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Testing the Nexus between Official Development Assistance, Governance Quality and CO_2 Emissions: Fresh Evidence from Sub-Saharan African Countries

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Abstract

The aim of this paper is to explore the nexus between official aid assistance, governance quality and CO_2 emissions. The study used the pooled mean group ARDL estimator used for a panel of 45 Sub-Saharan African countries (expecting Somalia and Eretria) over the period 2006-2022. Composite indexes of governance are used (political, economic and institutional governance). The empirical methodology is based on cross-sectional dependence and regressions analysis using second-generation analysis techniques. We use the pooled mean group ARDL estimator as the regression analysis technique to examine e short-run and long-run relationship. Results indicate that official development assistance decreases environmental damages for SSA countries. In addition, good governance and official aid assistance can play a crucial role in combating climate change in sub-Saharan countries. Therefore, effective governance and adequate financial support are essential to help sub-Saharan African countries reduce their CO_2 emissions and adapt to the impacts of climate change, while pursuing sustainable economic development.

Keywords

Official Development Assistance, Governance Quality, CO_2 Emissions, Sub-Saharan African Countries, ARDL

1. Introduction

Over the last decade climate change mitigation presents significant challenge to organizations worldwide, environmental scientists, and policymakers. So that, enhancing the effectiveness of international treaties on climate change (Habiba & Xinbang, 2022; Ahmad et al., 2022; Anser et al., 2021), which serve as the primary mechanisms for cooperation, is under discussion. Scientists have predicted that if drastic measures are not enacted soon, global warming will lead to catastrophic changes in the climate, desertification, and a rise in coastal flooding, which would all but destroy many communities and even small countries located at sea level (IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, 2019).

Hence, the environmental damage we are witnessing across developing countries and mainly the African continent holds negative consequences for all people on the continent. Among the most vulnerable are traditional peoples who rely on biomass energy, natural products such as firewood, wild animals, and wild edible fruits and roots to maintain their way of life. Most of Sub-Saharan countries of Africa.

In recent years, however, it has confronted new challenges, including the decline in global commodity prices, a fragile health system, and the rise of terrorism and violent extremism. In response to these issues, the African Union (AU) Summit held in 2015 adopted the "Agenda 2063," a new development agenda for Africa. In addition, during the same year, the UN newly adopted the "2030 Agenda for Sustainable Development." As such, the international community has started to tackle the challenges by closely supporting Africa's own efforts.

In this way, empirical studies confirmed that financial development is important to promote environmental sustainability for Sub-Saharan African countries.

In this context, this study attempts to explore the impact of governance quality and financial development on CO_2 emissions for a panel of 45 Sub-Saharan African countries. Studies focusing on the impact of financial development, ODA and governance on CO_2 emissions, the interaction between ODA, Governance and ODA financial development for the Sub-Saharan countries of Africa.

The rest of the document is organized as follows. In section 2, we outline the literature on the relationship between governance, financial development and mountaineering CO_2 emissions. The methodology and data are described in section 3. The results are reported and discussed in section 4, and the conclusion is presented in section 5.

2. Literature Review

Recent literature highlights the fact that the financial development and good governance contribute to mountaineering CO_2 emissions across the globe (Caselles & Sanz, 2021).

2.1. We First Present Different Studies Focusing with the Impact of Governance Quality and CO_2 Emissions

Gök & Sodhi (2021) used system-generalized method (SYS-GMM) of moments for 115 countries clustered as high, middle, and low income over the period of 2000 to 2015, to study the environmental impact of governance. The results show that improvement in governance increases environmental quality in high-income countries.

Dincă et al. (2022) examined the impact of governance quality and educational level on environmental performance for a set of 43 countries European Union (EU) members and The Group of Twenty (G20) states. The data were collected for the 1995-2020 period. The research uses three estimations methods, respectively Pooled ordinary least squares (POLS), Fixed effects model (FE) and Random effects model (RE), together with a two-step dynamic GMM model, to address the endogeneity issue as well. The main results show that all the independent variables reflecting institutional quality from a technical point of view, included in the model when considering the PCSE estimation, have a direct and positive link to CO_2 emissions' level, with control of corruption variable being the only one to influence in a positive manner *CO_2 emissions* at a significant level.

Azimi (2022) studied and examined the effects of governance on environmental quality, for 180 countries, over the period 1999 to 2021. They employed Cross-sectional augmented autoregressive distributed lags model, to analyze the stationarity properties of the variables. The findings show that CGI is crucial to improving environmental quality by decreasing CO_2 emissions across all panels. They found that while CGI sustains the same magnitude, the size of its effects substantially varies according to the income level across panels. Moreover, the findings approve that financial development and the human development index reduce CO_2 emissions, while energy consumption, population growth rate, trade openness, and urbanization are significantly decrease environmental quality.

The literature also reveals that Azimi et al. (2023) evaluated the impact of good governance on environmental quality and energy consumption for a panel of 66 developing countries over the period 1991 to 2017 using the GMM method. The authors constructed a governance index using three indicators such as political stability, administrative capacity, and democratic accountability. They found that, though good governance has been significantly positive in affecting energy consumption, globalization has been found to be insignificant in increasing environmental quality.

