طبقة انبعاث الكاربون وأثرها على الانتاج الزراعي وجهة نظر من حساسية الاستجابة وتحليل مكونات التباين

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الملخص:

قضايا الإنسانية والبيئة لا ينفصلان. في الماضي ، أثرت الأنشطة البشرية على البيئة دون مخاوف من حدوث آثار عكسية ، ولكن في الآونة الأخيرة ، تعد تأثيرات الانعكاس أهم التهديدات للبيئة والتنمية الزراعية والاقتصاد وصحة الإنسان. تبحث هذه الدراسة في العلاقة بين التلوث (انبعاث الكربون) والتنمية الزراعية في نيجيريا باستخدام البيانات الفصلية الممتدة من.1980Q1–2019 Q4 دعمت نظرية منحنى كوزنتس البيئي الديناميكي صياغة نماذج الانحدار الذاتي, الديناميكي التي تم تحليلها باستخدام عدد كبير من طرق الاقتصاد القياسي. كشفت نتيجة نموذج تصحيح خطأ المتجه واستجابة النبض واختبار تحلل التباين عن علاقات منحنى كوزنتس البيئي على شكل N بين انبعاث الكربون والإنتاج الزراعي في نيجيريا ، مقابل التوقع النظري لعلاقة عكسية على شكل حرف U. بناءً على النتيجة ، خلصت الدراسة إلى أن منحنى كوزنتس البيئي على شكل N لنيجيريا وليس منحنى كوزنتس البيئي المقلوب على شكل حرف U. وبالتالي ، فإن الجهود المبذولة لتطوير القطاع الزراعي في نيجيريا يجب أن تأخذ في الاعتبار آثار التلوث وأدوار تدفقات الاستثمار الأجنبي المباشر الوافدة.

الكلمات المفتاحية: الإنتاج الزراعي؛ انبعاث كربوني؛ منحنى كوزنتس البيئي ؛ الاستثمار الأجنبي المباشر؛ استجابة نبضيه؛ نموذج تصحيح خطأ الموجه ؛ تحلل التباين.

Carbon Emission Threshold and its effects on Agricultural Output: Evidence from Impulse Response and Variance Decomposition Analyses

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Abstract

Humanity and environmental issues are inseparable. In the past, human activities influenced the environment without concerns for reversal effects, but in recent times, the reversal effects are the most significant threats to the environment, agricultural development, the economy and human health. The study investigates the relationship between environmental pollution proxied by carbon emission and agricultural development in Nigeria using quarterly data spanned 1981Q1-2019Q4. The dynamic Environmental Kuznets Curve theory supported the formulation of the dynamic autoregressive models analysed using a plethora of econometric methods. The result of the Vector Error Correction Model, impulse response and variance decomposition test revealed an N-shaped Environmental Kuznets curve relations between carbon emission and agricultural output in Nigeria, against the theoretical expectation of an inverted U-shape nexus. The implications of the N-shaped relationship are enormous for agricultural development, foreign direct investment attraction and carbon emission curbing strategies in Nigeria.

Keywords: Agricultural Output; Carbon Emission; Environmental Kuznets Curve; Foreign Direct Investment; Impulse Response; Vector Error Correction Model; Variance Decomposition.

1.0 Introduction

Environmental pollution is the world's most significant threat to human health, the economy, natural vegetation and the entire ecosystem where agricultural activity lies (Landrigan*et al.*, 2018; Perera, 2018). Environmental pollution was responsible for 15 percent of all deaths globally in 2017 and accounted for 275 million disabilities (Global Alliance on Health and Pollution, GAHP, 2019). In 2017, 3.6 billion people, who comprised 47 percent of the global population, were exposed to air pollution (GAHP, 2019).

Environmental and Resource Economists of the neo-classical school had attempted to quantify what is injected and extracted into and from the environment; none of these disciplines has sufficiently addressed the ecological and economic costs due to welfare losses to ecological and environmental pollution. Thus, environmental pollution effect on social welfare is ignored mainly in terms of its economic costs of development due partly to measurement difficulties. Also, development policies do not adequately account for the world's most vulnerable (who are predominantly engaged in agriculture) to environmental damages.

Green-house gas emission, oil exploration, exploitation, refinement and transportation in Nigeria have disrupted the natural environment. Those living in poverty and most vulnerable people are increasingly exposed to mortality risks and life-time illness associated with deteriorating ecological conditions which culminates in social welfare losses in terms of sources of livelihood such as agricultural output, depleting income and worsening health outcomes.

Figure 1.1 shows that between 1999 and 2019, CO emission got to its peak in 2011 at 0.81 metric tons, while between 2012 and 2019, it has consistently declined, and it reached 0.57 metric tons in 2019. However, compared to the global average of 0.05 metric ton per capita, Nigeria's figure of 0.57 metric tons per capita of carbon emission remains significantly higher than the world average.Giannadaki*et al*. (2018) and Li *et al*. (2020) assert that the immediate economic hazard of environmental pollution is dwindling agricultural outputs globally.

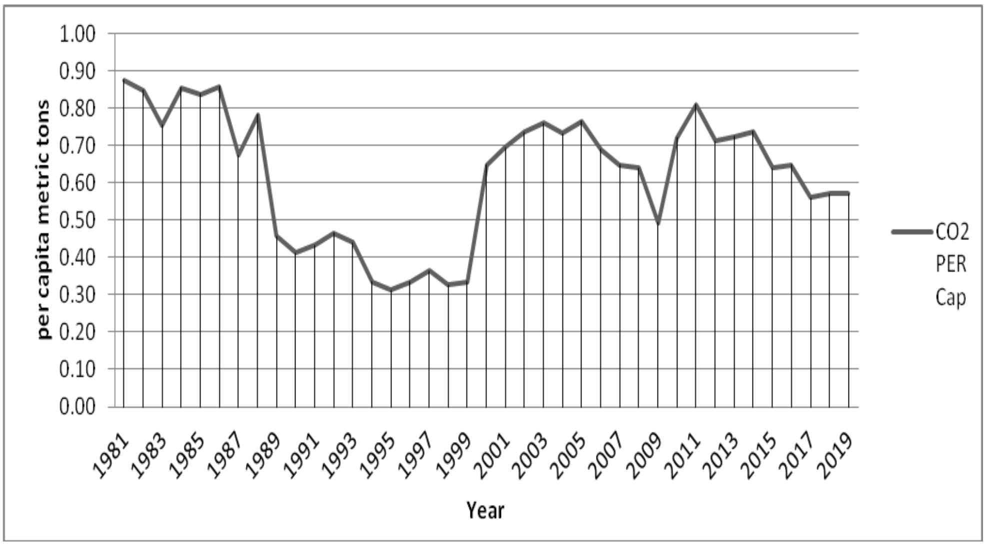

Figure 1.1 Trend in C.O. emission per capita in metric tons (1981 – 2019)
Source: Author's presentation

Nonetheless, environmental pollution causes a decline in the quality of agricultural output. Such effects are further exacerbated on the quality of crop production, livestock and fishery which humans consume daily. Unfortunately, these agriculture components are indispensable for human survival, as it produces products that satisfy the necessary and sustenance needs of man. Ironically, these products- crops, livestock and fish are easily exposed to environmental hazards, and when consumed, could seriously affect the stock of human health. Giannadaki et al. (2018) noted that the agricultural sector's rising contributions to national output depicted in Figure 1.2 could be reversed by environmental pollution.

