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DOES FINANCIAL INCLUSION MODERATE CO_2 EMISSIONS IN SUB-SAHARAN AFRICA? EVIDENCE FROM PANEL DATA ANALYSIS

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Abstract: The threat posed by climate change has become a reality in the public sphere. This research looks at how financial inclusion affects carbon dioxide emissions in Sub-Saharan Africa (SSA) countries from 2004 to 2017. The panel autoregressive distributed lag and panel granger causality approaches are used to determine if financial inclusion reduces CO_2 emissions in Sub-Saharan African countries. The PARDL results demonstrated that, over time, financial inclusion, GDP per capita, industrialization, and trade openness have a substantial beneficial influence on carbon emissions in SSA countries. The result suggests that these considered variables contribute significantly to CO_2 emissions while urbanization and energy intensity reduce CO_2 emissions in SSA. Financial inclusion and other control variables have no significant impacts on carbon emission in SSA in the short run. The findings of the granger causality test further confirm the direction of causality, revealing that financial inclusion, GDP per capita, industrialization, energy intensity, and trade openness, granger cause carbon emission in SSA countries. Meanwhile, carbon emission does not granger cause any of the considered factors. The study concludes that financial inclusion increases carbon emission in SSA countries, given the poor state of financial inclusion. Our findings advocate for a policy framework that would focus efforts on connecting financial inclusion measures with environmental legislation across SSA nations.

Keywords: CO_2 emissions; financial inclusion; panel ADRL; sub-Saharan Africa.

JEL code: O16, O57, C33.

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1. Introduction

Climate change has become a significant issue in the last two decades, attracting the attention of environmental organizations and global agencies. Carbon dioxide (CO_2) causes climate change, exacerbated by the increased use of polluting energy sources and hurts human health. Africa emitted approximately 43 billion tonnes of CO_2, accounting for 2.73 percent of total global emissions. Despite its minor influence on the global emissions data, sub-Saharan Africa (SSA) persists as one of the regions susceptible to CO_2 emissions due to her greater dependence on energy resources for agricultural output, and a lack of technological innovation (Adzawla, Sawaneh & Yusuf, 2019). Besides, a large corpus of empirical literature has been piloted on the nexus between financial development and Co_2 emissions or environmental quality by investigating the dynamics as well as instituting causal linkages but with divergent outcomes (see Acheampong, 2019; Ali, Law, Lin, Yusop, Chin, et al., 2018; Biu, 2020; Charfeddine & Kahia, 2019; Cucchiella, D'Adamo, Gastaldi Koh & Santibanez-Gonzalez, 2020; Dong et al., 2020; Shahbaz et al., 2020; Demetriades & Andrianova, 2004; Gök, 2020; Jiang & Ma, 2019; Khan, Saleem& Syeda, 2018; Kong & Wei, 2017; Salahuddin, Alam, Ozturk & Sohag, 2018; Sunday, Yang, Deyong & Kamah, 2017; Tsaurai, 2019; Zhang, 2011, amongst others). Moreover, the documentation on the financial inclusion-carbon dioxide emissions nexus in the African continent is scarce while few studies provide conflicting outcomes.

While the detrimental contribution of financial development on carbon dioxide emissions is still a questionable issue, the impacts of financial inclusiveness on carbon emissions is a challenge that is far from an inference due to a lack of data and methodological differences. Moreover, financial inclusion offers a pivotal role in accelerating the quality of the financial sector and the economy. The sustainability of the economy requires all ages and enterprises to have access to equal financial services to meet their basic requirements in a sustainable manner (World Bank, 2018). Recent studies have argued that financial inclusion will enhance access to financial services and intensify the carbon footprint but can contribute to the long-term growth of the financial sector and result in investors taking environmentally friendly steps to minimize CO_2 emissions (Le, Le & Taghizadeh-Hesary, 2020). Theoretically, the impact of inclusive financial services is transmitted to carbon emissions through trade openness, foreign direct investment (FDI), environment-friendly technology, and a host of others. Greenhouse gas emissions are decreased when financial markets assist domestic firms in acquiring ecologically friendly and clean technical instruments (Frankel & Rose, 2012; Tsaurai, 2019, Jiang & Ma, 2019). It also enhances carbon dioxide emissions by encouraging FDI, which increases energy consumption and the scope of economic behavior in the receiving country (Tsaurai, 2019). Nevertheless, some foreign investors may heavily invest in clean energy-associated research and development projects and bring along their environment-friendly technology, which produces a minimal amount of carbon emissions (Aye & Edoja, 2017). Besides, more consumer credit can increase the scale of purchasing machinery and automobiles, which consume a lot of energy (Xing et al., 2017).

