NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 6, ISSUE 6, June -2020

OPEN DEFECATION IN CHAD: A BOX-JENKINS ARIMA APPROACH

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ABSTRACT:

Using annual time series data on the number of people who practice open defecation in Benin from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2018 – 2022. This study applies the Box-Jenkins ARIMA approach. The diagnostic ADF tests show that the ODH series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (4, 1, 0) model as the optimal model. The diagnostic tests further reveal that the presented forecasting model is stable and its residuals are stationary in levels. The results of the study indicate that the number of people practicing open defecation in Benin is likely to decline over the period 2018 – 2022, from 67% to 66% of the total population. This means that by 2022, open defecation in Chad would have reduced by a merely 1%!!! This is simply unacceptable and it points to the fact that the practice of open defecation in Chad has become habitual and strongly persistant. The good news is that, with adequate commitment, it is possible to end open defecation in Chad. The study suggested a 3-fold policy recommendation to be put into consideration, particularly by the government of Chad.

INTRODUCTION:

Open defecation is serious public health threat which affects approximately 1 billion people worldwide and contributes significantly to an estimated 842 000 deaths resulting from sanitation related diseases such as diarrhea, typhoid and cholera (Gbadegesin & Akintola, 2020). Open defecation also has lamentable consequences on the economy of any country in the sense that it reduces the human capital of a country's work force and consequently inhibits people's physical and cognitive development. Open defecation happens when a person defecates outside rather than inside a toilet; in places such as fields, bushes, forests, ditches, streets canals or other open spaces.

In Chad, more than 50% of the total population practice open defecation. Most defecators reside in rural areas of Chad. Most people in Chad practice open defecation just because they have grown up seeing family members, peers, and others in the community defecate in the open and as such see this practice as habitual, natural and part of a daily routine. When children grow up in an environment where open defecation is widespread, they are also bound to be open defecators as well. This is attributed to the fact that norms and practices held from childhood usually stick and become a way of life such that even where the sanitation facilities are available and ready for use, the practice of open defecation remains the best option. In Chad, unreliable water supplies are a big blow to residents in urban areas who end up failing to use their toilets and then resort to open defecation.

Why it that open defecation is so widespread in Chad? This is because most people in the country, especially those who stay in rural areas are so poor that they do not even afford to build themselves a toilet. So they resort to open defecation. Literature, for example, Osumanu & Kosoe (2013), Osumanu et al. (2019) and Gbadegesin & Akintola (2020) also supports the existence of a relationship between wealth or social status and open defecation in the sense that high income earners, because of their social status are more concerned about hygienic ways of disposal of waste as compared to low income earners and hence high income earners (or the rich) do not practice open defecation but rather practice standard sanitation and hygiene.

The main aim of the study is to model and forecast the number of open defecators in Chad. This study is quite important because it will contribute significantly to the fight against the scourge of open defecation in Chad. Ending open defecation will go a long way in improving the sanitation and hygiene level in Chad and this can best be achieved through the estimation of forecasting and control models such as the Box-Jenkins ARIMA model.

OBJECTIVES OF THE STUDY:

i. To investigate the trends of open defecation in Chad.
ii. To forecast the number of people practicing open defecation in Chad for the period 2018 – 2022.
iii. To examine the trend of open defecation in Chad for the out-of-sample period.

LITERATURE REVIEW:

