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Industrial Pollution and its Attendant Effects on Public Health in Nigeria

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Abstract

Air pollution from rapid industrialization and the use of energy have led to increasing deterioration in environmental quality which poses serious challenges to human health. This study estimated the effect of industrial pollution on public health in Nigeria using time series data sourced from World Development Indicators (WDI) data from 1971-2011.. The stationarity tests reveal that except for GDP growth which was stationary at its level, all other variables were stationary at first difference. The cointegration test shows the existence of three cointegrating equations which implies that the series cannot drift too far apart and hence the need for an estimation of the VECM model. The VECM shows a negative relationship between life expectancy (a proxy for public health) and carbon dioxide emission (industrial pollution) both in the short and long run. The coefficient of Error Correction Term (-0.0802) of the model was significant and negative meaning that the system corrects its previous period disequilibrium at a speed of approximately 8% annually. The impulse response analysis revealed that after the first quarter, a one standard deviation shock in carbon emission has a negative and significant impact on life expectancy, thereby validating the negative relationship between life expectancy and carbon dioxide emission in Nigeria. The study therefore recommends that efforts aimed at improving public health should focus on observing the Kyoto Protocol (KP) agreement which is targeted at reducing the emission of green house gases responsible for climate change with severe health implications. This objective can be achieved by imposing taxes, use of quotas or fostering collective bargaining between the parties involved.

Keywords: Life expectancy, public health, industrial pollution, carbon dioxide emission, VECM, Nigeria

1. INTRODUCTION

The central role played by industry in the economy of any nation is clearly evident in being one of the main determinants of economic growth and development. This is made possible through its role in increasing both national and per capita income, augmenting international trade, job creation, facilitating the growth of domestic markets, urbanization, among others. Although industrialization is inevitable, various devastating ecological and human disasters which have continuously occurred over the years implicate industries as major contributor to environmental degradation and pollution processes of various magnitudes (Dan'azumi and Bichi, 2010). Industrial pollution is caused by particles especially waste gases like carbon monoxide, sulfur oxides, and nitrogen oxides which are the waste products of industry which ultimately end up in the air (Gull et al, 2013). Most of the pollution on the planet can be traced back to industries of some kind (Heredia, 2014) and industrial emissions are the second largest pollutants of the atmosphere after automotive exhausts (Gull et al, 2013).

The issue of industrial pollution is presently receiving a universal attention because it affects the climate of the environment and its impact is therefore global. Its health implication, which is a form of negative externality imposed on other agents in the economy who are non polluters, makes the issue of grave importance. Air pollution is now the world's largest single environmental health risks, and is fast becoming one of the leading causes of illness and death in developing countries (UNEA, 2014). These industrial emissions have the potential of aggravating the problem of climate change which poses serious health challenges in terms of cardiovascular and cerebrovascular diseases among the elderly as it is usually associated with excessive temperatures and heat waves that can alter arterial pressure and blood viscosity (Odusanya et. al 2014). Other human health effects due to air pollutants include asthma, carcinogenicity, pulmonary tuberculosis, cerebrospinal meningitis, pneumonia, whooping cough and measles (Tawari and Abowei, 2012; Nwachukwu and Ugwuanyi, 2010; Ugwuanyi and Obi, 2002). The World Health Organisation (WHO) estimates that outdoor air pollution alone accounts for around 2% of all heart and lung diseases, about 5% of all lung cancers, and about 1% of all chest infections. The number of deaths attributable to outdoor pollution has significantly increased, with 176,000 deaths annually from outdoor air pollution in Africa, and 3.7 million deaths globally (UNEA, 2014).

Nigeria is also not left out of the worrisome effect of pollution as it has a high record of some of the worst health and healthcare statistics in the world. For example, life expectancy at birth had remained low which is put at 52.62 years in 2014 (CIA World Factbook, 2015). Mortality is high, with infant mortality rate in 2013 pegged at 74 percent per 1000 live births and maternal mortality rate was 560 per 100,000 live births (WDI, 2014).

Respiratory diseases which are major pollution related diseases especially influenza and Pneumonia, asthma and lung disease have been found to account for 249,211 deaths in Nigeria (WHO, 2010). These diseases account for about 15% of the total deaths in Nigeria with influenza and pneumonia being among the top 3 causes of death. Also, the WHO report shows that tuberculosis and meningitis accounts for 7.71% of the total deaths in Nigeria (131604 deaths). Following the health situation described above and in addition to other health indicators, WHO ranked the Nigerian health system as 187th of the 191 countries evaluated in 2000.