There appears to be a mounting accord that inclusiveness in financial services and products helps increase the resilience to climate change of disadvantaged populations (see Le et al., 2020; Yoshino & Morgan, 2016). Hence, it is assumed that increasing the financial inclusion levels will initiate a decrease in CO_2 emissions. Thus financial inclusion can be regarded as a mitigation strategy. Perhaps more documentation is needed to analyze effective methods of leveraging financial inclusion to mitigate changes in carbon dioxide emissions and integrate financial products into intervention strategies to protect vulnerable households and maintain unexpected revenue streams arising from climate change challenges. Given the preceding, the policy thrust of the current study is to gauge the nexus regarding CO_2 emission and financial inclusion. Our motivation centers on the hypothesis, trends, and its impact on sub-Saharan Africa (SSA), a sub-region that imports cheaper and unfriendly CO_2 emissions equipment from foreign firms and investors; and the region that lags behind other regions in the continent with only 30 percent and 12 percent of adults within SSA reportedly have an account at a formal financial institution and a mobile account in 2014 (Asuming, Osei-Agyei & Mohammed, 2018). Sub-Saharan African countries, in contrast to other regions in the continent, have low performance in terms of financial inclusion indexes (Ajide, 2017).

Does the fascinating question remain whether the provision of inclusive financial products to all individuals and enterprises will eliminate or reduce SSA carbon dioxide emissions? As a result, this study empirically assesses the nexus between financial inclusion and CO_2 emissions utilizing panel data of twenty (20) SSA nations spanning from 2004 to 2017. This study contributes to the expanding context of financial inclusion by concentrating on SSA nations with notably relatively low financial inclusiveness. Secondly, to better understand the influence of financial inclusion on carbon emissions, the study creates a financial inclusion index using principal component analysis on penetration, availability, and usage dimensions. A large corpus of prior empirical research used various proxies without examining how dimensions of financial service penetration, availability, and consumption affect or reduce CO_2 emissions. Third, most of the existing research focused on traditional panel estimating methods such as VEC and VAR, generalized method of moments, OLS, and wholly modified OLS, which neglect cross-sectional dependency and provide contradictory findings.

This study adds to the corpus of literature by engaging the panel autoregressive distributed lag (PARDL). The classic ARDL paradigm provides the PARDL with most of its benefits. It can instantly measure short and long-run dynamic forces, and various delays can be employed on different variables in the event of mixed order of integration (Shin, Yu, & Greenwood-Nimmo, 2014). Second, our technique takes into consideration the possible endogeneity of the financial inclusion index and other control factors. Consequently, this method accounts for unobserved heterogeneity for each cross-sectional by estimating varying slope parameters at characteristic frequencies. Finally, panel ARDL results are more significant than traditional OLS results because they are less susceptible to outlying dependent variable observations, especially when the error term is not natural (Alsayed et al., 2020, Ogede, 2020). The finding from this study would compel policymakers to implement appropriate environmental policies because the methodology outstrips traditional estimation methods. The result suggests that these considered variables contribute significantly to CO_2 emissions while urbanization (MAN) and energy intensity (REN) reduce CO_2 emissions in SSA. FI, GPC, IND, MAN, REN, and TR have no significant impacts on carbon emissions in SSA in the short run. The other part of the paper is categorized into four sections. Section 2 focuses on the related literature. Section 3 methodologies and data sources. The empirical results, summary and policy implications are reported in Section 4 and Section 5 respectively.

