Unveiling the Impact of Income Inequality on CO_2 Emissions in Sub-Saharan Africa Countries (SSA)

Jimoh S. Ogede[1], Hammed O. Tiamiyu[2]

Abstract: Carbon dioxide emissions and income disparity have become crucial unclear challenges threatening the environment and humanity over the past three decades. Erstwhile environment studies have claimed that greater energy use contributes to poor environmental quality but ignored the significance of financial development in mediating with income inequality on carbon dioxide or environmental quality. Our study employed both panel autoregressive distributed lag model (ARDL) and causality tests to investigate whether income inequality impacts Co_2 emissions and how the interaction between income inequality and financial development impacts Co_2emissions in sub-Saharan Africa (SSA) countries from 2004–2019. The findings revealed that financial development and all other control variables except trade/GDP ratio positively impact carbon emission in SSA in the long run. The result shows that the trade/GDP ratio is contrariwise related to carbon emission in SSA. In the short run, all the control variables, income inequality, population density, financial development trade to GDP, energy consumption, per capita income and urbanization, are not statistically significant. In contrast, per capita income, population density and urbanization have an inverse relationship with carbon emission in SSA. The analysis of the interaction between income inequality and financial development on carbon emission revealed that financial development plays a significant role as a moderator in increasing carbon emission coming from income inequality. The study concludes that financial development plays a significant role as a moderator in increasing carbon emissions coming from income inequality. As such, the governments of these SSA nations and other stakeholders should work to combine economic disparity and financial instability to prevent harm to the environment by cutting carbon emissions.

Keywords: Income inequality; CO2 emissions; sub-Saharan African Countries; panel ARDL

JEL Classification: D33

1. Introduction

Greenhouse gas emissions and income disparity have become crucial unclear challenges threatening the environment and humanity over the past three decades. Erstwhile environment studies have claimed that greater energy use is a contributing factor to poor environmental quality. Following that, Africa's Sub-Saharan Africa countries (SSA) witnessed fast economic expansion, widening socioeconomic disparities, and a deteriorating environment, raising worries about the current and future effects of environmental degradation on SSA's development results (Asongu & Vo, 2020). Furthermore, the sub-

[1] PhD, Department of Economics, Olabisi Onabanjo University, Nigeria, Corresponding author: sinaogede@oouagoiwoye.edu.ng.
[2] PhD, Department of Economics, Olabisi Onabanjo University, Nigeria, E-mail: tiamiyuhammed@gmail.com.

environmentally region's unsustainable economic expansion has resulted in a surge in carbon dioxide (CO_2) emissions, the prime initiator of climate change. Thus, a further and clear demonstration of understanding of the underlying nexus between income disparity and CO_2 emissions in SSA will assist in the formulation and implementation of policies that address both global warming risks and inequalities. This one-of-a-kind study adds to the literature on the subject by empirically exploring the relationship between income inequality and CO_2 emissions in the selected SSA countries from 2004 to 2019.

Numerous contributory factors, except for aggregate income, have been defined as environmental efficiency determinants. It is imperative to identify that the root cause of income disparity has been explicitly ignored. Theoretically, a larger income gap may speed up or slow down CO2 emissions. The demand-income interaction determines the cumulative influence of growing income disparities on environmental quality. If the relationship between demand for environmental quality and income is linear, re-allocating income from the poor to the affluent does not affect the environmental quality (Boyce, 2003). Given the above circumstance, the victors determine the benefit of the process, whereas the failures will suffer. It is assumed that if they are significantly rich, the winners will press the government to loosen the regulatory system, thus causing environmental degradation. Consequently, if the losers are wealthy, they may compete with the beneficiaries and exploit the authorities to create strict environmental conditions (Wolde-Rufael & Idowu, 2017). Another potential explanation of why income inequality can or may not improve environmental productivity is linked to the studies such as Barra and Zotti (2017). The authors stated that rising income levels are leading to major economic transformations. Furthermore, repositioning the economic structure from severely polluted regions and toward less polluted ones will lessen the environmental pollution.

Thus, following the work of Ravallion, Heil, and Jalan (2000), a plethora number of empirical studies has provided diverse outcomes on the income inequality-CO_2 emissions nexus and explicitly argued whether income inequality contributed to worsening CO_2 emissions. The first strand of the literature resolved that income inequality impacts CO_2 emission or environmental degradation (see Zhang & Zhao, 2014; Qu & Zhang, 2011; Knight, Schor & Jorgenson, 2017; Ridzuan, 2019; Bai, Feng, Yan, et al., 2020; amongst others). Furthermore, research such as Ravallion et al. (2000), Hailemariam, Dzhumashev and Shahbaz (2019), Huang and Duan (2020) have shown that the growing income disparity favours CO_2 emissions decrease. For example, Ravallion et al. (2000) examined the income disparity-CO_2 nexus and that increasing inequality has aided the lessening of CO_2 emissions across countries. In contrast to the above studies, from 2004 to 2014, Asongu and Vo (2020) employed quantile regressions to analyze the impact of CO_2 emissions in mediating the relationship between financial development and income disparity in Sub-Saharan African (SSA) nations. These authors believed that financial expansion inherently diminishes income disparities, with increasing negative consequences. The authors went on to say that the relationship between financial development and CO_2 emissions is positive. Furthermore, Hübler (2017) demonstrated a negative relationship between income inequality and CO_2 emissions using quantile regression (QR), but no interplay involving income disparity and greenhouse gasses.

