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OPEN DEFECATION RESURGENCE IN TANZANIA? EARLY WARNING SIGNALS FROM THE BOX-JENKINS APPROACH

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ABSTRACT:

Using annual time series data on the number of people who practice open defecation in Tanzania from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2018 – 2021. The study applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that the Q series under consideration is an I (2) variable. Based on the AIC, the study presents the ARIMA (0, 2, 2) model as the optimal model. The diagnostic tests further reveal that the presented model is stable and its residuals are not serially correlated and are also normally distributed. The results of the study indicate that the number of people practicing open defecation in Tanzania is likely to continue on an upwards trajectory, over the period 2018 – 2022, from approximately 11.8% to almost 12% of the total population. Indeed, open defecation is a "persistant habit" in Tanzania, especially in rural areas. Hence, the ambition of attaining an open defecation free status by 2021 in Tanzania can no longer be realized. The study suggested a 3-fold policy prescription to be put into consideration, especially by the government of Tanzania.

INTRODUCTION:

Open defecation remains a serious global challenge. Nearly a quarter of the world's population lacks access to a facility that hygienically separates excreta from human contact (WHO, 2017). Open defecation can be defined as the practice of defecating in fields, forest, bushes, bodies of water or other open spaces, or disposal of human faeces with solid waste (WHO, 2008). Open defecation increases human exposures to enteric pathogens and is considered a major risk to children's health and development (Waddington et al., 2014). At least 5.4 million Tanzanians have no latrine and defecate in the open (WSP, 2012). Faecal contamination of the environment is the root cause of an annual average of 5800 cases of cholera affecting Tanzania (WHO, 2009). Approximately 26500 Tanzanians, including 18500 children under 5 years of age, die each year from diarrhoea – nearly 90% of which is directly linked to open defecation and poor sanitation practices (WSP, 2012). Open defecation has also considerable social costs such as loss of dignity and privacy or risk of physical attack and sexual violence (ibid).

Tanzania is making rapid progress on many human development and economic indicators (UNDP, 2018) and has ambitiously set a goal of achieving open defecation free status by 2021 (SNV, 2017) but sanitation (Czerniewska et al., 2019), particularly, open defecation remains a significant health threat. This is attributed to the fact that in Tanzania, the people in poverty, the elderly people, people with disabilities and those with other specific vulnerabilities still practice open defecation (SNV, 2020). Thus, it has become inevitable for public health researchers to model and predict the number of people practicing open defecation in order to formulate evidence-driven policies to end open defecation. The main purpose of this study is to predict the annual number of open defecators in Tanzania over the period 2018 – 2021. This study, besides being the first of its kind in the case of Tanzania, will go a long way in uncovering the possibility of ending open defecation in the country.

OBJECTIVES OF THE STUDY:

i. To investigate the years during which open defection was practiced by people more than 9% of the total population in Tanzania.
ii. To forecast the number of people practicing open defecation in Tanzania for the period 2018 – 2021.
iii. To examine the trend of open defecation in Tanzania for the out-of-sample period.

LITERATURE REVIEW:

Sara & Graham (2014) studied the factors that facilitate latrine adoption in rural Tanzania. The study was based on cross-section of 1000 households in rural districts in Tanzania. Results of the study basically showed a significant association between use of improved sanitation and satisfaction with current facility. In another Tanzanian study Nyanza et al. (2018) investigated the utilization and determinants of access to sanitation facilities among pastoral communities in rural areas of Tanzania. The study was cross-sectional in nature and was done in Ngorongoro Conservation Area. The study concluded that there is limited access to water and sanitation facilities in the Ngorongoro Conservation Area. In the case of Ghana, Alhassan & Anyarayor (2018) examined the adoption of sanitation innovations introduced in Nadowli-Kaleo district in Upper West region of Ghana as part of the efforts to attain Open Defecation Free (ODF) status. Interviews were employed to gather data. The study indicate that while effective communication of innovation resulted in widespread awareness, low income levels significantly accounted for households' inability to sustain and utilize latrines. In a study, done in Madagascar, Nyoni & Nyoni (2020) applied the ARIMA model and predicted that the country is likely to face increased number of open defecators over the period 2018 – 2022, from 45% to nearly 47% in 2022. This study, in line with Nyoni & Nyoni (2020), will adopt the ARIMA method in analyzing open defecation trends in Tanzania and is apparently the first of its kind in the country.

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). This approach will be used to analyze the Q series under consideration.

