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Entrepreneurship and Carbon Footprints in Sub-Saharan Africa

Przedsiębiorczość i ślad węglowy w Afryce Subsaharyjskiej

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Abstract

This study examines the impact of entrepreneurship on carbon footprints in sub-Saharan Africa (SSA). The study applied the generalised method of moments on the data sourced from the World Development indicators (WDI) and World Governance Indicators (WGI). Result shows that entrepreneurship has a negative but not statistically significant impact on carbon footprints in SSA. Furthermore, across SSA subregions, entrepreneurship has a positive and statistically significant impact on carbon footprints in Central Africa (0.052%) and Southern Africa (0.1914%), while entrepreneurship has a negative and statistically significant impact on carbon footprints in Eastern Africa (0.064%) and Western Africa (0.0273%). Based on findings, the study concludes that entrepreneurs can develop and promote clean technologies, renewable energy projects, circular economy initiatives, sustainable agriculture practices, green transport solutions, and educational programs to lower carbon footprints. This calls for collaboration between stakeholders to create an enabling environment for sustainable entrepreneurship and accelerate Africa's transition towards a low-carbon future. The findings of the study contribute to the policy dialogue for the actualisation of sustainable development goals of good health and wellbeing (SDG 3), clean water and sanitation (SDG 6), promotion of development-oriented policies that support productive activities, decent job creation and entrepreneurship (SDG 8.3); sustainable cities and communities (SDG 11), climate action (SGD 13), life below water (SDG14) and life on land (SDG 15), respectively.

Key words: carbon footprints, entrepreneurship, environmental sustainability, sustainable development

Streszczenie

W niniejszym artykule zbadano wpływ przedsiębiorczości na ślad węglowy w Afryce Subsaharyjskiej (SSA). Wykorzystano dane pochodzące ze wskaźników rozwoju świata (World Development indicators, WDI) i wskaźników zarządzania światowego (World Governance indicators, WGI). Wykazano, że przedsiębiorczość ma negatywny, ale nieistotny statystycznie wpływ na ślad węglowy w Afryce Południowej. Ponadto przedsiębiorczość ma pozytywny i statystycznie istotny wpływ na ślad węglowy w Afryce Środkowej (0,052%) i Afryce Południowej (0,1914%), natomiast ma negatywny i statystycznie istotny wpływ na ślad węglowy w Afryce Wschodniej (0,064%) i Afryce Zachodniej (0,0273%). Stwierdzono, że przedsiębiorcy mogą opracowywać i promować czyste technologie, projekty w zakresie energii odnawialnej, inicjatywy dotyczące gospodarki o obiegu zamkniętym, praktyki zrównoważonego rolnictwa, ekologiczne rozwiązania transportowe i programy edukacyjne mające na celu zmniejszenie śladu węglowego. Wymaga to współpracy między zainteresowanymi stronami w celu stworzenia sprzyjającego środowiska dla zrównoważonej przedsiębiorczości i przyspieszenia przejścia Afryki w kierunku niskoemisyjności. Wyniki przyczyniają się do dialogu politycznego na rzecz realizacji Celów zrównoważonego rozwoju, takich jak dobre zdrowie i dobre samopoczucie (SDG 3), czysta woda i warunki sanitarne (SDG 6), promowanie polityk zorientowanych na rozwój, które wspierają działalność produkcyjną, tworzenie miejsc pracy i przedsiębiorczość (cel zrównoważonego rozwoju 8.3); zrównoważone miasta i społeczności (SDG 11), działania w dziedzinie klimatu (SDG 13), życie pod wodą (SDG 14) i życie na lądzie (SDG 15).

Słowa kluczowe: ślad węglowy, przedsiębiorczość, zrównoważenie środowiskowe, zrównoważony rozwój

1. Introduction

Entrepreneurship has emerged as a critical catalyst for employment, livelihood (Osabohien et al., 2023a, 2022a; 2022b), sustainable development and carbon footprint reduction in Africa. This study examines the interrelationship amongst entrepreneurship and carbon footprint in Africa, which has been a subject of exclusion in the extant literature, highlighting the key role that entrepreneurs play in addressing environmental challenges while fostering green growth. By leveraging innovative solutions, entrepreneurs in Africa are actively driving the transition to a low-carbon economy (Osabohien et al., 2023b).

Furthermore, entrepreneurs in Africa are promoting clean technologies that minimize environmental impacts in various sectors. By introducing energy-efficient appliances, sustainable agricultural practices, waste management systems, and green building materials, they are transforming traditional industries and stimulating the adoption of environmentally friendly alternatives. This shift towards clean technologies not only reduces carbon emissions but also drives economic growth and job creation (Adeleye et al, 2021; Afolabi & Uhomoibhi, 2014; Akpan & Akpan, 2014; Onabote et al., 2021).

A circular economy approach is gaining traction among African entrepreneurs, who are spearheading initiatives focused on waste management, recycling, and upcycling. By designing products and systems that eliminate waste, maximize resource efficiency, and promote reuse, these entrepreneurs are diverting materials from landfills and reducing the carbon footprint associated with linear production and consumption models. Entrepreneurs are championing sustainable farming practices such as organic farming, agroforestry, precision agriculture, and efficient irrigation systems. By adopting these practices, they enhance soil health, reduce deforestation, and minimize the use of harmful agrochemicals, thereby mitigating carbon emissions while ensuring food security (Adeleye et al., 2021; Hanif, 2018).