Hence, fascinating features of the erstwhile studies have ignored the significance of financial development in mediating with income inequality on carbon dioxide or environmental quality. The financial sector is a key factor that can enhance economic growth and lessen CO_2 emissions by providing more money for the production of the environment. There is also a lack of empirical literature on the correlation between income inequality and environmental quality or carbon emissions in SSA countries. The study will probably achieve accurate, consistent results by intruding financial development into the income disparity-CO_2 nexus and addressing the question of the specification of the problem. The current study contends that these empirical outcomes may be subjective, assuming that the heterogeneity of CO_2 emissions returns is ignored. Furthermore, structural reforms, advances in environmentally friendly technology, changes in government environmental regulations, and fluctuations in rapid urbanization have occurred throughout time, all of which are potential sources of unpredictability in CO_2 emissions returns. Hence, this study investigates whether income inequality impacts CO_2 emissions and how the interaction between income inequality and financial development impacts CO_2 emissions in SSA from 2004–2019.

Our paper contributes to the repository of learning in various ways. To begin, we generated a panel autoregressive lag model to account for rising income disparity and CO_2 emissions. Another feature is that we investigate how financial development impacts the relationship between income disparity and CO_2 emissions. The nexus between environment and economic growth is endangered due to a lack of symmetric data during a moment of financial turbulence (Richard, 2010). Given these stated factors, the study concludes that financial development and economic disparity may significantly influence environmental quality. As a result, examining the interaction impact of income inequality and financial development on CO_2 emissions in the selected SSA countries is critical and novel. Third, because growing economies are more sensitive to environmental deterioration, this study focuses on developing nations (Argyriou, 2020). Finally, most prior research has used standard mean regression approaches to explore the influence of inequality on CO_2 emissions, assuming that economic variable data is distributed normally (Lin & Xu, 2018). However, real-world economic circumstances and statistics exhibit its distribution surges, flat tails, and heteroskedasticity (Chen, Xian, Zhou & et al., 2020).

Our result reveals that financial development and all other control variables except trade/GDP ratio positively impact carbon emission in SSA in the long run. The empirical finding shows that the trade/GDP ratio is contrariwise related to carbon emission in SSA. In the short run, all the control variables, income inequality, population density, financial development trade to GDP, energy consumption, per capita income and urbanization, are not statistically significant. In contrast, per capita income, population density and urbanization have an inverse relationship with carbon emission in SSA. The analysis of the interaction between income inequality and financial development on carbon emission revealed that financial development plays a significant role as a moderator in increasing carbon emission coming from income inequality. The remainder of the article is structured as follows. The literature review is discussed in Section 2. The data and methodology are presented and discussed in Section 3. Section 4 discussed the empirical analysis, while implications and policy recommendations are reported in Section 5.

2. Review of Related Empirical Literature

There is a large body of work on the link between wealth disparity and environmental deterioration, but it is far from conclusive. The first strand of the literature resolved that income inequality impacts carbon dioxide emission or environmental degradation (see Ravallion et al. 2000; Zhang & Zhao, 2014; Qu &

Zhang, 2011; Knight et al., 2017; Ridzuan, 2019; Hailemariam et al., 2019; Bai et al., 2020; amongst others). For example, Ravallion et al. (2000) examined the income disparity-CO_2 nexus and that increasing inequality has aided the lessening of CO_2 emissions across countries. Similarly, Kasuga and Takaya (2017) investigated the relationship between wealth disparity and several environmental emission measures in 85 Japanese cities between 1990 and 2012. According to the researchers, rising income distribution affects air pollution, SO2 emissions, and NOx emissions in the selected cities. Knight, Schor, and Jorgenson (2017) examined the connection between income distribution and CO2 emissions in 26 industrialized countries and concluded that growing inequality exacerbates environmental damage. Grunewald, Klasen, Martnez-Zarzoso, and colleagues (2017) established a link between wealth disparities and CO2 emissions from 1980 to 2008. The outcomes of the study found a correlation between wealth disparity and CO2 emissions for low- and middle-income countries.