2. Literature review

A large corpus of prior empirical research has investigated the financial development- CO_2 emissions or environmental quality nexus by investigating the dynamics as well as instituting causal linkages but with divergent outcomes (see Charfeddine & Kahia, 2019; Biu, 2020; Cucchiella et al., 2020; Dogan et al., 2020; Demetriades & Andrianova, 2004; Gök, 2020; Jiang & Ma, 2019; Khan et al., 2018; Kong & Wei, 2017; Sunday et al., 2017; Tsaurai, 2019; Zhang, 2011, amongst others). While the adverse effects of financial development on carbon emissions remain debatable, evaluating the financial inclusion-CO2 emissions nexus is a problem which is far from a conclusion owing to a paucity of data and methodological variations. For example, Kong and Wei (2017) employed panel data methodology to investigate the relationship regarding financial development and carbon emissions across China's 30 provinces from 1997 to 2013. The findings indicated that there is direct nexus between financial development and greenhouse gases emissions in China's provinces. Salahuddin et al. (2018) also argued that economic development, energy consumption, and foreign direct investment considerably boost carbon dioxide emissions on Kuwait's environmental quality from 1980 to 2013 in the short and long run.

Ali et al. (2018) studied the effect of financial development and economic growth on Nigeria's carbon dioxide (CO_2) emissions from 1971 to 2010. The results reveal a long-run cointegration connection between the parameters. The long-run estimate, on the other hand, indicated that economic growth, financial development, and energy consumption all had a positive and considerable contribution to carbon dioxide emissions. Khan, Saleem, and Syeda (2018) used modified ordinary least squares (FMOLS) to evaluate the impacts of financial development (FD), energy usage, and per capita GDP on CO_2 emissions for a sample of Asian nations. They found that, except for India, financial development had a substantial negative connection with CO_2 emissions in the three Asian nations studied. The findings also indicated that whereas wealth disparity reduces CO_2 emissions in Pakistan and India, Bangladesh has the reverse effect. Tsaurai (2019) contended that only domestic credit provided by the financial sector resulted in a considerable increase in carbon emissions in West African nations from 2003 to 2014.

Other recent studies were piloted by Gök (2020), Dogan, Amin, and Khan (2020), and Biu (2020) on the financial development-CO_2 emissions nexus. Gök (2020), for example, used a meta-regression analysis to examine 275 estimated findings from 72 primary investigations. The findings showed that there is a significant positive empirical effect of financial development on CO_2 emissions, notwithstanding reporting bias. As a result, financial development wreaks havoc on the ecosystem. Similarly, Bui (2020) used a simultaneous least square estimator to look at the consequences of financial development on Co_2 emissions for hundred selected countries from 1990 to 2012. The empirical data support the idea that financial growth has a direct influence on conservation deterioration. It has been shown that increased financial development leads to increased energy demand and, as a result, increased emission levels. From 1980 to 2014, Dogan et al. (2020) employed the quantile regression technique to evaluate the financial liberalization- carbon emission nexus. The findings show that financial development (FD) has different effects on carbon emissions across quantiles; moreover, the impact of FD on carbon emissions changes not just between quantiles but also among multiple FD proxies.

However, based on the above analysis of the empirical data, it may be concluded that financial development decreases carbon emissions. The connection between FD and carbon emissions is minimal, implying that financial development promotes carbon emissions. Besides, the financial development-carbon emissions nexus depend on economic growth and institutional quality. The inconsistencies in the empirical findings as well as crucial econometric weaknesses may be responsible for the inconclusive debate on financial development and carbon emissions. From 2004 to 2014, Le et al. (2020) looked studied the connection between financial inclusion and CO_2 emissions in selected Asian nations. The findings revealed that financial inclusion, likely to have contributed to greater CO_2 emissions in the area. Meanwhile, growing openness to trade appears to be resulting in lower CO_2 emissions. In view of the above, only more empirical tests can help to clarify the financial inclusion-carbon emissions nexus to a more considerable extent have ignored the African region. The current research aims to unravel the complexities of the financial inclusion- carbon emissions nexus in SSA countries.

