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OPEN DEFECATION IN BENIN: 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 research applies the Box-Jenkins ARIMA technique. The diagnostic ADF tests show that the ODB series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (1, 1, 0) model as the parsimonious model. The diagnostic tests further point to the notion that the presented model is indeed stable and its residuals are stationary in levels. The results of the study indicate that the number of people practicing open defecation in Benin will slightly decline over the period 2018 – 2022, from 53% to 49.71% of the total population. Clearly, open defecation is likely to remain one of the major public health issues in Benin in future unless better sanitation policies are effectively implemented in the country. In order to help reinforce the effectiveness of already existing Water, Sanitation and Hygiene (WASH) policy frameworks, the study suggested a four-fold policy recommendation to be put into consideration, especially by the government of Benin.

INTRODUCTION:

Open defecation has continued to pose serious health challenges globally. This practice affects almost 1 billion people worldwide and is said to contribute significantly to an estimated 842 000 deaths resulting from sanitation related diseases such as diarrhea, typhoid and cholera (Gbadegesin & Akintola, 2020). On the other side of the same coin, good hygiene and sanitation practice is a major determinant of household well-being and development of community members (Sintondji et al., 2017). Open defecation can be defined as an unhygienic human practice of defecating outside rather than in a toilet. The alternatives to using a toilet usually considered include fields, bushes, forests, ditches, streets canals or other open spaces (Clansen et al., 2014).

Most people practicing open defecation 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. Norms and practices held from childhood tend to stick and become a way of life such that even where the facilities are available, the practice of open defecation remains the preferred option (Connell, 2014). The growth of open defecation is also attributed to the ever-increasing population and the absence of sanitation facilities in most homes in the cities thus resulting in the people finding alternatives to answer the call of nature. There is also a relationship between wealth or social status of the individual and open defecation. Improved sanitation owners are usually wealthier than those who engage in open defecation. High income earners, because of their social status are more concerned about hygienic ways of disposal of waste as compared to low income earners (Osumanu & Kosoe, 2013).

Economically, open defecation reduces the human capital of a country's workforce and inhibits people's physical and cognitive development (Mara, 2017). Care givers and parents have to bear the task of taking care of the sick children thereby loosing hours of labor productivity time and also income and long hours and finances are devoted towards taking care of the sick (Gbadegesin & Akintola, 2020). The main aim of the study is to model and forecast the number of people practicing open defecation in Benin. This study is necessary because it will contribute significantly to the fight against the scourge of open defecation. Ending open defecation will go a long way in improving the sanitation level in Benin and this can best be achieved through the application of forecasting and control models such as the Box-Jenkins ARIMA model.

LITERATURE REVIEW:

Guterres et al. (2014) investigated factors that influence household to use and maintain latrines in Thailand. Their study was designed as a cross-sectional survey, based on a quantitative data design. Their study basically 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 revealed 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 also revealed 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) investigated sociocultural and economic factors determining open defecation in the Wa Municipality in Ghana. The study used 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 applied to determine the factors that significantly influence open defecation. The findings basically 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 also 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 Benin. This study is the first of its kind in the case of Benin and is anticipated to speed-up the eradication of open defecation in Benin.

METHODODOLOGY:

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 ODB series under consideration.

2 The Moving Average (MA) model:

Given:

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

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). ODB is the annual number of people (as a percentage of the total population) who practice open defecation in Benin 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 The Autoregressive (AR) model:

Given:

$$ODB_t = \sum_{i=1}^{p} \beta_i ODB_{t-1} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $ODB_{t-1} \ldots ODB_{t-p}$ are previous period values of the ODB 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).

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:

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

5 The Autoregressive Integrated Moving Average (ARIMA) model:

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

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

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

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 ODB] (as a percentage of total population) in Benin. Out-of-sample forecasts will cover the period 2018 – 2022. All the data was gathered from the World Bank online database.