3.2 The Moving Average (MA) model:

Given:

$$Q_t = \sum_{i=1}^{q} \alpha_i \mu_{t-i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [1]$$

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). Q is the annual number of people (as a percentage of the total population) who practice open defecation in Tanzania 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:

$$Q_t = \sum_{i=1}^{p} \beta_i Q_{t-i} + \mu_t \ldots\ldots\ldots.\ldots\ldots\ldots [2]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $Q_{t-1} \ldots Q_{t-p}$ are previous period values of the Q series and μ_t is as previously defined. Equation [2] 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. Thus, by combining equations [1] and [2]; an ARMA (p, q) process may be specified as shown below:

$$Q_t = \sum_{i=1}^{p} \beta_i Q_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \ldots\ldots\ldots.\ldots [3]$$

3.5 The Autoregressive Integrated Moving Average (ARIMA) model:

A stochastic process Q_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 $\Delta^d Q_t$ satisfies an ARMA (p, q) process; then the sequence of Q_t also satisfies the ARIMA (p, d, q) process such that:

$$\Delta^d Q_t = \sum_{i=1}^{p} \beta_i \Delta^d Q_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \ldots. [4]$$

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 [OD, denoted as Q] (as a percentage of total population) in Tanzania. Out-of-sample forecasts will cover the period 2018 – 2021. All the data was gathered from the World Bank online database.

