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Environmental Quality, Health Outcomes and Economic Development in Nigeria: Evidence from Vector Autoregressive (VAR) Model

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ABSTRACT

Empirical literature gesticulates that most of the developing countries in Africa (Nigeria inclusive) faced consistent threats to their environment thereby worsen health status of the humans as a result of activities involving a high use of energy on a daily basis. Arising from the foregoing, this study is out to investigate the interactions among environmental quality, health outcomes and economic development in Nigeria. The study used annual time series data spanning between 1980 and 2023 and sourced from Central Bank of Nigeria Statistical Bulletin (various issues) and World Bank, World Development Indicator of 2023 edition database. Vector Autoregressive (VAR) model was employed as estimation technique for the study. Results showed that GDP per capita exhibit strong positive short-run influenced by its own lag and past value of life expectancy rate, while negatively affected by lagged CO_2 emissions. Further, CO_2 emissions influenced by their own past value but declined with increases in past GDP per capita and life expectancy values. This implies that economy and healthcare improvements will result to better environmentally friendly outcomes in the country. In addition, life expectancy also exhibits strong persistence and positive impacted by past GDP per capita, but adversely affected by CO_2 emissions. Exchange rate and inflation displayed significant autoregressive behavior, with inflation notably declining in response to improvements in past GDP per capita and life expectancy values. Based on the findings, the study therefore recommends that government and policymakers should embark on appropriate environmental policy measures such as carbon taxes, subsidies for renewable energy, regulations for energy efficiency standards and amongst others that will reduce consumption of fossil fuel so as to mitigate the negative effect of CO_2 accumulation in the air, which in turn improve health outcomes in Nigeria. Afterwards, economic development can be better appreciated and enhanced greatly in the country at the expense of quality environment and healthy citizenry.

KEYWORDS: **Economic Development, Environmental Quality, Health Outcomes, VAR Model**

1. INTRODUCTION

Most of the developing nations in Africa (Nigeria inclusive) faced consistent threats to their environment thereby worsen health status of the humans as a result of activities involving a high use of energy on a daily basis (Balan, 2016). However, the issue of environmental quality in Nigeria had received increased attention at often interval, creating awareness on the adverse consequence of a deteriorated environment that may occur if the environment in nations of the World continues to be uncared for by the society. For instance, widespread pollution poses a real threat to industrialized countries, whereas quality of life until recently was measured almost solely by the growth of material output alone (Samimi & Nouri, 2023).

Since 1970s, global discoveries pointed to a potential challenge about the earth's ecosystems, as it was seen to be increasingly fragile. The ecosystems fragility and degeneration have been attributed to increase in human economic activities. This became more evident through intense natural resource consumption, industrial activities as well as increased vehicular and automated processes. Basically, the environment is linked to production activities, since resources generated from the environment are transformed into economic goods. But when the environment is disturbed by overuse and huge amount of wastes, it cannot discharge its functions of cleaning up waste, maintaining genetic diversity and stabilization of ecosystems (Hussen, 2000). A reduction in environmental quality is usually a result of pollution and hazards, which are in the form of air pollution, water pollution, land pollution, as well as deforestation.

Further, these aforementioned interactions affect the quality of life, years of healthy life lived, and health disparities. However, the World Health Organization (2006) defines environment, as it relates to health, as all the physical, chemical, and biological factors external to a person, and all the related behaviors. Environmental health consists of preventing or controlling disease, injury, and disability related to the interactions between people and their environment. Recent studies showed that health outcomes such as life expectancy of a nation is reflected in the social, economic, demographic and environmental conditions (Agbanike, et al., 2019; Perera, 2018; Lu et al., 2017; Wu, 2017; Abbas & Awan, 2018).

Again, poor environment affects individual's health which in turn impacts negatively on the individual's ability to make a livelihood. To be specific, a poor-quality environment makes the environment unconducive for teaching and learning. The implication of this is that human capital development is severely affected. More so, food for human consumption is affected through the effect of poor-quality environment on plants and animals, thus as a result, humans suffer hunger and poor nutrition which is another channel through human health is affected. Alege (2017) noted that one of the highest producers and consumers of fossil fuel (adjudged to be a major source of carbon dioxide emissions contributing to climate change globally is Nigeria. Emission of CO_2, which is a major gaseous component of fossil fuel combustion, is identified to be a contributory factor to climate change as it multiplies and accumulates in the atmosphere (Sharma, 2017) thereby, deteriorating the quality of the environment, which has serious implications for human health and the country's drive towards sustainable development. This follows from the fact that apart from negatively impacting human health and individuals' welfare, the effect of environmental degradation on society is enormous by way of substantial public health care financing (Balan (2016). The challenge of poor health in a country will attract a greater proportion of the nation's budget allocation to redress the situation with high opportunity costs. While articulating the adverse effects of gaseous emissions on humans, Matthew et al., (2018) identified children as the most susceptible age group due to their peculiar nature.

Due to the activities of humans involving a high use of energy, threats to the environment have been on the increase causing poor health, which has led to reduction in some health outcomes like life expectancy and high rates of mortality. Nigeria still has a high rate of under-5 mortality (estimated at 70 per 1,000) and a high maternal mortality rate (120 per 100,000 live births) (United Nations, 2016). According to Dhanya (2015), an increase in production and productive activities of a country is a catalyst and antidote for growth, but these activities are usually plagued with a rising spate of air pollution, especially in developing countries (Nigeria inclusive). In Nigeria, productive activities are often associated with massive pollution due to the poor supply of electricity and poorly maintained state of mechanical engines. World Bank, (2014) reported that Nigeria needs an average of 8,000 to 10,000 megawatts to meet energy needs; however, current supply which falls short by over 80% leaves room for an alternative source of electricity filled majorly by electricity generating sets. Unfortunately, the effects of powering up industrious activities release unhealthy portions of carbon dioxide into the atmosphere, causing pollution that increasingly causes threats to not just human health but to other living creatures on earth.

Several studies have been conducted on the relationship among environmental quality, health outcomes and economic development, however, majority of these studies focussed on economic growth and ignored economic development (e.g. Omojolaibi, 2010); Ani et al., 2021); Oyedele and Tella, 2021); Afolayan & Aderemi, 2019), while Onuonga, 2020); Mesagan & Nwachukwu, 2018) examined environmental quality and financial development only. However, this form lacuna for this present study to be filled.

Premised on foregoing, the study intends to answer question of what are the interactions among environmental qualities, health outcomes and economic development in Nigeria? While the fulcrum of broad and specific objectives, are to investigate the interrelationship among environmental quality, health outcomes and economic development in Nigeria respectively, covering the period between 1980 and 2023. However, the study will significantly be instructive to note that in a resource-constrained environment, policymakers must make informed to take decisions about resource allocation and policy prioritization. Decision-making on how to improve access to clean water and sanitation, reducing air pollution, and strengthening healthcare infrastructure towards achieving optimal health and economic outcomes.

