Chapter 8
Nigerian COVID-19 Incidence Modeling and Forecasting with Univariate Time Series Model

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Abstract The occurrence of COVID-19 has given rise to dreadful medical difficulties due to its hyper-endemic effects on the human population. This made it fundamental to model and forecast COVID-19 pervasiveness and mortality to control the spread viably.

The COVID-19 data used was from February, 28, 2020 to March 1, 2021. ARIMA(1,2,0) was selected for modeling COVID-19 confirmed and ARIMA (1,1,0) for death cases. The model was shown to be adequate for modeling and forecasting Nigerian COVID-19 data based on the ARIMA model building results. The forecasted values from the two models indicated Nigerian COVID-19 cumulative confirmed and death case continues to rise and maybe in-between 189,019–327,426 and interval 406–3043, respectively in the next 3 months (May 30, 2021). The ARIMA models forecast indicated an alarming rise in Nigerian COVID-19 confirmed and death cases on a daily basis.

The findings indicated that effective treatment strategies must be put in place, the health sector should be monitored and properly funded. All the protocols and restrictions put in place by the NCDC, Nigeria should be clung to diminish the spread of the pandemic and possible mortality before immunizations that can forestall the infection is developed.

Keywords COVID-19 · ARIMA model · Confirmed cases · Death cases · Modeling · Forecasting

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8.1 Introduction

COVID-19 is considered an emergency of international importance for public health. About 15% of cases are in patients with a chronic form of the disease (Zhang et al. 2020). Aging individuals and those with pre-existing medical problems are likely to become severely ill (Holingue et al. 2020). The 2019 Coronavirus disease (COVID-19), which first took place in Wuhan, China, in December 2019, has spread to almost all of the world (Adenomon et al. 2020; Igwe 2020). argued that the global economy faces the worst-ever economic recession due to the outbreak of the COVID-19. He also noted that the shock from this virus would raise instability that will adversely impact the economic and financial environment of every country (Adenomon et al. 2020). reported on the Zombie epidemic that could be close to COVID-19, the study concluded that a mild zombie outbreak would lead to a decrease in GDP and the stock market of 23.44% and 29.30%, respectively, leaving one million people dead in the main developed world.

On February 27, 2020, the COVID-19 case was officially identified in Nigeria, and many more cases were identified after that (Adegboye et al. 2020). The effects of COVID-19 on Nigeria's economy and financial markets as to do with the economic lockout of major cities (Abuja, Lagos, Ogun States) on March 30, 2020, resulting in economic losses, particularly for the everyday earners of small–medium-sized firms, the removal of capital from the market by buyers and the collapse in oil prices (Abulude and Abulude 2020). Furthermore, if the impact of COVID-19 on the economy and financial markets are not adequately recognized and controlled, this virus has the potential to completely crash any country, such as Nigeria's health sector or economy (Ajibo 2020). Especially in the absence of a vaccine, while studies have shown that it is not possible to reinfect a recovered population (Mumbu and Hugo 2020). Chukwuka and Mma (2020). recognized the effect of the COVID-19 epidemic on the Nigerian economy, their result revealed that Nigeria's economy based on GDP should rise by 2.5% in 2020; this was truncated by the pandemic and led to a high increase in the nation's debt services and income ratio at 60% amid declining oil prices (Akanni and Gabriel 2020). stated that the COVID-19 pandemic has led to the destruction of operations and economic turmoil as the United Trade and Development Agency cost the economic loss to the outbreak around $2 trillion. Factors such as social distancing, stay at home, spending restrictions and supply factors have been shown to harm economic development. The National Bureau of Statistics (NBS) survey 2020 ranked Nigeria 21 among 181 counties with a high unemployment rate of 23.1%, with an estimated 87 million living with less than $2 a day benchmark.

Olufemi and Bolanle (2018) Investigated the diversification of the Nigerian stock market's foreign portfolio, the analysis was concluded using the vector autoregressive granger causality test for relationship revealed that there is no relationship between the stock market of Nigeria and the other five developed countries. However, applying the Generalized Moment Regression approach, the result revealed that established capital markets have an effect on the Nigerian stock market

after the crisis period and before the crisis period. This was also inferred that before the COVID-19 crisis, Nigeria's stock market was safe for investors, but the COVID-19 situation has made investment impossible.