2.2. The Second Group Leads with the Relationship between Financial Development and Environment Quality

Jamel et al. (2017) employed causality test and OLS model for a yearly panel data of 40 European economies, during the period of study from 1985 to 2014, to analyze the link between financial development and CO_2 emissions. Their study revealed that financial development measured by domestic credit provided by banks to private sectors has an insignificant effect on CO_2 emissions.

Aluko & Obalade (2020) examined the nexus between financial development and environmental quality, for a panel of 35 in sub-Saharan Africa (SSA) countries for the period 1985-2014, using the augmented mean group estimator. The findings. First, financial development is a positive (negative) driver of environmental quality (CO_2 emissions). Second, financial development has an unfavourable technology effect on environmental quality. Lastly, lower environmental quality is associated with increase in population, affluence and technology. They also find, via the Dumitrescu-Hurlin panel causality test, that there is a bidirectional causal relationship between financial development and CO_2 emissions.

Emenekwe et al. (2022) analyzed the nexus between financial development (FD, and its key dimensions) carbon dioxide (CO_2) emissions for 37 Sub-Saharan African (SSA) countries from 2000 to 2016, using cross-sectional dependence, causality, and regressions analysis using second-generation analytical techniques. The regression analysis technique was the pooled mean group ARDL estimator. They used the dynamic generalized method of moment estimator to provide robustness checks. The findings indicate that overall FD reduces CO_2 emissions in the region and supports the environmental Kuznets curve (EKC) hypothesis. Specifically, the results reveal that a 1-unit increase in the overall FD index results in a 2.867% reduction in CO_2 emissions over the long run.

Habiba and Xinbang (2022) used two-stage system GMM and panel data over the period 2000 - 2018, to examine the impact of financial development on CO_2 emissions for developed and emerging countries. The empirical results show that the overall financial market development and its sub-indices (FM-access, FM-depth, and FM-efficiency) reduce CO_2 emissions in developed and emerging countries. The results further show that the overall financial institution development and its sub-indices, such as FI-access, FI-depth, and FI-efficiency foster the environment quality in developed economies, while these indices impede the environmental quality in emerging economies.

2.3. The Third Stand's Studies Highlights the Impact of ODA on CO_2 Emissions

Wang et al. (2022b) used the dynamic panel threshold regression model is employed to explore the effects of ODA and carbon emissions in 59 low-income and lower-middle-income countries. Results indicate that in ODA leads to an increase in carbon emissions. Lee et al. (2020) investigated the relationship between official development assistance (ODA) on CO_2 emissions based on both direct and indirect frameworks, using the annual panel data of 30 recipient countries of Korea from 1993 to 2017. They employed a modified impact, population, affluence, and technology (IPAT) model and a simultaneous equation framework for the direct model and indirect model, respectively. The empirical results suggest that ODA reduces CO_2 emissions for these countries.

Li et al. (2020) examined the impact of Official Development Aid (ODA) on carbon emissions in recipient countries and if institutional quality matters for the effectiveness of green ODA. For 86 green ODA recipient countries over the period 2003-2014, using a two-step system generalized method of moment (GMM). They found a significant effect of institutional quality on the effectiveness of green ODA.

3. Empirical Methodology and Data

The objective of our study is to examine the interrelationship between governance quality, financial development and CO_2 emissions, using the Cobb-Douglas production function.

3.1. Variables and Data

In this study, we evaluate the impact of foreign aid assistance and governance quality on environmental sustainability for a panel of 45 countries[1] according to the data availability over the period 2006-2022 (**Table 1**).

Based on the study of Kassi et al. (2023) and Azimi et al. (2023), we construct a composite governance index (CGI) and a composite index. Here, we use the principal component analysis (PCA)'s technique following recent studies by Asongu and Nnanna (2019) and Asongu and Odhiambo (2019) and Habiba & Xinbang (2022). The composite index of financial development we refer to (Kassi et al., 2023) of financial development to capture the extensive effects of governance and financial development on environment quality.

In this study, we use intermittent variables of governance quality. Data obtained from worldwide government indicators (WGI, 2022), specially the political stability and absence of violence/terrorism (PS), Voice and accountability (VOICE), control of corruption (COR), the rule of law (LAW), government effectiveness (GE), and the regulatory quality (RQ).

In this study, the variables of World Development Indicators (WDI, 2022) for CO_2 (CO_2 emissions, metric tons per capita), (trade openness (TRADE), foreign direct investment (FDI, net inflows, % GDP), URBN (Urban population % of total population)

Unlike previous studies, we use the ODA variable for Sub-Saharan countries of Africa, the both of composite indicators to governance quality and financial development, to evaluate their impact of environment quality for a sample of Sub-Saharan countries of Africa.

