A TIME SERIES MODELLING OF ENVIRONMENTAL DEGRADATION AS ITS AFFECTS MORTALITY

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***ABSTRACT*:** The relationship between air pollution and mortality has gained increasing attention in the past decade. Many time-series analyses have been conducted worldwide, including in all the major cities in the Africa, United States, Europe, and Asia. This conducted time-series analysis of Oyo State of Nigeria and then use a time series model to pool the results and construct a dose-response relationship and generate a predictive model. The study analyses the effect of environmental pollution on mortality in Oyo State, Nigeria. Data from the study were analyses using the Vector Autoregressive (VAR) Model. The study revealed that environmental pollution has impact on mortality in Oyo State, Nigeria. In conclusion, the study recommended a collaborative policy by government, and other stakeholders on curb diseases in oil producing areas.
KEYWORDS: Air pollution, vector autoregressive, modelling

1. INTRODUCTION

Oyo State is an oil and agricultural producing State in Nigeria, situated in the region known as the South-South geo-political zone with a population of over 4 million people, with estimated total land area of 16,842 square kilometers. The State has a huge deposit of crude oil and is also one of the largest producers of petroleum products in Nigeria. These natural endowments are not with their attendant problems, such as oil spillage, environmental degradation, etc. This leads to health-related challenges in the State.

There is a general perception that the various health challenges are as a result of constant exposure to pollution of the environment daily. The severity of the effect of environmental pollution varies from fatality to less severe cases such as such as increased use of inhalers by asthmatics [3]. Studies in advanced countries have shown that nearly 1% extra deaths may be brought forward by every 10 µg/m3 increase in PM_{10} (i.e., particulate matter with less than 10µm in diameter); for example, it is estimated that particles contribute to around 8,100 deaths per year in urban areas of Great Britain [4]. In 2002, the World Health Organization (WHO) Health Report, environmental pollution is the 13th greatest provider of deaths in the world [10].

Environmental pollution is the largest emission source of many health-related environmental pollutants such as carbon monoxide CO (59%), nitrogen oxides NOx (45%), benzene (32%), 1,3-butadiene (75%) and primary PM_{10} (25%), some of which contribute to the formation of ozone (O_3) and secondary particles [11]. These pollutants are often responsible for increase in admissions to hospital and even deaths among vulnerable population.

In modelling environmental pollution, several statistical methods have been suggested such as regression models, neural networks [5]. But these techniques are not sufficient in providing competence in modelling extreme concentration values. The search for better forecasting techniques to get reliable forecast is always vital. The frequently used forecasting models are univariate time series models like autoregressive model, moving average model, autoregressive moving average model, etc. or multivariate time series model. The merit of using multivariate time series model is such that along with incorporating past information of the target variable, allows the incorporation of inter-temporal interdependence of other variables for improving the forecasting performance. The commonly used multivariate time series model is vector autoregressive (VAR) model, but, the major setback of this model is the problem of overparameterization. By the nature of the model, it requires to estimate large number of parameters which leads to large standard error. So, if some restriction can be imposed on the parameters then the performance of the model can be improved. The objective of this study is to critically assess the impact of environmental pollution on mortality.

2. LITERATURE REVIEW

Etuonovbe (2009) study highlighted the dimensions, nature and characteristics of environmental problems and went to examine the effects of environmental degradation on the health and socio-economic well-being of the people of oil producing areas in Nigeria. Isola and Mesagan [9] also focused on the impact of oil production on human condition in Nigeria. The paper used environmental degradation, life expectancy, and infant mortality rate as proxies of human condition. The data were obtained from the statistical bulletin of the Central Bank of Nigeria and World Development Indicator. The study covered 1980 to 2012. Vector autoregressive (VAR) model and variance decomposition analysis were explored. The result indicated that oil production of the first period positively impacted environmental degradation, while it was negative in the second period; and that its first period lag has positive relationship, but second period lag has negative relationship with life expectancy. Also, the variance decomposition analysis showed that oil production worsened environmental degradation and adversely impacted on infant mortality rate, while it positively affected life expectancy

Related is a study carried out by Adekola at all [1], which evaluated health risk communication in the oil rich Niger Oyo region of Nigeria. The study was based on 69 interviews conducted in the Niger Oyo region. The study argued for and suggests ways in which health risk communication processes can be improved in the Niger Oyo. A multi-dimensional framework for public health risk communication is developed as a means of advancing understanding, practice, and policy.

