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Modeling Metrological Parameter via Vector Autoregressive

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Abstract: The study modeling metrological data using vector autoregressive focuses on analyzing of monthly rainfall and temperature over a selected state in Southern Nigeria, covering a period of 1972 – 2011. One of the key objectives of every study of meteorological parameters is to determine the fluctuations and trend over the years and area of study. The research aims at providing quantitative analysis of the dynamics on meteorological parameters the rainfall and temperature in Niger Delta. This study utilizes secondary data obtained from the meteorological station. The sample covers monthly data from 1972 - 2011. The study employed the newly developed multivariate time series estimation technique via Vector Autoregressive modeling to model the rainfall and temperature over the period of study. The study on the evaluation of rainfall and temperature trends in the Niger Delta region of Nigeria reveals some facts about the meteorological parameter of selected stations in Niger Delta for the period under investigation. The research obtained a stable model for the vector autoregressive for the two meteorological parameters. The study has examined recent trends and fluctuations of annual rainfall and temperature of southern Nigeria between 1972 to 2011. The predicted value from the modeled data suggests continues increase in amount of monthly rainfall and temperature with their confidence interval.
Keywords: Modelling, time series, metrological parameter, rainfall, temperature, var.

INTRODUCTION

Extreme weather and climate events have constituted serious threat to global economic growth over the past few years, especially to the socio-economy of developing nations. In Nigeria, especially the Southern part, severe floods, windstorms, heat waves and several other extreme weather and climate events have impacted negatively on its socio-economy and many people have been affected physically and psychologically. This has prompted calls for action at every level of government and across many sectors of economy and society.

Global warming refers to an average increase in the earth's temperature, which in turn causes changes in climate [1]. The term "climate change" is often used interchangeably with "global warming." However, given the wide range of impacts beyond temperature variations, the former is generally the preferred in the scientific community because it helps convey that there are other changes in addition to rising temperatures [2]. Climate change refers to the variation in the earth's global climate or in regional climates over time. It describes changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities [3]. In recent usage, especially in the context of environmental policy, the term "climate change" often refers only to changes in modern climate, including the rise in average surface temperature known as global warming. In some cases, the term is also used with a presumption of human causation [2].

It is therefore pertinent to establish a suite of coordinated activities that will examine the serious and sweeping issues associated with global climate change, including the science and technological challenges involved, and provide advice on actions and strategies nation can take to respond to it.

Meteorological Parameter under Study

Two basic parameters were seemed to have profound effect on the micro climate of the southeastern Nigeria and for which data are available for a period of forty years. These parameters are air temperature and amount of rainfall.

Air Temperature

Air temperature is a measure of how hot or cold the air is. It is the most commonly measured weather parameter. More specifically, temperature describes the kinetic energy, or energy of motion, of the gases that make up air. As gas molecules move more quickly, air temperature increases. Air temperature affects nearly all other weather parameters. For instance, air temperature affects the rate of evaporation, relative humidity, wind speed and direction, precipitation patterns and types, such as whether it will rain, snow, or sleet [4]. Maximum and minimum temperatures are measured by specialized thermometers called minimum and maximum thermometers. They are generally fitted with two indices such that one moves only when liquid in the tube shrinks and the other when it expands. This is how the minimum and maximum temperatures are noted. Today we have automated devices with memory which stores the maximum and minimum temperatures after every 24 hours. In Nigeria, surface air temperatures are generally high especially in the northern part of the country since it lies in the tropic Newman *et al.* [5].

