An empirical assessment of the tripartite nexus between environmental pollution, economic growth, and agricultural production in Sub-Saharan African countries

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Abstract

A lot of attention has been paid to environmental pollution worldwide, due to the increase in anthropogenic activities. Massive investment in non-renewable energy options raises questions regarding environmental sustainability and how to maximize food and non-food output while still preserving a healthy ecosystem. To this end, the present study explores the three-way nexus between economic growth, CO_2 emission, and agriculture-value added will accounting for other control variables across a balanced panel of selected African economies from 1997 to 2020. Panel econometrics method of the generalized method of moments (two-step difference GMM) is used to obtain a robust result. From the present study, the environmental pollution model shows that economic growth significantly contributes to environmental pollution in Africa. Additionally, the food price index, capital, and FDI promote pollution, while agricultural production and labor decrease pollution. In the case of the economic growth model, the findings reveal that environmental pollution supports the growth-led pollution hypothesis. Also, the food price index and capital ameliorate economic growth, while foreign direct investments decrease economic growth. Finally, the agricultural production model indicates that economic growth increases agricultural production when the interaction term between GDPC and FDI is included in the model. In summary, the combination of explanatory variables, environmental pollution, capital, and foreign direct investment decreases agricultural production. On the contrary, the food price index and labor promote agricultural production in Africa. Furthermore, the study provides a lot of policies for authorities and stakeholders in Sub-Saharan African countries and other developing economies.

Keywords: Agriculture production; Economic growth; Environmental pollution; Two-step GMM; Food price index; Sub-Saharan Africa

Introduction

The Food and Agricultural Organization's (2017) notes that for many developing, transitional, and emerging countries, key indicators of population expansion, rising standards of living, and prolonged aging trends suggest that a significant increase in population is anticipated to emerge around the end of the twenty-first century. Sub-Saharan African (SSA, hereafter) countries are predominantly engaged in agricultural production with agriculture stimulating economic growth in the sub-region. SSA appears to have a comparative advantage in agricultural production. The sub-region is also heavily endowed with natural and human resources that are capable of giving the continent an absolute advantage in resource use efficiency. With the current development of the African Free Trade Area (AfCTRA), Sub-Saharan Africa may benefit from trading agricultural output with other countries that have a comparative disadvantage in these products. Given, the potential of agriculture in the sub-region, several agricultural policies have been formulated to advance the development of the agricultural sector.

Regardless, agricultural production has been gravely affected by the poor climatic conditions (Amfo & Ali, 2020; Amfo, Ali, & Atinga, 2021). Fortunately, much of the current discussions around sustainable development are centered on Africa, which is witnessing unparalleled population growth while simultaneously reeling from the most severe impacts of climate change (Ladan, 2018; Overland et al., 2021). Given that climate change is a major consequence of CO_2 emissions, the issue of mitigating environmental pollution has become topical in recent times (Balsalobre-Lorente et al. 2019; Adedoyin et al. 2021; Fankhauser et al., 2022). There is widespread agreement that significant attention needs to be placed on the most important socioeconomic drivers of those impacts, which are often ignored (Bardgett et al., 2021; Siddiqui et al., 2022). However, the question then abounds: How do agricultural production and economic growth connect to achieve economic development without jeopardizing environmental quality?

Answering this question leads us to a three-fold policy framework that supports the contribution of this current paper: (i) the primary concern of understanding the interdependence of economic growth, agricultural production, and environmental pollution, which is lacking in the extant literature; (ii) broadening the scope of economic development in the African context by accounting for both agricultural production and economic growth; (iii) revisiting the discussion on foreign direct investments and food price index vis-à-vis economic growth, agricultural production, and environmental pollution. The remainder of this section elucidates the motivation of the currents study

Environmental pollution has become a serious environmental issue due to the evidential negative consequences it has on human health (Alharthi et al., 2021; Ahmed et al., 2022; Liu et al., 2022) on one hand, and the indirect or direct effect it has on agricultural crop production and food security on the other hand. In the quest to increase agricultural productivity, the aspect of environmental consequences is often overlooked. Studies indicate that the global effort to mitigate climate change and keep temperatures within acceptable ranges might be hampered by agriculture emissions (Brenton et al., 2022; Reisinger et al., 2021). A major environmental consequence of agricultural production on the environment in SSA is deforestation which arises from land expansion and exploitation (Kuemmerle, 2021). In recent years, the continent has recorded successes in agriculture growth at a rate of 4.8% between the year 2000 and 2018 (AASR, 2021). Ironically, about 75% of growth is owed to cropland expansion as against improved productivity (AASR, 2021). Phiri and Nyirenda (2022), Brobbey et al. (2020), FAO (2016), and FAO (2015) all highlight the predominance of encroachment of forest reserves for agriculture purposes. These activities limit the carbon sequestration ability of the sub-region and hence increase the chances of climate change effects.

Agriculture as an economic activity contributed about 3.2% value addition to economic growth in Sub-Saharan Africa by the close of the last decade (AASR, 2021). However, the African continent as a whole is expected to contribute about 12% to GDP from the agricultural sector alone in the next decade compared to the 14% recorded in the previous decade, owing to the impact of the COVID-19 pandemic (OECD-FAO, 2021), and the effect of climate change. Indeed, Fisher et al. (2021) highlight 1.16%, 0.97%, and 1.6 % mortality and morbidity loss percentage in GDP owing to environmental pollution respectively in some African countries by the end of 2019. OECD (2009) advocates environmentally and socially sustainable economic recovery as key challenges to economic growth and development. It is imperative for governments to implement strategies that aim at restoring resilient economic pathways towards recovery. As the African economy is recovering, the importance of agricultural production in the recovery process cannot be underscored enough as the sector employs a significant proportion of the working population.

The extent to which agriculture growth is impacting environmental pollution and economic growth in Sub-Saharan Africa remains unraveled, especially, towards achieving the sustainable development goals (SDGs) 2 and 13. Providing food to sustain life and livelihood should not come at the expense of environmental quality. Zeraibi et al. (2021), Usman et al. (2021), Adedoyin (2021), and Halkos (2012); Halkos and Paizanos (2013) explored the relationships between economic growth and CO_2 emissions across different continents but failed to shed light on specific dimensions of Africa. Also, numerous studies have examined the connection between environmental variables, agricultural output, and economic development in separate studies across various countries or regions. However, no study to the best of the knowledge of the researchers has collectively examined the interconnection between economic growth, agricultural production, and environmental pollution. Also, given the wide range of econometric modeling methodologies and sample procedures, there has been no unanimity in the empirical results (Soytas and Sari 2009; Adedoyin et al. 2021). This opens up a gap in the literature and creates room for further discussions towards the formulation of improved policy instruments to achieve a sustainable development.