Aworawo (n.d) examined the interlocking relationship between environmental degradation, poverty, and violent conflict in the oil-producing enclave of Nigeria. The article drew data from government records and reports of intergovernmental and non-governmental organizations as well as oral information gathered by the author from fieldwork between 2007 and 2012. The article concludes that the effective tackling of the environmental crisis would surely reduce poverty and violence in the area. The negative impact of oil pollution in Nigeria was also highlighted by [6] who opined that the situation has increased the vulnerability of households thereby affecting their wellbeing adversely, with a threat on the region's future means of sustenance; while governments response and remediation efforts aimed at restoring the regions ecosystem have not been very effective. It therefore calls for strengthening of the appropriate federal laws relating to oil exploration to ensure that oil companies operating in the region do so in compliance with proper environmental standards and international best practice.

Ejumudo [7], relied on focused group discussions, interviews and content analysis of relevant academic texts and journals to examined the environmental pollution and the effects of the serious health challenges it poses to people. The study which also revealed that the above abnormality is further aggravated by the somewhat disconnected and largely poor functioning and low performing health care delivery system in Nigeria.

3. MATERIALS AND METHODS

Vector Autoregressive (VAR)

A process y_t is said to be a vector autoregressive process of order p denoted by VAR (p) if it satisfies the equation

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t, \quad t = 0, \pm 1, \pm 2 \ldots, \; u_t \sim N(0, \sigma^2) \tag{3.1}$$

where $y_t = (y_{1t}, \ldots, y_{kt})'$ is a $(k \times 1)$ random vector, the A_i are fixed $(k \times k)$ coefficient matrices, $V = (V_1, \ldots V_k)'$ is a fixed $(k \times 1)$ vector of intercept terms allowing for the possibility of a non-zero mean, $E(y_t)$. Finally $u_t = (u_1, \ldots u_t)'$ is a k-dimensional white noise or innovation process, that is,

$$E(u_t) = 0$$
$$E(u_t u_t') = \Sigma_u$$
$$E(u_t u_s') = 0 \quad for\ t \neq s$$

The covariance matrix Σ_u is assumed to be non-singular, if not otherwise stated.

For P = 1, $VAR(1)$ model:

$$y_t = v + A_1 y_{t-1} + u_t \tag{3.2}$$

A stochastic process is stationary if its first and second moments are time invariant. In other words, a stochastic process y_t is stationary if

$$E(y_{t)} = \mu \; for\ all\ t \tag{3.3}$$

and

$$E(y_t - \mu)((y_{t-h} - \mu)') = \Gamma_y(h) = \Gamma_y(-h)' \quad \forall\ t\ and\ h = 0,1,2,\ldots \tag{3.4}$$

For a higher order $VAR(p)$ process,

$$y_t - \mu = A_1(y_{t-1} - \mu) + \cdots + A_p(y_{t-p} - \mu) + U_t \tag{3.5}$$

The Yule-Walker equations are also obtained by post multiplying with $(y_{t-h} - \mu)'$ and taking expectations. For h= 0, using $\Gamma_y(i) = \Gamma_y(-i)'$.

$$\Gamma_y(0) = A_1\Gamma_y(-1) + \cdots + A_p\Gamma_y(-p) + \Sigma_u = A_1\Gamma_y(1)' + \cdots + A_p\Gamma_y(p)' + \Sigma_u \tag{3.6}$$

and for $h > 0$,

$$\Gamma_y(h) = A_1\Gamma_y(h-1) + \cdots + A_p\Gamma_y(h-p) \tag{3.7}$$

These equations may be used to compute the $\Gamma_y(h)$ recursively for $h \geq p$, if $A_1, \dots, A_p$ and $\Gamma_y(h-p), \dots, \Gamma_y(0)$ are known.
The initial autocovariance matrices for $|h| < p$can be determined using the $VAR(1)$ process,

$$Y_t - \mu = A(Y_{t-1} - \mu) + U_t \qquad (3.8)$$

whereY_t , A, and U_t as in (7) and $\mu = (\mu', \dots, \mu') = E(Y_t)$.
Since the autocovariance depend on the unit of measurement used for the variables of the system, they are sometimes difficult to interpret. Therefore, the autocorrelations $\rho_y(h) = D^{-1}\Gamma_y(h)D^{-1}$ are usually more convenient to work with as they are scale invariant measures of the linear dependencies among the variables of the system. Here D is a diagonal matrix with the standard deviations of the components of $y_t$on the main diagonal. That is, the diagonal elements of D, are the square roots of the diagonal elements of $\Gamma_y(0)$. Denoting the covariance between $y_{i,t}$and $y_{j,t-h}$ by $\Sigma_{ij}(h)$ is the i, t, h elements of $\Gamma_y(h)$ the diagonal elements $\gamma_{11}(0), \dots, \Sigma_{kk}(0)$ of $\Gamma_y(0)$ are the variances of $y_{1t}, \dots, y_{kt}$. Thus

