European Journal of Public Health Studies
ISSN: 2668 - 1056
ISSN-L:2668 - 1056
Available on-line at: www.oapub.org/hlt

DOI: 10.46827/ejphs.v4i2.106

Volume 4 │ Issue 2 │ 2021

COMPARING THE ACCURACIES OF FORECASTING MODELS FROM THE TIME SERIES DATA OF COVID-19 INFECTION IN NIGERIA

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Abstract:
A variety of forecasting models are now fast becoming among the most important application areas in the analyses of recent COVID-19's future trends as they provide insight to policy-makers about the development of the disease and on healthcare delivery. However, since there is no one-size-fit-all approach in forecasting the future trends of epidemics, the reliability of these approaches is questioned partly due to time series data characteristics (e.g. quality of the data), uncertainty and nature of the modelling approach (e.g. numerical efficiency of the algorithm). This makes comparison of forecasting models necessary in order to provide an evidence-based information with regards to model performance. This study compared the accuracies of ten models in forecasting the number of population to be affected from Coronavirus in Nigeria (specifically for the whole country, as well as for the Federal Capital Territory (FCT) Abuja and Lagos state). Results show that bagged (bootstrap aggregation) model can

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provide more consistent accurate results (mean absolute error (MAE) of 48 for Nigeria, 32.80 for Lagos and only 13.48 for FCT) than all models assessed in this study. Other models with good performance include exponential smoothing (Nigeria, MAE = 53.65, Lagos = 36.35, FCT = 14.83), structural time series (Nigeria, MAE = 53.62, Lagos = 34.35, FCT = 14.86), ARIMA (Nigeria, MAE = 53.64, Lagos = 36.34, FCT = 14.83), and theta models (Nigeria, MAE = 53.65, Lagos = 36.35, FCT = 14.83). Although forecasting is challenging as models cannot generally provide accurate daily estimates of the COVID-19 infection, daily COVID-19 cases estimated from these models closely reflect the variation in the original data. The study suggests that combining different approaches is of great value to forecasting modelling and therefore, decision makers should treat results from these approaches with caution and base on analysing scenarios.

Keywords: forecast, covid-19, pandemic, infection, models, vaccine, mortality, accuracy, Nigeria

1. Introduction

The novel severe acute respiratory syndrome, coronavirus 2 (SARS-CoV-2), is increasingly recognized as a serious, worldwide public health concern. Since the declaration of the novel Coronavirus (COVID-19) as a pandemic by the World Health Organization (WHO), the number of confirmed cases has continued to increase in Africa. In recent times, there are strong concerns that African countries may be at disadvantage for their inability to contain the epidemic, compared to advanced countries of the world (Massinga Loembé et al. 2020; Gilbert et al. 2020; Kalu 2020). Given the current trends coupled with the poor health care system delivery, Africa has been predicted to be the next epicenter of the COVID-19 pandemic (Massinga Loembé et al. 2020). In Nigeria, there is growing concern on measures to halt the ever fast-spreading COVID-19 raging for medical attention, adopting measures such as self-isolation, social distancing and total/partial lockdown policies. Nigeria has experienced significant increase in COVID-19 confirmed cases since the beginning of May, 2020. The numbers had increased exponentially, on the 1st of May 2020 a total of 2,170 confirmed cases were reported and by 18th July 2020 (within the space of about two months), the numbers had risen to 36,107. This raised significant health concern among the stakeholders, knowing that a continuation of the trend could cause a major health disaster for the country.

An account of the rate of spread of the virus can offer a strong insight to locations with potential significant high rates, which can then be used to strengthening decision and management efforts to contain the pandemic. Although, the provision of quarantine facilities and the availability of rapid diagnostic kits for quick testing are challenging in African counties (such as in Nigeria), and the country would be even more vulnerable if it lacked insight of projected rates and future trends.