African entrepreneurs are actively engaged in raising awareness and promoting environmental education. Through educational programs, workshops, and digital platforms, they are fostering environmental literacy and driving behavioural changes that contribute to carbon footprint reduction. By empowering individuals and communities with knowledge and tools, entrepreneurs are fostering a culture of sustainability across the continent. Entrepreneurship is playing a pivotal role in addressing carbon footprints in Africa and advancing sustainable development (Lin et al., 2015). By harnessing the continent's renewable energy potential, promoting clean technologies, embracing circular economy principles, revolutionizing agriculture, and transforming transportation systems, entrepreneurs are driving positive change.

2. Literature Review

Acheampong (2022) assessed the influence of de facto economic, political, and social globalization on Ghana's CO_2 emissions using the stochastic effects by regression on population, affluence, and technology (STIRPAT) framework. To calculate the impact of de facto economic, political, and social globalization on Ghana's carbon emissions, the nonlinear autoregressive distributed lag model was utilized. According to the findings, long-term changes in social globalization both positive and negative reduce CO_2 emissions while long-term changes in political globalization raise them. The asymmetric outcomes also showed that CO_2 emissions are neutrally affected by favorable as well as adverse impacts on economic globalization. The symmetric autoregressive distributed lag model's long-run findings also revealed that Ghana's CO_2 emissions rose as the outcome of political, social, and economic globalization by 0.600%, 0.239%, and 0.293%, significantly.

Dada et al. (2022) looked at the (a)symmetric impact of financial development in the context of economic growth, energy consumption, urbanization, and foreign direct investment on South Africa's ecological condition from 1980 to 2017, Utilizing a linear and non-linear autoregressive distributed lag, the investigation's goals were achieved. The symmetric evaluation's findings indicated that, while financial development reduces non-carbon footprint, it promotes carbon footprint and ecological footprint in the short term. Financial development has a long-term, profoundly detrimental impact on ecological footprint and carbon footprint. Meanwhile, the asymmetric estimation indicated that while there is no asymmetric significance in the long run, there is a significant asymmetric impact in the short run. The short-run asymmetry estimation indicated that while beneficial trends in financial development decrease non-carbon footprint, effective shocks in financial development enhance ecological and carbon footprints. On the other side, adverse impacts on financial development have an advantageous result on ecological, non-carbon, and carbon footprints.

Kwakwa et al. (2022) studied the impact of sectoral and aggregate carbon emissions on Ghana's agricultural development. For the study, time-series data from 1971 to 2017 were utilized. The study used both regression analysis and a variance decomposition method. The findings demonstrated that while overall carbon emissions have a detrimental impact on the nation's agricultural development, economic growth, labour, and capital have a positive impact. Additionally, Ghana's agriculture is negatively impacted by industrial development and emissions from the transport, industrial, as well as additional sectors.

Lamprey et al. (2021) investigated a structure for the implementation of green business models to promote sustainable development in Ghana's construction industry. They conducted semi-structured interviews with 13 executives of construction companies. The interview transcripts were coded using a thematic technique and a qualitative data estimation computer program. The findings revealed how construction company managers define the six types of green business models. The research also demonstrated the necessity of creating green business models to deal with circularity concerns and sustainability objectives to lower carbon footprints in the building sector. In a similar vein, the study discovered a variety of resources for data to promote the recognition, comprehension, and implementation of the elements of green business models.

Nathaniel et al. (2021) investigated the link between CO_2 emissions and economic progress in a few African countries between 1990 and 2014. With support from both static and dynamic models, the findings indicated that expanding energy consumption has a large and advantageous impact on economic growth, demonstrating that Africa's economy is essentially energy dependent. According to other research, CO2 emissions have no discernible simultaneous impact on economic growth but do so at a one-period lag. Both the static and dynamic analyses invariably support the importance of the impacts.

Osadume (2021) looked into how economic expansion affected carbon emissions in some West African nations between 1980 and 2019. The economic growth theory proposed by Simon-Steinmann offers a pertinent theoretical underpinning. This study's major goal was to determine if economic expansion have an impact on carbon emissions. The research employed secondary data from the World Bank Group website that covered the years 1980–2019 using panel econometric methods of statistical evaluation. It chose six West African nations as its sample. The results demonstrated that the independent variable had a short-term, significantly beneficial and substantial result on the dependent variable for the pooled samples.

Tawaih et al. (2021) investigated the environmental effects of various China-Africa trade paths. The analysis of data from 50 African nations utilizing the Fully Modified Ordinary Least Square (FMOLS) model revealed that various Chinese operations have varying environmental effects. It appeared that China's construction operations have a detrimental impact on the environment because the researchers discovered an association between construction revenue and carbon emissions. Likewise, export damages the environment and raises carbon emissions. On the other hand, it was discovered that there was an adverse association between imports from China and carbon emissions, suggesting that China has a beneficial environmental impact in Africa. The findings for foreign direct investment demonstrated that it benefits the environment and that this association is greater in non-resource nations. The findings suggested that, in the long run, African non-resource-rich economies are most probable to profit from China's significant investment in cleaner energy, particularly after the development of the system. This is because the majority of Africa's exports are natural resources.

Omoke et al. (2020) examined the asymmetric dynamic impacts of financial development on the ecological footprint in Nigeria from 1971 to 2014. The study utilized the nonlinear autoregressive distributed lag (NARDL) model. According to the findings, in Nigeria, a beneficial change to financial development has a substantially lesser impact on the ecological footprint (i.e., enhances ecological sustainability) than an adverse reaction to financial development, which has a relatively larger impact (i.e., worsens ecological sustainability). The asymmetry analysis revealed that there is no variation in non-carbon footprint when comparing the effects of both beneficial and adverse changes to financial development on carbon footprint and overall ecological footprint.

