

Interplay of Environmental Pollution, Health Status and Economic Productivity in Adamawa State, Nigeria

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ABSTRACT

This study analyzed the linkage between environmental pollution, health status and economic productivity of 440 workers across 55 communities in Adamawa state. Ordered logistic regression technique was employed for analysis. The results indicate an insignificant negative relationship between environmental pollution and worker productivity ($\beta = -0.198$; OR = 0.820; $p = 0.339$), suggesting that higher pollution is associated with lower odds of being in a higher productivity category. In contrast, health status, income, gender and worker category exhibit positive and statistically significant relationships with worker productivity. Improved health status is associated with 29.4% higher odds of being in a higher productivity category (OR = 1.294; $p = 0.048$), while a one-unit increase in income corresponds to 36.5% higher odds (OR = 1.365; $p = 0.001$). Gender is also positively associated with productivity, with the category coded 1 having 56.7% higher odds of being in a higher productivity category relative to the reference category (OR = 1.567; $p = 0.022$). Similarly, workers in the category coded 4 have 28.9% higher odds of being in a higher productivity category (OR = 1.289; $p = 0.012$). The study concludes that environmental pollution, health status and economic productivity are closely interconnected, especially health status and worker productivity with each having important implications for workers' productivity. Based on these findings, the study recommends that institutions and organizations should adopt effective measures to prevent and reduce environmental pollution in the workplace. Such measures should include proper waste management, improved environmental hygiene and the adoption of practices that minimize the generation of pollution. Institutions and organizations should also ensure that workers undergo regular medical check-ups to facilitate early detection and treatment of health conditions that may affect their productivity. In addition, appropriate welfare packages and supportive working conditions should be provided to improve workers' well-being, morale and motivation, thereby contributing to higher levels of economic productivity.

Keywords: Environmental pollution, Health status, Economic productivity, Ordered logistic regression, Adamawa state, Nigeria.

INTRODUCTION

As the world faces increasing problem of environmental pollution and public health crises, it is becoming clearer that health of individuals and their economic prosperity are unavoidably linked to the environment. According to the Office of Disease Prevention and Health Promotion Environmental Quality (2020), a healthy environment includes air, water and land that is safe for human health, supports healthy lifestyles and is free from hazards that can reduce quality of life and create health problems. The physical environment therefore is a necessary habitat for hosting and supporting the continuous survival of ecosystem including human being and its interaction in a safe and healthy space. Therefore, the efficacy and functionality of human being are thus achieved in a healthy environment where all risk factors that can cause problems in human health are eliminated or minimized. Albeit, the environment has been contaminated and harmful substances have been introduced by unwholesome and unregulated economic activities that have made the physical environment a major concern for promoting human health and economic productivity.

In Nigeria, environmental pollution has become a serious problem to every human endeavours as observed by Chinedu et al. (2018). They opined that solid waste management is a major environmental challenge in most Nigerian cities and this has been corroborated by Wolf et al. (2022) where they observed that Nigeria has the worst environmental performance index (EPI) in the world. Similarly, the Clean Up Nigeria report (CUN,

2021) indicates that Cleanliness Performance Index rating shows over 172.7 million Nigerians living in unclean environment in 2021, compared to 170 million in 2020. In the year preceding 2020, Health Effect Institute reported a worsening condition of air quality in Nigeria which has caused the death of people more than any other country in Africa and 6th in the world.

At the subnational level, in major parts of Adamawa state environmental pollution is a common sight and can be regarded as a major factor for unhealthy living. The problem of pollution can majorly be attributed to bad sanitary habits and poor management of waste in most of the communities within the State. It is common to see people dumb refuse indiscriminately and this has caused serious environmental pollution problems. Open defecation is still prevalent and adds to the problem of environmental pollution. According to National Demographic and Health Survey (2019), 22.8 percent of the population in Adamawa State defecates in the open in 2018. Open defecation has consequences of increasing the cases of diarrhea, cholera and dysentery in the State. The incidence and prevalence of sanitation related diseases are therefore likely to increase the spread of environmentally induced diseases in human health. Similarly, CUN report (2022) that covers refuse dump in open places, streets and roads cleanliness, personal hygiene and sanitation and open defecation, Adamawa state ranks as the 12th dirtiest State in Nigeria. The United Nation Environment Programme Agency observed that wastes that are not managed properly, especially solid waste from households are a serious health hazard and can lead to the spread of infectious diseases (UNEP, 2006).

The prevalence of diseases and the performance of key health indicators in Adamawa State remain a major concern. Evidence from the 2024 Nigeria Demographic and Health Survey (NDHS) indicates persistent challenges in child survival in the State. In Adamawa State, neonatal mortality was estimated at 42.8 deaths per 1,000 live births, while infant mortality stood at 75.3 deaths per 1,000 live births. Child mortality was estimated at 74.5 deaths per 1,000 live births, resulting in an under-five mortality rate of approximately 144.2 deaths per 1,000 live births (Federal Ministry of Health and Social Welfare of Nigeria, National Population Commission [NPC], & ICF, 2025). These mortality outcomes demonstrate the continuing health challenges confronting the State and have important social and economic implications. Poor health can increase healthcare expenditure, absenteeism and loss of productive working time, thereby adversely affecting labour productivity and household welfare. The continued burden of childhood mortality and malnutrition in Adamawa therefore highlights the importance of improving environmental conditions, preventive healthcare, access to quality health services and workers' health.