Using panel estimation, Rafiq, Salim, and Nielsen (2016) investigated the effects of urbanization and trade openness on emissions and energy intensity in 22 emerging economies. According to the study, the key sources of emissions and pollutants are population density, per capita income, and the use of nonrenewable energy. Ridzuan, Ismail, Hamat, and colleagues (2017) explored the relationship between income distribution and the environment in four Association of South-East Asian Nations (ASEAN) nations. Based on Autoregressive Distributed Lag (ARDL) estimates and yearly data from 1971 to 2013, the authors claim that a more fair distribution of wealth leads to a greater quality of environment in Indonesia and Thailand.

Conversely, trade liberalization and economic growth (GDP) will have a negative impact on the environment. Jorgenson, Schor, and Huang (2017) explored the relationship between income inequality and carbon emissions in the United States at the state level. When the authors studied income inequality in the top 10% of wealth, they identified a positive association between income disparity and CO2 emissions (2017). Furthermore, there was no connection between CO2 emissions and income inequality when income difference was evaluated by means of the Gini coefficient. Uddin, Mishra and Smyth (2020) studied the nexus between income inequality and carbon emissions, exploring a non-parametric panel estimation technique as well as time-varying coefficients over the period 1870–2014. The statistics show that the link between economic disparity and CO2 emissions is significantly non-linear. Furthermore, from 1870 to 1880, the income inequality index has a significant positive impact on CO2 emissions and a significant detrimental impact from 1950 to 2000. Besides, Chen, Xian, Zhou, et al. (2020) employed simultaneous quantile regression analysis to demonstrate that equal income distribution promotes lower CO2 emissions per capita, while income inequality has no influence on CO2 emissions in developed countries.

In contrast to the preceding research, Asongu and Vo (2020) used quantile regressions to investigate the effect of carbon dioxide (CO2) emissions in mediating between financial development and income disparity in SSA from 2004 to 2014. According to the authors, financial development unconditionally reduces income disparity with rising negative magnitude. Interactions between financial development and CO2 emissions, on the other hand, have the opposite impact, with a rising positive magnitude. Mathonnat and Williams (2020) examined the nexus between financial development and the redistributive effect of banking crises of selected 54 countries spanning from 1977 to 2013. Due to the nature of income distribution data, which varies slowly over time but considerably among nations, the authors used cross-section analysis versus panel data. The findings of the article suggest that financial development is connected with a large increase in income inequality following the banking crisis. The finding further highlighted that the relationship between financial development and the redistributive implications of banking crises is not susceptible to a threshold effect and is higher in emerging nations. To sum up, it is sufficient to conclude that previous research on the income inequality- carbon dioxide emission nexus has ignored the crucial financial uncertainty of the mediation of the nexus. The financial sector is a key factor that may stimulate and enhance output growth and lessen carbon dioxide emissions by providing funds for environmentally friendly products.

3. Sources of Data and Methodology

3.1. Data Description and Measurement

The purpose of this paper is to explore if income inequality has an influence on CO2 emissions and how financial development has an impact on CO2 emissions in the selected SSA nations. The panel samples of 26 Sub-Saharan Africa (SSA) countries for 2004–2019 were employed. Countries were assessed from West, South, and East Africa. Table 1 provides the information on the appraised countries in SSA. However, the choice of these countries is motivated by the need to limit the attention paid to the sub-Saharan African countries, the availability of reliable data, the level of urbanization, and income disparity. The dependent variable is Co_2 emissions in this study, while the income inequality and financial development index remain crucial variables. The income inequality is a proxy with the Gini coefficient. Gini coefficient is used to explain the degree of inequality in a country's income distribution following the work of Ogede (2020). Financial development and other control elements are predicted to have an influence on carbon dioxide emissions, needing justification for inclusion. Economic growth, as measured by GDP per capita, has a significant impact on CO2 emissions (Grossman & Krueger, 1995; Bai et al., 2020).

Table 1. List of Selected Countries in SSA

Southern Africa	East Africa	West Africa	Central Africa
Lesotho, Namibia, and South Africa	Burundi, Kenya, Madagascar, Malawi, Uganda, Zimbabwe, and Rwanda	Burkina Faso, Ghana, Benin, Nigeria, Liberia, Guinea, Guinea-Bissau, Togo, Senegal, Mali, Niger, and The Gambia	Central African Republic, Angola, Gabon and Cameroon

In addition, urbanization is incorporated into the model to reflect sparsely inhabited areas and the transition from an agrarian to an industrial environment, in accordance with the work of Muhammad et al (2020). The population density is also used to determine how an increasing population influences CO2 emissions (Chen et al., 2020, Li et al., 2020). Any country with a higher population density appears to be better positioned to benefit from the scaling impacts of infrastructure investments, as well as the ability to reduce Co2 emissions per capita. Likewise, energy consumption (EC) represents a crucial source of Co_2 emissions that may impact Co_2emissions (Chen et al., 2018). The ratio of trade to GDP is explored to verify whether trade impacts environmental degradation through technological and composition effects (see Ogede, 2014; Yang et al. 2020).

