The spread of COVID-19 outbreak in the first 120 days: A comparison between Nigeria and seven other countries

Ayo Stephen Adebowale
University of Ibadan College of Medicine
Adeniyi Francis Fagbamigbe
University of Ibadan College of Medicine
Joshua Odunayo Akinyemi
University of Ibadan College of Medicine
Olalekan K Obisesan
University of Ibadan
Emmanuel J Awosanya
University of Ibadan
Rotimi Felix Afolabi (rotimifelix@yahoo.com)
University of Ibadan College of Medicine https://orcid.org/0000-0002-0744-1787
Selim A Alarape
University of Ibadan
Sunday O Obabiyi
University of Ibadan

Research article

Keywords: COVID-19, Situation assessment, Model fit, Nigeria

Posted Date: November 18th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-45408/v3

Version of Record: A version of this preprint was published on January 12th, 2021. See the published version at https://doi.org/10.1186/s12889-020-10149-x.

Abstract

Background: COVID-19 is an emerging global public health crisis. The increase in the daily COVID-19 confirmed cases in Nigeria is worrisome vis-a-vis its large and dense population. This study aims at assessing the pattern of spread in the first 120 days of COVID-19 case confirmation in Nigeria, and its comparison with seven other countries.

Methods: Data extracted from the World Bank's website were used for the descriptive assessment and modelling of COVID-19 disease using the first 120 days of the index case in Nigeria and seven other countries. Linear, quadratic, cubic and exponential methods of regression model were used to fit the data (α=0.05).

Results: The COVID-19 growth pattern in Nigeria was similar to that of Egypt, Ghana and Cameroun; Nigeria's COVID-19 daily death distribution was comparable to six of the other seven countries considered. There was an increasing trend in the daily COVID-19 confirmed cases in Nigeria. During the lockdown, the growth rate of COVID-19 in Nigeria was 5.85 (R^2=0.728, p<0.001); however, it was 8.42 (R^2=0.625, p<0.001) after the lockdown relaxation. Across all the countries investigated, the cubic polynomial model (CPM) provided the best fit for predicting COVID-19 cumulative cases and there was a clear deviation from the exponential growth model. Using the CPM, all things being equal, a 3-month (30 September 2020) prediction of COVID-19 cases in Nigeria was 155,467 (95% CI:151,111-159,824, p<0.001).

Conclusions: An improvement in COVID-19 control measures and strict compliance with the COVID-19 recommended protocols are essential. A contingency plan is needed to provide care for the active cases in case the predicted target is realised.

Background

The novel Coronavirus disease (COVID-19) is one of the diseases that have constituted a global threat in human history. The daily increase in the global sum of cases and deaths associated with COVID-19 is enormous [1–3]. The infection rate of the disease is high and, unfortunately, there is no definite vaccine for its prevention. The COVID-19 cases have been confirmed in different parts of the world, Africa including Nigeria [3]. The first case of COVID-19 was confirmed in Nigeria on 27 February 2020 [2] and by the first 120 days (25 June 2020) after the index case confirmation, the total cumulative case has risen to 22,614 [2]. There is an apprehension that the total confirmed case does not reflect the true situation in Nigeria due to low testing.

Comparing the rate of COVID-19 tests in Nigeria with other countries in Africa and others with comparable population size, the Nigeria testing rate is low. Although there was a challenge to testing apparatus and kits in terms of demand and supply at the early stage of COVID-19 pandemic in Nigeria, the Nigeria Centre for Disease Control (NCDC) has claimed that strict adherence to their protocol and guideline for testing

might be responsible for the low testing [2]. However, in recent times, there has been an increase in number of testing centres and improvement in COVID-19 testing capacities across the country.

The daily reported COVID-19 infected individuals in Nigeria is a major concern despite the control strategies instituted by the government to curb its spread. Nigeria is a low-income country with weak and fragile health infrastructure; besides being the most populous African country, its major cities are densely populated. These situations indicate that widespread infection would be difficult to handle and has therefore made COVID-19 a scary public health emergency in Nigeria. Going by the experience of some other affected countries, we attempted to monitor and assess the disease situation in Nigeria using the data for the first 120-day COVID-19 case confirmation and projected for a three-month COVID-19 cumulative case to inform policy. In addition, we compare the disease spread, death, and the fitted model with seven other countries. Consequently, these two research questions were addressed: (i) how does the spread of COVID-19 cases and mortality compare to other countries in the first 120 days? (ii) Given the prevailing testing regime and interventional efforts, all things being equal, what is the 3-month projected cumulative case of COVID-19?

Methods

The cross-sectional study was conducted in Nigeria, a country with a population size of over 200 million from February 27 to June 25, 2020. The country has many international land borders and a few international airports. As at the time of writing this report, situation assessment shows that the compliance with the government directive on precautionary measures against COVID-19 is still very low in Nigeria [2].

The secondary data utilised for this study were extracted from the World Bank database on COVID-19 [1]. Apart from Nigeria, seven other countries (Bangladesh, Egypt, Cameroun, Nigeria, South Africa, Mexico, Ghana and Indonesia) were purposively selected from Africa, Asia and South America. These countries were selected because they experienced the outbreak of COVID-19 almost concurrently and the magnitude of the cumulative confirmed cases follows one another on the World COVID-19 table as at the time of data extraction for this study. Additionally, the countries are similar in terms of their economic conditions classified as Low-Middle income. The extracted data were restricted to the first 120 days of the outbreak of COVID-19 in these countries. The population figure, population density [4] and number of confirmed cases of COVID-19 as at the 120th day of the outbreak of the disease in the selected countries are represented in Table 1.

Data were presented with charts and line graphs. Four classes of regression model were used to fit the cumulative data on COVID-19. These are: linear, quadratic, cubic and exponential models. The equations representing each model are presented in Table 2.

Further, the model of best fit was used to predict a 3-month (30 September 2020) COVID-19 cumulative confirmed case in Nigeria.

Results

The data as presented in Figure 1 show an increasing trend in the daily confirmed cases of COVID-19 in Nigeria, from the 1st day through the 120th day of the COVID-19 confirmation. There was a consistent increase in the number of cases after the relaxation of lockdown measures in Nigeria. During the lockdown, the growth rate of COVID-19 in Nigeria was 5.85 (95% CI:5.41,6.29; R^2=0.728; p<0.001) and this increased to 8.42 (95% CI:8.41,8.43; R^2=0.625; p<0.001) after the relaxation of the lockdown.

Figure 1: Daily COVID-19 confirmed cases as at the first 120 days of the outbreak in Nigeria

Figure 2 shows the cumulative daily confirmed cases of COVID-19 in the first 120 days after the outbreak in eight countries. The findings showed that the pattern of Nigeria's cumulative daily confirmed cases aligned with three (Ghana, Egypt and Cameroun) of the seven other countries, particularly within the first 97 days. The trajectory of the spread of COVID-19 in Nigeria aligned perfectly with Ghana's pattern and slightly differs from the pattern exhibited by Cameroun after the 97th day. There was a clear difference in the pattern observed between Nigeria and Mexico, Bangladesh, South Africa and Indonesia respectively.

Figure 2: COVID-19 cumulative confirmed cases in some countries as at the first 120-day of the outbreak

The distribution of deaths associated with COVID-19 within the first 120 days after its outbreak shows that the observed pattern for Nigeria was nearly the same to six of the seven countries compared. In particular, the Nigeria pattern was identical to that of the countries from West-Africa (Cameroun and Ghana) (Figure 3).