According to International Labour Organization, productivity is an important economic indicator that is closely linked to economic growth, competitiveness and living standards within an economy (ILO, 2023). In Adamawa state, key socioeconomic and human development indicators continue to present challenges for labour productivity and living standards. In terms of multidimensional poverty, the Nigeria Multidimensional Poverty Index reports substantial deprivation across Adamawa's three senatorial zones, with multidimensional poverty incidence of 63.0% in Adamawa Central, 70.9% in Adamawa North and 71.8% in Adamawa South (NBS, 2022).

The persistence of environmental pollution constitutes a major risk factor for human health which is an important determinant of economic productivity. Day by day, people become sick by the increasing amount of environmental pollution they come in contact with as they pursue their daily lives. Given the prevalence of environmental pollution and its effect on health, household individuals have to spend their income in preventing and treating diseases that are caused by pollution. In a country where there is high rate of poverty, spending huge amount of money as out-of-pocket expenditure on health can further impoverish the masses and retard human welfare.

Economic activities have caused serious environmental pollution in Adamawa state which have led to waste discharges that have not been managed effectively. Heaps of refuse and littered environment are a common sight in addition to discharges of waste water and indiscriminate burning of solid waste. It is habitual and 'normal' for people to carelessly dump waste in a public place, or dispose off waste out of a moving car. Open defecation is still prevalent where people find it convenient to openly defecate in uncompleted buildings or dump sites. Manufacturing and industrial activities have also contributed significantly to the problem by the amount of waste discharges that industries produce but have not been mopped up. Despite the increase in environmental pollution, environmental sanitation exercises hardly take place and therefore have been

ineffective in curbing environmental pollution in the State.

The persistence of environmental pollution has increased the rate of environmentally induced diseases such as malaria fever, typhoid fever, diarrhea and cholera which require frequent visits to health centres. To access treatments, most citizens make out-of-pocket payments which tends to increase household expenditures on health. High out-of-pocket payments on health in the State is capable of increasing the level of poverty, making households poorer and less productive. Where households cannot afford out-of-pocket payment for health, they may die from such diseases or continue to suffer illness which is capable of keeping them away from work. The State government Health Insurance Scheme does not cover all the people. Those who are not covered by the scheme pay for their healthcare needs out of their pockets which are costly most of the times and difficult for low-income earners especially when the medical condition involved is a severe one. Where services are available for those covered by the Scheme, expensive drugs are usually not available for severe medical conditions thus making the Scheme ineffective in meeting the healthcare needs of the citizens.

From the foregoing, the prevalence of environmentally induced sicknesses and poor productivity amidst growing environmental pollution in Adamawa state is a major concern. Labourforce is overwhelmed by rising cases of morbidity and poor state of healthcare facilities which are required to boost health. The lack of healthcare utilization especially among workers is likely to worsen health outcomes in the State. Thus, it is becoming increasingly difficult for labourforce to perform optimally in view of the need to grow productivity. The persistence of environmental pollution and increasing rate of diseases are likely to bear adverse effect on labour force productivity. Specifically, Adamawa state's economic progress is potentially being undermined by environmental pollution and poor health status while economic activities may exacerbate environmental degradation requiring a holistic investigation of these dynamics. Therefore, studying this interplay is necessary to guide policy interventions in addressing the problems of environmental pollution, poor health and low level of productivity among labour force in the State. WHO (1986) recognized that health is a resource for everyday living and a tool for determining the level of productivity of a people as well as their standard of living. The United Nations (1973) sees the effort to reduce pollution as a way to boost healthy living and enhance economic productivity which should be pursued to ensure improvements in standard of living that is in harmony with the environment.

EMPIRICAL LITERATURE REVIEW

Several empirical studies have examined the nexus between environmental pollution, health status and economic productivity in Nigeria, integrating the three variables into a single analytical framework, while others have focused on either the pollution and health relationship or the health and economic growth relationship. For instance, Jolaosho, et al. (2025) examined the impact of economic growth on environmental pollution in Nigeria using annual data from 1986-2024. Applying the ARDL model, the study found evidence supporting the Environmental Kuznets Curve hypothesis while also showing that Foreign Direct Investment significantly contributed to carbon emissions under weak environmental regulations. The study stressed that unchecked environmental degradation could erode the productivity gains associated with economic growth by worsening public health conditions. Previous similar study by Sani, et al (2022) found that industrial expansion and economic growth contributed significantly to rising carbon emissions due to weak environmental regulations and dependence on fossil fuels and concluded that although industrialization stimulates production, its associated environmental costs may undermine long-term productivity through adverse health effects unless supported by sustainable environmental policies.