3.7 Diagnostic Tests & Model Evaluation:

3.7.1 Stationarity Tests: Graphical Analysis:

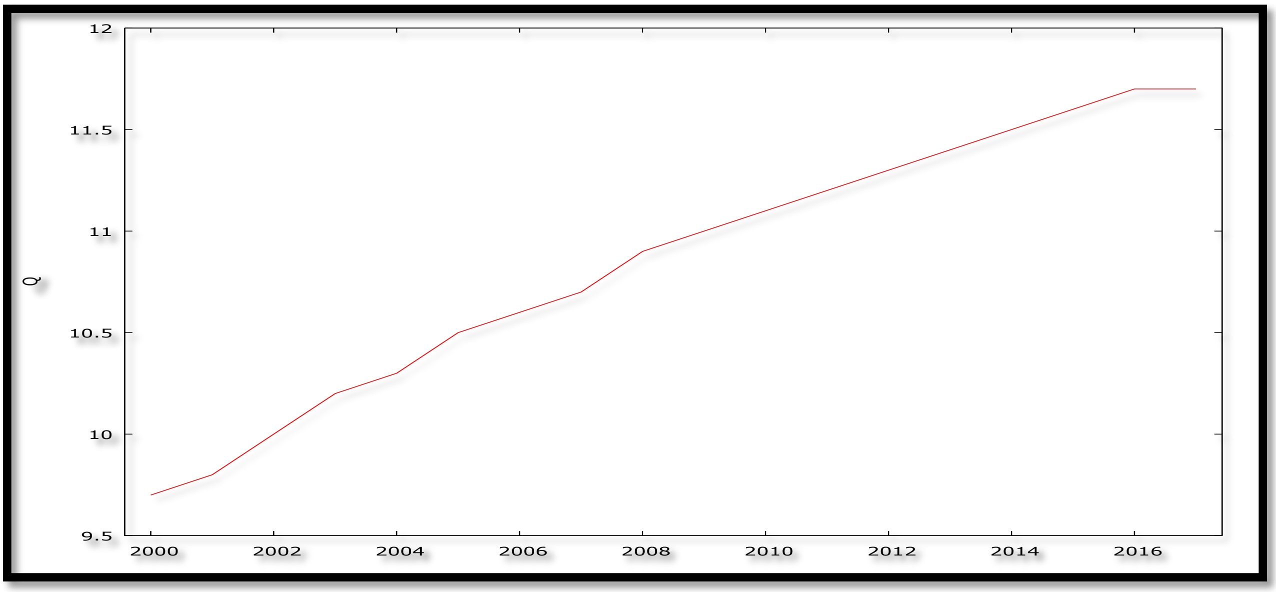

Figure 1

3.7.2 The Correlogram in Levels

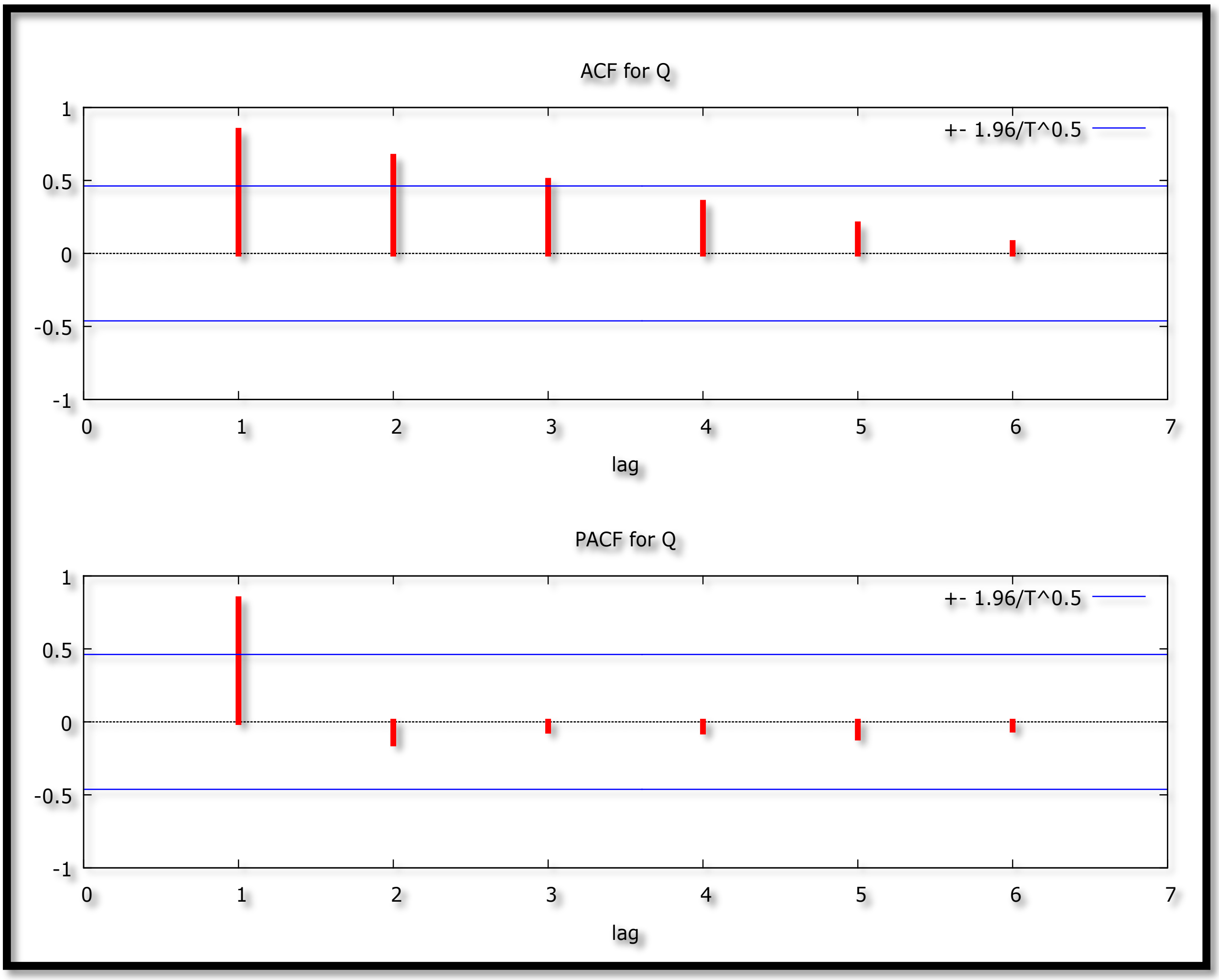

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Q	-5.471504	0.0006	-3.959148	@1%	Stationary
			-3.081002	@5%	Stationary
			-2.681330	@10%	Stationary

Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Q	-1.003706	0.9120	-4.728363	@1%	Non-stationary
			-3.759743	@5%	Non-stationary
			-3.324976	@10%	Non-stationary

Table 1 shows that Q is not stationary in levels while table 2 shows exactly the opposite.