Guterres et al. (2014) assessed factors that influence household to use and maintain latrines in Thailand using a cross-sectional survey, based on a quantitative data design. Their study apparently found out that 47.2% of the households continued to use and maintain latrines and 52.8% had stopped by one year after the open defecation free declaration in Haupu village. Level of education is one of the most critical factors seen to be influencing household to use and maintain latrines. Sintondji et al. (2017) assessed the influence of socio-demographic factors on household hygiene and sanitation behaviour in Benin using interviews and the results of their study showed that 68% of households did not cover their containers during the transport of water, 58% of respondents defecated in water and 31% in the open air. The study further showed that only 40% of households washed their hands with water and soap after defecation; 42% of the respondents evacuated their wastewater into the water body while 51% preferred to pour them into the wild. Osumanu et al. (2019) analyzed sociocultural and economic factors determining open defecation in the Wa Municipality in Ghana. The study applied a mixed method approach involving questionnaire administration to 367 households systematically selected from 21 communities, observation, and eight key informant interviews. The mixed logit model was estimated to determine the factors that significantly influence open defecation. The findings generally show that 49.8% of the households had no form of toilet facility at home and were either using communal/public toilets or practicing open defecation. The study further revealed that six factors (education, household size, occupation income, traditional norms, and beliefs and owners of a toilet facility) were positively significant in determining open defecation. No study has been done to forecast the number of open defecators in Chad. This study is the first of its kind in the case of Chad and is envisioned to speed-up the eradication of open defecation in Chad.

METHODODOLOGY:

3.1 The Box – Jenkins (1970) Methodology:

The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic testing shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018c). The Box-Jenkins approach will be used to analyze the ODH series under consideration.

3.2 The Moving Average (MA) model:

Given:

$$ODH_t = \sum_{i=1}^{q} \alpha_i L^i \mu_t + \mu_t \ldots \ldots [1]$$

where L is the lag operator.

or as:

$$ODH_t = \alpha(L)\mu_t \ldots \ldots [2]$$

where:

$$\alpha(L)=\theta(L) \ldots \ldots [3]$$

Where μ_t is a purely random process with mean zero and varience σ^2. Equation [1] is reffered to as a Moving Average (MA) process of order q, usually denoted as MA (q). ODH is the annual number of people (as a percentage of the total population) who practice open defecation at time t, $\alpha_0 \ldots \alpha_q$ are estimation parameters, μ_t is the current error term while $\mu_{t-1} \ldots \mu_{t-q}$ are previous error terms.

3.3 The Autoregressive (AR) model

Given:

$$ODH_t = \sum_{i=1}^{p} \beta_i L^i ODH_t + \mu_t \ldots \ldots [4]$$

Or that:

$$\beta(L)ODH_t = \mu_t \ldots \ldots [5]$$

where:

$$\beta(L)=\phi(L) \ldots \ldots [6]$$

or that :

$$ODH_t = (\beta_1 L + \cdots + \beta_p L^p)ODH_t + \mu_t \ldots \ldots [7]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $ODH_{t-1} \ldots ODH_{t-p}$ are previous period values of the ODH series and μ_t is as previously defined. Equation [4] is an Autoregressive (AR) process of order p, and is usually denoted as AR (p).

3.4 The Autoregressive Moving Average (ARMA) model:

An ARMA (p, q) process is just a combination of AR (p) and MA (q) processes. Hence, by combining equations [1] and [4]; an ARMA (p, q) process can be specified as shown below:

$$\phi(L)ODH_t = \theta(L)\mu_t \ldots \ldots [8]$$

where $\phi(L)$ and $\theta(L)$ are polynomials of orders p and q respectively, algebraically defined as:

$$\phi(L) = 1 - \beta_1 L \ldots \beta_p L^p \ldots \ldots [9]$$

$$\theta(L) = 1 + \alpha_1 L + \cdots + \alpha_q L^q \ldots \ldots [10]$$

It is vital to remember that the ARMA (p, q) model, just like the AR (p) and the MA (q) models; can only be applied for stationary time series data. However, empirically, many time series are non – stationary. In fact, in this study, the ODH series has been found to be an I (1) variables (that is, it only became stationary after first differencing). Because of that, ARMA models are not suitable for modeling and forecasting non – stationary time series data. In such situations, the model described below is the one that should ideally be used.

3.5 The Autoregressive Integrated Moving Average (ARIMA) model:

A stochastic process ODH_t is referred to as an Autoregressive Integrated Moving Average (ARIMA) [p, d, q] process if it is integrated of order "d" [I (d)] and the "d" times differenced process has an ARMA (p, q) representation. If the sequence $\Delta^d ODH_t$ satisfies an ARMA (p, q) process; then the sequence of ODH_t also satisfies the ARIMA (p, d, q) process such that:

$$\Delta^d ODH_t = \sum_{i=1}^{p} \beta_i \Delta^d L^i ODH_t + \sum_{i=1}^{q} \alpha_i L^i \mu_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$$

where Δ is the difference operator, vector $\beta \in \mathbb{R}^p$ and $\alpha \in \mathbb{R}^q$.