Rainfall

Climate and its changes manifest in various ways commonly expressed as elements among which is rainfall. Rainfall as climate element is a condensed water vapour in the atmosphere, which is a liquid form of manifestation of precipitation in the earth atmosphere system. It is often in the form of small drop of water, shower or storm. Nigeria is located in the low pressure zone of the earth and due to its proximity to the Atlantic Ocean; she experiences heavy rainfall especially in the southern part of the country. Rainfall is a climate parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive. Hence the study of rainfall is important and cannot be over emphasized [6]. Aside the beneficial aspect of rainfall, it can also be destructive in nature; natural disasters like floods and landslides are caused by rain [7]. Rain gauges are used to measure rainfall. The standard rain gauges consist of a funnel-shaped collector that is attached to a long measuring tube. Modern day rain gauges are automated with memory systems to measure various aspects of rainfall such as the rate of rainfall; daily, weekly and monthly totals. Some instruments incorporate other meteorological parameters such as maximum and minimum temperature and relative humidity [5].

Global Climate System

The key to understanding global climate change is to first understand what global climate system is and how it operates. At the planetary scale, the global climate is regulated by how much energy the Earth receives from the Sun. However, the global climate is also affected by other flows of energy which take place within the climate system itself. This global climate system is made up of the atmosphere, the hydrosphere, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere), which all affect, to a greater or lesser extent, the movement of heat around the Earth's surface. The atmosphere, however, does not operate as an isolated system. Flows of energy take place between the atmosphere and the other parts of the climate system, most significantly the world's oceans. The significance of the oceans is that they store a much greater quantity of heat than the atmosphere. The top 200 meters of the world's oceans store 30 times as much heat as the atmosphere [8]. Therefore, flows of energy between the oceans and the atmosphere can have dramatic effects on the global climate. A drastic change in the climate systems either due to natural forces or unsustainable human activities results in climate change. The alteration of the climate system which leads to climate variation and change is caused by both natural and anthropogenic factors. The cause of the current climate change has been attributed to anthropogenic factors and among these human factors; carbon is a major contributor.

Various scientists have studied the different components of climate change to some extent. The causes of climate change have been scientifically studied and showed that industrialization; urbanization, water pollution, deforestation and transportation are among the highest contributors [9-13]. Other researchers have concentrated on the effects of climate change and revealed that it has started impacting and will continue to impact on human health, ecological destabilization, melting of polar ice, sea level rise, coastal flooding, desertification, aggravation of coastal and gully erosion and extreme weather conditions among others [14-26] .Some research efforts have also been focused on mitigation and adaptation to climate change and the few studies in this area show that while climate change is caused more by the developed countries, the developing nations will suffer more of the effects because of their high level of vulnerability and low level of adaptation measures due to poverty and low technological development [27, 28, 2, 29-31. Climate change is expected to have serious environmental, economic, and social impacts on Nigeria in general and the Niger Delta in particular. The rural farmers, whose livelihoods depend on the use of natural resources, are likely to bear the brunt of adverse impacts of climate change. People's perception of climate change may be the most important factor determining their willingness to accept the scientific conclusion that humans are causing global warming. The above review shows quite an array of research works in the science of various aspects of climate change. But the pertinent question is this: Is the outcome of these studies on climate change available to the general populace? Rukevwe [32] shows that much emphasis has been devoted to the science of climate change but the education of the people and how they perceive the causes and impacts is lacking. Pam [33] also reveals that while the concept of climate change is fully known to majority of those in the atmospheric science, it might not be so for many educated individuals in other disciplines and the uneducated ones.

This study is designed to contribute to the continuing critical assessment of the state of the Nation's climate with specific objective of analyzing the trend of both air temperature and rainfall in the Niger Delta as it affects some selected locations in the region within a 40 year period (1972-2011).

RESEARCH METHODOLOGY

The data type and source of this study employ mainly, the secondary annual temperature and rainfall time series data. Data used in the analysis was sourced from Meteorological data 1972 to 2011in the respective three stations from the archives of Nigeria Meteorological services Department of Calabar, Portharcourt and Owerri. Availability and reliability of the annual rainfall and temperature data were considered foremost as these locations are longstanding operational synoptic stations, standard equipments and personnel. The descriptive and quantitatively method of analysis was employed, charts such as time plots and tables to aid in the empirical analysis.

