



# Daily COVID-19 Variables in Nigeria: Are They Nonstationary, Long Memory or Interminable Long Memory Process?

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## Abstract

The secular trend, cyclical fluctuation, seasonal and irregular variations are common features of time series that may be observed by using the ordinary time plot graph. However, the time plot graph has the shortcomings of exposing other important components that hide in time series. The non-stationary, Long Memory (LM) and recently Interminable LM (ILM) are features that are seen using the Correlogram and confirmed using the unit root and LM tests. This study presents the Nigeria total sample of COVID-19 tested between 20th April and 6th May 2020, described the Nigeria daily COVID-19 new cases between 27th February and 4th May 2020, its active cases between 17th March and 4th May 2020, death rate between 6th April and 4th May 2020 and recovery rate between 18th March and 4th May 2020. The COVID-19 new cases, active cases, death rate and recovery rate variables were described using the time plot graph and Autocorrelation Function (ACF). The description results were further confirmed by using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Local Whittle Estimator (LWE) and Geweke and Porter-Hudak (GPH) tests. The results show that daily new COVID-19 cases are LM and have long memory estimate in the range of  $0 < d < 1$ . Each of the COVID-19 active cases, death and recovery rate are non-stationary, ILM, produce differencing parameter approximately equal to unity ( $d=1$ ) and fractional unit root difference values in the range of  $1 < d < 2$ . Consequently, it was recommended that the Autoregressive Fractional Integral Moving Average (ARFIMA) model should be used for further analysis of daily COVID-19 new cases. Similarly, the Autoregressive Integral Moving Average (ARIMA) and Autoregressive Fractional Unit Root Integral Moving Average (ARFURIMA) models should be considered for modelling each of the COVID-19 active cases, death and recovery rate.

**Keywords:** Long Memory, Interminable Long Memory, GPH test, Fractional differencing, ARFURIMA model and daily COVID-19 Variables in Nigeria.

## 1. Introduction

The outbreak of Coronavirus Disease 2019 (COVID-19) put the world in an unexpected and huge dilemma affecting sports, social activities, corporate businesses activities and countries' economies. The first COVID-19 case was recorded on 13th January 2020 in Thailand. Since then, it was declared by the World Health Organization (WHO) as a global pandemic. As virologists, biologists, environmentalists and epidemiologists devoted huge time in finding solutions for the control of this catastrophe, the mathematicians and statisticians are also working in describing, analyzing and making predictions of the trend of COVID-19 variables. This is possible for statisticians specifically because the COVID-19 variables are collected and disseminated for public consumptions applying a time series approach.

On 27th February 2020, a 44-year old Italian citizen was diagnosed with COVID-19 in Lagos State, Nigeria. The case was the first to be reported in Nigeria since the first confirmed case was reported in China in January 2020. After the confirmation of the first case, the Nigeria Centre for Disease Control (NCDC) released advisories and statements to help Nigerians respond to the pandemic. As at 4th May 2020, over 19512 samples were tested representing 0.0098% of the Nigerian population. The total confirmed cases of COVID-19 was 2802,



and 2292 active cases. The discharged and death rate due to COVID-19 was 417 and 93 respectively. Besides, the new cases of COVID-19 are on the increase in Nigeria. There are 35 out of 36 states and FCT (Abuja) that so far recorded COVID-19 outbreak representing 94.59% spread rate as shown in Table 1. The Male to Female COVID-19 infection rate is 68:32 and the most affected age-group is 31-40 with 23% rate.

In the literature, some studies described the COVID-19 variables using a time series approach. For example, Cherniha and Davydovych (2020) described the total COVID-19 cases in China to be exhibiting sigmoid behaviour and exponential growing of the total number of the COVID-19 cases in Austria at the initial stage of the coronavirus spread. They showed that measured data in Austria have a strong association with data displayed by the worldometers website. Benvenuto *et al.*, (2020) studied the prevalence and incidence of daily COVID-19 from January 20, 2020, to February 10, 2020. The data they used was collected from the official website of Johns Hopkins University. They explained that the numbers of confirmed cases are increasing while the incidence is slightly decreasing indicating non-stationarity of both series. Also, they observed a slow decay in the series Autocorrelation Function (ACF) concluding that both prevalence and incidence of COVID-2019 are not influenced by the component of seasonality. The Augmented Dickey-Fuller (ADF) test confirmed the non-stationarity and presence of unit root in the series. They recommend that the Autoregressive Integral Moving Average (ARIMA) is the appropriate model to apply in analyzing prevalence and incidence of daily COVID-2019 series because of the observed non-stationarity behaviour.