3. Methodology and empirical data

3.1 Data Sources and Measurement

This section covers the econometric approaches employed to study the link between financial inclusion and carbon emissions in the twenty (20) Sub-Saharan African nations chosen (SSA). Panel data were used in the study rather than time series because they have greater explanatory power, less collinearity, and can tolerate heterogeneity (Hsiao, 2014; Kutu & Ngalawa, 2016; Magweva & Sibanda, 2020). The data from 2004 through 2017 were sourced from the World Bank Database. The selected countries are Cabo Verde, Benin, Burkina Faso, Gabon, Angola, Gambia, Ghana, Guinea, Kenya, Malawi, Mali, Namibia, Niger, Sierra Leone, Nigeria, Seychelles, Tanzania, Togo, Uganda, Zambia, and Zimbabwe. The study timeframe and countries were chosen based on data accessibility, the capacity to adjust for diversity, and lower collinearity (Kutu & Ngalawa, 2016).

The dependent variable in the analysis is carbon dioxide (CO_2) emissions. In this study, carbon dioxide (CO_2) represents a key component of greenhouse gases (GHG), crucial roots of intensifying climate change, and global warming (Innovation for Poverty Action, 2017). Financial inclusion and the other control factors are likely to hinder carbon dioxide emissions concurrently, necessitating more investigation into the control variables' selection. As a result, financial inclusion is gauged by developing a composite financial inclusion index following the Camara and Tuesta (2017) and Nguyen (2020). The financial inclusion index explores three aspects of financial inclusion, namely the dimension of penetration, availability, and usage, incorporated into the ensuing discussion. The index of financial inclusion is gauged using principal component analysis (PCA) as:

$$FI_t = q_1 P_t^a + q_2 P_t^b + q_1 P_t^c \quad (1)$$

which is further expanded as:

$$P_t^a = \beta_1 Dep\_Acc_t + \beta_2 Mob\_Money_t + \mu_{it} \quad (2)$$

$$P_t^b = \Psi_1 Branches_t + \Psi_2 ATM_t + \Psi_3 MMAgent_{t+} e_t \quad (3)$$

$$P_t^c = \omega_1 Depoits_t + \omega_2 Loans_t + \omega_3 MMTrans_{t+} \eta_t \quad (4)$$

Where $q_1 \dots q_3$ and P_t^a, P_t^b, P_t^c denote the relative weights and respective dimensions of penetration, availability, and usage, the GDP per capita is introduced to gauge income on carbon dioxide (CO_2). The empirical literature has documented conflicting results on the impact of income on carbon dioxide (CO_2). The predictive parameter of financial inclusion can either have a positive (Le et al., 2020) or a negative sign (Gill et al., 2019).

Table 1 Description of variables

Variable	Indicator	Description
Carbon dioxide emission	CO_2	Per capita CO*2* emission, metric tons
Gross domestic product per capita	GDP_t	GDP per capita, current US $
Industry	IND_t	The industry as a share of GDP
Trade Openness	TR_t	Trade divides by GDP
Energy intensity	REN_t	Energy intensity as a share of GDP
Urbanization	MAN_t	Net output of the manufacturing sector
Financial inclusion index	FI_t	PCA of the dimension of penetration, availability, and usage
Deposit Account	Dep_Acc_t	Account at a formal financial institution
Mobile money	Mob_Money_t	Mobile phone employed to send money
Bank branches	$Branches_t$	Bank branches per 100,000 adults
Mobile money agent	$MMAgent_t$	Nonbank financial institutions' agents
Deposit	$Depoits_t$	Ratio of deposit money in banks to GDP
Number of ATM users	ATM_t	ATMs per 100,000 adults
Loans	$Loans_t$	Loan from a financial institution
Mobile money transaction	$MMTrans_t$	Mobile phone engaged to pay bills

Note: WDI: World development indicator; AC: Author's computation.