3.6 Data Collection:

This study is based on annual observations (that is, from 2000 – 2017) on the number of people practicing Open Defecation in Chad (ODH), as a percentage of total population. Out-of-sample forecasts will cover the period 2018 – 2022. All the data was gathered from the World Bank online database.

3.7 Diagnostic Tests & Model Evaluation

3.7.1 Stationarity Tests: Graphical Analysis

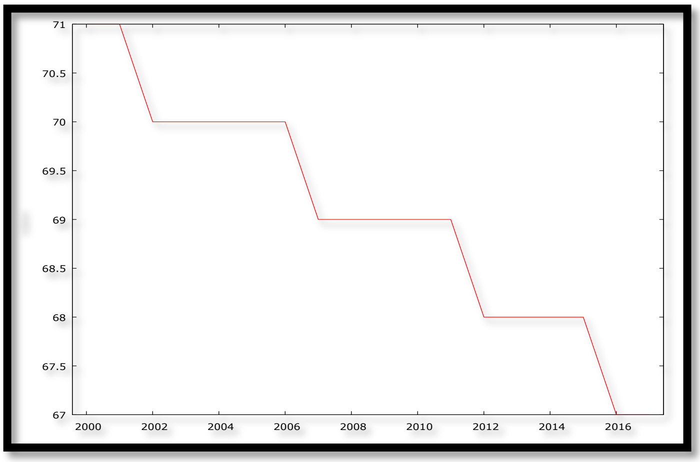

Figure 1

3.7.2 The Correlogram in Levels:

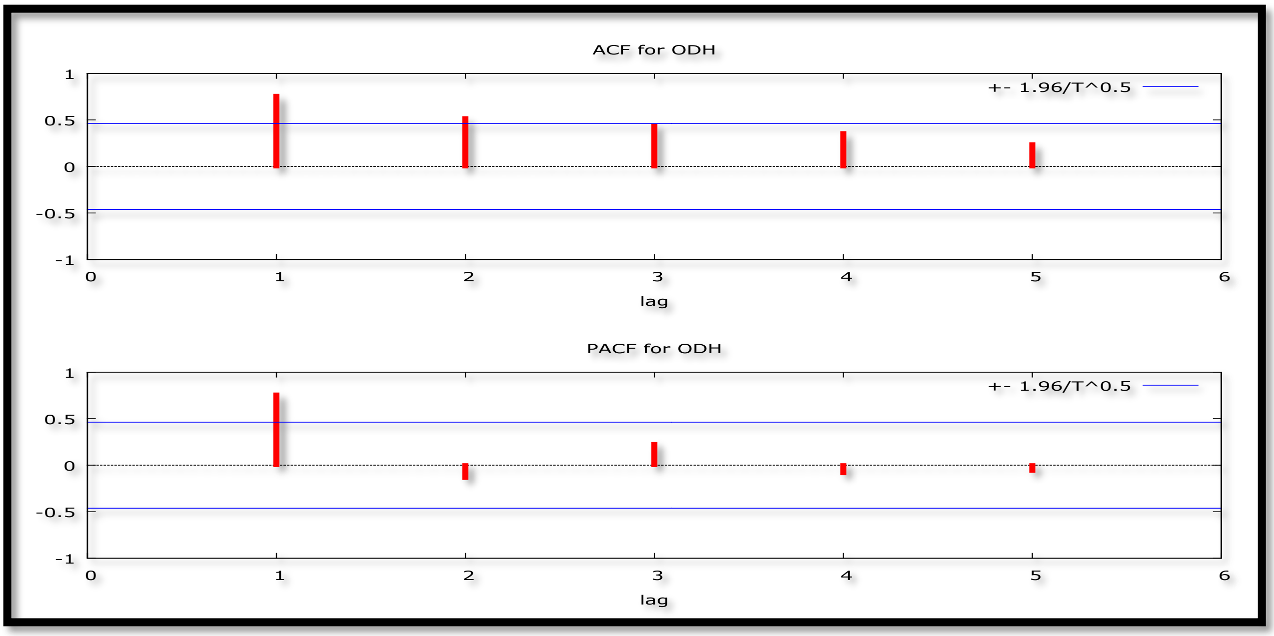

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODH	0.563602	0.9824	-4.004425	@1%	Non-stationary
			-3.098896	@5%	Non-stationary
			-2.690439	@10%	Non-stationary

Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODH	-4.145694	0.0265	-4.728363	@1%	Non-stationary
			-3.759743	@5%	stationary
			-3.324976	@10%	Stationary

Tables 1 and 2 show that ODH is not stationary in levels as already suggested by figures 1 and 2.