2. LITERATURE REVIEW AND THEORETICAL UNDERPINNING

Conceptual Review

Life expectancy as a measure, therefore, reflects not just the overall health or mortality of a population but also provides an insight into the social and economic conditions that interplay or exist to affect longevity within a region. It is a barometer for a healthy socio-economic system. The cliche, that health is wealth underscores the importance of a healthy nation and the length of life (life expectancy) a nation's citizens stand to enjoy. Several factors can affect life expectancy at birth which many studies suggest could be: social, economic, biological, medical, political, and environmental (Levine et al., 2016). These factors could also be grouped into demand-side factors and supply-side factors. Nevertheless, it is expected that the life expectancy rate for any nation should be high enough to guarantee sustainable growth and development. The third goal of the sustainable development goals is to ensure healthy lives and promote wellbeing for all ages (UNDP, 2020). This goal has 13 features, all of which touches on reducing death of all types by reducing the causes of such deaths. The idea is that if people can be made to live longer, then the life expectancy rate will increase and if the life expectancy rate increases then the economy can be sustained. The sustenance of the economy is possible since people with an increased life expectancy rate can supply more of their labour services to participate in every economic opportunity. Statistics from World Bank (2021) showed that the life expectancy in Nigeria for both sexes stood at 54.49 years in 2019, revealing an insignificant improvement, Nigeria was Ranked 161 out of 195 countries in the world based on life expectancy in 2019 which is lower than that of South Africa which stood at 61.46 years, Libya 70.61 years, Egypt 70.23 years, and India 69.16 years. The life expectancy rate for Nigeria over the past one decade is shown in the figure below;

Table 1

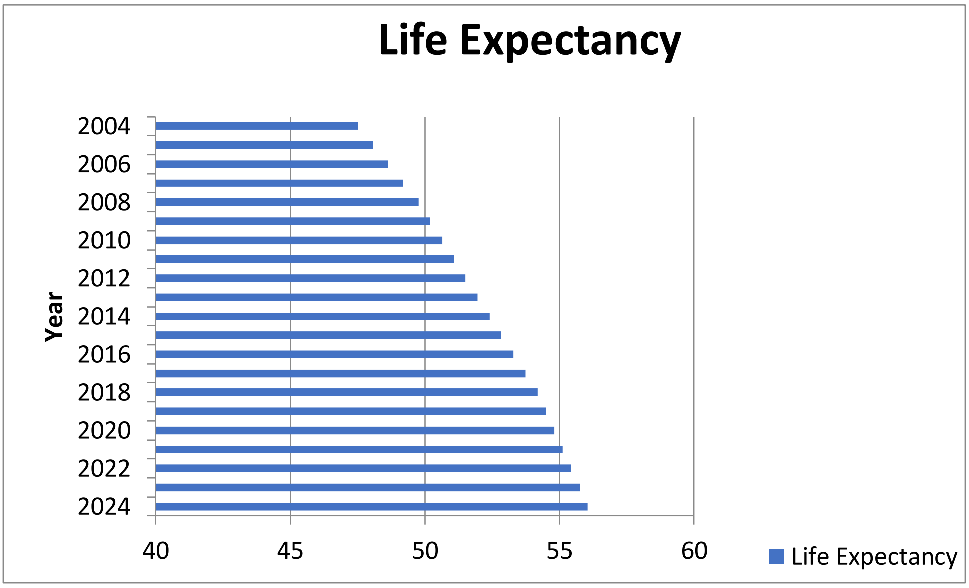


Figure 1: Life expectancy Rate in Nigeria

Source: World Bank (2021)

Empirical papers related to the theme of the study in developed, developing countries and Nigeria were reviewed to affirmed the gaps filled in the work which includes but not limited to the following:

Chen et al. (2013) used cross sectional data for China and found that industrialization and economic development increased perceived environmental hazards (which were measured using perceived air pollution, perceived water pollution and perceived industrial waste). Employing an ordered logistic regression and ordinary least-squares estimators, they also found that migration from rural to urban areas increased exposure to water pollution and greater environmental hazards in China. Perceived environmental risk factors had negative effects on the physical and mental health of individuals residing in urban areas with a greater negative effect obtained for those who migrated from rural to reside in urban areas.

Balan (2016) employs the panel least squares technique and reveals that while a bidirectional relationship exists between health outcome (life expectancy) and CO_2 emissions sourced from natural gas and petroleum in 25 EU countries, there is no significant causality relationship from coal-sourced CO2 emissions to life expectancy at birth. He adduced this outcome to significant and large decreases in the consumption of coal in 28 EU countries since the beginning of the 1990s. The substitutability of fossil fuels with renewable energy sources such as hydropower, solar energy, wind power and biofuels is being witnessed in these countries (Balan, 2016; Eurostat, 2015).

Lu et.al (2017) assessed the dynamic relationship between environmental quality, economic development and public health in China from 2002 to 2014. To control for potential endogeneity, a carefully designed simultaneous equation model (SEM) which comprises three equations that describe the relationships among economic development, environmental quality and public health was used. The result verified the negative effect of environmental pollution on public health. The study also noted that economic and social factors may also affect public health as real GDP per capita has a significant negative impact on perinatal mortality rates and education while medical conditions also contributed significantly to promoting economic growth.

Oyedele and Tella (2023) investigated the effect of environmental quality on health outcomes with specific consideration for forests for 16 selected sub-Saharan African countries from 2002 to 2016. The study employed panel estimation methods for robustness and also conducting a sensitivity analysis. The results showed that forest expansion initially seemed to worsen health outcomes; however, after a turning point, it ultimately improved health outcomes as shown by its reduction effect on under-five mortality and its increasing effect on life expectancy at birth. The study concludes that policies towards improving population health should consider forest expansion and conservation reforms.

Cleopatra and Osinubi (2020) investigates the relationship among environmental quality, economic growth and health expenditure in 47 African countries using both static (pooled OLS and fixed/random effect) and dynamic (system GMM) estimation methods. Data covering the period 2000 to 2018 are employed and three proxies (carbon dioxide, nitrous oxide and methane emission) are used to capture the effect of environmental quality. The findings of the study indicate evidence of a positive and significant effect of economic growth on health expenditure, while also revealing a positively significant relationship between poor environmental quality and health expenditure. The study concludes that health is a necessity good and a deterioration of the environmental quality increases health expenditure.