3.2 Model

Following research by Grossman and Krueger (1995) and extended by Katircioglu and Taspinar, 2017 and Dogan et al. (2020), which is based on Environmental Kuznets Curve (EKC) model. Hence, the study modified the model by including financial inclusion index as well as other relevant explanatory variables, which is specified as:

$$CO_{2_{it}} = \alpha_{1i} + \beta_{1i} TREND_t + \sum_{k=0}^{a} \lambda_{11ij}\, CO_{2_{it-1}} + \sum_{k=0}^{m1} \lambda_{12ij}\, FI_{it-1} + \sum_{k=0}^{m2} \lambda_{13ij}\, GPC_{it-1} + \sum_{k=0}^{m3} \delta\lambda_{14ij}\, IND_{it-1} + \sum_{k=0}^{m4} \lambda_{15ij}\, MAN_{it-1} + \sum_{k=0}^{m5} \lambda_{16ij}\, REN_{it-1} + \sum_{k=0}^{m6} \lambda_{17ij}\, TR_{it-1} + \mu_{1it} \quad (5)$$

where i = 1, 2, . . . , "n" represents the number of countries; t = 1, 2, . . . , "t" is the number of periods; per capita CO_2 emission is the dependent variable; Financial inclusion (FI), Gross Domestic Product per capita (GPC), industrialization (IND), urbanization (MAN), energy intensity (REN) and trade openness (TR) are the independent variables with the b ×1 vector of endogenous variables (b = 6); λ_{xij} are k ×1 coefficient vectors. δ_{1i} is the vector of scalars, and μ_{it} is an error term distributed with a zero mean and a finite variance. Thus, the study modelled the short-run dynamic nexus among the selected variable, equation (5) is written as follows:

$$DCO_{2_{it}} = \alpha_{1i} + \beta_{1i}TREND_t + \sum_{k=0}^{a} \lambda_{11ij}\, DCO_{2_{it-1}} + \sum_{k=0}^{m1} \lambda_{12ij}\, DFI_{it-1} + \sum_{k=0}^{m2} \lambda_{13ij}\, DGPC_{it-1} + \sum_{k=0}^{m3} \delta\lambda_{14ij}\, DIND_{it-1} + \sum_{k=0}^{m4} \lambda_{15ij}\, DMAN_{it-1} + \sum_{k=0}^{m5} \lambda_{16ij}\, DREN_{it-1} + \sum_{k=0}^{m6} \lambda_{17ij}\, DTR_{it-1} + \delta_{21ij}DCO_{2_{it-1}} + \delta_{22ij}FI_{it-1} + \delta_{23ij}DGPC_{it-1} + \delta_{24ij}DIND_{it-1} + \delta_{25ij}DPMAN_{it-1} + \delta_{26ij}DREN_{it-1} + \delta_{27ij}DTR_{it-1} + \mu_{2it} \quad (6)$$

where α_{1i} is the intercept, λ_{2i}, δ_{2xij}, x = 1,…4, and λ_{2wi}, w = 1,….4, are the parameters estimate, and μ_{2it} is the disturbance term. The above model is a prototype of Pesaran et al. (2001). The *a priori* expectation is that FI, GPC, IND, MAN, REN, and TR positively contribute to the emission of carbon dioxide in Sub-Saharan African countries. The study further verifies the direction of causality among the variables. The Granger-causality assessment was performed to examine the direction of causality among carbon dioxide emission (CO_2), financial inclusion, and other explanatory variables. The test is conducted after a PARDL estimation. This allows testing for panel Granger-causality in both the short and the long run and is stated as follows:

$$CO_{2_{it}} = \alpha_i + \sum_{i=1}^{n} \beta_i\, FI_{it} + \sum_{i=1}^{n} \beta_i\, Y_{it} + \varepsilon_{it}. \quad (7)$$

$$FI_{it} = \alpha_i + \sum_{i=1}^{n} \beta_i\, CO_{2_{it}} + \sum_{i=1}^{n} \beta_i\, Y_{it} + \varepsilon_{it}. \quad (8)$$