Adams and Acheampong (2019) used imbalanced data from 1980 to 2015 to investigate the effects of democracy and green power on carbon emissions for 46 sub-Saharan African nations. The research discovered that green power and democracy both lower carbon emissions utilizing an instrumental variable generalized approach of the moment. Likewise trade openness, population increase, and economic and demographic expansion were the main drivers of carbon emissions in sub-Saharan Africa. The Environmental Kuznets curve was not discovered. The outcomes also showed that it is unclear how urbanization will affect carbon emissions. When different econometric estimate methods were applied, these findings remained reliable.

Hanif (2018) analzed the effects of economic growth, urbanization, and the use of fossil fuels, solid fuels, and clean energy sources on environmental degradation in Sub-Saharan Africa's developing nations. The research used a panel of 34 developing nations spanning 1995 to 2015 and a system generalized method of moment (GMM) to illustrate its conclusions in depth. According to the findings, the use of fossil and solid fuels for cooking and the growth of metropolitan areas both play a substantial role in increasing air pollution and carbon dioxide emissions. Additionally, an inverted U-shape association between per capita economic expansion and carbon emissions was seen in the findings. This relationship established the presence of an environmental Kuznets curve (EKC) in Sub-Saharan Africa's middle- and low-income economies. The results also showed that the deployment of clean energy sources enhances the atmosphere by reducing carbon emissions and household exposure to harmful pollutants directly.

Olusuyi et al. (2016) assessed the pattern of energy use in the Nigerian hotel sector. To assess its impact on the emission level of diesel generators, Nigeria's primary method of electricity generation, energy usage was estimated. The approach of linear regression was used to characterize the energy usage index. Additionally, correlation estimation was used to examine the relationship between normalized energy usage and carbon footprint. The level of carbon dioxide emissions and energy use per guest room were shown to be significantly correlated.

Lin et al. (2015) examined the effect of industrial value-added on CO_2 emissions in Nigeria between 1980 to 2011. Utilzing the Kaya Identity framework, Augmented Dickey-Fuller (ADF), Johansen's co-integration technique, and the vector error correction model (VECM), the outcome of the ADF test showed that to accomplish economic upswing, industrialization, and a decrease in greenhouse gases, ongoing persistent strategies that impose lasting impacts on the variables are necessary. The analysis's findings indicated that there is no proof that industrialization in Nigeria boosts carbon emissions because there is an indirect and substantial association between industrial value-added and CO_2 emissions. Population and GDP per capita have favorable and substantial effects on CO_2 emissions. Energy and carbon intensity are positively correlated, but relatively unstable substantial effect (at a 10% level) on carbon emission.

Afolabi and Uhomoibhi (2014) studied the possible effects of energy use, green IT practices, and the function of entrepreneurship in fostering innovation and creativity in advanced engineering education and research on the Nigerian economy. They looked into the problems caused by subpar or ineffective IT exercises, the importance of entrepreneurship in engineering education and practice, as well as long-term, tactical IT solutions to address Greening Issues that may affect the economy. A review of data from numerous researches revealed that capital saved through different approaches could make it easier to put remedies to some of the challenges currently associated with green IT problems into practice for increased effectiveness and ecological sustainability.

Nkusi et al. (2014) researched South Africa's carbon trading industry's depiction of entrepreneurs. The research was explored using both an exploratory and a descriptive research methodology. The results stated that, despite several potentials, the terms and procedures of CDM project execution, the absence of a clear backing structure, entrepreneurs' constrained availability of funding, and most importantly their overall absence of awareness of the potential for trading by entrepreneurs remain the greatest obstacles for their involvement in the carbon market.

Rigot-Muller et al. (2013) showed an optimization strategy and the ensuing conclusions to reduce overall logistics-related carbon emissions for end-to-end supply chains. The study centered on two actual industrial instances in the UK. Furthermore, data gathered from Automatic Identification Systems (AIS) gave information on vessel specifications, enabling the utilization of more precise emission parameters for each shipping leg. Value Stream Mapping (VSM) was utilized to estimate the carbon footprint and emissions. Both instances demonstrated that, for far-off foreign destinations, the marine leg of the supply chain is the main source of greenhouse gases. In particular, one of the primary attribution methods (used by Defra in the UK) results in routes utilizing Ro-Pax vessels having less-than-ideal carbon footprints.

Akpan and Usenobong (2012) investigated the long-term and causative relationship between electricity usage, greenhouse gases, and economic growth in Nigeria utilizing annual time series data from 1970 to 2008. The results of the research, which used a Multivariate Vector Error Correction (VECM) framework, revealed that, over time, economic progress is linked to higher greenhouse gases, although rising power usage also raises greenhouse gases. These suggested that Nigeria's evolution procedure is highly polluting, and the country's electrical power usage has increased greenhouse gases, as shown by the apparent adverse connection between power usage and emissions. The proposed environmental Kuznets curve (EKC) received little support. Granger-causality findings indicated a one-way causality from economic growth to greenhouse gases, suggesting that greenhouse gas emission-lowering measures may be implemented in Nigeria without slowing down the country's economic growth. The lack of any connection between electricity and growth, in any direction, adds support to the Nigerian power dilemma.

