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Greening the Planet: Navigating Carbon Accounting for Sustaining Food Security in Sub-Saharan Africa

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Abstract: *This study seeks to investigate the effect of carbon accounting on food security in Sub-Saharan African nations. This study employs an ex-post facto research design, with secondary data obtained from several sources for 14 out of 48 Sub-Saharan African nations, spanning the years 2001 to 2019. The data were analysed using descriptive (descriptive statistics and correlation) and inferential (Panel GMM) statistics. The empirical evidence revealed that carbon emissions exerted a positive but insignificant effect on the food security of Sub-Saharan African nations. Also, environmental tax exerted a negative but insignificant effect on the food security of these countries. The study recommends that appropriate legislative measures and policies should be put in place to ensure environmentally friendly practices in the selected Sub-Saharan Africa countries.*

Keywords: Carbon accounting; Climate change; Economic development; Environmental taxation; Food security
JEL Classification: M12, M14, M41

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1. Introduction

Food security has been a global issue in recent times, particularly in the Sub-Saharan African region. This becomes paramount as the World Food Programme (WFP) has warned of a new peril on the horizon, a hunger pandemic (Context, 2020). According to the Food and Agricultural Organization (FAO), over a billion people are affected by food insecurity across the globe (FAO, 2018; Tian et al., 2016). Prior to the Covid-19 pandemic, poverty, population expansion, sickness, violence, and climate change all led to an increase in hunger (Pawlak & Kolodziejczak, 2020). Although many regions and countries face severe food security and hunger issues, this problem is most prevalent within Sub-Saharan Africa (Asongu & Odhiambo, 2023; Asogwa & Onyegbulam, 2021; Sani et al, 2019; FAO, 2018).

FAO studies support normal food safety and diet evaluation with the predictions of how the environment will be in 2030 if patterns persist from the last decade. Projections reveal that the planet is not progressing towards achieving UN Sustainable Development Goal (SDG) 2 of zero hunger by 2030, and most metrics are still not progressing in the achievement of the global nutritional goals (Asogwa & Onyegbulam, 2021; FAO, 2020). The United States leads diplomatic attempts to counter the need for sustainable supplies of nutritious food for people around the world (Sing & Chatu, 2021).

With the presence of Covid-19, there were predictions that the number of individuals living in severe food poverty will more than double after 2021. According to WFP estimates, 149 million people (including refugees) in 79 countries have become severely food insecure (faced with or worse food shortage situations, often referred to as integrated phase classification, phase 3 or above) in 2019. With the presence of Covid-19, the total amount of individuals undergoing severe food insecurity in all those countries is anticipated to reach 272 million by the end of 2021 (World Bank, 2020). Much of the current debate on SDG2 is centred on Africa, which is experiencing unprecedented population growth and is especially vulnerable to climate change's effects (Niang et al., 2014). Given widespread scepticism of output numbers, it is difficult to say how serious Africa's food crisis is (Jerven, 2013).

While striving towards achieving SDG 2, industrial and technological progress increased simultaneously (Vysochyna et al., 2020). These activities, on the other hand, have set off a chain reaction of negative consequences, most notably in terms of the environment. Academics claim that economic success is intrinsically related to environmental awareness, which has garnered a lot of attention recently (Sandberg et al, 2019). According to Marcotullio et al. (2021), Africa is the continent most likely to be affected by global warming to the greatest extent. The SDGs have gained widespread acceptance as concepts for global development until 2030. They were ratified at the UN Summit in New York in 2015. There are 17 objectives in all, each with its own set of 169 metrics.

With every facet of the global world and discipline striving towards contribution to the SDGs', accounting discipline is not left out. In past decades, the primary focus of accounting was on reporting the financial and corporate results of businesses as financial accounting or management accounting. The emergence of corporate stakeholder information demands is increasing the quantity and kind of information appropriate for the disclosure of companies. Accounting has proven itself to be a multidisciplinary discipline cutting across multiple areas of life and this has developed over time (Ben-Amar et al., 2017). To this day, accountants have not been at the forefront of climate change policy, although in recent years, their activity and involvement have grown dramatically, with a range of global networks developing (e.g., the Council of Climate Transparency Requirements, Accounting for Sustainability, Global Monitoring Project, International Integrated Reporting Council) (Deloitte, 2020; Lovell & Mackenzie, 2011).

The research gap captures that accounting is not well established in most poor nations to fulfil the modern purpose of giving relevant information to consumers, as it is in developed ones. Furthermore, empirical research on carbon accounting has not yielded clear-cut conclusions, such as when empirical research ends with normative recommendations for practice, or when a critical article uses empirical review (Feifei et al., 2017). Nonetheless, their results may be helpful in the field of social and environmental accounting (SEA). However, it is not completely adequate for addressing national and global problems like economic development. Additionally, Aitkazina et al. (2019) highlight that increased emissions of greenhouse gases (GHG) and increased usage of chemical fertilisers from agricultural operations pose a danger to long-term growth. Similarly, Sibanda and Ndlela (2020), Dkhili and Dhiab (2019), and Odermatt (2018) claim that higher carbon dioxide emissions harm firm performance, food security, as well as long-term economic growth. As a result, the objective of this study is to investigate the effect of carbon accounting on food security in Sub-Saharan Africa.

This paper comprises five sections designed to address the research objectives comprehensively: an introduction, literature review, theoretical framework and methodology, data analysis, and conclusion. The study's outcomes and recommendations aim to guide policy decisions and actions towards SDG achievement.

2. Literature Review

2.1 Conceptual

2.1.1 Carbon accounting

Carbon accounting is a subset of sustainability accounting that focuses on carbon emissions and their related costs (Gulluscio et al., 2020). The concept of a carbon footprint was created to quantify the impact of a product, service, or organisation on climate change (measured in carbon dioxide or CO2 equivalent) (Mulrow et al., 2019). Climate change and the need to reduce GHG emissions are massive concerns that touch almost every aspect of human life and values (Driga & Drigas, 2019). Management accountants are characterised by their academic credentials, expertise, and capacity to provide quantitative and high-quality data on the costs and benefits of climate change (Oyewo, 2021).