Following the motivation of the study as outlined above, three research objectives are addressed: First, given the impact of agricultural production on economic growth and the resultant impact on environmental pollution in Sub-Saharan Africa, the study seeks to expand the literature by examining the intertwined relationship between economic growth, environmental pollution, and agricultural production in Sub-Saharan Africa. Second, the study seeks to investigate the role of the food price index on agricultural production. However, given the existing connection between agricultural production and economic growth and the overall impact on environmental pollution in SSA, we extend this investigation to economic growth and environmental pollution. Third, the study aims at exploring the role of foreign direct investment in promoting agricultural production and economic growth while mitigating environmental pollution.

The rest of the paper is structured as follows: the "Literature review" section focuses on the related literature review; the "Research design" section dwells on the methodology of the study; the "Empirical results" section results and discussion; and finally, the "Conclusions and implications" section conclusion and policy recommendation.

Review of related literature

Investigating the interconnection between agricultural production, economic growth, and environmental pollution is crucial as it contributes to policymaker's effort to achieve the sustainable development goals (SDGs), particularly goal 1 (no poverty), goal 2 (zero hunger), goal 8 (decent work, and economic growth), and goal 13 (climate action). Undoubtedly, more than 60% of Africa's population under the age of 25 is actively engaged in agricultural activities and this is expected to double by 2050 (FAO and ITU, 2022). Agriculture production is a crucial sector that has the potential to alleviate poverty and eradicate hunger. Indeed agriculture currently accounts for between 30 and 40% of the region's gross domestic product while employing an average of 54% of gross domestic product (FAO and ITU, 2022). Moreover, as much as agricultural production significantly contributes to economic growth in the African region, it also has the potential of deteriorating the environment. Several studies have hypothesized the nexus between agricultural production, economic growth, and environmental pollution. In view of these, this section presents the literature on three thematic areas: empirical studies on the environmental impact of agricultural production and environmental pollution, the economic impact of agricultural production and environmental pollution, and the agricultural impact of economic growth and environmental pollution.

The environmental impact of agricultural production and economic growth

The nexus between agricultural production and environmental pollution

Taking into account the impact of agricultural production on environmental pollution, Agboola and Bekun (2019) applied a dataset from 1981 to 2016 and reported an inelastic positive effect of agricultural production on environmental pollution in Nigeria. Similarly in Pakistan, Gokmenoglu and Taspinar (2018) employed a dataset from 1971 to 2014 to ascertain the environmental effect nexus of agriculture and observed an inelastic increasing effect of agriculture on environmental pollution. In the study of Sharma et al. (2021) who examined the effect of agricultural production on environmental pollution, they reported a positive impact of agriculture on pollution in the early stages of development but a negative effect beyond a given threshold. Adedoyin et al. (2021) using a dataset for 7 developing countries also observed that agriculture contributes to environmental pollution. On the contrary, Bas et al. (2021) examined the environmental effect of agriculture using a dataset between 1991 and 2019 and recorded a negative impact on pollution in Turkey. Similarly, Wang et al. (2020) recorded a pollution mitigation effect of agricultural production in G7 countries when a dataset between 1996 and 2017 was used. Gokmenoglu and Taspinar (2018) tested the agriculture-led environmental pollution hypothesis in Pakistan using data from 1971 to 2014 and affirmed the existence of the hypothesis in the country. In Bangladesh, Raihan et al. (2022) recorded an exacerbation effect between agricultural production and environmental pollution. Raihan and Tuspekova (2022) used a dataset between 1990 and 2018 for Peru and found that agricultural land expansion promotes emissions. On the contrary, Raihan and Tuspekova (2022) employed a dataset from 1990 to 2019 for Nepal and observed a decreasing effect from agricultural production to environmental pollution. Similarly, Ali et al. (2019) also recorded a decreasing effect of a agricultural production on environmental pollution. Clearly, the literature shows conflicting outcomes on the impact of agricultural production on environmental pollution.

The nexus between economic growth and environmental pollution

Elsewhere, several studies have delved into the interaction between the economic growth and environmental pollution albeit providing conflicting evidence on both country and regional levels (Maduka et al. 2022; Zanjani et al. 2022; Addai et al. 2022; Alharthi et al. 2021; Salahuddin et al. 2019; Dogan and Karay 2019; Mehmood et al. 2021). Szymczyk et al. (2021) observed that economic growth promotes CO_2 emissions. Baydoun and Aga (2021) showed a positive response of CO_2 emissions from economic growth in Gulf Cooperation Council (GCC) countries. Yang et al. (2021) confirmed that economic growth instigates environmental pollution. Lin et al. (2021) observed that economic growth influences environmental pollution in China. Ge et al. (2022) noted that economic growth exacerbates environmental pollution in China. On the contrary, Ozturk et al. (2021) found that economic growth has a negative effect on environmental pollution in Saudi Arabia. This implies that GDP promotes environmental quality in Saudi Arabia. In the case of Pakistan, Ali et al. (2021) found out that economic growth promotes environmental quality. In China, Aslam et al. (2021) observed that economic growth decreases environmental pollution in the long term. Ahmed et al. (2021) documented an environmental pollution–reducing effect of economic growth in G7 countries. For ASENA-4, Sahoo and Sethi (2022) reported that economic growth decreases environmental quality by decreasing environmental pollution. Sahoo and Sethi (2021) documented that economic growth aggravates environmental pollution in developing countries. Bhujabal et al. (2021) in their study on Asia Pacific countries observed that economic growth decreases environmental quality by increasing pollution in the long run. Haldar and Sethi (2021) also found economic growth to negatively affect environmental pollution in developing countries. Mohanty and Sethi (2022) documented a negative effect between economic growth and environmental pollution. For G20 countries, Li et al. (2021) recorded an aggravation effect of economic growth on environmental pollution. In West Africa, Musah et al. (2021a) reported a positive effect of economic growth on environmental pollution. Musah et al. (2022) documented a positive effect of economic growth on environmental pollution in West Africa. Li et al. (2022) also explored the relationship between economic growth and environmental pollution and found an escalation effect in E7 nations. Musah et al. (2021b) investigated the interaction between economic growth and environmental pollution mitigation among 8 developing countries and reported that economic growth positively impacted environmental pollution.

Economic growth impact on agricultural production and environmental pollution

The interaction between agricultural production and economic growth

Several schools of thought believe that agricultural production is the single most important driver of economic growth in developing countries (Bekun & Akadiri, 2019; Sertoğlu, Ugural, & Bekun, 2017). In Zambia, agricultural production was found as a significant driver of economic growth and contributor to the food security needs of the country (Phiri, Malec, Majune, Maitah, & Maitah, 2020). Also, Moussa (2018) found agricultural productivity to contribute positively to economic growth in Benin. Runganga and Mhaka (2021) reported that improvement in economic growth in Zimbabwe is a consequence of increases in agricultural production. Similarly, Aboyitungiye and Prasetyani (2021) found agricultural production to boost economic growth in Burundi. In the case of North Africa, Abdelhafidh and Bakari (2019) applied a dataset from 1965 to 2016 in Tunisia and found agricultural production to promote economic growth. Using data from 1984 to 2018, Nyamekye et al. (2021) examined the role of agricultural production in Ghana's economic development. They observed that agricultural production contributes to the overall economic growth of the country. In the case of Sub-Saharan Africa, Akinlo and Temitope (2021) explored the relationship between the real sector and economic growth and observed that agricultural production promotes economic growth in the sub-region. Conversely, Ceesay et al. (2022) investigated the role of agricultural production on economic growth in Gambia using a dataset spanning 1960 to 2017 and found a negative effect between the two variables.