In another study, Yazdi and Khanalizadeh (2017) studied the Middle East and North Africa region states to determine the effects of economic performance and environmental value on health spending. A co-integration panel was found to exist among all three components. Also, using the ARDL approach, the authors found that income, CO_2 and PM 10 have statistically significant direct impact on health spending. Ibukun and Osunibi (2023) examines the relationship among environmental quality, economic growth and health expenditure in 47 African countries using both static (pooled OLS and fixed/random effect) and dynamic (system GMM) estimation methods. Data covering the period 2000 to 2018 was employed and three proxies (carbon dioxide, nitrous oxide and methane emission) were used to capture the effect of environmental quality. The study found a positive and significant relationship between economic growth and health expenditure.

Centring on an upper-middle-income country, Abdullah et al. (2016) examined the nexus between health expenditure and environmental quality in Malaysia using carbon dioxide, sulphur dioxide and nitrogen dioxide as proxies for environmental quality. Findings from the Auto Regressive Distributed Lag (ARDL) approach indicated that there is co-integration between the three measures of environmental quality and health expenditure which suggests that environmental quality affects health expenditure in both the long and short-run. Abid (2017) established a monotonically increasing link between carbon emissions and economic growth in the Middle East, Africa, and the European Union countries between 1990 and 2011.Al-mulali et al. (2013) focused on urbanization, energy consumption, and CO_2emissions in the Middle East and North African (MENA) countries. Their study established long-run bidirectional positive relationships between the variables investigated.

Nasreen (2021) examines the association between health expenditure; economic growth (EG) and environmental pollution in Asia between 1995 and 2017 using the effects mean group and heterogeneous panel causality test. The results provide evidence in support of a long run association between selected variables. The study found that EG and environmental pollution are positively associated with total health expenditures as well as with public and PRHEs in all countries. However, the magnitude of environmental pollution coefficient is greater from EG coefficient. Causality results demonstrate the existence of two-way causality between health expenditures and EG and unidirectional causality flowing from environmental pollution to health expenditures in Asian economies

Mesegan and Nwachuckwu (2018) analyzed the determinants of environmental quality on financial development in Nigeria from 1981-2016 using ARDL bound approach. The result showed that income, financial development, energy consumption and trade affect environmental quality while energy consumption and environmental degradation are related to each other with causality running from either direction.

Owolabi, Aderounmu and Ogunbiyi (2019) explored the effect of environment quality on poverty reduction in Nigeria using data from the World Bank World Development indicators over the period of 1990 to 2015. The study employed Augmented Dickey Fuller unit root test, and Autoregressive Distributed Lag (ARDL) estimation in analyzing data and the findings of the study revealed that improved environment quality as measured by improved access to sanitation and access to electricity positively and significantly increase poverty level in Nigeria, possibly on account of the increased financial and social costs of gaining access to sanitation and electricity.

Chucks (2020) investigated the effects of environmental quality on human health status in Nigeria using the Ordinary Least Square estimation techniques. The findings indicate the existence of a long-run relationship between health as measured by life expectancy and the explanatory variables included. The outcome also demonstrates that CO_2 emissions, an indicator for environmental quality significantly reduce life expectancy. It was also revealed that income and the linear combination of access to improved water source and access to improve sanitary facility significantly improves life expectancy. The study noted that it is important for the Nigerian government to strengthen environmental regulations meant to improve people's access to a better health status.

In a related study, Chuku (2011) employed standard- and nested-EKC models to investigate the income-environment relation for Nigeria, between 1960 and 2008. The results from the standard-EKC model provides weak evidence of an inverted-U shaped relationship with turning point (T.P) around $280.84, while the nested model presents strong evidence of an N-shaped relationship between income and emissions in Nigeria. The result also showed that economic development is compatible with environmental improvements in Nigeria.

Afolayan and Aderemi (2019) empirically examine the relationship between environmental quality (proxied by carbon dioxide, CO_2) and health effects; and its implications for achieving sustainable economic development in Nigeria. The period in focus is 1980 to 2016, and the techniques of estimation employed to address the objective of the study are Dynamic Ordinary Least Square (DOLS) and Granger causality. It was found that CO_2 emissions and mortality rate are negatively but insignificantly related. It was also revealed that, government health expenditure and mortality rate are significantly and positively related, implying inadequacy of public health expenditure to promote good health. The study recommended that government should formulate appropriate policies that will reduce the mortality rate through a reduction in the combustion of fossil fuel and CO_2 emissions, increase government health expenditure and ensure adequate electric power consumption.

Ibikunle (2020) examined the impact of environmental pollution on life expectancy in Nigeria from 1990 to 2019 using multiple regression and Johansen co-integration techniques. The variables used are life expectancy, CO_2 emissions from manufacturing, CO_2 emissions from other sectors, $PM_{2.5}$ air pollution, adult literacy, fertility and per capita income. The finding shows that the impact of environmental pollution on life expectancy was negative and significant. It was also revealed that longer life expectancy could be achieved significantly by a reduction in the ambient $PM_{2.5}$ concentrations, increasing per capita income and provision of effective adult education. The study recommends the transformation of low-carbon technologies aimed at reducing emissions so as to sustain economic growth.

Iyakwari, Awujola and Ogwuche (2023) examined the effect of health expenditure on life expectancy in Nigeria between 1990 to 2021 using the Autoregressive Distributed Lag and error correction (ARDL and ECM) models. The study found a negative relationship between health capital expenditure, health recurrent expenditure in the long run, while out-of-pocket health expenditure had a positive relationship with life expectancy. The study recommends that the Nigerian government should take action to address the negative correlation between health capital expenditure and life expectancy by allocating sufficient funding to the health sector as well as implementing policies such as tax incentives and subsidies to encourage citizens to invest more in their healthcare and reduce out-of-pocket expenses for essential healthcare service.

Theoretical Underpinning

This study considered three theories for this work which include health belief model (HBM), Grossman theory of 1972 and Schumpeter's theory of development. These theories are discussed thus:

The first is the Health Belief Model (HBM) is a psychological framework used to understand and predict health-related behaviors. It suggests that individuals are more likely to adopt preventative health behaviors if they perceive a threat to their health, believe that a specific action will reduce that threat, and feel confident in their ability to take that action. The Health Belief Model (HBM) was primarily developed by Irwin M. Rosenstock, Godfrey M. Hochbaum, S. Stephen Kegeles, and Howard Leventhal. These social psychologists, working in the

US Public Health Service in the 1950s, developed the model to understand why people weren't participating in disease prevention and screening programs, such as tuberculosis screening. Later uses of HBM were for patients' responses to symptoms and compliance with medical treatments. The HBM suggests that a person's belief in a personal threat of an illness or disease together with a person's belief in the effectiveness of the recommended health behavior or action will predict the likelihood the person will adopt the behavior. The HBM derives from psychological and behavioral theory with the foundation that the two components of health-related behavior are 1) the desire to avoid illness, or conversely get well if already ill; and, 2) the belief that a specific health action will prevent, or cure, illness. Ultimately, an individual's course of action often depends on the person's perceptions of the benefits and barriers related to health behavior. There are six constructs of the HBM. The first four constructs were developed as the original tenets of the HBM. The last two were added as research about the HBM evolved.