Ugeh et al. (2025) examined the effects of environmental quality and healthcare development on economic growth in Nigeria using the Autoregressive Distributed Lag (ARDL) approach and annual time-series data covering the period 1986-2024. The findings showed that improvements in environmental quality and healthcare development positively influenced economic growth in both the short run and the long run. The study concludes that environmental protection and investment in healthcare should be pursued simultaneously because healthier populations contribute more effectively to productive economic activities.

On environmental quality and health outcomes in Nigeria, Modibbo and Abubakar (2026) established that higher levels of carbon emissions significantly reduced life expectancy and increased mortality rates, confirming that environmental pollution remains a major threat to public health. By using the ARDL

cointegration technique with annual data covering 1980-2021, the study concludes that environmental sustainability policies are indispensable for improving health outcomes and enhancing the quality of human

capital required for productive economic activities. In a related study in Nigeria, Ucheje and Ikebude (2024) pointed out that environmental pollution poses risks to both ecosystems and human health. Their review particularly highlighted air pollution as an important environmental health concern and called for sustained monitoring and appropriate measures to reduce exposure to air pollutants.

Mgbomene (2024) explored the impact of environmental degradation (air pollution) on food productivity in Nigeria (1990-2023). The findings showed an insignificant negative impact of air pollution on food productivity, while rainfall and population growth positively affects food output. Similar outcome was obtained by Onotaniyohwo et al. (2024) where they found no significant influence with malnutrition and access to drinking water as health variables affecting productivity in 33 Sub-Saharan African countries. However, Ugbaka and Chijioke (2024) found a significant effect in both long and short runs when they used an ARDL model to assess how health outcomes (mortality, morbidity, infant mortality, life expectancy, literacy) influences industrial productivity in Nigeria from 1990-2022.

Usman (2022) concludes that improving environmental quality would not only reduce health risks but also strengthen labour productivity and sustainable economic growth. In the study covering data from 1990-2016, the determinants of environmental quality in Nigeria were examined using the Environmental Kuznets Curve (EKC) framework and ARDL estimation. Results show that corruption, internal conflicts and economic activities significantly worsened environmental quality, whereas renewable energy adoption contributed to environmental improvement. Conversely, Li et al. (2022) advocated for water quality management when they reviewed 85 studies linking water pollution to human health and disease. They found that over 80% of sewage water causes 80% of diseases and 50% of child deaths globally.

Yizhen et al. (2022) found that by using multivariate ordered logit and panel data models for China, economic level positively correlates with public health, while air pollution negatively affects it. The study concludes that public health improvements increased vulnerability to air pollution. But Asimea et al. (2022) found lower level of carbon monoxide during Covid-19 lockdown periods in Port Harcourt, Nigeria. They found restrictions of human activities during the Covid-19 pandemic to slow economic activities that were primarily the source of air pollution and kept the air people breath healthier. However, during periods when lockdown was not enforced carbon monoxide levels exceeded healthy levels.

Nchege and Okpalaoka (2022) showed that air pollution negatively impacts economic growth in Nigeria by using ARDL model. They recommended taxing industries generating pollution as a matter of government policy. However, Yang et al. (2022) found that policy uncertainty in 30 Chinese provinces from 2008-2020 inversely affects pollution emissions, with consumption effects outweighing investment effects.

Mbonigaba and Akinola (2021) found significant productivity loss in women with breast cancer (BC) and their income in Southwest Nigeria. They study used a cross-sectional data from 200 clinically diagnosed women. 62% of the women were absent from work for 7 days, 22% were absent for over two weeks. More results show that on average, women with breast cancer caused a 26.2% reduction in workplace productivity. Regression analysis showed that increased breast cancer incidence led to a 13.5% drop in income and a 19.5% decline in productivity. To curb declining productivity caused by ill-health, Aisha and Umar (2021) examined the impact of the National Health Insurance Scheme (NHIS) on worker productivity at the Federal College of Education, Yola and the American University of Nigeria. They found that NHIS benefits include accessibility to quality drugs, treatment and dental care which significantly reduced illness-related absenteeism. Notably, 61% of insured workers had not missed work due to illness in the past year. The study recommends strengthening NHIS services and improving healthcare delivery to enhance worker health, emphasizing the importance of preventive education on diseases like diabetes, hypertension and cancer.

Amos and Adofu (2021) evaluated the impact of ambient air pollution on mortality rate in Nigeria from 1970-2019. Time series data from World Development Indicators were analyzed using Auto Regressive Distributed Lag Model. Results revealed a positive relationship between air pollution and mortality rate in Nigeria. Specifically, air pollution was found to have a negative effect on life expectancy. The study concludes that air

pollution has negative effect on human health and causes death of humans. The study therefore recommends the use of technologies that generate less carbon dioxide and adoption of domestic practices that reduce the quantity of CO₂ produced in the environment.