Zhao *et al.*, (2020) used time series analysis and kinetic model analysis and showed that the cumulative diagnosis of COVID-19 in mainland China can reach 36,343 after one week (February 8, 2020) indicating a stable increase and exhibiting non-stationarity. Describing and analyzing this novel virus by using time series methods, COVID-19 variables are shown to be constant and deterministic (see Meddahi, 2020) and some are trendy and non-stationary (see Tandon *et al.*, 2020, Petropoulos and Makridakis, 2020, and Al-qaness *et al.*, 2020).

The idea underlying time series analysis is that systematic influences that are associated with time, affect time series values. The preliminary goal of the time series analysis is to identify and measure the influences of the different time-related factors or components which time series analysts classified into four basic types namely: secular trend (upward or downward), cyclical fluctuation, seasonal and irregular variations. These basic features play a significant role in describing components that dwell in time series and understanding the behaviour of data collected over time. This is particularly true when studying and modelling high-frequency data such as data collected based on seconds, minutes, hourly, daily and weekly time interval (Jibrin, 2019).

The COVID-19 parameters or variables recorded in Nigeria are total sample test carried out, new cases, active cases, recovery and death rate. The behaviour of these variables can be best describe and modelled when they are explained based on the present components. The objective of the current study is to investigate if the Nigeria daily COVID-19 variables can be described as non-stationary, Long Memory (LM) and Interminable LM (ILM) process. This approach will serve as a prelude in describing and shall play a key role in selecting the appropriate model(s) in studying the Nigeria daily COVID-19 time series variables.

## 2. Materials and Methodologies

Data used and the methods for testing non-stationary and LM are explained here.

### 2.1. Data

Data for this study are obtained from the website of the NCDC, Abuja-Nigeria and includes 17, 68, 49, 29 and 48 daily total sample tested, new cases, active cases, recovery rate and death rate respectively. The range of the variables is total sample tested (from 20th April to 6th May 2020), new cases (from 27th February to 4th May 2020), active cases (from 17th March to 4th May 2020), the death rate (from 6th April to 4th May 2020) and recovery rate (from 18th March to 4th May 2020).



Table 1: States with reported laboratory-confirmed COVID-19 cases, recoveries and deaths

STATES	CCC	NCC	CDC	NDC	CD	ND	TAC
Lagos	1183	76	261	14	30	0	892
Kano	365	23	0	0	8	2	357
FCT	297	19	40	0	3	0	254
Borno	100	18	0	0	14	2	86
Gombe	96	0	0	0	0	0	96
Ogun	85	5	12	2	2	0	71
Katsina	83	37	6	0	7	0	70
Kaduna	81	0	10	2	1	0	70
Bauchi	80	9	6	0	0	0	74
Sokoto	66	0	1	0	8	0	57
Edo	62	10	10	0	4	1	48
Jigawa	39	32	0	0	1	0	38
Oyo	39	5	9	0	2	0	28
Osun	37	1	30	8	4	1	3
Delta	17	0	2	0	2	0	13
Akwa Ibom	16	0	10	0	2	0	4
Kwara	16	0	8	0	0	0	8
Rivers	14	0	2	0	2	0	10
Ondo	13	0	3	0	0	0	10
Yobe	13	0	0	0	1	0	12
Zamfara	13	1	0	0	1	0	12
Adamawa	12	6	0	0	0	0	12
Ekiti	12	1	2	0	1	0	9
Kebbi	12	0	0	0	0	0	12
Nasarawa	11	0	0	0	0	0	11
Enugu	8	0	2	0	0	0	6
Taraba	8	0	0	0	0	0	8
Bayelsa	5	0	0	0	0	0	5
Ebonyi	5	0	0	0	0	0	5
Niger	4	1	1	0	0	0	3
Plateau	3	0	0	0	0	0	3
Abia	2	0	1	0	0	0	1
Benue	2	1	0	0	0	0	2
Imo	2	0	0	0	0	0	2
Anambra	1	0	1	0	0	0	0

Note: CCC=Cumulative Confirmed Cases, NCC=New Confirmed Cases, CDC=Cumulative Discharged Cases, NDC=New , Discharged Cases, CD= Cumulative Death, ND=New Death and TAC=Total Active Cases.