John (2020) discussed the COVID-19 pandemic, a battle to be fought and its economic implications for Africa. The study concluded that the International Monetary Fund has called on all official bilateral creditors to postpone all loan payments. The International Development Organization Countries are asking for forbearance to savage economic uncertainty as the effect of COVID-19 on the African economy cannot be decided yet, but as the situation progresses, there will be more insight into it.

Based on the discussion above, the purpose of this research is to use an Autoregressive integrated moving average model, which is a Univariate time series model, to forecast Nigerian COVID-19 incidences as a way to determine potential future occurrences.

Since forecasting is a process of predicting or estimating the future based on past and present data. It is important because it provides relevant and reliable information about past, present, and future events. It gives room for vivid planning and enhances the process of making important decisions and policies. Types of forecasting are qualitative and quantitative methods, where the latter involves the use of statistical methods. In particular, forecasting with time series analysis models, which include Autoregression (AR), Moving Average (MA), Autoregressive Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA) and Seasonal Autoregressive Integrated Moving Average (SARIMA). The data patterns can be a trend, cyclical, seasonal, and irregular in nature. But before the data can be model, stationarity is firstly attained by differencing the series and check for a possible seasonal component. Therefore, the appropriate model for forecasting stationary series without seasonal components is an autoregressive integrated moving average (Box et al. 2015). The basic steps in forecasting are problem definition, gathering information, preliminary exploratory analysis, choosing and fitting models and evaluating the forecasting model. The forecasting model is evaluated for accuracy using the forecast error, which is the difference between the actual and the forecast for a given period. The measures of forecast accuracy often used are mean absolute error (MAE), root mean square forecast error (RMSE) and mean absolute percentage error (MAPE) (Forecast Errors 2002).

8.2 Materials and Methods

8.2.1 Data Collection

The data used was obtained from Nigeria Center for disease control (NCDC) website. The COVID 19 confirmed and death cases dataset obtained span between February 28, 2020 to March 1, 2021.

8.2.2 Univariate Time Series Model

A Univariate time series model is a class of specifications used to model and forecast a particular time series using only information contained in their past values and possibly current and past values of an error term.

8.2.3 Autoregressive Integrated Moving Average (ARIMA) Model

ARIMA model is a Univariate time series model that consists of an autoregressive polynomial, an order of integration (d) and a moving average polynomial. The usual forms of AR(p) and MA(q) are written as

$$x_t = \varnothing_1 x_{t-1} + \varnothing_2 x_{t-2} + \ldots + \varnothing_p x_{t-p} + e_t \tag{8.1}$$

and

$$x_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q} \tag{8.2}$$

where $\varnothing$ and θ are the autoregressive and moving average parameters, respectively. x_t is the observed value at time t and ε_t is the value of the random shock at time t. It is assumed to be independently and identically distributed with a mean of zero and a constant variance (σ^2). ARMA (p, q) model is comprised of AR and MA models, in which the current value of the time series is defined linearly in terms of its previous values as well as current and previous error series.

The ARMA (p, q) model is given in (8.3) as

$$x_t = \varnothing_1 x_{t-1} + \varnothing_2 x_{t-2} + \ldots + \varnothing_p x_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q} \tag{8.3}$$

This can be simplified by a backward shift operator B to obtain

$$(B)\nabla^d x_t = \theta(B) w_t \tag{8.4}$$

Therefore (8.4) can be expressed as ARMA(p, d, q) where $\nabla^d = (1 - B)^d$ with $\nabla^d y_t$ and dth consecutive differencing. The basic steps used for ARIMA model buildings involve model identification, estimation, diagnostic, and forecasting.

8.2.3.1 Model Identification

A correlogram is a chart of correlation statistics, and it includes an autocorrelations function (ACF) and partial autocorrelation functions (PACF). The ACF is used to measure the amount of linear dependence between observations in the time series, and the partial autocorrelation function is used to determine the possible order of the ARIMA model. The Autocorrelations function (ACF) is denoted by

$$\rho_k = \frac{E[(x_t - \overline{x})(x_{t-k} - \overline{x})]}{E[x_t - \overline{x}]^2} \tag{8.5}$$

and partial autocorrelation functions (PACF) is given as

$$x_t = \rho_0 + \sum_{k=1}^{K} \rho_{kk} x_{t-k} \tag{8.6}$$

where ρ_{kk} is the kth autoregressive coefficient, $k = 1, 2, \ldots, K$. After the identification stage, the smallest values of Akaike Information criteria (AIC), Schwartz Bayesian Information criteria (SBC) and Hannan Quinn Information criteria (HQC) will be used to choose the appropriate model.