Table 2. Sources of Data, Measurement and Variable Definition

Variable(s)	Definition	Source
Carbon dioxide emissions (Co_2)	CO2 emissions (metric tons per capita)	WDI
Energy consumption (EC)	Fossil fuel energy consumption (% of total)	WDI
GDP per capita (GDP)	GDP per capita (current US$)	WDI
Population density (PD)	Population density (people per sq. km)	WDI
Trade (TR)	Trade (% of GDP)	WDI
Urbanization (UR)	Industry value added (% of GDP)	WDI
Income Inequality (INQ)	Gini index (World Bank estimate)	WDI&UNDP
Financial Development (FD)	Domestic credit to the private sector (% of GDP)	WDI

Except for the Gini coefficient index, which was obtained from two secondary sources, the United Nations Development Programme (UNDP) indicators and the World Bank Development indicator, the data series for this study were obtained from the World Bank's World Development Indicators (WDI) (see Table 1). The original dataset is transformed into a panel data format.

3.2. Methodology

Sparse literature has explored the heterogeneous impact of income inequality on carbon emission by panel data. This study aims to investigate whether income inequality impacts Co_2emissions and how financial development impacts Co_2emissions. Our panel sample has 26 countries and 15years and has fewer years than cross-sample units. Given the above, the study espoused the Panel Autoregressive Distributed Lag (PARDL) as proposed by Pesaran and Smith (1995) and Presaran et al. (2001). According to Fazli and Abbasi (2018) and Magweva & Sibanda (2020), the methodology derives most of its merits from the traditional ARDL model. These include the fact that the panel ARDL model can instantaneously gauge short and long-run dynamic forces. The methodology can also utilize the mixed order of integration and different lags on different variables (Shin, Yu, & Greenwood-Nimmo, 2014). Thus, following Pesaran et al. (2001), an ARDL (p, q, q,…q) is structured as:

$$CO_{2_{it}} = \sum_{j=1}^{p} \alpha_{ij} CO_{2_{i,t-j}} + \sum_{j=0}^{p} \delta_{ij} X_{i,t-j} + \mu_i + \epsilon_{it} \qquad (1)$$

where Y represents carbon dioxide emission (CO_2), X represents the vector of the index of income inequality (INQ), energy consumption (EC), GDP per capita (GDP), population density (PD), trade as a percentage of GDP (TR), urbanization (UR) and financial development (FD). Thus, the model is transformed to become equation (2) after re-parameterized the model eq. (1),

$$\Delta CO_{2_{it}} = \varphi_i \left(\Delta CO_{2_{i,t-1}} - \beta_i X_{it} \right) + \sum_{j=1}^{p-1} \alpha_{ij} CO_{2_{i,t-j}} + \sum_{j=0}^{q-1} \delta_{ij} \Delta X_{i,t-j} + \mu_i + \epsilon_{it} \qquad (2)$$

where β_i denotes various vectors that gauge the long-run impact of the explanatory variables while φ_i standing for the error corrector mechanism effect (ECT). The error terms ϵ_{it} are independently dispersed across time and units. Thus, to apply this methodology, the variables have to be a mixture of I(1) and I(0), and for the model to be read as an error correction mechanism as stated in Eq. (2), the variables have to be cointegrated. Consequently, the ensuing discussion will focus on stationary tests, description of statistics and finally, the panel ARDL estimator.

4. Empirical Results and Discussions

4.1. Stationary Test and Descriptive Statistics

We establish the stationary level of the variables using Hadri (2000) Lagrange multiplier (LM) tests. This second-generation unit root test has the null hypothesis that states that all the panels are stationary. Table 3 provides information on the Hadri LM panel unit root test for Sub Sahara Africa countries. The Hadri LM unit root test results revealed that all the variables are integrated of order zero. The descriptive statistics based on pooled observations data set presented in Table 4 showed that the mean value of all the variables tend towards the maximum values, which indicate that their values are generally high. The standard deviation of all the variables is relatively high, which indicates that a high degree deviation from the actual data resulted from their mean values. The descriptive data based on pooled observations statistics provided in Table 4 confirmed that the mean of all the variables tend closer to the maximum values, which suggests that their values are normally excessive.

Table 3. Hadri LM Unit Root Test

Variables	t-statistics	P-values	Level
CO_2	5.6885	0.0000*	I(O)
INQ	2.9412	0.0000*	I(O)
EC	22.9867	0.0000*	I(O)
GDP	22.2382	0.0000*	I(O)
PD	14.4316	0.0000*	I(O)
TR	10.5255	0.0000*	I(O)
FD	10.4001	0.0000*	I(O)
UR	6.0065	0.0000*	I(O)

Notes: Time trend not included. **(*)** denote probability statistical significance at the 1%.