where $CO_{2_{it}}$ represents the carbon emission of the country "i" at a time "t"; Fi_{it} represents the financial inclusion of country "i" at a time "t"; Y_{it} represents other explanatory variables as stated in the previous discussion. Consequently, the study espoused the panel autoregressive distributed lag (PARDL) and panel granger causality techniques following Fazli and Abbasi (2018) and Magweva & Sibanda (2020) to estimate equ. (3), (6), and (7). The classic ARDL paradigm provides the PARDL with most of its benefits. It can instantly measure short and long-run dynamic forces, and various delays can be employed on different variables in the event of mixed order of integration (Shin, Yu, & Greenwood-Nimmo, 2014).

4. Empirical Results

4.1 Preliminary results

This section reveals the outcomes from the various techniques employed. Table 2 shows the summary of descriptive statistics. The result showed that the mean value of all the variables moderately inclined towards the maximum values, showing that their values are moderate. Apart from CO_2, FI, and MAN, the standard deviation of all other variables is high, indicating a high degree of deviance from the accurate data caused by their mean values. Explicitly, carbon dioxide emission has a maximum value of 8.936 with a minimum value of 0.0490 and a mean of 0.8606, closer to the minimum. The standard deviation strongly confirms the claim as it is closer to the mean. Furthermore, financial inclusion as the primary independent variable has a maximum value of 3.840 and a minimum of -0.738, with a mean of -0.136 closer to the minimum value, which showed a standard deviation from the mean. Table 2 also showed stability in the relationship between carbon dioxide emission and financial inclusion in Sub-Saharan African countries.

Table 2 Summary of Descriptive Statistics

Measurement	Co_2	FI	GPC	IND	MAN	REN	TR
Mean	0.8606	-0.1363	2284.0	24.815	9.0545	51.664	72.750
Median	0.3104	-0.4833	908.56	22.621	8.9948	56.195	64.332
Maximum	8.9368	3.8409	15906	61.883	19.153	99.887	225.02
Minimum	0.0490	-0.7381	266.56	4.5559	1.5326	0.7533	20.723
Std. Dev.	1.4647	0.9009	3122.2	11.474	3.8669	32.855	35.605
Skewness	3.4016	2.3243	2.3983	1.5319	0.2084	-0.2248	1.8444
Kurtosis	15.574	7.6236	8.4273	5.3368	2.7094	1.7592	7.3873
Jarque-Bera	4.3971	4. 1052	6.0728	3.2241	3.0123	2.3223	3.3171
Probability	0.3255	0.4172	0.1725	0.2315	0.2217	0.5123	0.2513
Observations	280	280	280	280	280	280	280

Souce: Own processing.

The study employed Hadri LM stationary test to ascertain whether the variables are stationary before conducting panel ARDL estimation. The summary of the Hadri LM stationary test results at a 5% significance level is shown in Table 3. The null hypothesis (H_o) of no unit root was tested against the alternative hypothesis (H_1) has a unit root. From Table 3, the result indicated that all the variables have no unit root at a 1% significance level. That is, they are stationary at levels at 1% significance level.

Table 3 Panel Unit Root Test: Hadri LM test

Variables	T-statistics	P-values	Level
Co_2	14.8396	0.000*	I(O)
FI	12.3328	0.000*	I(O)
GPC	11.4764	0.000*	I(O)
IND	4.6771	0.000*	I(O)
MAN	9.5630	0.000*	I(O)
REN	7.2733	0.000*	I(O)
TR	8.3477	0.000*	I(O)

Souce: Own processing.