A country charges carbon explicitly using carbon taxes. Businesses that generate far more carbon are charged the highest; for example, oil and gas firms (McLaughlin, et al., 2019). Of course, the tax will be passed on to organisations, and the public will be responsible for it as with everything else. However, this money transfer—from carbon-intensive economic endeavours to renewable energy-intensive endeavours—will ultimately have the desired positive impact. Carbon taxes, on the other hand, provide a permanent incentive to reduce carbon emissions (Timilsina, 2022). In recent years, stakeholders have been particularly worried about business activities' impact on climate change (Dahlmann et al., 2019). The introduction and sustainability of carbon tax to control climate change serve as a strong contribution of accountants to the discussion on climate change adaptation strategies as other disciplines and professions have greatly contributed to this global phenomenon (McLaughlin et al., 2019).

2.1.2 Food security

Food security, according to the United Nations, is when every human being has constant access to enough safe and nutritious food to meet their dietary preferences and nutritional requirements for a physically, socially, and economically active and healthy life. In the coming decades, climate change and global population expansion will have a large yet unforeseeable impact on food stability, rising food costs, and wars (IFPRI, 2020). Many nations are experiencing high inflation of food prices (Gene, 2021). In low- and middle-income countries, this is vital because they spend more of their income on food than people in high-income nations do. Reduced calorie consumption and compromised diet challenge poverty reduction, and well-being improvements and may sustainably impair children's cognitive growth (Siddiqui et al., 2020).

Some food suppliers are at a loss as trends of demand change to cheaper foodstuffs (Serpil & Mehmet, 2020). Recent years have brought some comfort to Africa's grim outlook. The last ten years have seen sustained economic growth and political maturity, resulting in current confidence about Africa's resurgence (Ajakaiye & Jerome, 2015). While the worldwide commodities price boom has clearly assisted Africa's recovery, stronger governance has ensured a new perspective as well as confidence in Africa's capacity to chart its future (Ajakaiye & Jerome, 2015). There exists, nevertheless, some important difficulties to overcome. SDG 2 is without a doubt one of humanity's most pressing and difficult encounters.

2.2 Theoretical review

The epistemic community theory depicts accountants as a network of professionals with acknowledged experience and competence in a certain subject and an authoritative claim to policy-relevant information within that domain or problem area. This idea reflects the growing need for accountants to be at the forefront of the global discussion on food security and climate change. Haas (1989) developed the concept of an epistemic community (EC), which refers to a knowledge-based international community of experts, specifically a "network of professionals with recognised expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area." ECs have the following characteristics: shared sets of causal and principled beliefs, a consensual knowledge base, and a shared policy enterprise (Haas, 2015).

In the instance of accountants and climate change, interest in the topic has dramatically expanded, and several international networks have emerged to address the problem. Accounting for Sustainability, developed by the Climate Disclosure Standards Board, is one such example. Further, accountants have framed climate change in such a way that their expertise (in areas such as computation, measurement, etc.) is essential to policy solutions, adding to a broader framing of the issue as one of reshaping and expanding market processes and current corporate reporting procedures (and not radically altering or disrupting those processes and procedures). Advocates of the concept of ECs, such as Marianna and Sergey (2015), argue that it means that these scientific and professional organisations share ideas and resources to progress them (reputation, knowledge). Unlike organisations (e.g., non-governmental organizations or NGOs) that operate independently of the government, ECs are built within and treated as if they were always a part of it. According to Dunlop (2011), Haas emphasises the importance of experts' influence on decision-maker learning as a potentially crucial process affecting policy creation and change.

2.3 Empirical review

Kong et al. (2022) investigate China's carbon footprint reduction by 2050 utilising existing mitigation measures. They summarise current research on agricultural decarbonisation, provide domestic food production objectives, and project China's agrifood emission reductions. According to the report, sustainable development techniques in the agrifood industry make a major contribution to reducing GHG emissions. Mitigation options include increasing nitrogen use efficiency, altering food consumption structures, manure management, cover crops, reducing food waste, modifying diets, and using covered manure. A 10% increase in nitrogen usage efficiency might save 5.03% of GHG emissions by 2050.

Affoh et al. (2022) examine the association between climatic factors such as rainfall, temperature, and CO_2 emissions and food security in 25

Sub-Saharan African nations between 1985 and 2018. The findings reveal that rainfall improves food availability, accessibility, and utilisation, but warmth reduces availability and accessibility but not utilisation. CO_2 emissions enhance availability but not utilisation. The research also discovered a short-run causal link between food availability and CO_2 emissions, food accessibility and temperature, and CO_2 emissions and precipitation.

Kim et al. (2021) focus on enhancing crop production in Sub-Saharan Africa by identifying common practices and assessing their impact on GHG emissions. Common practices include expanding agricultural land, developing water harvesting and irrigation techniques, and increasing cropping intensity and fertiliser use. Alternatively, Wang et al. (2021) address the problem of food loss and waste (FLW) in the food supply chain, emphasising the present linear nutrient utilisation model, which jeopardises food security and environmental sustainability. They propose a circular economy model that reduces and recycles FLW, but note that a more concentrated evaluation of FLW reduction and recycling is required.

Firdaus et al. (2019) investigate the effects of climate change on food security from the perspectives of many disciplines and nations (food availability, accessibility, food utilisation and the stability of food systems). According to scholarly research, climate warming will have devastating effects on worldwide food supplies. There would be repercussions if any of these four factors affecting food security are compromised. This is consistent with the research conducted by Islam and Wong (2017), who aimed to provide a more nuanced perspective and, by extension, a better understanding of the intricate interplay between climate change and food security. It is also consistent with the findings of Rosegrant et al. (2016), who conducted a conceptual analysis of the effects of climate change on crop productivity and found that it may impact domestic agricultural output, consumption, and food security. Frank et al. (2017) examine how carbon prices influence efforts to reduce GHG emissions and provide adequate nutrition, and find that carbon pricing systems provide efficient and cost-effective mitigation for all sectors. Furthermore, in low-productivity regions, where the price of carbon would rise, agricultural commodity prices rise, leading to an increase in GHG emissions.