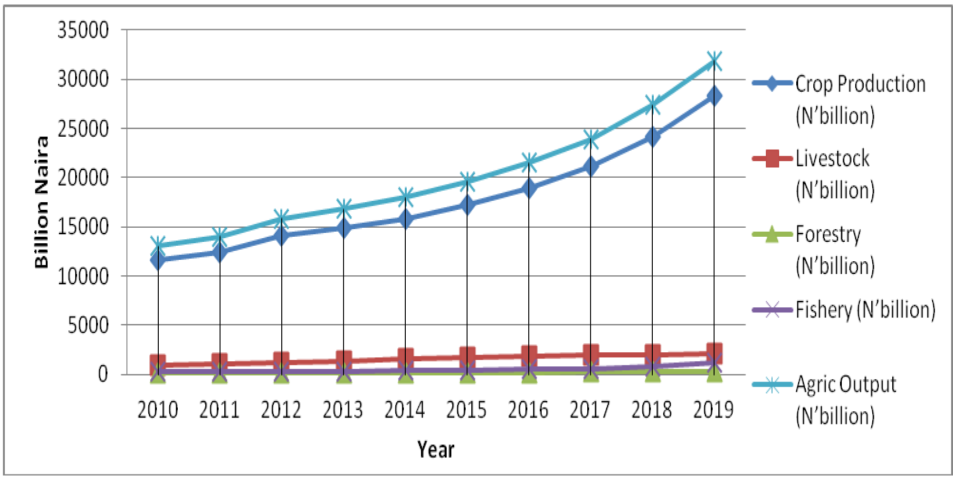

Figure 1.2: Trends in sub-sectoral performance of Agricultural sector
Source: Author's computation using CBN data

Earlier studies in this research space are mainly in developed economies; instead of developing economies where the effect of pollution is more significant and worrisome (Liang & Yang, 2019; Lu *et al.*, 2017; Shkrabtak*et al.*, 2018; Xie*et al.*, 2019).

Several studies on environmental pollution in the sub-Saharan Africa region exist (Amegah&Agyei-Mensah, 2017; Lapworth*et al.*, 2017; Zaidi&Saidi, 2018); nevertheless, most ignored the pollution-agricultural relationship. However, only studies by Mele andMagazzino (2020) for India, and Appiah*et al.* (2018) for Ghana, explored the relationship between air pollution and agricultural output. Unfortunately, Nigeria, an agrarian economy, the largest economy in the continent, and the fourth-deadliest country globally, do not have studies on the linkages between air pollution and agricultural output.

Against this background, the study examined the relationship between carbon emission and agricultural output in Nigeria. The findings of the study are relevant threefold. The study extended the tenets of the Environmental Kuznets Curve (EKC) to capture pollution-agriculture nexus.

The empirical evidence justified the inverted U-shaped EKC while establishing an N-shaped EKC in Nigeria. Second, dynamic EKC models against conventional static EKC models prompted the adoption of the modern dynamic Vector Error Correction Models (VECM), variance decomposition, impulse response and Granger causality tests. Third, the policy recommendations of the study pointed out the need for a foreign direct investment inflows strategy that would simultaneously curb the emission of pollutants, which would be the strategy for agricultural development in Nigeria.

2.0 Literature Review

- *Concept of Environmental Pollution*

In certain climes, access to a quality environment is considered a human right because of the strong relationship between the natural environment and improved standard of living (Hajjar-Leib, 2011). To conceptualise environmental pollution, it is necessary to understand the term "environment" used in this study.

The construct "environment" has both a narrow and broad range of conceptualisations. The environment could simply be used to mean nature (Horton, 2020). It is a natural landscape and its non-human processes and features (Gorman, 2017). These initial definitions of the environment are narrow, as they viewed it as a pristine landscape that human activities have not perceptively changed.The preceding definitions of the environment without including the notion of interaction and relationship among the environment components are incredibly inadequate.

Thus, the study conceptualises the environment as space where a series of interactions, relationships, and interdependence occurs between entities. The notion of the interrelationship between the entities in the environment is of great interest to ecological economists, environmental systems, and management scientists due to their interests in damages and degradation occasioned by these interactions. These damages result from the emission of pollutants into the environment beyond the environmental limit.

According to Environmental Management (2017), "environmental pollution is the contamination of the physical and biological components of the earth/atmospheric system to such an extent that normal environmental processes are adversely affected." The scourge of environmental pollution is one of the topical challenges ravaging the globe in recent times. The plague of pollution is found in air, water, and land (Ashraf &Hanfiah, 2017).

Emphatically, the study conceptualises environmental pollution from the perspective of air pollution. Air pollution is the most pronounced environmental challenge the world over. Its deleterious effects could last between 15-200 years (Halkos&Paizanos, 2013); it is also mostly responsive to water and land pollution through carbon dioxide (C0 emission or Sulphur Nitrate (PM3 emission) (Huang *et al.,* 2020; Mishra, 2017). In ecological literature, Carbon monoxide (C0) emission is the most adopted measure of pollution (Campbell-Lendrum&Prüss-Ustün, 2019; Halkos&Paizanos, 2013; Islam &López, 2013) because it affects and presents in the atmosphere last between 50-200 years (Halkos&Paizanos, 2013).

Carbon emission (CO) is a colourless, tasteless, odourless but toxic air pollutant produced when carbon combustion from gasoline, oil, coal, natural gas and wood is incomplete. Sources of this poisonous gas include industrial emissions, agricultural emissions, indoor cooking emissions, vehicular emissions, generator emissions, among others. For instance, in the United States, vehicle emissions are the largest carbon emission source (National Research Council, 2002); while in Nigeria, open fire and industrial/fuel emission are the two most pronounced sources of carbon monoxide emissions (Marais et al., 2014). Also, Carbon dioxide (CO2) emission, though a non-poisonous gas, significantly accounts for ozone layer depletion, which results in global warming.

Thus, environmental pollution in the context of the study refers to air pollution, except otherwise stated. It is conceptualised as the depletion of air quality due to pollutants such as chemical, biological or physical pollutants. Air pollution is undesirable impurities and an abnormal increase in the quantity of visible or invisible pollutants in the atmosphere. Air pollution could be considered from three different perspectives: local, regional, and global.

The local dimension of air pollution deals with the consideration and concerns of air quality within a few kilometres radius. The regional dimension considers the degradation of air quality up to a thousand kilometresdue to low water quality, photochemical reactions, and acid rain. From the global perspective, the consideration is the worldwide emission of greenhouse gas (CO2) with severe implications for global warming and ozone layer depletion.

- *Causes of Air Pollution*

The presence of toxic substances in the atmosphere beyond the environmental limit is the broad cause of air pollution. These toxic substances are produced by either human actions such as industrialisation(dos Santos Mascarenhas*et al.*, 2019; Hu *et al.*, 2020), agricultural activities(Charles *et al.*, 2017; Pozzer*et al.*, 2017), transportation (Litman, 2017; Wang *et al.*, 2017), telecommunication (Husko*et al.*, 2018; Park *et al.*, 2017) or as a result of a natural disaster like a dust storm, wildfire, dwindling air quality and volcanic eruptions as depicted in Figure 2.1.

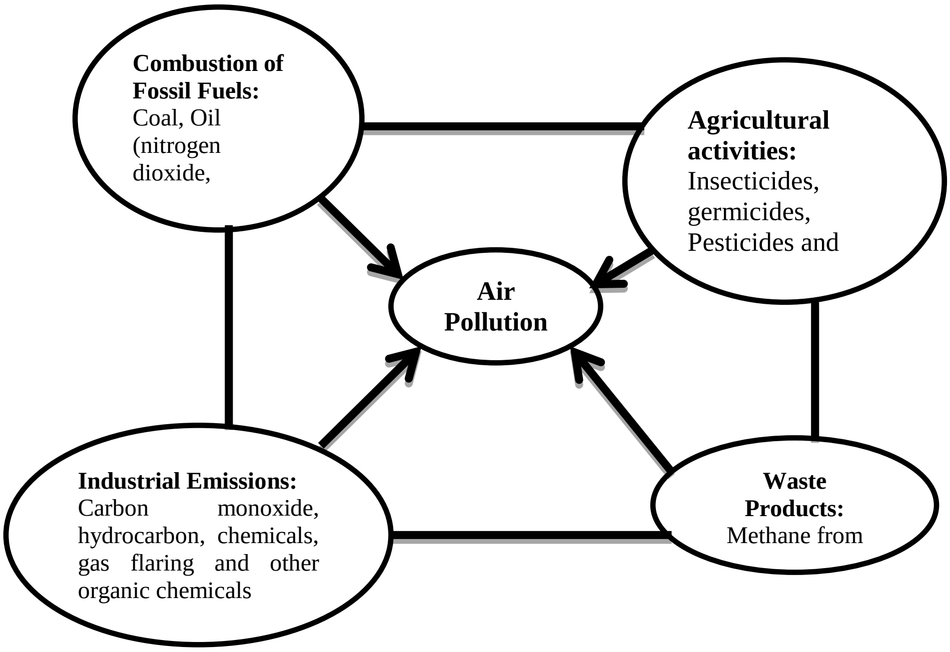

Figure 2.1: Sources of Air Pollution (Air Pollution web-chain)
Source: Author design (2020)