Figure 3: COVID-19 cumulative daily deaths for the first 120 days in some countries

The summary of the model and estimated parameters is shown in Table 3. Across all the eight countries included in the analysis, the Cubic Polynomial Model (CPM) was identified as the best fit to model COVID-19 data and this model perfectly fits the Mexico data with R-square being 100%. The R-square for Nigeria was 99.9%, an indication that 99.9% of the variation in the cumulative daily confirmed cases of COVID-19 in Nigeria can be explained by time. The predictive models for Nigeria are as follows: Linear: , Quadratic: , Cubic: , Exponential: (Table 3).

The data as presented in Figure 4 depict the observed and predicted cumulative cases of COVID-19 in the selected countries as at the first 120 days after the outbreak confirmation. The trajectory of observed COVID-19 cumulative cases in Nigeria deviates from the exponential and linear models but perfectly fits the quadratic and cubic regression models. The exponential model fits the data for South Africa and to some extent Egypt in the first 70 days of the outbreak confirmation in those countries. The simple linear regression model does not in any way fit the data for any of the studied countries.

Figure 4: Predictive model of cumulative cases of COVID-19 in Nigeria

The observed and estimated values of cumulative cases of COVID-19 in Nigeria using both quadratic and cubic polynomial models are presented in Figure 5 as shown below. The predicted COVID-19 cumulative case, for 30 September 2020, was: Quadratic - 93,988 (95% CI: 91,209-96,767) and cubic - 155,467 (95% CI:151,111-159,824).

Figure 5: Observed and projected COVID-19 cumulative cases in Nigeria

Discussion

The goal of this paper is to assess the spread and mortality in the first 120 days of COVID-19 in Nigeria and compare it to seven selected countries in diverse developmental contexts. First, our analysis showed the spread of the pandemic increased following relaxation of lockdowns. Both spread and mortality patterns in Nigeria compared well to other African countries (Ghana, Cameroun and Egypt). Lastly, the findings suggested that different predictive models gave the best fit across countries.

In this study, the COVID-19 data in Nigeria show an increasing trend. The curve for Nigeria is unlike a typical propagated epidemic curve that would have been expected in the case of COVID-19 being an infectious disease. The transmissibility interval of COVID-19, that is its reproductive number which signifies the number of people a single case can infect with the virus, was estimated to be from 1.4 to 2.5, 3.6 to 4.0, and 2.24 to 3.58 by earlier studies [3, 5–7]. An indication that the disease will continue to be on the increase. Therefore, the observed pattern found in our study agrees with the known pattern of spread of the disease. We also found a higher number of cases reported after the relaxation of lockdown than during the lockdown period. This suggests a wider spread of the disease after the relaxation of lockdown, which could be due to poor adherence to the standard precautionary measures in Nigeria. Asides, the increased spread following relaxation of lockdown is not surprising for when restrictive measures are lifted, the rate of exposure to disease risk becomes higher. Consequently, an increased number of infections is likely to follow. This is in tandem with evidence from developed countries where the transmission dynamics and effectiveness of control measures have been rigorously studied [8,9]. However, an increase in capacity for testing may be the possible explanation for the current finding. In comparison with Ghana and South Africa, the testing capacity in Nigeria is generally low. While Nigeria has only 2,755 people tested for COVID-19 per 1,000,000 people, the estimate was 16,206 and 76,067 Ghana and South Africa [10].

We found a similar pattern in the number of cumulative cases of COVID-19 in Nigeria, Ghana and Cameroon possibly due to similarity in capacity for testing in the first 120 days after the first outbreak in these countries. Conversely, a difference was observed in the pattern exhibited by Nigeria compared to four of the seven countries investigated (Mexico, Bangladesh, South Africa and Indonesia). As at the 120th day after first case confirmation in these four countries, the total COVID-19 test conducted and test per 1 million population was strikingly higher than Nigeria's over the same period [1, 10]. Except for Indonesia, which has a comparable population size with Nigeria, the population figure for each of the other seven countries was extraordinarily lower. Due to environmental factors like temperature and

humidity [11, 12], one would have expected the pattern of the disease spread in Nigeria to be similar to that of Mexico, Bangladesh, South Africa and Indonesia, all things being equal. Thus, it is tempting to conclude that low testing capacity in Nigeria is responsible for variability in the observed pattern of COVID-19 cases compared to the four countries. The implication is that community testing has not commenced fully in Nigeria as it is done in South Africa; the disease is presently having a sporadic cluster of local transmission in Nigeria.

We further found, within the study period, that the distribution of COVID-19 associated death observed for Nigeria was comparable to 6 of the other 7 countries investigated and aligned perfectly with the Cameroun and Ghana patterns. The prominent difference in COVID-19 related death trajectory found in Mexico compared to other countries may be explained by the higher number of observed COVID-19 cases within the study period. The compactness in the similarity in COVID-19 deaths between Nigeria, Ghana and Cameroon, countries from west Africa may be attributed to other factors aside from the COVID-19 testing capacity and case management capabilities.

Cubic Polynomial Model (CPM) was identified as the model of best fit among the four models used in this study. Next to the CPM is the quadratic model (QM). The CPM and QM have been identified in the previous studies as predictive models for some infectious diseases including Ebola and COVID-19 [13, 14]. None of the data for the countries follows the exponential model except South Africa which aligns with the data within the first 70 days of the outbreak confirmation. A similar remark has been made in the past on the suitability of the exponential model for fitting the spread curve of infectious disease [15]. Nonetheless, differences in the level and mode of testing in each country could be responsible for South African's exemption. Aside the case reporting, a community testing approach to identify more cases of COVID-19 was instituted early in South Africa which countries like Nigeria, Ghana and Cameroon did not do within the study period. In addition, one cannot overrule the marked difference in atmospheric and environmental conditions between countries as another pertinent reason [11,12].

In our study, the predicted COVID-19 cumulative case for 30 September 2020 using QM and CPM was 93,988 and 155,467 respectively, provided the present testing capacity for COVID-19 and the level of compliance with the preventive measures to mitigate the disease spread is sustained throughout the period. Of course, the wide gap between the two estimates could be linked to the differences in equations governing the usage of QM and CPM, and as such different parameters used for the estimation. The fact that the best fitting models appear to differ across countries is an indication of variation in the epidemiological context and transmission dynamics and control efforts. Although some of these countries share similarities in demographic and developmental profile, there are differences in factors including testing capacity, risk profile, enforcement of containment measures and exposure to infected individuals.

The public health implication of our study is enormous, there is a need for adequate emergency preparedness. The identified trajectory of COVID-19 infection in Nigeria is an impetus for increased surveillance, enhanced testing capacity and succinct plan for clinical management of cases as well as

psychosocial management of discharged cases. Also, the preventive measures may have to be sustained for the spread of the pandemic in Nigeria and other countries to be contained.

Limitations

The Nigeria data was premised on testing suspected cases who either reported at the testing centres or symptomatic individuals at homes who call the NCDC response team lines for help. The differential in the scope of testing and atmospheric conditions in different countries should not be overruled while interpreting our findings. This is because there is some evidence on the relationship between weather conditions and transmission risks of COVID-19 [11,12]. Inaccessibility to data on socio-demographic profile and health history of the COVID-19 patients and survivors limits the opportunity to do some statistical and mathematical modelling.

Conclusions

The spread of COVID-19 is increasing daily and the projection provides insight into what the situation could be in days ahead in Nigeria. Thus, enhanced and enlarged emergency preparedness and contingency plans to mitigate the COVID-19 spread are urgently required. There is need to increase testing capacities both at State and Local government levels as current testing is limited. An improvement in COVID-19 control measures and strict compliance with the COVID-19 recommended protocols is strongly recommended. Preparation should be made for the case management of COVID-19 cases in Nigeria in case the figure predicted is realised by the 30 October 2020.