Source: NCDC.

## 2.2. Nonstationary Testing Methods

Several tests have been proposed to investigate the stationarity condition of a given time series as well as the order of integration. For this study, the ADF and Phillips-Perron (PP) test for the unit root or non-stationary is considered.

### 2.2.1. The Augmented Dickey-Fuller Stationary test

The ADF test was introduced by Dickey and Fuller (1979, 1981). It tests the null hypothesis that a unit root is present in a time series sample. The presence of a unit root in a time series indicates non-stationarity. The alternative hypothesis is usually stationarity or trend-stationarity. The ADF statistic's probability value (p-value), used in the test, is a small number. The smaller it is compared to the chosen level of significance, the stronger the rejection of the hypothesis that there is a unit root at some level of confidence. The testing procedure for the ADF test applied to the Autoregressive of order one denoted by AR(1) model is:

$$y_t = \mu + \gamma_t + \varphi_1 y_{t-1} + \varepsilon_t. \quad (1)$$

The ADF adds lagged differences to these models so that

$$\Delta y_t = \mu + \gamma_t + \varphi_1 y_{t-1} + \delta_1 \Delta y_{t-1} \dots + \delta_p \Delta y_{t-p} + \varepsilon_t, \quad (2)$$

and

$$\Delta y_t = \mu + \gamma_t + \varphi_1 y_{t-1} + \sum_{i=1}^p \delta_i \Delta y_{t-i} + \varepsilon_t, \quad (3)$$

where  $\mu$  is a constant,  $\gamma$  the coefficient on a time trend,  $p$  the lag order of the AR model and  $\varepsilon_t \sim i.i.d(0, \sigma_\varepsilon^2)$ .

### 2.2.2. The Phillips-Perron Stationary test

The PP unit root test was introduced by Phillips and Perron (1988). It is used in time series analysis and modelling. It is an extension of the Dickey-Fuller unit root test. The PP test has the following equation:

$$\Delta y_t = (\rho - 1)y_{t-1} + \varepsilon_t, \quad (4)$$

where  $\Delta$  is the first-difference operator and  $\varepsilon_t$  is defined as in (3). The PP test hypothesis can be stated:

$H_0: \rho = 1$  (the series  $y_t$  is integrated of order 1, I(1))  $H_1: \rho < 1$  (the series is integrated of order 0, I(0)).

The null hypothesis  $H_0$  is rejected if the p-value is less than the significance level  $\alpha$  (0.05).

## 2.3. Long Memory Testing Methods

For LM modelling, it is important to test for long-range dependence and estimate fractional differencing value (Jibrin, 2015). In this study, we consider the Local Whittle Estimator (LWE) and Geweke and Porter-Hudak (GPH)

for estimation of LM, ILM and are discussed in turns the next sub-section.

### 2.3.1. The Local Whittle Estimator

The LWE is discussed by Kunsch (1987) and introduced by Robinson (1995). The LWE is determined by minimizing the objective function,

$$R^{LW}(d) = \ln \left[ \frac{1}{T} \sum_{j=1}^T \theta_j^{2d} I(\theta_j) \right] - \frac{2d}{T} \sum_{j=1}^T \ln(\theta_j), \quad (5)$$

with respect to fractional differencing value  $d$ , where  $\theta_j = \frac{2\pi j}{T}$  for  $j = 1, \dots, T$  and  $I(\theta_j) = \left(\frac{1}{2\pi T}\right) \left|\sum_{t=1}^T y_t \exp(i\theta_j t)\right|^2$  is the periodogram. The estimator depends on the choice of bandwidth,  $T$ , which is chosen as  $T = N^\tau$  where  $0 < \tau < 0.8$ ;  $N$  is the sample size.

