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The Green Economy and Inequality in Sub-Saharan Africa: Avoidable Thresholds and Thresholds for Complementary Policies

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The Green Economy and Inequality in Sub-Saharan Africa: Avoidable Thresholds and Thresholds for Complementary Policies

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Abstract

The study examines nexuses between carbon dioxide (CO_2) emissions, renewable energy consumption and inequality in 39 Sub-Saharan African countries for the period 2004-2014. The empirical evidence is based on Quantile regressions. First, in the 25th quantile of the inequality distributions, as long as CO_2 emissions metric tons per capita are kept below 4.700 (4.100), the Gini coefficient (Atkinson index) will not increase. These are avoidable CO_2 emissions thresholds. Second, renewable energy consumption should be complemented with other policies to: (i) reduce the Gini coefficient when renewable energy consumption is at 50.00% of total final energy consumption and (ii) mitigate the Atkinson index when renewable energy consumption is at 62.500 % of total final energy consumption in the bottom quantiles of the Atkinson index distribution and at 50.00% of total final energy consumption in the 75th quantile of the Atkinson index distribution. These are renewable energy consumption thresholds for complementary policies. The novelty of this study in the light of extant literature is fundamentally premised on providing policy makers with avoidable thresholds of CO_2 emissions as well as corresponding thresholds of renewable energy consumption for complementary policies, in the nexus between the green economy and inequality.

JEL Codes: H10; Q20; Q30; O11; O55

Keywords: Renewable energy; Inequality; Finance; Sub-Saharan Africa; Sustainable development

1. Introduction

There is a growing importance of fossil fuels and renewable energy consumption surrounding policy and scholarly issues in the sustainable development agenda of most countries (Yang, Shuangqing, Bing and Ping, 2019; Wang et al., 2019; Ivanovski, Hailemariam and Smyth, 2020). This study investigates nexuses between environmental quality and income inequality in Sub-Saharan Africa (SSA) and provides actionable policy thresholds underlying the nexuses that can be leveraged by policy makers to promote inclusive and sustainable development in the sub-region in the post-2015 development agenda. Interactions between policy variables and policy syndromes in the economic development literature can engender cut-off points or thresholds which represent actionable critical masses that policymakers can leverage upon to influence the outcome variable in one direction or the other[1]. This can be the case in the nexus between environmental quality and income inequality in a sub-region where concerns about income inequality and the environmental degradation are comparatively more concerning[2]. The sub-region is SSA and the two underlying concerns are critically engaged in what follows in order to clearly articulate the problem statement within the context of extant literature as well as the attendant policy and scholarly concerns pertaining to the issues.

First, on the front of income distribution and by extension income inequality, it is worthwhile to emphasize that the over two decades of economic growth resurgence in SSA has not moved hand-in-glove with inclusive development in terms of equal distribution of the fruits of economic prosperity across the population. Contemporary studies supporting this perspective include, Meniago and Asongu (2018), Tchamyou, Erreygers and Cassimon (2019a) and Asongu and Odhiambo (2019a, 2020a). The attendant literature also maintains that close to half of countries in SSA did not reach the millennium development goal (MDG) extreme poverty target because the fruits of the over two decades of economic growth resurgence did not trickle down to the poor fractions of societies. Moreover, current projections posit that unless the glaring concern of income inequality is addressed by means of more inclusive growth, the sustainable development goal (SDG) target of mitigating extreme poverty to a threshold of below 3% would not be achieved (Bicaba, Brixiova and Ncube, 2017). It follows from this narrative that inequality which is the outcome variable in this study remains a critical concern for both scholars and policy makers in the sub-region. The underlying concern can be compounded or mitigated by environmental degradation or

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[1] A policy variable is a variable with a favorable macroeconomic signal and thus should be promoted (e.g. renewable energy consumption) while a policy syndrome is an unfavorable macroeconomic signal that should not be promoted (e.g. income inequality).

[2] Income inequality and inequality are used interchangeably throughout the study.

the green economy as established by the attendant literature on the nexus between inequality and environmental quality (Grunewald, Klasen, Martínez-Zarzoso and Muris, 2017; Uzar and Eyubolgu, 2019; Demir, Cergibozan and Gök, 2019; Liu, Wang, Zhang, Li and Kong, 2019).