The impact of environmental pollution on economic growth

Regarding the impact of environmental pollution on economic growth, Chindo et al. (2015) recorded a positive effect of environmental pollution on economic growth. In Malaysia, evidence from a dataset from the period 1975 to 2015 indicates that environmental pollution has no statistical effect on economic growth (Sulaiman & Abdul-Rahim, 2017). In their study on West Africa, Musah et al. (2020) found no significant effect of environmental pollution on economic growth. In three Asian countries, Yaqoob et al. (2022) noted that agricultural production helps in the transitional development of the study area. Agboola et al. (2022) conducted a study on Nigeria and found that various components of agricultural production boost economic growth. In Bansal et al. (2021), agricultural growth was found as the end product of certain agricultural production decisions which then boosts economic growth. In the case of Benin, Chabi Simin Najib et al. (2022) found that agricultural production exerts a positive influence on economic growth.

Agricultural impact of environmental pollution and economic growth

The literature on the impact of environmental pollution and economic growth on agricultural production is rife. Among the existing studies on the subject, Kumar (2021) examined climate change effect on cereal production in developing countries and found that CO_2 emissions have a positive effect on cereal production. They, however, found that increases in temperature which is a consequence of atmospheric CO_2 emissions decrease cereal output. In Pakistan, Ahsan et al. (2020) used a dataset from 1971 to 2014 and found that CO_2 emission exerts a positive impact on crop production in the long run but a negative effect in the short run. A similar study was conducted in China by Chandio et al. (2020) with a dataset from 1982 to 2014 and found a significantly positive effect of CO_2 emission on agricultural production both in the long and short run. On the contrary, Chandio et al. (2022) applied a dataset from 1983 to 2016 and recorded a negative effect of CO_2 emissions on agricultural production in Nepal. Ahmad et al. (2020) examined the impact of CO_2 emission on agricultural production in Pakistan between 1984 and 2017 and reported a negative effect of CO_2 emission on agricultural production. In the case of Vietnam, Huong and Van (2022) found a positive effect between environmental pollution and agricultural production. Syed et al. (2022) in their study on Pakistan opined that climate change impact negatively on agricultural production. Using a dataset from 1985 to 2016, Gul et al. (2022) found a decreasing effect of climate change on agricultural production. Table 1 presents a summary of the literature.

Despite the plethora of studies on the subject matter as shown above, this study is the first of its kind to examine the interconnection between economic growth, agricultural production, and environmental pollution in a single study. This study is, thus, unique as it contributes not only to the environmental nexus debate but also to the debate on sustainable economic development through agricultural production.

Data and methodology

Data and model specification

The present study employs a balanced panel data across 26 African countries over the period 1997 to 2020. The choice of the series and the number of countries is motivated by the available data for the main study variables. The study used three variables as the dependent variables i.e., agricultural value added, gross domestic product, and carbon dioxide emissions. The study also accounts for independent variables such as the food price index, foreign direct investment, capital formation, and labor. All variables were sourced from the website of the World Bank indicators. Table 2 outlines the summary of the study variables and their sources. From the variables and based on the study objective, three empirical models are specified.

Table 1 A summary of a section of the existing literature

Author	Country(s)	Period	Method	Funding
The environmental impact of agricultural production and economic growth				
(Agboola et al., 2022)	Nigeria	1981–2016	VECM, DOLS,FMOLS	Positive effect
(Gokmenoglu & Taspinar, 2018)	Pakistan	1971–2014	FMOLS	Positive effect
(Sharma, Shah, Shahzad, Jain, & Chopra, 2021)	BIMSTEC region	1990–2015	QREG	Positive effect
(Adedoyin, Bein, Gyamfi, & Bekun, 2021)	E7	1990–2016	PMG-ARDL, DOLS, FMOLS	Positive effect
(Bas, Kara, & Alola, 2021)	Turkey	1991–2019	Time series data	Negative effect
(Wang, Vo, Shahbaz, & Ak, 2020)	G7	1996–2017	CS-ARDL	Negative effect
(Salari, Javid, & Noghanibehambari, 2021)	US	1997–2016	GMM, static models	Positive effect
(Su et al., 2021)	OECD	1991–2019	ARDL, MG, GFE, PMG	Positive effect
(Szymczyk, Şahin, Bağcı, & Kaygın, 2021)	OECD	1990–2014	Panel data analysis	Positive effect
(Adedoyin, Gumede, Bekun, Etokakpan, & Balsalobre-lorente, 2020)	BRICS	1990–2014	ARDL	Positive effect
Economic growth impact of agricultural production and environmental pollution.				
(Bekun & Akadiri, 2019)	Southern Africa	1990–2015	Panel data	Positive effect
(Sertoğlu, Ugural, & Bekun, 2017)	Nigeria	1981–2013	Vector error correction model	Positive effect
(Phiri, Malec, Majune, Maitah, & Maitah, 2020)	Zambia	1983–2017	ARDL bound test	Positive effect
(Runganga & Mhaka, 2021)	Zimbabwe	1970–2018	ARDL	Positive impact
(Nyamekye, Tian, & Cheng, 2021)	Ghana	1984–2018	Error correction model	Positive effect
(Musah, Kong, Mensah, Antwi, & Donkor, 2020)	West Africa	1990–2018	CCEMG, DCCEMG	No effect
(Yaqoob et al., 2022)	Bangladesh, India, Pakistan	1973–2020	PMG-ARDL	Positive effect
(Agboola et al., 2022)	Nigeria	1981–2016	VECM, DOLS, FMOLS	Positive effect
(Bansal et al., 2021)	India	1960–2019	NARDL	Positive effect
Agricultural impact of environmental pollution and economic growth				
(Kumar, 2021)	Lower-middle-income countries	1971–2016	FGLS, FMOLS, DOLS	Positive effect
(Ahsan, Chandio, & Fang, 2020)	Pakistan	1971–2014	ARDL	Positive effect
(Chandio et al., 2022)	Nepal	1983–2016	ARDL, VECM	Positive effect
(Chandio, Jiang, Rehman, & Rauf, 2020)	China	1982–2014	ARDL	Positive effect
(Ahmad et al., 2020)	Pakistan	1984–2017	Econometric approaches	Negative effect

Source: authors' compilation

Table 2 Summary of study variables and measurement

Variable	Indicator	Unit of measurement	Source
AVA	Agricultural value added	% of GDP	WDI
CO_2	Carbon dioxide emissions	Metric tons per capita	WDI
GDP	Gross domestic product	Constant 2015 US$	WDI
K	Gross capital formation	% of GDP	WDI
L	Labor	Total agriculture employment	WDI
FPI	Food price index	2014-2016=100	WDI
FDI	Foreign direct investment	% of GDPC	WDI