Stationary test was carried out on the variables, further study adopts the multivariate time series analysis of vector autoregressive model (VAR) approach to model, estimate and forecast the metrological parameters in the selected region. All analysis and estimations were carried out using the statistical and econometrics package e.g. (R, E-View and SPSS).

Model Specification

Model specification in the present context involves selection of the VAR order. Lutkepohl [34] because the number of parameters in these models increases with the square of the number of variables it is also often desirable to impose zero restrictions on the parameter matrices and thereby eliminates some lagged variables from some of the equations of the systems. The most common procedures for VAR order selected are sequential testing procedure and application of model selection criteria. For the purpose of this research study the model selection criteria was applied.

Gebhard and Jurgen [35], to estimate the system, the order p i.e. the maximal lag of the system has to be determined. The multivariate case with k variables, T observations, a constant term and a maximal lag of p, these criteria is

Akaike information criterion (AIC)

$$AIC\ (P) = ln\left|\Sigma_{\hat{u}\hat{u}(p)}\right| + (K + Pk^2)\frac{2}{T}$$

where $/\sum \hat{u}\hat{u}(p)\ /$ is the determinant of the variance covariance matrix of the estimated residuals.

Lutkepohl [34], AIC suggests the largest order; the choice of the best model is based on the model selection criteria, the minimum model selection criteria compared to others.

VAR Representation

Sims [36] developed VAR model and the stochastic part y_t is a assumed to be generated by a VAR process of order p (VAR (p)) of the form.

$$Y_t = A_{1y_{t-1}} + A_{2y_{t-2}} + \cdots + A_{py_{t-p}} + \mu_t + \varepsilon_t \qquad (3.1)$$

Where

$A_i \quad \forall i = 1,2, \dots p$ are (kxk) parameter matrices.

The error process $\mu_t = (\mu_{1t}\mu_{2t}, \dots \mu_{kt})'$ is a k – dimensional zero mean white noise process with covanance matrix.

$E(\mu_t, \mu_t') = \varepsilon_\mu$

In matrix notations the m time series

$$y_{it}, \quad i = 1,2, \dots m, \quad \text{and} \quad t = 1, \dots T$$

Where

t is the common length of the time series.

Also employing the bivariate case of the parameters the study produced the VAR (2) model based on the input series of interest at every input defined as.

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} a_{11}^{(1)} & a_{12}^{(1)} \\ a_{21}^{(1)} & a_{22}^{(1)} \end{pmatrix} \begin{pmatrix} y_{1,t-1} \\ y_{2,t-1} \end{pmatrix} + \begin{pmatrix} a_{11}^{(2)} & a_{12}^{(2)} \\ a_{21}^{(2)} & a_{22}^{(2)} \end{pmatrix} \begin{pmatrix} y_{1,t-2} \\ y_{2,t-2} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \quad (3.2)$$

Where

$Y_t = (y_{1t}, y_{2t}, \dots y_{mt})'$ denote $(nx1)$ vector of time series variables

A_i are (nxn) coefficient matrices

ε_t is an $(nx\ 1)$ unobservable zero mean white noise vector process.

Portmanteau Test

The portmanteau test for residual autocorrelation checks the null hypothesis that all residual autocovariances are zero, that is

$$H_o: \epsilon(u_t, u'_{t-1}) = 0 \quad i = 1\ 2 \dots..$$
$$H_1: \epsilon(u_t, u'_{t-1}) \neq 0 \quad i = 1\ 2 \dots..$$

The test statistic is based on the residual autocovariances and has the form

$$Q_h = T \sum_{j=1}^{h} t_r\left(\hat{C}_j' \hat{C}_o^{-1} \hat{C}_j \hat{C}_0^{-1}\right) \quad (3.3)$$

Where

$\hat{C}_j = T^{-1} \sum_{t=j+1}^{T} \hat{u}_t \hat{u}'_{t-j}$

$\hat{u}'_t$ are the estimated residuals.