Iseghohi et al. (2021) examined the effects of health status on labour productivity from 2000Q1-2018Q4 in Nigeria. Health status was proxied by malaria cases, proportion of undernourished Nigerians and life expectancy rate at birth. The results showed that malaria cases constituted drag to labour productivity during the study period. Furthermore, secondary school enrolment rate, proportion of malnourished Nigerians and life expectancy rate at birth had no significant effect on output per worker. A similar study by Andrew et al. (2021) found that prevalent of diseases such as malaria adversely impacts productivity and labour supply of workers.

Musa and Maijama'a (2020) examined the relationship between economic growth, energy consumption and environmental pollution in Nigeria using annual data from 1981-2014. The Autoregressive Distributed Lag (ARDL) approach was used. Results show that economic growth and energy consumption had significant positive effects on environmental pollution in both the short and long run, while crude oil price exerted a significant negative effect on environmental pollution. The study concludes that Nigeria's growth process remains environmentally unsustainable because rising energy demand continues to increase environmental pollution, thereby posing significant risks to public health and labour productivity.

Urhie, et al. (2020) investigates the relationship between economic growth, air pollution and health outcomes in Nigeria using a moderated mediation framework. The study reported that increasing carbon emissions from industrial and construction activities significantly deteriorated health conditions through increased respiratory and environmentally related diseases. The study argued that poor health reduces workers' efficiency and productivity, thereby weakening overall economic performance. In a related study, Afolayan and Aderemi (2019) examined the relationship between environmental degradation, public health and sustainable development in Nigeria using time-series econometric techniques. Their findings revealed that environmental degradation significantly worsens public health conditions by increasing exposure to pollution-related diseases. The study concludes that declining health status reduces labour efficiency and productivity, thereby limiting economic performance. The study recommends stronger environmental regulations and greater investment in pollution control to enhance both public health and economic productivity.

Focusing on the contribution of health to economic performance, Kelani et al. (2019) employed the ARDL bounds testing approach to investigate the relationship between health status and economic growth in Nigeria from 1981-2017. The results showed that improvements in health status exerted a positive and statistically significant effect on economic growth. The study emphasized that healthier individuals are more productive because they possess greater physical and cognitive capacities, experience fewer work absences and contribute more effectively to national output. The study therefore advocates increased public investment in the health sector as a means of enhancing labour productivity and sustaining long-run economic growth.

Nwani et al. (2018) investigates the impact of environmental pollution on health outcomes in Nigeria using annual time-series data from 1981-2017 and the Autoregressive Distributed Lag (ARDL) approach. The study found that carbon dioxide (CO₂) emissions significantly reduced life expectancy, indicating that environmental pollution adversely affects population health. Conversely, public health expenditure was found to improve health outcomes. The study concludes that reducing environmental pollution through effective environmental policies is essential for improving health and promoting sustainable economic development. Their findings imply that deteriorating environmental quality weakens the productive capacity of the labour force through poor health.

Nigerian literature consistently demonstrates that environmental degradation lowers health status by increasing exposure to pollutants, reducing life expectancy and increasing disease prevalence. Poor health subsequently diminishes labour efficiency through reduced physical capacity, absenteeism and lower cognitive performance, thereby constraining economic productivity. Conversely, improvements in environmental quality and healthcare investment strengthen human capital and support sustainable economic growth. These findings are consistent with the Grossman Health Capital Model, which regards health as an investment that enhances labour productivity and Lucas' (1988) Endogenous Growth Theory, which identifies human capital as a critical driver of long-run economic growth.

METHODOLOGY

The study is based on the assumption that environmental pollution causes diseases and thus has effect on health status which in turn affects economic productivity that is viewed as a key driver of economic growth. This study adopts a quantitative, cross-sectional survey design. The design enables the collection of data at a single point in time from a diverse population, allowing for the identification of associations between environmental pollution, health status, and economic productivity. A cross-sectional approach is particularly suited for exploring the assumed relationships between these variables in the context of Adamawa state. The study was conducted in ten (10) Local Government Areas (LGAs): Girei, Hong, Yola North, Madagali, Michika, Mubi South, Ganye, Jada, Mayo-Belwa, and Shelleng. These LGAs were purposively selected due to their significant involvement in economic activities such as trade, agriculture and commerce. The geographical diversity and economic vibrancy of these areas make them suitable for examining the interplay between environmental pollution, health status and economic productivity.

The vast arable land in Adamawa state and distinct climatic conditions support extensive agricultural activities, a key driver of economic productivity. However, these activities can also contribute to environmental pollution through practices such as improper waste disposal, chemical runoff and deforestation. A significant population of the State is heavily reliant on agriculture, livestock production and trade. These sectors are highly sensitive to environmental conditions and health outcomes. Any disruptions caused by pollution can cascade into reduced productivity and economic losses. The prominence of smallholder farming and other informal economic activities amplify the potential impact of environmental and health challenges, making the study highly relevant for policy and development planning.