Secondly, Grossman Theory: the first approach based on the Grossman (1972) health capital model assumes that an individual is born with a stock of health that diminishes over time, but can be replenished through acts of health investment. The available health stock of the person produces a stream of healthy time payoffs that determines the individual’s market (investment) and non-market (consumption) participation in the economy. When this health stock deteriorates below a certain point, death occurs. In this model, individuals use medical care and their own time to produce “good health.” Thus, the health of the individual after birth depends on the investment, he/she makes which depends on the amount of time the individual spends producing health and the amount of medical inputs purchased (both preventive and curative) in improving his/her health status. Grossman (1972) presents this investment in health care by an individual as a utility maximizing problem where the individual maximizes his/her utility subject to the constraints of budget and time. This is done in an inter-temporal framework, where the individual maximizes his/her lifetime utility. The utility function of the individual is made up of the consumption of health (Ht) and other goods (Zt). In maximizing the utility, Grossman makes a distinction between the demand for health and the demand for health care. The demand for health is necessary for the individual to carry out his/her day to day activities.

While the third theory is Schumpeter’s theory, which also known as innovation theory of development. This theory assigns paramount role to the entrepreneur and innovations in the process of economic development. According to Schumpeter, the process of production is marked by a combination of material and immaterial productive forces. The material productive forces arise from the traditional factors of production, viz., land and labour and among others, while the immaterial set of productive forces are conditioned by the ‘technical facts’ and ‘facts of social organization’. Schumpeter argued that the rate of growth of the output depends upon the rate of growth of productive factors, the rate of growth of technology and the rate of growth of investment friendly socio-cultural environment. Schumpeter held that the alterations in the supply of productive factors can only bring about gradual, continuous and slow evolution of the economic system. On the other hand, the impact of technological and social change calls for spontaneous, discontinuous change in the channels of output flow. Schumpeter regarded land to be constant. The growth component will, therefore, include only the effects of changes in population and of increase in the producer goods. But Schumpeter further maintains that there does not exist any a priori relationship between the changes in population and the changes in the flow of goods and services. In other words, Schumpeter considers the population growth to be exogenously determined. The increase in producer goods results from a positive rate of net savings. The major part of savings and accumulations are attributed by Schumpeter to profits. According to him, the profits can arise if innovations are introduced. Hence ultimately it is the change in the technical knowledge which is responsible for any change in the stock of producer goods, i.e., the rate of capital accumulation directly depends on the rate of technical change. In other words, according to Schumpeter, the growth of output is geared by the rate of innovations.

3. METHODOLOGY

Following the theoretical framework of the Grossmann (1972) model to develop a theoretical human capital model which can be used to conceptualize the structure of a health production function. Thereafter, the study adopts the model of Afolayan and Aderemi (2019) for economic development model which is implicitly stated thus:

$$MOT = f(CO_2, GHE, ELCON, LEC) \qquad (1)$$

Where: MOT = under five mortality rates (proxy for development); CO2 = Carbon Dioxide emission; GHE = Government Health expenditure; ELCON = Electricity Consumption; and LEX = Life Expectancy. Equation (1) was further modified by considering importance attached to human development and per capita income in the development process. Thus, the model employed gross domestic product per capita as proxy for economic development.

$$EDEV(GDPPC) = f(CO2, LER, EXR, INF) \quad (2)$$

Where: EDEV = Economic development proxy by gross domestic per capita (GDPPC)
CO_2 = Carbon Dioxide emission, LER = Life expectancy rate, EXR = Exchange rate, INF= Inflation rate.
The interaction among gross domestic product per capita, health outcomes and economic development is represented by these endogenous variables**:** VAR specification is given explicitly as:

$$GDPPC_t = \mu_0 + \mu_{11}GDPPC_{t-1} + \mu_{12}CO_{2t-1} + \mu_{13}LER_{t-1} + \mu_{14}EXR_{t-1} + \mu_{15}INF_{t-1} + \upsilon_1 .....(3)$$

$$CO_{2t} = \delta_0 + \delta_{21}CO_{2t-1} + \delta_{22}GDPPC_{t-1} + \delta_{23}LER_{t-1} + \delta_{24}EXR_{t-1} + \delta_{25}INF_{t-1} + \omega_2 ....(4)$$

$$LER_t = \varphi_0 + \varphi_{31}LER_{t-1} + \varphi_{32}CO_{2t-1} + \varphi_{33}GDPPC_{t-1} + \varphi_{34}EXR_{t-1} + \varphi_{35}INF_{t-1} + \psi_3 ....(5)$$

$$EXR_t = \alpha_0 + \alpha_{41}EXR_{t-1} + \alpha_{42}CO_{2t-1} + \alpha_{43}LER_{t-1} + \alpha_{44}GDPPC_{t-1} + \alpha_{44}INF_{t-1} + \xi_4 ....(6)$$

$$INF_t = \theta_0 + \theta_{51}INF_{t-1} + \theta_{52}CO_{2t-1} + \theta_{53}LER_{t-1} + \theta_{54}EXR_{t-1} + \theta_{55}GDPPC_{t-1} + \gamma_5 ....(7)$$

Sources of Data

The study uses time series data covering the period between 1980 and 2024. The data were obtained from various issues of the Central Bank of Nigeria Statistical Bulletin (various issues) as well as World Bank Development Indicator (2024)

Estimation Technique

Unit Root Test

The estimation commences with an extensive unit root test to confirm the stationary structure of the variables that entered the models. The study used both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root approaches. These two tests of unit root are adopted in order to guarantee that our inferences regarding the important issue of integrating orders in the model is not likely driven by the choice of the testing procedure used.

The testing procedure for the ADF test is as follows:

$$\Delta X_t = \lambda_0 + \beta t + \gamma X_{t-1} + \delta_1 \Delta X_{t-1} + ... + \delta_p \Delta X_{t-p} + \mu_t \quad (8)$$

Where: X = variables under investigation; λ_0 = an intercept (showing the presence or absence of drift), βt = the coefficient on a time trend; t = the deterministic time trend; p = the lag order of the autoregressive process, and Δ = the difference operator.

The unit root test is then carried out under the null hypothesis γ = 0 against the alternative hypothesis of γ < 0. Next is to compare the computed value of the test statistic with the relevant critical values for the test. For instance, if the computed test statistic is greater (in absolute value) than the critical values at 10%, 5% and 1% level of significance, then the null hypothesis of γ = 0 is rejected and thus no unit root is present, otherwise, unit root is accepted. The test for unit root is first conducted in level, however, if the variable is not stationary in level; we then difference it and test for the stationary of the differenced variable. Supposing the variable is stationary in first difference, we conclude that that particular variable is integrated of order one (Δ = 1), otherwise it is integrated of higher order (Δ > 1).