Amaka et al. (2016) analyse Nigeria's food security from 1991 to 2015 using descriptive data, and find that since the country's population is expanding at a rate of 3.2% per year while food production is growing at a rate of less than 1% per year, it is clear that there is a food shortage in the nation. This demonstrates that the population's need for food is more than what the world can provide due to reasons including inconsistent government policies, environmental deterioration, and unsustainable agricultural production (agricultural output). The study also highlights Nigeria's reliance on food imports.

Wu and Thomassin (2018) conduct studies on the effects of Canada's carbon tax on food costs and consumption. The research focused on the state and federal carbon tax systems and made use of pricing model applications on both a national and regional scale. The technique for the national pricing model was taken from the model for Canadian price data. The research found that carbon taxes had a detrimental influence on food prices and consumer spending. Saxeena (2016) and Springmann et al. (2017), however, suggest that imposing an environmental tax on food prices could reduce agriculture's environmental costs and promote eco-friendly, healthier food options. They used an estimated emissions price of US$52 per metric tonne of CO_2 and a global comparative risk assessment technique.

Based on the above review, the main objective of this study is to investigate how carbon accounting affects the food security of selected Sub-Saharan African countries. Specifically, to find out the effect of carbon emission and environmental tax on food security of selected countries from the region.

3. Methodology

This study examines the impact of carbon accounting on food security in SSA. The ex-post facto research design is adopted in this study because the researchers were unable to alter the independent variable, but still wanted to investigate its influence on the dependent variable. Secondary panel data was utilised, obtained from a variety of sources, i.e., FAO and Organization for Economic Cooperation and Development (OECD) statistics, as well as the World Development Indicators (WDI), during the period under consideration. The panel data were analysed retrospectively in this research to determine causes, connections, or associations, as well as their interpretations. The research attempts to assess the effect of how carbon accounting (CO_2 and environmental tax) influences food security in Sub-Saharan Africa. This data spans the years 2001 to 2019 and both the independent and dependent variables exist and are seen at the same time since the former had an impact on the latter before this time. Several researchers, including Okere et al. (2021), have utilised this study design. This study's population consists of the 48 nations of Sub-Saharan Africa. With the population stated above, 14 nations were chosen with the understanding that the sample taken reflects at least 10% of the overall population, each for the period 2001 to 2019. The period was chosen due to the availability of data required for the study.

3.1 Description and measurement of variables

Table 1 describes the variables used in the analysis.

Table 1: Description and Measurement of Variables

Variables	Description and measurement	Source of data
Dependent variable (FS)		
Food Production Index (FPI)	Food production index covers food crops that are considered edible and that contain nutrients	WDI 2021
Independent variables		
Carbon Emissions (CO_2)	CO_2 emissions in Metric tons	WDI 2021
Control variables		
Population growth	Population growth is the increase in the number of individuals in a population	WDI 2021
Agricultural productivity (Proxied by Agricultural value added)	Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs	WDI 2021
Capital Input	Gross fixed capital formation (annual % growth)	OECD 2021
Environmental Taxation	Environmental tax revenue	OECD 2021; Mahmoud, Walid, & Damien (2020)

3.2 Model specifications

The general specification is given as:

$$Y = f(X)$$

where Y = dependent variable (food security); X = independent variables (carbon accounting) food security (FS) = *f* (carbon accounting (CA)). In order to analyse the research objective of this study, the model of Mesike and Esekhade (2014) is adapted. The original model recognises that labour input (LAB), climate change (CLI), subsidy (SUB), gross capital formation (GCF), consumer price index (CPI), and oil exports (EOX) determine food productivity. This model can be represented mathematically as:

$$FPI = f(LAB, CLI, SUB, GCF, CPI, OEX) \tag{1}$$

Equation (1) is adjusted and represented mathematically as:

$$FPI = f(ENVTAX, CO_2, AP, PG, CAP) \tag{2}$$

Equation (2) is restated in linear form by taking its natural logarithm. Hence, equation (2) becomes:

$$FPI_{it} = \beta_0 + \beta_1 ENVTAX_{it} + \beta_2 AP_{it} + \beta_3 PG_{it} + \beta_4 CAP_{it} + \mu_{it} \tag{3}$$

where *FPI* refers to food production index; $C0_2$ to carbon-dioxide emission in metric tons; *AP* to agricultural productivity proxied by agriculture, forestry and fishing, value added (% of GDP); *PG* to population growth (annual %); *GCF* to gross fixed capital formation (annual % growth); and *ENVTAX* to environmental tax. β_0 is the intercept of the model; β_1 to β_4 are the parameter estimates; and μ the stochastic disturbance error term. The subscripts *i* and *t* are used to index countries and time periods respectively.

Therefore, equation (3) is specified to form the generalized method of moments (GMM) model as follows:

$$FPI_{it} = \beta 0_{it} + \Omega FPI_{it-1} + \beta_1 ENVTAX_{it} + \beta_2 AP_{it} + \beta_3 PG_{it} + \beta_4 CAP_{it} + \mu_{it} \tag{4}$$

where Ω is the coefficient of the first lag of the dependent variables in equation 4.

Multiple regression models were used to obtain numerical values of the model parameters. Given that the number of cross-sectional observations exceeds the number of periods (i.e., big N and short t), the GMM estimate method would be sufficient. The ordinary least squares (OLS) estimating method has a significant difficulty in that it fails to address the endogeneity problem of the independent variables caused by the correlation between the delayed dependent component and the residuals. The least square dummy variable (LSDV) model combined with the lagged dependent variable offers a response from past or current shocks to the present dependent variable. This requirement is handled in the GMM approach of Arellano and Bond (1991) and Arellano and Bover (1992).

4. Data Analysis and Interpretation

4.1 Descriptive statistics

In this descriptive statistical analysis (see Table 2), the study explores the characteristics of five variables (AP, FPI, CAP, CO_2, ENVTAX, PG), each representing different aspects of a dataset. These variables offer valuable insights into the central tendency, dispersion, and distributional characteristics of the data. Let us delve into the detailed discussion of each variable. Starting with AP, the mean value of 20.9784 indicates the average for this variable. However, the presence of a relatively high standard deviation of 12.0180 suggests considerable variability in the dataset.