- *Effects of Air Pollution*

The consequences of air pollution are inexhaustible. However, the significant effects of air pollution are visible on the environment, global warming, and human health. Figure 2.2 depicts the impact of air pollution on the environment, which includes inhibition of plats photosynthesis and does affect the purification of oxygen that constitutes the air breathed by human beings. Photosynthesis prevention due to air pollution has implications for crop production, and the quality of air affect fishery and livestock (Agrawal*et al.,* 2003;Vandyck*et al.,* 2018; Wang *et al.*, 2020).

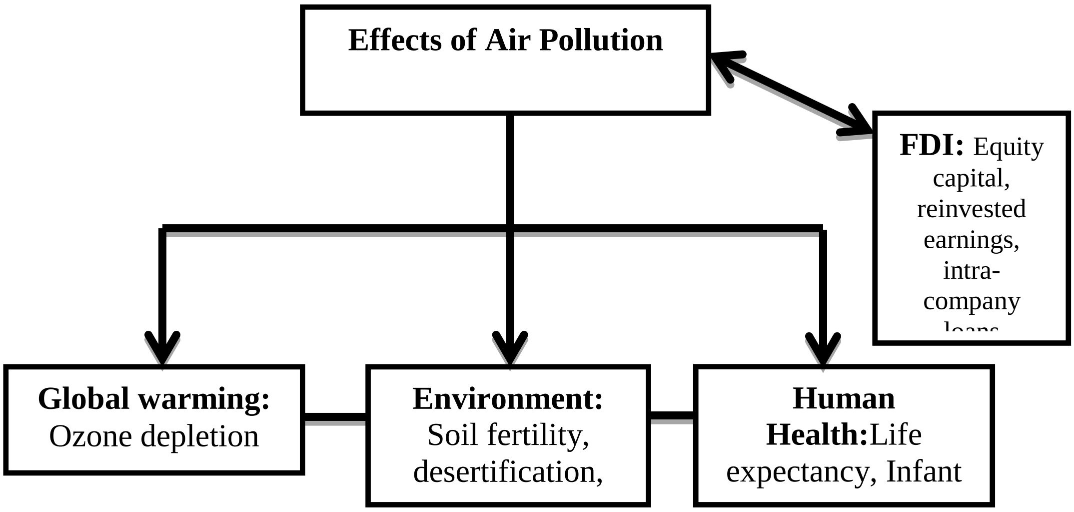

Figure 2.2: Chain effects of air pollution
Source: Author's design (2020)

The environmental consequences of air pollution further include acid rain formation that is transformed in the atmosphere when mixed with water steam (Aydin&İlkiliç, 2017). Another notable effect of air pollution is its contribution to climate change and global warming occasioned by excess carbon dioxide emissions resulting in the greenhouse effects (Volenzo et al., 2019). Air pollution is the most hazardous type of pollution, and it accounts for human health deterioration through its effects on the cardiovascular organs, respiratory system, and lung destruction (Manisalidis*et al.*, 2020; Munawer, 2018).

- Pollution Abatement Policies in Nigeria

The environment is natural life support to humanity as it provides pure, clean and hospitable air, water and land for human. However, advances in science and technology, and the quest for economic development have resulted in an ecological imbalance that could prove long term disaster to humanity. To combat the anticipated health and economic effect of pollution, nations have developed national regulations and adopted international treaties on pollution abatement.

National legal framework and legislative supports for pollution abatement were largely inchoate and inadequate in Nigeria before 1988. The dumping of hazardous waste in Koko, Delta state by five Italian ships exposed the absence of regulatory capacity to contain pollution in Nigeria. The kernel of this section is to review air pollution abatement policies in Nigeria critically.

a. The Associated Gas Re-Injection Act

This Act, enacted in September 1979, was aimed at regulating gas flaring in the country. The Associated Gas Re-Injection Act targeted January 1, 1984, as the deadline for the cessation of gas flaring in Nigeria, with the requirement that oil and gas companies document their gas re-injection and utilisation plans to the ministry of petroleum. Under this Act, the minister of petroleum had the power to grant gas flaring permit to oil and gas firms with evidence of inappropriateness to re-inject gas into their operations. Such firms were required to pay some levies for the volume of gas permitted to be flared. The Act further made it clear that in the event of any violation, the oil firm would forfeit the concession granted in the field where the provisions of the Act were violated.

Due to poor enforcement of the provisions of The Associated Gas Re-Injection Act, implementation was low, and gas flaring continued. To address the Act's weakness, the Petroleum Minister evoked the regulatory authority under section 3 and 5 to establish the gas version was continued flaring of the Associated Gas Flaring Act in 1984.

The new version of the Act monetised gas flaring at ₦10.00 per cubic feet of gas flared. The monetisation of gas flaring at N10.00 per cubic feet was somewhat too economically viable for oil firms to adopt. It was a motivation for oil firms to continue to flare their associated gas against making efforts to conserve, re-inject and utilise the gases they generate. This continued gas flaring regulation was not punitive enough to deter oil firms from gas flaring.

b. The Environmental Impact Assessment Act

In December 1992, the EIA Act was enacted to promote environmental consideration in development projects. The Act mandated private and public institutions to embark on environmental impact assessment before executing any project. The Act provided the procedure to be followed during the EIA, and such project must await the Federal Environmental Protection Agency (FEPA) approval. The Act further revealed that failure by an individual to comply with the provision of the Act is liable to an offence punishable on conviction with a fine of ₦100,000 or five years imprisonment. For institutional offenders, fine ranged between ₦50,000 and ₦1,000,000. Despite the strong provisions and punitive measures of the EIA Act of 1992, gas flaring was not abated because it Act did not consider the right of Nigerians to participate in environmental governance since it did not make provisions for public interest litigations and citizens suits.

c. *The National Oil Spill Detection and Response Agency Act*

The Act founded NOSDRA under the Federal Ministry of Environment to implement the National Oil Spill contingency plan. Also, NOSDRA ensures rapid, timely and effective response to oil pollution incidents in the country. The Act further stipulates that oil firms that fail to officially provide a written report of the incidence of an oil spill would be liable to a daily fine of N500,000 for each day it fails to provide a report. Besides, a daily fine of ₦1,000,000 is levied on firms that fail to clean up areas affected by oil pollution.

d. *The National Environmental Standards and Regulations Enforcement Agency Act.*

The NESREA Act repealed the FEPA Act and was necessitated by the enforcement vacuum created after the merger of FEPA and other relevant environmental bodies to form the Federal Ministry of Environment. NESREA is saddled with compliance enforcement of environmental regulations in Nigeria. The Act empowered NESREA to set national air quality standards and atmospheric pollution in Nigeria. Under the Act, an individual violator of the air quality standards shall be liable to a maximum of N200,000 fine, and or imprisonment not exceeding 12 months. The main limitation of the NESREA Act is that it did not empower the agency to regulate the oil and gas sector, where a preponderance of air pollutants are emitted and flared.

e. *Climate and Air Coalition Partner*

To address the fundamental problem of air pollution, Nigeria joined the climate and clean air coalition in 2012. In 2019, the national action plan to reduce air pollutants was approved by the national council of ministers.