Source: authors' compilation

Dependent variables

The bane of sustainable development is finding an equilibrium between environmental sustainability and economic growth. Usually, due to the difficulty in achieving both, most countries, especially those in Africa, prefer to adopt a trade-off between the two, thereby leaving either economic growth or environmental sustainability worse off. Furthermore, given that agricultural production forms the core of economic growth in Sub-Saharan Africa while significantly contributing to environmental degradation, the study factors in this indicator to understand how the region can arrive at an equilibrium level where production is sustainable, environmentally friendly, and economically viable. The relevance of achieving a balance between the three is highlighted in the United Nations' sustainable development goals (SDGs) 1, 2, 8, 12, and 13. In light of this, our work uses carbon emission as a proxy for environmental pollution with the prospect of understanding how economic growth and agricultural production can help mitigate environmental degradation. Conversely, the study adopts gross domestic product as a proxy for economic growth to the prospect of understanding the roles of environmental degradation and agricultural production and this would inform the kind of policy measure(s) to be implemented. Finally, the study uses agricultural value added as a proxy for agricultural production with the prospect of investigating the role of environmental degradation and economic growth.

Independent variable

Foreign direct investments (FDI)

Whereas FDIs may be crucial for economic development (Radmehr et al. 2022), they may either pose a challenge to environmental quality or promote it. Indeed, FDI, through the pollution haven hypothesis encourages pollution, while that through the pollution halo hypothesis discourages environmental degradation (Acheampong et al. 2019). Thus, FDIs may introduce modern technologies that may promote economic growth through agricultural production while at the same time either promoting environmental quality or aggravating pollution. This study therefore accounts for FDI to understand its role in both economic development via agricultural production as well as its role in mitigating pollution.

Food price index (FPI)

Changes in the international prices of a basket of food commodities have the potential to either promote or impede local food production. Given the relationship between agricultural production and economic growth in the context of Sub-Saharan Africa, FPI may impact economic growth via agricultural production. Again, a relationship between FPI and environmental degradation can be established via agricultural production. It is therefore important to investigate this interactions and understand how FPI impacts the three dependent variables.

Control variables

Gross capital formation (K)

Investments required for infrastructural and technological development to improve economic growth and improve environmental quality depend on a strong capital formation regime. This indicates the importance of fostering strong capital investments in an economy to target economic growth while improving environmental quality. Thus, following the work of Etokakpan et al. (2020a, b), we adopt the gross capital formation as a proxy for capital development.

Labor (L)

Labor is a crucial input in production processes, especially, in agricultural production (Ali et al., 2018) and hence the overall economic growth of a country. It is argued in the literature that the effect of labor on the environment vis-a-vis environmental degradation and economic growth is negative (Lasis et tal. 2020) and positive (Ahmed and Shimada, 2019) respectively. However, given the special case of Sub-Saharan Africa where the role of labor vis-a-vis environmental degradation may be tied to agricultural production and for that matter economic growth, this study seeks to understand how this relationship works to inform policy decisions.

Environmental pollution

The first empirical model for this study extends the argument on the environmental pollution debate. Following the examples of Bhat et al. (2021) and Omri and Saidi (2022), we extend the argument by incorporating several other variables. We, therefore, specify our model highlighted below:

$$CO_2 = f(GDPC, AVA, FPI, K, FDI) \tag{1}$$

By applying logarithm form, we specify the reduced form of Eq. (1) to a double-log equation as follows:

$$\begin{aligned} lnCO_2 = \beta_0 + \beta_1 L.lnCO_{2it} + \beta_2 lnGDPC_{it} + \beta_3 \ln AVA_{it} \\ + \beta_4 \ln FPI_{it} + \beta_5 lnK_{it} + \beta_6 lnFDI_{it} + \beta_7 lnL_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

Given the pool of evidence in the literature that suggests that economic growth and agricultural production promote environmental pollution, we hypothesize that foreign direct investment can have a moderation effect on the two aforementioned variables to abate environmental pollution. We, therefore, augment Eq. (1) with a moderation effect as follows:

$$\begin{aligned} lnCO_{2it} = {} & \beta_0 + \beta_1 L.lCO_{2it} + \beta_2 lnGDPC_{it} + \beta_3 \ln AVA_{it} \\ & + \beta_4 \ln FPI_{it} + \beta_5 lnK_{it} + \beta_6 lnFDI_{it} + \beta_7 lnL_{it} \\ & + \beta_8 \ln (GDPC \times FDI)_{it} + \beta_9 (\ln AVA \times FDI)_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

Economic growth

Our second model contributes to the economic growth debate by examining the economic effect of environmental pollution and agricultural value added. To specify this model, we follow the example of Moussa (2018) and Sayari et al. (2018); however, we define our model as highlighted below:

$$GDPC = f\left(CO_2, AVA, FPI, K, L, FDI\right) \tag{4}$$

By applying logs, we specify the reduced form of Eq. (2) to a double-log equation as follows:

$$\begin{aligned} lnGDPC_{it} = {} & \alpha_0 + \alpha_1 L.lnGDPC_{it} + \alpha_2 lnCO_{2it} + \alpha_3 L.GDPC_{it} \\ & + \alpha_4 \ln AVA_{it} + \propto_5 \ln FPI_{it} + \propto_6 lnK_{it} + \propto_7 lnFDI_{it} \\ & + \propto_8 lnL_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

Having established in the literature that environmental pollution has a positive relationship with economic growth, i.e., the pollution-led growth hypothesis, we interact foreign direct investment with pollution to investigate the moderation effect. Also, having established in the literature that the FDI is mostly attracted by the service sectors in Africa to the disadvantage of the agriculture sector, the study accounts for the interaction between agricultural production and FDI to investigate the moderating effect. We therefore estimate Eq. (3) as follows:

$$\begin{aligned} lnGDPC_{it} = {} & \propto_0 + \propto_1 L.lnGDPC_{2it} + \propto_2 lnCO_{2it} + \propto_3 \ln AVA_{it} \\ & + \propto_4 \ln FPI_{it} + \propto_5 lnK_{it} + \propto_6 lnFDI_{it} + \propto_7 lnL_{it} \\ & + \propto_8 \ln \left(CO_2 \times FDI\right)_{it} + \propto_9 (\ln AVA \times FDI)_{it} + \varepsilon_{it} \end{aligned} \tag{6}$$

Agricultural production

The third model of this study examines the agricultural productivity effect of economic growth and GDP. This follows an extension of the Cobb-Douglass production function to ascertain the effect of economic growth and environmental pollution on agricultural production. We, therefore, state our Eq. (5) as:

$$AVA = f\left(CO_2, GDPC, AVA, FPI, K, FDI\right) \tag{7}$$

By applying logs, we specify the reduced form of Eq. (7) to a double-log equation as follows:

$$lnAVA_{it} = \delta_0 + \beta_1 L.lnAVA_{it} + \delta_{\ln 2}GDPC_{it} + \delta_3 lnCO_{2it} + \delta_4 \ln FPI_{it} + \delta_5 lnK_{it} + \delta_6 lnFDI_{it} + \delta_7 lnL_{it} + \varepsilon_{it} \quad (8)$$