### 2.3.2. The Geweke and Porter-Hudak Estimator

Given,  $y_t$ , a fractionally integrated series, a semi-parametric approach for estimating LM value is:

$$\hat{d}_{GPH} \rightarrow N\left(d, \frac{\pi^2}{6 \sum_{i=1}^m (y_i - \bar{y})^2}\right), \quad (6)$$

where  $N$  is the sample size,  $\bar{y}$  is the mean of  $y_t$  and  $\pi$  is constant. See GPH (1983) for the derivation of equation (6).

## 3. Results

This section provides the data presentation, descriptive statistics, unit root, LM tests and time series classification of daily COVID-19 variables. The variables recorded are daily total sample tested, new cases, active cases, recovery rate and death rate.

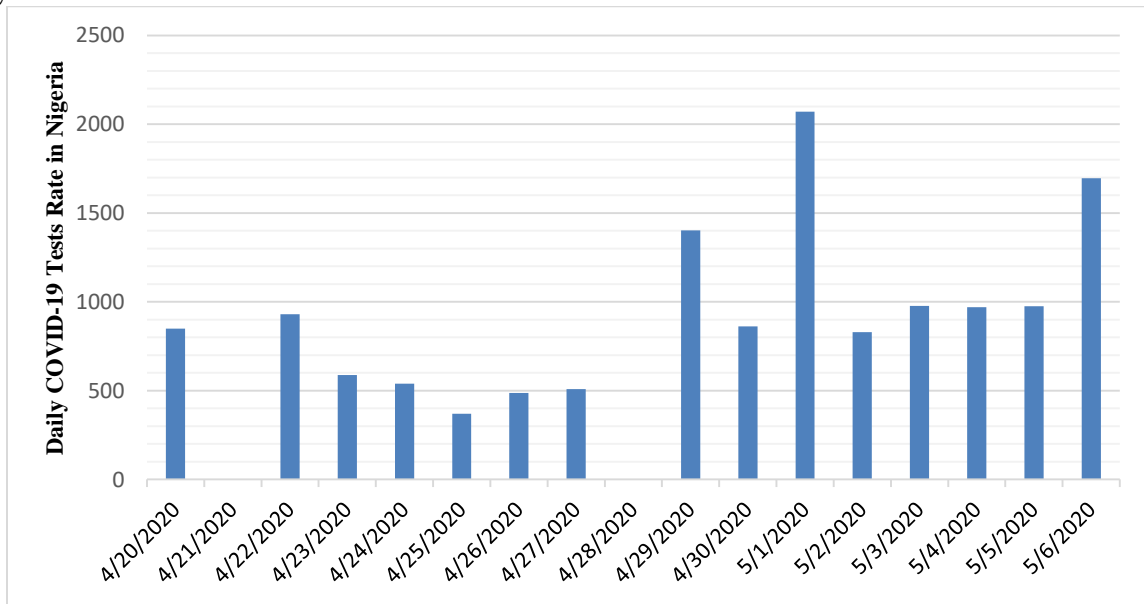


Figure 1: Bar Chart for Daily COVID-19 Tests Rate in Nigeria

Figure 1 presents the bar chart for the daily sample of COVID-19 test rate. Based on the range of data used, it was noticed that the COVID-19 test was not carried out on 21st and 28th April 2020. This could be because samples were not submitted by states or due to inadequate testing kits. The lowest and highest number of daily COVID-19 test was carried out on 25th April and 1st May 2020 representing 370 and 2070 samples respectively.

Figure 2 presents the bar chart for the daily new COVID-19 cases. The first case of COVID-19 was confirmed in Nigeria on 27th February 2020. However, as of 4th May 2020, 35 were the highest daily new cases and occurred on 1st April 2020.

