Journal of Environmental Economics and Policy

ISSN: 2160-6544 (Print) 2160-6552 (Online) Journal homepage: www.tandfonline.com/journals/teep20

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To cite this article: Segun Thompson Bolarinwa & Munacinga Simatele (2024) Informality and the climate change-poverty nexus: empirical evidence from African countries, Journal of Environmental Economics and Policy, 13:1, 1-16, DOI: 10.1080/21606544.2023.2195684

To link to this article: https://doi.org/10.1080/21606544.2023.2195684

JOURNAL OF ENVIRONMENTAL ECONOMICS AND POLICY
2024, VOL. 13, NO. 1, 1–16
https://doi.org/10.1080/21606544.2023.2195684

Informality and the climate change-poverty nexus: empirical evidence from African countries

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ABSTRACT

The present paper introduces informality into the climate change-poverty nexus using 40 Sub-Saharan African countries selected from high-, middle and low-income countries between 1990 and 2019. The empirical results show that informality is an important variable that can mitigate the impact of climate change on poverty. The moderation of the poverty-climate change nexus is nonlinear in income. Informality reduces the negative effect of climate change on poverty in middle income countries while exacerbating its effect in low-income countries. Possible channels of influence are identified. Policy makers need to rethink the role of informality in an environment where informality is mainly seen as a nuisance, to see it as an ally that can achieve key results for the fight against environmental degradation and extreme poverty.

ARTICLE HISTORY
Received 28 September 2022
Accepted 22 March 2023

KEYWORDS
Informality; Africa; CO_2; poverty; climate change

1. Introduction

The duo issues of climate change and poverty are two of the prominent and concurrent development problems facing the African continent and thus have attracted the attention of academic research, international organizations and policymakers. The subject matter of poverty becomes more challenging considering the recent sustained growth performance and yet the daunting poverty prevalence on the continent (World Bank Group 2001; Ravallion, Chen, and Sangraula 2009; Bolarinwa, Adegboye, and Vo 2021). Sub-Sharan Africa has the highest poverty incidence in the world (see Figure 1). In addition, the African continent frequently suffers most from global climate disasters despite the 5% negligible contribution to the global greenhouse gases emission (Henderson, Storeygard, and Deichmann 2017; Cobbinah 2021; Finn and Cobbinah 2022). As a result, the United Nations, and other international organizations are championing effective policy formulations for climate change management as articulated in the United Nations' Sustainable Development Goal 13-Climate Action and impacts agenda.

Arguably, one of the most important outcomes of this agenda is the eradication of extreme poverty. The empirical literature shows a negative relationship between climate change and poverty in both developed and developing economies, particularly in Africa (Wang et al. 2020; Dada, Ajide, and Adeiza 2022). Poor households tend to be involved in economic activities that are highly sensitive to climate change because a large proportion of the poor engage in agricultural and primary activities that are associated with climate change. These activities suffer from climate change risks such as a high number of frequent storms, flooding, landslides, heat waves and constraints on freshwater that emanate from climate change risks (Parnell and Walawege 2011; Simatele and Simatele 2015a; Nyantakyi-Frimpong, Arku, and Inkoom 2016; Hallegatte and Rozenberg 2017; Dodman,

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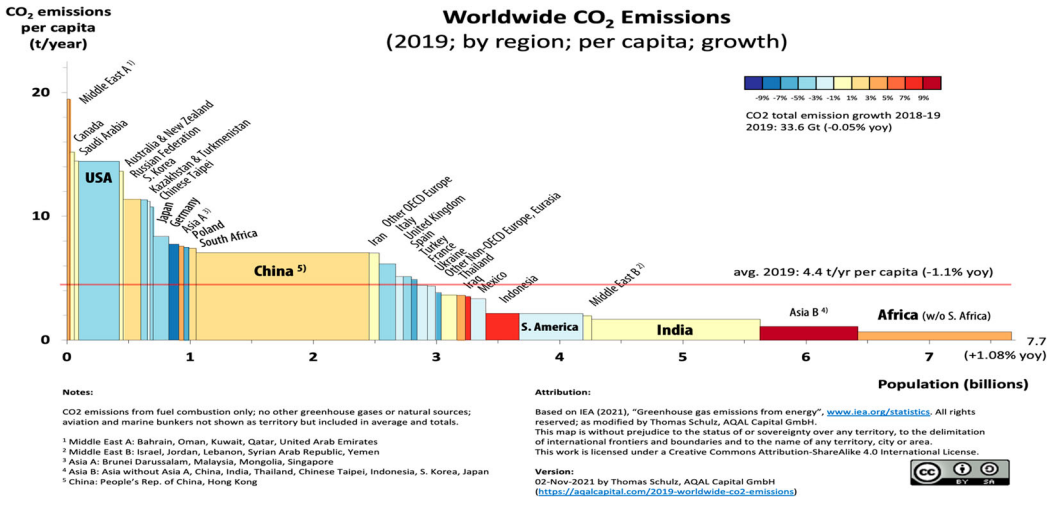

Figure 1. 2020 Worldwide CO_2 emissions (by region, per capita). Source: Greenhouse Gas Emission Across the World. Source and Adopted from Thomas Schulz (2022) and Wikipedia (2022). https://en.wikipedia.org/wiki/Greenhouse_gas_emissions.

Archer, and Satterthwaite 2019; Larsen, Yeshitela, and Mulatu 2019; Finn and Cobbinah 2022). Furthermore, climate change issues in the rural areas drive more rural poor to the urban areas for employment opportunities resulting in increased informal competition, reduced informal wages and the intensity of poverty in urban areas. Evidence also shows that climate disasters increase the probability of workers moving into the informal economy (Garzon and Jose 2017; Mendoza and Jara 2020; Figure 2).