Second, concerns surrounding environmental degradation are comparatively more apparent in SSA because despite being the continent that emits the least carbon dioxide (CO_2) emissions, it is projected that the consequences of global warming would be most detrimental in the sub-region compared to other continents and regions of the world (Asongu, le Roux and Biekpe, 2017, 2018). Moreover, the post-2015 policy and scholarly literature is consistent on the need to promote renewable consumption of energy in order to limit the potential unfavorable consequences of environmental degradation on economic and human developments in the sub-region (Bekun, Emir and Sarkodie, 2019; Samour, Isiksal and Resatoglu, 2019; Niranjan, 2019; Asongu and Odhiambo, 2020b, 2020c; Nathaniel and Bekun, 2020; O'Ryan, Nasirov and Álvarez-Espinosa, 2020). In the light of these underlying policy and scholarly concerns, the focus of this study is to assess how environmental degradation (in terms of CO_2 emissions) and renewable energy consumption affect inequality: a positioning that is both consistent with policy requirements and a gap in the literature.

Third, the literature on the nexus between income equality and environmental degradation has largely focused on how income inequality affects environmental outcomes. However this study focuses on how environmental quality affects inequality outcomes. Some of the extant studies focusing on the underlying opposite nexus include, *inter alia*: Grunewald et al. (2017) which has examined the trade-off between CO_2 emissions and income inequality to establish that higher income inequality in lower and middle-income countries is associated with lower CO_2 emissions whereas in high-income and upper-middle income countries, per capita emissions is increased by higher levels of income inequality. Lui et al. (2019) have established that inequality in the distribution of income, especially within the remit of spatial income distribution, increases CO_2 emissions. Uzar and Eyubolgu (2019) have shown that CO_2 emissions are positively affected by income inequality. Conversely, Demir, Cergibozan and Gok (2019) conclude that income inequality mitigates environmental degradation.

A common denominator of above studies is that the attendant research focuses on the effect of inequality on environmental degradation. However, this study is positioned on the reverse nexus (i.e. the incidences of environmental pollution and renewable energy consumption on income inequality variables). In other words, instead of focusing on how inequality affects the green economy, the present study departs from the extant studies by focusing on how dynamics of the green economy (i.e. CO_2 emissions and renewable energy consumption) affect income inequality throughout the conditional distribution of income inequality. Moreover, beyond establishing nexuses among the macroeconomic variables, the present study also departs from the underlying strand of research by providing actionable critical masses or thresholds that policy makers can leverage upon in order to reduce income inequality, in the light of challenges of inclusive development in the post-2015 agenda. Hence, the policy-relevant thresholds this study aims to provide in view of informing policy makers on environmental quality measures that can contribute towards mitigating income inequality are: (i) avoidable CO_2 emissions thresholds and (ii) renewable energy consumption thresholds for complementary policies. The novelty of this study in the light of extant literature is fundamentally premised on providing policy makers with avoidable thresholds of CO_2 emissions as well as corresponding thresholds of renewable energy consumption for complementary policies, in the nexus between the green economy and inequality.

The theoretical underpinnings motivating this study are broadly consistent with those surrounding the "Environmental Kuznets Curve" (EKC), the Kuznets hypothesis (Kuznets, 1955; Selden and Song, 1994; Grossman and Krueger, 1995) and "Carbon Kuznets Curve" (CKC) (Xu and Song, 2011) because for the most part, the adopted outcome variable in the study is income inequality, whereas renewable energy consumption is an independent variable of interested variable of interest. Hence, a nexus being considered, *inter alia*, is how enhancing renewable energy consumption affects inequality. The remainder of this study is structured in the following manner. This introduction is followed by a data and methodology section before another section on empirical results. The last section concludes with implications and future research directions.

2. Data and methodology

2.1 Data

To examine the problem statement discussed in the previous section, the present study uses a panel of 39 countries in SSA with data from 2004 to 2014[3]. The selection of countries and corresponding periodicity is motivated by constraints in the availability of the relevant information at the time of study. The data is obtained from four principal sources, namely: (i)

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[3] The 39 sampled countries are: "Angola; Benin; Botswana; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo Democratic Republic; Congo Republic; Cote D'Ivoire; Eswatini; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; South Africa; Sudan; Tanzania, Togo and Uganda"

the World Development Indicators (WDI) of the World Bank; (ii) the World Bank's Financial Development and Structure Database (FDSD); (iii) the Global Consumption and Income Project (GCIP) and (iv) the World Bank's World Governance Indicators (WGI).