3.7.4 The Correlogram (at First Differences)

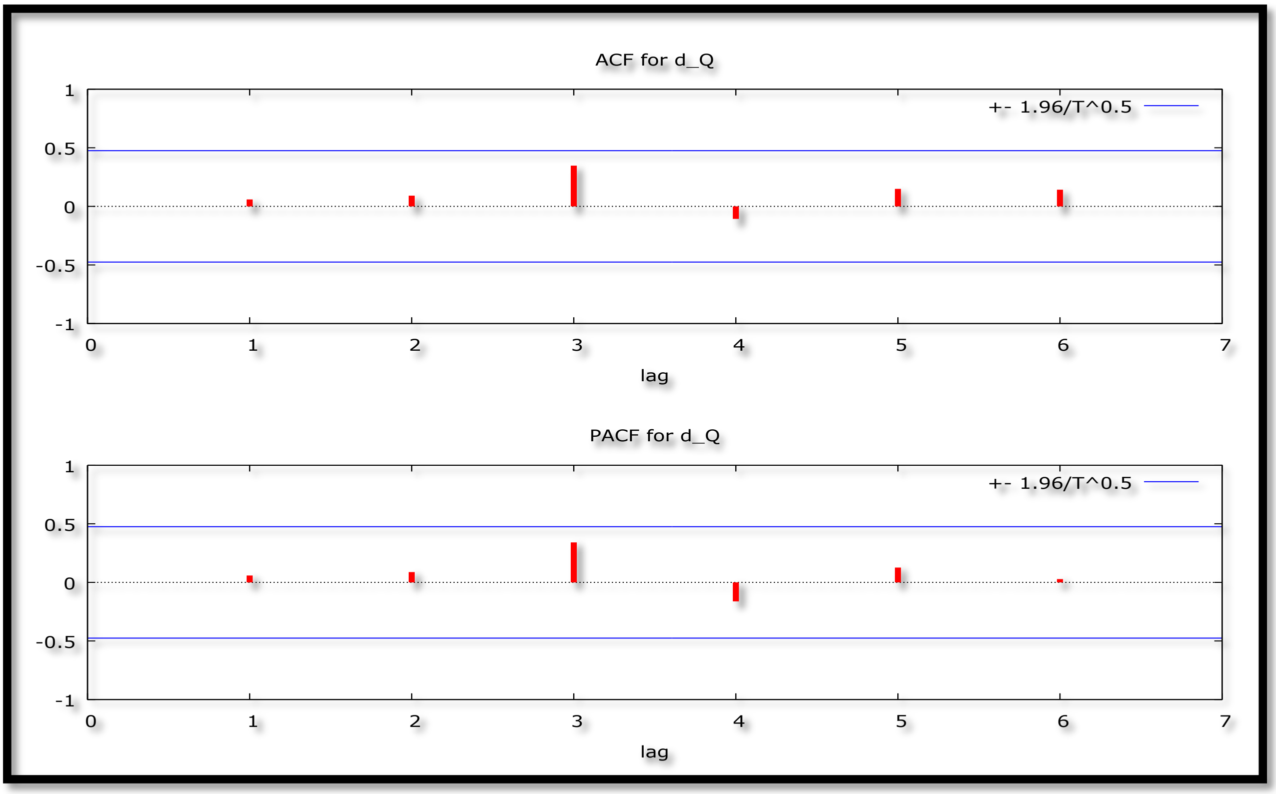

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔQ	-0.563507	0.8497	-4.004425	@1%	Non-stationary
			-3.098896	@5%	Non-stationary
			-2.690439	@10%	Non-stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔQ	-3.513571	0.0803	-4.886426	@1%	Non-stationary
			-3.828975	@5%	Non-stationary
			-3.362984	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that Q is not an I (1) variable.

3.7.6 The Correlogram (at Second Differences)

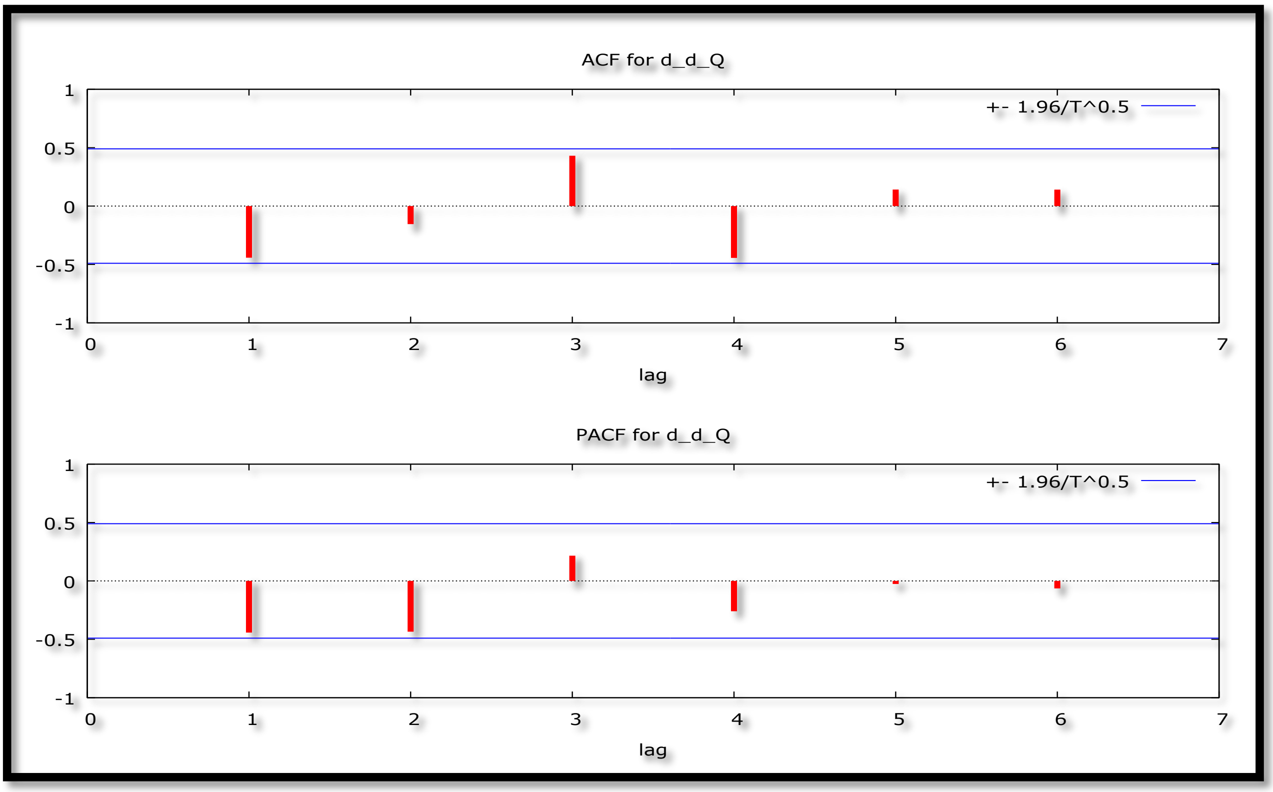

Figure 4: The Correlogram (at Second Differences)