Couth and Trois (2010) evaluated the strategies for reducing greenhouse gases from waste management techniques across Africa. According to a study, urban municipal solid waste in Africa has a prevalent organic content of 56% and contributes significantly to greenhouse gas emissions through decomposition. The newspaper concluded that from house to house extraction of dry recyclables from garbage at collection locations, composting of the available biogenic waste in windrows, employing the matured compost as a substitute fertilizer, and disposal of the left fossil waste in regulated waste dumps are the most effective and economical ways to regulate waste in a significant number of African urban communities and thus reduce greenhouse gases.

3. Methodology

3.1. Data and Variables

In this study, the dependent variable, carbon footprint data, which was proxied by total greenhouse gas emissions was sourced from the WDI database. Some of the independent variables used in this study which include population and electricity were also sourced from the WDI database. Other independent variables such as entrepreneurship and government institutions were sourced from the IEA, and WGI database, respectively. To achieve the objectives of this study, a panel data analysis on selected sub-Saharan Africa countries was carried out (see Appendix A for the list of countries). Detailed information on the variables used in this study is summarised in Table 1.

Table 1. Variables, Measurements, and Sources (Authors' Compilation)

Variable	Code	Measurement	Source	Expectations
Carbon Footprints	CFP	Total greenhouse gas emissions (kt of CO_2 equivalent)	WDI	Not Applicable
Entrepreneurship	ENT	Time required to start a business (days)	WDI	Negative (-)
Population	POP	Population growth (annual %)	WDI	Positive/ Negative (+/-)
Electricity	ELECT	Access to electricity (% of Population)	WDI	Positive/ Negative (+/-)
Government Institutions	GOVE	Government Effectiveness	WGI	Negative (-)

NB: WDI, and WGI mean World Development Indicators, and World Governance Indicators, respectively

3.2. Model Specification and Estimation Techniques

The techniques used in this study to analyse the impacts of entrepreneurship on carbon footprints in Africa were the pooled ordinary least squares (POLS) and the one-step system generalised method of moments (GMM). Each technique was used because of its benefits. The rationale for using each technique is explored below.

The Pooled Ordinary Least Squares (POLS): The POLS technique treats the intercept term and the coefficients of the independent variables as constant across time and space (countries). In order words, it offers the benefit of treating all independent variables as non-stochastic and exogenous while exploring the impacts of the independent variables on the dependent variable across time and space. In this study, the POLS technique was used as the baseline estimation technique before the GMM was used. Despite the benefits of this technique, it suffers setbacks (Aggarwal and Padhan, 2001). Some of the setbacks of this technique are the inability to address the heterogeneity problems, and the inability to capture country-specific effects (Aggarwal and Padhan, 2001). Hence, the POLS estimation technique is expressed in equation (1) below:

$$lnCFP_{it} = \beta_0 + \beta_1 lnENT_{it} + \beta_2 lnC'_{it} + \mu_{it} \quad (1)$$

Where $lnCFP_{it}$ represents the logarithm of the carbon footprints. In addition, $lnENT_{it}$, and lnC'_{it} represent entrepreneurship, and the covariate of the control variables in this study, respectively. Also, β_0 is the intercept term in the POLS model above, β_1, and β_2 are the coefficients of the independent variables, μ is the disturbance term, *i* represents the countries country and *t* represents the study period. The list of countries, according to their sub-regions are presented in Appendix A.

The One-Step System Generalised Method of Moments (GMM): Some of the setbacks of the POLS technique are addressed by the GMM technique. One of the benefits of the GMM estimation technique is that it is effective when dealing with instruments (Arellano and Bond, 1991). This technique also plays a key role in addressing endogeneity problems when analysing a panel data with endogeneity issues (Kam and Tse, 2020). Hence, the GMM estimation technique is expressed in equation (2):

$$lnCFP_{it} = \beta_0 + \beta_1 lnCFP_{it-1} + \beta_2 lnENT'_{it} + \beta_3 lnC'_{it} + \mu_{it} \quad (2)$$

Where $lnCFP_{it}$ represents the logarithm of the carbon footprints, $lnCFP_{it-1}$ represents the first lag of logarithm of carbon footprints. In addition, $lnENT'_{it}$, and lnC'_{it} represent the covariate of the natural logarithm of entrepreneurship, and the control variables in this study, respectively. Also, β_0 is the intercept term in the GMM model above, β_1 is the coefficient of the lagged dependent variable (carbon footprints), β_2, and β_3 are the coefficients of the independent variables, μ is the disturbance term, *i* represents the country ID which spans from 1 to 45, and *t* represents the period with spans from 1 to 17.

4. Result and Discussion

4.1. Summary Statistics

Table 2 shows the descriptive statistics of the variables which include carbon footprints (CFP), entrepreneurship (ENT), population (POP), electricity (ELECT), and government institutions (GOVE) for the full sample and the individual regions.

The average emissions of carbon footprints in the full sample (Africa) was 41238.39 kilotons. This indicates that on average, Africa emits about 41238.39 kilotons of greenhouse gases. When analysing individually, it was revealed that the average emission in the Southern Africa region (112518.5) was the largest as compared to other regions and the Eastern African region (29861.33) has the least average greenhouse emissions. Also, the country which emits 101.55 kilotons of greenhouse gas which is the minimum value in Africa was recorded in the Central Africa region while the country which emits 560857 kilotons of greenhouse gas which is the maximum value in the entire region was recorded in the Southern Africa region.