By its geographical location, Adamawa state is suitable for both local and international trade, facilitating movement of goods and services in commerce thus exposing the State to cross-border environmental challenges, such as pollution from trade-related transportation and industrial activities. The geographic linkages highlight the need to balance economic growth with sustainable environmental practices to protect public health and productivity.

Adamawa State dual seasons (dry and rainy), expose the citizens to extreme weather conditions, including extreme cold, dusty winds and intense heat. These conditions increase the risk of environmental pollution, particularly air and water pollution, which directly impacts health status. Harsh weather conditions, particularly during harmattan, exacerbate the spread of respiratory and waterborne diseases consequently reducing labour productivity. Studying this relationship can provide critical insights into the seasonal effects of environmental pollution on health and economic outcomes.

The study utilized primary data generated from survey with the aid of a designed questionnaire. The questionnaire asked simple questions that helped individual respondents answer questions on environmental pollution, health status and economic productivity in Adamawa state. Their personal experiences such as where they reside, the level of exposure to pollution and the severity of the effect of pollution on their health and productivity. The use of questionnaire provided an opportunity for face-to-face interaction with respondents who are considered relevant to the study. Descriptive statistics was used to examine the socioeconomic characteristics of the respondents while ordered logistic regression was used to evaluate the specific objectives.

According to projection by National Population Commission, the population of Adamawa state is 4,902,100 (NBS, 2022). The target population comprises individuals aged 18 and above who are actively engaged in economic activities within the selected LGAs. These include farmers, traders, artisans, small-scale entrepreneurs, civil servants among others.

The Taro Yamane method was used to determine the sample size while Probability Proportional to Sampling technique (PPS) was used to select LGAs and wards where the study took place. By Probability Proportional to Sampling (PPS) technique, ten (10) LGAs were selected. These LGAs are Girei, Hong, Yola North, Madagali, Michika, Mubi south, Ganye, Jada, Mayo-belwa and Shelleng.

By the Taro Yamane method, approximately 400 was obtained. However, additional 40 questionnaire was

added so that all the selected communities would get the same number of questionnaires that was administered. Therefore, a total of 440 questionnaire was used to generate data. The distribution of questionnaires was based on selected political wards across Senatorial Districts in Adamawa's LGAs.

Table 1.1 Generated sample for selected LGAs by PPS

State	Senatorial District	Number of LGA	Cumulative	Selected LGA	Number of selected LGA
	Central	7	7	2, 4, 6	3
Adamawa	Northern	5	12	8, 10, 12	3
	Southern	9	21	14, 16, 18, 20	4
	Total	21			10

Sampling interval = Cumulative of LGA/cumulative of selected LGA $21/10 \approx 2$; Selected Random start = 2

Table 1.2 Generated sample for selected wards

State	Senatorial District	Number of selected LGA	Number of wards in selected LGA	Selected wards	Number of selected wards
	Central	3	33	2, 4, 6, 8, 10, 12 15	15
				14, 16, 20, 22, 24, 26	
				28, 30, 32	
Adamawa	Northern	3	36	34, 36, 38, 40, 42, 44, 46 18	18
				48, 50, 52, 54, 56, 58, 60	
				62, 64, 66, 68	
	Southern	4	43	70, 72, 74, 76, 78, 80, 82 22	22
				84, 86, 88, 90, 92, 94, 96	
				98, 100, 102, 104, 106, 108	
				110, 112	
	Total	10	112	55	

Sample interval for ward selection = 2, Random start = 2

By Taro Yamane's formular, approximately 400 population size was determined. However, 55 wards/communities were selected for survey by Probability Proportional to Sample size technique for questionnaire administration. Therefore, $400/55 = 7.3$ questionnaires per ward/community. Although it is difficult to determine 7.3 questionnaire per ward/community, 1 questionnaire was added for each ward/community making a total of 8 questionnaires per ward/community. Thus, a total of 440 questionnaires, 8 in each ward/community were administered across 55 wards/communities in 10 LGAs. The technique for selecting the appropriate respondents was by random sampling technique. Random sampling technique has advantages over other techniques because it eliminates biases and ensures that every element has equal chance of being chosen.