3.7.7 The ADF Test (at Second Differences)

Table 5: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Δ^2Q	-7.793198	0.0000	-4.004425	@1%	Stationary
			-3.098896	@5%	Stationary
			-2.690439	@10%	Stationary

Table 6: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Δ^2Q	-7.442057	0.0002	-4.800080	@1%	Stationary
			-3.791172	@5%	Stationary
			-3.342253	@10%	Stationary

Figure 4 as well as table 5 and 6 confirm that Q is an I (2) variable.

3.7.8 Evaluation of ARIMA models (with a constant):

Table 7: Evaluation of ARIMA Models (with a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 2, 0)	-40.35686	0.4295	0.0037853	0.058153	0.43027
ARIMA (2, 2, 0)	-49.69564	0.30621	0.0097994	0.046106	0.33043
ARIMA (3, 2, 0)	-47.73368	0.30611	0.0098847	0.046064	0.3311
ARIMA (0, 2, 1)	-47.25275	0.3414	0.0093526	0.0489	0.35874
ARIMA (0, 2, 2)	**-54.23210**	0.28197	0.0089856	0.042732	0.31459
ARIMA (0, 2, 3)	-53.70052	0.28163	0.0064034	0.042631	0.30482
ARIMA (1, 2, 1)	-48.52487	0.32575	0.010034	0.047146	0.3495
ARIMA (2, 2, 2)	-51.70792	0.26073	0.010133	0.041354	0.28645

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 (0, 2, 2) model is finally chosen.