Table 2: Descriptive Statistics

	AP	FPI	CAP	CO_2	ENVTAX	PG
Mean	20.9784	89.5417	6.6370	29.0804	1.0075	2.3958
Median	22.6291	94.0700	5.5452	3.1559	0.7200	2.6486
Maximum	55.7719	128.2700	95.0366	502.2594	12.3900	3.9072
Minimum	1.8283	44.8400	-38.5330	0.2345	0.0000	0.0322
Std. Dev.	12.0180	17.0648	14.5222	95.3235	1.3284	0.8628
Skewness	0.2732	-0.6035	1.3435	4.0673	3.7759	-0.8143
Kurtosis	2.7494	2.7211	9.6849	18.3839	27.0715	3.1984
Jarque-Bera	6.2940	26.7353	904.0816	5274.3940	11085.2000	46.8836

	AP	FPI	CAP	CO2	ENVTAX	PG
Probability	0.0429	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	8768.974	37428.450	2774.296	12155.610	421.1500	1001.458
Sum Sq. Dev.	60228.77	121434.30	87943.65	3789103.00	735.87	310.44
Observations	418	418	418	418	418	418

The skewness of 0.2732 suggests a slight rightward skew and a kurtosis of 2.7493 indicates a distribution that is platykurtic. The Jarque-Bera test, with a *p*-value of 0.0429, which is less than the significant level indicates a departure of the data from normality. The maximum value of 55.7719 and minimum value of 1.8283 highlight a broad range of values. Moving on to the FPI, the mean and median values of 89.54174 and 94.0700 respectively are close, suggesting a symmetric distribution. The standard deviation value of 17.06486 indicates moderate variability. The negative skewness (-0.6035) suggests a leftward skew, and the kurtosis (2.7211) indicates a platykurtic distribution with moderate peakness. The Jarque-Bera test with a p-value of 0.0000, significantly lesser than the statistically significant level, strongly rejects normality. The range between the maximum (128.2700) and minimum (44.8400) values is substantial.

For gross fixed capital formation (GCF), the mean value (6.6370) and median (5.5452) indicate potential skewness. The high standard deviation (14.5222) points to significant variability. Positive skewness (1.3435) indicates a rightward skew and high kurtosis (9.6849) suggests a leptokurtic distribution with heavy tails. The Jarque-Bera test having a *p*-value of 0.0000 further confirms non-normality. The range is substantial, with a maximum of 95.0366 and a minimum of -38.5330. ENVTAX exhibits a mean value of 1.0075 and a median of 0.7200. The standard deviation (1.3284) implies moderate variability. The positively skewed distribution (skewness of 3.7759) and high kurtosis (27.0715) indicate a distribution with a long right tail. The Jarque-Bera test (*p*-value of 0.0000) strongly rejects normality. The minimum value of ENVTAX is 0 while the maximum value is 12.3900.

The mean value for CO_2 is 29.0804, and the median is substantially lower at 3.1559. This discrepancy between the mean and median suggests a right-skewed distribution, as the mean is influenced by the presence of higher values. The standard deviation is 95.3235, indicating a considerable degree of variability in the dataset. The skewness of 4.0673 indicates a pronounced rightward skew, affirming the distribution's asymmetry towards higher values. The kurtosis of 18.3838 suggests heavy tails and potential outliers, contributing to the non-normality of the distribution. The Jarque-Bera test, with a significantly low *p*-value of 0.0000, strongly rejects the null hypothesis of normality. Lastly, the population growth (PG) has a mean of 2.3958 and a median of 2.6486. The standard deviation of 0.8628 is relatively low, suggesting limited variability. The negatively skewed distribution (skewness of -0.8143) and moderate kurtosis (3.1984) indicate a distribution with a longer left tail. The Jarque-Bera test (*p*-value of 0.000000) strongly rejects normality. The minimum value is 0.0322 while the maximum value is 3.9072.

The non-normality observed in several variables emphasises the importance of considering alternative statistical approaches that do not assume a normal distribution when analysing this dataset.

The provided correlation matrix (Table 3) offers insights into the relationships between the variables AP, FPI, CAP, CO_2, ENVTAX, and PG. Correlation coefficients range from -1 to 1, with positive values indicating a positive correlation, negative values indicating a negative correlation, and zero indicating no correlation. A correlation coefficient close to 1 or -1 implies a strong correlation, while values close to 0 suggest a weak or no correlation.

Table 3: Correlation Analysis

	Correlation					
Probability	**AP**	**FPI**	**CAP**	**CO_2**	**ENVTAX**	**PG**
AP	1.0000					
	–					
FPI	-0.3252	1.0000				
	0.0000	–				
CAP	0.0976	-0.0875	1.0000			
	0.0461	0.0737	–			
CO_2	-0.3199	-0.0011	-0.0511	1.0000		
	0.0000	0.9809	0.2968	–		
ENVTAX	-0.0472	0.0119	-0.0555	0.1076	1.0000	
	0.3354	0.8069	0.2569	0.0278	–	
PG	0.7476	-0.2966	0.1650	-0.2347	0.0052	1.0000
	0.0000	0.0000	0.0007	0.0000	0.9144	–

AP exhibits a negative and slightly weak correlation with FPI with a correlation value of -0.3252, which suggests that as AP increases, FPI tends to decrease. A positive but very weak correlation is observed with CAP, with a correlation value of 0.0976. Notably, there is a weak negative correlation with CO_2 (-0.3199), suggesting that increased agricultural productivity is associated with lower CO_2 levels and a very strong positive correlation of 0.7476 with PG. The positive correlation with CAP indicates a weak tendency for both variables to increase together. The strong positive correlation with PG implies a substantial positive relationship between AP and PG. FPI with a correlation value of -0.3252 shows a negative and weak correlation with AP, and the strength of this relationship is statistically significant (*p*-value of 0.0000). This suggests that as FPI increases, AP tends to decrease. The correlation with CO_2 is negative and very weak and negligible with a value of -0.0011, while with CAP, it is negative but weak (-0.0875), indicating a slight tendency for FPI and CAP to decrease together.