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

4.2 Empirical Results

The examination of the impact of financial inclusion on carbon emission in sub-Saharan African countries using a Panel autoregressive distribution lag (PARDL) technique is reported in Table 4. From Table 4, in the long run, all the exogenous variables are statistically significant. Financial inclusion (FI), gross domestic product per capita (GPC), industrialization (IND), urbanization (MAN), energy intensity (REN), and trade openness (TR) have significant positive impacts on carbon emissions in SSA countries. This result implies that the poor FI, GPC IND, and TR significantly contribute to or increase the carbon emission in SSA. The findings that financial inclusion (FI), gross domestic product per capita (GPC), industrialization (IND), and trade openness (TR) positively impact carbon emission are in tandem with erstwhile studies (Saboori, Rasoulinezhad & Sung, 2017; Le et al., 2020; Renzhi & Baek, 2020), which report positive impacts of these parameters on CO_2 emissions. Industrialization is also anticipated to have a favorable influence on carbon emissions, as numerous studies have shown (Le et al., 2020; Le & Quah, 2018). The increasing urbanization of several economies in Sub-Saharan Africa has increased energy requirements for industries. The result that trade openness appears to raise CO_2 emissions in SSA is uninspiring. This result indicates that the trade treaties can mar the potential for stakeholders to confront environmentally unfriendly challenges in the sub-region. Meanwhile, MAN and REN have significant negative impacts on carbon emissions in SSA. It indicates that the improvement in the level of MAN and REN significantly reduced the rate of carbon emission in SSA. The negative impacts of energy intensity (REN) and urbanization (MAN) are also contrary to erstwhile like Le and Quah (2018) and Saboori et al. (2017). The result showed that there is a long-run relationship between carbon emission and other exogenous variables.

As indicated in Table 4, there is a long-run causality jointly stemming from the FI, GPC, IND, MAN, REN, and TR to CO_2 in SSA. The findings suggest that the errors in CO_2 emission in the current year will be corrected in the FI, GPC, IND, MAN, REN, and TR at an adjustment speed of 25.7% annually. Besides, the impact of financial inclusion on CO_2 emission in the short run in SSA is also presented in Table 4. In the short run, FI, GPC, IND, MAN, REN, and TR have no significant impacts on carbon emissions in SSA. Also, in the short run, the impacts of FI, GPC, MAN, REN, and TR on carbon emission are positive but not significant at a 5% significance level. Meanwhile, IND has a negative and insignificant effect on c Co_2 emission in SSA. These results indicate that to a certain extent, FI, GPC, MAN, REN, and TR increase CO_2 emission, and IND condenses CO_2 emission in the short run in SSA countries. Surprisingly, the leading factor, financial inclusion, appears to have increased carbon dioxide emissions in SSA. This study suggests that, as access to financial services improves, people in SSA may purchase more ecologically unfriendly items, increasing the nation's use of carbon fuels and resulting in increased CO_2 emissions in the sub-region. Furthermore, the data suggest that there are no connections between financial intermediation and global warning mitigation policies. Given the above, the study concludes that financial inclusion increases carbon emission in SSA countries, given the poor state of financial inclusion. Furthermore, the normality test (Jarque-Bera statistics) of 1.6272 and probability of 0.251 implies that the residuals are normally distributed.

Table 4 Long run and Short-run Panel ARDL Lag result

Variables	Coef.	Std. Err	Variables	Coef.	Std. Err
Long run result			**Short-run result**		
FI	0.1016	0.01916***	**DFI**	0.60173	0.5146
GPC	0.0001	0.00002***	**DGPC**	0.00013	0.0000
IND	0.00802	0.00149***	**DIND**	-0.11207	0.1163
MAN	-0.0298	0.00535***	**DMAN**	0.12941	0.1287
REN	-0.0005	0.00027**	**DREN**	0.82040	0.8184
TR	0.0009	0.00036**	**DTR**	0.00460	0.0040
COINTEQ01	-0.2574 {0.117**}				
Normality Test	1.627 {0.251}				

Souce: Own processing.

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

Consequently, the study further ascertains the effects of financial inclusion (FI), GPC, IND, MAN, REN, and TR on CO_2 emission in SSA, by employing the panel Granger causality test. The results of the panel Granger causality are presented in Table 5. It is indicated there is unidirectional causality stemming from the FI, GPC, IND, MAN, REN, and TR to carbon emission in SSA countries. Meanwhile, carbon emission does not granger cause any of the independent variables. This result implies that the carbon emission rate depends on financial inclusion (FI), GPC, IND, MAN, REN, and TR in SSA countries.