Twenty-two(22) sectoral priority targets would result in 83 percent reduction in black carbon emission, and a 61 percent reduction in methane emissions by 2030. The plan further targets 22 percent average reduction in air pollution, with health benefits to include saving 7,000 lives from premature death attributable to low air quality. Also, increasing crop yield, and improving food security for 3 million Nigerians suffering from food insecurity are other anticipated benefits from the coalition.

2.2 Empirical Review

As empirical evidence surges on the relationship and causal linkages between pollution and economic growth across countries, serious attention has been paid to the causes of environmental pollution than its effects on sectoral outputs. In this study, one of the sectors considered in a disaggregated analysis is agriculture, which over the last two decades has contributed more to growth than the industrial sector in Nigeria. However, from the empirical point of view all over the world, few studies have integrated agricultural impact of environmental pollution in their analysis.

The rising incidences of air pollution due to modernity has continued to reduce living standard, accentuate respiratory diseases and hurt food security through its impact on agriculture (Affrin*et al.*, 2017). Farmers use chemical and other hazardous materials to combat pestilence and crop diseases without addressing the challenge of pollution associated with such practices. It has been asserted that rising air pollution causes an adverse reduction in agricultural output (Affrin*et al.*, 2017). Also, industrial activities are known for pollutants' emissions, and the consequences of relocating manufacturing plants from urban to rural environs are enormous on agriculture. From the preceding, Marchand*et al.* (2020) examined the impact of wastewater pollution from industry on rice yield in Jiangsu

Province of China between 2011 and 2015. The study further revealed that industrial wastewater pollution is detrimental to the growing process of agricultural products, and suggested an improved understanding of industry-agriculture development conflicts in the local regions.

The second strand of the literature shows that agricultural activities cause environmental pollution. In this regard, Li *et al.* (2020) analysed the frequent air pollution experienced by agrarian cities in Northeastern Chinese city of Suihua. The study collected data from multiple sources, and their results showed that when the agricultural practice of straw burning was prohibited, the quality of air improved significantly in Suihua city of China. Their finding indicates an inverse relationship between best agricultural practices and pollution; that is, cruel agriculture contributes to the degradation of the quality of atmospheric air. The study submitted that weather conditions and promotion of agricultural by-product usage are better strategies to improve the environment's quality. Although Affrin*et al.* (2017) drew the attention of scholars and researchers to the economic health and agricultural implications of air pollution, none of the studies so far reviewed fathomed that agricultural component such as crops, fishery, forestry and livestock as possible channels through which pollution could impact on human health.

2.3 Theoretical Foundation

The theory of Environmental Kuznets Curve postulates a bi-directional relationship between economic output and environmental pollution. Sharma (2011) posits that economic actions and pollutants emitted by Green House Gas (GHG), that is, Carbon dioxide emission (CO_2) are interlinked. The EKC theory asserts that a hike in environment degradation when national development is low over a period, but, as the economy records output expansion, environmental pollution reduces (Matthew*et al.*, 2018). The reduction in environmental pollution reduction leads to an upturned "U-shaped" relationship between the economy and pollution emissions (Sharma, 2011). Following the position of Sharma (2011) the combustion of fossil fuel releases a lot of carbon dioxide which contaminates the environment, which in turn harms the health of the individuals living in such an environment. Notwithstanding the observed effect of higher economic growth on the emissions of CO_2, at least in the short-run, the health of individuals is still adversely affected (Sharma, 2011).

The rapid growth, therefore, leads to higher use and utilisation of natural resources and a subsequently higher level of pollutants which degrade and reduces environmental quality, and also affect the stock of health quality of the people.

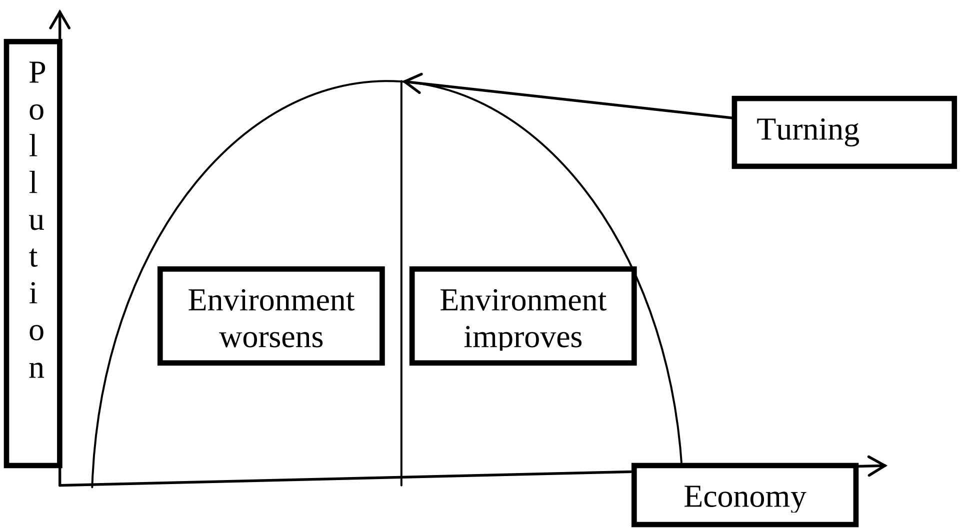

Figure 2.3: The Environmental Kuznets Curve

Source: Author's design (2020)

- *Static EKC Model*

The EKC theoretical model has static and dynamic versions. Earlier studies that include (Andreoni& Levinson, 1998; Elkins, 1996; Jaeger, 1998; Lantz&Feng, 2006; Lopez, 1994) espoused the EKC theory static perspective. Andreoni and Levinson (1998) adopt a static partial equilibrium model to analyse the relationship between consumption and investment in environmental quality by minimising pollution. Their study found that pollution curbing investment is a rising function of income. Increasing returns to pollution curbing technologies causes the EKC to rise (Usenata, 2018). The work of Elkins (1996) which utilise the scale, technique and composition effects using a single static equation reported the possibility of existing EKC theory due to the technique and composition effects outweighing the scale effects. In his application in 1998, Jaeger employs a static general equilibrium model to choose between clean and dirty goods. Lopez (1994) built an output-pollution model that inferred consumers' preferences over some level of defined income, output price and the level of pollution. In the situation where producers do not pay pollution price or pay a fixed price as a pollution tax, then, environmental pollution level would rise irrespective of technology adoption or preferences.

- *Dynamic EKC Model*

The dynamic models used to explain the EKC is limited in recent studies. However, studies such as (Anusuategi&Perrings, 1999; John &Pecchenino, 1994; Jones *et al.*, 1995; Selden & Song, 1995; Stokey, 1998) developed the dynamic models to explain the EKC overtime. Specifically, John and Pecchenino (1994) and Jones *et al.* (1995) developed the overlapping generations model, that posits that the stock of environmental quality depletes as the economy grows, due to the fact environmental quality is a finite stock of economic resource. They suggested that the only way to replenish environmental quality is through investment in environmentally sustainable ventures.

- *Critique of the Environmental Kuznets Curve*

The static model of the EKC has been criticised for its irrelevance for long-run environmental planning and decision-making. Its irrelevance in long-term planning and decisions stems from the spurious and inexact prediction of the relationship between economic output and pollution. Usenata (2018) observe that the static model treats pollution as a harmless flow variable, which is misleading and erroneous.

Studies on the relationship between the economy and environmental pollution continue to generate controversy due to the complex nature of economic growth-pollution nexus. Empirical studies (Grossman & Krueger, 1991; Selden & Song, 1994) have documented supports for the EKC, while others (Gershuny& Weber, 2009; Saboori&Soleymani, 2011) have found evidence that contradicts the EKC.