The standard deviation of all the variables is rather high, which shows that an excessive degree deviation from the observations resulted from their mean. Precisely, the carbon emission has a maximum value of 9.9795 and a minimum value of 0.0209 with a mean of 0.8219, which is closer to the minimum. The standard deviation value shows the above result as it is closer to the mean. Also, the maximum value of income inequality is 64.800, and the minimum is 31.500 showing that the mean value is closer to the maximum. The result showed that the flow of carbon emission and inequality in SSA countries are stable.

Table 4. Summary Descriptive Statistics

Variable/ Statistics	**CO_2**	**INQ**	**EC**	**FD**	**GDP**	**PD**	**TR**	**UR**
Mean	0.8219	43.575	28.844	22.230	1585.6	94.014	66.123	23.524
Median	0.2552	42.600	21.310	14.516	780.55	57.056	57.949	21.942
Maximum	9.9795	64.800	88.148	160.13	10809.6	498.66	311.35	61.884
Minimum	0.0209	31.500	9.2000	1.2480	128.34	2.3172	20.723	4.9996
Std. Dev.	1.7496	7.7299	18.773	27.621	1992.2	103.49	34.581	10.719
Skewness	4.0052	0.9403	1.3984	3.5489	2.3591	1.9802	3.0993	1.5651
Kurtosis	18.886	3.4457	4.5879	15.761	8.0984	6.7356	18.343	5.9002
Jarque-Bera	548.7	64.751	179.28	3695.9	836.41	513.75	746.4	315.63
Probability	0.1325	0.2142	0.1032	0.2011	0.1872	0.1522	0.1539	0.2001

4.2. Results and Discussions

The study employed Panel Autoregressive Distribution Lags (ARDL) to deconstruct the impact of income inequality on carbon emission in SSA, and the outcome is reported as follows. The result shows that income inequality, population density, and financial development are positively significant in the long run, and trade to GDP is inversely significant with carbon emission in SSA. Furthermore, from Table 5, it is evident that energy consumption, per capita income and urbanization, are not statistically significant, showing that they did not aid carbon emission in SSA. The meaning of this result is that in the long run, an increase in income inequality, population and poor financial development aid carbon emission in SSA and that improvement in the trade as a percentage of GDP reduces carbon emission in SSA. Also, an increase in energy consumption, per capita income, and urbanization does not significantly impact carbon emission in SSA. This result submits that a higher level of income inequality, population, and poor financial development reduce the desired level of carbon emission in the long run. In contrast, an improvement in the trade as a percentage of GDP moved the region closer to the desired carbon emission rate in SSA.

The findings that in the long run, income inequality, population density, energy consumption, urbanization and financial development are positively significant with carbon emission are tandem with the empirical work of Sharma (2011), Solarin and Lean (2016), Hao et al. (2016), (Chen et al., 2018) and Muhammad et al. (2020). For instance, Sharma (2011) argued that urbanization negatively impacts carbon emissions. Besides, the study's findings that there exists a positive nexus between population density and Co_2emissions supports the findings of Chen et al. (2020) and Li et al. (2020). These authors contended that countries with higher population densities are more likely to have more access to the scale effects of public transportation and other public services and the ability to reduce Co_2emissions. Given that the ratio of trade to GDP is explored to verify whether trade impacts environmental degradation through technological and composition effects, our findings reveal a negative nexus with regards to the contention. The results are contrary to the findings of Antweiler et al. (2001), Yang et al. (2020); Chen et al. (2020), who suggests that countries gain from technical spill-overs initiated by the flow of commodities as well as comparative advantage in industries in terms of the global specialization. It is obvious from Table 5 that there are long-run relationships between carbon emissions and independent variables. It implies a long-run causality jointly running from the income inequality, population density, financial development, trade to GDP, energy consumption, per capita income and Urbanization in SSA. The errors in carbon emission in the previous years will be corrected in the current year by the dependent variables at an adjustment speed of 17%% annually.

Table 5. Long Run and Short-Run Panel ARDL Lag Result

Variables	Coefficients	Std. Err	Variables	Coefficients	Std. Err
Long run result			**Short-run result**		
INQ	0.01223	0.0019***	INQ	0.0007456	0.0022
EC	000580	0.0011	**EC**	0.0151548	0.00922
GDP	0.00003	0.0000**	**GDP**	-0.00000	0.00004
PD	0.00231	0.0006***	**PD**	-0.235617	0.23284
TR	-0.00175	0.0004***	**TR**	0.000066	0.00091
FD	0.01392	0.00184	**FD**	-0.0019912	0.00372
UR	0.00195	0.00123	**UR**	-0.0040585	0.08153
COINTEQ01	-0.169{0.083}**				
Normality Test	1.3013 {0.183}				

*** ,** and * represent statistical significance level at 1%, 5% and 10%, respectively.

In the short run, all the exogenous variables, income inequality, population density, financial development trade to GDP, energy consumption, per capita income and urbanization, are not statistically significant. It implies that all the variables have no significant impacts on carbon emission in SSA. Furthermore, from Table 5, income inequality, energy consumption and trade to GDP have positive relationships with carbon emission in SSA. In contrast, per capita income, population density and urbanization have an inverse relationship with carbon emission in SSA. The result suggests that income inequality does not have a significant impact on carbon emission in SSA in the short run though its effect is positive. In all, the result suggests that income inequality significantly deter the desired level of carbon emission in SSA countries.