Declarations

Acknowledgements

The authors acknowledge the Nigeria Centre for Disease Control, the European Centre for Disease Prevention and Control / WHO and the World Population Pyramid for granting free access to the data used for the study

Authors' Contributions

ASA, AAF, JOA, OKO, RFA and SOO conceptualised and designed the study. ASA analysed the data while ASA, AAF, JOA and OKO interpreted the analysed data. ASA, AAF and RFA drafted the original manuscript. ASA, AAF, JOA, OKO, EJA, RFA, SOO and SAA reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

Availability of data and materials

Data sharing is not applicable to this article as no new data were created or analysed in this study. The data is accessible at https://www.ecdc.europa.eu/en/publications-data

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

Abbreviations

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2; WHO: world health organization; NCDC: Nigeria centre for disease and control; ECDC: European centre for disease prevention and control; R^2: coefficient of determination; FCT: Federal capital territory; CPM: cubic polynomial model

References

1. European Centre for Disease Prevention and Control. Publications & Data. 2020. https://www.ecdc.europa.eu/en/publications-data. Accessed 2 Jul 2020.
2. Nigeria Centre for Disease Control. 2020. https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An update of COVID-19 outbreak in Nigeria. Accessed 2 Jul 2020.
3. World Health Organisation. Coronavirus (COVID-19) events as they happen. 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen. Accessed 1 Jul 2020.
4. United Nations, Department of Economic and Social Affairs, Population Dynamics. World Population Prospects: The 2019 Revision. United Nations. United Nations. 2020. https://population.un.org/wpp/. Accessed 11 Jul 2020.
5. Read JM, Bridgen JRE, Cummings DAT, Ho A, Jewell CP. Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions. doi:10.1101/2020.01.23.20018549.
6. Majumder M, Mandl KD. Early Transmissibility Assessment of a Novel Coronavirus in Wuhan, China. SSRN Electron J. 2020. doi:10.2139/ssrn.3524675.
7. Imai N, Cori A, Dorigatti I, Baguelin M, Donnelly CA, Riley S, et al. Report 3: Transmissibility of 2019-nCoV. 2020.

8. Fang Y, Nie Y, Penny M. Transmission dynamics of the COVID-19 outbreak and effectiveness of government interventions: A data-driven analysis. Journal of medical virology. 2020;92(6):645-59.
9. Liu P, He S, Rong L, Tang S. The effect of control measures on COVID-19 transmission in Italy: Comparison with Guangdong province in China. Infectious Diseases of Poverty. 2020; 9:130. doi.org/10.1186/s40249-020-00730-2
10. Wordometer COVID-19 Coronavirus Pandemic: Reported Cases and Deaths by Country, Territory, or Conveyance. https://www.worldometers.info/coronavirus/#countries. Accessed 11 June 2020.
11. Ogaugwu C, Mogaji H, Ogaugwu E, Nebo U, Okoh, H, Agbo S et al. Effect of Weather on COVID-19 Transmission and Mortality in Lagos, Nigeria. Scientifica (Cairo). 2020; 2562641. doi:10.1155/2020/2562641.
12. Prata, DN, Rodrigues W, Bermejo PH. Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil. Sci Total Environ, 2020; 729:138862. doi:10.1016/j.scitotenv.2020.138862.
13. Valeri L, Patterson-Lomba O, Gurmu Y, Ablorh A, Bobb J, Townes FW, et al. Predicting Subnational Ebola Virus Disease Epidemic Dynamics from Sociodemographic Indicators. PLoS One. 2016;11:e0163544. doi:10.1371/journal.pone.0163544.
14. Malato G. Covid-19 infection in Italy. Mathematical models and predictions. 2020. https://towardsdatascience.com/covid-19-infection-in-italy-mathematical-models-and-predictions-7784b4d7dd8d. Accessed 11 Apr 2020.
15. Solis FJ, Tapia B, Romero J V., Moreno J. Quadratic infectious diseases mathematical models: Chronic states, sanity levels, and treatment. Math Comput Model. 2005;42:1315–24.

Tables

Table 1

Distribution of the population figure, population density and COVID-19 confirmed cases by some countries[#]

Country	Population figure	Population Density (person/km^2)	Total COVID-19 CC
Bangladesh	164,689,353	1,116	149,258
Egypt	102,334,903	102.2	41,304
Cameroun	26,545,868	55.84	12,192
Nigeria	206,139,587	223.2	22,614
South Africa	59,308,689	48.65	159,333
Mexico	128,932,753	65.63	231,770
Ghana	31,072,970	130.26	18,134
Indonesia	273,523,620	143.14	54,010

[#]*as at the 120th day of the outbreak in the respective counties*

Sources: *United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2019 Revision;* https://www.ecdc.europa.eu/en/publications-data

Due to technical limitations, table 2 is only available as a download in the supplementary files section.

Table 3
Model Summary and Parameter Estimates

	Summary	Parameter Estimates			
Country	***R Square***	***Constant***	β_1	β_2	β_3
Bangladesh					
Linear	0.767*	-33018.645	1122.635		
Quadratic	0.987*	13105.539	-1222.663	20.045	
Cubic	0.999*	-313.915	124.858	-8.625	0.163
Exponential	0.915*	9.628	0.098		
Egypt					
Linear	0.699*	-8039.316	256.061		
Quadratic	0.956*	4274.644	-349.544	5.005	
Cubic	0.995*	-1566.637	218.015	-6.673	0.064
Exponential	0.893*	2.352	0.094		
Cameroun					
Linear	0.860*	-2845.963	112.376		
Quadratic	0.992*	591.439	-59.494	1.444	
Cubic	0.993*	146.269	-15.528	.525	0.005
Exponential	0.820*	15.465	0.069		
Ghana					
Linear	0.894*	-3633.083	156.014		
Quadratic	0.995*	268.922	-49.354	1.817	
Cubic	0.995*	183.709	-40.501	1.622	0.001
Exponential	0.853*	29.047	0.068		
Indonesia					
Linear	0.887*	-10357.170	422.333		

Significant at 0.1%

	Summary	Parameter Estimates			
Quadratic	0.997*	1439.768	-157.844	4.795	
Cubic	0.999*	-550.761	35.562	.815	0.022
Exponential	0.782*	56.394	0.069		
Mexico					
Linear	0.823*	-50669.386	1832.606		
Quadratic	0.995*	14390.013	-1447.700	27.799	
Cubic	1.000*	1958.116	-209.705	1.682	0.148
Exponential	0.868*	97.206	0.079		
Nigeria					
Linear	0.785*	-4937.222	164.210		
Quadratic	0.991*	1748.194	-164.581	2.717	
Cubic	0.999*	151.233	-9.415	− .475	0.018
Exponential	0.911*	2.245	0.090		
South Africa					
Linear	0.667*	-29085.662	929.637		
Quadratic	0.941*	17807.574	-1395.647	19.377	
Cubic	0.995*	-7413.468	1074.917	-31.878	0.285
Exponential	0.865*	50.331	0.075		
Significant at 0.1%					