Despite the controversies on the EKC's validity in explaining the relationship between the economy and environmental pollution, the EKC leads theoretical frameworks that offer explanations to demonstrate the interdependencies between the economic outputs and environmental pollution (Usenata, 2018). Lending credence to the inverted "U-shaped" pattern of the EKC, Grossman attributes EKC pattern to the joint scale, composition and technique effects which refute the previous held monotonic relations between economic growth and environmental pollution.Moseley *et al*. (2014) emphasise that the EKC reflects the Pollution Haven Hypothesis, the second theoretical framework that undergirds this study. In their study, it was stated that wastes influx from post-industrialised to pre-industrialised economies are the catalysts of environmental pollution. Also, through foreign direct investment from the polluting firms, environmental degradation could be curbed, which is depicted in the downward sloping section of the EKC. The study thus extends the EKC to the relations between the agricultural sector and pollution.

3.0 Methodology

- Model Specification

To examine the relationship between carbon emission and agricultural output, the study formulated dynamic autoregressionmodels presented in equation 3.1 and equation 3.2 below. The models' parameters provided empirical evidence to establish the relationship between carbon emission and agricultural output, and the ascertained the direction of causality between carbon emission and agricultural output in Nigeria.

$$\Delta LnAGRI_t = \beta_0 + \sum_{i=0}^{n} \varphi_i \Delta LnAGRI_{t-1} + \sum_{i=0}^{n} \gamma_i \Delta CO_{t-1} + \sum_{i=0}^{n} \lambda_i \Delta LFEXPT_{t-1} + \sum_{i=0}^{n} \psi \Delta LnFDI_{t-1} + \alpha_1 LnGSEXP_{t-1} + \alpha_2 LnGDPPC_{t-1} + \alpha_3 LnSER_{t-1} + u_{11} \quad (3.1)$$

$$\Delta CO_t = \beta_0 + \sum_{i=0}^{n} \varphi_i \Delta CO_{t-1} + \sum_{i=0}^{n} \gamma_i \Delta LFEXPT_{t-1} + \sum_{i=0}^{n} \lambda_i \Delta LnAGRI_{t-1} + \sum_{i=0}^{n} \psi \Delta LnFDI_{t-1} + \alpha_1 LnGSEXP_{t-1} + \alpha_2 LnGDPPC_{t-1} + \alpha_3 LnSER_{t-1} + u_{11} \quad (3.2)$$

From equation 3.1, β_0 >0, is the model's intercept and expected to be positive. Also, φ_i >0, implies that the slope coefficient of the lag of agricultural output, and is expected to have a positive effect on the current level of *AGRI*. γ_i <0, is the slope coefficient of the lag of carbon emission on agricultural output and is expected to affect agricultural output negatively. λ_i >0, depicts the effect of life expectancy on agricultural output, which is expected to be positive. ψ >0, represents the effect of *FDI* on agricultural output, expected to be positive theoretically. α_1 >0, implies an a priori positive relationship between *GSEXP* and *LNAGRI;*α_2>0, shows an expected positive effects of *GDPPC* on *LNAGRI*, and α_3>0, indicates a positive relationship between school enrolment rate and agricultural output.

In the short-run, equations 3.3 and 3.4 depict the short-run dynamics captured by the Error Correction Term (*ECT*).

$$\Delta LnAGRI_t = \varphi_0 + \sum_{i=0}^{n} \theta_i \Delta LnAGRI_{t-1} + \sum_{i=0}^{n} \delta_i \Delta CO_{t-1} + \sum_{i=0}^{n} \lambda_i \Delta LnFDI_{t-1} + \sum_{i=0}^{n} \beta_i \Delta LFEXPT_{t-1} + \varphi ECT_{t-1} + \in_{3t} \quad \text{.......................................(3.3)}$$

$$\Delta CO2_t = \lambda_0 + \sum_{i=0}^{n} \delta_i \Delta CO_{t-i} + \sum_{i=0}^{n} \alpha_i \Delta LFEXPT_{t-1} + \sum_{i=0}^{n} \varphi_i \Delta LnFDI_{t-1} + \sum_{i=0}^{n} \theta_i \Delta LnAGRI_{t-1} + \varphi ECT_{t-1} + \in_{2t} \quad \text{.......................................(3.4)}$$

Where φ <0 implies the *ECT's* coefficient and is expected to be negative and statistically significant. It effectively measures the speed of adjustment between short-run disequilibrium to the long-run equilibrium position of the model.

4. Data Analysis and Discussion of Findings

- *Descriptive Statistics*

The study employed descriptive statistical tools to ascertain the fundamental properties of the variables that made up the empirical models of the study. Necessary descriptive statistical tools employed included the measures of central tendency, dispersion, shape and normality. These statistics enhanced the identification of the unique properties of the variables. It provided a simple summary of the sample statistics' statistical properties, including the mean, median, mode, range, standard deviation, skewness, kurtosis, and the Jarque-Bera distribution. These statistical measures provided insight into the observations' dispersion from their respective central values and gave preliminary evidence of their suitability in the regression models.

Table 4.1: Summary of Descriptive Statistics

	Variable						
Statistics	***CO***	***LFEXPT***	***LNAGRI***	***LNFDI***	***GSEXP***	***GDPPC***	***SER***
Mean	0.618035	48.32599	8.750878	21.15111	58.96316	0.595958	93.08001
Median	0.653394	46.35813	8.480948	21.11923	31.24991	1.017711	91.10564
Maximum	0.874309	54.49000	9.951849	22.90268	264.6905	11.51855	113.0788
Minimum	0.312014	45.63700	7.708326	19.05813	0.237600	-13.01584	78.66348
Std. Dev.	0.166034	2.976278	0.710461	1.135873	65.77873	4.850614	8.045536
Skewness	-0.443916	0.814856	0.123702	-0.007786	0.945435	-0.585398	0.932110
Kurtosis	1.973447	2.078548	1.483957	1.663376	2.890456	3.184514	3.180785
Jarque-Bera	11.97337	22.78273	15.33737	11.61424	23.31803	9.131263	22.80198
Probability	0.002512	0.000011	0.000467	0.003006	0.000009	0.010403	0.000011
Sum	96.41348	7538.854	1365.137	3299.573	9198.253	92.96942	14520.48
Sum Sq. Dev.	4.272949	1373.026	78.23704	199.9823	670660.4	3646.911	10033.25
Observations	156	156	156	156	156	156	156

Source: Author's computation (2021)

Table 4.1 indicates the summary result of the descriptive statistics of the variables employed in the study such as quarterly carbon emission (*C.O.* in metric tons per capita), quarterly life expectancy (*LFEXPT* in years), natural log of quarterly agricultural output (*LNAGRI* in ₦' billion), natural log of quarterly foreign direct investment inflows (*LNFDI* in ₦' billion), quarterly government social expenditure (*GSEXP* in ₦' billion), quarterly growth rate in Gross Domestic Product Per Capita (*GDDPC* in annual growth), and school enrolment rate (*SER* as the primary school enrolment rate as % of gross enrolment).

The result of the mean value of the observations showed that the observed averages over the period (1981:Q1 – 2019:Q4) for *C.O.*, *LFEXPT*, *LNAGRI*, *LNFDI*, *GSEXP*, *GDPPC*, and *SER* are 0.61 mt, 48.32 years, ₦8.75 billion, ₦21.15 billion, ₦58.96 billion, 0.59 percent and 93 percent respectively. The coefficient of skewness measured the shape of the distribution of each variable. The result indicated that some variables such as (*LEXPT*, *LNAGRI*, *GSEXP*, and *SER*) are positively skewed with a long tail to the right, while others (*C.O.*, *LNFDI*, and *GDPPC*) are negatively skewed with a long tail to the left. However, the kurtosis coefficient of the variables implied that *GSEXP*, *SER*, and *GDPPC* are mesokurtic or approximately symmetrical with kurtosis coefficient of approximately 3. However, *CO*, *LEXPT*, *LNAGRI* and *LNFDI* are platykurtic since their kurtosis values are less than 3; thus, these variables have flat-top shape, which is not symmetrical or approximately normally distributed. The lack of peakedness of the central explained and explanatory variables informed the need for further pre-estimation tests such as the Jarque-Bera statistic.