The outcome inequality variables are sourced from the GCIP, namely: the Gini coefficient and the Atkinson index. The Gini coefficient represents the distribution of income across the population while the Atkinson index denotes the percentage of total income that a specific society is prepared to sacrifice in order to improve the distribution of income in the attendant society. The choice of the Atkinson index to complement the Gini coefficient is motivated by the fact that the latter has been documented not to emphasize the tails or extreme points of the inequality distribution (Naceur and Zhang, 2016; Meniago and Asongu, 2018; Tchamyou et al., 2019a, 2019b). Hence, it is for the purpose of robustness that the Atkinson index is used to complement the Gini coefficient.

The independent variables of interest are obtained from WDI of the World Bank, notably: (i) CO_2 emissions (metric tons per capita) and (ii) renewable energy consumption (% of total final energy consumption)[4]. The latter is a positive environmental signal while the former is a negative environmental signal. Both are used for the purpose for robustness. The choice of the environmental quality indicators is also informed by contemporary literature on the subject (Nathaniel and Iheonu, 2019; Asongu et al., 2019; Akinyemi et al., 2019; Asongu, 2018; Asongu and Odhiambo, 2020c).

In order to control for variable omission bias, five non-dummy and two dummy variables are used in the estimation exercise. The non-dummy variables are: financial access, mobile phones, regulation quality, trade openness and urban population while the dummy variables are middle-income countries and petroleum-exporting countries. The variables which are from WDI, FDSD and WGI of the Bank and Asongu, Nwachukwu and Pyke (2019), as apparent in Appendix 1, are informed by contemporary inclusive development literature (Demirguc-Kunt and Klapper, 2012; Demirgüç-Kunt, Klapper and Van Oudheusden, 2015; Asongu and Nwachukwu, 2016; Asongu and Asongu, 2018; Asongu and Odhiambo, 2018, 2019b; Murendo, Wollni, De Brauw and Mugabi, 2018; Tchamyou, 2019a, 2019b, 2020). With the exception of urban population and the middle income dummy that are expected to increase income inequality, the other variables are anticipated to have the opposite effect. However, it is important to note that the expected signs can also be influenced by two more dynamics. On the one hand, given that quadratic terms are involved in the

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[4] CO_2 emissions (metric tons per capita), CO_2 emissions and CO_2 emissions per capita are used interchangeably throughout the study.

regression exercise, the quadratic terms can be correlated with the independent variables of interest and hence, some expected signs of variables in the conditioning information set can be affected. However, the concern of multicollinearity does not affect the main independent variables of interest because according to Brambor, Clark and Golder (2006), quadratic regressions are not interpreted as linear additive models. For this purpose, net effects and thresholds underlying the quadratic specifications are computed in the empirical results section.

On the other hand, since the nexuses are assessed throughout the conditional distribution of the inequality variables, the attendant effects can vary depending on initial levels of income inequality. It follows from the above narrative that this study focuses on the quadratic estimated variables to compute the attendant thresholds and net effects. The study is also only concerned about the significance of estimated coefficients of variables in the conditioning information set because the study makes abstraction of the expected signs in the light of the concerns discussed above. The definitions of variables and sources of data are disclosed in Appendix 1, the corresponding summary statistics and correlation matrix are provided respectively in Appendix 2 and Appendix 3.

2.2 Methodology

In accordance with the narrative in the previous section, the quantile regression approach is adopted for this study because it enables are assessment of investigated nexuses throughout the conditional distribution of the inequality outcome variables. Hence, the adopted estimation approach is such that, low, intermediate and high initial levels of income inequality are articulated. Hence, by accounting for existing levels of income inequality, there is an assumption that a modeling approach based on mean values of the outcome variable is unlikely to produce robust and policy-relevant estimates, unless the initial levels of income inequality are taken on board in order to avoid blanket policy implications.