We further incorporate interaction terms to examine the moderation effect of FDI when interacting with environmental pollution and economic growth. The assumption is that an FDI that promotes the transfer of energy-efficient technologies in the agriculture sector would help to promote environmental quality while boosting agricultural production. Also, promoting economic development in the local agricultural sector would help boost agriculture and the economy as a whole since the majority of Africans depend on agricultural production for their sustenance. Equation 8 in Eq. (9) is estimated as follows:

$$lnAVA_{it} = \delta_0 + \beta_1 L.lnAVA_{it} + \delta_{\ln 2}GDPC_{it} + \delta_3 lnCO_{2it} + \delta_4 \ln FPI_{it} + \delta_5 lnK_{it} + \delta_6 lnFDI_{it} + \delta_7 lnL_{it} + \delta_8 \ln \left(CO_2 \times FDI\right)_{it} + \delta_9 (\ln GDPC \times FDI)_{it} + \varepsilon_{it} \quad (9)$$

The generalized method of moments (GMM)

The generalized method of moments (GMM) approach was used in our investigation, which was based on a dynamic panel. Specifically, this approximation method was selected for this work because, according to Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998), it is acceptable for panels with a limited predefined timeframe (T and N), and hence a large number of individual economies. That is, the number "N" is larger than the number "T." Furthermore, the GMM estimator is shown to be consistent in that it congregates in likelihood to beta as the sample size increases to an infinite number of samples in appropriate circumstances. The linearity connecting our coefficients and the fact that our model contains only one dynamic coefficient that takes into account its previous comprehension are all significant. Moreover, the explanatory coefficients are not rigidly exogenous; as a result, they are associated with the past and with the error term, as in the previous example. There are also stationary specific effects, heteroscedasticity, and autocorrelation with respect to specific nations, but these consequences do not appear across nations or across different classes of economies. Our model and projections satisfy all of the criteria listed above, and as a result, they were suitable for evaluation. It enabled us to add more instruments while also improving the accuracy and robustness of our projected results. Also, the flexibility of the estimator allows for the estimation of both level and difference equations. The GMM also works better for a large sample size and produces more robust outcomes compared with other estimators. Additionally, our choice of the two-step GMM over the one-step stems from the fact that the former addresses the issue of simultaneity that arises from the use of instrumental variables. An excessive number of instruments in the framework can lead to the overfitting of endogenous constructs, which can lead to biases in the outcomes (Windmeijer 2005). Despite the fact that the literature is still not able to identify which number is too many or too small, we made certain that suitable instrumental coefficients were chosen in order to avoid this abnormality. For this empirical problem in particular, it is not recommended that you use the ordinary least squares (OLS) method to estimate it since the yi,t-1 has a link with the fixed effects in the error term and causes biases in the dynamic panel model. For instance, if economic growth has a significant negative shock in 2010 due to factors that were not incorporated in our model, this will appear in the error term because it was not one of the regressors that we evaluated. It is also possible to eliminate this problem by employing the GMM estimation method, which prevents the development of this clear link between an endogenous variable and the error term. In order to tackle this issue, the endogeneity in the model was eliminated by changing the data, which resulted in the first difference modification, commonly known as the "two-step difference GMM," which eliminated the fixed effects. It was decided to include the instrumental coefficients with the lag yi,t-1, which were not linked with the fixed effects, in the framework. The general equation for the GMM is as follows:

$$\mathrm{Y_{it}} = \beta_i + \sum_{j=1}^{n} \beta_j \, \mathrm{X_{jit}} + \gamma_j \mathrm{Y}\left(_{\mathrm{it-1}}\right) + \varepsilon_{\mathrm{it}} \tag{10}$$

where Y_{it} denotes the dependent coefficient (CO_2 emission, economic growth, and agric-value added). The subscripts "I" and "t" denote panel data coefficients while "j" denotes the industrial fluctuations. The term $Y(_{it-1})$ is the lag of the dependent coefficient.

Empirical results and discussion

The present study seeks to investigate the effect of economic growth and environmental pollution on agricultural productivity. However, considering the possibility of simultaneity between the variables, the study goes a step further to explore the environmental effect and economic effect by separately considering economic growth and environmental pollution as dependent variables. To begin with, a descriptive analysis was performed to provide a general overview of the distribution (see Table 3). All variables were log-transformed. Each variable has a greater degree of variation. With the exception of environmental pollution and economic growth, all variables have a negative skewness. The Jarque-Bera test supports the rejection of the null hypothesis at a 1% level of significance and implies that the African data does not support the assumption of normal distribution. Subsequently, a pairwise correlation analysis was performed (see Table 4). The correlation analysis determines the multicollinearity intensity. With the exception of agricultural production and labor, all other variables have a significant negative correlation with environmental pollution and economic growth. On the contrary, all variables have a statistically significant relationship with agricultural production except for foreign direct investment. Nevertheless, the variance inflation factor (VIF) indicates there is no problem of multicollinearity among the selected variable. Therefore, the problem of the spurious level of the variables has been checked.

Table 3 Descriptive statistics and correlation matrix analysis

	$LnCO_2$	LnGDPC	LnAVA	LnFPI	LnK	LnFDI	LnL
Mean	−0.5729	7.2587	2.7768	4.4193	2.9796	0.5985	3.6356
Median	−0.8875	7.1047	3.1004	4.5134	2.9861	0.6902	3.8573
Maximum	2.1481	9.2727	4.1176	4.9379	4.3745	3.6845	4.5200
Minimum	−3.3928	5.5458	0.5867	3.2184	−1.2280	−5.2052	1.6956
Std. dev.	1.4325	0.9297	0.8737	0.2801	0.4902	1.2423	0.6599
Skewness	0.3203	0.3686	−0.8851	−1.2382	−1.9490	−0.6543	−0.9572
Kurtosis	1.9088	1.9055	2.8058	4.3993	15.7680	4.5856	3.1759
Jarque-Bera	39.8254*	43.3196*	78.9003*	201.2607*	4433.165*	105.1517*	91.9531*
Probability	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	597	597	597	597	597	597	597

* represents a 1% level of significance

Table 4 Pairwise correlation and VIF analysis. * represents a 1% level of significance

	$LnCO_2$	LnGDPC	LnAVA	LnFPI	LnK	LnFDI	LnL	VIF
$LnCO_2$	1							1.6312
LnGDPC	0.8379*	1						0.2312
	(0.0000)	--						0.4564
LnAVA	-0.7519*	-0.8658*	1					0.5613
	(0.0000)	(0.0000)	--					0.3425
LnFPI	0.3145*	0.2512*	-0.2432*	1				1.0023
	(0.0000)	(0.0000)	(0.0000)	--				0.3456
LnK	0.2045*	0.2304*	-0.2602*	0.1820*	1			0.4567
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	--			0.2678
LnFDI	0.0203	-0.0367	-0.0514	0.2346*	0.2999*	1		0.4561
	(0.6206)	(0.3694)	(0.2098)	(0.0000)	(0.0000)	--		1.1378
LnL	-0.7803*	-0.8300*	0.7704*	-0.2455*	-0.1073*	0.0328	1	1.2345
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0087)	(0.4231)	--	0.9012