3.7.4 The Correlogram (at First Differences)

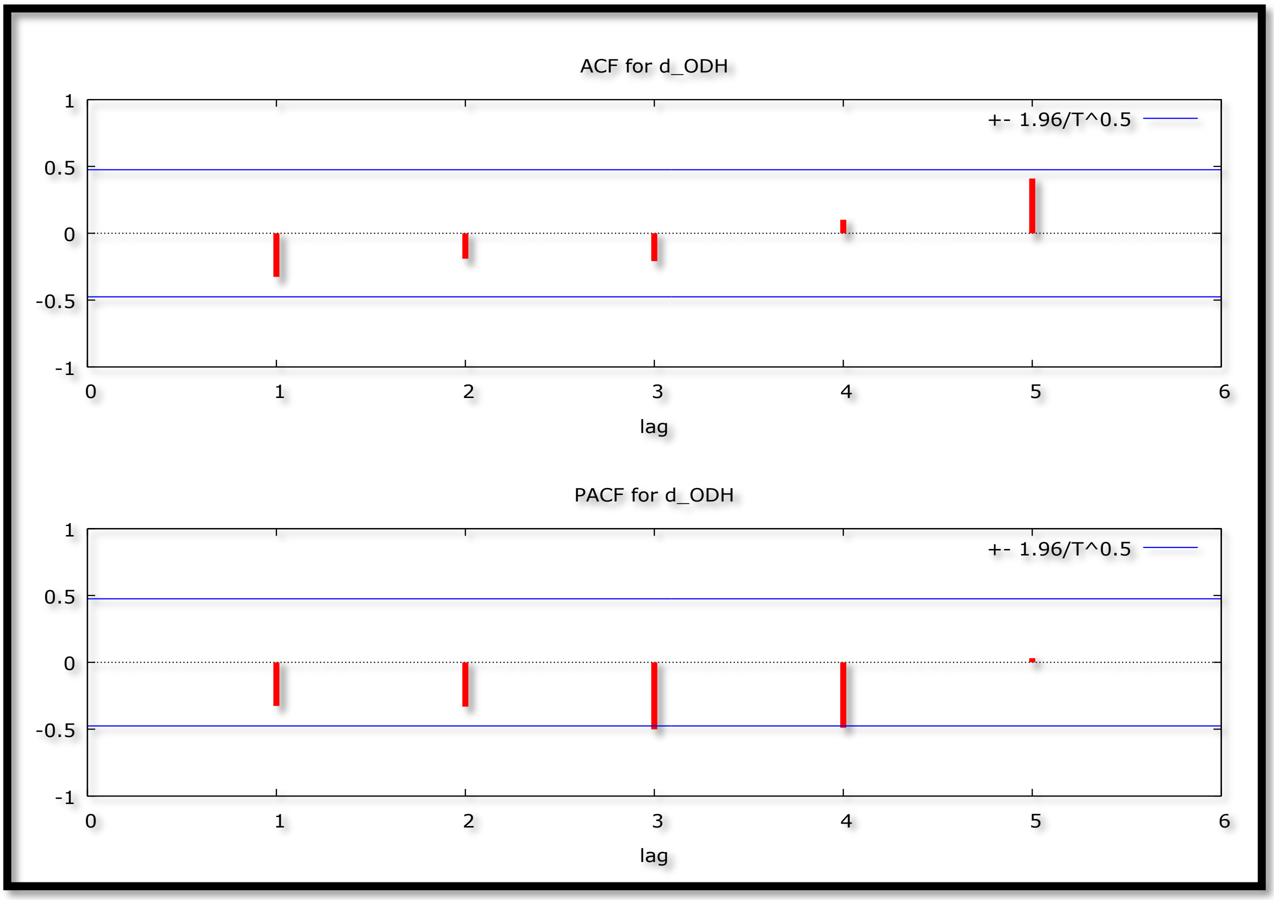

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔOD	-5.244881	0.0014	-4.057910	@1%	Stationary
			-3.119910	@5%	Stationary
			-2.701103	@10%	Stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔOD	-5.743454	0.0029	-4.886426	@1%	Stationary
			-3.828975	@5%	Stationary
			-3.362984	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that ODH is an I (1) variable.

3.7.6 Evaluation of ARIMA models (with a constant)

Table 5: Evaluation of ARIMA Models (with a constant)

Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (1, 1, 0)	23.20774	0.81815	0.004561	0.32487	0.40055	0.47163
ARIMA (2, 1, 0)	23.00072	0.77253	-0.0093474	0.2805	0.37872	0.40685
ARIMA (3, 1, 0)	18.81829	0.65314	-0.02185	0.19661	0.3227	0.28421
ARIMA (4, 1, 0)	**13.19234**	0.54545	-0.02722	0.13522	0.27012	0.1958
ARIMA (5, 1, 0)	15.19234	0.54545	-0.02722	0.13522	0.27012	0.1958

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018b) Similarly, the U statistic can be used to find a better model in the sense that it must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018a). In this research paper, only the AIC is used to select the optimal model. Therefore, the ARIMA (4, 1, 0) model is finally chosen.

3.8 Residual & Stability Tests:

3.8.1 ADF Test (in levels) of the Residuals of the ARIMA (4, 1, 0) Model:

Table 6: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-3.461675	0.0240	-3.920350	@1%	Non-stationary
			-3.065585	@5%	Stationary
			-2.673459	@10%	Stationary

Table 7: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-4.021441	0.0307	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Stationary
			-3.310349	@10%	Stationary

Tables 6 and 7 indicate that the residuals of the chosen optimal model, the ARIMA (4, 1, 0) model; are stationary. Hence, the model is very stable.