$$D^{-1} = \begin{pmatrix} \frac{1}{\sqrt{\Sigma_{11}(0)}} & 0 \\ 0 & \frac{1}{\sqrt{\Sigma_{kk}(0)}} \end{pmatrix}$$

and the correlation between $y_{i,t}$ and $y_{j,t-h}$ is

$$\rho_{ij}(h) = \frac{\Sigma_{ij}(h)}{\sqrt{\Sigma_{ii}(0)}\sqrt{\Sigma_{jj}(0)}} \qquad (3.9)$$

which is just the ithelement of $\rho_y(h)$.

Vector Autoregressive VAR Models Analysis

The vector autoregressive model will be used to examine several economic time series at a time. The vector autoregression (VAR) will be used to determine the inter-relationship between economic time series and analyzing the dynamic impact of random disturbances on the system of variables. The VAR approach sidesteps the need for structural modeling by treating every endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system. The VAR process is defined as;

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + Bx_t + u_t \qquad (3.10)$$

where y_t is a k vector of endogenous variables, x_t is a d-vector of exogenous variables, $A_1, \dots, A_p$and B are matrices of coefficients to be estimated, u_t and is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.
In this study, the relationship between environmental pollution and mortality will be examined by VAR

4. EMPIRICAL ANALYSIS AND RESULTS

The result of various analysis carried out in this research work are presented in this section.

4.1 Data Used

PM – Particle Matter
Mortality – Mortality Rate
The models (VAR (2)) to be fitted to the data are
Model I:

$$PM_t = \alpha_1 MOR_{t-1} + \alpha_2 MOR_{t-2} + \beta PM_{t-1} + e_t$$

4.2 Descriptive Analysis

The trend plot was used to explain the characteristics of the variables with a view of showing the important features.

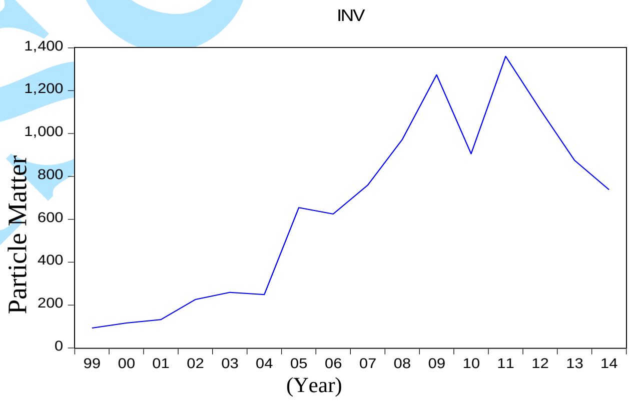

Fig. 1 Time series plot of Particle Matters, Oyo State 2000-2015

The time plot for the PM shows a sinusoidal increase in the values of the PM over the period of time.

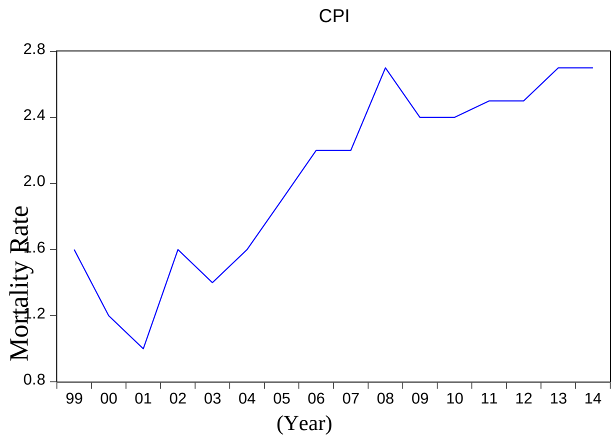

Fig. 2: Time series plot of Mortality Rate, 2000-2015

The time plot for Mortality Rate shows an upward movement, which indicates an increase of mortality overtime

4.3 Test for Stationarity

In testing for stationarity, the Augmented Dickey-Fuller (ADF) test was used. The test results are as presented below:

Table 4.1: Augmented Dickey-Fuller Unit Root Test

Series	ADFR Test Statistic	5% Critical Values	10% Critical values	Order	Remarks
PM	-1.783871	-3.0124	-2.6461	I(1)	Stationary
Mortality Rate	-4.680257	-3.0207	-2.6504	I(1)	Stationary

The empirical tests on unit root test above shows that investment by PM and Mortality Rate are integrated of order one. Thus, the series are said to be stationary at that level.