This evidence on the poverty-climate change and informality-climate change nexuses suggests a causal link between poverty, informality and climate change. This relationship is particularly probable in developing countries where a large proportion of the population is involved in precarious

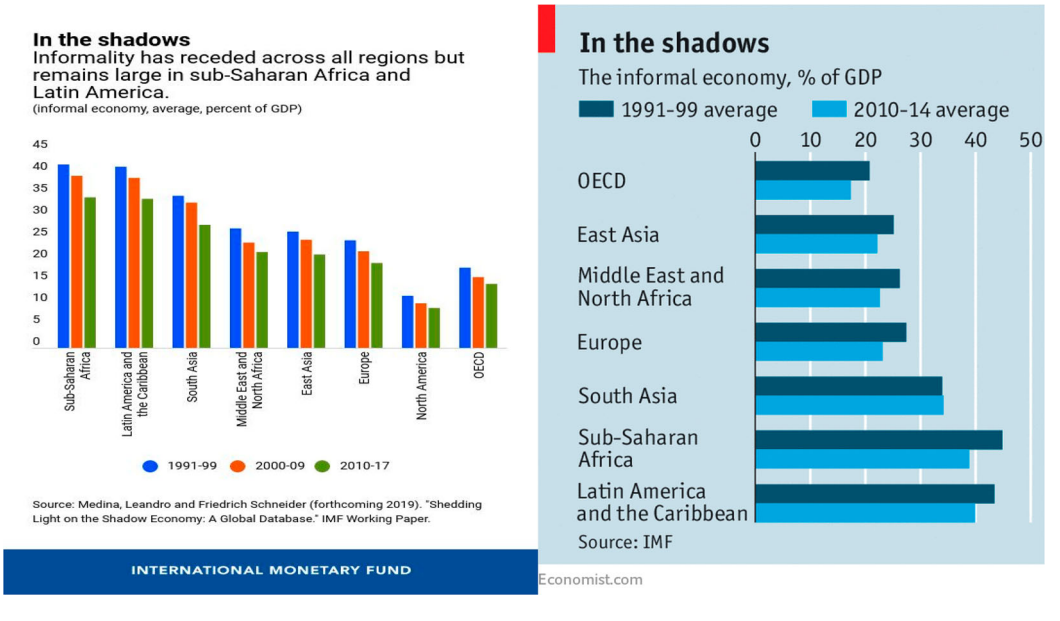

Figure 2. CO_2 emissions and economic growth across the regions.

economic activities in the informal sector. For example, the (ILO 2018) indicates that over 80% of employment in Africa is in the informal sector. Furthermore, it is a known fact that most workers in African informality are poor. If this is the case, the relationship between poverty, climate change and informality should not be seen as a pair of dichotomous nexuses but rather as a relationship with a trio of interlaced and interlinked variables (Figure 3).

Some limited literature that explores this relationship exists. For instance, Scheinberg (2012), Skinner and Watson (2020) and UN-Habitat Report (2018) argued that 'green workers and entrepreneurs' in the informal sector such as waste pickers, street traders and home-based workers are associated with lower carbon footprints because they are associated with natural packaging, recycling, less or no electricity, thus could help in mitigating the effect of climate change. On the other hand, Paz et al. (2015) show that informality contributes more to climate change issues using selected informal sector case studies such as the brick industry, Taxi business and informal mining. This is because the associated firms adopt low-quality machinery that discharges high carbon waste into the environment due to their low financial status (Figure 4).

The present paper contributes to this scanty literature on the link between climate change, informality and poverty by asking two questions. First, does informality provide a moderating effect for the effect of climate change on poverty? Second, if such an effect exists, is this effect non-linear in income so that the effects are different at different levels of poverty? From a research perspective, this implies that more integrated research is needed. From a policy perspective, it would imply that effective policy formulation for poverty reduction needs to be considered in tandem with the effects of climate change on the informal economy and vice versa. The rest of the paper is structured as follows. Following the introduction, Section Two discusses the literature review while section Three presents the methodology. Section Four presents empirical findings and discussions of the results. Lastly, Section Five concludes the paper and proposes recommendations.

2. Brief literature review

The theoretical underpinning of this work is the environmental Kuznets Curve (EKC). The hypothesis provides a sound and theoretical framework for understanding the interactions and

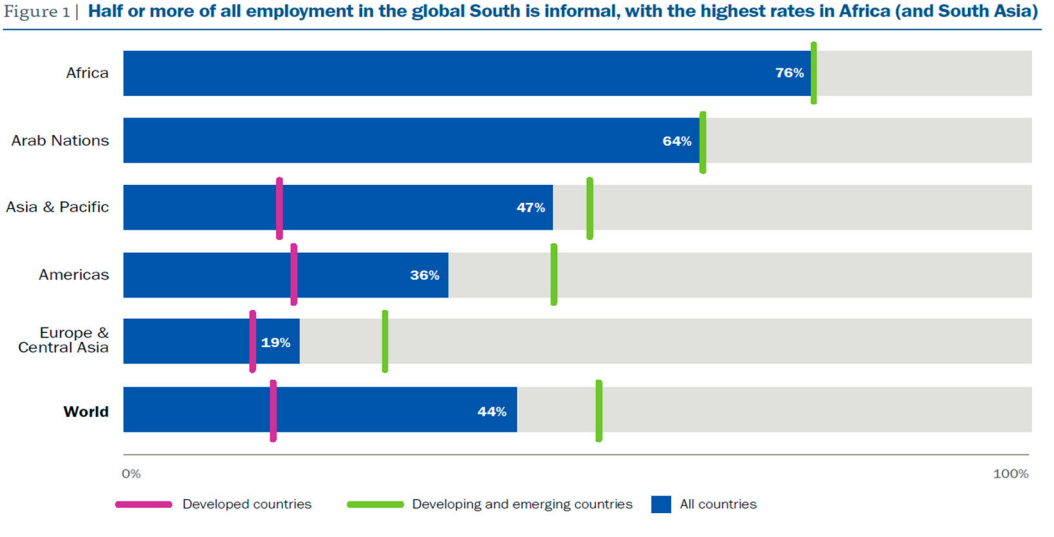

Figure 3. Informality around the regions.