3.8 Residual & Stability Tests:

3.8.1 Correlogram of the Residuals of the ARIMA (0, 2, 2) Model:

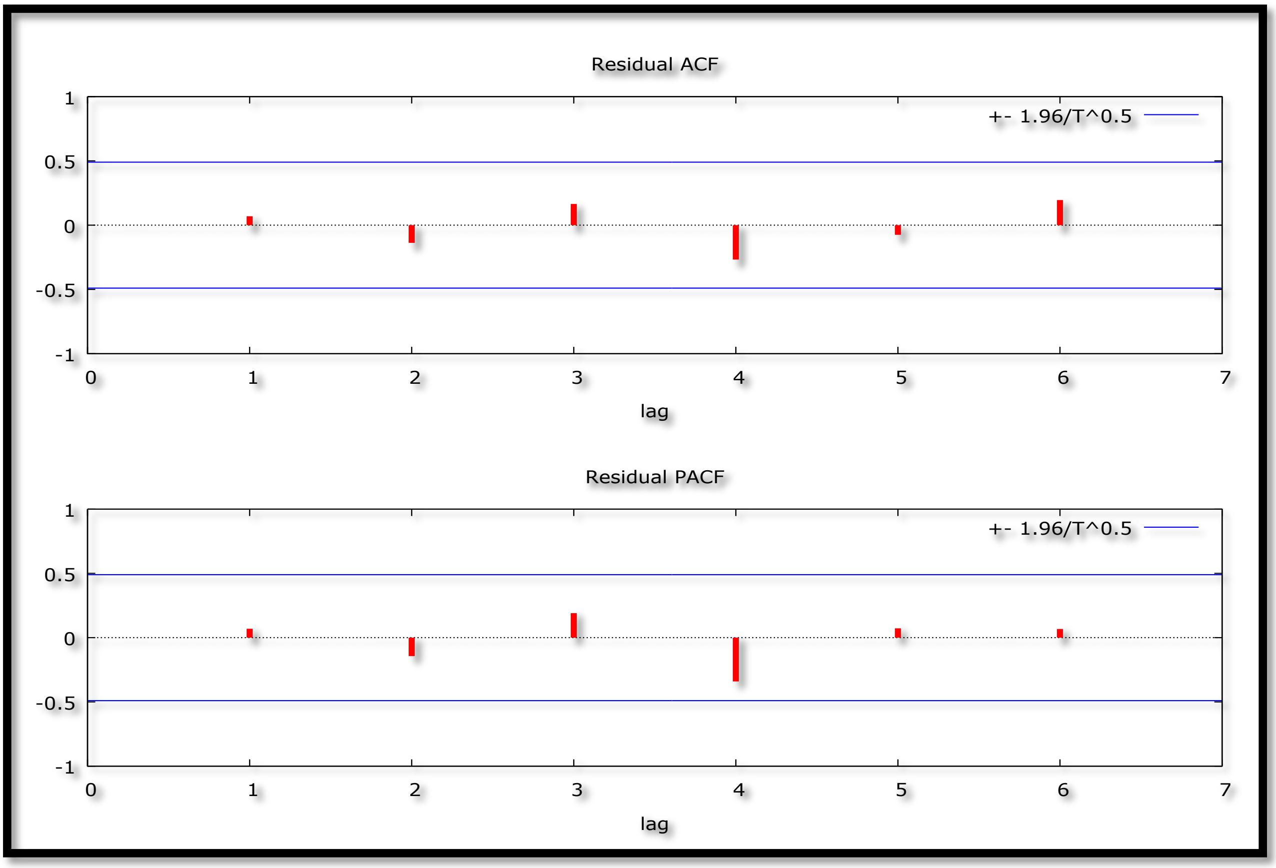

Figure 5: Correlogram of the Residuals

Figure 4 reveals that the estimated model is adequate since ACF and PACF lags are quite short and within the bands. This apparently points to the fact that the "no autocorrelation" assumption is not violated in this research.

3.8.2 Normality Test of the Residuals of the ARIMA (0, 2, 2) Model:

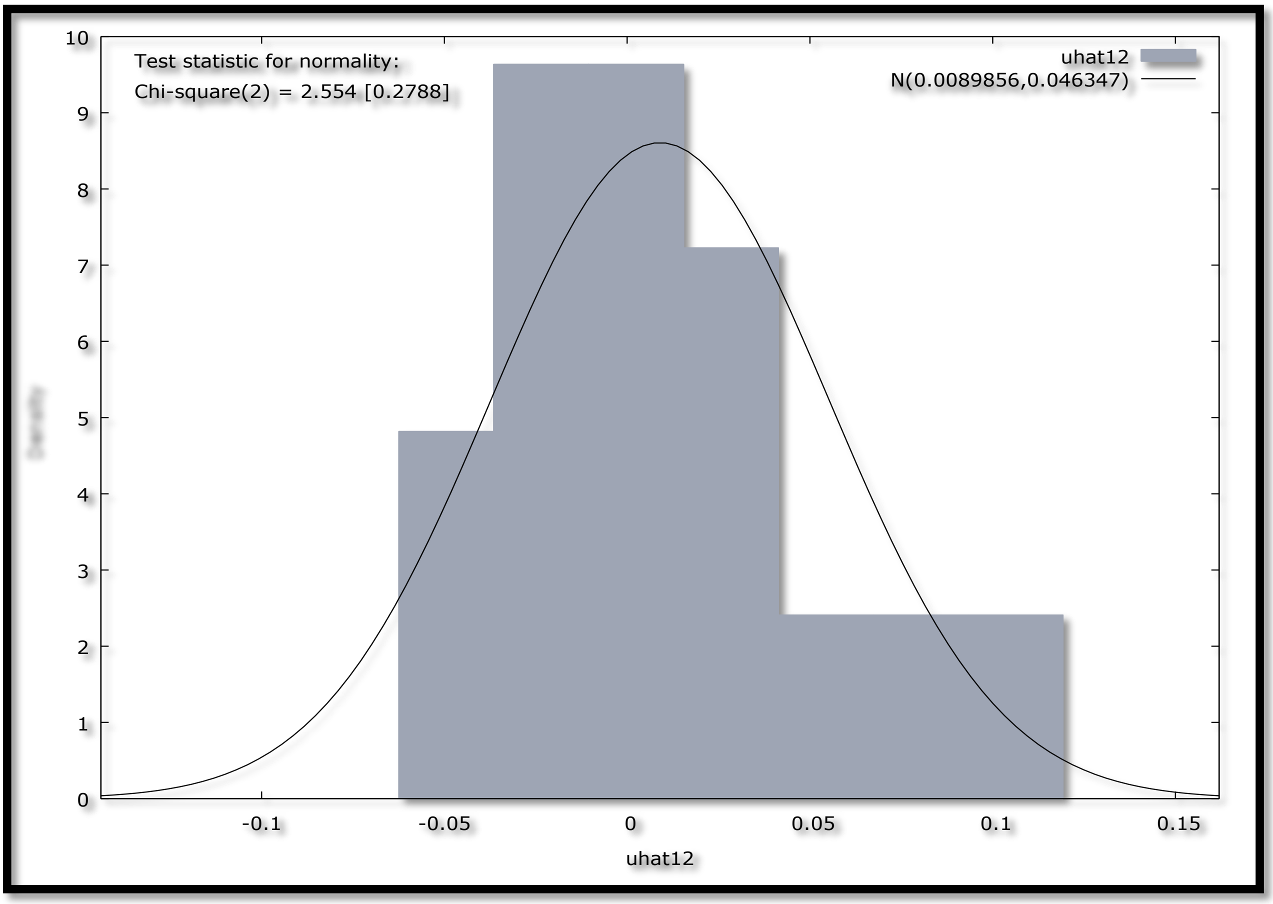

Figure 7: Normality Test

Guided by the insignificance of the probability value of the chi-square statistic, we reject the null hypothesis and conclude that the residuals of the ARIMA (0, 2, 2) model are normally distributed. In line with figure 5 and 6, figure 7 implies that the selected optimal model is stable.