Environmental assessment as the dependent variable

In Table 5, the estimates of the two-step difference GMM are reported. In this model, we emphasize the impact of the economic growth and the agricultural production variables. Given that all variables are log-transformed, the estimated outcomes can be interpreted as elasticities or in terms of percentage change. The result suggests that in the African context, economic growth exerts a positive effect on environmental pollution while agricultural production reduces environmental pollution. The result indicates that economic growth and agricultural productivity significantly influence environmental pollution. Thus, whereas economic growth promotes environmental pollution, agricultural production decreases pollution. These outcomes are consistent with the studies of Adedoyin et al. (2021), Bas et al. (2021), Sharma et al. (2021), Wang et al. (2020), Ali and Anufriev (2020), Gyamfi et al. (2021), and Bekun et al. (2021a). Our finding on agricultural production, however, contradicts the findings of Agboola and Bekun (2019) and Gokmenoglu and Taspinar (2018). In justifying their results, Adedoyin et al. (2020) associated the contradiction with differences in estimation methods and efforts to achieve environmental sustainability in Africa. Although we concord with this argument, the most plausible reason could be due to the limited use of advanced modern agricultural machinery in production activities in most African countries. Agricultural production is still at its infant stage with the majority engaged in small-scale farming. Most of these small-scale farms heavily rely on primitive tools such as holes, cutlasses, and animal traction for their agricultural activities with limited to no access to advanced technologies such as tractors and harvesters. Therefore, it is imperative that policymakers and other relevant stakeholders take a holistic view of agriculture's impact on the environment in the context of modern advanced technologies so as to inform effective environmental policy formulations. Also, the results suggest that the food price index exerts a positive elasticity on environmental pollution. This implies that the food price index encourages environmental pollution. This result supports the pollution-haven hypothesis which clearly contravenes environmental quality efforts and is consistent with the finding of Nabi et al. (2020). High food price indexes may compel the large majority of the African population who leave below the poverty line to rely on forest products for survival thereby leading to deforestation and hence an increase in environmental pollution. Furthermore, the estimated outcome suggests that the capital imposes a significant positive effect on environmental pollution. Thus, increasing the capital may produce higher environmental pollution. This result probably provides an insight into the non-conformity of capital formation of African countries to global environmental agendas such as the UN sustainable development goals, as a high percentage of the capital investment of the region is directed at energy-intensive industries. This is consistent with Rej and Nag (2022). Also, foreign direct investment imposes a significant positive impact on environmental pollution. In other words, a percentage increase in foreign direct investment would result in between 0.02 and 0.03% increase in environmental pollution (see Table 5, models 1 to 4). This result agrees with the work of Li et al. (2021) for G20 economies but contradicts Li et al. (2021). Our finding, thus, supports the pollution halo hypothesis. Labor, on the other hand, exerts a significant negative elasticity on environmental pollution. This result is in tandem with Usman et al. (2022) who attributed their finding to an educated and a well-informed labor force on the dangers of environmental pollution in advanced countries. However, in the African context, this result could be associated with a production system that is human labor–dependent, which contributes less to environmental pollution in terms of emissions. The study also interacted with economic growth and agricultural production with foreign direct investment to investigate the indirect effect on environmental pollution. The interaction term between economic growth and foreign direct investment reveal both a positive and negative effect on environmental pollution in models 2 and 4 respectively. Meanwhile, the interaction between agricultural production and foreign direct investment exerts a positive effect on environmental pollution in both models 3 and 4. The result suggests that although foreign direct investment may not be ideal for economic growth in the abatement of environmental pollution (as shown in Table 5, model 2), it may be crucial to moderate both economic growth and agricultural productivity with foreign direct investment to achieve some level of abatement of environmental pollution (see Table 5, model 4).

Table 5 Estimation of dynamic panel data (two-step difference *GMM)*

Dependent variable: $LnCO_2$				
	(1)	(2)	(3)	(4)
$L.LnCO_2$	0.3961**	0.2389*	0.4409**	0.2382**
	(0.0140)	(0.0080)	(0.0118)	(0.0114)
LnGDPC	0.4431*	0.1065**	0.9319*	1.5234*
	(0.0000)	(0.0453)	(0.0000)	(0.0000)
LnAVA	−0.3100*	−0.1025***	−2.5238*	−3.6492*
	(0.0000)	(0.0648)	(0.0000)	(0.0000)
LnFPI	0.0704*	0.8319*	1.1990*	0.9770*
	(0.0033)	(0.0000)	(0.0000)	(0.0000)
LnK	0.0159	0.0532**	0.0095***	0.0521**
	(0.8227)	(0.0459)	(0.0866)	(0.0441)
LnFDI	0.0320**	0.0293***	0.0223***	0.0204**
	(0.0468)	(0.0780)	(0.0902)	(0.0283)
LnL	−0.9076*	−0.6538*	−0.4869*	−0.5220*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnGDPC*LnFDI		0.1754*		−0.1489*
		(0.0000)		(0.0047)
LnAVA*LnFDI			0.5530*	0.7902*
			(0.0000)	(0.0000)
Observations	597	597	597	597