Also, the entrepreneurship level has an average value of 36.59 in Africa. On a sub-regional level, it was noted that the highest mean value of entrepreneurship was 57.59 and it was recorded in the Central Africa region while the least mean value of entrepreneurship was 25.28 and it was recorded in the West Africa region. Also, the country which has an entrepreneurship value of 2.5 which is the minimum value in Africa was recorded in the Western Africa region, and the country which has an entrepreneurship value of 260.5 which is the maximum value in the entire region was also recorded in the Western Africa region.

The average population growth rate in the full sample (Africa) was 2.46%. This indicates that on average, the population in Africa grows by about 2.46%. When comparing the subregions, it was revealed that the average population growth rate in the Central Africa region (2.97) was the largest as compared to other regions and the Southern African region (1.23) has the least average population growth rate. Also, the country which has a population growth rate of -2.63 which is the minimum value in Africa was recorded in the Eastern Africa region, and the country which has a population growth rate of 5.63 which is the maximum value in the entire region was also recorded in the Western Africa region.

The average population's access to electricity in the full sample (Africa) was 40.61%. This indicates that on average, the population's access to electricity in Africa is about 40.61%. When comparing each subregion, it was revealed that the average population's access to electricity in the Southern Africa region (53.43) was the largest as compared to other regions and the Eastern African region (37.23) has the least average population's access to electricity. Also, the country which has a population access to electricity value of -0.64% which is the minimum value in Africa was recorded in the Eastern Africa region, and the country which has a population access to electricity value of 100 which is the maximum value in the entire region was also recorded in the Eastern Africa region.

Lastly, government institutions as measured by the government effectiveness index, has an average index value of -0.78 in Africa. On a sub-regional level, it was noted that the highest mean index value of the government effectiveness index was -0.07 and it was recorded in the Southern Africa region while the least mean value of the government effectiveness index was -1.89 and it was recorded in the Central Africa region. Also, the country which has a government effectiveness index value of -2.45 which is the minimum value in Africa was recorded in the Eastern Africa region, and the country which has a government effectiveness index value of 1.16 which is the maximum value in the entire region was also recorded in the Eastern Africa region.

Table 2. Descriptive Statistics of the Variables (Authors' Compilation)

	Full Sample		**Central Africa**		**Eastern Africa**		**Southern Africa**		**Western Africa**	
Variable	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)
CFP	41238.39 (86850.96)	101.55 (56086)	37880.97 (30277.26)	101.55 (90124.86)	29861.33 (34452.46)	323.94 (150963.1)	112518.5 (211009.5)	2204.23 (560857)	31482.04 (63305.49)	614.956 (308179.8)
ENT	36.59 (37.23)	2.5 (260.5)	57.59 (47.55)	7 (158.5)	30.77 (25.73)	4 (179)	51.13 (21.1)	15 (125)	25.28 (37.62)	2.5 (260.5)
POP	2.46 (0.93)	-2.63 (5.63)	2.97 (0.83)	-0.08 (4.78)	2.35 (0.97)	-2.63 (5.08)	1.23 (0.56)	-0.40 (2.08)	2.65 (0.63)	.9 (5.63)
ELECT	40.61 (26.31)	0.64 (100)	43.03 (26.47)	4.86 (91.57)	37.23 (30.37)	0.64 (100)	53.43 (21.66)	9.67 (85.9)	38.43 (21.91)	1.28 (94.16)
GOVE	-0.78 (0.64)	-2.45 (1.16)	-1.19 (0.33)	-1.89 (-0.61)	-0.73 (0.78)	-2.45 (1.16)	-0.07 (0.45)	-0.95 (0.58)	-0.81 (0.43)	-1.79 (0.36)

4.2. POLS Estimation Results

This study proxied carbon footprints (CFP), entrepreneurship (ENT), population (POP), electricity (ELECT), and government institutions (GOVE) by greenhouse gas emissions, the time required to start a business (days), population growth rate, access to electricity, and government effectiveness, respectively. Pooled OLS was used in the section to estimate the impact of entrepreneurship on carbon footprints in Africa and its subregions. The results are summarised in Table 3.

All the variables excluding population growth rates in this study were logged. The implication is that the interpretation would be made in percentage form. The independent variables in this model would be regarded as significant if the P-value falls within the significance level at 10%, 5%, and 1%. The F-statistic revealed that the independent variables (ENT, POP, ELECT, and GOVE) were jointly significant in explaining the systemic variations in the dependent variable (CFP) in both the full sample and the subregions (Central Africa, Eastern Africa, Southern Africa, and Western Africa).

The result in Table 3 revealed that entrepreneurship has a positive and statistically significant impact on carbon footprints for the full sample. This indicates that an increase in the number of new businesses in Africa would result in an increase in carbon emissions. This finding agrees with the expectations established in this study and the work of Xushi et al., (2023) in their work on the impact of entrepreneurship and environmental pollution on green growth in the Asian regions and does not correspond to the work of Udemba et al. (2022) who examined the effect relationship between entrepreneurship and sustainable environment. The POLS estimate on the full sample predicted that a 1% increase in the number of new businesses would result in a 0.17% increase in the number of carbon emissions.