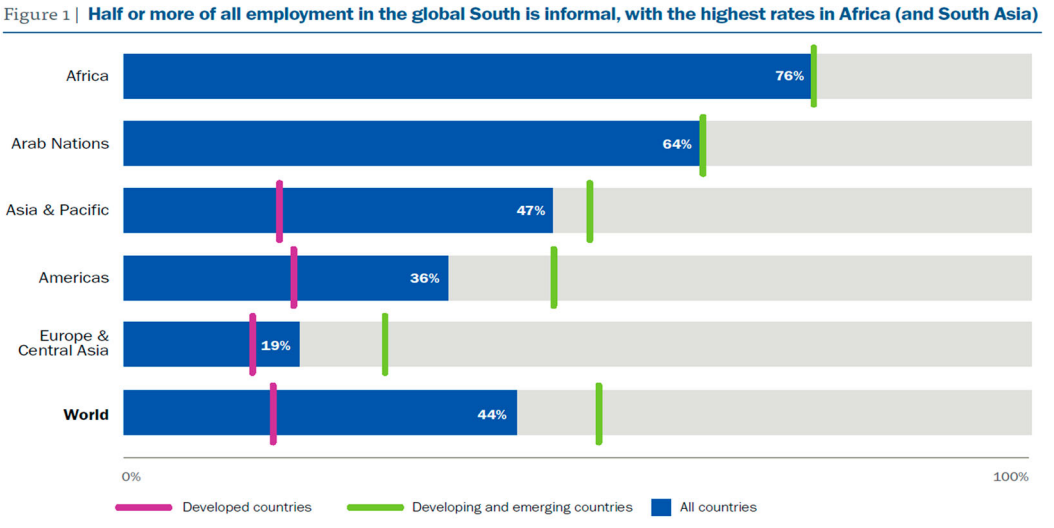

Figure 4. Employment generation in the Global South. Source: Adopted from Medina, Leandro and Friedrich Schneider (2019) from Shedding Light on the Shadow Economy: A Global Database , IMF Working Paper. For the second Graph: adopted from Mark Elliot (2019), '3 ways to get Africa's informal economy on the books'. https://www.weforum.org/agenda/2019/08/3-ways-to-get-africas-informal-economy-on-the-books/.

interrelationships between economic activities and environmental performance (Grossman and Krueger 1991, 1995; Shafik and Bandyopadhyay 1992). The hypothesis proposes an inverted U-shaped relationship between environmental degradation and economic growth. This implies that at the initial level of the development process, the environment suffers from degradation resulting from unregulated and unmanaged economic activities. However, with adequate regulatory policies to regulate economic activities, the damage to the environment is reduced as the economy attains development and later addresses environmental degradation to attain environmental sustainability.

Originally, the hypothesis fails to acknowledge the roles of informality and institutional quality in the environmental-economic growth process, however, recent submissions have acknowledged the roles of these important variables (Swain, Kambhampati, and Karimu 2020; Dada, Ajide, and Adeiza 2022). More recent analysis of the hypothesis incorporates the role of informality in the framework. Besides, the integration of the attributes associated with initial economic development termed, pre-industrial economies in the EKC framework shows that the hypothesis can explain the qualities of most African economies which are largely undeveloped and less industrialized.

This empirical paper brings various strands of literature together. First, the literature shows that there is a positive and significant relationship between poverty and climate change. A significant amount of this literature uses cross country evidence (Masron and Subramaniam 2019; Baloch et al. 2020; Awad and Warsame 2022; Khan, Yahong, and Zeeshan 2022; Koçak and Çelik 2022). Other studies use country-level analysis (Zhao et al. 2021; Dada, Ajide, and Adeiza 2022; Eichsteller, Njagi, and Nyukuri 2022). These papers find a negative relationship between poverty and environmental degradation.

The second strand of literature shows a relationship between informality and climate change. This literature suggests a two-way relationship. The more dominant strand of literature shows that causality runs from informality to climate change but empirical results are contradictory.

The first result indicates that economic activities in the informal sector are mostly pollution-intensive and increase environmental degradation (Dada, Ajide, and Adeiza 2022). For instance, Benkraiem et al. (2019) reported that energy consumption by informal businesses harms the environment. Moreover, Elgin and Oztunali (2014) provided global evidence on informality-environmental pollution. The results show an inverted U relationship with energy usage by firms. The study found that small and large informal firms are associated with a low discharge of pollution while middle-size firms relate to a large discharge of environmental pollution. Related evidence at the micro level suggests that specific activities in the informal sector can contribute positively to the fight against environmental degradation and the effects of climate change. Evidence shows that waste management schemes that integrates informal recycling have lower greenhouse gas emissions (Skinner and Watson 2020).

The third strand of literature relates to the relationship between poverty and informality. Here, the evidence suggests a bi-directional relationship whose impact is subject to the income level of a country (Wu and Schneider 2019; Bolarinwa and Simatele 2022). At lower levels of income, informality has a reducing effect on poverty suggesting that it is central in fighting severe poverty. On the other hand, informality tends to increase poverty in countries at higher levels of income. A final and emerging strand of literature suggests that climate change can affect participation in the informal sector. Studies by Mendoza and Jara (2020) and Paz et al. (2015) show that climate change induced natural disasters increase participation in the informal sector.

The reliance on subsistence and informal agriculture by the poor for example, means that climate change induced increased temperatures and the resultant droughts and floods will negatively affect the livelihoods of the poor who lack alternatives and have very few assets for adaptation and mitigation (Simatele and Simatele 2015b; Dodman, Archer, and Satterthwaite 2019). Similarly, the urban poor who are highly reliant on the informal economy are particularly vulnerable to climate change. Increasing temperatures affect not only their economic activities (Simatele and Simatele 2015b; Hallegatte et al. 2016) but also their health (Kubicz et al. 2021; Alcayna et al. 2022; Dodman et al. 2022), and settlements through increased flooding (Simatele and Simatele 2015b; Dodman, Archer, and Satterthwaite 2019). Given these strands of literature, it is reasonable to assume that informality can moderate the effect of climate change on poverty. On the one hand, activities such as waste picking in the informal sector are expected to mitigate the impact of climate change on poverty. On the other hand, environmentally degrading informal activities are expected to exacerbate the effects of climate change on poverty.

3. Methodology

3.1. The empirical model

Following the extant literature on the drivers of poverty (Bolarinwa, Adegboye, and Vo 2021; Dollar and Kraay 2002; Ravallion and Datt 2002; Odhiambo 2010), the following empirical models are specified for the study:

$$\begin{aligned} POV_{it} = {} & \alpha_1 POV_{it-1} + \theta_1 FIND_{it} + \theta_2 ECG_{it} + \theta_3 INQ_{it} + \theta_4 SCHENR_{it} + \theta_5 TRADE_{it} \\ & + \theta_6 CO_2 it + \theta_7 INFORMAL_{it} + \mu_i + \varepsilon_{it} \quad for \quad i \\ & = 1, \ldots, n; \; t = 1, \ldots T \end{aligned} \tag{1}$$