8.2.3.2 Parameter Estimation

The coefficient of the ARIMA model will be obtained using the ordinary least squares estimation method. The coefficient will be obtained using

$$\widehat{\varnothing} = \sum_{t=2}^{n} (x_{t-1})(x_t) \Big/ \sum_{t=2}^{n} x_{t-1}^2 \tag{8.7}$$

8.2.3.3 Diagnostic Checking

The stability of the estimated model will be diagnosed using Modified Box-Pierce (Ljung-Box) Chi-Square Statistic. This is defined as

$$Q(m) = n(n+2) \sum_{j=1}^{m} \frac{r_j^2}{n-j} \tag{8.8}$$

where n is the number of usable data points after any differencing operations.

8.2.3.4 Forecasting

There are two kinds of forecasts, and these are sample period forecasts and post-sample period forecasts. The former will be used to develop confidence in the model, and the latter will be used to generate genuinely desired forecasts. In forecasting, the goal is to predict future values of a time series, x_{t+m}, $m = 1, 2, \ldots$ based on the data collected to the present, $x = \{x_t, x_{t-1}, \ldots, x_1\}$.

8.3 Result and Discussion

A daily cumulative dataset for confirmed and death cases of COVID-19 occurrences from February 28, 2020 to March 1, 2021 was considered. Time plots of the confirmed and death cases of COVID-19 data are presented in Figs. 8.1 and 8.2 to

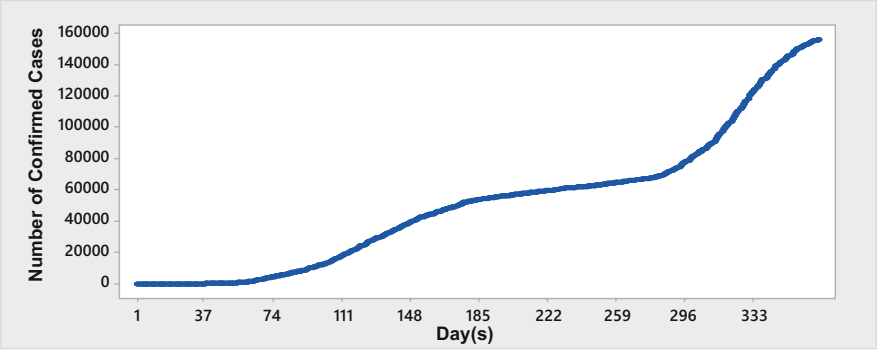

Fig. 8.1 Time plot of confirmed cases from February 28, 2020 to March 1, 2021

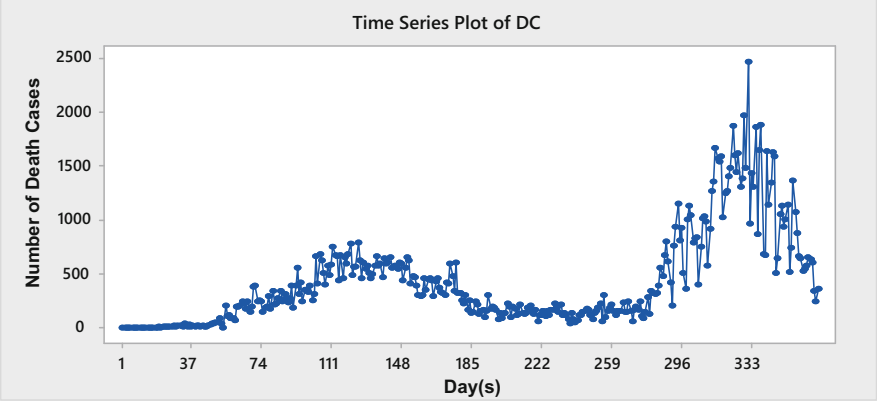

Fig. 8.2 Time plot of death cases from February 28, 2020 to March 1, 2021

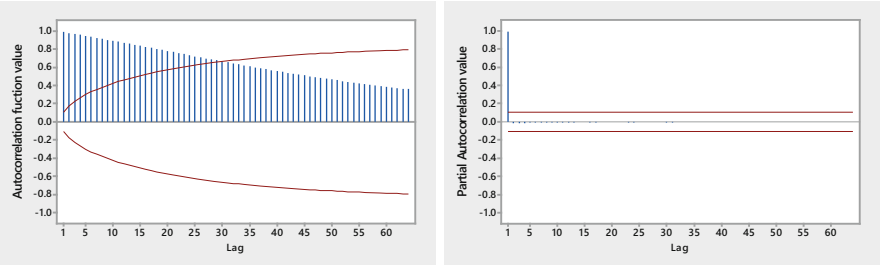

Fig. 8.3 (a) Autocorrelation function for confirmed cases. (b) Partial autocorrelation function for confirmed case