7 Diagnostic Tests & Model Evaluation

7.1 Stationarity Tests: Graphical Analysis

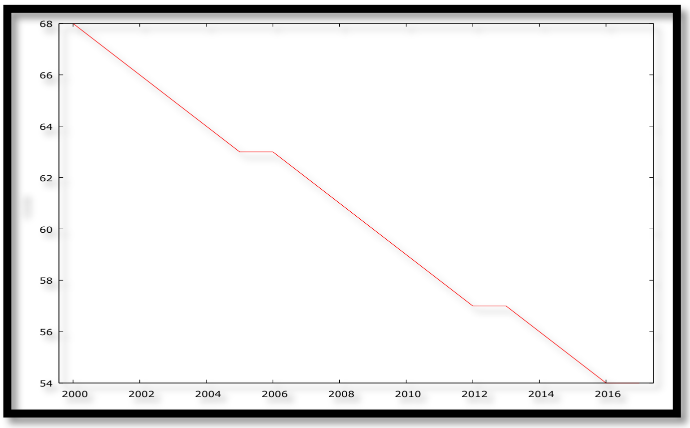

Figure 1

7.2 The Correlogram in Levels

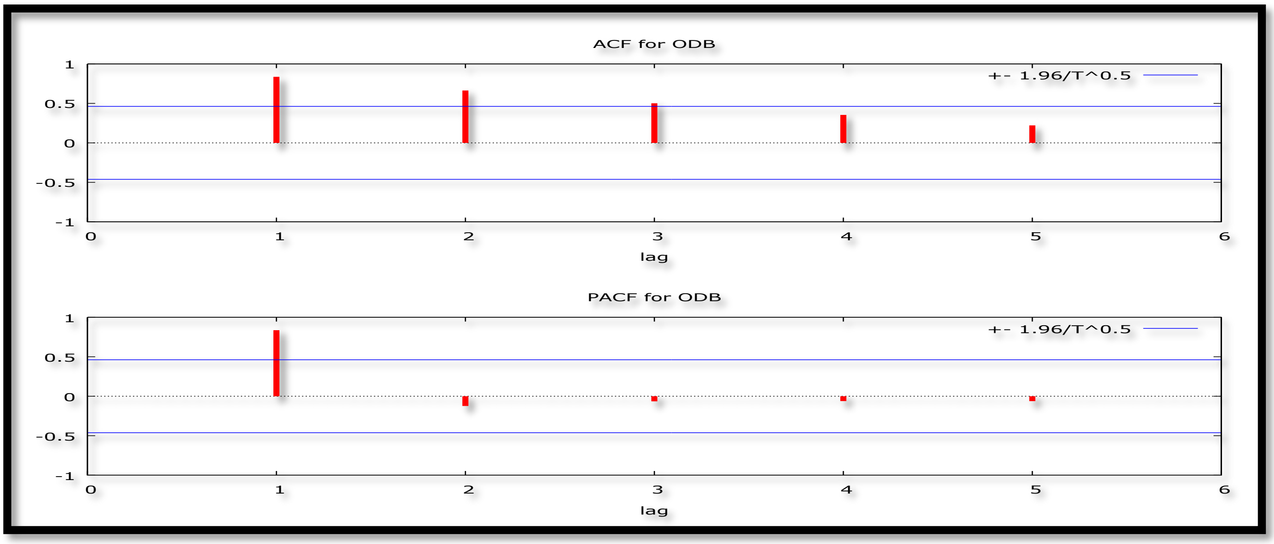

Figure 2: Correlogram in Levels

7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODB	-1.297880	0.6053	-3.886751	@1%	Non-stationary
			-3.052169	@5%	Non-stationary
			-2.666593	@10%	Non-stationary

Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODB	-2.573830	0.2942	-4.616209	@1%	Non-stationary
			-3.710482	@5%	Non-stationary
			-3.297799	@10%	Stationary