The Jarque-Bera statistic revealed that the variables probability values, which are less than 1%, 5%, and 10% level of significance for all the variables (*CO*, *LEXPT*, *LNAGRI*, *LNFDI*, *GDPPC*, *GSEXP*, and *SER*), indicated that the series is not symmetrically and asymptotically normally distributed. The p-values provided evidence to reject the null hypotheses of "normal distribution" and accept the alternative hypotheses of "the absence of normal distribution" for all the variables.

Therefore, it was apparent from the summary of descriptive statistics of the sampled data, the variables exhibited divergent statistical properties, which required further probe using higher pre-estimations tests such as the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (P.P.) stationarity tests to ascertain the suitability of the series and the appropriate estimations techniques.

- *Unit Root Tests*

The study employed the Augmented Dickey-Fuller (ADF), and the Phillips-Perron Unit Root tests to discern which of the techniques provided a consistent outcome that informed the choice of estimation technique adopted.

The results of the unit test are presented in Table 4.2 below. The outcomes showed that both techniques differed in order of integrations of the series. The ADF test indicated a mixed order of integration of the variables of *I(1)* and *I(0)*. However, the P.P. test indicated that all series are integrated after the first difference-*I(1)*.

The contradictory result between the ADF and the P.P. tests was resolved by selecting the P.P. result to decide the suitable estimation techniques. The choice of the P.P. over the ADF is based on three rationales and justifications. First, the P.P. result is more reliable and robust when the data points are large; thus, with 156 observations, the P.P. result is chosen over the ADF test. Second, the P.P. test corrects the statistic from heteroskedasticity and autocorrelation (HAC), and third, the P.P. is non-parametric, which does not require the pre-specification of lag length for autoregressive distributed estimation (Asumadu-Sarkodie&Owusu, 2016). Thus, the study relied on the Phillips-Perron result instead of the Augmented Dickey-Fuller test.

Table 4.2: Unit Root Results

	Augmented Dickey-Fuller (ADF)			Phillips-Perron (P.P.)			Decisions
Variable	**Level**	**First Difference**	**Order of Integration**	**Level**	**First Difference**	**Order of Integration**	***I(d)***
CO	**-2.4144** (0.3706)	**-3.1538***** (0.0981)	*I(1)*	**-1.9496** (0.6236)	**-4.4711*** (0.0023)	*I(1)*	*I(1)*
LEXPT	**-3.9234**** (0.0450)	-	*I(0)*	**-1.5201** (0.8187)	**-11.2313*** (0.0000)	*I(1)*	*I(1)*
LNAGRI	**-1.8778** (0.6610)	**-3.5505**** (0.0378)	*I(1)*	**-2.0667** (0.5598)	**-6.5235*** (0.0000)	*I(1)*	*I(1)*
LNFDI	**-2.1869** (0.4930)	**-5.3446*** (0.0001)	*I(1)*	**-2.5183** (0.3190)	**-5.4745*** (0.0001)	*I(1)*	*I(1)*
GDPPC	**-2.9550** (0.1486)	**-5.9446*** (0.0000)	*I(1)*	**-2.8010** (0.1992)	**-6.1149*** (0.0000)	*I(1)*	*I(1)*
GSEXP	**-2.4198** (0.3678)	**-4.0138**** (0.0103)	*I(1)*	**-2.8801** (0.1719)	**-9.8976*** (0.0000)	*I(1)*	*I(1)*
SER	**-3.8929**** (0.0146)	-	*I(0)*	**-2.1218** (0.5293)	**-4.0709*** (0.0085)	*I(1)*	*I(1)*

Source: Author’s computation (2021). Note: *, ** & *** denote 1%, 5% and 10% significance levels respectively, and t stats (p-values)

The Phillips-Perronstationarity test implied that none of the series was stationary at level; however, after the first difference; all variables became stationary at a 1% level of significance. Thus, the study, ascertained whether a cointegrating relationship exists among the models'variables. The Trace statistic and the maximum Eigenvalues are presented in Table 4.3 and Table 4.4 below.

Table 4.3: Unrestricted Cointegration Rank Test (Trace)

Hypothesised No. of C.E. (s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.428294	201.1526	125.6154	0.0000
At most 1 *	0.242499	116.7238	95.75366	0.0009
At most 2 *	0.161485	74.78660	69.81889	0.0190
At most 3 *	0.120923	48.19212	47.85613	0.0465
At most 4	0.101074	28.73086	29.79707	0.0660
At most 5	0.049754	12.64105	15.49471	0.1287
At most 6 *	0.032153	4.934912	3.841466	0.0263

Trace test indicates 4 cointegratingeqn(s) at the 0.05 level;
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Author's computation (2021)

Table 4.4: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesised No. of C.E. (s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.428294	84.42874	46.23142	0.0000
At most 1 *	0.242499	41.93724	40.07757	0.0305
At most 2	0.161485	26.59448	33.87687	0.2857
At most 3	0.120923	19.46126	27.58434	0.3797
At most 4	0.101074	16.08981	21.13162	0.2196
At most 5	0.049754	7.706136	14.26460	0.4094
At most 6 *	0.032153	4.934912	3.841466	0.0263

Max-eigenvalue test indicates 2 cointegratingeqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Author's computation (2021)

The cointegration test was utilised to analyse the presence of a long-run relationship among *LEXPT, CO, LNAGRI, LNFDI, GSEXP, GDPPC* and *SER.* The series is assumed to be cointegrated if there is evidence of long-run co-movement. Essentially, a vector of I(1) random variables is said to be cointegrated if there exists a vector if-such that βi-Yt is stationary. Thus, the Trace and Maximum Eigenvalue tests showed that the series are cointegrated. The Trace statistics revealed four cointegrating equations, while the Maximum Eigenvalue affirmed the existence of at least two cointegrating equations in the model at a 5% level of significance.

- *Estimations*

Since the variables utilised were not stationary at levels, applying the Ordinary Least Square (OLS) estimation technique would produce a spurious result (Engle & Granger, 1987; Granger *et al.*, 1974). Engle and Granger (1987) propounded the two-step technique ECM, which was based on the OLS estimation of the long-run cointegrating equation and the unit root test of the residuals. One of the ECM shortcomings is the inability to identify different cointegrating vectors using a single equation approach in a multiple regression model (Ankrah, 2016). Also, in the case of a single cointegrating vector, the single equation approach of the ECM is inefficient; if not, all the explanatory variables become weakly independent (Ankrah, 2016).

To address the shortcomings of this ECM technique, Johansen (1988, 1991) and Juselius (1990, 1992) developed the Vector Error Correction (VEC) modelling, a multivariate approach that overcomes most of the limitations of the ECM two-step estimation technique. Thus, having conducted the cointegration tests, the study employed the vector error correction model (VECM) that examines the long-run relationship among the variables, the dynamics, and the short-run error correction.

- ***Relationship between Carbon Emission on Agricultural Output***

Table 4.5: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1905.399	NA	394.6862	25.84323	25.98499	25.90083
1	-47.07335	3515.751	9.50e-09	1.392883	2.526963	1.853657
2	285.9556	598.5520	2.05e-10	-2.445345	-0.318945*	-1.581394
3	296.7858	18.44060	3.48e-10	-1.929537	1.189184	-0.662408
4	341.7029	72.23164	3.75e-10	-1.874364	2.236677	-0.204057
5	463.3102	184.0543	1.45e-10	-2.855544	2.247818	-0.782060
6	679.8165	307.2048*	1.59e-11*	-5.119142*	0.976540	-2.642480*
7	696.8267	22.52701	2.64e-11	-4.686847	2.401155	-1.807008
8	739.7763	52.81648	3.16e-11	-4.605086	3.475237	-1.322069

* indicates lag order selected by the criterion

Source: Author's computation (2021)

Before estimating the VEC model, it is essential to ascertain the optimal lag length of the dynamic model to ensure a set of estimated parameters that are consistent. The optimal lag length selection criteria employed included the Final prediction error test, the Sequential Modified L.R. test, Akaike Information Criterion (AIC), Schwarz Information Criterion (S.C.), and the Hann-Quinnin Information Criterion (H.Q.).