Sequel to the foregoing, numerous studies have investigated the effect of air quality on health using health care spending as a measure of health status (Narayan and narayan, 2008; Boachie et al, 2014; Hanson and Selte , 2000; Kiymaz et al, 2006; Odusanya et al, 2014) but few studies exist on the influence of industrial pollution on public health using life expectancy as a measure of health status . As the concerns and questions about industrial pollution and its accompanying effect on humans and the environment grow louder, understanding its effect on the public health of Nigerians becomes increasingly important. Is there a way we can link the deteriorating health situation in Nigeria to industrial pollution? If there is a link, what policies should be designed and implemented to reduce the level of emission generated from industrial activities? Or should industrial pollution be permitted as industries are major drivers of economic growth and development? If they are to be permitted, what quota of emissions is to be allowed that will not be detrimental to human health? Are there other factors besides industrial emissions responsible for the health status of Nigerians? This paper provides an overview of the methods and issues arising in each case, and presents empirical work on the health implications of industrial emission and suggests policies based on the research findings. The remaining part of the study is divided into five sections: Section 2 overviews the relevant literature and theoretical underpinnings regarding the industrial pollution-public health relationship with an overview of the analysis of externalities. Section 3 presents an exposition on the tradeoff between industrial emission and economic growth. Section 4 explains the structure and the results of the model explaining the determinants of public health in Nigeria which is measured in terms of life expectancy at birth. Finally, Section 5 concludes.

2. Theoretical Underpinnings and Literature Review

2.1 Theory of Externality

The health implications of industrial pollution can be better understood using the externality theory. An externality is present whenever the wellbeing of a consumer or production possibilities of a firm is/are directly affected by the actions of another agent in the economy. A consumer or firm may in some circumstances be directly affected by the actions of other agents in the economy; that is, there may be external effects from the activities of other consumers or firms. For example, a range of external costs is associated with manufacturing industries, the most prominent impacts being noise and dust (Kemiki et al, 2014) with on overall effect on the health of the people and value of surrounding properties. Likewise, a fishery's catch may be impaired by the discharges of an upstream chemical plant.

Externality can be one of two types: simple bilateral externality, which is the simplest possible externality, and multilateral externalities. Simple bilateral externality is the one that involves only two agents in the economy, where one of the agents engages in an activity that directly affects the other. In most cases, externalities are generated and felt by numerous parties. This is particularly true of those externalities, such as industrial pollution, smog caused by automobile use, or congestion, that are widely considered to be important policy problems. This study therefore concentrates on the analysis of multilateral externalities as illustrated by Mas-Colell et. al (1995) .

2.2 Analysis of Multilateral Externalities

An important distinction can be made in case of multilateral externalities according to whether the externality is depletable or nondepletable. Depletable externalities have the feature that experience of the externality by one agent reduces the amount that will be felt by other agents. Depletable externalities therefore share the characteristics of the usual (private) sort of commodity. In contrast, air pollution is a non depletable externality: the amount of air pollution experienced by one agent is not affected by the fact that others are also experiencing it. Non depletable externalities therefore have the characteristics of public goods (or bads). In the analysis of multilateral externalities, a partial equilibrium approach is adopted and it is assumed that agents take as given the price vector p of all traded L goods. There are J firms that generate the externality in the process of production. Given price vector p , the firm j's derived profit function over the level of the externality its generates, $h_j \geq 0$, is denoted by $\pi_j\,(h_j)$. There are also J consumers, who have quasilinear utility functions with respect to a numeraire, traded community. Given price vector p, consumer I's derived utility function over the amount of the externality $\bar{h}_i$ he/she experiences is denoted by $\phi_i(\bar{h}_i)$

Depletable Externalities

It is easy to see that the level of the (negative) externality is excessive at an unfettered competitive equilibrium. Indeed, at any competitive equilibrium, each firm j will wish to set the externality-generating activity at the level h_j^* satisfying the condition

$$\pi_j(h_j^*) \leq 0, with\ equality\ if\ h_j^* > 0 \qquad (1)$$

Any Pareto optimal allocation involves the levels of $\bar{h}_i^o, \dots \bar{h}_j^o, h_i^o \dots h_i^o$ that solves

$$\begin{array}{ll} Max & \sum_{i=1}^{I} \phi_i(\bar{h}_i) + \sum_{j=1}^{J} \pi_j\,(h_j) \\ (h_i \dots h_j) \geq 0) & \\ (\bar{h}_i \dots \bar{h}_j) \geq 0) & \\ & s.t\ \sum_{j=1}^{J} h_j = \sum_i^I \bar{h}_i \end{array} \qquad (2)$$

Letting µ be the multiplier on this constraint, the necessary and sufficient first-order conditions for the constraint as represented by equation 2 are

$$\phi_i(\bar{h}_i) \leq \mu, \text{with equality if } \bar{h}_i^o > 0, i = 1, \dots, I, \qquad (3)$$

$$\mu \leq -\pi_j'(h_j^o), with\ equality\ if\ h_j^o > 0, j = 1, \dots, J. \qquad (4)$$

Conditions (3) and (4) along with the constraint in problem (2) characterize optimal level of externality generation and consumption.