FINDINGS:

4.1 Descriptive Statistics:

Table 8: Descriptive Statistics

Description	Statistic
Mean	10.844
Median	10.95
Minimum	9.7
Maximum	11.7

As shown in table 8 above, the mean is positive, that is, 10.844. This means that, over the study period, the annual average number of people practicing open defecation in Tanzania is approximately 11% of the total population. The minimum number of people practicing open defecation in Tanzania over the study period is approximately 9.7% of the total population, while the maximum is 11.7% of the total population. In fact, the number of people practicing open defecation in Tanzania has increased over the years from 9.7% in 2000 to 11.7% of the total population in 2017.

4.2 Results Presentation:

Table 9: Main Results

ARIMA (0, 2, 2) Model:

Guided by equation [4], the chosen optimal model, the ARIMA (0, 2, 2) model can be expressed as follows:

$$\Delta^2 Q_t = -0.00623615 - 1.94487\Delta^2\mu_{t-1} + 0.999999\Delta^2\mu_{t-2} \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.00623615	0.000468674	-13.31	0.0000***
α_1	-1.94487	0.235766	-8.249	0.0000***
α_2	0.999999	0.234154	4.271	0.0000195

Table 9 shows the main results of the ARIMA (0, 2, 2) model.

Forecast Graph

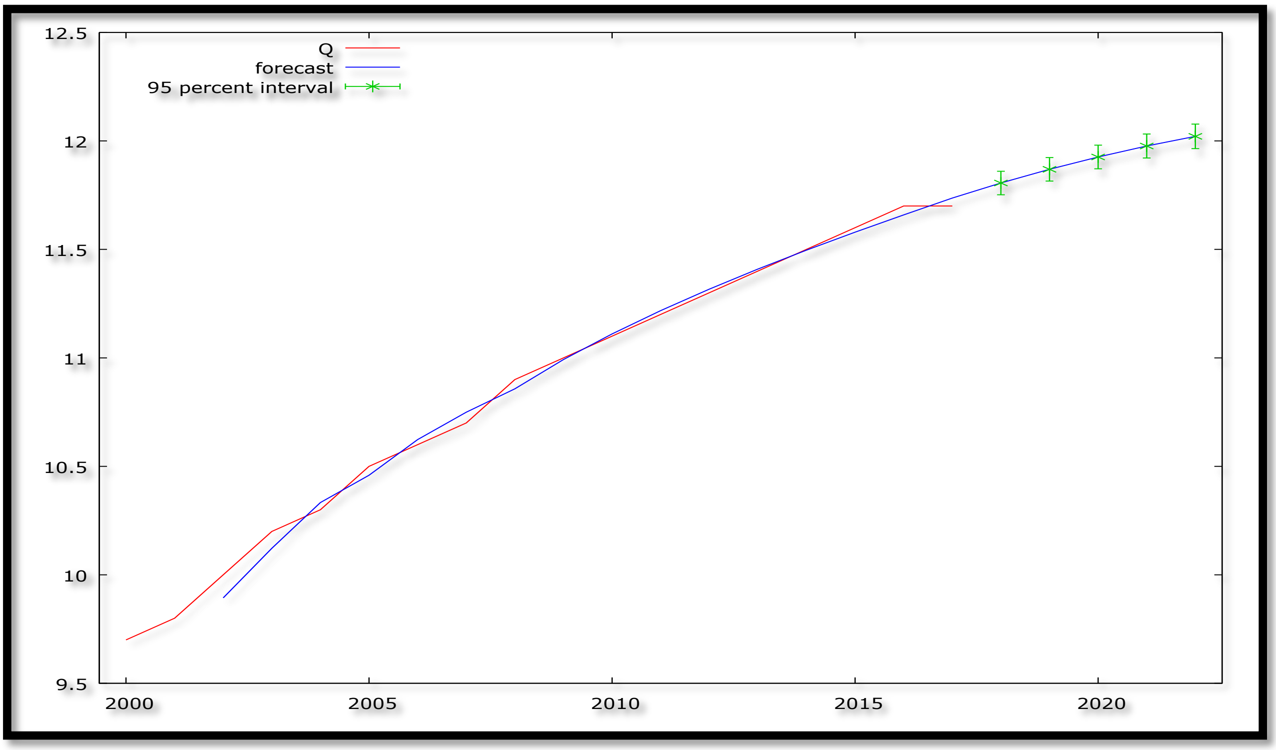

Figure 8: Forecast Graph – In & Out-of-Sample Forecasts

Figure 8 shows the in-and-out-of-sample forecasts of the Q series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted Q – Out-of-Sample Forecasts Only