For an unrestricted stationary VAR (p) process the null distribution of Q h can be approximated by a $k^2(k^2(h-p))$

Distribution if T and h approach infinity such that h/T → 0. If there are parameters restriction the degrees of freedom of the approximated x^2 distribution are obtained as the differences between the number of (non-instantaneous) auto-covariance included in the statistics (k^2h) and the number of estimated VAR parameters.

Forecasting

Forecasting from a VAR (p) is a straight forward extension of forecasting from an Autoregressive (p), Nwafor *et al*. [37]. The multivariate wold form is

$Y_t = \mu + \varepsilon_t + \Psi_1 \varepsilon_{t-1} + \Psi_2 \varepsilon_{t-2} +$ (3.4)

$$Y_t = \mu + \varepsilon_t + \Psi_1 \varepsilon_{t+h-1} + \cdots + \Psi_{h-1} \varepsilon_{t+1}$$

Noted that

$$E(Y_t) = \mu$$
$$Var(Y_t) = E[(Y_t - \mu)(Y_t - \mu)']$$
$$= E\left[\left(\sum_{k=1}^{\infty} \Psi_k \varepsilon_{t-k}\right)\left(\sum_{k=1}^{\infty} \Psi_k \varepsilon_{t-k}\right)^{/}\right]$$

$= \sum_{k=1}^{\infty} \Psi_k \sum \Psi_k'$ (3.7)

The minimum MSE linear forecast of Y_{t+h} based on it is

$$Y_{t+h}/t = \mu + \Psi_h \varepsilon_t + \Psi_{h+1} \varepsilon_{t-1} +$$

The forecast error is

$\varepsilon_{t+h/t} = Y_{t+h} - Y_{t+h/t},$

The forecast error MSE is

$$MSE\left(\varepsilon_{t+\frac{h}{t}}\right) = E\left[\varepsilon_{t+h/t} \varepsilon'_{t+h/t}\right]$$
$$= \sum + \Psi_1 \sum \Psi_1' + \cdots + \Psi_{h-1} \sum \Psi_{h-1}'$$
$$= \sum_{s=1}^{h-1} \Psi_s \sum \Psi_s'$$

RESULTS AND DISCUSSION

The descriptive statistics of the variables are presented in table 4.1 that is the summary statistics of the transformed data for the stations under study. This is to ascertain the degree of variability in each of the series which is necessary to ensure that they can be used in any analysis. There is variability in the raw data since all of them have different units of measurement. Therefore, there is a need for transformation in order to bring stability in the data and variables of interest. The data was then transformed to the natural logarithm (ln). From the VAR (2) it was show in table 4.9 that the test is valid only for lags larger than the VAR lag order which indicates that the model selected achieves its adequacy or is adequate enough to be used in the economic policy. The model checking technique applied in this study was effective enough; also the stability analysis on the model indicates the adequacy of the model at the lag order selection criterion.

Based on the summary of the model selection criteria, Table 4.2, 4.3, and 4.4 computes various criteria to select the lag order of an unrestricted VAR in Portharcourt, Calabar and Owerri respectively. The table displays various information criteria for all lags up to the specified maximum. (If there are no dependent variables in the VAR, the lag starts at 1; otherwise the lag starts at 0.) The table indicates the selected lag from each column criterion by an asterisk “*”. For columns 0–2, these are the lags with the smallest value of the criterion. All the criteria are discussed in Lütkepohl [34].

Table 4.6 present the rate of change of annual rainfall and temperature in the study area it was observed that the rate differs to stations [38]. From the analysis it indicates that Owerri have the highest rate of change as regards to the two parameters in view to rainfall and Calabar having the least rate.