To explore the impact of financial development-governance on CO_2 emissions,

[1]Data were selected from the WDI, and WGI, we selected 47 countries according to the data availability: Algeria, Angola, Cameroon, Central African Republic, Chad, Congo Rep, Demo Congo, Equatorial Guinea, Gabon, Sao Tome and Principe, Botswana, Namibia, South Africa, Central African Republic, Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Egypt, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Togo, Sierra Leone, Burundi, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Rwanda, Seychelles, Uganda, Tanzania, Tunisia, Zambia, Zimbabwe. Countries excluded are the following: Somalia, Eswatini, Eretria, South Sudan, Sudan, Djibouti, Lesotho, Libya.

Table 1. Description of variables.

Variables	Measurement	Source
Dependent variable		
CO_2 emissions	CO_2 emissions (metric tons per capita)	**WDI**
Financial development variables		
Governance indicators		**WGI**
CC	Control of Corruption	
GOV	Government Effectiveness	
PS	Political Stability and Absence of Violence/Terrorism	
REG	Regulatory Quality	
RULE	Rule of law	
VOICE	Voice and accountability	
Control variables		**WDI**
TRADE openness	Trade (% of GDP)	
URBN	Urban population (% of total population)	
FDI	Foreign direct investment, net inflows (% of GDP)	
ODA	Net Official Aids Received (% of GDP)	
POP	Population growth (annual %)	
REN	Renewable energy consumption (% of total)	
GOV * ODA	The interaction between governance and ODA	
GOV * FD	The interaction between governance and FD	
ODA * FD	The interaction between ODA and FD	

we refer to Wen et al. (2022) and Hunjra et al. (2023) and innovatory, we use dynamic panel data for composite indexes of financial development and governance with ODA variable. Otherwise, to test cointegration of variables, we use a dynamic model for panel data with cointegration. The ARDL model used in this study is a type of autoregressive model of order p in the dependent variable $CO2_{it}$, with the form ARDL. In addition, we estimate a dynamic heterogeneous panel data model using a heterogeneous panel of observations using pooled mean group (PMG) and mean group (MG) estimator approaches. The MG estimator is based on the estimate of N time series regressions and the average of their coefficients. Giving to the PMG estimator, we must primarily identify the short-run dynamics for each country. We use this estimator to estimate the long-run effects and the adjustment to the long run rate. The utility of the PMG estimators that they are effective and consistent (Blackburne & Frank, 2007), even in the presence of endogenous and non-stationary regressors. On the other hand, in order to determine whether the two estimators' differences are systematic, we use the Hausman test.

Hence, we consider the panel equation to explain the relationship under analysis using a panel ARDL model as follows:

$$C_{it} = \alpha_{it} P_{it}^{b} A_{it}^{c} T_{it}^{d} \varepsilon_{it}$$

where i represents the country, t denotes time, α is a constant, and ε is the error term. The natural logarithm transformation give the following panel data model:

$$C_{it} = ln\alpha_0 + blnP_{it} + clnA_{it} + dlnT_{it} + \epsilon_{it}$$

The subscript i measures the country $i = 1, \ldots, 45$; t is the time period from 2000 to 2022; Furthermore, b, c, and d define the estimated percentage.

$$\begin{aligned} \text{CO2}_{it} = {} & \alpha_0 + \alpha_1 GOV_{it} + \alpha_2 GDP_{it} + \alpha_3 ODA_{it} + \alpha_4 URBN_{it} \\ & + \alpha_5 FDI_{it} + \alpha_6 POP_{it} + \alpha_7 INF_{it} + \alpha_8 TRADE_{it} + \epsilon_{it} \end{aligned}$$

where i denotes countries and t signifies study period α_1, α_2 and α_3 are the slope coefficients; CO_2 represents carbon emissions.

Where ϵ_{it} represents error terms, i is cross section and t is the period. GOV is the composite index of governance, trade indicates trade openness, POP is the population growth, ODA is official aids received, and GDP denotes Gross domestic product per capita growth.

3.2. Panel Unit Root Test

Due to the CSD considerations, this study will not utilize only first-generation unit root tests (First-GURTs), as they could generate biased outcomes. As a result, the current study assessed the stationarity characteristics of panel data from SSA countries using second-generation unit root tests (Second-GURTs). The Second-GURTs, such as the cross-sectional augmented Dickey-Fuller (CADF) test, described in depth in Pesaran (2007), are used in this study. In addition to the CADF, we do a Fisher-type unit root test in the way described by Oikonomou et al. (2021).

3.3. Haussman Test

The Hausman test makes it possible to make a choice between the PMG and MG estimators by testing the null hypothesis of a non-systematic difference between the model coefficients. Furthermore, it also serves as a criterion for choosing between MG and DFE, notably by testing the null hypothesis of a recurring minimal endogeneity bias in dynamic fixed effects models. However, it should be noted that the Hausman test does not allow the PMG and DFE estimators to be compared since the nature of the latter is in agreement with the hypothesis of a non-systematic difference between the model coefficients.