3.8.2 Correlogram of the Residuals of the ARIMA (4, 1, 0) Model:

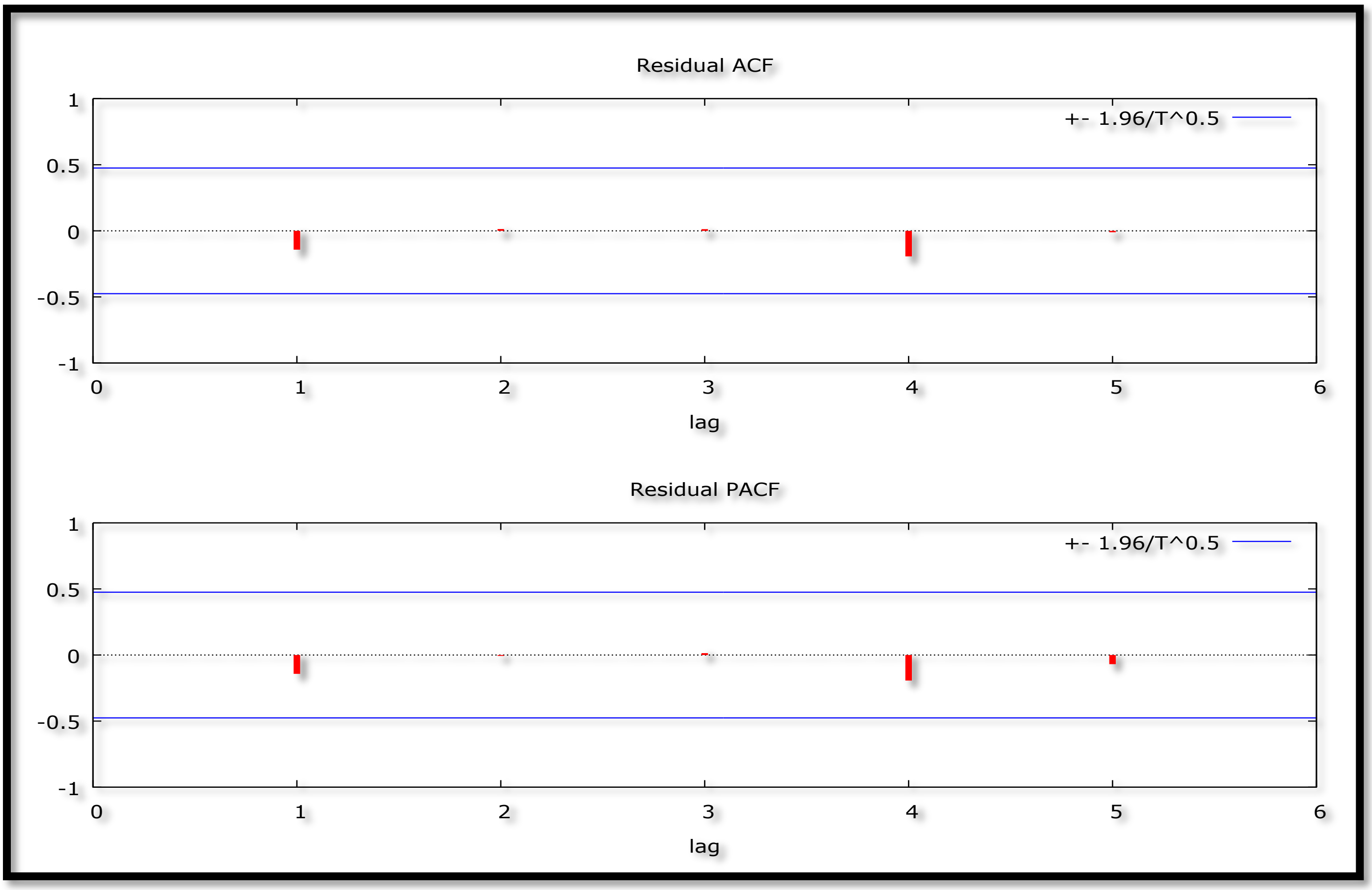

Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated ARIMA (4, 1, 0) model is adequate since ACF and PACF lags are quite short and within the bands. This proves that the "no autocorrelation" assumption is not violated in this study.

3.8.3 Stability Test of the ARIMA (4, 1, 0) Model:

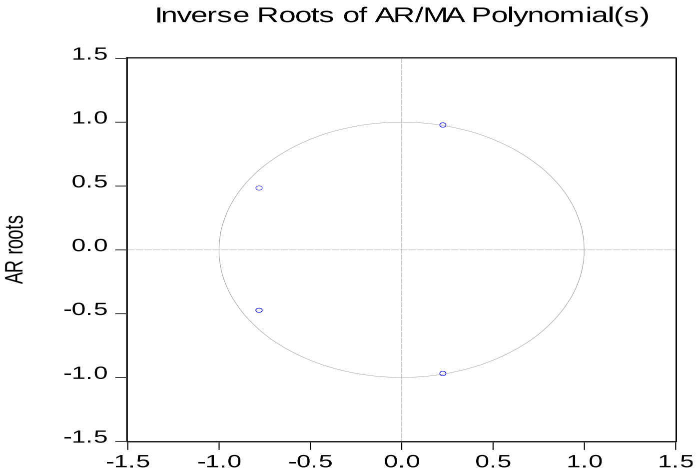

Figure 5: Inverse Roots

Since all the AR roots, basically, lie inside the unit circle, it implies that the estimated ARIMA process is (covariance) stationary; thus confirming that the ARIMA (4, 1, 0) model is really stable and suitable for forecasting annual number of people practicing open defecation in India.