Fluctuation and trend in annual rainfall and temperature in three stations shown in fig.1, 2, 3. The fig1 particularly the Portharcourt, within the study area had the highest rainfall in 2004 with the least rainfall in 1986 the study also had an upward trend in the periods under investigation with a great fluctuations over the periods. From the study one can observe that Portharcourt experiences much rainfall from 1992 to 2011. The temperature of Port Harcourt from the study shows very slow increase in temperature over the investigated time.

The fig.2 Calabar, within the study area had the highest rainfall in 2004 with the least rainfall in 1989 the study also had an upward trend in the periods under investigation with a great fluctuations over the periods. The study reviews that Calabar experiences much rainfall from 2000 to 2011. The temperature changes very small with little changes as to compare to the other two parameters[39].

The fig.3 Owerri, within the study area had the highest rainfall in1976 with the least rainfall in 1989 the study also had an upward trend in the periods under investigation with a great fluctuations over the periods. The study reviews that owerri experiences much rainfall from 1997 to 2011. The temperature changes very small with little changes with a rate of change of 0.010.

There is an obvious indication that rainfall is key in determining the activities pertaining to the meteorological parameters over time. These parameters are sensitive and hence affect every sector of the economy[40]. It is therefore not surprising that temperature and rainfall are of great important to man and environment.

Table-4.1: Descriptive Statistics for Portharcourt, Calabar and Owerri

STATION	PH	PH	CALABAR	CALABAR	OWERRI	OWERRI
Statistic	RAINFALL	TEMP	RAINFALL	TEMP	RAINFALL	TEMP
Mean	4.97	3.31	5.01	3.29	4.35	3.27
Median	5.46	3.31	5.52	3.29	5.23	3.27
Maximum	6.67	3.39	6.68	3.44	6.05	3.39
Minimum	0.18	3.16	-2.30	3.12	-3.22	3.19
Std. Dev.	1.38	0.04	1.42	0.05	1.71	0.05
Skewness	-1.36	-0.50	-1.85	-0.14	-1.27	0.37
Kurtosis	4.15	3.45	6.85	3.34	3.70	2.14
Probability	0.00	0.00	0.00	0.16	0.00	0.00
Sum	2366.08	1576.72	2300.66	1510.12	1873.36	1410.16
Sum Sq.Dev.	900.85	0.68	929.36	1.01	1256.77	0.93

The Meteorological Parameter Model

The Port Harcourt model

$$RAINFALL = 0.65348 * RAINFALL(-1) - 0.09996 * RAINFALL(-2) - 4.7979 * TEMP(-1) + 7.90578 * TEMP(-2) - 8.0764$$

$$TEMP = -0.00346 * RAINFALL(-1) - 0.00638 * RAINFALL(-2) + 0.47004 * TEMP(-1) - 0.03269 * TEMP(-2) + 1.9127$$

The Calabar model

$$RAINFALL = 0.500163 * RAINFALL(-1) - 0.0617 * RAINFALL(-2) - 8.2949 * TEMP(-1) + 9.6816 * TEMP(-2) - 1.7639$$

$$TEMP = -0.00735 * RAINFALL(-1) - 0.00586 * RAINFALL(-2) + 0.61475 * TEMP(-1) - 0.1659 * TEMP(-2) + 1.8897$$

The Owerri model

$$RAINFALL = 0.7023 * RAINFALL(-1) - 0.14694 * RAINFALL(-2) - 6.94005 * TEMP(-1) + 11.412 * TEMP(-2) - 12.69455$$

$$TEMP = -0.004985 * RAINFALL(-1) - 0.0097 * RAINFALL(-2) + 0.5476 * TEMP(-1) - 0.2369 * TEMP(-2) + 2.3142$$

Table-4.3: Vector Autoregressive Lag Order Selection Criteria for Calabar

Lag	LogL	LR	FPE	AIC	SC	HQ
0	2.530571	NA	0.003419	-0.002521	0.016684	0.005069
1	209.2429	410.4786	0.001305	-0.965524	-0.907910	-0.942755
2	236.9456	54.74745*	0.001166*	-1.078126*	-0.982102*	-1.040177*