In Equation (1), the POV, FIND, ECG, INQ, SCHENR, TRADE, CO_2 and INFORMAL represent poverty, financial development, economic growth, inequality, school enrolment, trade, CO_2 emission and informality. To investigate the effectiveness of informality-based climate change policies for addressing poverty in Africa, the interaction of informality and climate change is

introduced into the model. This is illustrated in Equation (2) as follows:

$$POV_{it} = \alpha_1 POV_{it-1} + \theta_1 FIND_{it} + \theta_2 ECG_{it} + \theta_3 INQ_{it} + \theta_4 SCHENR_{it} + \theta_5 TRADE_{it} + \theta_6 CO_2 it + \theta_7 INFORMAL_{it} + \theta_8 (CO_2 * INFORMAL) + \mu_i + \varepsilon_{it} \quad for \quad i = 1, \ldots, n; \; t = 1, \ldots T \tag{2}$$

The control variables are selected due to their effects on the model. Financial development through financial access reduces poverty (Odhiambo 2010; Rashid and Intartaglia 2017); economic growth reduces poverty through its redistributive effects (Dollar and Kraay 2002; Ravallion and Datt 2002). Also, inequality increases the gap between the rich and the poor thereby allocating more finance to the rich at the expense of the poor. School enrolment reduces poverty through its leverage effect and chances of providing gainful employment opportunities (Bolarinwa, Adegboye, and Vo 2021) while trade openness increases growth which later translates to poverty reduction (Dada, Ajide, and Adeiza 2022). The interaction of both informality and carbon emission implies that simultaneous actions of both are expected to have a significant effect on poverty reduction in Africa.

3.2. Method of analysis

One major weakness of the Ordinary Least Square is the inability to address simultaneity and endogeneity inherent in panel analysis. Moreover, the dynamics have been acknowledged in poverty analysis (Bolarinwa, Adegboye, and Vo 2021). Extant studies captured this attribute by introducing the lag of poverty into the empirical models. Both dynamics and endogeneity issues are not adequately addressed in the Ordinary Least Square (OLS). Hence, the present study adopts the generalized method of moments (GMM) to estimate the relationship, following extant literature (Masron and Subramaniam 2019; Baloch et al. 2020). Specifically, the paper adopts the system GMM (Arellano and Bover 1995; Blundell and Bond 1998). SGMM addresses issues with small sampling bias, persistence and issues associated with unbalanced panels.

3.3 Sources of data and measurement

The paper adopts the data of forty (40) countries selected from lower-income, lower-middle and high-income Sub-Saharan Africa during the periods between 1991 and 2019, following the United Nations Income economic grouping (See Table 1). The selection of these countries is constrained by data availability. The paper relies on the World Bank Database, 2022 for most of the data adopted asides from inequality. The inequality data is sourced from the Standardized World Income Inequality Database (SWIID), an inequality database created and maintained by Solt (2009). The data are based on the Luxembourg Income Study (LIS) along with the United Nations University World Income Inequality Database (WIID). The measures and sources of all data are shown in Table 2. Following the literature (Arestis and Caner 2010; Rashid and Intartaglia 2017; Bolarinwa, Adegboye, and Vo 2021), the paper adopts a four-year average to address short-run disturbances of the business cycle and to maximize country observations. Also, the panel is segregated into high- and low-income countries to provide empirical evidence from income levels, using 20 countries from each segment.

Table 1. Countries adopted in the study according to income grouping.

Upper middle income Countries ($3,896 – $12,055)	Lower middle income Countries ($996 – $3,896)	Lower-income countries ($996 or Lower)
Seychelles, Equatorial Guinea, Botswana, Gabon, Mauritius, Namibia, and South Africa.	Angola, Cameroon, Cape Verde, Congo, Cote d'Ivoire, Ghana, Kenya, Lesotho, Mauritania, Nigeria, Sao Tome, and Principe, Swaziland, and Zambia.	Benin, Burkina Faso, Central African Republic, Chad, Democratic Republic of Congo, Eritrea, Ethiopia, Gambia, Liberia, Malawi, Mali, Mozambique, Niger, Rwanda, Senegal, Tanzania, Togo, Sierra Leone, Uganda and Zimbabwe.

Table 2. Data, sources and measurement.

Indicators	Measurement	Source
Informality 1	Based on Dynamic general equilibrium model-based (DGE) estimates of informal output (% of official GDP).	World Bank Informality Database (WBID), 2022.
Informality 2	Based on Multiple indicators multiple causes model-based (MIMIC) estimates of informal output (% of official GDP).	WBID
Poverty 1	The poverty gap at $1.90 a day (2011 PPP) is the mean shortfall in income or consumption from the poverty line of $1.90 a day, expressed as a percentage of the total population.	World Bank Poverty Database (WBPD), 2022.
Poverty 2	The national poverty headcount ratio is the percentage of the population living below the national poverty line of $1.90 per day (2011 PPP).	World Bank Development Database
Poverty 3	Poorest quintile: This is the ratio of income of the economy that falls to the poorest 20% of the population.	World Bank Development Database
Poverty 4	The poverty gap at $3.20 a day (2011 PPP) is the mean shortfall in income or consumption from the poverty line of $3.20 a day, expressed as a percentage of the total population.	World Bank Development Database
Economic Growth	GDP per capita is gross domestic product divided by population, expressed in constant 2015 U.S. dollars.	World Bank Development Database
Carbon Emission	This is measured as the proportion of carbon emission to GDP in a given year.	
Income Inequality	This is the GINI of household income.	Standardized World Income Inequality Database (SWIID).
School Enrolment	This is the ratio of secondary school enrolment to the total population.	World Bank Development Database
Financial Development	This measures the financial deepening of the real sector, measured as the ratio of private credit to GDP	World Bank Development Database

4. Empirical results and discussion

4.1. Descriptive statistics and unit root results

The discussion of the empirical results starts with the descriptive analysis, to provide an overview of the variables. The results are presented in Table 3. For an adequate understanding of the attributes of poverty in Africa, four different measures are used: poverty headcount at $1.90 and poverty gap at $1.90 represent severe poverty, the poverty headcount at $3.20 and poverty gap at $3.20 capture mild poverty status. Overall, 41% of the African population falls below the severe poverty line using the headcount measure. However, there is a great variation across countries for the different measures of poverty. For example, only 1% of the population is considered severely poor in the richest country compared to 94% of the population in the poorest country. Similarly, mild poverty measured using the headcount measure is at an average of 31% for the region but country levels vary from only 4% in to 98%.

The data also shows high and varying levels of informality using both measures. On average, 40% of the economic activities take place in the informal sector. The most industrialized African

Table 3. Descriptive statistics of the variables.