Figures

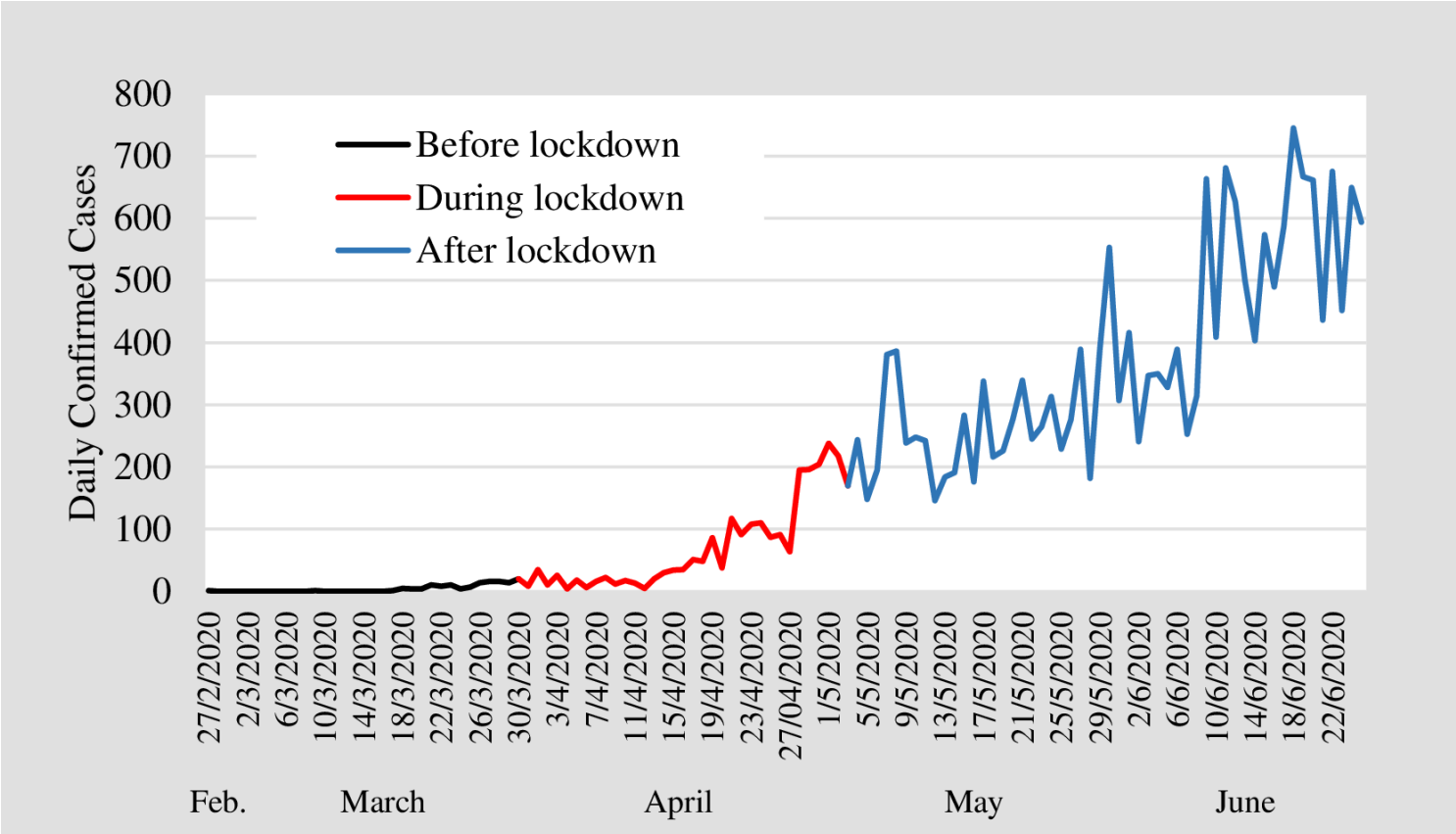

Figure 1

Daily COVID-19 confirmed cases as at the first 120 days of the outbreak in Nigeria

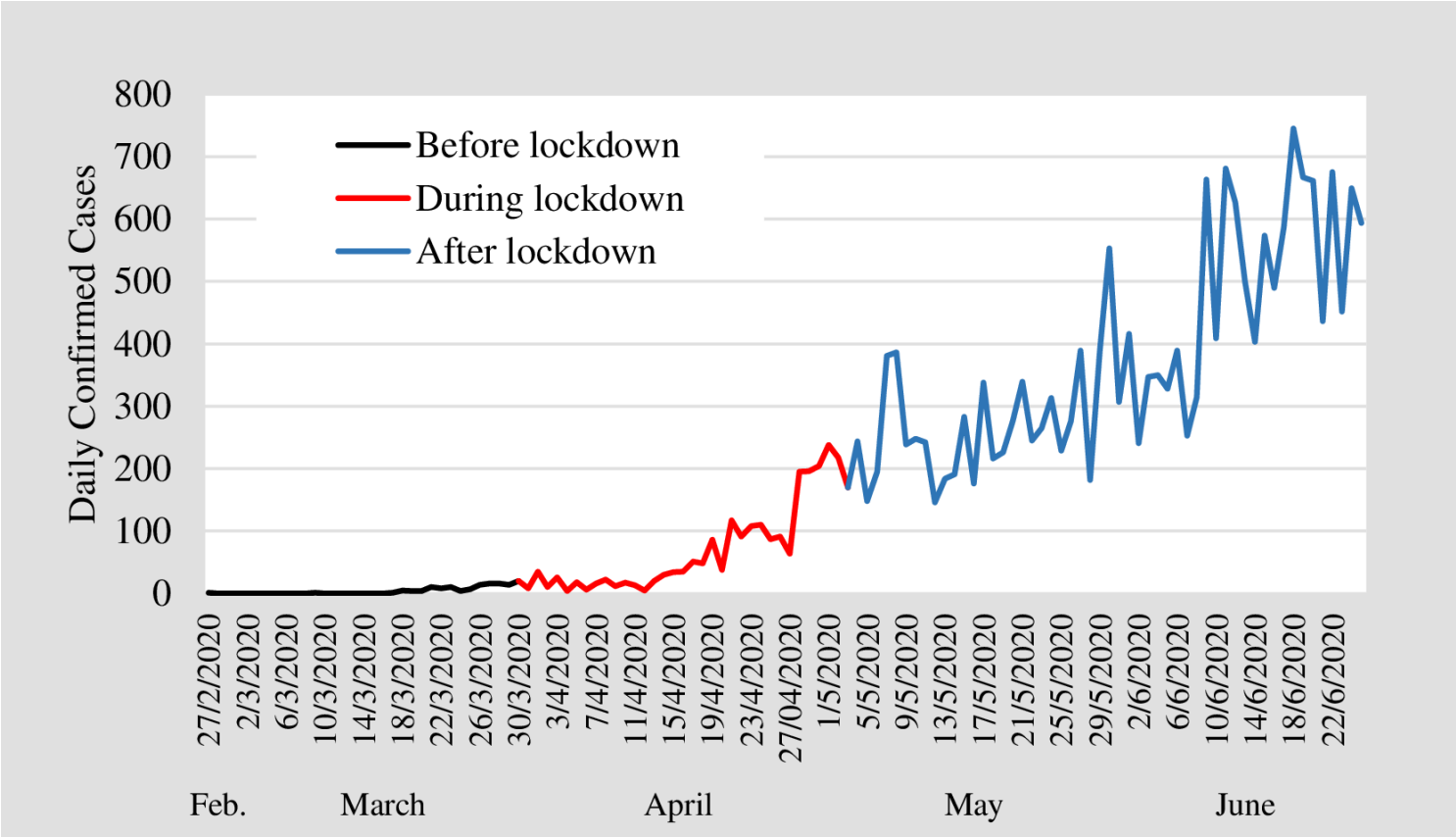

Figure 1

Daily COVID-19 confirmed cases as at the first 120 days of the outbreak in Nigeria