Table-4.4: Vector Autoregressive Lag Order Selection Criteria for Owerri

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3.884237	NA	0.003542	0.032600	0.054145	0.041165
1	186.4922	377.5887	0.001261	-0.999957	-0.935322	-0.974259
2	234.0925	93.88209*	0.000991*	-1.241510*	-1.133785*	-1.198681*
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level))						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

The results indicate that the VAR (2) model estimated does not suffer from serial correlation and the residuals are normally distributed. Also since the eigen values are found in the unit circle, the VAR is said to be stable. The inverse roots of autoregressive characteristic polynomial explains better of the AR Graph see fig 4.

More so, the Vector Autoregressive model satisfies the stability condition that the Eigen values of the companion matrix have modulus less than one. The roots of characteristic polynomial on the parameters could be found in figure 4.

The specification and estimating a model and checking its adequacy is of great interest. The VAR Residual Portmanteau Tests for Auto correlations applied in the study shows that the VAR (2) was adequate for the study. Hence the model is adequate for economy policy in Nigeria. The results of these diagnostics are also presented in the study (table 4.5).

Table-4.5: VAR Residual Portmanteau Tests for Autocorrelations

Null Hypothesis: no residual autocorrelations up to lag h					
Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	5.518125	NA*	5.533453	NA*	NA*
2	20.93107	NA*	21.03227	NA*	NA*
3	26.64756	0.004	26.79666	0.0004	7
4	46.17448	0.0000	46.54237	0.0000	11
5	55.75958	0.0000	56.26209	0.0000	15
6	60.55496	0.0000	61.13852	0.0000	19
7	77.77517	0.0000	78.69924	0.0000	23
8	88.89709	0.0000	90.07321	0.0000	27
9	92.61220	0.0000	93.88331	0.0000	31
10	98.23721	0.0000	99.66858	0.0000	35
11	114.0993	0.0000	116.0292	0.0000	39
12	243.9152	0.0000	250.3087	0.0000	43
*The test is valid only for lags larger than the VAR lag order.					
df is degrees of freedom for (approximate) chi-square distribution					

Table-4.6: Rate of Change of Annual Rainfall and Temperature in the Study Area

Station	Rainfall(mm)	Temperature(c)
Calabar	0.004	0.002
Porthacourt	0.097	0.012
Owerri	0.116	0.010