The VAR Model

To investigate the response of economic development to asymmetric and innovations in environmental quality and health outcomes, an unrestricted Vector Autoregressive model (VAR) is adopted. The VAR model provides a multivariate framework where changes in a particular variable are related to changes in its own lags and to changes in other variables and the lags of those variables. The unrestricted VAR model of order p is presented in equation (9) below:

$$y_t = A_1 y_t + ... + A_P y_t - P + Bz_t + £_t. \quad (9)$$

Where yt is a vector of endogenous variables, zt is a vector of exogenous variables, A and B are coefficient matrices and p is the lag length. The innovation process $£_t$ is an unobservable zero-mean white noise process with a time invariant positive-definitive variance -covariance matrix. The VAR system can be transformed into its moving average representation in order to analyze the system's response to economic development shock. In the restricted VAR models, the vector of endogenous variables, according to Cholesky ordering are per capita income, air pollution, life expectancy ratio, exchange rate and inflation rate.

The innovations of current and past one-step ahead forecast errors are orthogonalised using Cholesky decomposition so that the resulting covariance matrix is diagonal. This assumes that the first variable in a pre-specified ordering has an immediate impact on all variables in the system, excluding the first variable and so on. A VAR is a linear equation model in which each variable is in turn explained by its own lagged values, plus current and past values of the remaining variables. The VAR model presents all variables as dependent which have the dynamic power to reflect the impact of random disturbances on the variables, thereby modelling every endogenous variable in the system as a function of the lagged values of all the endogenous variables in the system. Thus, the unrestricted VAR can be presented as:

$$\alpha_t = \sum_{i=1}^{k} Ai\alpha_{t\,i} + \varepsilon_t \qquad (10)$$

Where α_t = is column vector of observations at time 't' on all the variables in the model, i.e.
The matrix form of the VAR model used in this study is given as:

$$\begin{bmatrix} GDPPC_t \\ CO2_t \\ LER_t \\ EXR_t \\ INF_{t\,t} \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_{13} \\ \lambda_{14} \\ \lambda_{51} \end{bmatrix} + \sum_{j=1}^{K} \begin{bmatrix} \alpha_{11}\alpha_{12}\alpha_{13}\alpha_{14}\alpha_{15} \\ \alpha_{21}\alpha_{22}\alpha_{23}\alpha_{24}\alpha_{25} \\ \alpha_{31}\alpha_{32}\alpha_{33}\alpha_{34}\alpha_{35} \\ \alpha_{41}\alpha_{42}\alpha_{43}\alpha_{44}\alpha_{45} \\ \alpha_{51}\alpha_{52}\alpha_{53}\alpha_{54}\alpha_{55} \end{bmatrix} \begin{bmatrix} GDPPC_{t-1} \\ CO2_{t-1} \\ LER_{t-1} \\ EXR_{t-1} \\ INF_{t-1} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} \qquad (11)$$

4. RESULT AND DISCUSSIONS

Table 4.1: Descriptive Statistics

	GDPPC	CO_2	EXR	INF	LER
Mean	271244.8	10.87060	125.2784	18.91714	48.80244
Median	250500.9	11.34798	111.2313	12.87658	47.61900
Maximum	379251.6	15.55317	907.1100	72.83550	61.79010
Minimum	199311.3	4.249597	0.561234	5.388008	45.48700
Std. Dev.	65247.81	2.777919	165.5647	16.33763	3.356560
Skewness	0.341489	-0.725341	2.734509	1.874180	1.445646
Kurtosis	1.463976	2.829330	12.80083	5.474882	2.077791
Jarque-Bera	5.062945	3.822715	225.6897	3.614732	3.194965
Probability	0.079542	0.147879	0.000000	0.330048	0.142700
Sum	11663528	467.4359	5386.972	813.4372	2098.505
Sum Sq. Dev.	1.79E+11	324.1070	1151290.	11210.56	473.1929
Observations	43	43	43	43	43

Source: Researcher's Computation (2025)

Table 4.1 presents the descriptive statistics for the selected variables in the study. The mean values show that Gross Domestic Product per Capita (GDPPC) recorded the highest average value of 271,244.8, while the lowest average value came from carbon dioxide emissions (CO_2), which stood at 10.87. This implies that, on average, GDP per capita was the most dominant figure among the variables examined, reflecting its overall magnitude in economic analysis, while CO_2 had the smallest average, being measured in emissions per capita or per unit.

The skewness statistics indicate that some of the variables are positively skewed (skewed to the right), while others are negatively skewed (skewed to the left). The positively skewed variables include GDPPC (0.34), exchange rate (2.73), inflation rate (1.87), and life expectancy rate (1.45). These values suggest that the distributions of these variables have long right tails, indicating the presence of a few high values that raise the mean. On the other hand, carbon dioxide emissions are negatively skewed at -0.73, implying a distribution that is tilted to the left, with more observations clustered on the higher side of the scale.

The standard deviation for GDP per capita is 65,247.81, which is the highest among the variables, indicating substantial variability over the study period. This is followed by the exchange rate, which has a standard deviation of 165.56, suggesting considerable fluctuations. The higher levels of dispersion in these two variables may be attributed to Nigeria's exposure to external shocks, fluctuating oil prices, and policy instability. Other variables such as inflation (16.34), life expectancy (3.36), and CO_2 (2.78) exhibit relatively lower levels of dispersion, indicating more stability in their observed values.

Further analysis of the maximum and minimum values reveals the range of values over the study period. For example, GDP per capita ranges from 199,311.3 to 379,251.6, while the exchange rate ranges widely from 0.56 to 907.11, reflecting periods of high currency devaluation. Inflation varies from 5.39 to 72.84, life expectancy from 45.49 to 61.79, and CO_2 emissions from 4.25 to 15.55. These ranges underscore the fluctuations observed across different macroeconomic indicators. The kurtosis results show that GDP per capita (1.46), CO_2 (2.83), and life expectancy rate (2.08) are platykurtic, indicating distributions that are flatter than the normal distribution with lighter tails. In contrast, exchange rate (12.80) and inflation (5.47) are leptokurtic, suggesting distributions with heavier tails and a higher likelihood of extreme values. The Jarque-Bera statistics indicate that most of the data series are normally distributed. This is implying just the probability value of Jarque Bera statistics which for most series were significantly different from zero at 5 percent significant level.