Variables	Mean	Std Dev.	Min	Max
Informality1	39.74513	8.60296	20.66142	64.47993
Informality2	41.15652	8.46328	21.44893	62.05723
Carbon Emission	0.98308	1.769311	0.0011149	10.76711
GDPPC	2247.493	3175.492	193.8673	18654.16
School Enrol.	41.07787	22.2174	5.21012	107.1769
Financial Dev.	21.59889	23.5088	0.1000	148.6112
Trade openness	80.83003	46.07058	23.2	462.1821
PovertyG$1.90	16.0268	1.520228	0.1	63.6
PovertyG$3.20	31.1808	11.21269	0.4	77.1
Poverty HC$1.90	40.6081	15.66819	0.2	94.1
Poverty HC$3.20	62.74422	23.96611	1.1	98.5

economy has only 21% of the activities in the informal while the most informal African country reports 64% of economic activities in this sector. The two measures of informality give very similar levels of informality. The CO_2 emission as a proportion of GDP show that carbon emissions are quite low in Africa. The variation between countries is also low with a standard deviation of 1.8. Income variations are quite large with a minimum per capita income of $194 per year and a maximum of $18,654. These large differences justify the segregation of the countries into income groups to provide a better understanding of the relationships among the key variables.

The unit root tests are run using five different tests and the results are presented in Table 4. The results show that inequality and school enrolments are I(1) while the rest of the variables are I(0). This mix suggest that ordinary least square method is not appropriate for the estimation of the models. Instead, the System generalized Method of Moments (GMM) is used for the estimation of the results. The adoption of GMM is also in line with related literature. The arguments we make for the possible links between the key variables of informality, poverty and climate change imply some possible feedback relationships which cannot be accounted for in the ordinary least squares method. These dynamics and possible endogeneity in the relationship have been accounted for in the literature through the use of GMM (Khan, Yahong, and Zeeshan 2022; Koçak and Çelik 2022). The paper investigates the correlation between the variables. The result is presented in Table 5. Although few coefficients are high, the system GMM addresses the inherent issue of simultaneity.

4.2. Poverty, climate change and informality: baseline results

We start the analysis with baseline estimations of the poverty-informality and poverty-climate change nexuses. The results are presented in Table 6 (for high income countries) and Table 7 (for low-income countries). Each table presents results for four models; each model using a different measure of poverty. The results reported here use the DGE measure of informality. Robustness results using the MIMIC measure are reported in the appendix. In all the models, the Sargan test shows that the estimates are stable. This is justified by the satisfaction of the condition of the overidentifying restriction of the null hypothesis that shows the instruments adopted in the models do not correlate with the error term. Similarly, the Arellano and Bond test of autocorrelation also shows that the models do not suffer from the issue of autocorrelation. Although most of the models suffer from the first-order autocorrelation, AR (1), test, this is not an issue as they are corrected by second-order autocorrelation AR(2) (Arellano and Bover 1995). Hence, the estimates are consistent and reliable.

In general, the results in line with existing literature. Climate change has a positive effect on poverty in both low- and middle-income countries, although this effect is only significant for extreme

Table 4. Unit rot test of the variables.

Variables/Tests	LLC	Breitung	IPS	ADF-Fisher	PP-Fisher
Informality1	−8.7504***	−3.6143***	−3.6143***	81.0128***	220.940***
Informality2	−13.7339***	−7.83492***	−12.4253***	232.542***	254.150***
Carbon Emission	−14.1946***	−10.2977***	−10.2826***	368.708***	829.359***
Inequality	−7.9901***	9.1377	−2.2666**	77.2194	93.5650**
ΔInequality	−19.9515***	−2.8675***	−5.7846***	136.600***	135.276***
GDPPC	−21.8616***	−14.7881***	−22.4847***	574.770***	835.168***
School Enrol.	−3.85153***	9.35678	4.45209	56.7901	58.2738
ΔSchool Enrol.	−350.676***	2.7E-12	−7.10831***	212.401***	230.102***
Financial Dev.	−11.7528***	−4.5194***	−7.5809***	221.938***	491.743***
Trade openness	−3.40603***	−2.02710**	−1.93356**	120.091***	121.259***
PovertyG$1.90	−11.7528***	−4.5194***	−7.5809***	221.938***	491.743***
PovertyG$3.20	−8.7504***	−3.6143***	−3.6143***	81.0128***	220.940***
Poverty HC$1.90	−6.45098***	−3.61376***	−4.45929***	157.502***	168.910***
Poverty HC$3.20	−14.1946***	−10.2977***	−10.2826***	368.708***	829.359***

Note: Δ represents first difference and ***,** and * represents 1%, 5% and 10% significant levels respectively.

Table 5. Correlation matrix of the variables.

	Informality1	Informality2	Carbon	GDPPC	School Enr	Financial D	Trade	PovertyG$1.90	PovertyG$3.20	Poverty HC$1.90	Poverty HC$3.20
Informality1	1.0000										
Informality2	0.8465***	1.0000									
Carbon Emission	−0.3877***	−0.3877***	1.0000								
GDPPC	−0.3906***	−0.4018***	0.8726***	1.0000							
School Enrolment	−0.4379***	−0.4340***	0.4702***	0.5057***	1.0000						
Financial Dev.	−0.4279***	−0.4462***	0.5178***	0.3166***	0.6067***	1.0000					
Trade openness	−0.1582***	−0.2591***	0.2687***	0.3774***	0.1936***	0.2482***	1.0000				
PovertyG$1.90	0.3862***	0.3896***	−0.2708***	−0.3311***	−0.5314***	−0.3786***	−0.2141***	1.0000			
PovertyG$3.20	0.4509***	0.4517***	−0.3380***	−0.4205***	−0.6146***	−0.4198***	−0.2595***	0.9630***	1.0000		
Poverty HC$1.90	0.4401***	0.4384***	−0.3266***	−0.4074***	−0.6092***	−0.4144***	−0.2530***	0.9570***	0.9971***	1.0000	
Poverty HC$3.20	0.4951***	0.4971***	−0.3943***	−0.4994***	−0.6566***	−0.4313***	−0.2954***	0.8279***	0.9464***	0.9430***	1.0000