Table 5 Granger Causality Tests

Null Hypothesis:	Causality	F-Statistic	Prob.
FI ≠> Co_2		7.35454*	0.0008
Co_2 ≠> FI	FI → Co_2	5.75192	0.1433
GPC ≠> Co_2		37.9258*	0.0005
Co_2 ≠> GPC	GPC → Co_2	1.78530	0.1700
IND ≠> Co_2		0.23976*	0.0031
Co_2 ≠> IND	IND → Co_2	0.37084	0.6906
MAN ≠> Co_2		0.22558*	0.0043
Co_2 ≠> MAN	MAN → Co_2	0.10449	0.9008
REN ≠> Co_2		0.02209*	0.0003
Co_2 ≠> REN	REN → Co_2	0.29758	0.7429
TR ≠> Co_2		5.29664*	0.0056
Co_2 ≠> TR	TR → Co_2	4.52041	0.4317

Source: Own processing.

Notes: Asterisk(s) *, **, *** represent(s) the rejection of the null hypothesis at 1% and 5% significance levels. The symbol → denotes unidirectional causality, ↔ denotes bidirectional causality and ≠ implies neutrality while ≠> implies does not Granger cause.

5. Conclusions

A considerable number of empirical literature has carried investigation of the financial development- carbon emission nexus globally. However, there are areas of knowledge gap on the impacts of financial inclusion on carbon emission in sub-Saharan African countries. As a result of this knowledge gap and growing concern for variations in methodologies and scope, the debate on the nexus between financial inclusions and carbon emission is not beyond controversy. Consequently, this study set out to empirically examine the nexus between financial inclusion and carbon emission in twenty selected sub-Saharan African countries spanning from 2004 through 2017. The study employs panel autoregressive distributed lag (PARDL) and panel granger causality techniques to verify whether financial inclusion moderates CO_2 emissions in sub-Saharan African countries.

The findings of the PARDL show that, in the long run, financial inclusion (FI), gross domestic product per capita (GPC), industrialization (IND), and trade openness (TR) have significant positive impacts on carbon emissions in SSA countries. The finding suggests that these considered variables appear to have led to more significant Co_2 emissions in SSA while urbanization (MAN) and energy intensity (REN) reduce CO_2 emissions. In the short run, FI, GPC, IND, MAN, REN, and TR have no significant impacts on carbon emissions in SSA. It implies that to a certain extent, FI, GPC, MAN, REN, and TR increase carbon emission, and IND reduces carbon emission in the short run in SSA countries. The findings of the granger causality test further confirm the direction of causality, reveal that FI, GPC, IND, MAN, REN, and TR granger cause carbon emission in SSA countries. Meanwhile, carbon emission does not granger cause any of the considered factors. Given the above, the study concludes that financial inclusion increases carbon emission in SSA countries, given the poor state of financial inclusion.

Our findings advocate for a policy framework that would focus efforts on connecting financial inclusion measures with environmental legislation across SSA nations. Financial inclusion should be viewed as a macroeconomic instrument as well as a strategy for minimizing global warming by stakeholders. Governments should strive to make ecological financing more accessible and inclusive in order to aid the poor and economically disadvantaged elements of society in dealing with growing CO_2 emissions. Individuals and small and medium-sized businesses should also have access to financing to participate in local CO_2 reduction and adaptation campaigns. The finding that openness to trade triggers CO_2 emissions in SSA requires special attention. This result indicates that the trade treaties can mar the potential for stakeholders to confront environmentally unfriendly challenges in the sub-region. This call for the intervention of various government from the sub-region to set up regulatory and legal frameworks that will guide against the unfavorable impacts of trade openness on CO_2 emissions.

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Author Contributions
Jimoh Sina OGEDE designed the study, developed the data analysis, and wrote the original draft manuscript. He was also responsible for the literature review section. Hammed O. TIAMIYU was responsible for data analysis, interpretation, and drafting of the preliminary manuscript.

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