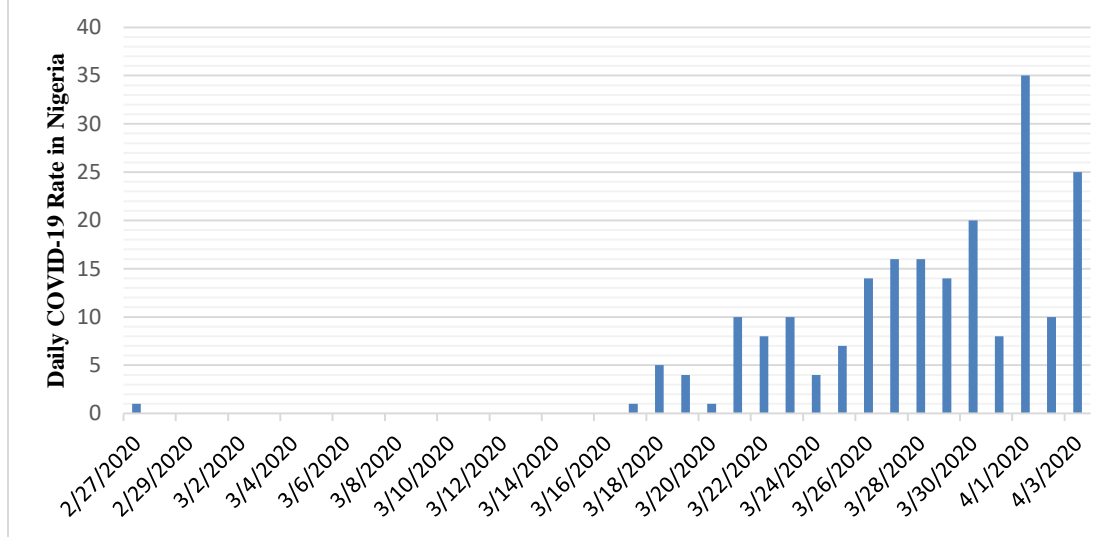


Figure 2: Bar Chart for Daily COVID-19 Rate in Nigeria

All the time series plot of the COVID-19 daily new cases, active cases and recovery rate as shown in Figure 3(a)-5(a) exhibit upward trend behaviour and this is due to an average increase in the variables of COVID-19. Also, the COVID-19 pandemic exhibit regime-switching or shift in mean value over time. The ACF in Figure 3(b)-4(b) and 5(b)-6(b) shows a very slow and slow decay respectively. These are either evidence of LM or ILM. Series that exhibits LM can produce LM value as  $0 < d < 1$  and  $1 < d < 2$  if is ILM (Jibrin & Rahman, 2019). Given this, the variables of COVID-19 considered in the current study are either generated by an LM or ILM process. The LWE and GPH test shall confirm these components observed in the COVID-19 variables. Hence, it can be stated that the four series are affected by variability and trends.

Table 2 presents the descriptive statistics and normality test for the four COVID-19 variables. The mean for the daily new COVID-19 cases, active cases, death and recovery rate is 41, 47, 3 and 9 respectively. The standard deviation is 65 for daily new COVID-19 cases, 63 for the active cases, 4 for death rate and 11, for recovery rate. The estimates of skewness and kurtosis for all the COVID-19 variables revealed evidence of asymmetric. Also, the Jarque-Bera test results indicate that for all the four series, the null hypotheses of symmetric distribution each case is rejected at the 0.05 significance level.