Table 3. Pooled OLS Estimates (Authors' Compilation)

	Full Sample	**Central Africa**	**Eastern Africa**	**Southern Africa**	**Western Africa**
entrepreneurship	0.1724*** (0.008)	-0.2952* (0.070)	0.4113*** (0.000)	-0.7228* (0.062)	0.3052*** (0.001)
Population	0.5767*** (0.000)	1.1847*** (0.000)	0.4439*** (0.000)	-1.4719*** (0.000)	1.1417*** (0.000)
Renewables electricity	-0.1565** (0.047)	-0.5081** (0.040)	-0.4255*** (0.001)	1.6101*** (0.000)	0.3172*** (0.006)
Institution	0.2827* (0.069)	-1.7884** (0.025)	0.2949 (0.110)	8.0877*** (0.000)	0.4592 (0.146)
Cons	7.889*** (0.000)	9.5405*** (0.000)	8.3224*** (0.000)	0.8772 (0.584)	5.8055*** (0.000)
R^2	0.1191	0.3883	0.2175	0.6308	0.2642
F-Stat	24.58*** (0.000)	22.22*** (0.000)	16.88*** (0.000)	33.31*** (0.000)	22.53*** (0.000)

Note: *, **, *** means significant at 1%, 5% and 10%, respectively.

The POLS estimates revealed for the impact of entrepreneurship on carbon footprints across the four subregions was heterogeneous, that is, entrepreneurship has a negative and statistically significant impact on carbon footprints in Central Africa (-0.30) and Southern Africa (-0.72), while entrepreneurship has a positive and statistically significant impact on carbon footprints in Eastern Africa (0.41) and Western Africa (0.31).

The result from Table 3 also revealed that population has a positive and statistically significant impact on carbon footprints for the full sample. The result was in line with the expectations established in this study. In Africa, the majority of the countries have a large proportion of the rural population compared to the urban population. Also, there is a large proportion of the population in Africa who source energy from non-renewable sources. The technique (POLS) predicted that a 1% increase in the population in Africa would result in a 0.58% increase in greenhouse gas emissions in the region.

One notable observation from the results in Table 3 was that population has a positive and statistically significant impact on carbon footprints in Central Africa, Eastern Africa, and Western Africa but a negative and statistically significant impact on carbon footprints in Southern Africa. The level of development in the regions is one factor responsible for this. The majority of the countries in Southern Africa including Botswana, Namibia, and South Africa are developed compared to the countries in the other subregions. The POLS estimated that an increase in population in Southern Africa by 1% would result in a 1.47% reduction in carbon footprints in the region. It also predicted that an increase in population in Central Africa, Eastern Africa, and Western Africa would result in an increase in carbon emissions in each respective region by 1.18%, 0.44%, and 1.14%, respectively. The implication of this finding is that the subregions especially the Central, Eastern, and Western Africa should focus on promoting the population use of sustainable energies.

Electricity has a negative and statistically significant impact on carbon emissions in Africa. This agrees with my expectations which predicted it to have either a negative or positive impact. The findings from Akpan and Usenobong (2012) on the long-term relationship between electricity usage, greenhouse gases, and economic growth were not in line with my study. My finding revealed that an increase in the population with access to electricity is associated with a reduction in carbon emissions in the region. Using estimates, it was predicted that a 1% rise in the population's access to electricity is associated with a 0.16% reduction in carbon emissions in that region.

On a sub-regional level, the negative impact of electricity on carbon emissions was also seen in Central Africa and Eastern Africa but not in Southern Africa and Western Africa. This indicates that the population's access to electricity in Central Africa and Eastern Africa was significant in reducing carbon emissions in each region. In addition, the population's access to electricity in Southern Africa and Western Africa was not significant in reducing carbon footprints in each region. The POLS estimates indicated that the population's access to electricity increases carbon emissions in Southern Africa and Western Africa by 1.61% and 0.31%, respectively but decreases carbon emissions in Central Africa and Eastern Africa by 0.51% and 0.43, respectively.

Government institutions have a positive and statistically significant impact on carbon emissions in Africa. This disagrees with my expectations which predicted it to have a negative impact. My finding was in line with the findings of Acheampong (2022) who analysed the influence of de facto economic, political, and social globalization on Ghana's CO_2 emissions. The result in Table 3 revealed that an improvement in government institutions is not associated with a reduction in carbon emissions in Africa. The POLS estimates predicted that a 1% improvement in government institutions is associated with a 0.28% rise in carbon emissions in that region.

When the regions were analysed individually, it was revealed that government institution has a negative and significant impact on carbon emissions in the Central Africa Region. In the Southern region, a positive relationship between institutions and carbon footprints was revealed. A positive but not significant relationship between institutions and carbon footprints was revealed in both Eastern and Western Africa. It can be inferred from this finding that government institutions play a role in reducing carbon emissions in the Central Africa than in the other subregions.

4.3. GMM Estimation Results

The one-step system GMM was used in the section to estimate the impact of entrepreneurship on carbon footprints in Africa and its subregions. The results are summarised in Table 4. Similar to the POLS estimates, the independent variables in this model would be regarded as significant if the P-value falls within the significance level at 10%, 5%, and 1%. The AR (1) and AR (2) were used to check for autocorrelation and the result from Table 4 indicates that there is no presence of autocorrelation in all the regions as the coefficient of AR (1) was statistically significant while the coefficient of AR (2) was not statistically significant.