CAP has a weak positive correlation with AP (0.0976) and a weak negative correlation with FPI and CO_2 (-0.0875 and -0.0511, respectively). The correlations have *p*-values of 0.0461, 0.0737 and 0.2968, respectively, indicating statistical significance except that of CO_2. These weak correlations suggest limited linear relationships between CAP and the other variables. ENVTAX, interestingly, has weak correlations with all other variables. It shows a weak negative correlation with AP (-0.0472), a very weak positive correlation with FPI (0.0119), a weak negative correlation with CAP (-0.0555), and no significant correlation with PG (0.0052). These results suggest that ENVTAX may not have a strong linear relationship with the other variables in the dataset. PG exhibits a strong positive correlation with AP (0.7476), a statistically significant result with a *p*-value of 0.0000. This implies that as PG increases, AP tends to increase as well. PG has a weak negative correlation with FPI (-0.2966) and CO_2 (-0.2347), indicating a tendency for PG and CO_2 to decrease as FPI increases. The correlation with CAP (0.1650) is positive but weak, and there is almost no correlation with ENVTAX (0.0052).

Furthermore, a reason for the correlation analysis is to check for multicollinearity between the independent variables. There is no problem of multicollinearity since the correlation coefficients of all the variables are lower than the recommended threshold of more than 0.8. As a rule of thumb, Okere et al. (2021) suggest that if the correlation is greater than 0.8 then severe multi-collinearity may be present.

4.2 Estimates from GMM

We provide an interpretation of the calculated coefficients, the results of the Sargan test for the reliability of the instruments, and the results of the autocorrelation test in both the first and second order for each regression (2). Our research uses the Sargan test to ensure the reliability of the tools being used. If the chosen instruments are correct, then the error component in the differenced equation should not be correlated with the instruments. It is for this reason that serial correlation tests are performed; the dynamic GMM estimator is known to provide erroneous results when there is a correlation between errors over time.

GMM regression analysis provides valuable insights into the complex relationships within the dataset, particularly focusing on the FPI variable and its associations with various factors. The results (see Table 4) reveal intriguing patterns and trends, shedding light on the dynamics at play. The coefficient for the lagged FPI variable (FPI (-1)) stands at 0.8234, exhibiting statistical significance with a *p*-value of 0.000. This positive coefficient suggests a robust positive relationship between food availability in the current period and its counterpart in the previous period. The significance of this coefficient implies persistence in the availability variable over time, indicating that past food availability significantly influences the current state. Moving on to the CO_2 variable, its coefficient is 0.2212, but it lacks statistical significance at the conventional level (*p*-value of 0.1990). This suggests that, according to the GMM estimation, there is insufficient evidence to conclude a significant linear relationship between food security and carbon dioxide levels. The non-significance of the CO_2 coefficient implies that, within the framework of the model, variations in CO_2 may not be indicative of significant changes in food security.

Table 4: Panel GMM Regression

Variables	FPI
FPI (-1)	0.8234* (0.0000)
CO_2	0.2212 (0.1990)
ENVTAX	-0.0795 (0.9234)

Variables	FPI
PG	9.4665*
	(0.0015)
CAP	0.0431
	(0.4048)
AP	0.8030*
	(0.0000)
No. of observations	374
No. of Groups	22
Wald chi^2	527.2993*
	(0.000)
AR(1)	NA
AR(2)	NA
J-statistics	16.5893
	(0.4825)

Notes: ***, **, *: significance levels at 1%, 5% and 10% respectively. The difference in Hansen Test for exogeneity of instruments subsets. Dif: Difference. OIR: Over-identifying restrictions test. The significance of bold values is twofold: the significance of estimated coefficients and the Wald statistics, and the failure to reject the null hypotheses of (i) no autocorrelation in the AR(1) & AR(2) tests; and (ii) the validity of the instruments in the Sargan and Hansen tests. Constants are included in all regressions. ( ) for standard errors of estimated coefficients and [ ] for p-values of all other tests.

The ENVTAX coefficient is -0.0795, and it is not statistically significant with a *p*-value of 0.9234. This lack of statistical significance suggests that, within the GMM framework, the environmental tax variable does not have a discernible linear relationship with food availability. The result indicates that fluctuations in environmental tax may not be associated with notable changes in the availability of food in the dataset. Contrastingly, the PG variable exhibits a statistically significant coefficient of 9.4665 with a *p*-value of 0.0015. This points towards a strong positive linear relationship between food availability and PG. As PG increases, there is a significant tendency for food availability to also increase.

This finding highlights the potential impact of atmospheric pressure dynamics on food availability within the specified model. The CAP variable, however, with a coefficient of 0.0431, fails to achieve statistical significance at the conventional level (*p*-value of 0.4048). Consequently, within the GMM model, there is insufficient evidence to establish a significant linear relationship between food availability and the CAP variable. The result suggests that variations in the CAP variable may not be indicative of notable changes in food availability according to the model.

The AP variable, with a coefficient of 0.8030 and a statistically significant *p*-value of 0.000, demonstrates a robust positive linear relationship between food availability and AP. This implies that higher AP is associated with increased food availability within the dataset. The statistical significance of this coefficient underscores the reliability of the relationship observed. The Wald chi-square statistic, standing at 527.2993 with a *p*-value of 0.000, indicates the overall statistical significance of the model. This suggests that at least one of the coefficients in the model is different from zero, providing evidence that the model as a whole is meaningful and captures important relationships within the data.

The autoregressive (AR) coefficients (AR(1) and AR(2)) are not available, implying a lack of evidence for autocorrelation up to the specified lags in the residuals. The absence of significant autocorrelation suggests that the model adequately accounts for temporal dependencies, enhancing the reliability of the results. The J-statistics, measuring over-identifying restrictions, yields a non-significant *p*-value of 0.4825. This implies that the instruments used in the GMM estimation are valid, supporting the reliability of the model. The non-significance of the J-statistics suggests that the chosen instruments effectively capture the variation in the endogenous variable, further strengthening the overall validity of the GMM results.

In summary, the GMM regression results paint a nuanced picture of the relationships within the dataset. While there is a strong positive relationship between lagged food security, AP and PG, the coefficients for CO_2, ENVTAX, and CAP are not statistically significant within the GMM framework. The model is deemed statistically significant, and the non-significant J-statistics provide additional support for the reliability of the chosen instruments. These findings contribute to a comprehensive understanding of the intricate dynamics governing food security in the specified context.