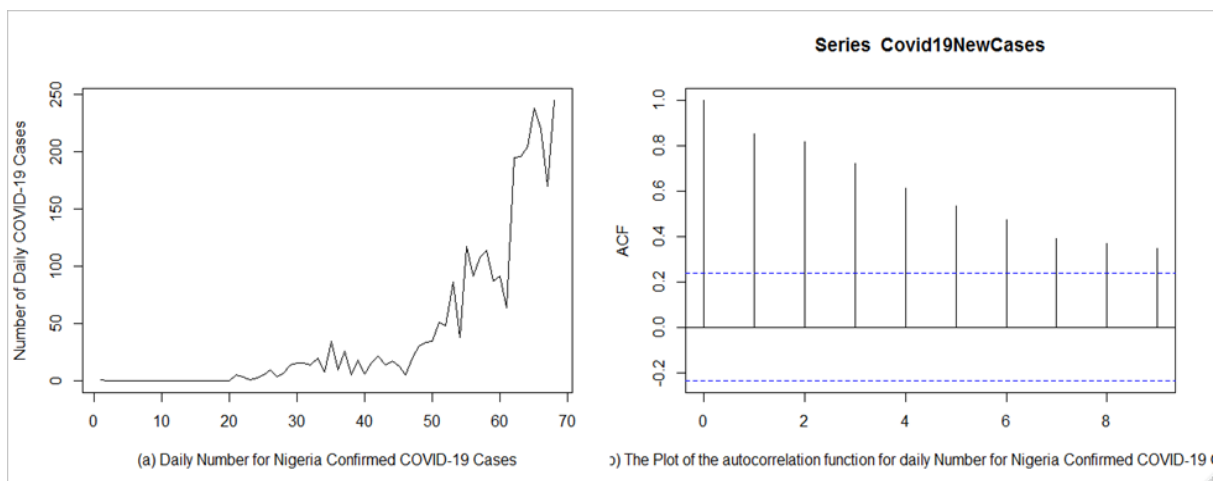


Figure 3: The Time Series Plot and ACF for daily Number for Nigeria Confirmed COVID-19 Cases (27th February – 4th May 2020).

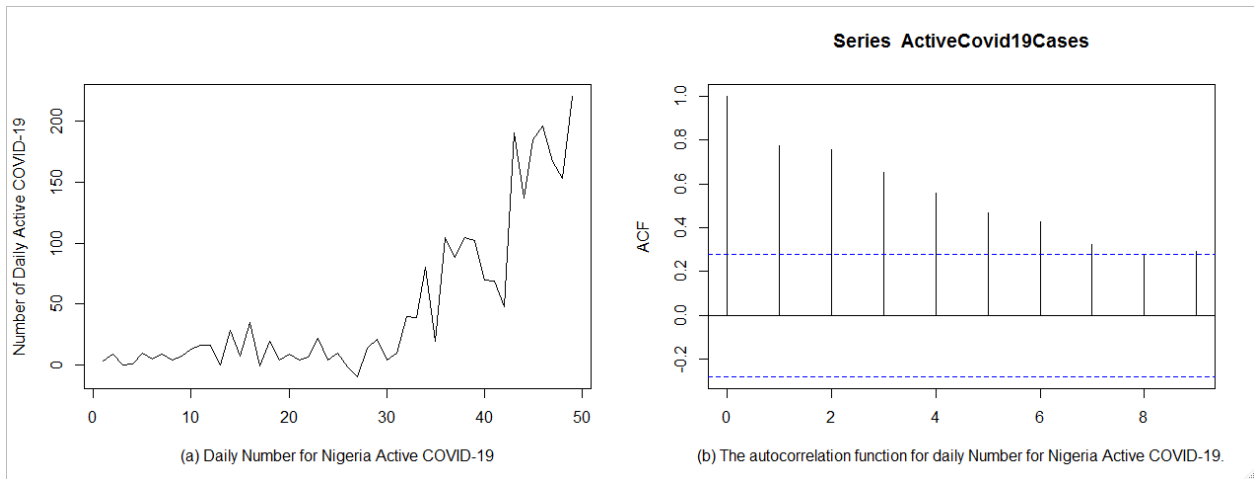


Figure 4: The Time Series Plot and ACF for daily Number for Nigeria Active COVID-19 (17th March– 4th May 2020).