Following the attendant literature on the subject matter (i.e. contemporary and non-contemporary sources), the quantile estimates are obtained by solving the optimization problem presented in Equation (1) below without subscripts to enhance readability and flow (Koenker and Bassett, 1978; Koenker, 2005; Hao and Naiman, 2007; Okada and Samreth, 2012; Tchamyou and Asongu, 2017; Asongu and Odhiambo, 2019c):

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_{i'}\beta\}} \theta \left| y_i - x_{i'}\beta \right| + \sum_{i \in \{i: y_i < x_{i'}\beta\}} (1-\theta) \left| y_i - x_{i'}\beta \right| \right], \qquad (1)$$

where $\theta \in (0,1)$. Contrary to Ordinary Least Squares (OLS) which is founded on minimizing the total sum of squared residuals, the Quantile regressions is focused on minimizing the weighted total of absolute variations. For example, the 10th or 90th quantiles (with θ=0.10 or 0.90 respectively) are estimated by weighing the residuals approximately. The conditional income inequality or y_i given x_i is:

$$Q_y(\theta / x_i) = x_{i'}\beta_\theta \quad , \tag{2}$$

where, parameters that are characterized by a single slope are estimated for each the θ^{th} specific quantile. Equation (2) is analogous to $E(y/x) = x_{i'}\beta$ in the OLS slope where parameters to be estimated rely on the conditional distribution of income inequality. It is important to articulate that in the underlying equation, y_i represents income inequality (i.e. the Gini coefficient and the Atkinson index) while x_i contains: a constant term, CO_2 emissions, renewable energy consumption, financial access, mobile phone penetration, regulation quality, trade openness, urban population, middle income countries and petroleum-exporting nations.

3. Empirical results

The empirical results are provided in this section in Tables 1-2. While Table 1 presents linkages between the Gini coefficient, CO_2 emissions and renewable energy consumption, Table 2 discloses the corresponding findings for the Atkinson index, CO_2 emissions and renewable energy consumption. Each of the tables is divided into two main categories of quantile specifications: one corresponding to CO_2 emissions and the other to renewable energy consumption. It is important to note that from the left-hand side to the right-hand side of both tables, the inequality levels of increase. It follows that in the 10th (90th) quantile, the level of inequality is lowest (highest).

The following findings can be established from Table 1. First, CO_2 emissions unconditionally (conditionally) decrease (increase) inequality in the 25th quantile of the conditional distribution of the Gini coefficient. The corresponding overall net effect of growing CO_2 emissions on the Gini coefficient is -0.037 while the threshold at which the negative unconditional effect changes to positive is 4.700.

Table 1: The Gini Coefficient, CO_2 emissions and renewable energy consumption

	Dependent variable: The Gini Coefficient									
	CO_2 emissions (CO_2)					Renewable Energy Consumption (REC)				
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	0.565***	0.582***	0.586***	0.594***	0.607***	0.611***	0.612***	0.623***	0.618***	0.614***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CO_2 emissions (CO_2)	-0.004	-0.047***	-0.013	0.005	0.015**	---	---	---	---	---
	(0.821)	(0.000)	(0.168)	(0.656)	(0.011)					
REC	---	---	---	---	---	-0.002***	-0.002***	-0.001***	-0.001**	-0.0002
						(0.000)	(0.000)	(0.000)	(0.033)	(0.858)
$CO_2 \times CO_2$	0.001	0.005***	0.002**	0.001	0.0005	---	---	---	---	---
	(0.463)	(0.000)	(0.012)	(0.230)	(0.339)					
REC × REC	---	---	---	---	---	0.00002***	0.00002***	0.00001***	0.00001**	4.73e-06
						(0.000)	(0.000)	(0.000)	(0.031)	(0.702)
Financial Access	-0.00004	-0.00008*	-0.0001**	-0.0001**	-0.0001***	-0.0003***	-0.0003***	-0.0003***	-0.0002*	-0.0001
	(0.741)	(0.075)	(0.047)	(0.049)	(0.001)	(0.004)	(0.000)	(0.000)	(0.060)	(0.671)
Mobile Phone	-0.0001	-0.0001***	-0.0001**	-0.00003	0.00002	-0.00004	-0.00005	-0.0001**	-0.00002	-0.00002
	(0.141)	(0.004)	(0.027)	(0.646)	(0.500)	(0.658)	(0.260)	(0.025)	(0.729)	(0.902)
Regulation Quality	-0.003	0.005	0.004	0.004	0.012	0.016**	0.018***	0.024***	0.033***	0.036
	(0.723)	(0.130)	(0.375)	(0.515)	(0.000)	(0.014)	(0.000)	(0.000)	(0.000)	(0.022)
Trade Openness	-0.0001	-0.0001***	-0.0001**	0.00002	-0.00008**	-0.00002	2.08e-06	-0.00004	-0.00005	-0.00006
	(0.112)	(0.000)	(0.032)	(0.750)	(0.013)	(0.737)	(0.966)	(0.446)	(0.501)	(0.756)
Urban Population	0.001**	0.001***	0.0008***	0.0001	0.0003**	0.001***	0.001***	0.001***	0.001***	0.0009
	(0.013)	(0.000)	(0.000)	(0.619)	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)	(0.208)
Middle Income	0.007	0.009***	0.002	-0.005	-0.014***	0.011*	0.015***	0.010***	0.005	0.007
	(0.500)	(0.008)	(0.560)	(0.314)	(0.000)	(0.060)	(0.000)	(0.006)	(0.285)	(0.598)
Petroleum Exporting	-0.044***	-0.010***	-0.013***	-0.009	-0.005**	-0.036***	-0.019***	-0.012***	-0.005	-0.007
	(0.000)	(0.004)	(0.007)	(0.115)	(0.056)	(0.000)	(0.000)	(0.003)	(0.328)	(0.662)
Net Effects	na	-0.037	na	na	na	0.0006	0.0006	0.0003	0.0003	na
Thresholds	na	4.700	na	na	na	50.000	50.000	50.000	50.000	na
Pseudo R²	0.304	0.312	0.295	0.385	0.623	0.331	0.265	0.202	0.213	0.360
Observations	246	246	246	246	246	245	245	245	245	245

