0.035)**	-0.00008 (0.849)	**-0.001** (0.018)**	-0.0002 (0.326)	**-0.002*** (0.000)**	-0.0002 (0.595)	**-0.001* (0.056)**
Credit	**0.002*** (0.000)**	**0.0007** (0.019)**	**0.002*** (0.000)**	**0.001*** (0.002)**	**0.001*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**
Foreign Aid	-0.0002 (0.198)	**-0.001*** (0.000)**	**-0.0009** (0.031)**	**-0.007*** (0.000)**	-0.0001 (0.214)	**-0.002*** (0.000)**	**-0.0009** (0.024)**	**-0.006*** (0.000)**
FDI	0.0002 (0.198)	**0.001*** (0.003)**	**0.0009** (0.031)**	0.001 (0.147)	0.0002 (0.239)	**0.002*** (0.001)**	**0.001** (0.036)**	**0.003*** (0.006)**
Net effects	0.0477	0.1011	na	na	na	0.0042		0.0056
Within	0.237		0.307		0.304		0.293	
LR Chi-Square		**346.83*** **		**156.11*** **		**218.21*** **		**158.95*** **
Log Likelihood		406.620		195.029		342.312		209.098
Pseud R^2		-0.743		-0.667		-0.467		-0.613
Fisher	**12.75*** **		**9.91*** **		**17.89*** **		**9.76*** **	
Countries	41		22		41		28	
Observations	292	292	162	162	292	192	175	175

*,**,***: significance levels of 10%, 5% and 1% respectively. Na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The mean value of CO2mtpc: 0.901. The mean value of CO2elehepro is: 23.730. The mean value of CO2lfcon is: 78.880. The mean value of CO2inten is: 2.044. FE: Fixed Effects regressions. Tobit: Tobit regressions.

Table 2: Generalised Method of Moments Regressions

	Dependent variable: Inequality Adjusted Human Development (IHDI)							
	CO2 emissions per capita (CO2mtpc)		CO_2 emissions from electricity and heat production(CO2elehepro)		CO_2 emissions from liquid fuel consumption (CO2lfcon)		CO_2 intensity (CO2inten)	
Constant	**-0.041** (0.049)**	0.006 (0.416)	**0.021** (0.015)**	-0.364 (0.468)	**0.030** (0.021)**	0.008 (0.677)	0.008 (0.164)	-0.074 (0.168)
IHDI (-1)	**1.136*** (0.000)**	**0.969*** (0.000)**	**0.971*** (0.000)**	**1.088*** (0.000)**	**0.959*** (0.00)**	**0.967*** (0.000)**	**0.991*** (0.000)**	**1.078*** (0.000)**
CO2mtpc	**-0.026*** (0.001)**	0.005 (0.108)	---	---	---	---	---	---
CO2elehepro	---	---	-0.0003 (0.113)	-0.010 (0.522)	---	---	---	---
CO2lfcon	---	---	---	---	**-0.001** (0.018)**	0.00004 (0.891)	---	---
CO2inten	---	---	---	---	---	---	**-0.0003* (0.058)**	0.002 (0.162)
CO2mtpc× CO2mtpc	**0.002*** (0.000)**	**-0.001** (0.012)**	---	---	---	---	---	---
CO2elehepro ×CO2elehepro	---	---	**0.000005* (0.097)**	-0.0002 (0.524)	---	---	---	---

CO2lfcon ×CO2lfcon	---	---	---	---	**0.00001**** **(0.017)**	0.0000001 (0.916)	---	---
CO2inten× CO2inten	---	---	---	---	---	---	**0.000004**** **(0.038)**	-0.00001 (0.216)
Education	---	**0.0002***** **(0.004)**	---	0.001 (0.601)	---	0.00007 (0.381)	---	**0.0009*** **(0.090)**
Credit	---	0.00003 (0.609)	---	0.006 (0.552)	---	**0.0001**** **(0.0339)**	---	-0.0002 (0.353)
Foreign Aid	---	**-0.00004**** **(0.035)**	---	0.003 (0.476)	---	**-0.00007***** **(0.004)**	---	0.0004 (0.126)
FDI	---	**0.0003***** **(0.000)**	---	-0.0008 (0.645)	---	**0.0003***** **(0.000)**	---	0.0005 (0.277)
Net Effects	-0.0223	na	na	na	0.0577	na	-0.0002	na
AR(1)	**(0.116)**	(0.031)	**(0.165)**	**(0.455)**	**(0.109)**	(0.035)	**(0.161)**	**(0.542)**
AR(2)	(0.073)	**(0.537)**	(0.086)	---	**(0.674)**	**(0.558)**	**(0.234)**	**(0.549)**
Sargan OIR	**(0.608)**	(0.006)	**(0.823)**	(0.000)	**(0.524)**	(0.054)	**(0.982)**	(0.020)
Hansen OIR	**(0.437)**	**(0.439)**	**(0.549)**	**(1.000)**	**(0.367)**	**(0.205)**	**(0.417)**	**(1.000)**
DHT for instruments								
(a)Instruments in levels								
H excluding group	**(0.914)**	(0.006)	**(0.758)**	**(1.000)**	**(0.498)**	(0.055)	**(0.894)**	**(0.761)**
Dif(null, H=exogenous)	**(0.241)**	**(0.439)**	**(0.373)**	**(1.000)**	**(0.285)**	**(0.573)**	**(0.229)**	**(1.000)**
(b) IV (years, eq(diff))								
H excluding group	---	**(0.160)**	---	**(0.993)**	---	**(0.437)**	---	**(0.867)**
Dif(null, H=exogenous)	---	**(0.795)**	---	**(1.000)**	---	**(0.141)**	---	**(1.000)**
Fisher	**4870.85*****	**119009*****	**140543*****	**817.14*****	**3486.38*****	**11002*****	**24864*****	**12368*****
Instruments	22	37	22	37	22	37	22	37
Countries	41	37	22	19	41	37	26	23
Observations	346	237	197	132	346	237	206	141