3.4. Cross Section Dependence Test

When estimating one or more covariate varias, it can ascent spurious regression. Hence, the first difference strategy, often used, is to make the variables stationary. To this end, two tests explore the effect of country-specifc slope heterogeneity: Pedroni (1999) and Westerlund's (2005) test. Westerlund's (2005) test is specified as follows:

$$\Delta y_{it} = \omega_i + \alpha_i \left(y_{it-1} - \beta_i x_{it-1} \right) + \sum\nolimits_{k=1}^{p} \alpha_{1i} \Delta y_{it-k} + \sum\nolimits_{m=1}^{p} \beta_{1i} \Delta x_{it-m} \varepsilon_i$$

where α_i presents the coefficient of the correction term. The null hypothesis is $\alpha_i = 0$ for all panels, while an alternative hypothesis of $\alpha_i < 1$ for at least one panel. Accepting the alternative hypothesis recommends the presence of a long-run equilibrium relationship.

3.5. Panel Cointegration Test

Due to the CSD considerations, this study will not utilize only first-generation unit root tests (First-GURTs), as they could generate biased outcomes. As a result, the current study assessed the stationarity characteristics of panel data from SSA countries using second-generation unit root tests (Second-GURTs). The Second-GURTs, such as the cross-sectional augmented Dickey-Fuller (CADF) test, described in depth in Pesaran (2007), are used in this study. In addition to the CADF, we do a Fisher-type unit root test in the way described by Oikonomou et al. (2021).

3.6. The MG and PMG Estimators

Pesaran et al. (1999) proposed an estimator called PMGE (pooled mean group estimator), which combines both pooling and averaging. In fact, this method imposes a constraint of equality on the long-term coefficients and allows the short-term coefficients to be different from one country to another. The MG estimator is the unweighted average of the coefficients from the different individual regressions. However, the fundamental difference between the two estimators is the fact that the MG estimator does not take into account the possibility that some parameters in the groups may be the same. The PMG estimator constitutes a good estimator in the case where the imposed restriction is verified; but if there is heterogeneity this estimator is biased. The choice between the PMG and MG is made using a Hausman test whose null hypothesis is the non-systematic difference between the coefficients from the MG and PMG.

3.7. Hausman Specification Test

Hausman (1978) test the hypothesis of homogeneity of the long-term policy parameters cannot be accepted a prior. The impact of heterogeneity on the means of the coefficients can be dictated by the Hausman-type test. If the parameters are in certainty homogenous, the PMG regressors are more efficient than MG. In other words, the efficient regressors under the null hypothesis, which is PMG is favoured. Nevertheless, on the off chance that the null hypothesis is rejected, at that point, the efficient estimator MG is accepted.

4. Estimation Results and Discussion

4.1. Descriptive Statistics

Descriptive statistics are reported in Table 2. This table reveals that, on average, the highest level of CO_2 is equal to 2.133, CC is equal to 1.698, FDI is equal to 4.491, CO_2 is equal to 2.133, INF is equal to 10.076, GOV is equal to 1.150, GDPgr is equal to 4.945, TRADE is equal to 5.463, and ODA is equal to 4.533. Then, we can remark that the highest level of risk (standard deviation) is for CO_2 (1.369), followed by FDI (1.305) and ODA (1.253), respectively.

Table 2. Summary of descriptive statistics.

variables	Obs	Mean	Std.Dev	Min	Max
Dependent variable					
CO_2	1454	−1.217	1.369	−3.826	2.133
Governance indicators					
CC	1117	−0.625	0.655	−1.936	1.698
GOV	1113	−0.787	0.645	−2.439	1.150
PS	1116	−0.538	0.917	−3.312	1.283
REG	1116	−0.712	0.646	−2.547	1.196
RULE	1116	−0.713	0.670	−2.590	1.044
VOICE	1116	−0.576	0.744	−2.226	1.007
Independent variables					
TRADE	1251	4.115	0.446	2.979	5.463
REN	1036	4.210	0.485	2.034	4.588
URBN	1551	3.522	0.487	1.689	4.507
GDPgr	983	0.896	1.059	−6.031	4.945
POP	1517	0.834	0.533	−6.078	2.810
FDI	783	−1.830	2.142	−15.587	4.491
ODA	1390	1.781	1.253	−5.651	4.533
INF	1206	1.835	1.305	−3.305	10.076

Principle component analysis of governance and financial development variables

$$GOVE = (PGOV, EGOV, IGOV, GOV)$$

Governance variables were grouped into three dimensions, namely, political governance (P.GOV), institutional governance (I.GOV) and economic governance (E.GOV).

We built three components of governance indicators I.GOV I.GOV and E.GOV, using PCA method. Results demonstrate that the first component

P.GOV 82.96% of the information contained in its constituents with an eigenvalue of 1.65.

Simultaneously, the first components of I.GOV and E.GOV and the overall index represent 92.96%, 96.07% and 81.65 of the variance in their constituents, with eigenvalues of 1.85, 1.92 and 4.89, respectively. PGOV =f (FRE, PSTA), EGOV=f (REG, GEF), IGOV (COR, LAW). Hence, the highest eigenvalue is for Economic index (Table 3).