Table 4 revealed that entrepreneurship has a negative but not statistically significant impact on carbon footprints for the full sample. This indicates that an increase in the number of new businesses in Africa would not result in an increase in carbon emissions. This finding does not correspond with that which was revealed by the POLS estimates as summarized in Table 3. The GMM estimates summarised in Table 4 predicted that a 1% increase in the number of new businesses would result in a 0.05% decline in the amount of carbon emissions. The GMM estimates revealed for the impact of entrepreneurship on carbon footprints across the four subregions was also heterogeneous as predicted by the POLS estimates. Unlike the POLS estimates, the GMM technique predicted that entrepreneurship has a positive and statistically significant impact on carbon footprints in Central Africa (0.05) and Southern Africa (0.19), while entrepreneurship has a negative and statistically significant impact on carbon footprints in Eastern Africa (-0.06) and Western Africa (-0.03).

The estimates summarised in Table 4 revealed that population has a positive and statistically significant impact on carbon footprints for the full sample. This finding was similar to that which was revealed by the POLS estimates as summarized in Table 3. The GMM technique predicted that a 1% increase in the population in Africa would result in a 0.10% increase in the amount of greenhouse gas emissions in the region.

Just like the POLS, GMM revealed that population has a positive impact on carbon footprints in Eastern Africa, and Western Africa, and a negative impact on carbon footprints in Southern Africa. The GMM also revealed that there was a negative relationship among the two variables and that finding did not correspond to that of the POLS. Also, unlike the finding of the POLS, population did not have a statistically significant impact on carbon footprints in both Central Asia and Southern Africa. The GMM estimated that a 1% increase in population in Central Africa and Southern Africa would result in a reduction in carbon footprints in each region by 0.05% and 0.23%, respectively. It also predicted that an increase in population in Eastern Africa, and Western Africa would result in an increase in carbon emissions in each region by 0.05%, and 0.08%, respectively.

Just like the POLS, GMM revealed that electricity has a negative and statistically significant impact on carbon emissions in Africa. This agrees with the expectations established in this work. The result in Table 4 revealed that an increase in the population with access to electricity is associated with a reduction in carbon emissions in the region. Using estimates in Table 4 below, it was predicted that a 1% rise in the population's access to electricity is associated with a 0.02% reduction in carbon emissions in that region.

On a sub-regional level, the GMM estimates indicated that the negative impact of electricity on carbon emissions was seen in Central Africa and Eastern Africa but not in Southern Africa and Western Africa as predicted by the POLS estimates. In addition, the impact of electricity on carbon footprints was not statistically significant only in the Central Africa region. This means that in other subregions, the population's access to electricity was not significant in affecting carbon footprints. The GMM estimates indicated that the population's access to electricity reduces carbon emissions in Central Africa and Eastern Africa by 0.01% and 0.02%, respectively but increases carbon emissions in the Southern Africa and Western Africa by 0.35% and 0.02, respectively.

In Table 4, It was shown that government institutions have a positive and statistically significant impact on carbon emissions in Africa. This finding is in line with that which was predicted by the POLS estimates. The result revealed that an improvement in government institutions is not associated with a reduction in carbon emissions in Africa. The GMM estimates predicted that a 1% improvement in the quality of government institutions is associated with a 0.02% rise in carbon emissions in that region.

When the regions were analysed individually, it was revealed that government institution has a negative but not statistically significant impact on carbon emissions in the Eastern Africa Region. In all subregions excluding the Eastern Africa region, a positive and statistically significant relationship between institutions and carbon footprints was revealed. It can be inferred from this finding that the quality of government institutions' role is not effective in reducing carbon emissions in all subregions. Due to the bureaucracy and other setbacks in the government institutions in Africa, there are failures in implementing some of the carbon emission policies which could play a role in reducing the amount of greenhouse gas emissions.

Table 4. GMM Results (Authors' Compilation)

	Full Sample	Central Africa	Eastern Africa	Southern Africa	Western Africa
ENT	-0.0504 (0.173)	0.0522** (0.041)	-0.0644* (0.095)	0.1914* (0.091)	-0.0273** (0.046)
POP	0.1047** (0.028)	-0.0531 (0.164)	0.0472*** (0.008)	-0.2306 (0.137)	0.08190*** (0.001)
ELECT	-0.0194** (0.017)	-0.0149 (0.395)	-0.0407** (0.017)	0.3556** (0.034)	0.0198** (0.021)
GOVE	0.0168* (0.095)	0.14751** (0.030)	-0.0223 (0.198)	1.47948* (0.084)	0.0442** (0.025)
cons	1.8487** (0.041)	-0.2960 (0.293)	1.4809** (0.018)	-0.6564* (0.088)	0.4159*** (0.006)
AR (1)	-9.20*** (0.000)	-4.87*** (0.000)	-6.01*** (0.000)	-3.26*** (0.001)	-4.42*** (0.000)
AR (2)	-1.43 (0.153)	0.32 (0.751)	0.82 (0.411)	-1.10 (0.271)	-0.86 (0.392)

Note: Variables are logged; *, **, *** means significant at 1%, 5% and 10%, respectively.

4.4. Discussion

The techniques above were used to assess the effects of entrepreneurship on carbon footprints in Africa and in its subregions. The findings were summarised in Table 3 and Table 4 above. The findings revealed that entrepreneurship has a positive impact on carbon emissions in Africa. Despite the negative impact entrepreneurship exhibited on carbon footprints when the GMM was used, its impact was not regarded as significant. As earlier stated, this finding follows the conclusion of Xushi et al., (2023). This same impact in Africa was also reflected in most of its subregions.