Nondepletable Externalities

For specificity, the total amount of the externality produced by the firms which is assumed to be $\Sigma_j h_j$, is the level of the externality experienced by each consumer. In an unfettered competitive equilibrium, each firm j's externality generation h_j^* again satisfies condition (1). In contrast, any Pareto optimal allocation involves the levels ($h_i^o \dots h_i^o$) that solves

$$\begin{array}{ll} Max & \sum_{i=1}^{I} \phi_i(\Sigma_j h_j) + \sum_{j=1}^{J} \pi_j\,(h_j) \\ (h_i \dots h_j) \geq 0) & \end{array} \qquad (5)$$

This problem has necessary and sufficient first-order conditions for each firm j's optimal level of externality generation, h_j^o, of

$$\sum_{i=1}^{I} \phi_i'\ (\Sigma_j h_j^o) \leq -\pi_j'(h_j^o), \quad with\ equality\ if\ h_j^o > 0 \qquad (6)$$

Condition (6) is exactly analogus to the optimality condition for a public good, where $-\pi_j'(.)$ is firm *j's* marginal cost of externality production.

2.3 Industrial Pollution and Economic Growth- The growing debate

Industrial pollution has become an issue of growing public interest in recent years with highly polarized view being presented by different stakeholders about the merits of industrialization in relation to its environmental and health impacts. Pollution levels directly affect the health of a country's citizens. As c02 emerges as the main pollutant in the industrial sector (Acar and Tekce, 2014), greater carbon dioxide emissions mean that more of a country's air is polluted with this harmful chemical (Kossis, 2010). However, countries with low carbon emissions can attain a reasonably high life expectancy, but cannot achieve high levels of income (ScienceDaily, 2012).

Until recently, the following correlations have been held to be true: Human development depends on economic growth, economic growth requires additional energy and thus leads to increased emissions of greenhouse gases (ScienceDaily, 2012). Implicatively, output growth will inevitably lead to exploitation of natural resources which further increases the level of emissions and hence translates into environmental quality degradation. This bi-causal relationship has engendered various research investigations.

Numerous studies have been conducted on the relationship between economic growth and environmental pollution in which the most important one is the proposition of Environmental Kuznets Curve (EKC) hypothesis, which presumes an inverted U-shaped relationship between selected pollution indicators and per capita income, following the original Kuznets Curve approach that postulates a similar relationship between income inequality and per capita income (Kuznets and Simon, 1955). Based on the reverse U shape relationship between economic growth and environmental pollution, it is believed that as an economy experiences growth in terms of per capita income, the emission level grows in the initial stages, reaches a peak level and then starts declining after a threshold level of per capita income has been reached. In the higher stage of economic development, the high-polluting industrial economy turns into service economy or technology-based economy and resultantly the change in the economic structure of the country is expected to improve environmental quality (Grossman and Krueger, 1991; Vukina et al., 1999)

Steinberger et al (2005) revealed that most carbon exporting countries can be found in the in the middle range, both in terms of life expectancy and in terms of income while carbon-importing countries consists of two groups: one group is made up of the poorest countries forced to import expensive fossil fuels as well as goods produced at high carbon intensity and the other group includes countries with the most developed socio-economic status, the highest life expectancy and a greater average per capita income. The country comparison shows that while it is possible to simultaneously achieve low carbon emissions and high life expectancy, it only becomes applicable when the population's income is moderate.

In passing, regardless of the economic benefits associated with the extraction of natural resources, the health implication of these industrial emissions should be foremost if the main reason behind the much professed economic growth is for human development as this will not be achieved if we have most of the human population in an ailing condition due to pollution related diseases which are the leading causes of deaths in most countries. Researchers have demonstrated that a wide variety of development opportunities exist in countries which do not necessarily follow global trends since countries currently exist with the same life expectancies as the UK and the US, but with a small fraction of their carbon emissions (and incomes); therefore prioritizing economic growth at the expense of climate stability seems less and less defensible (cited in Science Daily, 2012).

2.4 Empirical review of the impact of industrial pollution on Health

The global effect of air pollution both on the environment and human health has engendered quite a number of studies which tried to establish the relationship between these key issues. Narayan and Narayan (2008) in their study of the influence of environmental quality on health expenditure in eight selected OECD countries found that two of their three measures of environmental quality - sulphur oxide emissions, and carbon monoxide emissions have a positive and statistically significant impact on per capita health expenditure in the long run. The relationship between carbon monoxide emissions and per capita health expenditure was statistically significant at 1% level while the relationship between sulphur oxide and per capita health expenditure was statistically significant at 5% level.

Chen et al (2013) in their measurement of the sensitivity of mortality rate to different pollution levels in northern china in the 1900s, revealed that lifelong exposure to 100 micrograms of “total suspended particulates,” or TSPs, (minuscule solid particles floating in the air, such as pollutants) per meter of air cubed will shorten a person’s life by three years, on average. The study showed that airborne pollution in China may have shortened the lives of 500 million Chinese by 2.5 billion years. In addition, Correia et. al (2013) found out that a decrease of 10 $\mu g/m^3$ in the concentration of particulate matter ($PM_{2.5}$) was associated with an increase in mean life expectancy of 0.35 years (SD = 0.16 years, $P = 0.033$). This association was stronger in more urban and densely populated counties. Hanson and Selte (2000) while examining the relationships between air pollution and human health in Oslo, reported that an increase in particulate matter impact negatively on labour productivity through increases in sick leaves.