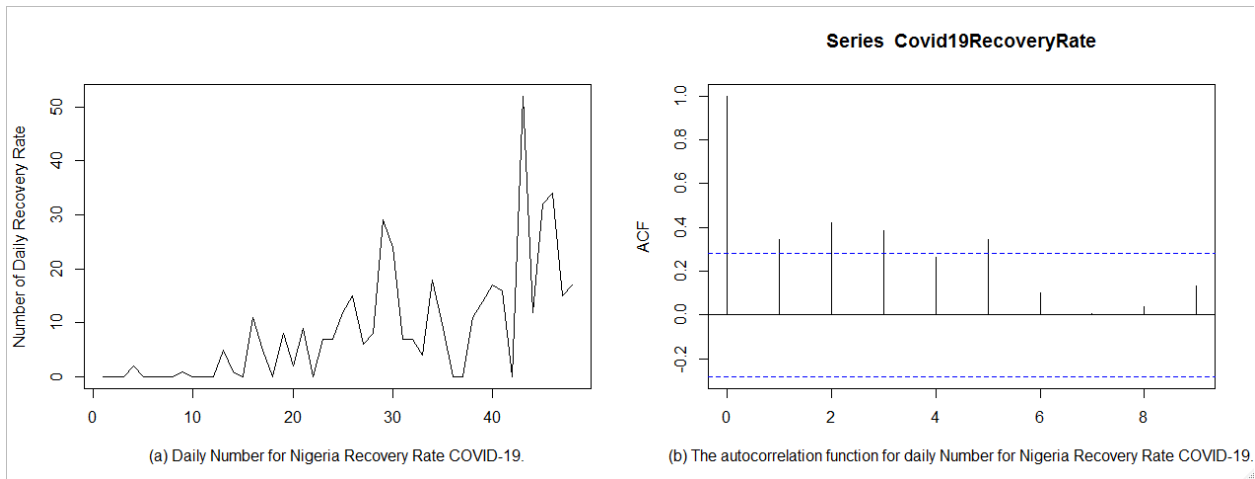


Figure 5: The Time Series Plot and ACF for daily Number for Nigeria Recovery Rate COVID-19 (18th March– 4th May 2020).

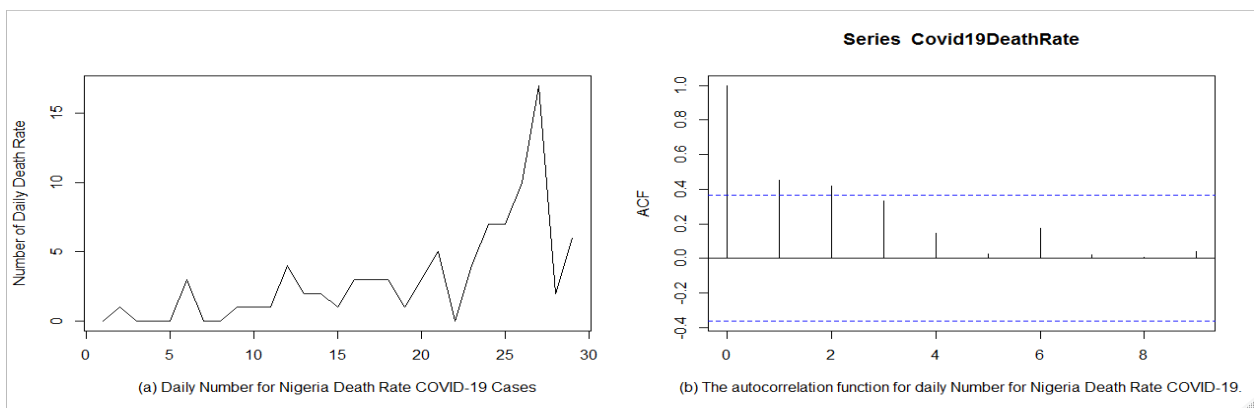


Figure 6: The Time Series Plot and ACF for daily Number for Nigeria Death Rate COVID-19 (6th April – 4th May 2020).



Table 2: Descriptive Statistics

Statistics	New COVID-19 Cases	Daily Active Occurrence	COVID-19 Death Rate	COVID-19 Recovery Rate
Mean	41	47	3	9
Maximum	245	221	17	52
Std. Dev.	65	63	4	11
Skewness	1.886	1.430	2.173	1.863
Kurtosis	2.433	0.800	5.366	3.981
Jarque-Bera	129.461	54.158	24.929	33.543

Notes: Jarque-Bera test and it corresponds to the test statistic for the null hypothesis of normality in the distribution of sample data.