*,**,***: significance levels of 10%, 5% and 1% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The mean value of CO2mtpc: 0.901. The mean value of CO2elehepro is: 23.730. The mean value of CO2lfcon is: 78.880. The mean value of CO2inten is: 2.044.

Four principal information criteria are used to investigate if the GMM models are valid[7]. In addition to the information criteria, it is important to note that the second-order Arellano and Bond autocorrelation test (AR(2)) is more relevant as an information criterion than the corresponding first-order test because some studies have exclusively reported a higher order with no disclosure of the first order (e.g. Narayan *et al*., 2011; Asongu & Nwachukwu, 2016c).

The following findings are apparent in Table 2 on GMM regressions. First, unconditional effects and conditional impacts are respectively negative and positive from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a U-shaped curve because of consistent evidence of increasing returns. Second, the

[7] "*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fischer test for the joint validity of estimated coefficients is also provided*" (Asongu & De Moor, 2017, p.200).

corresponding net effects are overwhelmingly negative. Most of the significant control variables have the expected signs.

It is important to note that the findings in Table 1 are broadly consistent with the neoliberal theoretical underpinning discussed in the introduction because it anticipates that despite the negative effect of environmental degradation on human wellbeing, the overall or net effect will be positive on human wellbeing due to "creative destruction" and technological innovation. The theoretical underpinning is consistent with the findings because of the consistent positive net effects of environmental degradation on inclusive human development.

Conversely, the findings in Table 2 are more in accordance with the Hegemonic school because of corresponding net negative effects of environmental degradation on inclusive human development. The study leans more towards results of Table 2 because corresponding estimates are more robust. Accordingly, over-exploitation of natural resources, air pollution and environmental degradation have been associated with income levels that are below subsistence thresholds (Petras & Veltmeyer, 2001), owing to a contemporary global mode of production and distribution of resources and commodities that underestimate redistribution mechanisms of Keynesian Social democracy (Asongu, 2014). The findings are therefore in line with Smart (2003) and Tsai (2006) who maintain that unhealthy opportunities of globalization (such as the over-exploitation of resources and disrespect for environmental standards) have provided avenues that promote self-interest to the detriment of common values such inclusive economic and human developments. These perspectives are consistent with Sirgy *et al*. (2004) on the negative consequences of globalization and Scholte (2000) on the benefits of globalization that favour the wealthy to the detriment of the socio-economically disadvantaged.

Socio-economic externalities can be observed from the perspective of income, health and education. In summary, if the negative net effect of environmental degradation on inclusive development is driven by all components of the inequality adjustment human development index (education, health and income), then the findings are consistent with studies which have established that environmental degradation is negative on income (Zivin, 2011; Neidell, 2012), long life and health (Rich, 2017; Boogaard *et al*., 2017) and education (Currie *et al*., 2009; Clark *et al*., 2012; Sunyer *et al*., 2015).

4. Concluding implications and future research directions

The purpose of this study has been to integrate three contemporary trends in policy and academic circles, notably: growing non-inclusive development in Africa, poor management of in the energy and environmental sectors and gaps in the literature. In the light of these motivations, this study has investigated how increasing CO_2 emission affects inclusive human development in 44 countries in Sub-Saharan Africa (SSA) for the period 2000-2012. Inclusive human development is measured with the inequality adjusted human development index. Four main CO_2 emission variables are used, namely: CO_2 emissions per capita; CO_2 emission from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity. Three main empirical strategies have been employed, namely: (i) Fixed effects (FE) regressions to control for the unobserved heterogeneity; (ii) Generalised Method of Moments (GMM) to control for persistence in the outcome variable and (ii) Tobit regressions to account for the limited range in the dependent variable.

The following findings have been established from FE and Tobit regressions. First, unconditional effects and conditional impacts are respectively positive and negative from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a Kuznets shaped curve because of consistent evidence of decreasing returns. Second, the corresponding net effects are consistently positive. The following findings are apparent from GMM regressions. First, unconditional effects and conditional impacts are respectively negative and positive from CO_2 emissions per capita, CO_2 emissions from liquid fuel consumption and CO_2 intensity. This implies a U-shaped curve because of consistent evidence of increasing returns. Second, the corresponding net effects are overwhelmingly negative.