Aston (2001) in the study conducted in Europe by EPA identified through a questionnaire that the dust and unhealthy air in factory area was a major factor in the high incidence of tuberculosis, bronchitis and asthma amongst residents. The result is difficulty in breathing, asthma, etc. Nkwocha and Egejuru (2008) calculated the effects of industrial air pollution on the respiratory health of 250 children in Nigeria who were divided into two zones and monitored on a weekly basis. Results showed that there was a strong association between industrial air pollution and symptoms of diseases among children. The effect was found to be strongest among children below two years of age in the high polluted than in the less polluted area.

3. Data and Methodology

This paper employs annual time series data on life expectancy at birth, health expenditure per capita (current US$), Gross Domestic Product (GDP) growth, total population and carbon dioxide (CO_2) emissions in metric tons per capita. The study used life expectancy at birth and carbon dioxide emissions as proxies for life expectancy and industrial pollution respectively. The data were obtained from World Development indicators (WDI) and spanned over the period 1971-2011.

3.1 Model Specification

In order to test the hypothesis of the effect of the industrial pollution on public health, the vector auto-regressive model for analysis was adopted. VAR was used because it does not require apriori assumption of exogeneity of variables and it allows each variable to interact with itself and others in the system without having to impose a theoretical structure on the estimates. However, if all variables in our VAR cointegrate with order I(1), and if the cointegration relationships among them exist, Vector Error Correction Model (VECM) is used to estimate the impulse response functions. In order to test the long-run relationships, the following multivariate model was investigated in the study using the VECM (Equations 3.1 and 3.2).

For a bivariate VAR, where X and Y are I (1) and co-integrated

$$\Delta X_t = \lambda_1 Z_{t-1} + \beta_1 \Delta X_{t-1} + \cdots + \alpha_1 Y_{t-1} + \cdots \ldots . . + \varepsilon_{xt'} \qquad (3.1)$$

$$\Delta Y_t = \lambda_2 Z_{t-1} + \gamma_1 \Delta X_{t-1} + \cdots + \delta_1 Y_{t-1} + \cdots \ldots . + \varepsilon_{xt} \qquad (3.2)$$

Where (ε_{xt}' ε_{xt}) is a bivarate white noise and $Z_t = X_t + AY_t \rightarrow I\ (0)$, and at least one $\lambda_1 \neq 0$

Y_t =Life expectancy at birth (LFE); X_t = explanatory variables which are: Health expenditure per capita in current US$ (HELTEXP), Gross Domestic Product growth (GDPG), Total population (POP) and carbon dioxide emissions (CO_2).

3.2 Times Series Properties and Diagnostic Tests

The properties of the time series variables- Life expectancy, GDP growth,health expenditure per capita, total population and CO_2 emissions were tested using the Augmented Dickey & Fuller (ADF) unit root test, Johansen an d Juselius Cointegration test, and Vector Error Correction Model. Also, the overall stability and strict adherence to underlying classical assumptions for the estimated autoregressive models were ensured by conducting a series of diagnostics tests. These include the Histogram normality test, Breusch Godfrey serial correlation LM test to determine presence of higher order and serial correlation and Breusch-Pagan-Godfrey heteroskedasticity test.

3.2.1 Augmented Dickey & Fuller (ADF) Unit Root Test

The Augmented Dickey-Fuller (ADF) test was used for testing the stationarity of data. This is the basic test for checking the unit root in the series. There are three types of different conditions in the ADF test which could be applied to any time series. First, random process includes no intercept (c) and trend (t). Second, random process includes intercept (c) but no trend (t). Third, random process includes intercept (c) and trend (t). The study utilized the second and third conditions following Alimi and Atanda (2011). It was found that first condition will be most suitable for the data series in this study. The test model equations are expressed as:

$$\Delta Z_t = \vartheta_0 + \vartheta_1 Z_{t-1} + \sum_{i=1}^{n} \pi_i \Delta Z_{t-1} + V_t \qquad (3.5)$$

$$\Delta Z_t = \vartheta_0 + \vartheta_1 Z_{t-1} + \vartheta_1 t + \sum_{i=1}^{n} \pi_i \Delta Z_{t-1} + V_t \qquad (3.6)$$

The time series variable is represented by Z, t and V_t as time and residual respectively. If a series is stationary without any differencing it is designated as I (0), or integrated of order 0. On the other hand, a series that has stationary first differences is designated I (1), or integrated of order one (1).