The lag selection criteria results presented in Table 4.5 indicates that the L.R., FPE, AIC and H.Q. criteria affirmed the optimal lag of 6, while the SC suggested 2 lag periods as optimal. Since the majority of the selection criteria indicated a lag period of 6 quarters, the study, therefore, estimated the VECM parameters using 6 lag periods.

- *Vector Error Correction Model (VECM) Result*

To enhance the versatility, flexibility and quality of a dynamic system econometric model specified in the study, and to capture the short-run dynamics with the long-run equilibrium relationship of the model, the Vector Error Correction Model (*VECM*) estimation technique was applied, and *VECM* estimates are presented in Table 4.6 below.

Table 4.6: Vector Error Correction Model (*VECM*) Results

Dependent Variable: D(*LNAGRI*)

Predictor	Coefficient	Standard Error	t-statistic	P-values
ECT(-1)	-0.678800	0.12225	-5.55241	0.0000
D(LNAGRI(-1))	0.872469	0.17361	5.02545	0.0000
D(LNAGRI(-2))	-0.016606	0.19596	-0.08474	0.9098
D(LNAGRI(-3))	0.007356	0.14084	0.05223	0.9110
D(LNAGRI(-4))	-0.353489	0.14084	-2.50991	0.0470
D(LNAGRI(-5))	0.319491	0.21584	1.48022	0.1217
D(LNAGRI(-6))	-0.083916	0.19510	-0.43011	0.6207
D(CO(-1))	0.242000	0.08913	2.71513	0.0110
D(CO(-2))	-0.460690	0.10416	-4.42267	0.0001
D(CO(-3))	-0.397801	0.13079	-3.04161	0.0009
D(CO(-4))	-0.086651	0.09571	-0.90531	0.2096
D(CO(-5))	0.102685	0.11651	0.88138	0.2239
D(CO(-6))	0.112439	0.10041	1.11980	0.1493
D(LNFDI(-1))	-0.004811	0.01673	-0.28751	0.8406
D(LNFDI(-2))	-0.000663	0.01909	-0.03476	0.3608
D(LNFDI(-3))	0.002331	0.01377	0.16935	0.5249
D(LNFDI(-4))	0.012257	0.01380	0.88793	0.6014
D(LNFDI(-5))	-0.016315	0.02041	-0.79949	0.0168
D(LNFDI(-6))	0.004817	0.01851	0.26025	0.0375
D(GDPPC(-1))	-0.001429	0.00303	-0.47170	0.7104

D(GDPPC(-2))	-0.002128	0.00320	-0.66517	0.3118
D(GDPPC(-3))	-0.000699	0.00161	-0.43431	0.7675
D(GDPPC(-4))	-0.002893	0.00161	-1.79698	0.0964
D(GDPPC(-5))	0.001497	0.00283	0.52825	0.4230
D(GDPPC(-6))	-0.002032	0.00265	-0.76627	0.3516
D(GSEXP(-1))	-2.55E-05	0.00030	-0.08386	0.9090
D(GSEXP(-2))	-0.000105	0.00040	-0.26358	0.6230
D(GSEXP(-3))	-9.53E-05	0.00034	-0.27774	0.6112
D(GSEXP(-4))	0.000223	0.00035	0.64521	0.7983
D(GSEXP(-5))	-0.312001	0.08233	-3.78964	0.0067
D(GSEXP(-6))	-0.000153	0.00033	-0.45716	0.6441
D(SER(-1))	0.000750	0.00218	0.34450	0.7902
D(SER(-2))	-0.002185	0.00266	-0.81991	0.2087
D(SER(-3))	-0.000340	0.00203	-0.16734	0.8872
D(SER(-4))	-0.001913	0.00203	-0.94186	0.1712
D(SER(-5))	0.001680	0.00235	0.71371	0.3207
D(SER(-6))	-0.001424	0.00193	-0.73730	0.3100
C	0.017236	0.00563	3.06060	0.0198

R-squared	0.669476	Akaike AIC	-5.406145
Adj. R-squared	0.534119	Schwarz SC	-4.519073
Sum sq. resids	0.021695	Mean depvar	0.014716
S.E. equation	0.014374	S.D. dependent	0.021059
F-statistic	4.945986	Log-likelihood	446.7578
Durbin-Wat stat	2.061987		

Source: Author's computation (2021)

From Table 4.6, the R-squared (coefficient of determination) value of 0.669476 obtained from the short-run estimated model reveals that the explanatory variables: lag of agricultural output, carbon emission, life expectancy, foreign direct investment, government social expenditure, GDP per capita and school enrolment jointly accounted for 66.9 percent of the variations in agricultural output. The F-statistic of 4.945986 is relatively high and thus, provides evidence of a good fit and the adequacy of the overall estimated model. Based on these estimated statistics from the *VECM* analysis, the model is suitable for policy purposes.

The adjusted coefficient of determination $(\bar{R})^2$minimises the influence of the number of multiple explanatory variables in the model; its value of 0.534119 implies that after adjusting the influence of the explanatory variables in the estimated model, the explained variable is predicted by the model to the tune of 55.8 percent, and the Durbin-Watson statistic (D.W.) of 2.062 indicates a minimal level of autocorrelation and a good fit for the estimated VEC model.

Nevertheless, the VECM estimates revealed mixed findings and resulted in varying statistical significance level for some of the coefficient. The short-run dynamic coefficients revealed that life expectancy had predominantly positive effects on agricultural output, except in the fourth period of lag where it had a significant negative relationship with agricultural output. Specifically, a period and fifth periods lag in life expectancy were found to influence agricultural output significantly in a current period. A percentage increase in the lag of life expectancy by one period increases current agricultural output by 0.064828 percent, but, 0.751028 percent after 5 lags (quarters), and are statistically significant at a 10% and a 5% level of significance respectively.

In light of the main argument of the second objective of the study, for carbon emission, the first lag coefficient of 0.242000 was statistically significant at a 5% significance level, indicating a strong positive relationship against the expected negative expectation. However, the second, third, and fourth lags coefficients of -0.460690, -0.397801, and -0.086651 showed a negative effect of carbon emission on agricultural output in Nigeria. Interestingly, the second and third lagged coefficients were statistically significant at a 1% significance level. Finally, the fifth and sixth lagged coefficients indicated a positive relationship between carbon emissions and agricultural output. The positive-negative-positive relationship estimated between carbon emission and agricultural output in Nigeria corroborates the N-shaped Environmental Kuznets Curve Theory for Nigeria, against the inverted U-shaped EKC for developed economies. The outcome of the study further lend credence to some earlier studies (Affrin*et al.*, 2017; Gershuny& Weber, 2009; Saboori&Soleymani, 2011; Li *et al.*, 2020) on the relationship between pollution and economic output with evidence of N-shaped Environmental Kuznets Curve, and refutes (Grossman & Krueger, 1991; Selden & Song, 1994; Sharma, 2011; Usenata, 2018), which reported evidence for an inverted U-shaped Environmental Kuznets Curve.

Also, agricultural output is impacted by foreign direct investment both positively and adversely within the period under investigation. The *VECM* result further showed that significant effect of *FDI* on agricultural output are mixed at lagged five and six periods. Interestingly, the fifth lagged period of *FDI* coefficients of -0.016315 was statistically significant at a 5% level of significance. The slope coefficient value implies that a 5 quarter lag in *FDI* inflow hurts agricultural output by 0.016315 percent. However, in the sixth lagged period, FDI accentuates agricultural output by 0.004817 percent for every one percent rise in FDI inflow. The most notable reason for the initial negative relationship is that rising FDI leads to environmental degradation, which further causes land, water, and air pollution through industrial emission. Rising industrial emission into the atmosphere and land causes low land fertility, which leads to poor agricultural output. The government intervenes by control and command strategies to curb industrial emission caused by FDI inflows, which leads to a lower level of emission, improved land fertility and better agricultural yield, thus, a positive relationship between FDI and agricultural output.