Table 3: Unit Root and Long Memory Tests and their Estimation

Tests	New COVID-19 Cases	Daily Active Occurrence	COVID-19 Death Rate	COVID-19 Recovery Rate
ADF	3.02(0.9999)	0.59(0.9995)	-1.59(0.7985)	-4.28(0.9352)
PP	-1.10(0.9206)	2.49(0.3275)	-4.67(0.0045)[28]	-7.21(0.0000)
LWE	4.39(0.0000)[0.7761]	5.49(0.0000)[1.0385]	4.49(0.0000)[1.0049]	5.48(0.0000)[1.0356]
GPH	10.79(0.0000)[0.7862]	2.69(0.0003)[1.5369]	2.91(0.0000)[1.1419]	4.15(0.0009)[1.0241]

Note: p-values are in parenthesis (.) and LWE and GPH fractional differencing values are in square brackets.

### Time Series Classification of Daily COVID-19 Variables

The non-stationarity, LM and ILM are used to describe or classify the components of Nigeria daily COVID-19 variables. It is pertinent to note that the three identified components will be used to guide in the choice of appropriate models for modelling and forecasting COVID-19 variables in future research.

Table 4 provides a summary classification of COVID-19 time series data for the four series used in this study. Because of the attributes exhibited by the four different data, the daily new COVID-19 cases are LM process due to LM value of  $0 < d < 1$ . However, each of the daily COVID-19 active cases, death and recovery rate are non-stationary and ILM process because each can be difference approximately by using the first difference transformation ( $y_t - y_{t-1}$ ) method because of ( $d \approx 1$ ). They also have fractional unit root differencing values in the range of  $1 < d < 2$ . For fractional differencing and fractional unit root differencing approach, see Granger & Joyeux (1980) and Jibrin & Rahman, (2019) respectively.

Table 4: Time Series Classification and Remarks

Data	LM ( $0 < d < 1$ )	IO ( $d=1$ )	ILM ( $1 < d < 2$ )	Remarks
New COVID-19 Cases	Yes	No	No	Use ARFIMA models only
Daily Active Occurrence	No	Yes	Yes	Compare ARIMA and ARFURIMA models
COVID-19 Death Rate	No	Yes	Yes	Compare ARIMA and ARFURIMA models
COVID-19 Recovery Rate	No	Yes	yes	Compare ARIMA and ARFURIMA models

Note: LM=Long Memory, IO=Integrated Order and ILM=Interminable Long Memory.





#### 4. Discussion

The time plot graph is usually used in describing the characteristics of time series data. However, other unwanted components of time series that are needed to be reduced or eliminated before the modeling process required application of higher time series tools before they can be identified. The non-stationary, LM and recently ILM are features that are identified using the Correlogram and sometimes the Periodogram tools. In this study, we used the ACF, a part of Correlogram and a graph tool and determine that the daily new COVID-19 cases exhibit LM while each of daily COVID-19 active cases, death and recovery rate are non-stationarity and ILM. Consequently, the ADF, PP, LWE and GPH were used to confirm time-series properties of these variables identified using the graph tool.

The findings show that the daily new COVID-19 cases series satisfied all the assumptions listed before applying the ARFIMA model. This is because the COVID-19 new cases are LM with positive autocorrelations. Applying LM estimators, LWE and GPH, produce LM value of  $0 < d < 1$ . Each of daily COVID-19 active cases, death and recovery rate are shown to have  $d \approx 1$  and also have fractional unit root differencing values in the range of  $1 < d < 2$ .

#### 5. Conclusions

The finding of the study indicates that the daily new COVID-19 Nigeria cases series is an LM process. Consequently, each of daily COVID-19 active cases, death and recovery rate are shown to be non-stationary and ILM process. The study has the implications to serve as a guide to help the Nigerian Government provide insights into what might happen, prepare and respond to the challenges of the COVID-19 pandemic.

#### Recommendations for further study

The classification of COVID-19 variables in Nigeria revealed that the daily new COVID-19 Nigeria cases series is an LM process while each of daily COVID-19 active cases, death and recovery rate are non-stationary and ILM process. Therefore, it is recommended that the daily new COVID-19 Nigeria cases series should be modelled by using the ARFIMA model. However, for comparison purposes, the ARIMA and ARFURIMA are recommended to study and make predictions for each of the daily COVID-19 active cases, death and recovery rate.

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