Table 3. PCA of Governance variables

Principle component	Governance indicators		
	Initial Eigenvalues		
	Total	% of variance	Cumulative %
Political governance PGOV (PS, VOICE)			
1	1.653	82.966	82.696
2	0.346	17.313	100
Institutional governance EGOV (GEF, REG)			
1	1.859	92.96	92.96
2	0.140	7.04	100
Economic governance IGOV (CORR, LAW)			
1	1.921	96.07	96.07
2	0.0786	3.93	100
Governance (PS, VOICE, GE, REG, COR, LAW)			
1	4.898	81.65	81.65
2	0.460	7.68	89.33
3	0.293	4.89	94.21
4	0.182	3.04	97.25
5	0.087	1.45	98.71
6	0.077	1.29	100

4.2. Empirical Tests

4.2.1. Cross-Section Dependence Test

When the statistics associated with the tests are significant at the 5% threshold, the null hypothesis is accepted and the first-generation stationarity tests are valid. Then, second-generation tests apply (Table 4).

4.2.2. Panel Cointegration Test

The results of the adjusted LM test of Pesaran and Yamagata (2008), contained in Table 5, confirm the cross-sectional dependence of the series at the 5% threshold. In this regard, second generation unit root tests are the appropriate ones where appropriate.

Table 4. Cross-section dependence test.

Variables	CD
lnCO_2 Emissions	30.99*** (0.000)
lnODA	38.12*** (0.000)
lnREN	55.62*** (0.000)
lnURBN	104.21*** (0.000)
lnTRADE	14.90*** (0.000)
lnFDI	28.26*** (0.000)

Notes: The null hypothesis of cross-section dependence CD ~ N (0, 1).

Table 5. Panel cointegration test

	Pedroni (excluding time trend)	Pedroni (including time trend)	Westerlund
Modifed Phillips-Perron t	1.728*	1.895**	
Phillips-Perron t	−4.594***	−4.231***	
Augmented Dickey-Fuller t	−8.513***	−6.955***	
Variance ratio			−4.014***

Null hypothesis H0: there is no long-run relationship between the variables included in the panel. ***, ** and * denote statistical significance at 1%, 5%, and 10% level respectively.

4.2.3. Panel Unit Root Test

We analyze the properties of all variables by running the unit root test in Im et al. (2003), Levin et al. (2002), Phillips and Perron (1988). These tests assume the null hypothesis that all variables are non-stationary at the level against the alternative hypothesis of stationary variables at the first difference. The test in Levin et al. (2002) supposes a standard unit root process, contrary to the three others. Result of panel unit root test reveal that all variables are not stationary in level, but they are stationary at first difference i.e., all variables are I (1). Therefore, we could apply the cointegration test to show that there is a long-term relationship or lack of relationship between variables (**Table 6**).

4.2.4. Results of PMG, MG and DFE Models

Pesaran et al. (1999) proposed an estimator called PMGE (pooled mean group estimator), which combines both pooling and averaging. In fact, this method imposes a constraint of equality on the long-term coefficients and allows the short-term coefficients to be different from one country to another. The MG estimator is the unweighted average of the coefficients from the different individual regressions. However, the fundamental difference between the two estimators is the fact that the MG estimator does not take into account the possibility that

Table 6. Unit root test results.

Variables	LLC		IPS		ADF		PP	
	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff
$lnCO_2$	−2.772* (0.002)*	−8.145* (0.000)	−0.929 (0.176)	14.175* (0.0000)	97.916* (0.006)	333.564* (0.000)	87.309 (0.040)	635.384* (0.000)
CC	−3.058 (0.001)*	27.512* (0.000)	−1.727 *(0.024)	−20.400* (0.000)	86.422*** (0.032)	610.261* (0.000)	92.663*** (0.011)	670.455* (0.000)
GOV	−5.686 (0.000)*	−23.591* (0.000)	−4.352* (0.000)	−21.309* (0.000)	133.029* (0.000)	453.048* (0.000)	177.707* (0.000)	635.256* (0.000)
PS	−4.853 (0.000)*	−25.478* (0.000)	−3.948* (0.000)	−22.434 *(0.000)	130.283* (0.000)	490.746* (0.000)	141.761* (0.000)	627.136* (0.000)
REG	−2.936 (0.001)*	−24.057* (0.000)	−1.967* (0.024)	−22.490 *(0.000)	88.661** (0.022)	478.892* (0.000)	91.635* (0.000)	876.520* (0.000)
RULE	−3.869 (0.000)*	−23.125* (0.000)	−2.520* (0.005)	−19.742* (0.000)	90.837** (0.015)	432.777* (0.000)	99.395* (0.003)	789.408* (0.000)
VOICE	−2.609 (0.004)*	−17.377* (0.000)	−0.523 *(0.000)	−15.036* (0.000)	81.515* (0.000)	315.548* (0.000)	81.201* (0.000)	338.647* (0.000)
LnTRADE	−2.094 (0.018)***	16.814* (0.000)	−1.869** (0.030)	−18.321* (0.000)	77.513*** (0.063)	410.948* (0.000)	102.581* (0.000)	708.943* (0.000)
lnURBN	0.329 (0.629)	30.848* (0.000)	2.908 (0.998)	−3.423* (0.000)	112.161* (0.000)	86.809*** (0.030)	247.843* (0.000)	149.607* (0.000)
lnFDI	−9.224 (0.000)*	−28.226 (0.000)	−10.444* 0.000)	−29.990* (0.000)	237.595* (0.000)	680.946* (0.000)	268.493* (0.000)	949.101* (0.000)
lnPOP	−5.281 (0.000)*	−45.743* (0.000)	−9.237* (0.000)	−22.725* (0.000)	248.483* (0.000)	289.734* (0.000)	166.170* (0.000)	324.925* (0.000)
lnGDPg	−16.250 (0.000)*	−25.950* (0.000)	−11.425* (0.000)	−20.727* (0.000)	291.559* (0.000)	465.706* (0.000)	269.550* (0.000)	533.382* (0.000)
lnODA	−5.714 (0.000)*	−33.288* (0.000)	−4.622* (0.000)	−33.600* (0.000)	117.269* (0.000)	800.107* (0.000)	113.916* (0.000)	836.985* (0.000)
LnINF	−11.507 (0.000)*	−34.535* (0.000)	−13.275* (0.000)	−32.794* (0.000)	295.575* (0.000)	739.799* (0.000)	337.107* (0.000)	1043.25* (0.000)
REN	1.799 (0.964)	−23.367* (0.000)	4.119 (1.000)	−22.892* (0.000)	46.843 (0.946)	539.439* (0.000)	47.994 (0.953)	578.366* (0.000)