*,**,***: significance levels of 10%, 5% and 1% respectively.. Lower quantiles (e.g., Q 0.1) signify nations where inequality is least. na: not applicable because at least one estimated coefficient needed for the computation of thresholds and net effects is not significant. The mean value of CO_2 emissions (metric tons per capita) is 0.934. The mean value of Renewable Energy Consumption is 66.216.

It is worthwhile to clarify that net effects and attendant thresholds are computed because, as documented by Brambor et al. (2006), in order to avoid the pitfalls of quadratic specifications, corresponding estimates from the independent variables of interest should not be interpreted as in linear additive models. The procedure for understanding and interpreting quadratic specifications is consistent with contemporary literature based on quadratic regressions (Asongu and Odhiambo, 2020d, 2020e). Hence, this study clarifies the computation of net effects and corresponding thresholds used to assess the overall effects and tendencies of enhancing environmental quality dynamics on income inequality. From the third column of Table 1, the net effect of enhancing CO_2 emissions on the Gini coefficient is -0.037 (2×[0.934× 0.005] + [-0.047]). In the computation of the underlying net effect, it is important to note that -0.047 is the unconditional effect of CO_2 emissions on the Gini coefficient, 0.934 is mean value of CO_2 emissions per capita, 0.005 is the marginal impact of CO_2 emissions per capita on the Gini coefficient whereas the leading 2 term is from the quadratic derivation.

The CO_2 emission threshold at which the overall effect of CO_2 emissions on inequality changes from negative to positive is 4.700 =[-0.047/ (2×0.005)]. It follows that at a critical mass of 4.700 CO_2 emissions per capita, the overall net effect is 0 (2×[4.700× 0.005] + [-0.047]). Hence, above the 4.700 threshold of CO_2 emission per capita, the net effect on inequality becomes positive. It follows that in the 25th quantile of the inequality distribution, as long as CO_2 emissions are kept below the 4.7 per capita critical limits, inequality would decrease. The same analytical scope is employed to understand estimation techniques on the right-hand side of Table 1 as well as corresponding estimations on both the right-hand and left-hand sides of Table 2.

The following findings are apparent on the right-hand side of Table 1. With the exception of the highest quantile (i.e. 90th quantile), the estimations are significant throughout the conditional distribution of the Gini coefficient. Second, renewable energy consumption unconditionally (conditionally) decreases (increases) the Gini coefficient and in order to maintain the dampening role of renewable energy consumption on inequality, renewable energy consumption should be complemented with other policies to reduce inequality when renewable energy consumption is at 50.00% of total final energy consumption. This threshold of renewable energy consumption for complementary policies is the same throughout the conditional distribution of the Gini coefficient.