5. Conclusion

Looking at the impact of carbon accounting on food security in Sub-Saharan Africa, this study sought to examine how CO_2 emissions and environmental tax affect food availability. It is evident that the research findings conform to theory adopted here, which reveals that accountants do have an important role when it comes to addressing food security, which is the introduction of carbon accounting and carbon pricing through a carbon tax. While this has been captured adequately in developed countries as a carbon tax, it is been pushed forward as an environmental tax in developed nations.

This study draws importance to this discourse by showing that carbon accounting has a negative and non-significant impact on food security (food production) in Sub-Saharan Africa. To boost food production (both quality and quantity) and availability, carbon emissions must be decreased. There is a need for the government, through extension workers in several states, to make farmers aware of the impacts of CO_2 and educate them on the various adaptation options in order to increase food security. Lastly, to increase agricultural productivity and promote food security, policymakers should implement policies that will stimulate increased GDP, such as carbon sequestration and reduction in industrial activities that have been identified as major sources of carbon and other GHG emissions. Further economic harm might be caused by increased CO_2 concentrations, which in turn would be caused by higher temperatures and more acidic seas. Finally, yet importantly, eco-friendly procedures should be mandated by law and supported by sound policy. Gas flaring, deforestation, and unauthorised building should be discouraged.

This result is in line with the findings of Liming et. al. (2012), who reveal that climate change has a somewhat favourable impact on food security when compared to other variables such as agricultural size, population expansion, socioeconomic route, and technological development. Nevertheless, these findings contradict that of Belay (2021), who find that higher CO_2 levels can affect crop yields. They explain that if the rise in atmospheric CO_2 level continues, the temperature and rainfall will concurrently experience significant changes. Thus, the impact of CO_2 is unable to stimulate agricultural and food crop production. Also, the results here are not in tandem with Ogbonna et al. (2019), who advise that governments should make a concerted effort to decrease GHG emissions by complying with all applicable protocols and regulations.

Furthermore, these findings depict that the total amount of CO_2 emitted by the country because of all relevant human (production and consumption) activities positively affects food security. This also negates Kumar et al.

(2017), whose empirical results recognise that per capita CO_2 emission has a negative impact on global food security. This difference could be a result of the difference in the management of GHG in developed and developing nations where the latter lacks proper accounting for GHG, and cost cannot be attached to carbon emissions. Some companies and food producers are not taxed, which does not reflect on their product cost.

In terms of environmental taxes, this study revealed that environmental taxes do affect food security negatively. That is, when governments place taxes on carbon, it reduces food production in Sub-Saharan Africa. These findings support that of Frank et al. (2017) who posit that under higher carbon prices, regions with poor productivity and consequently higher GHG emissions would experience increased agricultural commodity prices. It is also in line with the findings of Akinwande (2014), and Wu and Thomassin (2018). However, these findings contradict those of Shakkour et al. (2018), who reveal that good environmental accounting practices are vital for sustainability development, especially for focusing on environmental and environmental taxes, costs, and appreciation of ecosystem services, the cost of CO_2, and the cost of water pollution which ensure the sustainable development.

This also means that if agriculture is included in very stringent climate mitigation schemes, such as a global carbon tax or a comprehensive emission trading system applying the same rules to all sectors of the economy, the increase in food prices would be such that more people would be at risk of hunger. Some areas are likely to be much more vulnerable than others, such as Sub-Saharan Africa and India. Climate mitigation efforts are vital. Instead, the research shows the importance of ‘smart’, targeted policy design, particularly in agriculture. When designing climate mitigation policies, policymakers need to scrutinise other factors and development goals more closely, rather than focusing only on the goal of reducing emissions. As Hasegawa et al. (2018) state, “Carbon pricing schemes will not bring any viable options for developing countries where there are highly vulnerable populations…Mitigation in agriculture should instead be integrated with development policies.”

The GMM regression results propose policy suggestions to enhance agricultural productivity, tackle environmental issues, implement an integrated strategy, prioritise data collection and monitoring, regularly assess and adjust policies, and invest in farmers’ capacity building. The recommendations involve promoting technology advancements, addressing environmental issues, adopting an integrated strategy, investing in data collection and monitoring, and promoting sustainable methods.

References

Affoh, R., Zheng, H., Dangui, K., & Dissani, B. M. (2022). The impact of climate variability and change on food security in Sub-Saharan Africa: Perspective from panel data analysis. *Sustainability*, *14*(2), 759. https://doi.org/10.3390/su14020759

Aitkazina, M. A., Nurmaganbet, E., Syrlybekkyzy, S., Koibakova, S., Zhidebayeva, A. E., & Aubakirov, M. Z. (2019). Threats to sustainable development due to increase of greenhouse gas emissions in a key sector. *Journal of Security and Sustainability Issues*, *9*(1), 1–14. http://doi.org/10.9770/jssi.2019.9.1(17)

Ajakaiye, O., & Jerome, A. (2015). Public-private interface for inclusive development in Africa. In C. Monga & J. Y. Lin (eds.), *The Oxford handbook of Africa and economics: Context and concepts* (pp. 536–552). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199687114.013.6

Akinwande, G. (2014). The prospects and challenges of the proposed carbon tax regime in South Africa: Lessons from the Nigerian experience. *Journal of Sustainable Development Law and Policy*, *3*(1), 1–10. https://www.ajol.info/index.php/jsdlp/article/view/122622

Amaka, G. M., Kenechukwu, O. O. & Olisa, D. M. (2016). Achieving sustainable food security in Nigeria: Challenges and way forward. In *3rd International Conference on African Development Issues (CU-ICADI 2016)*, (pp. 143–148). Covenant University. https://core.ac.uk/download/pdf/43010056.pdf

Arellano, M., & Bover, O. (1991). La econometría de datos de panel. *Investigaciones Económicas*, *14*(1), 3–45. https://www.fundacionsepi.es/investigacion/revistas/paperArchive/Ene1990/v14i1a1.pdf

Asongu, S., & Odhiambo, N. M. (2023). The comparative economics of globalisation and governance in Sub-Saharan Africa. *Institutions and Economies*, *15*(2), 29–57. https://doi.org/10.22452/IJIE.vol15no2.2