Note: * and ** indicate significance at 1% and 5% levels, respectively.

some parameters in the groups may be the same. The PMG estimator constitutes a good estimator in the case where the imposed restriction is verified; but if there is heterogeneity this estimator is biased. The choice between the PMG and MG is made using a Hausman test whose null hypothesis is the non-systematic difference between the coefficients from the MG and PMG.

The PMG, or "Pooled Mean Group", method is often used to deal with panel data containing both stationary and non-stationary variables. The main idea behind the PMG method is to combine the advantages of fixed effects models and random effects models. It makes it possible to estimate long-term relationships between cointegrated variables while taking into account individual and temporal effects.

By using the PMG method, we estimate the long-run relationship between cointegrated variables, and obtain the error correction coefficient. This coefficient measures the adjustment of non-stationary variables towards their long-term equilibrium. Its presence confirms the existence of a long-term relationship between the variables.

The PMG method offers a powerful approach for modeling and analyzing economic relationships from panel data, taking into account both stationary and non-stationary variables, as well as individual and temporal effects. The results of PMG and MG are summarized in Table 7 below.

Table 7. Estimation of the regressor's impact of CO_2 emissions.

Variables	PMG	MG	DFE
Short run			
GOV	0.146*** (0.020)	0.151*** (0.021)	0.141*** (0.024)
GDP	−0.066*** (0.021)	0.507*** (0.113)	−0.068*** (0.041)
REN	−1.256 *** (0.076)	−0.468** (0.188)	−0.715** (0.112)
TRADE	0.085 (0.083)	−0.097 (0.115)	−0.327* (0.176)
URBN	0.336*** (0.087)	0.276** (0.121)	0.965*** (0.282)
ODA	−0.050** (0.021)	−0.109* (0.040)	−0.031 (0.076)
INF	−0.043*** (0.005)	0.0385 (0.033)	−0.011 (0.011)
POP	0.022*** (0.084)	0.079 (0.086)	0.131 (0.142)
FDI	−0.001 (0.003)	−0.015 (0.010)	0.020 (0.03)
Long run			
ECT	0.249*** (0.044)	−0.011*** (0.002)	0.287*** (0.043)
ΔGOV			
ΔGDP	0.009* (0.005)	0.002 (0.001)	−0.124* (0.048)

Continued

ΔREN	−3.757*** (0.717)	−0.562*** (0.136)	−0.957*** (0.094)
ΔTRADE	0.015 (0.031)	0.017 (0.049)	0.041* (0.019)
ΔURBN	−15.986** (7.376)	−0.561 (2.913)	−0.178 (0.492)
ΔODA	−0.009 (0.009)	0.004 (0.013)	−0.005 (0.010)
ΔINF	0.005 (0.004)	−0.002 (0.006)	−0.006 (0.004)
ΔPOP	0.058 (0.088)	−0.040 (0.068)	−0.027 (0.030)
ΔFDI	0.007 (0.003)	0.002 (0.002)	0.003 (0.003)
ECM	0.154*** (0.049)	0.200*** (0.023)	0.127*** (0.024)
Cons	−0.113 (0.114)	0.0153 (0.234)	−0.021 (0.236)
Hausman test of poolability (Ho: diference in coefcients not systematic)			
Comparison	PMG and MG	MG and DFE	PMG and DFE
χ^2 (p-value)	0.12 (0.928)	---	0.1 (1.000)
Decision	The PMG is preferred over the MG	---	The PMG is preferred over the DFE