Table 6. Result of an Interaction Effect between Income Inequalities and Financial Development

Variables→	Coefficients	Std. Err	P-values
INQ	0.108544	0.061264	0.0442
INQ_SQ	-0.001418	0.000686	0.0393**
FD_INQ	0.000985	3.81E-05	0.0000***
C	-2.212919	1.365780	0.1059

*** ,** and * represent statistical significance level at 1%, 5% and 10%, respectively.

The interaction between income inequality and financial development on carbon emission is represented in Table 6. The findings reveal that financial development plays a significant role as a moderator in increasing carbon emissions from income inequality. This result implies a significant interactive effect between income inequality and financial development, which also contributes significantly to the carbon emission in SSA. Given the Jarque-Bera statistics of 1.3013 and the corresponding probability of 0.183 as indicated in Table 5, it showed that the residuals from our model are normally distributed.

5. Conclusion

Greenhouse gas emissions and income disparity have become crucial unclear challenges threatening the environment and humanity over the past three decades. Erstwhile environment studies have claimed that greater energy use is a contributing factor to poor environmental quality. Following that, the sub-environmentally region's unsustainable economic expansion has resulted in a surge in CO2 emissions, the primary driver of climate change. As a result, a better understanding of the relationship underlying income disparity and CO2 emissions in SSA will assist in the formulation and application of strategies that will avert both global warming risks and inequalities. This one-of-a-kind study adds to the repository of learning on the subject by empirically investigating the nexus between income inequality and CO2 emissions in the selected SSA countries from 2004 to 2019. The study employed both panel autoregressive distributed lag model (ARDL) and causality test to investigate whether the income inequality impacts the Co_2 emissions and how the interaction between income inequality and financial development impacts Co_2emissions in SSA from 2004–2019.

The outcomes of the study reveal that financial development and all other control variables except trade/GDP ratio positively impact carbon emission in SSA in the long run. The result shows that the trade/GDP ratio is inversely related to carbon emission in SSA. The results suggest that an increase in income inequality, population and poor financial development aid carbon emission in SSA. At the same time, an improvement in the trade as a percentage of GDP reduces carbon emission in SSA. In the short run, all the exogenous variables, income inequality, population density, financial development trade to GDP, energy consumption, per capita income and urbanization, are not statistically significant. It implies that all the variables have no significant impacts on carbon emission in SSA. In contrast, per capita income, population density and urbanization have an inverse relationship with carbon emission in SSA. The result suggests that income inequality does not have a significant impact on carbon emission in SSA in the short run though its effect is positive. The findings from the analysis of the interaction between income inequality and financial development on carbon emission reveal that that financial development plays a significant role as a moderator in increasing carbon emission coming from income inequality. The study concludes that financial development plays a significant impact as a moderator in increasing carbon emissions coming from income inequality.

Given the study's findings, the ensuing policy thrust is proposed for implementation to minimize co2 emissions in the selected SSA nations. To begin, the revelation that financial development plays a significant role as a moderator in increasing carbon dioxide emissions caused by income inequality indicates a strong moderating impact between income inequality and financial development, which also contributes significantly to carbon emissions in SSA. The governments of these nations and other stakeholders should work to combine economic disparity and financial instability to prevent harm to the environment by cutting carbon emissions. The selected nations should hasten urbanization to encourage the coordinated growth of cities to circumvent overcrowding in major cities. Similarly, the discovery that energy use has a favourable impact on CO2 emissions. This finding indicates that energy usage is critical in limiting carbon emissions. According to the findings, boosting energy consumption by raising expenditures in environmental research projects and fostering self-determining innovation will maximize the environmental quality among SSA nations.

References

Antweiler, W.; Copeland, B. R. & Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review*, 91, pp. 877–908. https://doi.org/10.1257/aer.91.4.877.

Argyriou, M. (2019). *There's no Reason Countries can't Still Prosper without Increasing Emissions*. pp. 1–5. Available online: https://theconversation.com/developing-countries-can-prosper-withoutincreasing-emissions-84044.

Asongu, S. & Vo, X. (2020). *The Effect of Finance on Inequality in Sub-Saharan Africa: Avoidable CO2 emissions Thresholds.* African Governance and Development Institute WP/20/030

Baek, J. & Gweisah, G. (2013). Does income inequality harm the environment? Empirical evidence from the United States. *Energy Policy*, 62, pp. 1434–1437, doi:10.1016/j.enpol.2013.07.097.