Table 6. Drivers of Poverty in Africa in High-Income African Countries: The Role of Climate Change: Informality 1.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
Lag of Poverty	0.3354***(0.0969)	0.4477***(0.1005)	0.6007***(0.1094)	0.4797***(0.1141)
Informality	0.3066***(0.0984)	0.3743**(0.1534)	0.5519***(0.1708)	0.5695***(0.1667)
CO_2 Emissions	1.1166**(0.5014)	2.1813***(0.4323)	2.4559**(1.0646)	0.9661(1.0162)
Inequality	−0.0159(0.0785)	0.0186(0.0872)	−0.0180(0.1538)	0.2669**(0.1239)
GDPPC	−0.0007**(0.0004)	−0.0008(0.0006)	−0.0011(0.0008)	−0.0009*(0.0005)
School Enrolment	−0.0279(0.0265)	−0.0012**(0.0489)	−0.1397(0.1361)	−0.2345**(0.1015)
Financial Dev.	−0.0194(0.0394)	−0.0019(0.0534)	0.0007(0.0954)	0.1221(0.0931)
Trade Openness	0.0086(0.0129)	0.0350**(0.0161)	0.0522**(0.0251)	0.0795**(0.0396)
F-Test(Prob.)	56993(0.000)	424.89(0.000)	2384(0.000)	8576(0.000)
Sargan Test(Prob.)	13.6772(0.8022)	11.9677(0.8870)	8.4092(0.4935)	11.7732(0.8951)
AR(1)(Prob.)	−1.6261(0.1039)	−2.4758(0.0133)	−2.6214(0.008)	−2.2502(0.0244)
AR(2)(Prob.)	1.5428(0.1229)	1.9799(0.1477)	2.1348(0.1328)	1.5446(0.1224)
Number of Countries	20	20	20	20

Table 7. Drivers of Poverty in Low-Income African Countries: The Role of Climate Change: Informality 1.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
Lag of Poverty	0.0893**(0.0352)	0.0309(0.0571)	0.0223(0.0746)	−0.1454(0.1306)
Informality	0.7878***(0.0641)	1.2481***(0.1189)	1.6287***(0.1738)	2.2434***(0.2761)
CO_2 Emissions	15.8540*(8.8246)	12.5185(8.1535)	10.5962(10.268)	0.0991(5.8111)
Inequality	−0.0007(0.0006)	−0.0013***(0.0004)	−0.0015**(0.0006)	−0.0019***(0.0006)
GDPPC	−0.0287***(0.0034)	−0.0320***(0.0046)	−0.0377***(0.0060)	−0.0280***(0.0052)
School Enrolment	−0.0046(0.0576)	−0.0398(0.0727)	−0.1233(0.1037)	−0.0896*(0.0530)
Financial Dev.	−0.3166**(0.1301)	−0.2729**(0.1422)	−0.3581**(0.1849)	0.1074*(0.0637)
Trade Openness	0.0350***(0.0122)	0.0481***(0.0090)	0.0706***(0.0109)	0.0483***(0.0071)
F-Test(Prob.)	8156(0.000)	5472(0.000)	2724(0.000)	13304(0.000)
Sargan Test(Prob.)	13.3859(0.1459)	14.3626(0.1100)	14.4745(0.1164)	8.0883(0.5253)
AR(1)Prob.	−1.8522(0.0640)	−1.5933(0.1111)	−1.3984(0.1620)	0.1647(0.869)
AR(2)Prob.	2.1155(0.1344)	−1.8192(0.1689)	−1.6013(0.1193)	−1.3844(0.1662)
Number of Countries	20	20	20	20

poverty in low-income countries. The positive result is in line with Masron and Subramaniam (2019), Baloch et al. (2020) and Koçak and Çelik (2022). The climate change variable is only significant for extreme poverty in low-income countries. This could be explained by the fact that poverty dynamics in low-income countries are driven by other critical factors that may not be related to climate change dynamics. Despite the allusion to agriculture and other primary activities made earlier, most African countries experiencing extreme poverty are also ravaged by conflict, which can explain a very significant share of poverty in these countries(World Bank 2020). Consequently, though climate change is important, it may not be significant enough to explain the variations in poverty observed in these countries. Informality has a significant and positive effect on poverty. Similar results are reported in Dada, Ajide, and Adeiza (2022) and Koçak and Çelik (2022) among others.[1]

Income and financial sector development are negatively related to poverty as expected. School enrollment is only significant in higher income countries and only for poverty headcount at $3.2 for low income countries. The significance of the lagged poverty variable shows a persistence of poverty especially in lower income countries in line with Bolarinwa, Adegboye, and Vo (2021). The significance of the lagged variables also validated the adoption of System GMM adopted for the analysis.

4.3. Poverty, climate change and informality: moderation effects

The main question raised in this paper is whether the two relationships that poverty has with informality and with climate change should in fact be considered as one relationship where informality is the moderating variable. To investigate this, the climate change and informality variables are

Table 8. Moderating Effect of Climate Change and Informality on Poverty in High-Income African Countries: Informality 1.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
	−0.0215(0.0926)	0.2111***(0.0770)	0.3822***(0.0841)	0.2915**(0.1459)
Informality	0.5295***(0.0829)	0.8771***(0.1338)	1.1790***(0.1869)	1.473***(0.2725)
CO_2 Emissions	4.2754***(0.7550)	7.3389***(1.0928)	10.3568(2.3487)	13.5600***(2.6898)
Inequality	−0.0116(0.0433)	−0.0539(0.0952)	−0.2088(0.1564)	0.1459(0.1839)
GDPPC	0.00002(0.0002)	−0.0003(0.0006)	−0.0009(0.0006)	0.0007(0.0008)
School Enrolment	0.0138(0.0458)	−0.1032(0.06769)	−0.0416(0.1321)	−0.2860***(0.1095)
Financial Dev.	−0.0537*(0.0286)	0.0636(0.0725)	0.0461(0.0896)	0.0508(0.1007)
Trade Openness	−0.0178**(0.0079)	−0.0152(0.0149)	−0.0288(0.0271)	−0.0365(0.0233)
Informality*CO_2	−0.1666***(0.0256)	−0.2730(0.0350)	−0.3677***(0.0551)	−0.5111***(0.0778)
F-Test(Prob.)	25012(0.000)	5153.53(0.000)	3857(0.000)	6576(0.000)
Sargan Test(Prob.)	11.5145(0.9053)	12.4658(0.8648)	6.9349(0.6439)	7.9895(0.9868)
AR(1)Prob.	−1.4112(0.1582)	−2.1967(0.0280)	−2.1841(0.0290)	−2.4745(0.0133)
AR(2)Prob.	1.1092(0.2674)	1.5829(0.1134)	1.8099(0.1703)	1.5559(0.1197)
Number of Countries	20	20	20	20