3.2.2 Co integration Test

To identify whether all the variables that are included in the system are cointegrated or not, the procedures proposed by Johansen and Juselius (1990) were adopted. The procedures use two tests to determine the number of cointegration vectors: the Maximum Eigenvalue test and the Trace test. The Maximum Eigenvalue statistic tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations for r = 0,1,2,…n-1. These test statistics are computed as:

$$LR_{max}\left(\frac{r}{n}+1\right)=T^{*}log\ (1-\hat{\lambda})$$

Where λ is the Maximum Eigenvalue and T is the sample size. Trace statistics investigate the null hypothesis of r cointegrating relations, where n is the number of variables in the system for r= 0,1,2…n-1. Its equation is computed according to the following formula:

$$LR_{tr}\left(\frac{r}{n}\right)=T^{*}\sum_{i=r}^{n}log(\ (1-\hat{\lambda}_i)$$

In some cases Trace and Maximum Eigenvalue statistics may yield different results and Alexander (2001) indicates that in this case the results of trace test should be preferred.

3.3.3 Vector Error Correction Model (VECM)

VECM is a kind of Vector autoregressive model used with co-integration restrictions. The purpose of the VECM is to focus on the short run dynamics while making them consistent with long run solution. If a number of variables are found to be cointegrated with at least one cointegrating vector, then there always exists a corresponding error-correction representation which implies that changes in the dependent variable can be formulated as a function of the level disequilibrium in the cointegration relationship and fluctuation in other explanatory variables. The regression equation form or VECM is as follows:

$$\Delta Y_t=\theta_1+\rho_1 e_1\sum_{i=0}^{n}\beta_{1i}\Delta Y_{t-1}+\sum_{i=0}^{n}\delta_{1i}\Delta X_{t-1}\sum_{i=0}^{n}\gamma_{1i}Z_{t-1}$$

$$\Delta X_t=\theta_2+\rho_2 e_{i-1}\sum_{i=0}^{n}\beta_{2i}Y_{t-1}+\sum_{i=0}^{n}\delta_{2i}\Delta X_{t-1}\sum_{i=0}^{n}\gamma_{2i}Z_{t-1}$$

In VECM, the cointegration rank shows the number of cointegrating vectors. For instance, a rank of two indicates that two linearly independent combinations of the non-stationarity variable will be stationary. A negative and significant coefficient of the ECM (i.e e_{i-1} in the above equations) indicates that any short term fluctuations between the independent variables and the dependent variable will give rise to a stable long run relationship between the variables.

4. Results and Discussion

Due to the typical non-stationarity property of almost all economic time series, it is expedient to test for stationarity before establishing any relationship between them. The research employed the Augmented Dickey Fuller (ADF) Test to check for stationarity as shown in Table 1 using two out of the three different conditions of ADF test - the random process including intercept only and that including both intercept and trend. It was found that first condition will be most suitable for the data series in this study. The result shows that except for GDP growth (GDPG) which was stationary at its level, I(0), all the other variables (life expectancy, Co2 emission, health expenditure and population total) were stationary at first difference I(1). Therefore the null hypothesis of no unit roots for all the time series are rejected at their first difference for all the variables except GDP growth since the ADF statistic values are less than the critical values at 1% level of significance.

Table 1: Augmented Dickey Fuller (ADF) Test for Stationarity

Variable	Level		First Difference		Order of integration
	Intercept	Intercept &Trend	Intercept	Intercept &Trend	
LFE	2.074464	0.855737	-6.649043***	-7.031889***	I(1)
Co_2	-2.136101	-2.628525	-8.534841***	-8.446865***	I(1)
HELTEXP	1.282077	-5.537250	-5.952419***	-6.192938***	I(1)
GDPG	-5.498409***	-5.955168***	-8.444566***	-8.350175***	I(0)
POP	-0.606220	2.531134	5.573403***	2.887918	I(1)

(*, **, ***) denotes 10%, 5% and 1% level of significant respectively
I (1): Integrated of order 1; I (0): Integrated of order zero

4.1 Determination of Lags

The optimal lag length for the vector error correction model was determined using 6 different selection criteria- Likelihood Ratio (LR), Final Prediction Error Criterion (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ). The six criteria suggest an optimal lag length of three and as a result the study employed this lag length which gives the specification of the right order for the VECM model.

Table2: Lag-order selection criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-962.0325	NA	8.74e+15	50.89645	51.11192	50.97311
1	-688.7765	460.2208	1.87e+10	37.83034	39.12317	38.29032
2	-643.9877	63.64713	7.11e+09	36.78883	39.15902	37.63212
3	-574.8677	80.03370*	8.46e+08*	34.46672*	37.91427*	35.69333*

* 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

4.2 Co-integration test

Cointegration test was estimated using Johansen-Juselius procedure. This was done to assess whether or not there exist a long run relationship among the variables. The procedure includes the Maximum Eigenvalue test and the Trace test which are used to determine the number of cointegrating vector. Table 3 shows the existence of three cointegrating equations for both trace and maximum Eigen value tests and the rejection of the null hypothesis of no cointegration at 5% level. Since there is at least one cointegrating equation, it therefore indicates that a long run relationship exist among the variables thereby justifying the estimation of the VECM model.