Bai, C.; Feng, C.; Yan, H.; Yi, X.; Chen, Z. & Wei, W. (2020). Will income inequality influence the abatement effect of renewable energy technological innovation on carbon dioxide emissions? *Journal of Environment Management*, 264, p. 110482. https://doi.org/ 10.1016/j.jenvman.2020.110482.

Barra, C. & Zotti, R. (2017). Investigating the non-linearity between national income and environmental pollution: International evidence of Kuznets curve. *Environmental Economics and Policy Studies*, 20, pp. 179–210, doi:10.1007/s10018-017-0189-2.

Borghesi, S. (2006). Income Inequality and the Environmental Kuznets Curve. *Environment, Inequality and Collective Action*, Routledge, Taylor & Francis Group, USA.

Boyce, J. K. (1994). Inequality as a cause of environmental degradation. *Ecological Economics*, 11, pp. 169–178, doi:10.1016/0921-8009(94)90198-8.

Chen, J.; Wang, P.; Cui, L.; Huang, S. & Song, M. (2018). Decomposition and decoupling analysis of CO2 emissions in OECD. *Applied Energy* 231, pp. 937–950. https://doi.org/ 10.1016/j.apenergy.2018.09.179.

Chen, J.; Xian, Q.; Zhou, J. & Li, D. (2020). Impact of income inequality on CO2 emissions in G20 countries. *Journal of Environmental Management*, 271110987

Drabo, A. (2011). Impact of income inequality on health: does environment quality matter? *Environment and Planning A* 43 (1), pp. 146–165.

Golley, J. & Meng, X. (2012). Income inequality and carbon dioxide emissions: the case of Chinese urban households. *Energy Economics* 34 (6), pp. 1864–1872.

Grossman, G. M. & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, 110, pp. 353–377. https://doi.org/10.2307/2118443.

Grunewald, N.; Klasen, S.; Martínez-Zarzoso, I. & Muris, C. (2017). The trade-off between income inequality and carbon dioxide emissions. *Ecological Economics*, 142, pp. 249–256, doi:10.1016/j.ecolecon.2017.06.034.

Guo, L. (2014). CO2 Emissions and regional income disparity: evidence from China. *The Singapore Economic Review*, 59, p. 1450007. https://doi.org/10.1142/S0217590814500076.

Hailemariam, A.; Dzhumashev, R. & Shahbaz, M. (2019). Carbon emissions, income inequality and economic development. *Empirical Economics*. https://doi.org/10.1007/ s00181-019-01664-x.

Hao, Y.; Chen, H. & Zhang, Q. (2016). Will income inequality affect environmental quality? Analysis based on China's provincial panel data. *Ecological Indicators*, 67, pp. 533–542. https:// doi.org/10.1016/j.ecolind.2016.03.025.

Heerink, N.; Mulatu, A. & Bulte, E. H. (2001). Income inequality and the environment: Aggregation bias in environmental Kuznets curves. *Ecological Economics*, 38, pp. 359–367, doi:10.1016/s09218009(01)00171-9.

Hossain, M. S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. *Energy Policy*, *39*(11), pp. 6991-6999.

Huang, Z. & Duan, H. (2020). Estimating the threshold interactions between income inequality and carbon emissions. *Journal of Environment Management*, Vol. 263, 110393. https://doi.org/ 10.1016/j.jenvman.2020.110393.

Hübler, M. (2017). The inequality-emissions nexus in the context of trade and development: a quantile regression approach. *Ecological Economics* 134, pp. 174–185. https://doi. org/10.1016/j.ecolecon.2016.12.015.

Jorgenson, A. K.; Schor, J. & Huang, X. (2017). Income inequality and carbon emissions in the United States: A state-level analysis, 1997–2012. *Ecological Economics*, 134, pp. 40–48, doi:10.1016/j.ecolecon.2016.12.016.

Jorgenson, A.; Schor, J.; Huang, X. & Fitzgerald, J. (2015). Income inequality and residential carbon emissions in the United States: a preliminary analysis. *Human Ecology Review*, 22, pp. 93–105. https://doi.org/10.22459/HER.22.01.2015.06.

Kasuga, H. & Takaya, M. (2017). Does inequality affect environmental quality? Evidence from major Japanese cities. *Journal of Cleaner Productionv*, 142, pp. 3689–3701, doi:10.1016/j.jclepro.2016.10.099.

Knight, K. W.; Schor, J. B. & Jorgenson, A. K. (2017). Wealth inequality and carbon emissions in high-income countries. *Social Currents*, 4, pp. 403–412, doi:10.1177/2329496517704872.

Koenker, R. & Bassett, G. (1978). Regression quantiles. *Econometrica*, 46, pp. 33–50. https:// doi.org/10.2307/1913643.