*The impact of the interaction GOV*ODA on environment quality.*

Variables	Interaction term GOV-ODA		
	PMG		
	PGOV	IGOV	EGOV
Short run			
GDP	−0.017* (0.009)	−0.014 (0.009)	−0.014 (0.009)
REN	−0.730* (0.335)	−0.753* (0.338)	−0.643* (0.334)
TRADE	−0.026 (0.148)	−0.054 (0.150)	−0.015 (0.148)
URBN	0.673*** (0.454)	0.414*** (0.508)	0.744*** (0.483)

Continued

INF	−0.013* (0.033)	−0.025* (0.032)	0.020 (0.031)
POP	0.023*** (0.132)	0.012*** (0.133)	0.050*** (0.129)
FDI	0.020 (0.026)	0.013 (0.026)	0.011 (0.025)
ODA	−0.190*** (0.270)	−0.799*** (0.057)	−1.055*** (0.212)
PGOV * ODA	−0.186*** (0.016)		
IGOV * ODA	−−	0.722*** (0.050)	
EGOV * ODA	−−		−0.062*** (0.240)
Long run			
ECM	0.163*** (0.033)	0.122*** (0.035)	0.015 (0.012)
ΔGDP	0.002 (0.001)	0.002 (0.001)	0.002 0.001)
ΔREN	−0.591*** (0.136)	−0.565*** (0.136)	−0.562*** (0.137)
ΔTRADE	0.020* (0.049)	0.010** (0.050)	0.020** (0.050)
ΔURBN	−0.797*** (2.917)	−0.677*** (2.926)	−0.397 (2.932)
ΔODA	0.007* (0.013)	0.005 (0.013)	0.004 (0.013)
ΔINF	−0.003 (0.006)	−0.003 (0.006)	−0.002 (0.006)
ΔPOP	−0.022 (0.068)	−0.037* (0.068)	−0.039 (0.068)
ΔFDI	−0.019 (0.021)	−0.065* (0.03)	−0.014 (0.030)
ΔPGOV * ODA	0.012 (0.016)		
ΔIGOV * ODA		−0.044 (0.037)	
ΔEGOV * ODA			0.002 (0.002)
Cons	0.181*** (0.055)	−0.334* (0.173)	−.0111 (0.027)

Variables	Interaction term GOV-FD					
	CC	GOV	PS	REG	RULE	VOICE
Short run						
GDP	−0.017* (0.009)	−0.014 (0.009)	−0.014 (0.009)	0.071 (0.056)	0.049 (0.057)	0.045 (0.060)
REN	−0.516* (0.083)	−0.421* (0.338)	−0.511* (0.298)	−0.446* (0.179)	−0.698 (0.449)	−0.514 (0.506)
TRADE	0.062 (0.114)	−0.054 (0.150)	0.042 (0.148)	0.042 (0.120)	−0.163 (0.281)	−0.146 (0.280)
URBN	0.742*** (0.314)	0.414*** (0.508)	0.661*** (0.450)	0.794*** (0.291)	0.534 (0.619)	0.659 (0.656)
INF	−0.013* (0.033)	−0.023* (0.032)	0.018 (0.031)	0.048* (0.040)	0.044* (0.086)	0.045 (0.073)
POP	0.023 (0.132)	0.019 (0.133)	0.014 (0.129)	0.044 (0.099)	0.068 (0.156)	0.024 (0.168)
FDI	0.013 (0.019)	0.013 (0.026)	0.014 (0.025)	0.016 (0.056)	0.014 (0.027)	0.011 (0.028)
ODA	−0.191*** (0.27)	−0.790*** (0.057)	−1.050*** (0.212)	−0.245*** (0.023)	−0171*** (0.021)	−0.042* (0.022)
CC * ODA	0.047*** (0.104)					
GOV * ODA		0.722*** (0.050)				
PS * ODA			−0.067*** (0.081)			
REG * ODA				−0.059 (0.121)		
RULE * ODA					−0.088 (0.240)	
VOICE * ODA						0.130 (0.282)
Long run						
ECM	0.297*** (0.059)	0.303*** (0.059)	0.308*** (0.060)	−0.367*** (0.061)	0.303*** (0.059)	0.286*** (0.106)
ΔGDP	0.002 (0.002)	0.002 (0.002)	0.002 0.001)	0.010 (0.012)	0.008 (0.012)	0.005 (0.012)
ΔREN	−0.978*** (0.143)	−0.961*** (0.136)	−0.970*** (0.144)	−0.586*** (0.054)	−1.091*** (0.219)	−1.077*** (0.219)
ΔTRADE	0.099*** (0.053)	0.101* (0.050)	0.020 (0.050)	0.050 (0.089)	0.050 (0.090)	0.045 (0.089)