In Africa, as more individuals are starting new businesses with the use of non-renewable energies which are readily available, the region could continue to see a massive increase in the amount of greenhouse gases emitted. This is because access to and the use of non-renewable energies like crude oil, wood, and coal emit a massive amount of greenhouse gas emissions, contributing to climate change and air pollution. This supports the findings of Xushi et al., (2023) that entrepreneurship plays a contributing role to carbon footprints. In order to curtail its impacts, this finding recommends that renewable energy should be made available in large quantities and at affordable prices to the population in order to combat climate change.

The two techniques also revealed that population remains a contributor to the level of emissions in Africa. This supports the findings of Hanif (2018) that the rise in the proportion of the population using solid fuels for cooking plays a substantial role in increasing air pollution and carbon emissions. In addition, it supports the findings of Couth and Trois (2010) that found the waste generated by the population to be highly organic and thus contributes significantly to carbon emissions.

Furthermore, the techniques above also revealed that the population's access to electricity does not result to the rise in the level of emissions in Africa. This disagrees with the findings of Akpan and Usenobong (2012) that rising power usage raises greenhouse gases emissions. It is not just electricity that contributes to greenhouse emissions but the source of electricity generation (Requia et al., 2018). If the majority of the source of electricity in the region is from renewable sources like dams, it is possible that there could be a decline in greenhouse gas emissions as the population's access to electricity increases. It was also revealed that the quality of institutions could not play a significant role in reducing carbon footprints in Africa. This finding agreed with the findings of Acheampong (2022) that the nature of the institutions raises carbon emissions in the long term. The results from those techniques disagree with my expectations that as the government becomes effective in promoting environment-friendly policies, the level of greenhouse gas emissions will drop. All these are essential to achieve carbon neutrality.

Though, Africa, as a continent, does not have a single unified plan to achieve carbon neutrality. However, several African countries have developed their own strategies and initiatives to reduce carbon emissions and work towards carbon neutrality. Here are some examples: South Africa aims to transition to a low-carbon economy through its National Climate Change Response Policy, which includes measures like increasing renewable energy generation, improving energy efficiency, and promoting sustainable transport. Also, Morocco has made significant investments in renewable energy, particularly solar power. It aims to generate 52% of its electricity from renewable sources by 2030 and has launched the Noor Solar Plan, which includes building large-scale solar power plants.

Furthermore, Kenya has set a target to achieve 100% renewable energy by 2030. It has made progress in geothermal power generation and plans to expand its wind and solar energy capacities. The country is also implementing initiatives to promote energy efficiency and sustainable agriculture. Ethiopia on the other hand, has set ambitious targets to become a carbon-neutral country by 2025. It has heavily invested in renewable energy sources like hydroelectric power and aims to increase forest coverage as a carbon sink. Ethiopia's Green Economy Strategy focuses on sustainable development across various sectors.

Rwanda has taken significant steps towards sustainability and green development. It aims to achieve carbon neutrality by 2050 and has implemented initiatives like the Green Fund, which supports projects related to renewable energy, afforestation, and waste management. Nigeria has developed the National Renewable Energy and Energy Efficiency Policy to promote renewable energy adoption and improve energy efficiency. The country aims to achieve 30% renewable energy contribution by 2030 and has implemented various projects in solar, wind, and hydroelectric power generation. It good to mention that these examples represent only a fraction of the African countries' efforts towards carbon neutrality. Many other nations on the continent are also working on their own plans and initiatives to reduce carbon emissions and transition towards sustainable development.

5. Summary and Conclusion

Environmental pollution is a major concern in the world as it has a major impact on the health of humans and animals, and also the world's climate. Combating environmental pollution is the responsibility of every country in every continent. Although Africa does not emit little carbon when compared to Asia and North America, it still has the potential in reducing carbon emissions. As African countries are pursuing policies to make them grow, they should also focus on the environmental and social effects.

Ensuring that entrepreneurs in Africa pursue sustainable business practices could see the amount of greenhouse gas emissions reduce drastically. This study employed the POLS as the baseline estimator and the one-step system GMM to address endogeneity problems. This study achieved it objectives by ascertaining that entrepreneurship increases the level of carbon emissions in Africa. As regards to that, policies should be aimed at supporting entrepreneurs who engage in sustainable or environmental-friendly business practices and ensuring entrepreneurs comply with rules relating to the use of non-renewable and renewable energy sources. The findings of the study contribute to the policy dialogue for the actualisation of sustainable development goals of good health and wellbeing (SDG 3), clean water and sanitation (SDG 6), promotion of development-oriented policies that support productive activities, decent job creation and entrepreneurship (SDG 8.3); sustainable cities and communities (SDG 11), climate action (SGD 13), life below water (SDG14) and life on land (SDG 15), respectively.

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Appendix A: List of Countries for the study

Central Africa	**East Africa**	**Southern Africa**	**West Africa**
Burundi	Burundi,	Angola	Benin,
Cameroon	Comoros	Botswana,	Burkina Faso
Central African Republic	Djibouti	Lesotho,	Cape Verde,
Chad	Ethiopia	Namibia,	Côte D'Ivoire
Congo Republic	Eritrea,	South Africa	Gambia
Democratic Republic of Congo	Kenya	Swaziland	Ghana
Equatorial Guinea	Madagascar	Madagascar	Guinea
Gabon	Malawi	Zambia	Guinea-Bissau
Sao Tome & Principe	Mauritius	Mozambique	Liberia
	Rwanda		Mali
	Seychelles		Mauritania
	Somalia		Niger
	Tanzania		Nigeria
	Uganda		Senegal
	Zimbabwe		Sierra Leone
			Togo