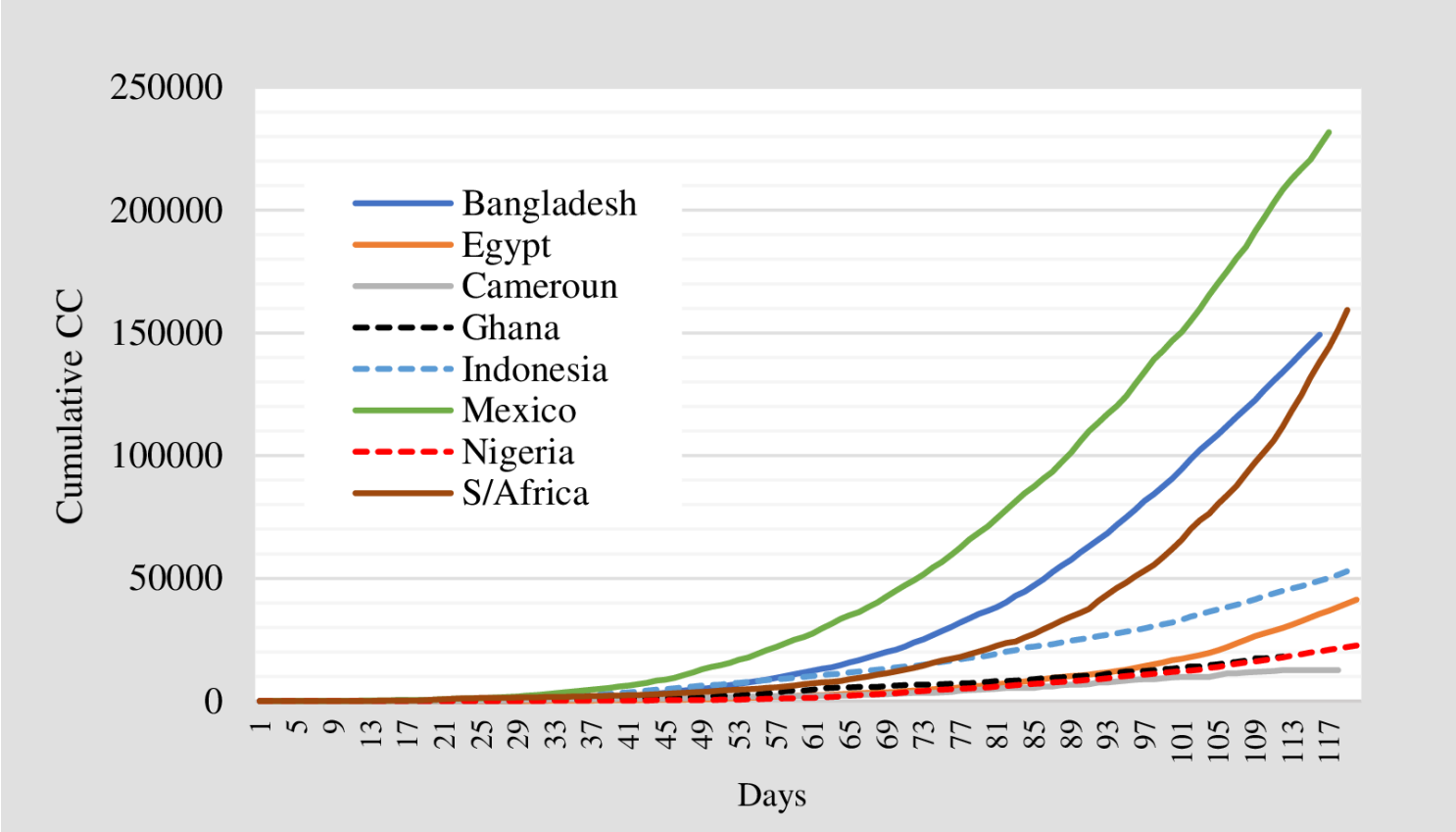

Figure 2

COVID-19 cumulative confirmed cases in some countries as at the first 120-day of the outbreak

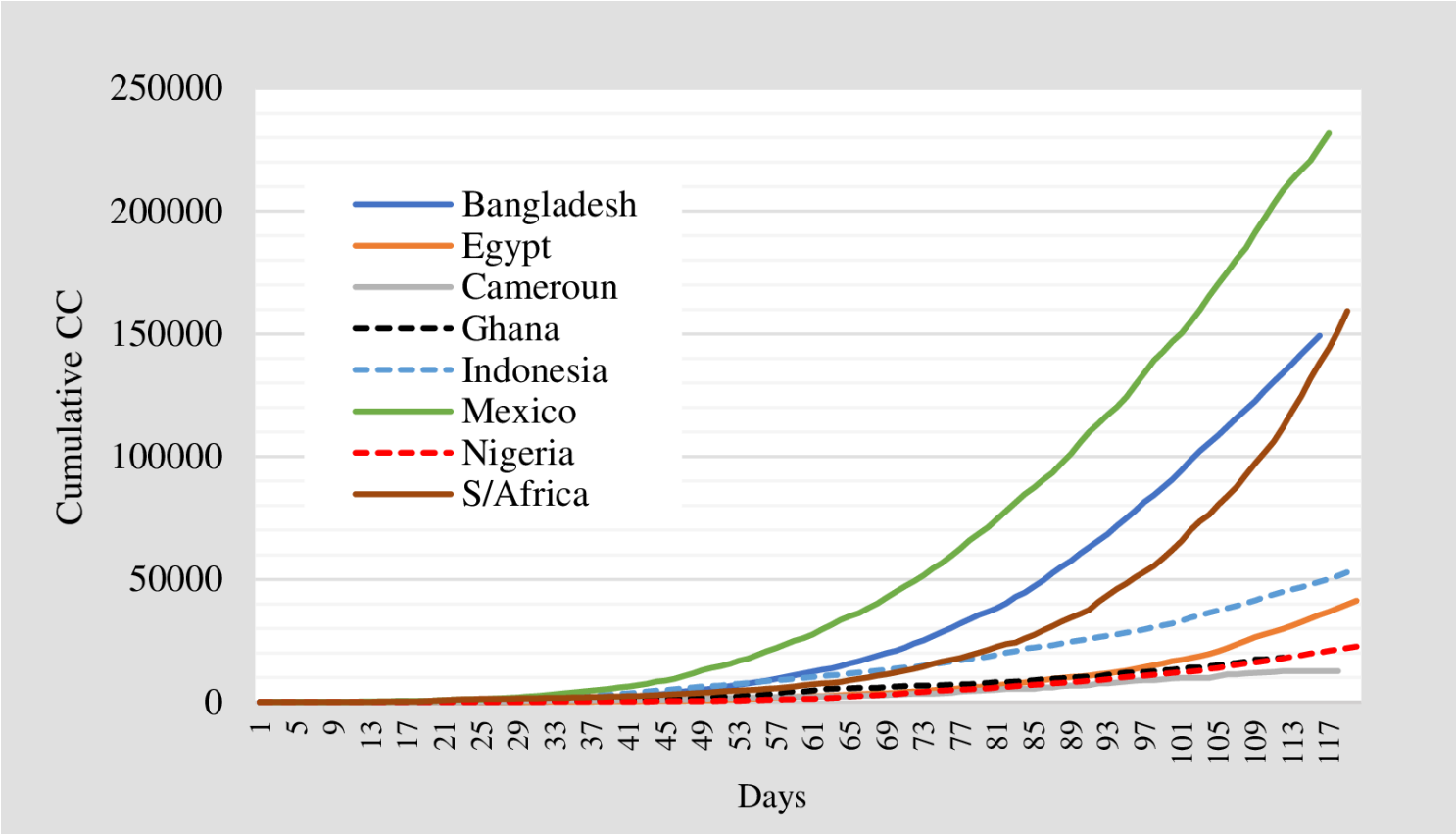

Figure 2

COVID-19 cumulative confirmed cases in some countries as at the first 120-day of the outbreak