Continued

ΔURBN	−0.797 (2.917)	−0.330 (2.926)	−0.397 (2.932)	0.744 (1.442)	0.382 (4.063)	0.833 (4.071)
ΔODA	0.007*** (0.013)	0.008*** (0.015)	0.004*** (0.013)	0.003*** (0.011)	0.019*** (0.021)	0.017*** (0.021)
ΔINF	−0.002 (0.006)	−0.002 (0.009)	−0.002*** (0.006)	0.014 (0.015)	0.005*** (0.014)	0.007 (0.015)
ΔPOP	−0.005 (0.034)	−0.005 (0.033)	−0.039 (0.068)	0.059 (0.032)**	0.069 (0.067)	0.049 (0.067)
ΔFDI	−0.001 (0.004)	−0.001* (0.004)	−0.014 (0.030)		−0.011 (0.009)	−0.011 (0.007)
ΔCC * ODA	0.012 (0.016)					
ΔGOV * ODA		0.016 (0.057)				
ΔPS * ODA			0.002 (0.002)			
ΔREG * ODA				0.032 (0.040)		
ΔRULE * ODA					−0.088 (0.240)	
ΔVOICE * ODA						0.183 (0.129)
Cons	1.651* (0.818)	1.945* (0.791)	–.0111 (0.027)	1.436*** (0.404))	0.943*** (1.101))	1.223* (1.093)

5. Results and Discussion

To examine the long- and short-run effect of financial development, official aids and governance quality, we use the pooled mean group (PMG) ARDL, the mean group (MG) ARDL, and the dynamic fixed effects (DFE) ARDL techniques. We first begin by confirming the presence of cross-section dependence test. Then, Haussman test was used to determine the most suitable model between second-generation methods such as PMG, MG, and DFE.

With reference to the PMG estimation results, the coefficients for official aids, renewable energy consumption, economic growth and urbanization are positive and statistically significant. In addition, official aids, inflation, trade openness and foreign direct investment are negative and statistically significant.

The overall index of financial development has negative and statistically significant impact on CO_2 emissions, this result is confirmed by Boufateh and Saadaoui (2020), Odhiambo (2020), Charfeddine and Kahia (2019), Atsu et al. (2021) and Emenekwe et al. (2022).

Results indicate that the issue of governance and aid to reduce CO_2 emissions in Sub-Saharan African countries is crucial to combating climate change and promoting sustainable development in the region.

According to the results, effective governance is essential for developing and implementing robust environmental and climate policies. This involves transparent decision-making processes, citizen participation, and strong government institutions.

Sub-Saharan African countries can benefit from strengthening their institutional and regulatory capacities to monitor, report and verify their CO_2 emissions, as well as to develop national climate action plans.

It is also important to ensure coordination between different levels of government (national, regional and local) and stakeholders, including civil society and the private sector.

The effect of ODA on CO_2 emissions is negative; Sub-Saharan African countries need significant financial support to face the challenges of climate change. This includes access to concessional finance and international climate funds such as the Green Climate Fund. These funds can be used to finance CO_2 mitigation projects, such as the deployment of renewable energy, improving energy efficiency, promoting sustainable agriculture, and protecting forest ecosystems. It is important that this funding is distributed equitably and takes into account the specific needs of countries and communities most vulnerable to the impacts of climate change.

In summary, effective governance and adequate financial support are essential to help sub-Saharan African countries reduce their CO_2 emissions and adapt to the impacts of climate change while pursuing sustainable economic development.

6. Conclusion and Policy Implications

This study examines the impact of ODA governance quality on CO2 emissions. The relationship between ODA, governance and CO2 emissions in sub-Saharan countries can vary depending on several factors. In many cases, ODA leads to mitigating climate change. However, in sub-Saharan countries, where economies may be less industrialized and dependent on foreign aids and natural resource sectors, the relationship may be more complex.

Furthermore, we opted to determine the impact of different components of governance on carbon emissions by examining several characteristics of economic, institutional and political dimensions.

In some cases, economic growth and urbanization focused on sectors like renewable energy, sustainable agriculture, and other lower-CO2-emitting industries can lead to economic growth without a significant increase in CO2 emissions. However, in other cases, rapid economic growth can lead to increased CO2 emissions if it is based on heavy and environmentally unfriendly industries.

Public policies such as investments in renewable energy, strict environmental standards for industries, and incentives to adopt sustainable practices can help mitigate the negative impact of governance on CO2 emissions in Sub-Saharan countries. Additionally, international assistance and regional co-operation can play a crucial role in supporting transitions to more sustainable, low-carbon economies in the region

Good governance and financial development can play a crucial role in comating climate change in sub-Saharan countries. Effective governance can encourage the adoption of favorable environmental and climate policies, such as protecting forests, promoting sustainable agriculture, and regulating industrial emissions. This can help reduce greenhouse gas emissions and mitigate the impacts of climate change.

Clean energy investments: Financial development can facilitate investments in renewable energy and clean technologies, such as solar, wind and hydro power. These alternative energy sources can reduce reliance on fossil fuels and contrib ute to a low-carbon economy. Financial funds can be used to build community resilience to the impacts of climate change, such as droughts, floods and storms. This can include investments in climate-resilient infrastructure, early warning systems, agricultural adaptation programs, and water resources management initiatives.

In summary, good governance and financial development can significantly contribute to mitigating climate change in sub-Saharan countries by fostering sustainable practices, boosting clean energy investments, promoting the institutions quality, the political stability. These efforts are essential to promote sustainable and climate-resilient development in the region.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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