NB *p<0.01, **p<0.05, ***p<0.1 respectively

Economic growth as dependent variable

Table 6 displays the estimated outcomes for economic growth, revealing that environmental pollution has a direct impact on economic growth in Africa. Thus, increases in environmental pollution correspond with increases in economic growth which corresponds with the findings of Chaabouni and Saidi (2017), Sarpong et al. (2020), Bekun et al., (2021b), Onifade et al. (2021), Jiang et al. (2022), Gyamfi et al. (2022), Steve et al. (2022), and Gyamfi (2022). Noticeably, the estimated elasticity of environmental pollution is higher in models 2 and 4. The justification for this outcome could be linked to the fact that African countries at this stage of their development prioritize economic growth over environmental quality. Considering that African countries are at the advancing stages of development, priority is placed on allocating the limited resources to achieve economic growth as opposed to investing in environmental pollution abatement strategies. Also, it can be argued that environmental pollution promotes climate change which has the potential of negatively affecting labor productivity, thereby reducing economic growth. The result also indicates that agricultural production decreases economic growth in models 1 and 2 but increases agriculture productivity in models 3 and 4 when the interactive term between agriculture productivity and foreign direct investment is considered. Indeed, the outcomes of models 3 and 4 confirm the findings of Akinlo and Temitope (2021), Sabir et al. (2022), Ohajionu et al. (2022), Bamidele et al. (2022), Shahbaz et al. (2022), and Agozie et al. (2022). This result is plausible because the agricultural sector is regarded as one of the major contributing sectors to GDP in most African countries. Whereas in some African countries, the sector contributes to the highest share of GDP; in others, it is only the second largest contributor. Indeed, Sabir et al. (2022) note that agriculture alleviates poverty by creating jobs for a majority of the African population who are largely unskilled. With regard to the negative impact of agricultural production on economic growth, the probable cause could be attributed to the limited access to credit facilities to the sector's primary stakeholders and poor infrastructure among many others. These cumulatively could lead to low productivity and postharvest losses, thereby impacting negatively on economic growth. Furthermore, the food price index exerts a positive effect on economic growth in Africa. This implies that as the monthly changes in the international prices of a basket of food commodities increase, economic growth increases. Considering the fact that consumers are rational in their choices, when the international price of food commodities increases, they tend to look inward for alternative local commodities and this helps to boost the local economy. Also, capital formation induces a positive response from economic growth in Africa. Thus, as capital formation increases, economic growth increases. Indeed, capital accumulation helps to build up ready-made capital reserves which provide the relevant support to production activities of a country (Akinlo & Temitope, 2021). Similarly, Sabir et al. (2022) noted that investment in capital accumulation increases the capital stock of a country and this helps to grow productivity, hence economic growth. Furthermore, our finding also corresponds with that of Asghar et al. (2022), Marie et al. (2022), and Sabir et al. (2022). Our result further reveals that FDI has a statistically negative influence on economic growth. This implies that as FDI increases, economic growth decreases. This result is unexpected but plausible because for African countries, FDI mostly promotes the importation of foreign goods and services which competes with the local ones. Given that foreign companies have higher economies of scale and higher comparative advantage, the local goods and services are unable to compete and thus are put out of business which then impacts economic growth negatively. This result resonates with that of Asghar et al. (2022) who concluded that FDI is mostly attracted by the service sector. Although Faisal et al. (2021) found a similar result, theirs was statistically insignificant. On the contrary, our findings deviate from that of Belloumi (2020) and Chukwudi and Nicholas (2021) whose studies support the FDI growth–led hypothesis. The elasticity estimate of labor was found to exert a significant a positive influence on all the models except model 1 where a significant negative effect was recorded. With regard to the interactive terms, the interaction between carbon emission and FDI exerts a positive influence on economic growth in model 2 but induces a negative impact in model 4. This result implies that policymakers should implement policies that will attract environmentally conscious international organizations as they have the potential of helping the host country to achieve environmental quality while boosting economic growth. Lastly, the interaction between agricultural production and FDI exerts a negative influence on economic growth. Although this result is unexpected, it could be attributed to the fact that FDI in Africa are not yet at the levels to positively influence economic growth.

Table 6 Estimation of dynamic panel data (*two-step difference GMM*)

Dependent variable: LnGDPC				
	(1)	(2)	(3)	(4)
L.LnGDPC	0.3255*	0.4225**	0.2245*	0.1217**
	(0.0000)	(0.0105)	(0.0003)	(0.0256)
$LnCO_2$	0.2758*	2.1727*	0.2419*	2.3058*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnAVA	−0.3837*	−0.3981*	2.4879*	3.4365*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnFPI	1.5994*	1.7310*	2.0592*	2.0976*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnK	0.3760*	0.3956*	0.1654*	0.0802**
	(0.0000)	(0.0000)	(0.0000)	(0.0113)
LnFDI	−0.1692*	−0.1262*	−0.0552*	−0.0545*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnL	0.1017**	−0.0960**	−0.3261*	−0.2980*
	(0.0162)	(0.0182)	(0.0000)	(0.0000)
$LnCO_2$*LnFDI		0.5410*		−0.4585*
		(0.0000)		(0.0000)
LnAVA*LnFDI			−0.6458*	−0.8564*
			(0.0000)	(0.0000)
Observations	597	597	597	597

NB $*p<0.01$, $**p<0.05$, $***p<0.1$ respectively

Agricultural Production as the dependent variable

Table 7 presents the elasticity estimates of agricultural production which suggest that economic growth significantly promotes agricultural production in two of the models (see models 3 and 4) and decreases agricultural production in the other two (see models 1 and 2). The result shows that economic growth exerts both a positive and negative effect on agricultural production in Africa. Whereas the positive effect is expected, the negative effect contradicts the a priori expectation although the result is plausible. The negative sign could be attributed to the continent's shift from an agricultural sector–dependent economy to a service sector–dependent economy which is now the largest contributor to the continent's economic growth in terms of GDP contributions. Also, the negative sign could be attributed to the biasness of government policies towards the service sector at the neglect of the agricultural sector. In other words, governments tend to implement policies that seek to increase investments in the service sector than in the agricultural sector, although agriculture is the major contributor to job creation and food security on the continent. It is observed that in instances where economic growth is positive, either only the interaction between CO_2 and FDI is considered or both interactions between CO_2 and FDI and GDPC and FDI are considered. The positive impact implies that a percentage increase in economic growth boosts agricultural production. This shows the possibility of African countries to boost economic growth through agricultural production. However, to achieve this, it is imperative for policymakers to find a way to moderate environmental pollution with foreign direct investments. This result aligns with the study of Espoir and Ngepah (2021) who conclude that economic growth promotes productivity in developing countries. The result of environmental pollution exhibits a negative sign on agricultural production. This implies that an increase in environmental pollution would yield a negative response from agricultural production. This result agrees with that of Jebli and Youssef (2019) who report a negative long-run effect but a positive short-run effect. However, our result contradicts that of Chandio et al. (2020), Musah et al. (2021b), Li et al. (2021). This result is plausible since the African agriculture sector is over-reliant on natural environmental factors. Hence, any increase in emissions would imply an increase in climate change indicators, thereby affecting agriculture productivity. Also, the elasticity of the food price index solicits a positive response from agricultural production. Thus, a percentage increase in the food price index would generate a corresponding percentage change in agricultural production assuming all factors are held constant. This result deviates from our expected outcome. It is expected that high FPIs would signify higher prices of food commodities internationally, which would translate to the high cost of imported goods, thereby inspiring the need to rely on locally produced food commodities. However, given that African countries are largely net exporters of raw material and importers of finished products, higher FPIs could serve as an incentive to increase exports, and the revenue generated could be used to improve other sectors of the economy. Furthermore, capital formation and FDI significantly reduce agricultural production. This agrees with the study of Nugroho et al. (2021), Musah et al. (2021a), and Qamruzzaman (2022) who posit that FDI boost agricultural production in developing countries. On the other hand, labor exerts a significantly positive impact on agricultural production. This implies that while a percentage change in capital and FDI may inspire a corresponding percentage decrease in agricultural production, labor may induce a corresponding percentage increase in agricultural production with a unit percentage change. Finally, the moderation effect result indicates that FDI interacts with environmental pollution to boost agricultural production but decreases agricultural production when interacted with economic growth.