The following findings can be established from Table 2. First, CO_2 emissions unconditionally (conditionally) decrease (increase) the inequality in the 25th quantile of the conditional distribution of the Atkinson index. The corresponding overall net incidence of growing CO_2 emissions on the Atkinson index is -0.0316 while the threshold at which the negative unconditional effect changes to positive is 4.100. Hence, above the 4.100 threshold of CO_2 emission per capita, the net effect on inequality becomes positive. It follows that in the 25th quantile of the inequality distribution, as long as CO_2 emissions are kept below the 4.100 per capita critical limits, inequality would decrease.

Table 2: The Atkinson index, CO_2 emissions and renewable energy consumption

Dependent variable: The Atkinson Index

	CO_2 emissions (CO_2)					Renewable Energy Consumption (REC)				
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	0.640***	0.672***	0.694***	0.693***	0.741***	0.738***	0.750***	0.671***	0.757***	0.743***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CO_2 emissions(CO_2)	-0.040	-0.041***	0.015	0.031**	0.031**	---	---	---	---	---
	(0.399)	(0.003)	(0.501)	(0.040)	(0.018)					
REC	---	---	---	---	---	-0.005***	-0.005***	-0.001	-0.002***	-0.0007
						(0.001)	(0.000)	(0.101)	(0.000)	(0.257)
$CO_2 \times CO_2$	0.005	0.005***	-0.00003	-0.001	-0.002	---	---	---	---	---
	(0.268)	(0.000)	(0.989)	(0.310)	(0.104)					
REC × REC	---	---	---	---	---	0.00004***	0.00004***	0.00001**	0.00002***	9.78e-06*
						(0.000)	(0.000)	(0.018)	(0.000)	(0.095)
Financial Access	-0.0001	-0.0002***	-0.0003**	-0.0003***	-0.0004***	-0.0008**	-0.0008***	-0.0002	-0.0005***	-0.0003**
	(0.607)	(0.006)	(0.020)	(0.000)	(0.000)	(0.015)	(0.000)	(0.129)	(0.000)	(0.025)
Mobile Phone	-0.0004	-0.0003***	-0.0002*	0.00004	0.0001	-0.0001	-0.0001	0.00001	0.00006	-0.00003
	(0.144)	(0.000)	(0.068)	(0.620)	(0.198)	(0.462)	(0.257)	(0.912)	(0.534)	(0.711)
Regulation Quality	-0.003	-0.006	-0.006	-0.012	0.016**	0.036**	0.029***	0.013	0.050***	0.051***
	(0.881)	(0.379)	(0.587)	(0.139)	(0.017)	(0.030)	(0.000)	(0.130)	(0.000)	(0.000)
Trade Openness	-0.0004	-0.0002***	-0.0001	0.0003***	0.0001*	-0.00001	0.00009	0.00008	0.0002***	0.0001
	(0.118)	(0.007)	(0.370)	(0.000)	(0.063)	(0.947)	(0.307)	(0.476)	(0.008)	(0.156)
Urban Population	0.004***	0.001***	0.0006	-0.0008***	-0.0004	0.004***	0.002***	0.001***	0.0006*	0.001***
	(0.000)	(0.000)	(0.183)	(0.008)	(0.114)	(0.000)	(0.000)	(0.001)	(0.057)	(0.000)
Middle Income	0.0001	0.013*	-0.001	-0.010	-0.016**	0.009	0.029***	0.024***	0.012*	0.007
	(0.994)	(0.051)	(0.865)	(0.181)	(0.015)	(0.545)	(0.000)	(0.004)	(0.072)	(0.260)
Petroleum Exporting	-0.074***	-0.012*	0.004	0.006	0.003	-0.060***	-0.020***	-0.001	0.007	0.016**
	(0.002)	(0.079)	(0.716)	(0.423)	(0.607)	(0.001)	(0.005)	(0.843)	(0.324)	(0.044)
Net Effects	na	-0.0316	na	na	na	0.0003	0.0003	na	0.0006	na
Thresholds	na	4.100	na	na	na	62.500	62.500	na	50.000	na
Pseudo R²	0.229	0.257	0.194	0.263	0.397	0.272	0.246	0.188	0.206	0.333
Observations	246	246	246	246	246	245	245	245	245	245

*,**,***: significance levels of 10%, 5% and 1% respectively.. Lower quantiles (e.g., Q 0.1) signify nations where inequality is least. na: not applicable because at least one estimated coefficient needed for the computation of thresholds and net effects is not significant. The mean value of CO_2 emissions (metric tons per capita) is 0.934. The mean value of Renewable Energy Consumption is 66.216.