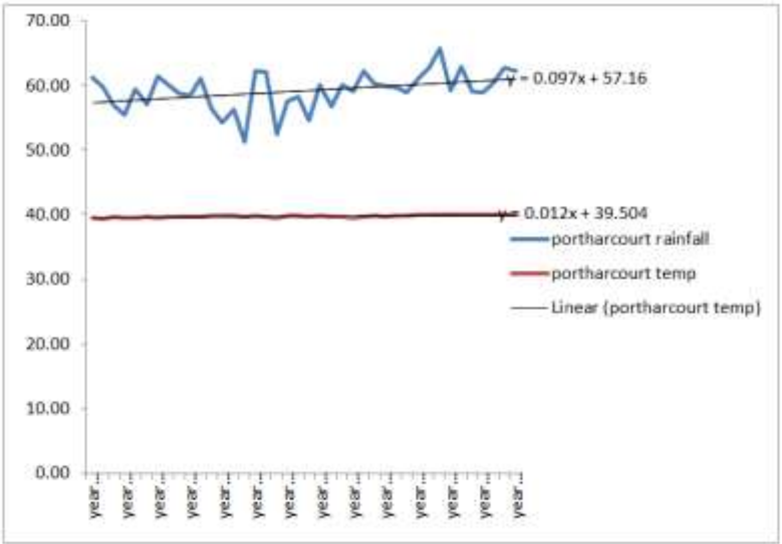

Fig-1: least square trend analysis for Portharcourt

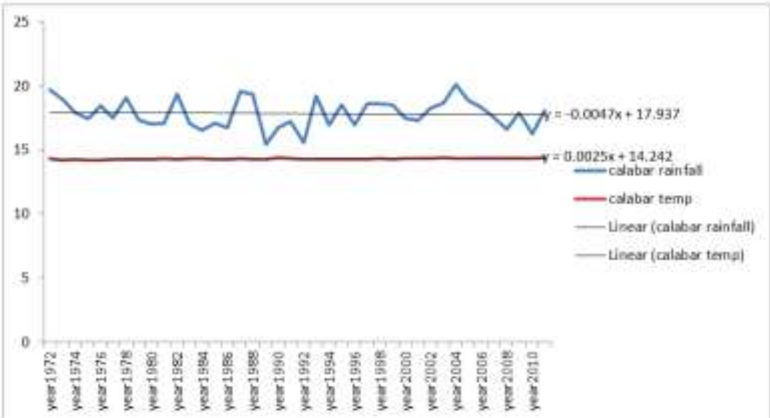

Fig-2: least square trend analysis for Calabar

Fig-3: least square trend analysis for Owerri

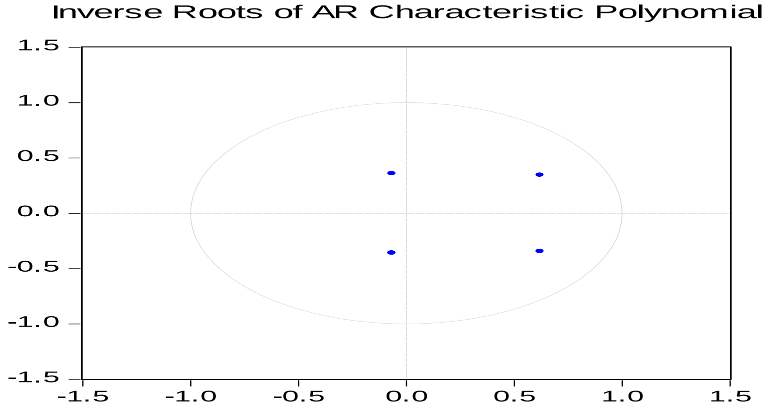

Fig-4: AR Characteristic Polynomial of the endogenous graph of the meteorological parameter

CONCLUSION

The present study has sought to model meteorological parameter in Niger Delta using the vector auto-regressive (VAR) model, estimate the parameters of the models, and establish model adequacy and stability analysis for the meteorological parameter. There are variations in the raw data because the entire meteorological parameter has different units of measure. In order to bring stability and uniformity, all the data was transformed or transformation was done in natural logarithm (ln).

The study reveals some facts about the meteorological parameter of selected stations in Niger Delta for the period under investigation. The research obtained a stable model for the vector autoregressive for the two meteorological parameters. The study also provides forecast value for the next two years from the last period of investigation. The study has examined recent trends and fluctuations of annual rainfall of southern Nigeria between 1972 and 2011. The temporal pattern suggests a fluctuating and significant increase trend in all the locations. The study concluded that at present, the climate of the region indicates a tendency towards wetter condition.

The policy implication is that the economy of Nigeria is quite responsive to specifically the meteorological parameters mentioned in this study. Consequently, predicting changes in the meteorological parameters by economic factors is of great importance in decision making. The fact is that regarding rainfall and temperature, the predictive ability is actually in order. Policy direction consequent upon the empirical results is to sensitize the economic and agricultural policy makers to carefully utilize the factors which affect some of these key parameters in Niger Delta particularly.

Finally, due to the importance and the impact of these parameters used in the study, some critical steps were recommended by the researcher based on his investigations to curb the economic meltdown or setback. These steps include:

- That the model should be applied in economy policy in Nigeria.
- That decision makers should critically look or help streamline the investment patterns of the economy with respect to the meteorological parameters.
- That further research should be conducted on other meteorological parameters.

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