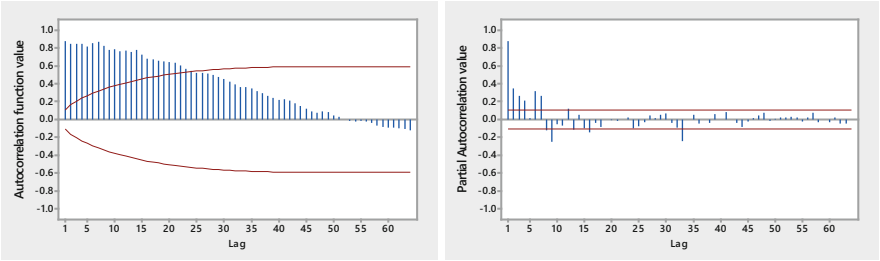

Fig. 8.4 (a) Autocorrelation function for death cases. (b) Partial autocorrelation function for death cases

investigate the trend and behavior of data concerning over a while. Figures 8.1 and 8.2 showed that confirmed and death cases of COVID-19 data exhibited a trend or secular movement. The Autocorrelation function plots in Figs. 8.3a and 8.4a and partial autocorrelation function plots in Figs. 8.3b and 8.4b were used to show that the COVID-19 confirmed and death cases are not stationary since autocorrelations diminish marginally. Consequently, the first difference was taken to balance out the mean of the COVID-19 information. To accomplish stationarity, the Dickey-Fuller unit root test was established, and from the outcome, the COVID-19 confirmed cases were stationary at the second difference ($d = 2$), and death cases were stationary at the first difference ($d = 1$).

The autocorrelation function (ACF) plots in Figs. 8.3a and 8.4a and partial autocorrelation function (PACF) plots in Figs. 8.3b and 8.4b were used to examine the randomness of the COVID-19 data. This is used to quantify the relation between lagged time series values. A further critical look showed that the autocorrelation function (ACF), and partial autocorrelation function (PACF) showed the ACF tailed off at lag 1 and PACF cut-off after lag 0. In essence, $p = 1$ and $q = 0$ or $p = 0$ and $q = 1$. Based on the values of p and q, the following models ARIMA(1,2,1), ARIMA

Table 8.1 Parameters estimate of ARMA(1,2,0) for COVID-19 confirmed cases

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
D(Confirmed Case,2)	0.0005	0.0007	0.0007	1.0000
AR(1)	−0.3962	0.0002	0.0030	0.0000
Constant	1.25	10.32	0.12	0.9040

Table 8.2 Parameters estimate of ARMA(1,1,0) for COVID-19 death cases

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
D(Death Case,1)	0.0003	0.0007	4.5374	1.0000
AR(1)	−0.3960	3.3728	0.0024	0.0000
Constant	1.24	1029	0.12	0.9040

Table 8.3 Modified Box-Pierce Chi-square statistic for COVID-19 confirmed cases

Lag	Chi-Square	Degree of freedom	*p*-value
12	143.68	10	0.0000
24	199.94	22	0.0000
36	215.82	34	0.0000
48	245.02	48	0.0000

Table 8.4 Modified Box-Pierce Chi-square statistic for COVID-19 death cases

Lag	Chi-Square	Degree of freedom	*p*-value
12	165.35	10	0.0000
24	274.09	22	0.0000
36	336.39	34	0.0000
48	361.90	48	0.0000

(0,2,1), ARIMA(1,2,0) were created for COVID-19 confirmed cases and ARIMA (1,1,1), ARIMA(0,1,1) and ARIMA(1,1,0) were created for COVID death cases.

ARIMA(1,2,0) was chosen for COVID-19 confirmed cases, and ARIMA(1,1,0) was chosen for COVID-19 death cases from the created models based on the least values the information criteria after the coefficients of the models were estimated using the least squares method for both confirmed and death cases of COVID-19 data. The fitted model results for confirmed and death cases of COVID-19 data are given in Tables 8.1 and 8.2. The adequacy of both models for forecasting Nigeria was confirmed, and death cases were determined based on Modified Box-Pierce (Ljung-Box) Chi-Square Statistic values given in Tables 8.3 and 8.4. In essence, the models can now be used to forecast Nigerian confirmed and death cases.