Table 10: Predicted

Year	Predicted Q	Standard Error	Lower Limit	Upper Limit
2018	11.8	0.03	11.8	11.9
2019	11.9	0.03	11.8	11.9
2020	11.9	0.03	11.9	12.0
2021	12.0	0.03	11.9	12.0
2022	12.0	0.03	12.0	12.1

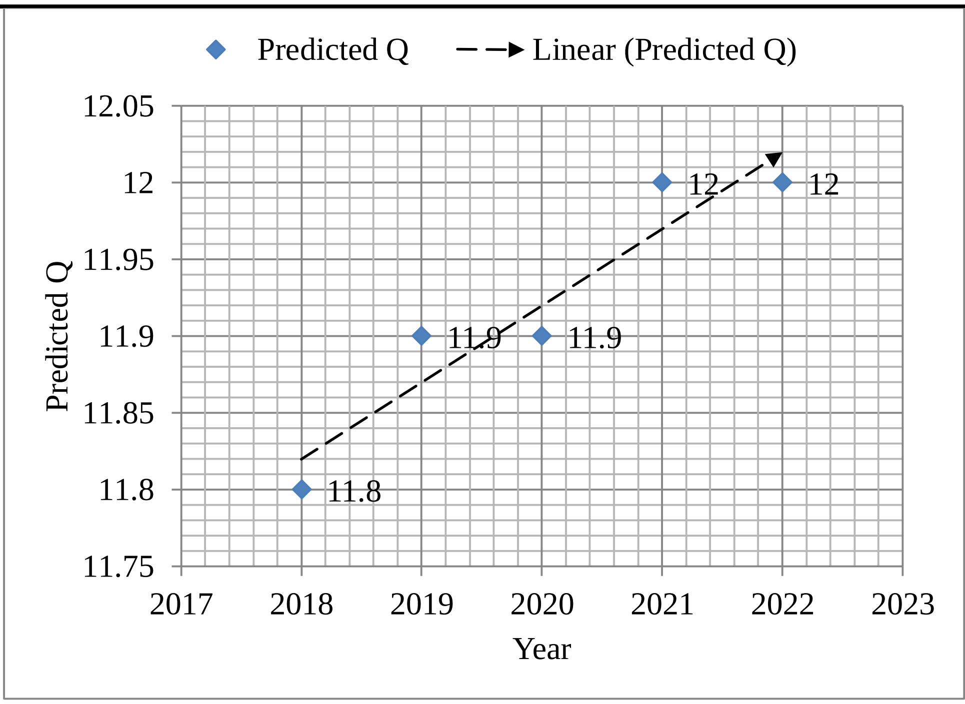

Figure 9: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 9 show the out-of-sample forecasts only. The number of people practicing open defecation in Tanzania is projected to increase from approximately 11.8% in 2017 to 12% of the total population by the year 2022. It is imperative to note that the country's goal of eliminating open defecation by 2021 has already failed. This resurgence in the practice of defecating in the open in Tanzania is not a desirable public health outcome; especially when considering that Tanzania is the 5th largest recipient of international aid in water, sanitation and hygiene (WHO, 2012). The results of this study are similar to Nyoni & Nyoni (2020): if policy makers in Tanzania are not careful, in the long run, open defecation levels will be out-of-hand just like what is currently happening in Madagascar and that is not are desirable health outcome. In fact, the ARIMA (0, 2, 2) model is points to serious health implications, especially with regards to various diarrhoeal diseases associated with open defecation. However, it is possible to reserve this projected trajectory, especially if the current Tanzanian government considers the policy directions suggested below.

4.3 Policy Implications:

i. The government of Tanzania should, first of all, make toilets a status symbol, especially in rural areas, so that Tanzanians consider toilets to be "rooms of happiness". This can potentially induce behaviour change. In this regard, there is need to intensify the Community-Led Total Sanitation (CLTS) approach along with increased funding for construction of toilets in rural areas. Furthermore Jirani Sanitation Groups (JSG) ought to be supported by both government and non-governmental institutions in the country.
ii. The government of Tanzania must create more demand for sanitation through teaching the public on the importance of investing in toilets. In this regard, there is need to promote context-specific sanitation technologies in the country.
iii. There is need for the government of Tanzania to spur a habit of using toilets, and not defecating in the open.

CONCLUSION:

The study shows that the ARIMA (0, 2, 2) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Tanzania over the period 2018 – 2022. The model predicts resurgence in the annual number of people practicing open defecation in Tanzania. Hence, open defecation can be described as "persistant" in Tanzania. These findings are essential for the government of Tanzania, especially for long-term planning with regards to materializing the much needed open defecation free society and getting rid of diseases associated with pathogens of faecal origin.

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