Table 9. Moderating effect of climate change and informality on poverty in low-income African Countries: informality 1.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
	0.0798**(0.0351)	0.0004(0.0567)	−0.0425(0.0759)	−0.1739(0.1395)
Informality	0.7989***(0.0613)	1.2622***(0.1125)	1.6869***(0.1666)	2.2452***(0.2617)
CO_2 Emissions	44.0081(35.5724)	−51.0539(38.9948)	−170.8239***(55.3234)	−171.6345***(36.2186)
Inequality	−0.0006(0.0007)	−0.0006(0.0007)	−0.0009(0.0009)	−0.0012(0.0013)
GDPPC	−0.0281***(0.0035)	−0.0323***(0.0045)	−0.0399***(0.0059)	−0.0291***(0.0042)
School Enrolment	−0.011(0.0561)	−0.0254(0.0745)	−0.0705(0.1093)	−0.0598(0.0612)
Financial Dev.	−0.3433**(0.1365)	−0.2655*(0.1509)	−0.3237*(0.1987)	0.2119***(0.0655)
Trade Openness	0.0363***(0.0121)	0.05382***(0.0086)	0.0799***(0.0102)	0.0581***(0.0050)
Informality*CO_2	−0.5662(0.6968)	1.3319*(0.7487)	3.8267***(1.0519)	3.5131***(0.6850)
F-Test(Prob.)	9950(0.000)	8558(0.000)	9259(0.000)	44471(0.000)
Sargan Test(Prob.)	13.3203(0.1486)	14.2385(0.1141)	13.6458(0.1355)	8.4611(0.4884)
AR(1)Prob.	−1.7591(0.0786)	−1.4978(0.1342)	−1.4221(0.1550)	−0.21161(0.8324)
AR(2)Prob.	2.0942(0.1362)	1.9845(0.1472)	1.9338(0.1531)	−1.3864(0.1656)
Number of Countries	20	20	20	20

interacted. The results are shown in Table 8 for middle income countries and Table 9 for low-income countries. The interacted variable is negative and significant in three out of the four models for high income countries. This implies that informality dampens the effect of climate change on poverty. In contrast, informality exacerbates the effect of climate change on poverty in low-income countries. It is therefore expected that the higher the levels of informality in low-income countries, the greater will be the effect of climate change on poverty.

These two contrasting results can be explained by the nature of informal economic activities as it differs between low- and middle-income countries. The literature suggests that informal activities such as waste picking and recycling have a positive effect on managing the effects of climate change. However, these activities are only common in middle income countries. Most low-income countries have not developed effective policies around recycling and therefore the effects of such activities are likely to be very minimal. In contrast, informal waste picking and recycling has become a significant source of livelihood in middle income countries, making them an important part of the waste management process (Simatele, Dlamini, and Kubanza 2017; Muheirwe, Kombe, and Kihila 2022).

In lower income countries, informal activities lie more in agriculture, trading and other primary activities which are sensitive to climate change. Subsistence agriculture for example is climate driven and susceptible to fluctuations in whether patters and resultant droughts and floods. Similarly, petty trading and street vending lack sufficient and protective shelter and easily affected by changes in the weather. In addition, the lack of assets for adaptation means that those in the informal sector are more likely to be affected by price adjustments resulting from the effects of climate change (Hallegatte et al. 2016). As a result, the effects of climate change in low-income countries will be amplified when the informal sector experiences climate change related shocks.

5. Conclusion and recommendations

The paper brings the literature on the poverty-climate change nexus and poverty-informality nexus together. Panel data between 1990 and 2019 for 40 African economies is used to estimate a System GMM model. The empirical results show that informality plays a moderating role in the poverty-climate change relationship. The relationship is non-linear and changes with income. Economic activities in the informal sector ameliorate the negative effects of climate change on poverty, most likely through the environmentally friendly informal activities such as waste picking and recycling. This however is only observed in higher income countries where such activities are prevalent. The effect in low-income countries is reversed. The results for these economies where most of the informal activities are environmentally degrading show that the informal sector magnifies the negative effect of climate change on poverty.

Policy conversations about poverty should incorporate both climate change and informality. A separation is likely to lead to ineffective policies. The role of informal waste pickers and recycling is increasingly being recognized. Yet many African governments do not have policies that incorporate these activities in their solid waste management frameworks. The informal sector is still largely seen through a pejorative lens. The benefits that can accrue to poverty alleviation and climate change management are therefore missed. Lower income countries where climate change management policies are still in infancy have the opportunity to maximize policy effectiveness by addressing informality and climate change in tandem.

We suggest several areas for future research. First, this study points out the moderating role of informality at a macro level. Extant literature shows the importance of informal waste picking and recycling as channels of moderation. To what extent are these channels effective? There is very little research into the quantification of these effects. Policy formulations around such results can only be effective if the quantum of effects justifies interventions. Secondly, to the extent that the development process entails the use of unclean technologies, at least in the initial stages of development as suggested in the EKC framework, can informal economy activities be greened to reduce the thresholds at which African countries can switch to green technologies? The literature highlighted in this paper suggest that there may be some feedback effects between informality and climate change. Some studies examining the empirical extent of these feedback relationships and their potential effects on the climate change-poverty nexus would help elucidate points of action for policy makers.

Note

1. Incorporation of dynamic effects, alluded to here but not accounted for in the analysis suggest that the relationship between poverty and informality is somewhat complex and has been shown to be negative in some cases. See Bolarinwa and Simatele (2022) and Pham (2022).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix: robustness checks

Drivers of Poverty in High-Income African Countries: The Role of Climate Change: Informality 2.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$1.90
Lag of Poverty	0.4086***(0.0970)	0.1899**(0.0907)	0.3043***(0.0953)	0.1725(0.1364)
Informality	0.4785***(0.0787)	0.7877***(0.1608)	1.1494***(0.2261)	1.8889***(0.2653)
CO_2 Emissions	0.7539***(0.2307)	0.4847(1.1924)	0.8251(1.0426)	0.6901(1.7936)
Inequality	−0.1347*(0.0747)	−0.0530(0.1317)	−0.2137(0.2329)	−0.2583(0.2309)
GDPPC	−0.0009***(0.0003)	−0.0009(0.0007)	−0.0013(0.0009)	−0.0021**(0.001)
School Enrolment	−0.0272(0.0495)	−0.0689(0.0484)	−0.0799(0.1358)	−0.3201***(0.1251)
Financial Dev.	0.0092(0.0425)	0.0559(0.0637)	0.0449(0.0971)	0.2889***(0.0914)
Trade Openness	0.0066(0.0103)	−0.0077(0.0184)	0.0085(0.0289)	−0.0076(0.0303)
F-Test(Prob.)	943.77(0.000)	936.32(0.000)	424(0.000)	2203.(0.000)
Sargan Test(Prob.)	6.9507(0.6423)	11.3186(0.9127)	7.2591(0.6102)	8.2830(0.5059)
AR(1)Prob.	−1.8251(0.0680)	−2.2642(0.0236)	−2.1933(0.0283)	−2.2449(0.0248)
AR(2)Prob.	1.7966(0.1724)	1.8282(0.1675)	1.9014(0.1572)	1.3465(0.1781)
Number of Countries	20	20	20	20