4.4 Vector autoregressive estimation

4.4.1 Vector Autoregressive Model for PM, 2000-2015

Vector Autoregression Estimates
Date: 03/01/19 Time: 12:16
Sample (adjusted): 2001 2015
Included observations: 14 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	PM
PM(-1)	0.386948
	(0.28946)
	[1.33679]
PM(-2)	0.187539
	(0.26089)
	[0.71886]
MORTALITY RATE	165.3001
	(76.4386)
	[2.16252]
R-squared	0.742619
Adj. R-squared	0.695822
Sum sq. resids	522979.6
S.E. equation	218.0450
F-statistic	15.86908
Log likelihood	-93.56282
Akaike AIC	13.79469
Schwarz SC	13.93163
Mean dependent	724.4918
S.D. dependent	395.3505

The model obtained is given as:

$$PM_t = 0.386948MOR_{t-1} + 0.187539MOR_{t-2} + 165.3001PM_{t-1}$$

This is the vector autoregressive model for PM, is explained and determined by the Mortality Rate in its first and second lag by observing the values of t-statistics in the parenthesis above. That is, Mortality Rate determines the PM in its first lag.

The value of R^2 (0.7426) shows that (74%) variation in the PM is explained by the MORTALITY RATE and the value of adjusted R^2 squared (0.6958) shows it is good fit.

4.4.2 Vector Autoregressive Model for Mortality Rate, 2000-2015

Vector Autoregression Estimates
Date: 03/01/19 Time: 12:16
Sample (adjusted): 2001 2014
Included observations: 14 after Adjustments
Standard errors in ( ) & t-statistics in [ ]

	MORTALITY RATE
MORTALITY RATE(-1)	0.742884
	(0.29598)
	[2.50991]
MORTALITY RATE(-2)	0.298360
	(0.27174)
	[1.09795]
PM	3.27E-05
	(0.00033)
	[0.10042]
R-squared	0.774921
Adj. R-squared	0.733998
Sum sq. resids	0.861729
S.E. equation	0.279891
F-statistic	18.93591
Log likelihood	-0.350041
Akaike AIC	0.478577
Schwarz SC	0.615518
Mean dependent	2.128571
S.D. dependent	0.542684

The model obtained is given as:

$$\mathrm{MOR_t} = 0.742884PM_{t-1} + 0.298360PM_{t-2} - 0.0000327MOR_{t-1}$$

This is the vector autoregressive model for Mortality Rate, is explained and determined by PM in its first lag and Mortality Rate in the first lag and second lag. The value of R^2 (0.7749) shows that (77%) variation in the Mortality Rate is explained by the PM and the value of adjusted R^2 squared (0.7339) shows it is good fit.

Table 4.3: Forecast for 2016

DATA	PREDICTIONS			
	PM		MORTALITY RATE	
	2015	2016	2015	2016
2000-2015	-	896.069	-	2.8

5. CONCLUSIONS AND RECOMMENDATIONS

The study examined the impact of environmental pollution on mortality rate in Oyo State, Nigeria. In the study, the data were tested for stationarity using the Augmented Dickey-Fuller test and the test showed that PM and Mortality Rate were all stationary and fit for modelling.

The study employed Vector Autoregression (VAR) model. PM was used as proxy for environmental pollution and mortality rate. The empirical analysis reveals that there is a long run relationship between environmental pollution and mortality in Oyo State, Nigeria and that the impact of environmental pollution on mortality in Oyo State, Nigeria is undesirable from the VAR result.

The model equation was obtained from the study using data for 2000-2015. We were able to obtain predicted results 2016. The results showed that the predicted PM for 2015 and the actual PM for 2015, there is wide difference between the two figures. The predicted PM for 2015 appears to higher than the actual PM for 2015. The predicted Mortality Rate for 2015 appears to be higher than the actual Mortality Rate for 2015. The predicted PM for 2016 using 2000-2014 data appears to higher than the predicted PM for 2016 using 2000-2015 data. Similarly, the predicted Mortality Rate for 2016 using 2000-2014 data appears to higher than the predicted Mortality Rate for 2016 using 2000-2015 data.

In conclusion, the study recommended a collaborative policy by government, and other stakeholders on curb diseases as a result of environmental pollution.

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