Definition and Coding of Variables

Table 1.3 Description of variables and coding

S/N	Name of Variable	Description	Coding
1	WPHour (Dependent Variable)	Worker productivity per hour, defined as work done per hour.	24 hours = 4 Above 12 hours = 3 Above 7 hours = 2 1–6 hours = 1

2	EnvPol (Independent Variable)	Environmental pollution, defined as the decline in the quality of the physical environment as a result of human activities.	Severe pollution = 3 Moderate pollution = 2 No pollution = 1
3	HS (Independent Variable)	Self-rated health status, defined as an individual's perception of their health status, rated as excellent, very good, good, or fairly poor.	Excellent = 4 Very good = 3 Good = 2 Fairly poor = 1
4	Income (Independent Variable)	Declared monthly income earned from work.	61,000–Above 100,000 = 4 41,000–60,000 = 3 21,000–40,000 = 2 1,000–20,000 = 1
5	Gender (Independent Variable)	Biological sex of the respondent, categorized as male or female.	Male = 1 Female = 0
6	WC (Independent Variable)	Worker category, defined as the type of occupation or employment an individual is engaged in.	Private sector = 4 Government = 3 Business = 2 Casual work = 1

METHOD OF DATA ANALYSIS

To evaluate the interplay of environmental pollution, health status and economic productivity, Ordered Logistic Regression approach was used. The study used a combination of the Grossman Health Capital Model and Human Capital Theory, with environmental economics providing the transmission mechanism. Economic productivity is denoted by worker productivity per hour and is expressed as;

$$WPHour = f(EnvPol, HS, Income, Gender, WC).$$

The Ordered Logistic Regression equation models the log-odds of being in or below a specific category of an ordinal dependent variable (in this case, economic productivity (WPHour) based on the independent variables. The ordered logistic regression model is specified as:

$$\text{Log} (\text{Pr} (WPHour_i \leq k) / \text{Pr} (WPHour_i > k)) = \beta_0 + \beta_1 EnvPol_i + \beta_2 HS_i + \beta_3 Income_i + \beta_4 Gender_i + \beta_5 WC_i$$

where;

$\text{Pr} (WPHour_i \leq k)$ is the probability that worker productivity by hours of the i-th individual is at or below category k.

$\text{Pr} (WPHour_i > k)$ is the probability that worker productivity by hours of the i-th individual is above category k.

$\beta_1, \beta_2, \beta_3, \beta_4$, and β_5 are the coefficients for the predictors ($EnvPol_i, HS_i, Income_i, Gender_i, WC_i$) for outcome category k.

A priori expectation

The a priori expectation is given thus: $\beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_4 \geq 0$ or $\lambda_4 \leq 0$ and $\beta_5 \geq 0$ or $\beta_5 \leq 0$. In the model, environmental pollution is expected to have a negative relationship with worker productivity because exposure to pollution can adversely affect workers' health, reduce their physical and cognitive efficiency and consequently lower productivity. Health Status is expected to have a positive relationship with worker's productivity. This is because better health enables workers to perform their tasks more efficiently, reduces illness-related absenteeism and improves their overall work capacity. Similarly, income is expected to have a positive effect on workers' productivity because higher income can enable workers to invest in better nutrition, healthcare, housing and other living conditions that enhance their health and productive capacity. In the model, gender is expected to either have a negative or positive relationship with productivity due to differences between male and female workers which may vary according to occupational roles, sector of employment,

working conditions and marital status. Finally, Worker Category is also expected to have either a negative or positive relationship with productivity because different occupational categories may involve varying skill requirements, levels of technology use, working conditions and degrees of exposure to environmental risks, all of which can influence workers' productivity differently.

The Grossman (1972) Health Capital Model views health as a durable capital stock that individuals invest in because it increases both utility and productive capacity. According to the theory, workers are producers of health through investments such as medical care, nutrition, exercise and healthy environments. Environmental pollution accelerates the depreciation of health capital by increasing illness and reducing physical and cognitive functioning. In this study therefore, environmental pollution is seen to reduce workers' health status through increased exposure to contaminants, diseases and occupational hazards. Poor health then lowers workers' productivity per hour by reducing physical strength, increasing absenteeism, decreasing concentration and limiting work effort. However, income influences the ability of workers to invest in health, while gender and worker category explain differences in health risks and productivity across demographic and occupational groups.

RESULTS AND DISCUSSION

The findings indicate that males constituted 50.68% of the respondents, while females accounted for 49.32%. The relatively balanced representation of both sexes reflects the participation of men and women in diverse economic activities and provides a broad basis for examining factors influencing economic productivity. The age of the respondents ranged from 18 to 61 years and above. Respondents aged 26–34 and 35–44 years jointly accounted for 65.68% of the sample, representing the largest proportion of the respondents. These age groups constitute a substantial segment of the economically active population, with considerable potential to participate in productive economic activities. Their involvement in trade, agriculture, commerce, and other forms of economic activity provides an important source of labour for improving productivity and supporting economic development.

The monthly income of the respondents ranged from ₦1,000 to ₦100,000, with a small proportion earning above ₦100,000. Specifically, 25.91% of the respondents reported monthly earnings of between ₦21,000 and ₦40,000, while 37.95% earned between ₦1,000 and ₦20,000. Approximately 4.77% reported earning above ₦100,000 per month. The variation in income levels may reflect differences in the nature of economic activities, occupational categories, skills, working conditions, and levels of productivity among the respondents. Income generated from legitimate economic activities contributes to workers' welfare and provides opportunities for consumption, savings, and investment. The observed income distribution therefore provides useful socioeconomic context for understanding the economic circumstances and productivity of the respondents.