Second, with the exception of the highest quantile (i.e. 90th quantile) and the median (i.e. 50th quantile), the estimations are significant throughout the conditional distribution of the Atkinson index. Renewable energy consumption unconditionally (conditionally) decreases (increases) the Atkinson and in order to maintain the dampening role of renewable energy consumption on inequality. Moreover, renewable energy consumption should be complemented with other policies to reduce inequality when renewable energy consumption is at 62.500 % of total final energy consumption in the bottom quantiles of the Atkinson index distribution and at 50.00% of total final energy consumption in the 75th quantile of the Atkinson index distribution.

The presented findings are novel in the light of extant literature because policy makers have been provided with avoidable thresholds of CO_2 emissions as well as corresponding thresholds for complementary policies in renewable energy consumption, in the nexus between the green economy and inequality. It follows that the non-linear tendency of the findings support the perspective that contrary to the attendant literature discussed in the introduction, the present study provides avenues along which policy shifts can be formulated and implemented in view of mitigating income inequality. This corresponding literature include, *inter alia*: Li et al. (2019) on the perilous role of gender inequality in the consumption of green households; Liu et al. (2019) and Uzar and Eyuboglu (2020) on the relationship between CO_2 emissions and income inequality; the conclusions of Demir, Cergibozan and Gok (2019) on the linkage between environmental degradation and income inequality as well as the plethora of studies on the nexus between the distribution of income and renewable energy consumption (McGee and Greiner, 2019; Uzar, 2020; Bai et al., 2020).

In the light of the above, it follows that, as opposed to the underlying studies on the inequality-"green economy" nexus which for the most part provide blanket policy implications based on mean values of the outcome variable, the dynamic nature of the present findings can be articulated on two fronts. On the one hand, the fact that the inequality variables are assessed throughout their conditional distributions in order to articulate initial levels of income inequality portrays aspects of non-linearity. On the other hand, thresholds of the independent variables of interest also reflect some non-monotonic features given that quadratic specifications have been adopted for the study.

4. Concluding implications and future research directions

The study has examined nexuses between CO_2 emissions, renewable energy consumption and inequality dynamics in terms of the Gini coefficient and the Atkinson index. It has focused on 39 countries in Sub-Saharan Africa using data from 2004-2014. Quantile regressions are adopted as estimation strategy in order to articulate conditional distributions of the inequality dynamics. The following findings are established. First, CO_2 emissions unconditionally (conditionally) decrease (increase) inequality at the 25th quantile of the conditional distributions of the Gini coefficient and the Atkinson index. The corresponding overall net effect of growing CO_2 emissions on the Gini coefficient (Atkinson index) is -0.037 (-0.0316) while the threshold at which the negative unconditional effect changes to positive is 4.700 (4.100). Hence, in the 25th quantile of the inequality distributions, as long as CO_2 emissions metric tons per capita are kept below 4.700 (4.100), the Gini coefficient (Atkinson index) will not increase.

Second, with the exception (s) the highest quantile (median and 90th quantile) of the Gini coefficient (Atkinson index), renewable energy consumption unconditionally (conditionally) decreases (increases) income inequality and in order to maintain the dampening role of renewable energy consumption on inequality, renewable energy consumption should be complemented with other policies to: (i) reduce Gini coefficient when renewable energy consumption is at 50.00% of total final energy consumption and (ii) mitigate the Atkinson index when renewable energy consumption is at 62.500 % of total final energy consumption in the bottom quantiles of the Atkinson index distribution and at 50.00% of total final energy consumption in the 75th quantile of the Atkinson index distribution.

It follows from the above findings that avoidable CO_2 emission thresholds have been provided as well as renewable energy consumption thresholds for complementary policies. The thresholds make economic sense and have policy relevance because they are within their respective statistical ranges disclosed in the summary statistics. Hence, the policy implications of this study are straight forward and directly apparent. The novelty of this study in the light of extant literature is fundamentally premised on providing policy makers with avoidable thresholds of CO_2 emissions as well as corresponding thresholds of renewable energy consumption for complementary policies, in the nexus between the green economy and inequality.