Krueger, A. B. & Grossman, G. M. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, 110, pp. 353–377.

Li, C.; Zuo, J.; Wang, Z. & Zhang, X. (2020). Production- and consumption-based convergence analyses of global CO2 emissions. *Journal of Cleaner Production* 264, p. 121723. https:// doi.org/10.1016/j.jclepro.2020.121723.

Lin, B. & Xu, B. (2018). Factors affecting CO2 emissions in China's agriculture sector: a quantile regression. *Renewable & Sustainable Energy Reviews*, 94, pp. 15–27. https://doi.org/ 10.1016/j.rser.2018.05.065.

Liu, Q.; Wang, S.; Zhang, W.; Li, J. & Kong, Y. (2019). Examining the effects of income inequality on CO2 emissions: Evidence from non-spatial and spatial perspectives. *Applied Energy*, 236, pp. 163–171, doi:10.1016/j.apenergy.2018.11.082.

Mathonnat, C. & Williams, B. (2020). Does more finance mean more inequality in times of crisis? *Economic Systems.* Doi: https://doi.org/10.1016/j.ecosys.2020.100818.

Muhammad, B. (2019). Energy consumption, CO2 emissions and economic growth in developed, emerging and the Middle East and North Africa countries. *Energy*, 179, pp. 232–245, doi:10.1016/j.energy.2019.03.126.

Muhammad, S., Long, X., Salman, M. & Dauda, L. (2020). Effect of urbanization and international trade on CO2 emissions across 65 belt and road initiative countries. Energy 196, 117102. https://doi.org/10.1016/j.energy.2020.117102.

Ogede, J. S. (2020). Deconstructing the impact of Entrepreneurship on Income Inequality in sub-Saharan Africa Countries (SSA). Economics and Business, Vol. 34, 273–284. oi.org/10.2478/eb-2020-0018

Rafiq, S., Salim, R., & Nielsen, I. (2016). Urbanization, openness, emissions and energy intensity: A study of increasingly urbanized emerging economies. *Energy Economics, 56,* pp. 20–28.

Ravallion, M.; Heil, M.; Jalan, J. (2000). Carbon emissions and income inequality. *Oxford Economic Papers*, 52, pp. 651–669, doi:10.1093/oep/52.4.651.

Ridzuan, A. R.; Ismail, N. A.; Hamat, A.; Md Nor, A. S. & Ahmed, E. M. (2017). Does Equitable Income Distribution Influence Environmental Quality? Evidence from Developing Countries of ASEAN-4. *Pertanika Journal of Social Science and Humanities*, 25 (1), pp. 385 – 400.

Ridzuan, S. (2019). Inequality and the environmental Kuznets curve. *Journal of Cleaner Production*, 228, pp. 1472–1481. https://doi.org/10.1016/j.jclepro.2019.04.284.

Sharma, S. S. (2011). Determinants of carbon dioxide emissions: empirical evidence from 69 countries. *Applied Energy*, 88, pp. 376–382.

Solarin, S. A. & Lean, H. H. (2016). Natural gas consumption, income, urbanization, and CO2 emissions in China and India. *Environmental Science and Pollution Research,* 23, pp. 18753–18765. https:// doi.org/10.1007/s11356-016-7063-9.

Uddin, M. M.; Mishra, V. & Smyth, R. (2020). Income inequality and CO2 emissions in the G7, 1870–2014: Evidence from non-parametric modelling. *Energy Economics*, 88, pp. 104780. doi.org/10.1016/j.eneco.2020.104780.

Vona, F. & Patriarca, F. (2011). Income inequality and the development of environmental technologies. *Ecological Economics* 70, pp. 2201–2213. https://doi.org/10.1016/j. ecolecon.2011.06.027.

Wolde-Rufael, Y. & Idowu, S. (2017). Income distribution and CO2 emission: A comparative analysis for China and India. *Renewable & Sustainable Energy Reviews*, 74, pp. 1336–1345, doi:10.1016/j.rser.2016.11.149.

Yang, B.; Ali, M.; Nazir, M. R.; Ullah, W. & Qayyum, M. (2020). Financial instability and CO2 emissions: Cross country evidence. *Air Quality, Atmosphere & Health*, 13, pp. 1–10. doi:10.1007/s11869-020-00809-7.

Yang, B.; Ali, M.; Hashmi, S. H., & Shabir, M. (2020). Income Inequality and CO2 Emissions in Developing Countries: The Moderating Role of Financial Instability. *Sustainability*, Vol, 12, p. 6810. doi:10.3390/su12176810

Zhang, C. & Zhao, W. (2014). Panel estimation for income inequality and CO2 emissions: A regional analysis in China. *Applied Energy*, 136, pp. 382–392, doi:10.1016/j.apenergy.2014.09.048.