The distribution of respondents by marital status shows that 52.27% were married, 28.86% were single, 7.50% were divorced, while 11.36% were widowed or widowers. Marital status is an important socioeconomic characteristic because family responsibilities and household structures can influence economic decisions, labour participation, consumption, saving, and investment behaviour. For example, married respondents may face decisions concerning the allocation of household income between consumption, savings, education, healthcare, and investment. Such household-level decisions can influence the economic well-being of individuals and their participation in productive activities. The relatively high proportion of married respondents therefore provides useful context for understanding the socioeconomic circumstances of the sampled workers.

In terms of educational attainment, 46.14% of the respondents had tertiary education, 24.55% had secondary education, while 12.73% had no formal education. The relatively high proportion of respondents with tertiary education suggests that a substantial share of the sample possesses advanced educational qualifications that may enhance access to skills, knowledge, and employment opportunities. Education can contribute to labour productivity by improving workers' ability to acquire and apply knowledge, adapt to new technologies, make informed decisions, and perform occupational tasks more effectively. Secondary education also provides foundational literacy, numeracy, and other skills that can facilitate participation in various economic activities.

Although 12.73% of the respondents had no formal education, their participation in economic activities remains relevant to the study of productivity. Individuals without formal education may acquire occupational skills through apprenticeship, informal training, practical experience, and on-the-job learning. Many may participate in agriculture, petty trading, craftwork, construction, and other informal economic activities. Their contribution demonstrates that economic productivity is not determined solely by formal educational attainment but may also depend on acquired skills, experience, working conditions, access to productive resources and the nature of the economic activity undertaken.

The results in Table 1.4 from the ordered logistic regression provide valuable insights into the relationship between environmental pollution, health status and worker productivity.

Table 1.4 Ordered logistic regression

WPHour	Coef.	OR	St.Err.	t-value	p-value	[95% Conf	Inter]	Sig
EnvPol	-.198	0.820	0.207	-0.96	0.339	-0.605	0.208	
HS	.258	1.294	0.13	1.98	0.048	0.002	0.513	**
Income	.311	1.365	0.091	3.41	0.001	0.132	0.49	***
Gender	.449	1.567	0.196	2.29	0.022	0.064	0.833	**
WC	.254	1.289	0.101	2.51	0.012	0.056	0.452	**

Mean dependent var	1.541	SD dependent var	0.547
Pseudo r-squared	0.04	Number of obs	440
Chi-square	27.8	Prob > chi2	0
Akaike crit. (AIC)	683.778	Bayesian crit. (BIC)	712.385
*** $p < .01$, ** $p < .05$, * $p < .1$			

Source: Stata 15 Authors' computation, 2026

Results in table 1.4 show that environmental pollution has a negative but statistically insignificant relationship with worker productivity ($\beta = -0.198$; OR = 0.820; $p = 0.339$). The odds ratio indicates that a one-unit increase in environmental pollution is associated with approximately 18.0% lower odds of being in a higher productivity category, holding other variables constant. A negative coefficient indicates that an increase in environmental pollution significantly reduces worker's productivity per hour, although not statistically significant. This outcome suggests that exposure to pollution might be less impactful on worker's productivity than the severity of environmental pollution being perceived to subsist in the environment. However, a similar study by Amos (2025) using the same set of data but different variables shows that increase in pollution in an environment decreases worker productivity by 35%. This aligns with the understanding that exposure to pollutants such as poor air or water quality can reduce physical and cognitive functioning, thus impairing productivity by the discomfort being experienced at work. Exposure to pollutants in environmentally unhygienic work place or home can lead to a wide range of health problems such as diarrhea, typhoid fever, malaria fever, allergies and skin problems such as eczema. Furthermore, consistent exposure to environmental pollutants can suppress the immune system, making individuals more susceptible to infectious diseases and reducing their ability to fight off infections. Therefore, taking measures to reduce environmental pollution at work and improve hygiene in addition to individual measures to protect oneself from exposure can help to mitigate these health risks and improve worker productivity.

From table 1.4, health status has a positive and statistically significant relationship with worker productivity ($\beta = 0.258$; OR = 1.294; $p = 0.048$). A one-unit improvement in health status is associated with approximately 29.4% higher odds of being in a higher productivity category, ceteris paribus demonstrating that better health outcomes directly contribute to enhanced worker's efficiency and output. This result is consistent with scholarly research linking improvements in health to increased physical and cognitive capacity for work for longer hours. From the results, health status has a positive effect on worker productivity. This means that

individuals with better health status are likely to be more productive. It can therefore be deduced that healthy individuals find it easy to work optimally thus increasing how many hours are spent in doing a particular work every day. However, when people are sick, they do not go to work so hours they would have worked is lost. This result is consistent with empirical study carried out by [(Siddique et al., 2020; Saif et al., 2019; Adeshina et al., 2019)]. They all found that improved health status is associated with increased productivity.