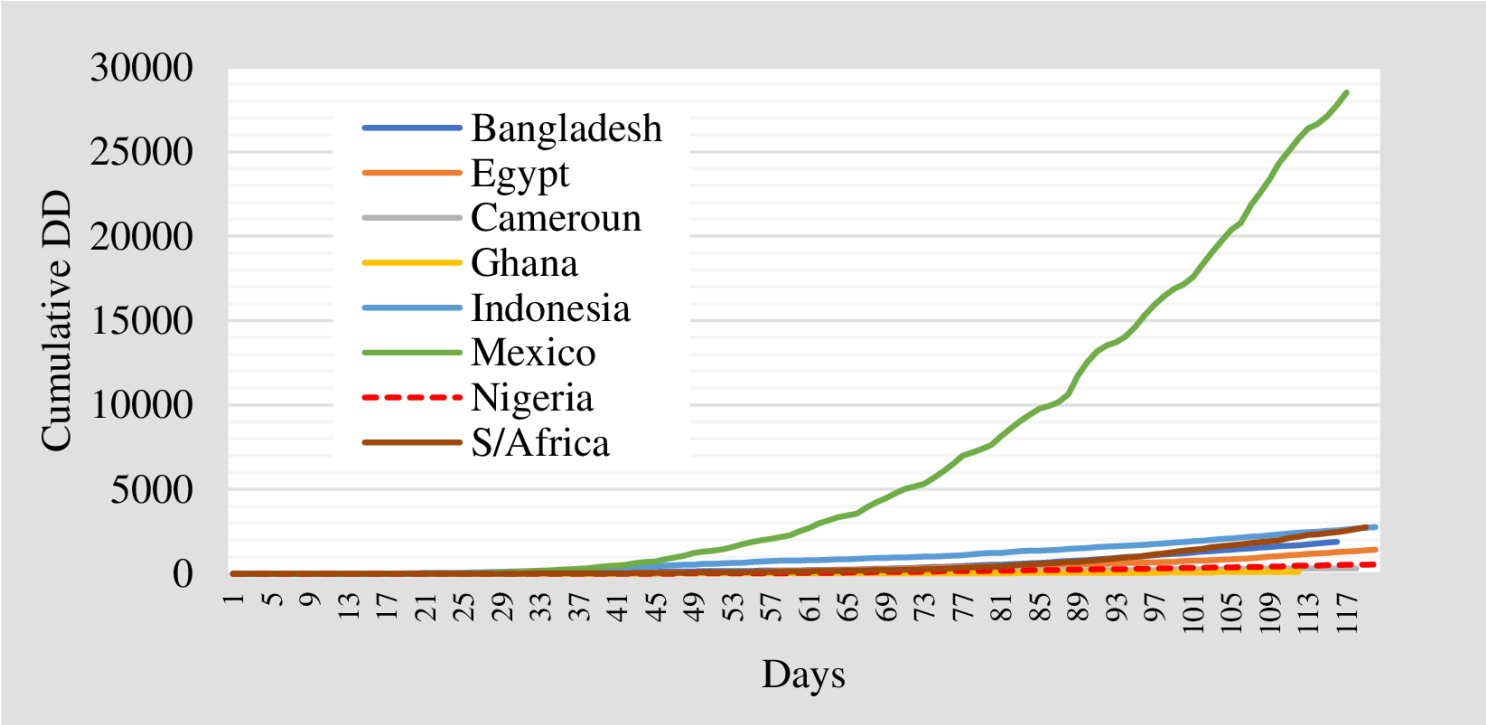

Figure 3

COVID-19 cumulative daily deaths for the first 120 days in some countries

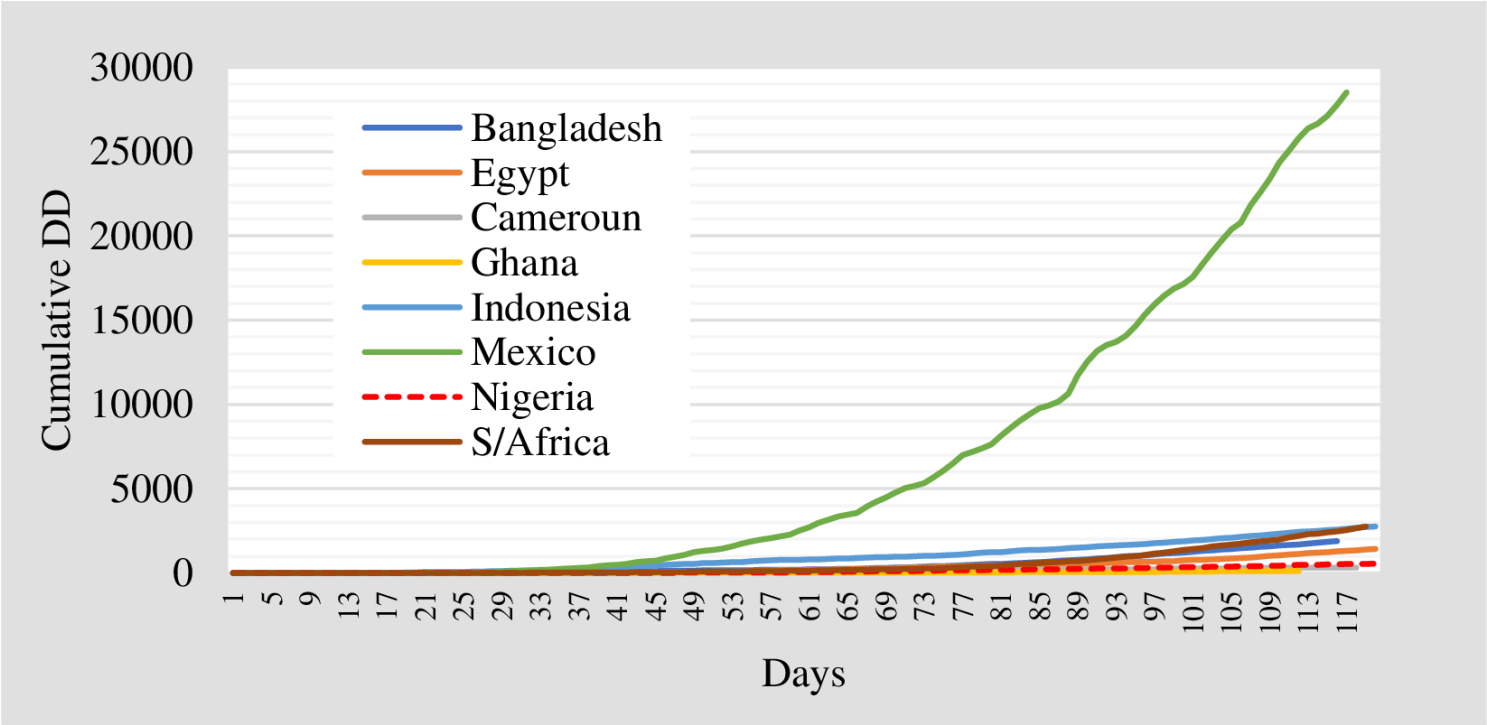

Figure 3

COVID-19 cumulative daily deaths for the first 120 days in some countries