Figure 8.5 was used to present the fitted and predicted values for Nigerian confirmed and death cases for the next 90-days. Table 8.5 further showed Nigerian

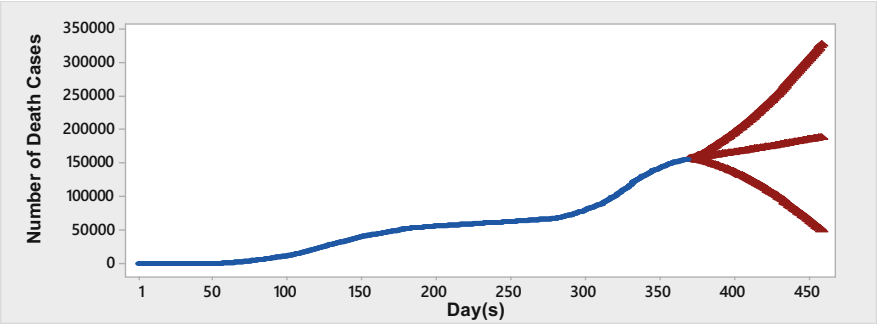

Fig. 8.5 Time plot of confirmed cases forecast from February 28, 2020 to May 30, 2021

cumulative confirmed and death cases forecast, upper and lower limit values. Based on Table 8.5 and Fig. 8.5, the Nigerian COVID-19 cumulative confirmed case continues to rise and maybe in between 189,019–327,426 confirmed cases in the next 3 months (May 30, 2021). While Fig. 8.6 depicts the fitted and predicted values for Nigerian cumulative death cases for the next 90-days. Table 8.5 as well is used to present the Nigerian cumulative death case forecast, upper and lower limit values, and this indicated that Nigerian COVID-19 death cases continue to increase, and this may rise between 406–3043 deaths in the next 3 months (May 30, 2021).

The ARIMA models forecast showed that Nigerian COVID-19 confirmed and death cases are increasing at an alarming rate on a daily basis. Accordingly, the ARIMA models forecast showed a disturbing ascent in Nigerian COVID-19 confirmed and death cases. These results benefit the Nigerian government at all level, local and international organizations and individuals that COVID-19 is a serious and deadly disease that can easily spread and harper human growth and existence. This as well gives a general awareness to Nigerian citizens that everyone has a role to play to put a stop to COVID-19 spread by adhering to all safety protocols recommended by World Health Organization (WHO) and National Center for Disease Control (NCDC), Nigeria. Therefore, based on the COVID-19 confirmed and death cases forecast, the Nigerian government must decide to put in place pro-activity and efficient treatment strategies. The health sector should be monitored and properly funded. All the protocols and restrictions put in place by the NCDC, Nigeria should be enforced in other to combat the spread of the pandemic, and possible mortality before immunizations that can forestall or fix the infection is created and readily available.

Table 8.5 Forecast of confirmed and death cases of COVID-19 in Nigeria from March 2, 2021 to May 30, 2021 with 95% confidence interval