Moreover, most of the coefficients of lagged periods in per capita income (GDPPC) had a negative relationship with agricultural output in Nigeria, but, were not statistically significant. The predominant negative relationship shows that as Nigerians become financial inclusive; they tend to depart from the agricultural sector, which is perceived as the occupation for the poor and vulnerable in rural areas. Within the same discussion, government social expenditure lagged coefficients are provided evidence of significant inverse relationship with agricultural output in Nigeria. The negative relationship portrays the trade-off between government expenditure on the social sector and the agricultural sector. Thus, as government allocation to health and education increases, fewer resources are available to be allocated for agricultural development, which has been the typical situation of Nigeria. Finally, school enrolment rate and agricultural output exhibited mixed relationship without evidence of statistically significant nexus between both variables.

The long-run component of the estimated *VEC* model is represented by the lagged error correction term: *ECT (-1).* From the estimates, the *ECT (-1)* coefficient of -0.678800 with a p-value of 0.0000 indicates that the explanatory variables are related to the explained variable through the error correction mechanism. The correctly signed and statistically significant *ECT (-1)* at a 1% level of significance signifies 67.88 percent adjustment speed in *LNAGRI* when there is a deviation from its long-run equilibrium value.

- *Variance Decomposition Test*

To ascertain the long-run determinants of agricultural output in the model the variance decomposition test was conducted, and the result presented in Table 4.7 revealed that in the long-run, carbon emission accounted for 39.561 percent of changes in agricultural output in Nigeria. In comparison, life expectancy accounted for 8.016 percent, foreign direct investment 18.341 percent, GDP per capita 8.008 percent, government social expenditure 7.734 percent and school enrolment 6.752 percent, while agriculture itself accounted for 9.231 percent. The result reiterates carbon emission and foreign direct investment in agricultural output growth in the country.

Table 4.7: Variance Decomposition of LNAGRI

Period	S.E.	LFEXPT	CO	LNAGRI	LNFDI	GDPPC	GSEXP	SER
1	0.014374	29.91234	0.112776	69.97488	0.000000	0.000000	0.000000	0.000000
2	0.027134	14.54658	0.106610	85.11074	0.010087	0.010044	0.056546	0.159383
3	0.040453	8.716946	0.052763	90.80932	0.078445	0.088826	0.120640	0.133057
4	0.053808	5.177411	0.175522	93.81383	0.204545	0.269020	0.256889	0.102782
5	0.116240	70.54015	0.101458	28.76067	0.088443	0.243150	0.241968	0.024158
6	0.129572	64.83128	0.093730	30.86084	0.282000	0.476306	2.513563	0.942284
7	0.137622	62.23604	0.179304	32.38125	0.404716	0.730119	3.230460	0.838113
8	0.156188	65.31970	0.408604	28.95006	0.348560	0.937294	3.383638	0.652146
9	1.335849	99.37216	0.009333	0.460624	0.006258	0.021540	0.113175	0.016907
10	2.354278	8.016807	39.56139	9.231466	18.34137	8.007921	7.734330	6.752433

Source: Author's computation (2021)

- *Granger Causality Test*

The lead-lag relationship between agricultural output and its determinants: carbon emission, life expectancy, foreign direct investment, GDP per capita, government social expenditure, and school enrolment in Nigeria, were examined using the Granger causality analysis based on the following causal hypotheses:

Null Hypothesis (Ho): Does not Granger cause AGRI

Alternative Hypothesis (H_1): Granger causes AGRI

The result of the Granger causality test is depicted in Table 4.8 below.

Table 4.8: VEC Granger Causality Result

Null Hypothesis (Ho)	Chi-square	P-value	Decision	Remarks
CO does not Granger cause AGRI	44.47098	0.0000	Reject Ho	Causality
AGRI does not Granger cause CO	1.046806	0.9838	Accept Ho	No causality
LEXPT does not Granger cause AGRI	8.309749	0.0998	Accept Ho	No causality
AGRI does not Granger cause LEXPT	14.75921	0.0466	Reject Ho	Causality
FDI does not Granger cause AGRI	15.44984	0.0456	Reject Ho	Causality
AGRI does not Granger cause FDI	20.57856	0.0001	Reject Ho	Causality
GSEXP does not Granger cause AGRI	2.390240	0.8805	Accept Ho	No causality
AGRI does not Granger cause GSEXP	1.165184	0.9786	Accept Ho	No causality
GDPPC does not Granger cause AGRI	10.20065	0.1165	Accept Ho	No causality
AGRI does not Granger cause GDPPC	43.67371	0.0000	Reject Ho	Causality
SER does not Granger cause AGRI	4.963921	0.5484	Accept Ho	No causality
AGRI does not Granger cause SER	1.870475	0.9312	Accept Ho	No causality

Source: Author's computation (2021)

As shown in Table 4.8, the VEC Granger causality Chi-square used to test the causality between carbon emission and agricultural output is significant at a 1% significance level with a value of 44.47098. Thus, the null hypothesis that *C.O.* does not Granger causes *AGRI* is rejected, while the alternative hypothesis that *CO* Granger causes *AGRI* is accepted. However, the p-value and chi-square value do not provide enough evidence to accept the alternative hypothesis of the possibility of a reversed causality from *AGRI* to *CO*, thus, the hull hypothesis that *AGRI* Granger causes *C.O.* is rejected. Therefore, there is a unidirectional causal relationship between carbon emission to agricultural output in Nigeria. The result corroborates earlier empirical results by Mele&Magazzino (2020), which concluded that carbon emission causes economic output in a unidirectional direction for India, but, disagreed with Appiah*et al.* (2018) that documented a unidirectional causal linkage from agricultural output to carbon emission for emerging economies. Additional evidence from the Granger causality test revealed a bidirectional causal nexus between agricultural output and foreign direct investment; unidirectional causation from agricultural output to GDP per capita. In a sharp departure from the causal linkages, the result indicated a lack of causation between agricultural output and government social expenditure and school enrolment rate in Nigeria. Interestingly, agricultural output was caused by carbon emission and foreign direct investment inflows within the study's period.

5.0 Conclusion

Empirical evidence from the *VECM* and Granger causality analyses indicated that carbon emission had a statistically significant positive and negative effect on agricultural output at various lagged periods. Also, carbon emission Granger caused agricultural output between 1981Q1 and 2019Q4. Thus, the results provided enough evidence to conclude that carbon emission, a proxy for air pollution, had a significant relationship with agricultural output in Nigeria.

Furthermore, the study provided an empirical answer to the research question "what is the relationship between carbon emission and agricultural output in Nigeria?" Carbon emission had an initial positive relationship with agricultural output, however, from the second lagged period a negative relationship was observed up to the fourth lag, and in the fifth and sixth lagged periods positive relations resurfaced. The N-shaped Environmental Kuznets Curve Theory supports the unstable relationship between agricultural output and carbon emission. In the case of Nigeria, the N-shaped relationship between carbon emission and agricultural output is rationalised by lack of pollution abatement technologies needed to reduce long-run environmental pollution as output increases. Moreover, weak enforcement of air pollution abatement policies and general environmental standards in Nigeria is also responsible for the N-shaped nexus between agricultural output and carbon emission in Nigeria. Finally, the study established an N-shaped Environmental Kuznets Curve in the relationship between environmental pollution and agricultural output in Nigeria. This result differs from the conventional inverted U-shaped EKC often found in the literature.

The principal argument deduced from the study's result is that air pollution and foreign direct investment are critical variables that influence agricultural output in Nigeria. Thus, the study suggests that policies that would encourage foreign direct investment inflows and simultaneously discourage the emission of pollutants are the strategic actions to actualise sustained agricultural output in Nigeria.

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