From table 1.4, income has a positive and statistically significant relationship with worker productivity ($\beta = 0.311$; OR = 1.365; $p = 0.001$). A one-unit increase in income is associated with approximately 36.5% higher odds of being in a higher productivity category, holding other factors constant. What this means is that with increase in income, workers are motivated to put in their best for optimum result. This is particularly true in work places where wages are determined by hours worked. Increase in income is strong motivation for more work because higher income can enable workers to invest in better nutrition, healthcare, housing and other living conditions that enhance their health and productive capacity

Result in table 1.4 indicates that the coefficient of gender is positive and statistically significant ($\beta = 0.449$; OR = 1.567; $p = 0.022$), indicating a positive relationship between gender and worker productivity. The odds ratio of 1.567 implies that workers in the category coded 1 have approximately 56.7% higher odds of being in a higher productivity category than workers in the reference category coded 0, holding other variables constant. This relationship is statistically significant at the 5% level. The finding suggests that gender is associated with differences in the likelihood of attaining higher levels of worker productivity. However, the result should not be interpreted as evidence that gender itself causes higher productivity, nor does it establish that particular jobs are inherently more suitable for males or females. Rather, the finding may reflect differences in occupational roles, working conditions, opportunities, access to resources or other factors associated with the gender categories. Consequently, policies that promote equal opportunities, non-discrimination and fair access to productive employment for both men and women may help ensure that workers can contribute effectively to economic productivity.

Worker category has a positive and statistically significant relationship with worker productivity ($\beta = 0.254$; OR = 1.289; $p = 0.012$). Workers in the category coded 4 (private sector) have approximately 28.9% higher odds of being in a higher productivity category than those in the other reference category, *ceteris paribus*. This outcome suggests that private-sector employment may incentivize higher productivity due to factors like performance-based rewards or better workplace dynamics. The ethics of privately own enterprise or private establishment is driven and deepened by incentives. Profit gains are the hallmark of such organizations, consequently worker performance is given topmost priority. Workers therefore must perform or they would be sacked. So it becomes necessary for private sector workers to put in their best to survive and attract more incentives.

The proportional-odds assumption was tested using the Brant test. Variable-specific tests showed that the assumption was satisfied for environmental pollution ($p = 0.140$), health status ($p = 0.321$), and gender ($p = 0.611$), but was violated for income ($p = 0.004$) and worker category ($p = 0.029$).

Results are contained in table 1.5. Thus, Income and WC are responsible for the evidence of violation, while the proportional-odds assumption is not rejected for EnvPol, HS and Gender.

Table 1.5 Brant test of parallel regression assumption

Variable	chi2	p>chi2	Df
EnvPol	2.17	0.14	1
HS	0.99	0.321	1
Income	8.34	0.004	1
Gender	0.26	0.611	1
WC	4.75	0.029	1

Source: Stata 15 Authors' computation, 2026

CONCLUSION

The study investigates the interrelationships between environmental pollution, health status and workers' economic productivity, with health status considered as a potential transmission mechanism through which environmental pollution affects productivity. The findings suggest that exposure to environmental pollution can adversely affect health status and consequently, reduce economic productivity. Therefore, improving the quality of the working environment and promoting workers' health are essential for enhancing productivity. Theoretically and empirically, environmental pollution is associated with adverse health outcomes, which can diminish workers' physical and functional capacity and consequently, their productivity. Conversely, economic activities that underpin productivity may generate waste and other pollutants, particularly where appropriate environmental management practices are inadequate. Thus, environmental pollution, health status and economic productivity constitute interconnected dimensions of sustainable economic activity. Examining these linkages is therefore important for generating evidence to support policies that simultaneously address environmental degradation, promote better health outcomes and enhance workers' productivity and economic well-being in Adamawa State.

Despite these advances, important gaps remain in the Nigerian empirical literature. First, most recent studies focus on either the environmental pollution and health relationship or the environmental pollution and economic growth relationship, without explicitly modelling health status as the transmission mechanism through which pollution influences productivity. Second, the majority of studies employ macroeconomic indicators such as carbon emissions, life expectancy and GDP growth, with limited use of household-level indicators of environmental pollution, health status and individual productivity. Third, few studies simultaneously estimate the direct effects of environmental pollution on productivity alongside its indirect effects operating through health status within a single empirical framework. Consequently, evidence on the complete environmental pollution, health status and economic productivity nexus in Nigeria remains limited. Addressing these gaps would provide more comprehensive evidence for designing integrated environmental, public health and economic policies aimed at promoting sustainable productivity and inclusive development which this study has addressed.

DECLARATION OF AI USE

This paper was the original idea of the authors from the inception: study design, data collection, data analysis, interpretation of results and scholarly discussion of the findings. Chat Generative Pretrained Transformer was used solely to assist in improving grammatical presentation in some parts of the paper. The authors accept full responsibility for the accuracy, integrity and final content of the manuscript.

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