FINDINGS:

4.1 Descriptive Statistics:

Table 8: Descriptive Statistics

Description	Statistic
Mean	69.056
Median	69
Minimum	67
Maximum	71
Standard deviation	1.2113
Skewness	-0.10763
Excess kurtosis	-0.88128

As shown in table 8 above, the mean is positive, that is, 69.056. This means that, over the study period, the annual average number of people practicing open defecation in Chad is approximately 69% of the total population. This is a warning alarm for public health policy makers in Chad with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Chad over the study period is approximately 67% of the total population, while the maximum is 71% of the total population. However, the number of people practicing open defecation in Chad has continued to decline, but slowly, over the years from 71% in 2000 to 67% of the total population.

4.2 Results Presentation:

Table 9: Main Results

ARIMA (4, 1, 0) Model:

Guided by equation [11], the chosen optimal model, the ARIMA (4, 1, 0) can be expressed as follows:

$$\Delta ODH_t = -0.215051 - 0.998765\Delta ODH_{t-1} - 0.998489\Delta ODH_{t-2} - 0.997834\Delta ODH_{t-3} - 0.648224\Delta ODH_{t-4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.215051	0.0131323	-16.38	0.0000***
ϕ_1	-0.998765	0.180482	-5.534	0.0000***
ϕ_2	-0.998489	0.212910	-4.690	0.0000***
ϕ_3	-0.997834	0.194567	-5.128	0.0000***
ϕ_4	-0.648224	0.203808	-3.181	0.0015***

Table 9 shows the main results of the ARIMA (4, 1, 0) model.

Forecast Graph:

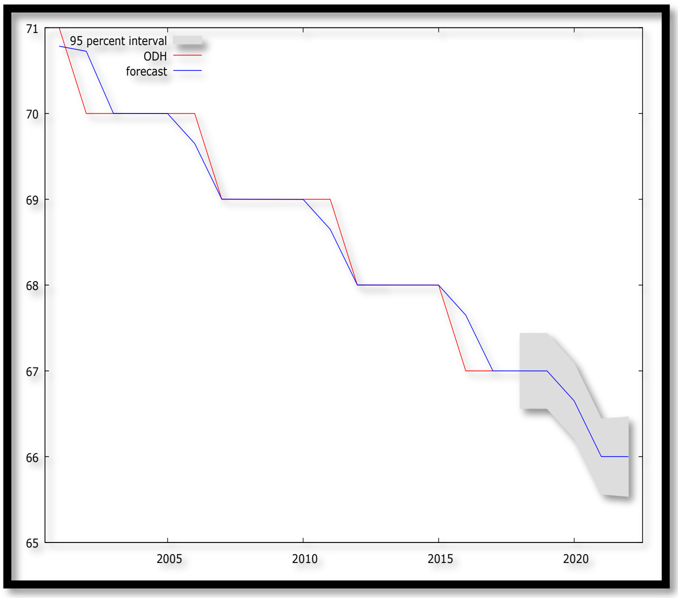

Figure 6: Forecast Graph – In & Out-of-Sample Forecasts

Figure 6 shows the in-and-out-of-sample forecasts of the ODH series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted ODH – Out-of-Sample Forecasts Only

Table 10: Predicted ODH

Year	Predicted ODH	Standard Error	Lower Limit	Upper Limit
2018	67	0.223	66.56	67.44
2019	67	0.223	66.56	67.44
2020	66.65	0.223	66.21	67.09
2021	66	0.223	65.56	66.44
2022	66	0.237	65.54	66.46