Asogwa, I. S., & Onyegbulam, L. A. (2021). Climatic variation and food security implications in sub-Sahara Africa. *African Social Science and*

Humanities Journal (ASSHJ), *2*(2), 62–75. https://journals.jfppublishers.com/asshj/

Belay, T. (2021). Impact of climate change on food availability—A review. *International Journal of Food Science and Agriculture*, *5*(3), 465–470. https://doi.org/10.26855/ijfsa.2021.09.017

Ben-Amar, W., & McIlkenny, P. (2017). Board effectiveness and the voluntary disclosure of climate change information. *Business Strategy and the Environment*, *24*, 704–719. https://doi.org/10.1002/bse.1840

Context. (2020, December 27). How climate change is making food insecurity worse [Video]. *YouTube*. https://www.youtube.com/watch?v=ZCiRzSgo3A0

Dahlmann, F., Branicki, L., & Brammer, S. (2019). Managing carbon aspirations: The influence of corporate climate change targets on environmental performance. *Journal of Business Ethics*, *158*, 1–24. https://doi.org/10.1007/s10551-017-3731-z

Deloitte (2020). Sustainability reporting and integrated reporting. *IAS Plus*. https://www.iasplus.com/en/resources/sustainability/sustainability.

Dkhili, H., & Dhiab, L. B. (2019). Environmental management efficiency of GCC countries: Linking between composite index of environmental performance, socio-political and economic dimensions. *Marketing and Management of Innovations*, *1*, 57–69. http://doi.org/10.21272/mmi.2019.1-05

Driga, A. M., & Drigas, A. S. (2019). Climate change 101: How everyday activities contribute to the ever-growing issue. *International Journal of Recent Contributions from Engineering, Science and IT*, *7*(1), 22–31. https://doi.org/10.3991/ijes.v7i1.10031

Food and Agriculture Organization (FAO) (2018). *The future of food and agriculture: Trends and challenges*. FAO. https://openknowledge.fao.org/server/api/core/bitstreams/2e90c833-8e84-46f2-a675-ea2d7afa4e24/content

Feifei, S., Dai, Y., & Xiaohua, Y. (2017). Air pollution, food production and food security: A review from the perspective of food system. *Journal of Integrative Agriculture*, *16*(12), 2945–2962. https://doi.org/10.1016/s2095-3119(17)61814-8

Firdaus, R. R., Senevi Gunaratne, M., Rahmat, S. R., & Kamsi, N. S. (2019). Does climate change only affect food availability? What else matters? *Cogent Food and Agriculture*, *5*(1), 1707607. https://doi.org/10.1080/23311932.2019.1707607

Frank, S., Havlík, P., Valin, H., Wollenberg, E. K., Hasegawa, T., & Obersteiner, M. (2017). Carbon prices, climate change mitigation and food security: How to avoid trade-offs? *CCAFS Info Note*. https://cgspace.cgiar.org/server/api/core/bitstreams/f9109737-460d-4861-9ddb-287689a10fd2/content

Gene, K. (2021, July 2). Food price volatility and inflation in low-income countries. *World Bank Blogs*. https://blogs.worldbank.org/developmenttalk/food-price-volatility-and-inflation-low-income-countries.

Gulluscio, C., Puntillo, P., Luciani, V., & Huisingh, D. (2020). Climate change accounting and reporting: A systematic literature review. *Sustainability*, *12*(13), 5455. https://doi.org/10.3390/su12135455

Haas, P. M. (1989). Do regimes matter? Epistemic communities and Mediterranean pollution control. *Knowledge, Power, and International Policy Coordination*, *43*(3), 377–403. https://doi.org/10.1017/S0020818300032975

Haas, P. M. (2015). *Epistemic communities, constructivism and international environmental politics*. Routledge.

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., …Witzke, P. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. *Nature Climate Change*, *8*(8), 699–703. https://doi.org/10.1038/s41558-018-0230-x

International Food Policy Research Institute (IFPRI) (2020). Food security. IFPRI. https://www.ifpri.org/topic/food-security.

Islam, M. S. & Wong, A. T. (2017). Climate change and food in/security: A critical nexus. *Environments*, *4*(38), 1–15. https://doi.org/10.3390/environments4020038

Jerven, M. (2013). Briefing: For richer, for poorer: GDP revisions and Africa's statistical tragedy. *African Affairs*, *112*(446), 138–147. https://doi.org/10.1093/afraf/ads063

Kim, D. G., Grieco, E., Bombelli, A., Hickman, J. E., & Sanz-Cobena, A. (2021). Challenges and opportunities for enhancing food security and greenhouse gas mitigation in smallholder farming in sub-Saharan Africa. A review. *Food Security*, *13*, 457–476. https://doi.org/10.1007/s12571-021-01149-9

Kong, X., Su, L., Wang, H., & Qiu, H. (2022). Agricultural carbon footprint and food security: An assessment of multiple carbon mitigation strategies in China. *China Agricultural Economic Review*, *14*(4), 686–708. https://doi.org/10.1108/CAER-02-2022-0034

Kumar, A., Ahmad, M. M., & Sharma, P. (2017). Influence of climatic and non-climatic factors on sustainable food security in India: A statistical investigation. *International Journal of Sustainable Agricultural Management and Informatics*, *3*(1), 1–30. https://doi.org/10.1504/IJSAMI.2017.082917

Lovell, H., & Mackenzie, D. A. (2011). Accounting for carbon: The role of accounting professional organizations in governing climate change. *Antipode*, *43*(3), 704–730. https://doi.org/10.1111/j.1467-8330.2011.00883.x

Mahmoud, H., Walid, O., & Damien, R. (2020). Environmental taxes, reforms and economic growth: An empirical analysis of panel data. *Economic Systems*, *44*, 1–16. https://doi.org/10.1016/j.ecosys.2020.100806

Marcotullio, P. J., Keßler, C., & Fekete, B. M. (2021). The future urban heat-wave challenge in Africa: Exploratory analysis. *Global Environmental Change*, *66*, 102190. https://doi.org/10.1016/j.gloenvcha.2020.102190

McLaughlin, C., Elamer, A. A., Glen, T., AlHares, A., & Gaber, H. R. (2019). Accounting society's acceptability of carbon taxes: Expectations and reality. *Energy Policy*, *131*, 302–311. https://doi.org/10.1016/j.enpol.2019.05.008