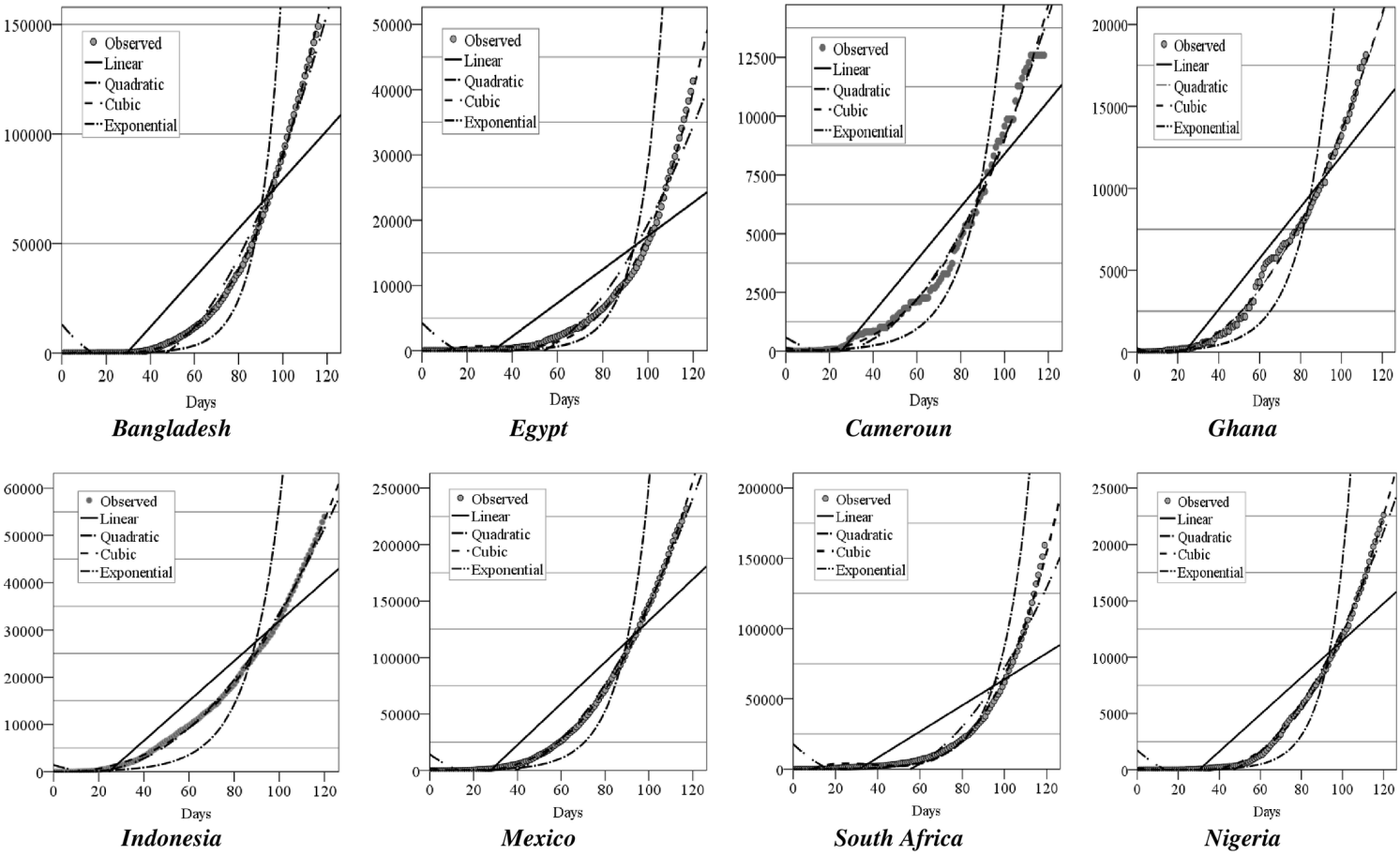

Figure 4

Predictive model of cumulative cases of COVID-19 in Nigeria

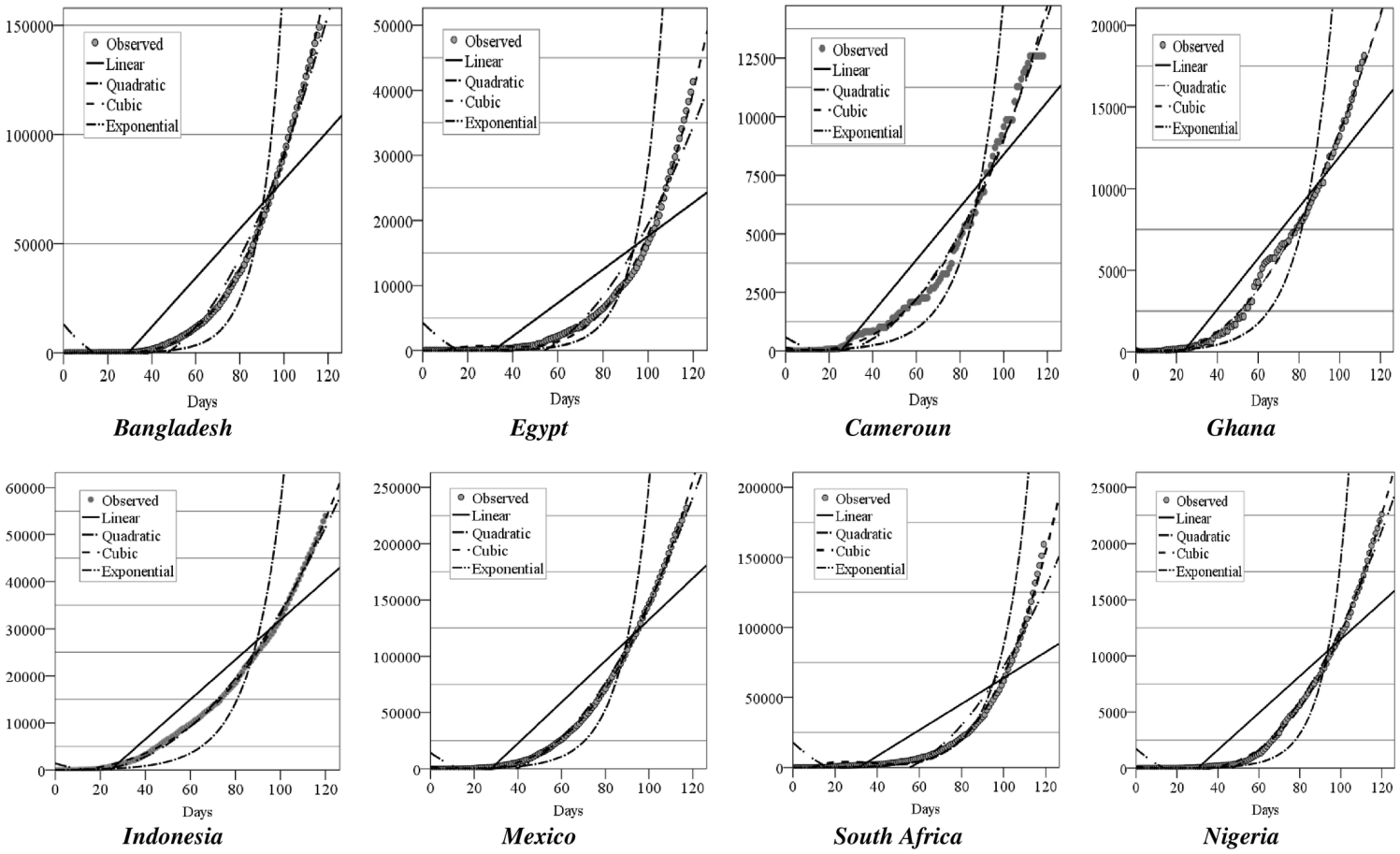

Figure 4

Predictive model of cumulative cases of COVID-19 in Nigeria

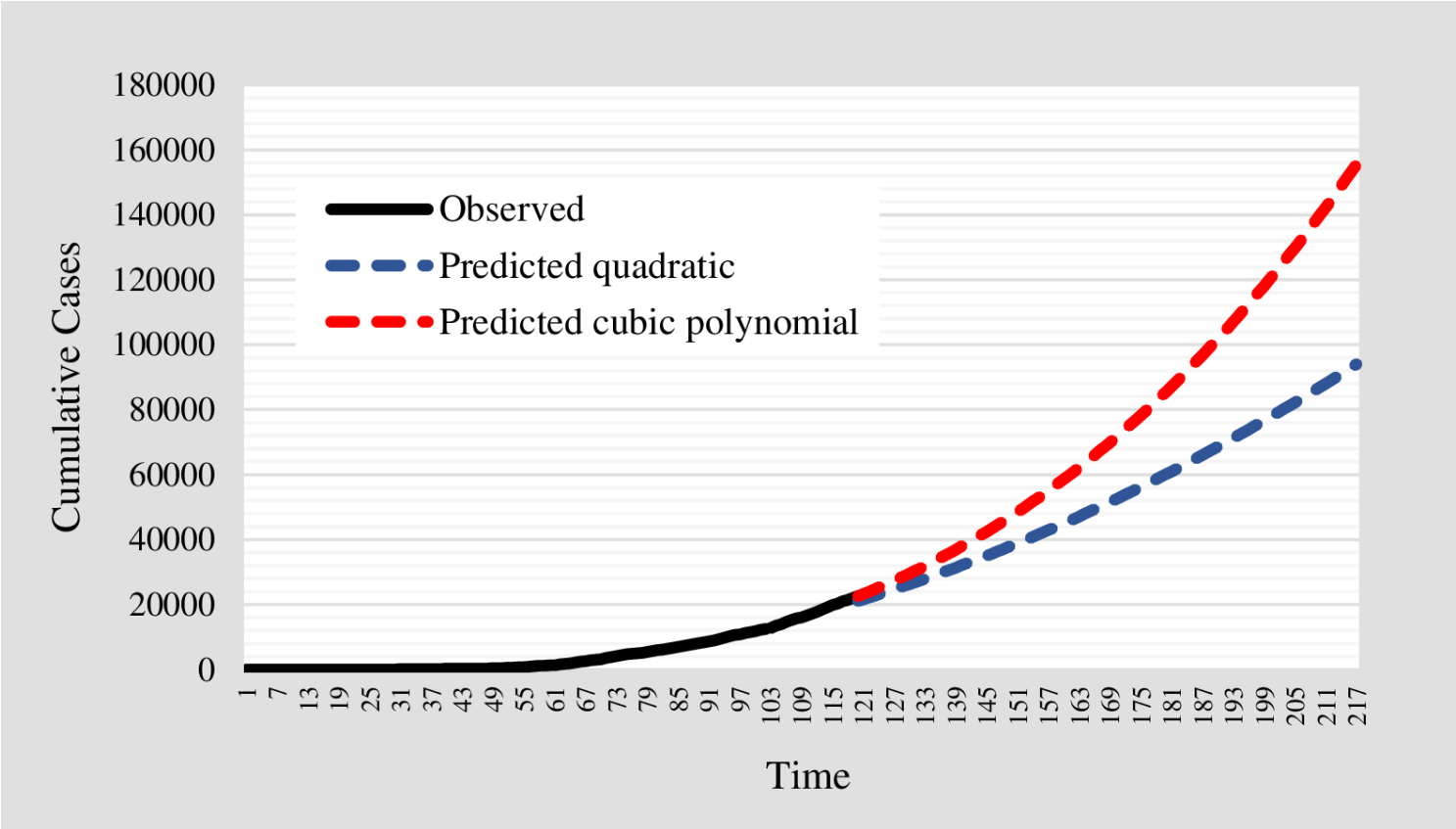