	Forecast for confirmed cases			Forecast for death cases		
Day(s)	Forecast	Lower limit	Upper limit	Forecast	Lower limit	Upper limit
Tuesday, March 2, 2021	156,331	155,944	156,718	314	0	700
Wednesday, March 3, 2021	156,664	155,933	157,395	333	0	785
Thursday, March 4, 2021	156,991	155,820	158,162	327	0	865
Friday, March 5, 2021	157,321	155,655	158,988	331	0	933
Saturday, March 6, 2021	157,652	155,433	159,871	330	0	995
Sunday, March 7, 2021	157,983	155,163	160,804	332	0	1051
Monday, March 8, 2021	158,316	154,847	161,784	332	0	1103
Tuesday, March 9, 2021	158,649	154,490	162,809	333	0	1152
Wednesday, March 10, 2021	158,983	154,093	163,874	334	0	1199
Thursday, March 11, 2021	159,319	153,658	164,979	335	0	1243
Friday, March 12, 2021	159,655	153,187	166,122	336	0	1285
Saturday, March 13, 2021	159,992	152,683	167,300	337	0	1325
Sunday, March 14, 2021	160,329	152,146	168,513	338	0	1364
Monday, March 15, 2021	160,668	151,577	169,759	339	0	1402
Tuesday, March 16, 2021	161,008	150,979	171,037	340	0	1438
Wednesday, March 17, 2021	161,348	150,350	172,346	340	0	1473
Thursday, March 18, 2021	161,690	149,694	173,685	341	0	1507
Friday, March 19, 2021	162,032	149,010	175,054	342	0	1541
Saturday, March 20, 2021	162,375	148,299	176,451	343	0	1573
Sunday, March 21, 2021	162,719	147,562	177,876	344	0	1605
Monday, March 22, 2021	163,064	146,799	179,328	345	0	1636
Tuesday, March 23, 2021	163,410	146,012	180,807	346	0	1666
Wednesday, March 24, 2021	163,756	145,201	182,312	347	0	1696
Thursday, March 25, 2021	164,104	144,366	183,843	348	0	1725
Friday, March 26, 2021	164,453	143,507	185,398	348	0	1753
Saturday, March 27, 2021	164,802	142,626	186,978	349	0	1781
Sunday, March 28, 2021	165,152	141,722	188,582	350	0	1808

(continued)

Table 8.5 (continued)

	Forecast for confirmed cases			Forecast for death cases		
Day(s)	Forecast	Lower limit	Upper limit	Forecast	Lower limit	Upper limit
Monday, March 29, 2021	165,504	140,797	190,210	351	0	1835
Tuesday, March 30, 2021	165,856	139,850	191,861	352	0	1862
Wednesday, March 31, 2021	166,209	138,882	193,535	353	0	1888
Thursday, April 1, 2021	166,562	137,894	195,231	354	0	1913
Friday, April 2, 2021	166,917	136,885	196,950	355	0	1939
Saturday, April 3, 2021	167,273	135,856	198,690	356	0	1963
Sunday, April 4, 2021	167,629	134,807	200,452	356	0	1988
Monday, April 5, 2021	167,987	133,738	202,235	357	0	2012
Tuesday, April 6, 2021	168,345	132,651	204,039	358	0	2036
Wednesday, April 7, 2021	168,704	131,545	205,864	359	0	2060
Thursday, April 8, 2021	169,064	130,420	207,709	360	0	2083
Friday, April 9, 2021	169,425	129,276	209,575	361	0	2106
Saturday, April 10, 2021	169,787	128,115	211,460	362	0	2129
Sunday, April 11, 2021	170,150	126,935	213,365	363	0	2151
Monday, April 12, 2021	170,514	125,738	215,289	363	0	2173
Tuesday, April 13, 2021	170,878	124,524	217,233	364	0	2195
Wednesday, April 14, 2021	171,244	123,292	219,196	365	0	2217
Thursday, April 15, 2021	171,610	122,043	221,177	366	0	2238
Friday, April 16, 2021	171,977	120,777	223,177	367	0	2259
Saturday, April 17, 2021	172,346	119,495	225,196	368	0	2281
Sunday, April 18, 2021	172,715	118,196	227,233	369	0	2301
Monday, April 19, 2021	173,085	116,881	229,288	370	0	2322
Tuesday, April 20, 2021	173,455	115,550	231,361	371	0	2342
Wednesday, April 21, 2021	173,827	114,203	233,451	371	0	2363
Thursday, April 22, 2021	174,200	112,840	235,559	372	0	2383
Friday, April 23, 2021	174,573	111,461	237,685	373	0	2402
Saturday, April 24, 2021	174,947	110,067	239,828	374	0	2422
Sunday, April 25, 2021	175,323	108,658	241,988	375	0	2442
Monday, April 26, 2021	175,699	107,233	244,164	376	0	2461
Tuesday, April 27, 2021	176,076	105,794	246,358	377	0	2480
Wednesday, April 28, 2021	176,454	104,339	248,568	378	0	2499
Thursday, April 29, 2021	176,833	102,870	250,795	379	0	2518

(continued)

Table 8.5 (continued)