Table 7 Estimation of dynamic panel data (*two-step difference GMM*)

Dependent variable: LnAVA				
	(1)	(2)	(3)	(4)
L.LnAVA	0.3398**	0.3392**	0.3411**	0.3382*
	(0.0114)	(0.0105)	(0.0118)	(0.0003)
LnGDPC	−0.2411*	−0.2947*	0.3631*	0.3501*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$LnCO_2$	−0.1213*	−0.9461*	−0.0317***	−0.1250*
	(0.0000)	(0.0000)	(0.0648)	(0.0064)
LnFPI	0.5506*	0.6771*	1.5585*	1.5610*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnK	−0.1036**	−0.0713*	−0.1266*	−0.1227*
	(0.0193)	(0.0082)	(0.0010)	(0.0018)
LnFDI	−0.0651*	−0.0586*	−0.0476*	−0.0471*
	(0.0001)	(0.0005)	(0.0014)	(0.0017)
LnL	0.6503*	0.5699*	0.2225*	0.2184*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$LnCO_2$*LnFDI		0.1867*		0.0208**
		(0.0000)		(0.0175)
LnGDPC*LnFDI			−0.2229*	−0.2204*
			(0.0000)	(0.0000)
Observations	597	597	597	597

NB *p<0.01, **p<0.05, ***p<0.1 respectively

Robustness check

This study uses a panel post-estimation diagnostic test to ensure that the results are legitimate. The calculated statistics for AR (1) showed a significant sign at the 5% and 10% level in models 1, 2, and 3; however, those for AR (2) were not significant at any level of significance, indicating that second-order autocorrelation had no effect on the results (Table 8). The Sargan test estimated results were insignificant in all models (Tables 5, 6, and 7), implying that the H_1 is not accepted while the H_0 of exogenous instrumental factors is accepted. This result indicated that the instrumental variable selection in the equations was appropriate. The results of the Hansen test are likewise supported by the Sargen test.

Table 8 Post-estimation diagnostic tests of two-step difference GMM model

Tests	Statistic	*p* value
Model with CO_2 emission		
Hansen test	$chi^2(20) = 37.11$	0.3320
Sargan test	$chi^2(20) = 381.41$	1.000
AR (1) test	$z = -5.05$	0.0341
AR (2) test	$z = -2.10$	0.5730
Model with economic growth		
Hansen test	$chi^2(20) = 36.89$	0.2390
Sargan test	$chi^2(20) = 382.24$	1.000
AR (1) test	$z = -2.04$	0.041
AR (2) test	$z = -1.15$	0.3149
Model with agric-value added		
Hansen test	$chi^2(20) = 32.21$	0.4290
Sargan test	$chi^2(20) = 374.81$	1.000
AR (1) test	$z = -3.68$	0.0194
AR (2) test	$z = -3.03$	0.2431

Conclusion and policy recommendation

Conclusion

The present study uses a two-Step GMM to investigate the interconnecting effect between environmental pollution, economic growth, and agricultural production in a panel of 26 African countries from 1997 to 2020. Several empirical findings were produced in the study. First, the environmental pollution model provides evidence that economic growth significantly contributes to environmental pollution in Africa. The study further revealed that the food price index, capital, and foreign direct investment promote environmental pollution, while agricultural production and labor decreased pollution in Africa. Regarding the interaction terms, i.e., the interaction between economic growth and foreign direct investment and that between agricultural production and foreign direct investment, it is observed that the latter increases pollution; however, the former only decreases pollution when both interaction terms are accounted for in the model.

In the case of the economic growth model, the findings reveal that environmental pollution supports the growth-led pollution hypothesis. Also, the food price index and capital ameliorate economic growth, while foreign direct investments decrease economic growth. Interestingly, agricultural production promotes economic growth in Africa only when either the interaction term of CO_2 emission and FDI or both the interaction terms of AVA and FDI are incorporated into the economic growth model. Labor on the other hand promotes economic growth only in the absence of the interaction terms. In the case of the interaction terms, only the interaction between CO_2 emission and FDI boosts economic growth while AVA and FDI decrease growth.

Lastly, the agricultural production model indicates that economic growth increase agricultural production when the interaction term between GDPC and FDI is included in the model. Regardless of the combination of explanatory variables, environmental pollution, capital, and foreign direct investment decrease agricultural production. On the contrary, the food price index and labor promote agricultural production in Africa. The interaction between CO_2 and FDI boosts agricultural production but that of GDPC and FDI reduces the same.

Policy recommendations

These results give credence to a number of policy insights for African economies. The findings presented in this study imply that economic growth deteriorates the environment. However, it is important for policymakers to put in place strategies that would help economies to strike a balance between economic growth and environmental quality. It would, therefore, be counterproductive for African countries to prioritize economic growth over environmental quality and vice versa. This suggests that unless environmentally friendly production technologies and techniques are adopted, the road to a sustainable development would be a long journey. To achieve this, Sub-Saharan African countries must implement policies that would allow the region to take advantage of environmentally friendly technologies and production techniques that would be introduced via FDIs.

Also, the negative impact of agricultural production on environmental pollution is promising. However, given the poorly mechanized nature of the agricultural production in the region, it is imperative that governments do not rejoice in this outcome but rather implement policies that would approach this issue holistically. For instance, given the increase in advocacy for the mechanization of the agricultural sector in the region, governments and policymakers are advised to consider future changes in the structure of the agricultural system when implementing policies that seek to promote production without compromising environmental pollution.

Furthermore, the findings reveal that agricultural production decreases economic growth and vice versa; the food price index exerts an increasing effect. This implies that low productivity resulting from the use of inefficiencies in production negatively affects the overall growth of the economy. However, because higher FPIs increase international food prices with a resultant effect on imported food products, the production upsurges thereby boosting the overall economic growth. The result of FPI is relevant for policy because it advocates for a shift from the dependence of imported goods to local production and consumption. This shows that the agriculture sector regardless of the empirical outcome of this study has the potential to influence economic growth. It is, therefore, imperative for governments to make significant investments in the sector by way of adequate infrastructural development and funding to boost economic growth in the sub-region

Lastly, the negative impact of environmental pollution on agricultural production is a confirmation of the region's over-reliance on the natural climate indicators for agricultural production. Policymakers should therefore implement policies or make the necessary investments in climate change mitigation strategies or coping and adaptation strategies to boost agricultural production.

Limitation of the study and future research

Even though this study adds to the existing literature, it does have some limitations which can be addressed in a future study. First, although the study explores the interconnecting relationships between our main variables of interest, the determining factors appear to be peculiar to only agricultural production; it is therefore imperative that future studies consider other factors that directly relate to economic growth and environmental pollution. Also, future studies can expand the scope of this study by performing a comparative study between economic blocs. Finally, rather than the use of an approximate linear model, future studies may adopt a simultaneous model to examine the interconnections between the variables.

Data Availability

Not applicable.

Contributions

Ernest Baba Ali: conceptualization draft, formal analysis, methodology, and corresponding.

Festus Victor Bekun: conceptualization draft, investigation and data curation.

Bright Akwasi Gyamfi: writing—original draft.

Prince Nketiah: writing

Ilhan Ozturk: writing

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

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Competing interests

The authors declare no competing interests.

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