Figure 5

Observed and projected COVID-19 cumulative cases in Nigeria

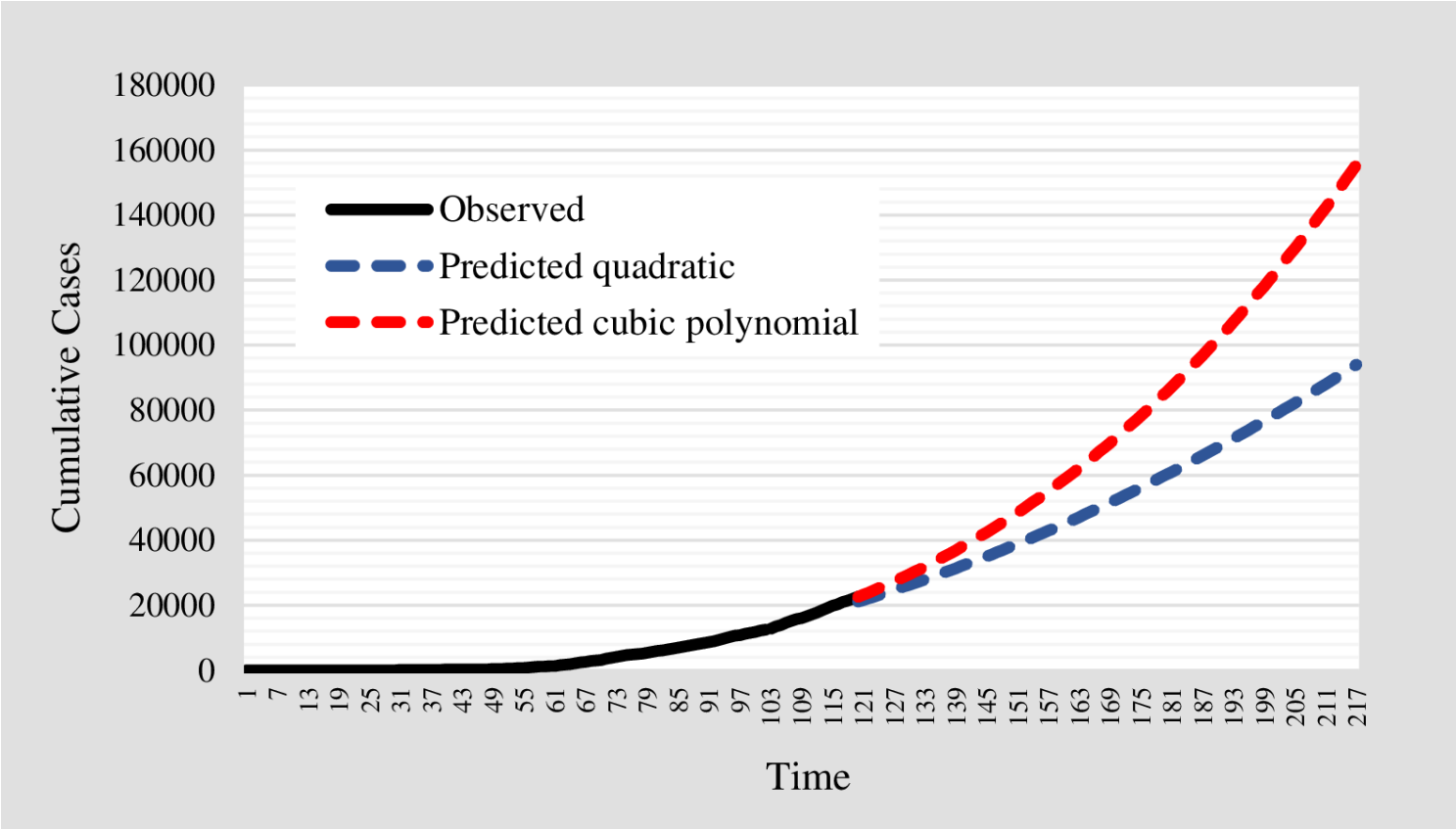

Figure 5

Observed and projected COVID-19 cumulative cases in Nigeria

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- table2.docx
- table2.docx