Drivers of Poverty in Low-Income African Countries: The Role of Climate Change: Informality 2.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
Lag of Poverty	0.0970***(0.0379)	0.0346(0.0591)	0.0265(0.0752)	−0.1247(0.1282)
Informality	0.7786***(0.0633)	1.2304***(0.1226)	1.5992***(0.1778)	2.1859***(0.2755)
CO_2 Emissions	13.8015*(8.5784)	9.6381(8.0486)	6.0246(10.4262)	0.7155(5.5237)
Inequality	−0.0007*(0.0004)	−0.0011**(0.0004)	−0.0010(0.0006)	−0.0014***(0.0005)
GDPPC	−0.0285***(0.0033)	−0.0309***(0.0046)	−0.0362***(0.0059)	−0.0277***(0.0051)
School Enrolment	−0.0046(0.0566)	−0.0285(0.0719)	−0.1119(0.1018)	−0.0770(0.0549)
Financial Dev.	−0.2842**(0.1415)	−0.2755**(0.1445)	−0.3409*(0.1896)	0.1116*(0.0664)
Trade Openness	0.0325***(0.0119)	0.0463***(0.0085)	0.0679***(0.0107)	0.0461***(0.0075)
F-Test(Prob.)	7720(0.000)	11299(0.000)	2589(0.000)	9387(0.000)
Sargan Test(Prob.)	12.6424(0.1795)	12.8753(0.1863)	14.2544(0.1136)	7.7628(0.5582)
AR(1)Prob.	−1.7991(0.0720)	−1.7684(0.0856)	−1.3421(0.1796)	0.13429(0.8932)
AR(2)Prob.	2.060(0.1394)	2.4354(0.1769)	−1.5794(0.1142)	−1.2833(0.1994)
Number of Countries	20	20	20	20

Moderating Effect of Climate Change and Informality on Poverty in High-Income African Countries: Informality 2.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$1.90
	0.3524**(0.1398)	0.3157***(0.1027)	0.1166**(0.0604)	0.0097(0.0945)
Informality	0.3419***(0.1030)	0.8067***(0.1565)	1.2053***(0.1912)	1.9202***(0.3019)
CO_2 Emissions	8.8064***(2.137)	1.7969*(1.0598)	17.8284***(4.5079)	20.2280***(4.5537)
Inequality	0.0049(0.0467)	−0.1345(0.1571)	−0.0843(0.1608)	−0.1259(0.22778)
GDPPC	−0.0003(0.0002)	−0.0009(0.0005)	−0.0006(0.0005)	−0.0004(0.0007)
School Enrolment	−0.0143(0.0381)	−0.0593(0.0864)	0.0004(0.1132)	−0.1889*(0.1048)
Financial Dev.	−0.0448(0.0327)	0.0662(0.0736)	−0.0416(0.0874)	0.1070(0.0746)
Trade Openness	0.0105(0.0118)	−0.0058(0.0199)	−0.0062(0.0208)	0.0106(0.0207)
Informality*CO_2	−0.2741***(0.0656)	−0.0715*(0.0408)	−0.6044***(0.1319)	−0.6810***(0.1403)
F-Test(Prob.)	5217.99(0.000)	474.23(0.000)	1524(0.000)	1090(0.000)
Sargan Test(Prob.)	6.2228(0.7174)	7.4331(0.5921)	5.8839(0.7515)	6.1439(0.7254)
AR(1)Prob.	−2.6758(0.0075)	−2.3366(0.0195)	−2.1599(0.0308)	−2.3034(0.0213)
AR(2)Prob.	2.0398(0.4014)	1.9711(0.2487)	1.7254(0.0845)	1.4049(0.1601)
Number of Countries	20	20	20	20

Moderating Effect of Climate Change and Informality on Poverty in Low-Income African Countries: Informality 2.

	PovertyGap$1.90	PovertyGap$3.20	PovertyHeadcount$1.90	PovertyHeadcount$3.20
	0.0862**(0.0353)	0.0062(0.0572)	−0.0374(0.0753)	−0.1455(0.1363)
Informality	0.7969***(0.0619)	1.2493***(0 0.1159)	1.6601***(0.1699)	2.1852***(0.2631)
CO_2 Emissions	82.7307**(34.7274)	−25.5671(39.9302)	−138.3218**(58.1933)	−111.7991**(58.2368)
Inequality	−0.0006*(0.0003)	−0.0009**(0.0004)	−0.0009*(0.0005)	−0.0012(0.0008)
GDPPC	−0.0274***(0.0034)	−0.0309***(0.0044)	−0.0368***(0.0055)	−0.0282***(0.0044)
School Enrolment	−0.0246(0.0549)	−0.0137(0.0729)	−0.0624(0.1053)	−0.0513(0.0601)
Financial Dev.	−0.3374***(0.1309)	−0.2825**(0.1430)	−0.3323*(0.1895)	0.1728**(0.0771)
Trade Openness	0.0340***(0.0114)	0.0493***(0.0087)	0.07314***(0.0121)	0.0514***(0.0083)
Informality*CO_2	−1.3812**(0.7299)	0.7147(0.8092)	2.9757***(1.1685)	2.2653**(1.1369)
F-Test(Prob.)	13920(0.000)	7306(0.000)	7486(0.000)	18674(0.000)
Sargan Test(Prob.)	12.4328(0.1900)	11.4853(0.2159)	13.7044(0.1332)	0.00135(0.9989)
AR(1)Prob.	−1.7447(0.0810)	−1.5635(0.0425)	−1.285(0.1988)	−1.2957(0.1951)
AR(2)Prob.	1.9955(0.1460)	1.8565(0.1278)	1.8717(0.1613)	8.1133(0.5228)
Number of Countries	20	20	20	20