Stationarity Test of the Variables

Table 4.2 Augmented Dickey Fuller Unit Root Test

Variable	ADF Test Statistic @ Level	ADF @ First Difference	5% Critical Value	Order of Integration	Remark
GDPPC	-0.7525	-4.7821	-2.9332	I(1)	Stationary
CO_2	-2.8861	-7.2867	-2.9314	I(1)	Stationary
EXR	—	-4.7785	-3.5298	I(1)	Stationary
INF	-2.6054	-3.0670	-2.9434	I(1)	Stationary
LER	2.1166	-3.1306	-2.9350	I(1)	Stationary

Source: Researcher's Computation (2025)

The result in the Table 4.2 indicates that all the variables were non-stationary at statistics level but became stationary at first difference. Specifically, GDP per capita, carbon dioxide emissions, exchange rate, inflation rate, and life expectancy rate all attained stationarity after first differencing. None of the variables were stationary at level, and none required second differencing to achieve stationarity. The implication of this result is that the variables are integrated of order one, I(1), and this supports the existence of a possible long-run equilibrium relationship among the variables, making them suitable for cointegration analysis.

Lag length Criteria for Model 1

Following the confirmation of stationarity in the data series employed, the study proceeded to check for suitable lags used for the model based on different criteria.

Table 4.3 Lag Length Criteria for Model 1

VAR Lag Order Selection Criteria
Endogenous variables: GDPPC CO_2 EXR INF

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-928.3636	NA	2.41e+16	49.07177	49.24415	49.13310
1	-790.1200	240.1073*	3.89e+13*	42.63790*	43.49978*	42.94455*
2	-779.1067	16.80990	5.22e+13	42.90035	44.45175	43.45233
3	-767.1405	15.74489	6.98e+13	43.11266	45.35357	43.90996

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Researcher's Computation (2025)

The optimum lag length for the model result was shown in Table 4.3. It indicates that the majority of the criteria including the LR, FPE and AIC criteria selected an optimal lag of 1 for the study.

Vector Autoregressive Estimates

Table 4.13: Vector Autoregressive Estimates

Vector Autoregression Estimates					
Date: 07/07/25 Time: 09:57					
Sample (adjusted): 1982 2020					
Included observations: 39 after adjustments					
Standard errors in ( ) & t-statistics in [ ]					
	LOG(GDPPC)	**CO_2**	**LER**	**EXR**	**INF**
LOG(GDPPC(-1))	1.024304	-1.029053	0.754033	-16.73367	98.87281
	[5.76720]	[-0.08370]	[0.86132]	[-0.16229]	[1.50288]
LOG(GDPPC(-2))	-0.375810	-5.523144	0.036384	25.17833	-38.67939
	[-2.85693]	[-2.89818]	[2.02133]	[0.32971]	[-0.79382]
CO_2 (-1)	-0.004523	0.519071	-0.033542	0.350533	0.038409
	[-1.66252]	[2.75662]	[-2.50154]	[0.22196]	[0.03812]
CO_2 (-2)	-0.000712	-0.171695	-0.005046	-1.447081	-0.305423
	[-3.39047]	[-0.79797]	[-0.32937]	[-0.80191]	[-0.26526]
LER(-1)	0.057464	-3.588315	1.211409	-24.98190	-34.72453
	[2.17173]	[-2.35478]	[6.74058]	[-1.18023]	[-2.57109]
LER(-2)	-0.013135	3.210352	-0.349920	23.67452	23.13191
	[-0.36410]	[1.28562]	[-1.96788]	[1.13044]	[1.73107]
EXR(-1)	-0.000214	-0.003879	0.001658	1.260822	0.103047
	[-0.62933]	[-0.16480]	[0.98922]	[6.38644]	[0.81805]
EXR(-2)	-0.000136	0.010630	0.000619	-0.178582	0.041274
	[-0.35779]	[0.40434]	[0.33074]	[-0.80993]	[0.29338]
INF(-1)	0.000565	0.017588	-0.001187	-0.043526	0.672700
	[1.32073]	[0.59368]	[-0.56280]	[-0.17518]	[4.24328]
INF(-2)	3.23E-05	-0.019332	-0.003493	-0.229286	-0.479663
	[0.07425]	[-0.64223]	[-1.62981]	[-0.90823]	[-2.97779]
C	2.301820	-30.82297	-1.856348	-21.16267	-181.3695
	[3.05568]	[-0.59112]	[-0.49996]	[-0.04839]	[-0.65000]
R-squared	0.985606	0.659095	0.997134	0.972621	0.612753
Adj. R-squared	0.980465	0.565914	0.996111	0.962843	0.474450
F-statistic	191.7257	2.376507	974.2776	99.46740	4.430523

Source: Researcher's Computation (2025)

Table 4.13 presents the vector auto-regression (VAR) estimates examining short-run relationships among GDP per capita, CO_2emissions, life expectancy rate (LER), exchange rate (EXR), and inflation (INF) for the period 1982–2020. The results indicate that GDP per capita exhibits strong short-run persistence. A percentage increase in its one-period lag leads to a 1.024 percent rise in current GDP per capita, showing a strong direct relationship. However, a percent increase in the two-period lagged GDP per capita reduces current GDP per capita by 0.376 percent, suggesting an inverse relationship, possibly due to short-term adjustment effects.

CO_2 emissions at the two-period lag negatively affect GDP per capita, where a percent increase in emissions reduces GDP per capita by 0.001 percent. This inverse relationship may indicate that environmental degradation undermines economic performance. Life expectancy from the previous period exerts a positive influence on GDP per capita; a percent increase in life expectancy raises GDP per capita by 0.057 percent, highlighting a direct relationship between improved health and economic output. CO_2 emissions are also influenced by their own past values. A percent increase in the one-period lag of emissions results in a 0.519 percent rise in current emissions, indicating a direct and persistent relationship. However, there is an inverse relationship between the two-period lagged GDP per capita and current CO_2 emissions, as a percent increase in the former reduces emissions by 5.523 percent. Additionally, a percent increase in life expectancy at the one-period lag reduces emissions by 3.588 percent, showing that better health outcomes can contribute to environmental improvements. Furthermore, life expectancy is strongly persistent. A percent increase in its one-period lag raises current life expectancy by 1.21 percent, showing a direct relationship. Moreover, a percent increase in the one-period lagged GDP per capita increases life expectancy by 0.754 percent. However, a percent increase in CO_2 emissions at the one-period lag reduces life expectancy by 0.034 percent, indicating an inverse relationship between pollution and health.

The exchange rate shows significant short-run persistence. A percent increase in its one-period lag results in a 1.261 percent increase in the current exchange rate, suggesting a direct relationship. However, the influence of GDP per capita, CO_2 emissions and life expectancy on the exchange rate is negligible in the short run.

Inflation is primarily influenced by its own past values. A percent increase in the one-period lagged inflation raises current inflation by 0.673 percent, showing a direct relationship. In contrast, a percent increase in the two-period lagged inflation decreases current inflation by 0.480 percent, reflecting a stabilizing correction. Additionally, inflation responds inversely to improvements in GDP per capita and life expectancy. Specifically, a percent increase in the two-period lagged GDP per capita lowers inflation by 38.679 percent, and a percent increase in life expectancy at the one-period lag reduces inflation by 34.725 percent.