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

7.4 The Correlogram (at First Differences):

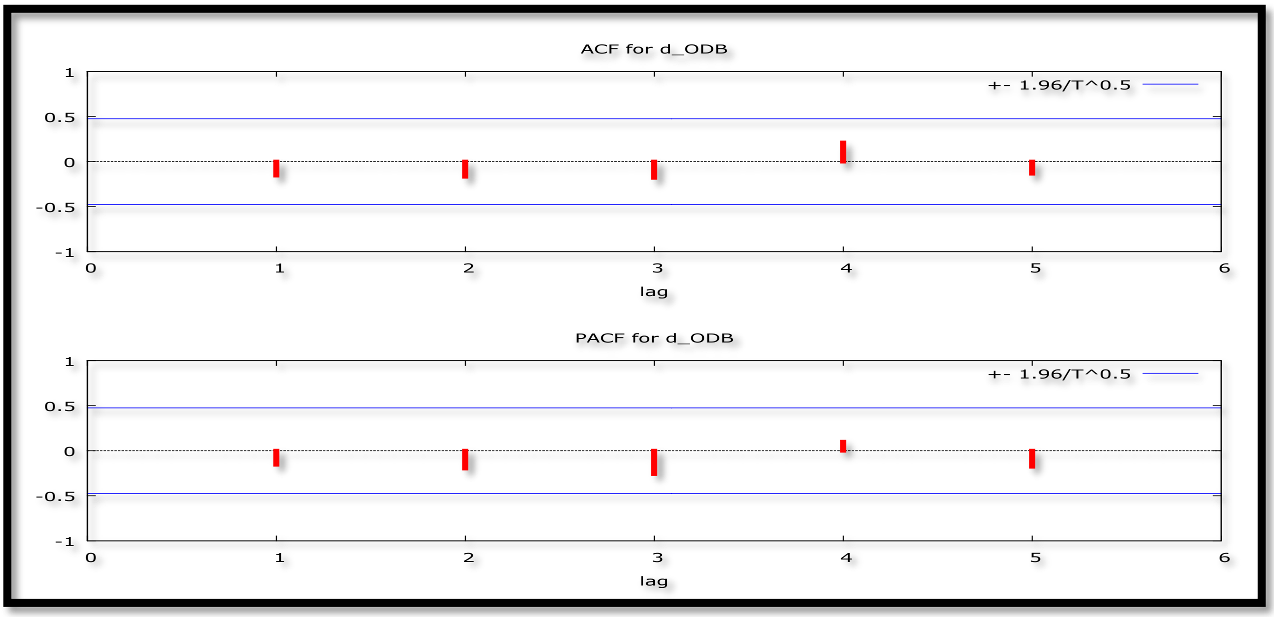

Figure 3: Correlogram (at First Differences)

7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODB	-3.914813	0.0101	-3.920350	@1%	Non-stationary
			-3.065585	@5%	Stationary
			-2.673459	@10%	Stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODB	-4.004132	0.0316	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Stationary
			-3.310349	@10%	Stationary

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

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)	20.90625	0.44368	-0.0020391	0.28278	0.37474	0.47886
ARIMA (2, 1, 0)	22.03493	0.42973	-0.0068204	0.27168	0.36425	0.45856
ARIMA (3, 1, 0)	22.38576	0.40306	-0.016537	0.25226	0.3447	0.42251

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 (1, 1, 0) model is finally chosen.

8 Residual & Stability Tests:

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

Table 6: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-3.365250	0.0288	-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	-3.481635	0.0760	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Non-stationary
			-3.310349	@10%	Stationary