Table 3: Johansen Cointegration Test

Null Hypothesis	Alternative hypothesis	Eigen value	Trace Statistics(λ_{trace})	5% critical value
r=0*	r≥1	0.818309	132.8546	69.81889
r≤1*	r≥2	0.526465	68.04757	47.85613
r≤2*	r≥3	0.489081	39.64149	29.79707
r≤3	r≥4	0.284631	14.12281	15.49471
r≤4	r≥5	0.036031	1.394436	3.841466

Null Hypothesis	**Alternative hypothesis**	**Eigen Value**	**Maximum Eigen Statistics (λ_{max})**	**5% critical value**
r=0*	r=1	0.818309	64.80703	33.87687
r≤1*	r=2	0.526465	28.40608	27.58434
r≤2*	r= 3	0.489081	25.51868	21.13162
r≤3	r=4	0.284631	12.72838	14.26460
r≤4	r=5	0.036031	1.394436	3.841466

*Note: *denotes rejection of null hypothesis at 5% level. Both Trace test and max- eigen value tests indicate the presence of 3 cointegrating equation at the 0.05 level.*

4.3 Vector Error Correction Estimates:

The presence of cointegrating vectors between variables indicates a long-run relationship among the variables; therefore, the VEC model can be applied. Structural short and long-run relationships are indicated in VECM estimation (Bulent, 2013) and their results are discussed in details below.

4.3.1 Long run estimates

The result of the long run relationship between life expectancy and the explanatory variables are presented in table 4..The result showed that the coefficients of carbon emission and health expenditure were significant at 1% ($p<0.01$) while that of GDP growth and total population were significant at 5% ($p<0.05$). It can be seen that carbon emission has the largest significant long run impact on life expectancy- an increase in the level of carbon dioxide emission in the atmosphere reduces life expectancy significantly in the long run. Greater carbon emission contaminates the air with harmful chemicals whose continual inhalation has been shown to lead to health issues involving the lungs, heart and cardiopulmonary system (Clive, 2003). This ultimately will decrease the life expectancy of citizens in the concerned countries. This result agrees to a large extent with previous studies (Chen et al, 2013; Kossis, 2010; Correia et. al, 2013). The result also shows a positive influence of health expenditure on life expectancy. A unit increase in health expenditure increases life expectancy by 232.6 percent. This result is in concordance with that of Kosis (2010) who found the coefficient for health expenditure to be statistically significant with a positive impact on life expectancy. The impact of the variable was approximately 2.31 percent. Increase in health expenditure per capita implies an increase in government spending on health services and advancement in medical technology. By implication, average life expectancy is expected to increase. The relationship between GDP growth and life expectancy is also positive and significant. A one percent increase in GDP results in about 45% increase in life expectancy in the long run. This result is in accordance with previous research findings (Lokpriy, 2013; Bilas et. al, 2014). Total population was also found to have a significant negative impact on life expectancy in the long run. As total population of a country increases with no attendant or corresponding increase in health expenditure, the available health services will be scrambled for by the burgeoning population thereby reducing the quality of health services and consequently life expectancy is negatively affected in the long run.

Table 4: Results of Vector Error Correction Model showing long run effects

Variables	Coefficient	Standard error	t-value
Co_2 (-1)	-28.53290***	5.35269	-5.33057
HELTEXP (-1)	2.325502***	0.60768	3.82683
GDPG (-1)	0.450701**	0.18034	2.49919
POP(-1)	-5.07E-07**	2.3E-07	-2.18604
C	-34.36988		

****, **,* denotes 1%, 5% and 10% significant levels respectively*

4.3.2 Short-run estimates

An error correction term (ECT) model, estimated to establish whether or not there exist a short run relationship between life expectancy and its fundamentals, is presented in Table 5. All the explanatory variables jointly explained 69% of the variation in life expectancy both in the short run and long run. The remaining 31% may be attributed to the influence of omitted variables life style factors (e.g consumption of alcohol, tobacco, food), education etc. The F-statistics of 2.81 indicates an overall significance (p>0.05) of the specified model.

The results presented in Table 5 shows that the ECM coefficients of equations is significant (p<0.01) and has negative sign which implies that the series cannot drift too far apart and convergence is achieved in the long run. More specifically, the coefficient of the speed of adjustment (ECM) indicates that a deviation from the long run equilibrium value in one period is corrected in the next period by about 8%. The results also shows that only lagged values of carbon emission, GDP growth and health expenditure per capita have significant impact on life expectancy in the short run. Lagged values of GDP growth and health expenditure per capita were found to have positive impact on life expectancy in the short run while carbon dioxide emission was found to have a negative influence on life expectancy in the short run.