	Forecast for confirmed cases			Forecast for death cases		
Day(s)	Forecast	Lower limit	Upper limit	Forecast	Lower limit	Upper limit
Friday, April 30, 2021	177,212	101,386	253,039	379	0	2537
Saturday, May 1, 2021	177,593	99,888	255,298	380	0	2555
Sunday, May 2, 2021	177,975	98,375	257,574	381	0	2574
Monday, May 3, 2021	178,357	96,848	259,866	382	0	2592
Tuesday, May 4, 2021	178,740	95,307	262,173	383	0	2610
Wednesday, May 5, 2021	179,125	93,752	264,497	384	0	2628
Thursday, May 6, 2021	179,510	92,183	266,836	385	0	2646
Friday, May 7, 2021	179,896	90,600	269,191	386	0	2664
Saturday, May 8, 2021	180,282	89,004	271,561	387	0	2681
Sunday, May 9, 2021	180,670	87,394	273,947	387	0	2699
Monday, May 10, 2021	181,059	85,770	276,348	388	0	2716
Tuesday, May 11, 2021	181,448	84,133	278,764	389	0	2734
Wednesday, May 12, 2021	181,839	82,483	281,195	390	0	2751
Thursday, May 13, 2021	182,230	80,820	283,641	391	0	2768
Friday, May 14, 2021	182,622	79,143	286,102	392	0	2785
Saturday, May 15, 2021	183,016	77,454	288,577	393	0	2802
Sunday, May 16, 2021	183,410	75,751	291,068	394	0	2818
Monday, May 17, 2021	183,804	74,036	293,573	395	0	2835
Tuesday, May 18, 2021	184,200	72,308	296,092	395	0	2852
Wednesday, May 19, 2021	184,597	70,568	298,626	396	0	2868
Thursday, May 20, 2021	184,994	68,815	301,174	397	0	2884
Friday, May 21, 2021	185,393	67,049	303,737	398	0	2901
Saturday, May 22, 2021	185,792	65,271	306,313	399	0	2917
Sunday, May 23, 2021	186,193	63,481	308,904	400	0	2933
Monday, May 24, 2021	186,594	61,679	311,508	401	0	2949
Tuesday, May 25, 2021	186,996	59,864	314,127	402	0	2965
Wednesday, May 26, 2021	187,399	58,038	316,759	403	0	2980
Thursday, May 27, 2021	187,802	56,199	319,406	403	0	2996
Friday, May 28, 2021	188,207	54,349	322,066	404	0	3012
Saturday, May 29, 2021	188,613	52,486	324,739	405	0	3027
Sunday, May 30, 2021	189,019	50,612	327,426	406	0	3043

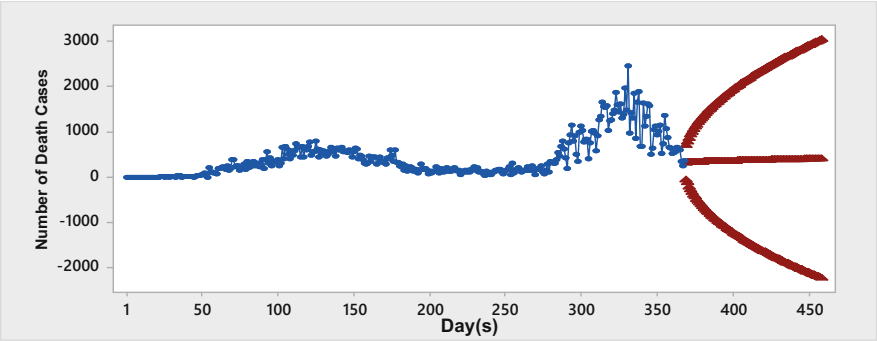

Fig. 8.6 Time plot of death cases forecast from February 28, 2020 to May 30, 2021

8.4 Conclusion

In this study, ARIMA models were used to model and forecast Nigerian confirmed and death cases as a result of the COVID-19 pandemic. This COVID-19 data considered was from February 28, 2020 to March 1, 2021. The ARIMA(1,2,0) and ARIMA(1,1,0) models were obtained as the appropriate models based on the steps of ARIMA model building. The forecasted values from the two models indicated Nigerian COVID-19 cumulative confirmed and death cases continues to rise and maybe in-between 189,019–327,426 confirmed cases and 406–3043 death cases respectively in the next 3 months (May 30, 2021). The ARIMA models forecast indicated an alarming rise in Nigerian COVID-19 confirmed and death cases on daily basis. These findings indicated that effective treatment strategies must be put in place, the health sector should be monitored and properly funded. All the protocols and restrictions put in place by the NCDC, Nigeria should be clung to diminish the spread of the pandemic and possible mortality before immunizations that can forestall the infection is developed and readily available.

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