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

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

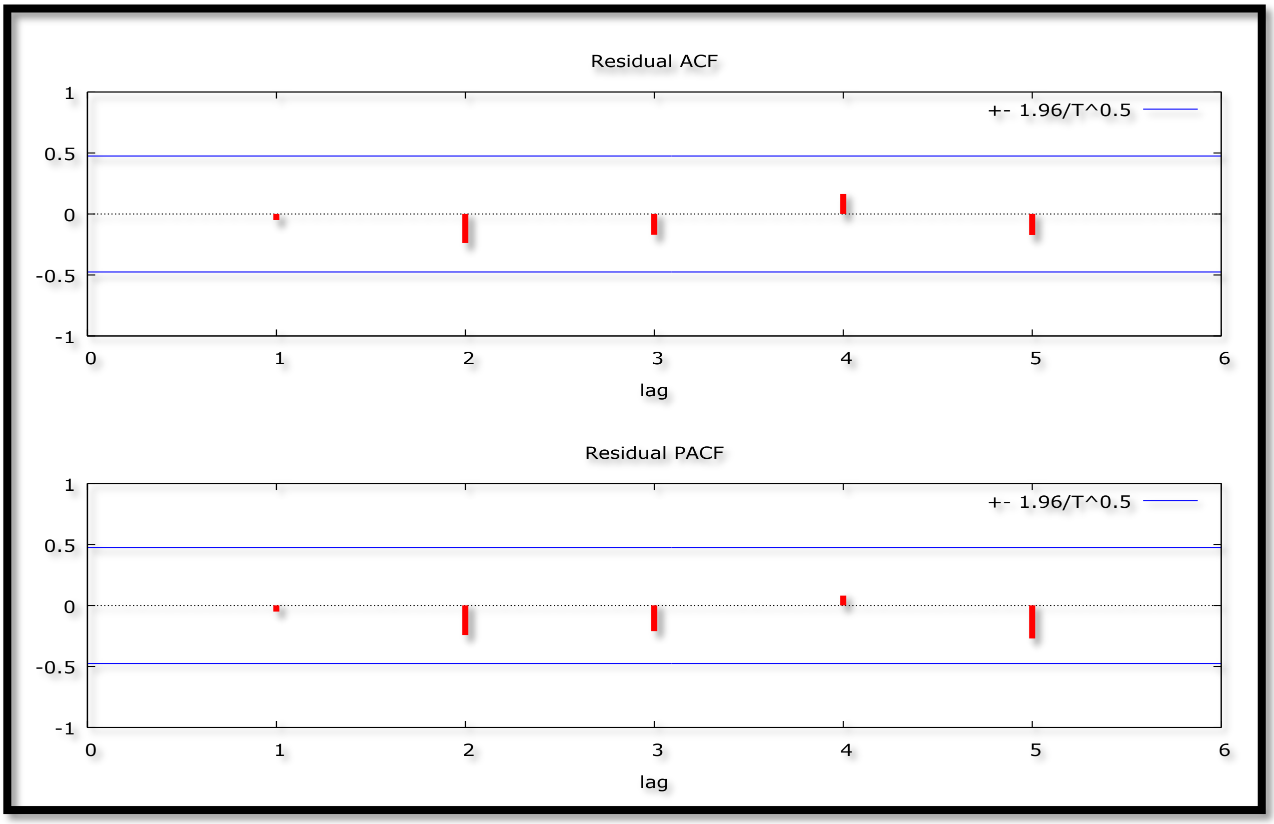

Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated model is adequate since ACF and PACF lags are very short and within the bands. This proves that the "no autocorrelation" assumption is not violated in this study.

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

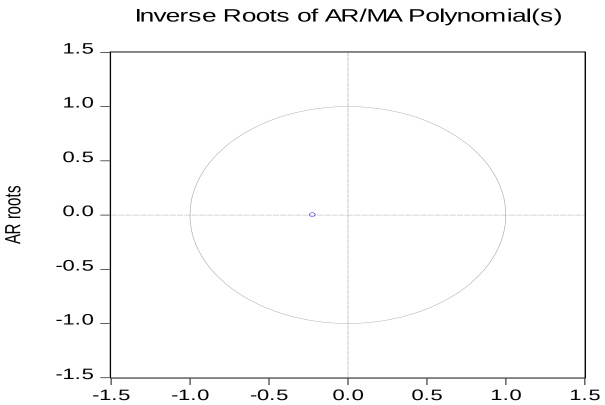

Figure 5: Inverse Roots

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

FINDINGS:

1 Descriptive Statistics:

Table 8: Descriptive Statistics

Description	Statistic
Mean	60.5
Median	60.5
Minimum	54
Maximum	68

As shown in table 8 above, the mean is positive, that is, 60.5. This means that, over the study period, the annual average number of people practicing open defecation in Benin is approximately 61% of the total population. This is a warning alarm for policy makers in Benin with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Benin over the study period is approximately

54% of the total population, while the maximum is 68% of the total population. However, the number of people practicing open defecation in Benin has slightly declined over the years from 68% in 2000 to 54% of the total population in 2017.