Table 5: Results of Vector Error Correction Model showing short run effects

Variables	Coefficient	Std. Error	t-Statistic	Probability
ECM(-1)	-0.080194***	0.024220	-3.311066	0.0035
D(LFE(-1))	-0.583047***	0.193185	-3.018076	0.0068
D(LFE(-2))	-0.242560	0.201260	-1.205208	0.2422
D(LFE(-3))	0.170078	0.169368	1.004190	0.3273
D(Co$_2$ (-1))	-1.164282	0.784765	-1.483606	0.1535
D(Co$_2$ (-2))	-0.527685	0.769361	-0.685875	0.5007
D(Co$_2$ (-3))	-1.664759**	0.728803	-2.284239	0.0334
D(GDPG (-1))	0.041827**	0.015125	2.765415	0.0119
D(GDPG (-2))	0.028443**	0.012393	2.294993	0.0327
D(GDPG (-3))	0.001428	0.009947	0.143605	0.8872
D(HELTEXP (-1))	0.104817	0.051935	2.018228	0.0572
D(HELTEXP (-2))	0.079832	0.046751	1.707573	0.1032
D(HELTEXP (-3))	0.089932**	0.036077	2.492820	0.0216
D(POP (-1))	1.85E-07	3.33E-06	0.055577	0.9562
D(POP (-2))	3.96E-06	6.51E-06	0.608581	0.5497
D(POP (-3))	-3.65E-06	3.42E-06	-1.067127	0.2986
C	-1.341417***	0.393853	-3.405880	0.0028

R-squared	0.692311	Mean dependent var	0.250811
Adjusted R-squared	0.446159	S.D. dependent var	0.577025
S.E. of regression	0.429425	Akaike info criterion	1.450993
Sum squared resid	3.688111	Schwarz criterion	2.191144
Log likelihood	-9.843362	Hannan-Quinn criter.	1.711931
F-statistic	2.812539	Durbin-Watson stat	2.062580
Prob. (F. stat)	0.015310		

4.4 Diagnostic Analysis

To ensure the overall stability and perfect specification of the estimated models, several diagnostic analyses were carried out and the results are presented in Table 6. The residual test for serial correlation shows that alternative hypothesis of serial correlation can be rejected since the reported probability value (0.2719) is greater than 5%. Jarque-Bera normality test statistics indicates that the residual of the model is normally distributed (p-value of 0.614). Finally, the result of diagnostic checking of heteroskedasticity shows that the null hypothesis of constant variance of the error term should be rejected.