Finally, it can be deduced from the VAR results that GDP per capita, emissions, health, inflation, and exchange rates are dynamically interlinked. While the result showed that there are direct relationships between GDP and its past values, life expectancy and GDP, and inflation and its own lags, there was an inverse relationship between CO_2 emissions and both economic and health outcomes, as well as between prior inflation and current inflation levels.

Forecast Error Variance Decomposition

Table 4.14: The Variance Decomposition

Variance Decomposition of LOG (GDPPC)						
Period	**S.E.**	**LOG(GDPPC)**	**CO2**	**LER**	**EXR**	**INF**
1	0.033440	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.051418	90.08046	5.309376	1.982842	0.981811	1.645514
3	0.066241	73.64337	13.56685	6.655611	2.884479	3.249698
4	0.079295	59.85847	20.73292	13.03145	3.674009	2.703149
5	0.091781	48.44736	25.57164	20.52937	3.317453	2.134173
6	0.104567	38.84459	28.37228	27.68128	2.624768	2.477083
7	0.117301	31.44451	30.16618	33.13235	2.107830	3.149142
8	0.129422	26.05853	31.57981	36.56594	2.003220	3.792506
9	0.140706	22.13492	32.71364	38.36089	2.435446	4.355101
10	0.151146	19.20442	33.52236	39.02564	3.424984	4.822598

Source: Researcher's Computation (2025)

In the first period, the variance decomposition shows that Gross Domestic Product per capita accounts for 100 percent of its own forecast error variance, with no influence from any of the other variables such as CO_2, LER, EXR, or INF. This indicates that GDP per capita is entirely self-determined in the immediate short run, with external shocks having no immediate effect.

By the second period, the influence of other variables begins to emerge. While LOG(GDPPC) still contributes the majority share at 90.08 percent, CO_2 emissions contribute 5.31 percent, LER accounts for 1.98 percent, EXR (0.98 percent), and INF (1.65 percent). Although modest, these contributions suggest that environmental, health and macroeconomic factors start influencing GDP per capita over time.

In the third period, LOG(GDPPC)'s share drops more significantly to 73.64 percent, while CO2 rises to 13.57 percent, LER to 6.66 percent, and EXR to 2.88 percent. INF increases to 3.25 percent. This indicates growing external influence, particularly from CO_2 emissions, suggesting a stronger linkage between environmental factors and economic productivity.

By the fourth period, the share of LOG(GDPPC) declines further to 59.86 percent, while CO_2 rises sharply to 20.73 percent, and LER to 13.03 percent. EXR and INF contribute 3.67 percent and 2.70 percent, respectively. This shows a gradual shift where environmental and health indicators are becoming more prominent in shaping economic performance.

In the fifth period, the share of GDP per capita drops to 48.45 percent, with CO_2 contributing 25.57 percent and LER rising to 20.53 percent with both surpass 20 percent influence. The share of EXR falls slightly to 3.32 percent, and INF decreases to 2.13 percent. This marks a structural shift where CO_2 and LER are becoming dominant factors driving economic outcomes.

By the sixth period, the contribution of LOG(GDPPC) falls below 40 percent, at 38.84 percent. At the same time, CO_2 rises to 28.37 percent and LER to 27.68 percent, nearly equal in influence. The decreasing role of GDP per capita's own dynamics reflects increasing dependence on environmental and health variable. EXR and INF remain low, at 2.62 percent and 2.48 percent, respectively.

In the seventh period, LER overtakes all other variables, becoming the most influential determinant at 33.13 percent, followed closely by CO_2 at 30.17 percent, while LOG(GDPPC) declines to 31.44 percent. EXR and INF continue to play minor roles. This trend shows the dominant roles of life expectancy and environmental quality in driving GDP per capita.

By the eighth period, LER rises further to 36.57 percent, establishing itself as the leading driver of GDP per capita, while CO_2 increases to 31.58 percent. The share of LOG(GDPPC) decreases to 26.06 percent, further reinforcing the reduced impact of its own historical behaviour. INF rises slightly to 3.79 percent, and EXR maintains a marginal influence at 2.00 percent.

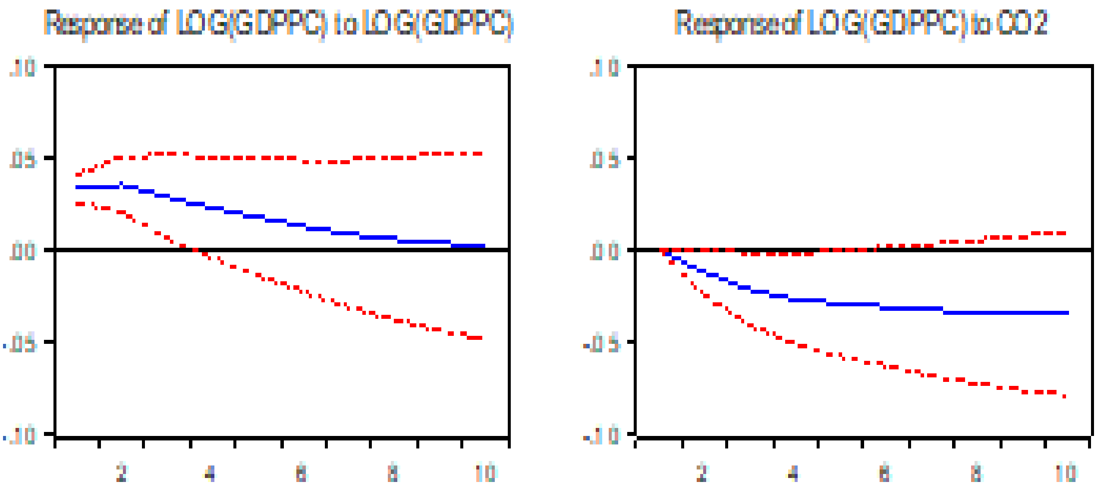
In the ninth period, the trend continues, with LER contributing 38.36 percent, CO_2 at 32.71 percent, and LOG(GDPPC) at 22.13 percent. INF increases gradually to 4.36 percent, and EXR to 2.44 percent, suggesting that inflation's role is slowly growing, while the exchange rate remains comparatively subdued in its effect.