2 Results Presentation:

Table 9: Main Results

ARIMA (1, 1, 0) Model:

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

$$\Delta ODB_t = -0.830111 - 0.0204043\Delta ODB_{t-1} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.830111	0.0768341	-10.8	0.0000***
β_1	-0.204043	0.283099	-0.7207	0.0931*

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

Forecast Graph:

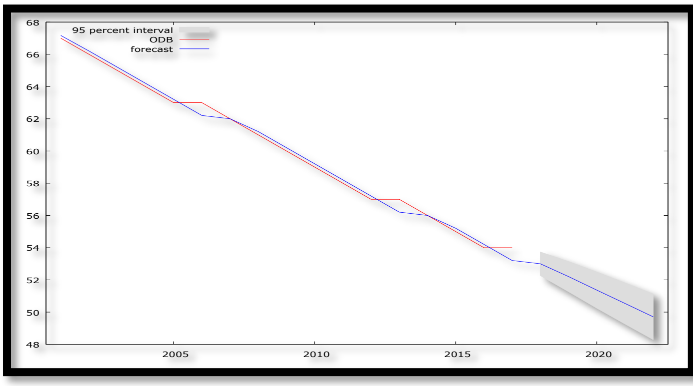

Figure 6: Forecast Graph – In & Out-of-Sample Forecasts

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

Predicted ODB – Out-of-Sample Forecasts Only

Table 10: Predicted ODB

Year	Predicted ODB	Standard Error	Lower Limit	Upper Limit
2018	53	0.375	52.27	53.73
2019	52.2	0.479	51.27	53.14
2020	51.37	0.573	50.25	52.49
2021	50.54	0.651	49.26	51.82
2022	49.71	0.722	48.29	51.12

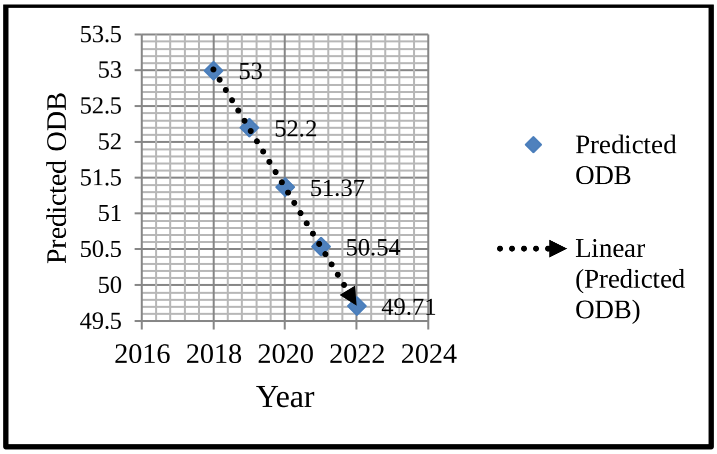

Figure 7: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 7 show the out-of-sample forecasts only. The number of people practicing open defecation in Benin is projected to fall from approximately 53% in 2018 to around 50% of the total population by the year 2022. This is just but a slight projected decrease in the number of open defecators in Benin. This shows that open defecation is generally persistant in Benin; many people in the country, especially those who stay in rural areas; are used to the habit of defecating in the open.

3 POLICY IMPLICATIONS:

i. The Republic of Benin should, first of all, make toilets a status symbol so that people stop thinking about toilets as "dark, dirty and smelly places" but rather consider toilets to be "rooms of happiness". Furthermore, the government of the Republic of Benin should also avail funds for the construction of toilets in rural areas.

ii. The Republic of Benin should create more demand for sanitation through teaching the public on the importance of investing in toilets, especially in light of disease transmission and other risks associated with open defecation.

iii. There is need to encourage a habit of systematic hand-washing, and not defecating in the open.

iv. The Republic of Benin should also continue engaging in institutional triggering in order to induce a strong feeling of disgust towards the practice of open defecation.

CONCLUSION:

The study shows that the ARIMA (1, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Benin over the period 2018 – 2022. The model, generally predicts a decrease in the annual number of people practicing open defecation in Benin. These results are quite important for the government of Benin, especially for future public health policy planning with regards to materializing the much needed open defecation free society.

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