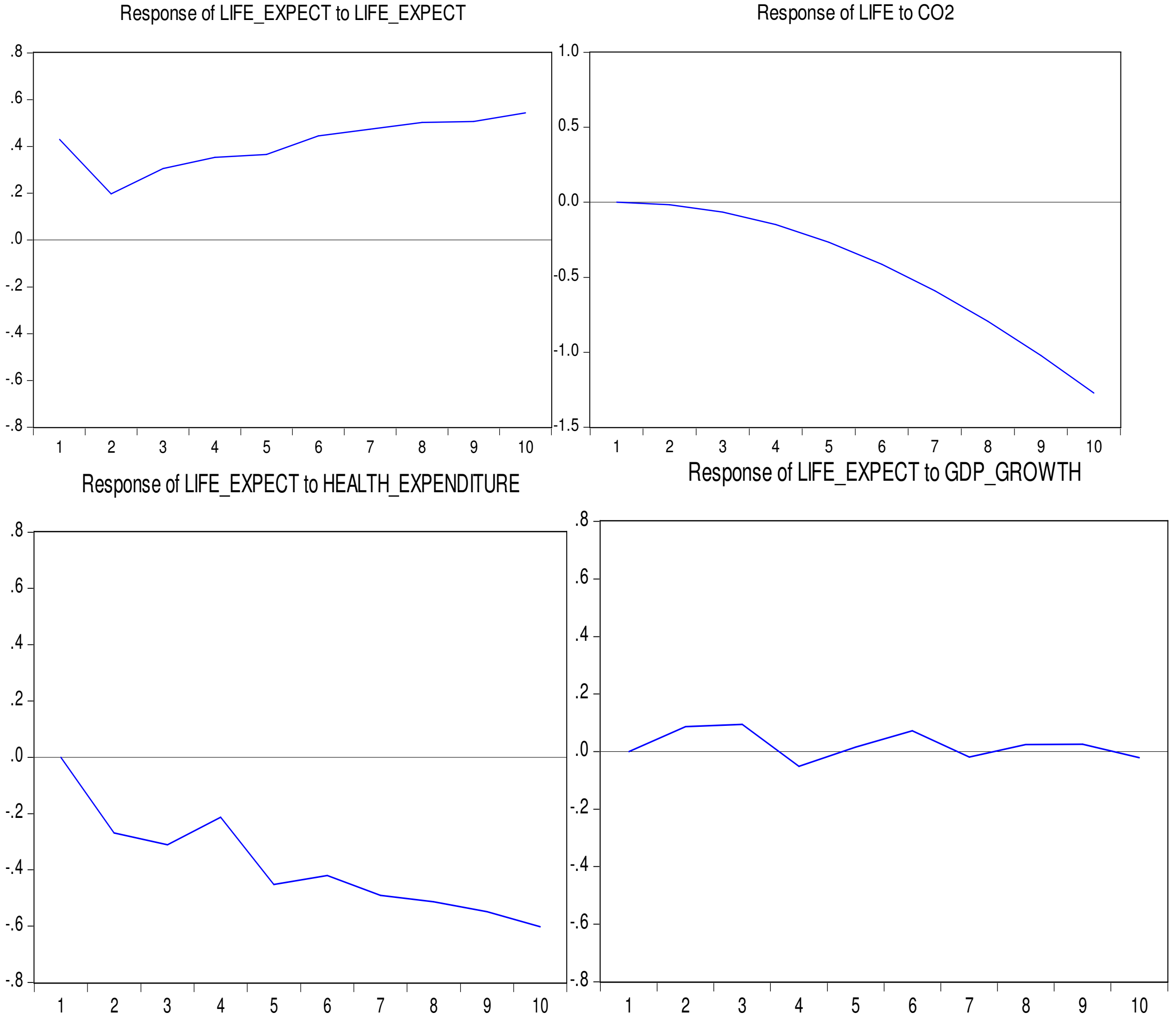
4.5 Impulse Response Analysis

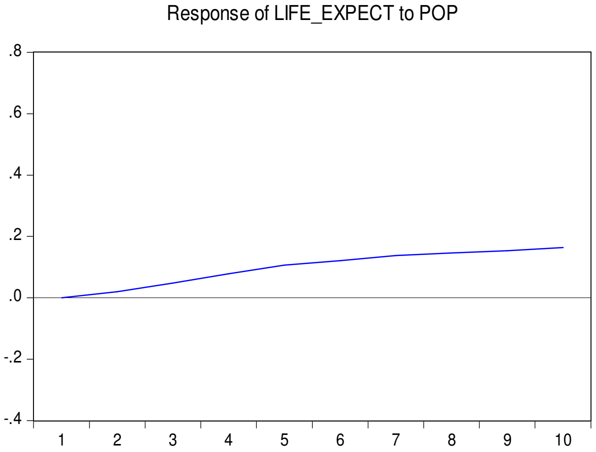
The impulse response functions trace the dynamic response to the effect of shock in one variable on the contemporaneous and future values of itself and on all other variables. The impulse responses of life expectancy to shocks in itself and the independent variables are shown in Figure 1. The initial response of life expectancy to an unanticipated change in life expectancy is positive throughout all the 10 quarters and significant for the first two periods after which it becomes constant. Life expectancy was initially irresponsive to a one standard deviation shock to carbon dioxide emission but becomes negative and significant from the second period onward. The response of life expectancy to shock in health expenditure per capita is negative and significant throughout all the quarters. Changes in GDP growth produces an initial positive impact on life expectancy which later becomes negative during the third period and returns to being positive after the fourth period and dies out afterwards. The response of life expectancy to shock in total population is positive throughout the 10 quarters and significant up to the fourth period after which the effect becomes muted as the time horizon increases. Thus, life expectancy responds differentially to shocks in the explanatory variables and the short-run equilibrium adjustment process is quite fast.

Table 6: Diagnostic tests neww

Breusch Godfrey Serial Correlation LM Test	
F-statistic	1.342830
Prob. (F. stat)	0.2719
Obs*R-squared	24.87137
Prob. (Chi-Square)	0.2064
Heteroskedasticity Test: Breusch-Pagan-Godfrey (BPG)	
F-statistic	2.958514
Prob. (F. stat)	0.0327
Obs*R-squared	10.14332
Prob. (Chi-Square)	0.2508
Histogram Normality Tests	
Jarque Bera	0.975427
Probability	0.614029

Figure 1: Response to generalized one S.D innovations





5. Conclusion

The paper examined the relationship between industrial pollution and public health in Nigeria using annual time series data for the time period 1971 - 2011. The relationships between life expectancy (a proxy for public health) , $C0_2$ emissions (a proxy for industrial pollution), GDP growth, health expenditure per capita and total population were established using cointegration, VECM and impulse response analysis. The stationarity tests reveal that except for GDP growth which was stationary at its level, all other variables were stationary at first difference. The cointegration test reveals the existence of three cointegrating equations which implies the presence of a long run relationship between the variables of interest. The vector error correction (VEC) estimates further establish presence of a causal relationship among the variables of which carbon dioxide emissions had the greatest impact on life expectancy both in the long run and in the short run. Impulse response analysis also indicates that the series are responsive to the various corresponding shocks.

6. Recommendations

The findings of the result show that carbon dioxide emission has the greatest impact on life expectancy in Nigeria. Therefore efforts aimed at improving public health should focus on observing the Kyoto Protocol (KP) agreement to reduce the emission of green house gases responsible for climate change of which carbon dioxide is the most significant factor. As c02 emerges as the main pollutant in the industrial sector, greater carbon dioxide emissions mean that more of a country's air is polluted which translates into serious health challenges with an overarching effect on life expectancy. The study therefore suggests ways of reducing the level of industrial emission from manufacturing industries and construction:

- Government should directly control industrial pollution by setting an optimal level of emission (externality) beyond which a firm is not allowed to produce.
- Nigerian government can also attempt to restore an optimal condition by imposing a tax on the firms responsible for the externality generation.; and
- Fostering bargaining between the parties (firms and consumers) involved to reach an optimal agreement on the level of externality.

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