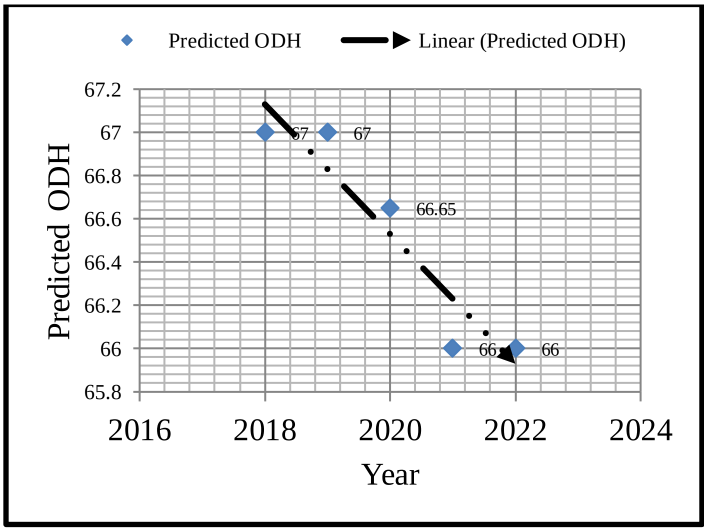

Figure 7: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 7 show the out-of-sample forecasts only. The number of people practicing open defecation in Chad is forecasted to slightly fall from approximately 67% in 2018 to 66% of the total population by the year 2022. The level of open defecation in Chad is highly unacceptable. This is clearly a serious warning sign to policy makers in the country with regards to recurrent disease outbreaks, especially cholera and typhoid.

4.3 Policy Implications:

i. There is need for the government of Chad to maintain peace and security in order to facilitate the full and proper implementation of open defecation initiatives and programs.

ii. The government of Chad should promote the use of toilets; toilets should be treated as rooms of happiness.

iii. The government of Chad should create more demand for sanitation, for example, through teaching the public on the importance of investing in toilets.

CONCLUSION:

The study shows that the ARIMA (4, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Chad over the period 2018 – 2022. The model predicts a slight decrease in the annual number of people practicing open defecation in Chad. Clearly, open defecation is persistant in Chad. The good news is that it is possible to create an open defecation free society even in Chad. These findings are very essential for the government of Chad and are envisioned to go a long in materializing the much needed open defecation free society.

REFERENCES:

1) Box, G. E. P., & Jenkins, G. M. (1970). Time Series Analysis: Forecasting and Control, Holden Day, San Francisco.
2) Gbadegesin, O. A., & Akintola, S. O. (2020). A Legal Approach to Winning the "Wash" War in Nigeria, European Journal of Environment and Public Health, 4 (2): 1 – 9.
3) Guterres, I. C. L., Yamarat, K., & Xenos, P. (2014). Factors Influencing Households to Use Latrines After the Open Defecation Free Declaration in Ermera District, Timor-Leste, Journal of Health Research, 28 (3): 191 – 198.
4) Nyoni, T (2018b). Modeling and Forecasting Inflation in Kenya: Recent Insights from ARIMA and GARCH analysis, Dimorian Review, 5 (6): 16 – 40.

5) Nyoni, T. (2018a). Modeling and Forecasting Naira/USD Exchange Rate in Nigeria: A Box-Jenkins ARIMA Approach, MPRA Paper No. 88622, University Library of Munich, Munich, Germany.
6) Nyoni, T. (2018c). Box – Jenkins ARIMA Approach to Predicting net FDI inflows in Zimbabwe, MPRA Paper No. 87737, University Library of Munich, Munich, Germany.
7) Osumanu, I. K., & Kosoe, E. A. (2013). Where Do I Answer Nature's Call? An Assessment of Accessibility and Utilization of Toilet Facilities in WA, Ghana, Ghana Journal of Geography, 5 (1): 17 – 31.
8) Osumanu, I. K., Kosoe, E. A., & Ategeeng, F. (2019). Determinants of Open Defecation in the Wa Municipality of Ghana: Empirical Findings Highlighting Sociocultural and Economic Dynamics Among Households, Journal of Environmental Science and Public Health, pp: 1 – 11.
9) Sintondji, L. O., et al. (2017). Socio-Demographic Characteristics of Households and Determinants of Access to Water, Hygiene and Sanitation in So-Ava, Benin, Journal of Environmental Science and Public Health, 1 (4): 253 –267.