Given conflicting results, our best estimator is the GMM estimator. This is essentially because, compared to Fixed Effects and Tobit estimators, it accounts for the unobserved heterogeneity in terms time invariant omitted variables and controls for simultaneity in the explanatory variables by means of the instrumentation process. Hence by accounting for the unobserved heterogeneity and simultaneity, GMM estimators have more bite on endogeneity compared to competing estimators. In the light of this choice and justification, the implications of the study are contingent on the GMM results.

Based on the robust findings, the net effect of increasing CO_2 emissions on inclusive human development is negative. This implies that in the post-2015 development era, policy makers would have to work towards reducing CO_2 emissions that are potentially very detrimental to human development. This study has provided policy makers with the basis or empirical validity needed to substantiate their positions of and arguments for effective measures to be put in place in order to address the sobering policy syndromes of non-inclusive development and environmental degradation. The negative effect of environmental degradation on inclusive development can be dampened by leveraging on mechanisms such as information and communication technologies (ICT). For instance, ICT can save transportation cost and such savings can be ultimately used for health and education purposes due to an increase in disposable income. The corresponding less exposure to CO_2 emissions is also associated with more health benefits and long life. All the highlighted associated positive externalities from the use of ICT are components of the inequality adjusted human development index which is the outcome variable of this study. Moreover, the policy recommendation is consistent with the relevance of enhancing ICT for environmental sustainability (Asongu *et al*., 2018).

Future studies can improve the extant literature by investigating whether the established findings withstand empirical validity within country-specific settings. Such idiosyncratic or country-oriented inquiries are relevant for more targeted country-specific implications. Moreover, generalization of the findings will be contingent on future research that is positioned on other regions of the world in order to assess if the established findings in this study withstand empirical scrutiny.

Appendices

Appendix 1: Variable Definitions

Variables	Signs	Variable Definitions (Measurements)	Sources
Inclusive development	IHDI	Inequality Adjusted Human Development Index	UNDP
CO_2 per capita	CO2mtpc	CO_2 emissions (metric tons per capita)	World Bank (WDI)
CO_2 from electricity and heat	CO2elehepro	CO_2 emissions from electricity and heat production, total (% of total fuel combustion)	World Bank (WDI)
CO_2 from liquid fuel	CO2lfcon	CO_2 emissions from liquid fuel consumption (% of total)	World Bank (WDI)
CO_2 intensity	CO2inten	CO_2 intensity (kg per kg of oil equivalent energy use)	World Bank (WDI)
Educational Quality	Educ	Pupil teacher ratio in Primary Education	World Bank (WDI)
Private Credit	Credit	Private credit by deposit banks and other financial institutions (% of GDP)	World Bank (WDI)
Foreign Aid	Aid	Total Official Development Assistance (% of GDP)	World Bank (WDI)
Foreign investment	FDI	Foreign Direct Investment net inflows (% of GDP)	World Bank (WDI)

WDI: World Development Indicators. UNDP: United Nations Development Programme.

Appendix 2: Summary statistics (2000-2012)

	Mean	SD	Minimum	Maximum	Observations

Inequality Adj. Human Development	0.450	0.110	0.219	0.768	431
CO_2 per capita	0.901	1.820	0.016	10.093	567
CO_2 from electricity and heat	23.730	18.870	0.000	71.829	286
CO_2 from liquid fuel	78.880	23.092	0.000	100	567
CO_2 intensity	2.044	6.449	0.058	77.586	321
Educational Quality	43.784	14.731	12.466	100.236	425
Private Credit	19.142	23.278	0.550	149.78	458
Foreign aid	11.944	14.712	-0.253	181.187	531
Foreign direct investment	5.381	8.834	-6.043	91.007	529

S.D: Standard Deviation. Adj: Adjusted.

Appendix 3: Correlation matrix (uniform sample size)

CO2 emissions dynamics				Control variables					
CO2mtpc	CO2elehepro	CO2lfcon	CO2inten	Educ	Credit	Aid	FDI	IHDI	
1.000	0.690	-0.721	0.805	-0.369	0.853	-0.367	-0.108	0.607	CO2mtpc
	1.000	-0.695	0.703	-0.502	0.561	-0.442	-0.276	0.396	CO2elehepro
		1.000	-0.551	0.246	-0.352	0.219	0.222	-0.132	CO2lfcon
			1.000	-0.509	0.705	-0.482	-0.183	0.734	CO2inten
				1.000	-0.460	0.516	0.151	-0.505	Educ
					1.000	-0.323	-0.195	0.614	Credit
						1.000	0.112	-0.633	Aid
							1.000	-0.043	FDI
								1.000	IHDI

CO2mtpc: CO_2 emissions (metric tons per capita). CO2elehepro: CO_2 emissions from electricity and heat production, total (% of total fuel combustion). CO2lfcon: CO_2 emissions from liquid fuel consumption (% of total). CO2inten: CO_2 intensity (kg per kg of oil equivalent energy use). Educ: Quality of primary education. Credit: Private domestic credit. Aid: Foreign aid. FDI: Foreign Direct Investment. IHDI: Inequality Adjusted Human Development Index.

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