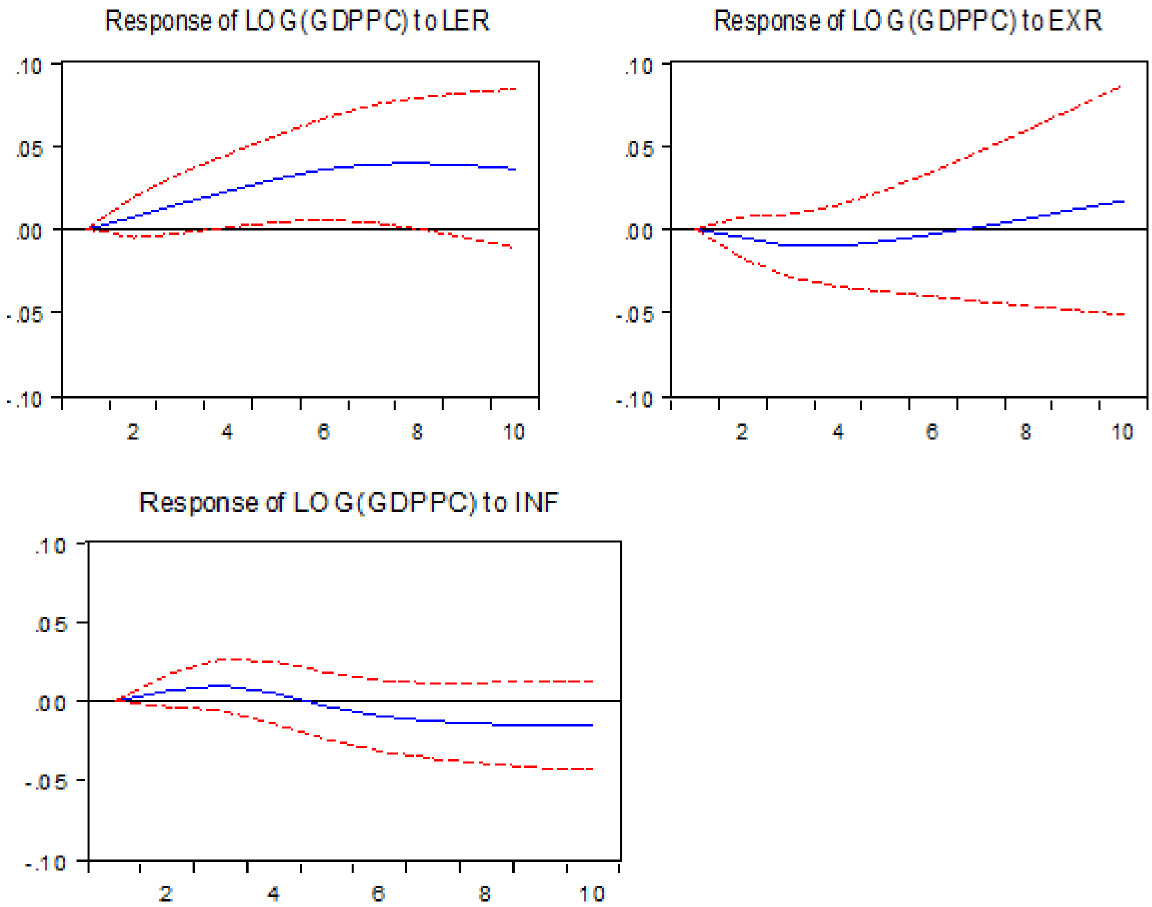
Finally, in the tenth period, LOG(GDPPC) contributes just 19.20 percent, having lost its position as the dominant driver. LER accounts for 39.03 percent, remaining the most significant factor, followed by CO_2 at 33.52 percent. INF rises further to 4.82 percent, and EXR increases to 3.42 percent. This confirms a long-run structural transformation where life expectancy rate (LER) and environmental quality (CO_2) become the primary forces shaping economic development, while macro variables like inflation and exchange rate play supporting roles.

Impulse Response Function

An impulse response function (IRF) traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. However, IRF charts for the VAR model are presented in figure below.

Figure 4.1: Impulse Response Function





Accumulative dynamic effects of structural shocks on LOG(GDPPC) are summarized in Figure 2 above. As expected, past values of GDP per capita exhibit a positive but gradually declining influence on current GDP per capita over the ten-period forecast horizon. The self-reinforcing impact is strongest in the first period but diminishes progressively, reflecting a stable and mean-reverting pattern in economic growth. The shock in CO_2 emissions has no immediate effect on GDP per capita. However, from the second period onward, the influence turns negative and becomes more pronounced with time. This suggests that rising carbon emissions gradually exert a harmful impact on economic development, through environmental degradation and its impact on productivity and human well-being.

Similarly, life expectancy (LER) shocks have no instantaneous effect on GDP per capita. However, by the second period, GDP per capita rises slightly to 0.0072, indicating the early signs of health improvements beginning to translate into economic gains. This positive trajectory continues, with life expectancy contributing more significantly in subsequent periods. By the third period, GDP per capita reaches one of its higher levels, despite the mounting negative effects from CO_2 emissions, exchange rate volatility, and inflationary pressures. Inflation's influence during this phase remains relatively minor but negative.

From the fourth period onward, the growth trajectory of GDP per capita begins to moderate. While improvements in life expectancy continue to provide a positive contribution to economic growth, the compounding negative effects of increasing CO_2 emissions, exchange rate depreciation, and inflation begin to erode these gains. Notably, the environmental burden posed by CO_2 emissions intensifies over time, emerging as a spersistent constraint on growth.

By the seventh period, the positive momentum in GDP per capita has nearly flattened, with life expectancy reaching its peak influence. However, the economic drag from rising emissions and inflation becomes more significant. The exchange rate, while still exerting a negative effect, does so less severely than the other variables but remains a concern.

In the final two periods, although GDP per capita remains positive, its growth rate continues to decline. By the tenth period, the influence of CO_2 emissions reaches its peak negative value, underscoring the long-term environmental risks to economic sustainability. Life expectancy, though still contributing positively, appears to stabilize and is no longer sufficient to counterbalance the mounting negative effects of inflation and exchange rate pressures. Interestingly, the exchange rate shows signs of a slight positive recovery by the end of the forecast horizon, but this is insufficient to reverse the overall downward trend. Inflation, in contrast, becomes increasingly harmful to economic performance. It is instructive to note that while rising life expectancy has consistently supported improvements in GDP per capita, these gains are ultimately diminished by the long-run adverse effects of rising CO_2 emissions, inflation, and exchange rate volatility.

5. CONCLUDING REMARKS AND RECOMMENDATIONS

The study concludes based on the findings of the study that gross domestic product per capita was influenced by dynamic variables like its lagged values, carbon dioxide emission; exchange rate; inflation rate and life expectancy rate. However, economic development can be enhanced and sustained in Nigeria at the expense of appreciable levels of environmental quality and life expectancy of the people. Given the above, the study therefore recommends that government and policymakers should embark on appropriate environmental policy measures such as carbon taxes, subsidies for renewable energy, regulations for energy efficiency standards and amongst others that will reduce consumption of fossil fuel so as to mitigate the negative effect of CO_2 accumulation in the air, which in turn improve health outcomes in Nigeria. Afterwards, economic development can be better appreciated and enhanced greatly in the country at the expense of quality environment and healthy citizenry.

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