Future studies can examine how the established findings are relevant to country-specific frameworks in order to provide findings with country-specific policy options. It would also be worthwhile to assess complementarities between renewable energy consumption and other policy variables that can mitigate income inequality, especially at established thresholds for complementary policies.

Appendices

Appendix 1: Definitions of Variables

Variables	Signs	Definitions of variables (Measurements)	Sources
Income Inequality	Gini Coefficient	“*The Gini coefficient is a measurement of the income distribution of a country's residents*”.	GCIP
	Atkinson Index	“*The Atkinson index measures inequality bydetermining which end of the distribution contributed most to the observed inequality*”.	GCIP
CO_2 emissions per capita	CO_2	CO_2 emissions (metric tons per capita)	WDI
Renewable energy	Renenc	Renewable energy consumption (% of total final energy consumption)	WDI
Financial Access	Pcrdof	Private domestic credit from deposit banks and other financial institutions (% of GDP)	FDSD
Mobile Phones	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Regulation quality	RQ	“Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development”	WGI
Trade Openness	Trade	Imports plus Exports of Goods and Services (% of GDP)	WDI
Urban Population	Upop	Urban Population (% of Total Population)	WDI
Middle Income	MI	“There are four main World Bank income groups: (i) high income, $12,276 or more; (ii) upper middle income,$3,976-$12,275; (iii) lower middle income, $1,006-$3,975 and (iv) low income, $1,005 or less”.	WDI, Asongu, Nwachukwu and Pyke (2019)
Petroleum Exporting	Oil	“Stratification by natural resource-wealth is exclusively based on petroleum exports which represent at least 30 percent of the country’s GDP for a minimum of one decade of the study period”	WDI, Asongu, Nwachukwu and Pyke (2019)

WDI: World Bank Development Indicators of the World Bank. FDSD: Financial Development and Structure Database of the World Bank. GCIP: Global Consumption and Income Project. WGI: World Governance Indicators of the World Bank.

Appendix 2: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Observations
Gini Coefficient	0.586	0.034	0.488	0.851	428
Atkinson Index	0.704	0.057	0.509	0.834	428
CO_2 emissions per capita	0.934	1.823	0.020	9.979	429
Renewable energy	66.216	25.810	0.354	97.882	406
Financial Access	21.055	25.319	0.873	150.209	414
Mobile Phones	47.148	37.672	1.272	171.375	425
Regulation quality	-0.601	0.544	-1.879	1.123	429
Trade Openness	76.756	41.186	19.458	311.354	415
Urban Population	16.792	11.034	4.595	59.915	264
Middle Income Countries	0.410	0.492	0.000	1.000	429
Petroleum Exporting Countries	0.179	0.384	0.000	1.000	429

S.D: Standard Deviation. CO_2: Carbon Dioxide.

Appendix 3: Correlation matrix (uniform sample: 245)

	Renenc	Gini	Atkin	Finance	Mobile	RQ	CO_2	Trade	Upop	MI	Oil
Renenc	1.000										
Gini	0.217	1.000									
Atkin	0.264	0.800	1.000								
Finance	-0.493	-0.104	-0.194	1.000							
Mobile	-0.021	0.181	0.032	0.079	1.000						
RQ	0.139	0.421	0.159	0.031	0.295	1.000					
CO_2	0.116	0.734	0.493	-0.078	0.444	0.496	1.000				
Trade	-0.087	-0.055	-0.095	-0.099	-0.004	-0.370	-0.049	1.000			
Upop	0.010	0.223	0.245	-0.106	0.359	-0.264	0.334	0.560	1.000		
MI	-0.071	0.124	0.087	-0.054	0.291	0.008	0.403	-0.180	0.200	1.000	
Oil	-0.080	-0.273	-0.099	-0.126	0.018	-0.478	-0.047	0.088	0.274	0.330	1.000

Renenc: Renewable Energy Consumption. Gini: the Gini Coefficient. Atkin: the Atkinson Index. Finance: Financial Access. Mobile: Mobile Phones Penetration. RQ: Regulation Quality. CO_2: Carbon dioxide emissions. Trade: Trade Openness. Upop: Urban Population. MI: Middle Income. Oil: Petroleum-Exporting Countries.

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