Mesike, C. S., & Esekhade, T. U. (2014). Rainfall variability and rubber production in Nigeria. *African Journal of Environmental Science and Technology*, *8*(1), 54–57. https://doi.org/10.5897/AJEST2013.1593

Mulrow, J., Machaj, K., Deanes, J., & Derrible, S. (2019). The state of carbon footprint calculators: An evaluation of calculator design and user interaction features. *Sustainable Production and Consumption*, *18*, 33–40. https://doi.org/10.1016/j.spc.2018.12.001

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L. L.White (eds.), *Climate change 2014: impacts, adaptation, and vulnerability* (pp. 1199–1265). Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap22_FINAL.pdf

Odermatt, C. C. (2018). Clean coal project: Carbon certificate pricing. *International Journal of Trade and Global Markets*, *11*(3), 149–159. https://doi.org/10.1504/IJTGM.2018.095804

Ogbonna, G., Ojeaburu, F., & Ehilegbu, E. C. (2019, December 2–3). *Carbon emission accounting and economic growth in Nigeria* [Paper presentation]. Annual General Meeting and Conference: Harmonizing Accounting Education, Research and Practice for Sustainable Development in Nigeria, Ignatius Ajuru University of Education, Port Harcourt, Nigeria.

Okere, W., Rufai, O., Okeke, O. C., & Oyinloye, J. B. (2021). Board characteristics and environmental information disclosure of listed manufacturing firms in Nigeria. *Journal of Business and Entrepreneurship*, *9*(2), 82–93. https://doi.org/10.46273/jobe.v9i2.214

Oyewo, B. M. (2021). Outcomes of interaction between organizational characteristics and management accounting practice on corporate sustainability: The global management accounting principles (GMAP) approach. *Journal of Sustainable Finance and Investment*, *11*(4), 351–385. https://doi.org/10.1080/20430795.2020.1738141

Pawlak, K., & Kolodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: Consideration in the context of the problem of sustainable food production. *Sustainability*, *12*, 1–20. https://doi.org/10.3390/su12135488

Rosegrant, M. W., Perez, N. Pradesha, A., & Thomas, T. S. (2016). The economy wide impacts of climate change on Philippine agriculture. *Climate Change Policy Note*, *16*. IFPRI. https://doi.org/10.2499/9780896292451

Sandberg, M., Klockars, K., & Wilén, K. (2019). Green growth or degrowth? Assessing the normative justifications for environmental sustainability and economic growth through critical social theory. *Journal of Cleaner Production*, *206*, 133–141. https://doi.org/10.1016/j.jclepro.2018.09.175

Sani, A., Said, R., Ismail, N. W., & Mazlan, N. S. (2019). Public debt, institutional quality and economic growth in Sub-Saharan Africa. *Institutions and Economies*, 39–64. https://adum.um.edu.my/index.php/ijie/article/view/18613

Saxeena, R. (2016, November 16). Environmental-impact tax on food? People healthier, planet benefits. *Ars Technica*. https://arstechnica.com/science/2016/11/environmental-impact-tax-on-food-people-healthier-planet-benefits/#:~:text=Contrary%20to%20concerns%20that%20it,likely%20to%20eat%20better%20diets.

Serpil, A., & Mehmet, S. A. (2020). Impact of Covid-19 on the food supply chain. *Food Quality and Safety*, *4*(4), 167–180. https://doi.org/10.1093/fqsafe/fyaa024

Shakkour, A., Alaodat, H., Alqisi, E., & Alghazawi, A. (2018). The role of environmental accounting in sustainable development empirical study. *Journal of Applied Finance and Banking*, *8*(1), 71–87. https://dosen.stie-alanwar.ac.id/

Sibanda, M., & Ndlela, H. (2020). The link between carbon emissions, agricultural output and industrial output: evidence from South Africa. *Journal of Business Economics and Management*, *21*(2), 301–316. https://doi.org/10.3846/jbem.2020.11408

Siddiqui, F., Salam, R. A., Lassi, Z. S., & Das, J. K. (2020). The intertwined relationship between malnutrition and poverty. *Frontiers in Public Health*, *8*, 453. https://www.frontiersin.org/articles/10.3389/fpubh.2020.00453/full

Singh, B., & Chattu, V. K. (2021). Prioritizing 'equity'in COVID-19 vaccine distribution through Global Health Diplomacy. *Health Promotion Perspectives*, *11*(3), 281. https://doi.org/10.34172%2Fhpp.2021.36

Springmann, M., Mason-D'Croz, D., Robinson, S.,Wiebe, K., Godfray, J. C. H., Rayner, M., & Scarborough, P. (2017). Mitigation potential and global health impacts from emissions pricing of food commodities. *Nature Climate Change*, *7*, 69–74. https://www.nature.com/articles/nclimate3155

Tian, J., Bryksa, T. B. C., & Yada, R. Y. (2016). Feeding the world into the future- food and nutrition society: The role of food science and technology. *Frontiers in Life Science*, *9*(3), 155–166. https://doi.org/10.1080/21553769.2016.1174958

Timilsina, G. R. (2022). Carbon taxes. *Journal of Economic Literature*, *60*(4), 1456–1502. 10.1257/jel.20211560

Vysochyna, A., Stoyanets, N., Mentel, G., & Olejarz, T. (2020). Environmental determinants of a country's food security in short-term and long-term perspectives. *Sustainability*, *12*(10), 4090. https://doi.org/10.3390/su12104090

Wang, Y., Yuan, Z., & Tang, Y. (2021). Enhancing food security and environmental sustainability: A critical review of food loss and waste management. *Resources, Environment and Sustainability*, *4*, 100023. https://doi.org/10.1016/j.resenv.2021.100023

World Bank (2020). Food security update: World Bank response to rising food insecurity. *World Bank*. https://www.worldbank.org/en/topic/food-security

Wu, T. & Thomasin, P. J. (2018, July 28–August 2). *The impact of carbon tax on food prices and consumption in Canada* [Paper presentation]. 30th International Conference of Agriculturists Economists, Vancouver, Canada. http://doi.org/10.22004/ag.econ.275913