Research in public health, for example, in epidemiology has been conducted in the past to evaluate the pattern and projected future trend of diseases. This is done with a view to providing options for policy makers to design mitigation measures. Time series models are often used to allow for the prediction of future trends, as they are based on mathematical, statistical and computational analyses of the recorded numbers of incidents. These models are therefore ideal as forecasting tools and can also provide situational awareness, or define counterfactual scenarios that help to disentangle the impact of public health policies (Vespignani et al. 2020). It should be noted however that in prediction, some researchers place more attention on explaining why the phenomena occur and what would happened if the trend is to continue, while other researcher base their predictions on forecasting the future incidence (Massad et al. 2005; Caswell 1989). Eker (2020) who discussed the validity and usefulness of COVID-19 models developed in the United Kingdom (UK), United State of America (US) and Austria, raised concerns on the lack of a thorough validation and a clear communication of their uncertainties (Eker 2020). For example, based on a model developed by MRC Centre for Global Infectious Disease Analysis at Imperial College London in collaboration with the World Health Organization (WHO), it has been projected that around 500,000 and 20,000 deaths will occur in the UK without and with strict measures, respectively. This has been observed by many individuals as central to government policies on strict social distancing and lockdown in the UK (Boseley 2020). However, the accuracy of these projections have been further questioned and the suggestions to change the model assumptions were proposed and debated (Sample 2020; Eker 2020). In this study, our focus is mainly on comparing various forecasting models by assessing their accuracies.

Despite the performance of a single model in forecasting epidemiology such as COVID-19 as demonstrated in previous studies (Petropoulos and Makridakis 2020; Ceylan 2020; Haushofer and Metcalf 2020), it is quite essential to ascertain the reliability of forecasting models by assessing their levels of accuracy, perhaps by comparing different models within and outside the same forecasting families (Ahlburg 1995). Although, the time series data characteristics can influence forecasting results, consideration to forecasting models is also useful since their applicability and accuracy vary significantly (Green and Armstrong 2015; Rogers 1995 ; Eker 2020). Ahlburg (1995) has questioned the wisdom for searching for a single best model or approach. He therefore suggested that combining forecasts may improve accuracy. In this study, a combination of ten forecasting models mainly from eight forecasting families were used to forecast the COVID-19 confirmed cases (from February to December, 2021) in Nigeria. We forecasted the Coronavirus infections for the whole country as well as for Abuja (the federal capital territory) due to its high number of cases and Lagos being the epicentre of the Virus in Nigeria. To the best our knowledge, so far, the COVID-19 data are not only the longest time series data analysed here, but also the longest forecast ever made on Coronavirus infection for the country (as of 08/12/2020). Our aim was to find out the most accurate model using mean absolute error (MAE) as standard statistical observations widely used for error measurement and reporting.

2. Methodology

2.1 Study area

Nigeria is situated in the West African region and lies between longitudes 3° and 15°E of the Greenwich meridian and latitudes 4°and 14° North of the Equator. The country has a land mass of ~ 923,768 km^2. It is bordered by the republics of Niger and Chad to the north, Republic of Benin to the west, Republic of Cameroon to the east and Atlantic Ocean to the south. The country has a population of about 200,962,417 estimated in 2019. The population is made up of about 374 ethnic groups (Embassy of the federal republic of Nigeria 2020). Based on the United Nation Development Report of 2019, which is the most recent (as the time of writing this paper), Nigeria has a Human Development Index of 0.534 and is therefore categorised as one of the low development countries. Similarly, given the country's status of being the most populous black nation in the world, there is no gain saying that the country's population constitutes one of the most vulnerable socioeconomic groups. This particularly makes it necessary to forecast disease transmission rates and carry out trend analysis (whether it is endemic or pandemic) to enable proper planning of health care delivery and implementation of the right prevention protocol at the right place and at the right time.

Lagos is one of the 36 states of Nigeria, and it is where the first confirmed COVID-19 case was reported. The first case was that of an Italian national who tested positive for the virus in February 2020 (Nigeria Centre for Disease Control 2020). So far, Lagos state has the highest records of confirmed cases of COVID-19 infection in Nigeria. Lagos is now regarded as the epicenter of the Coronavirus in the country. On the other hand, Abuja is the Federal Capital territory (FCT) of Nigeria. It is the region with the second highest number of confirmed cases of COVID-19 in the country. Being the Capital city of Nigeria, where people from different parts of the world visit, it is more than expected that the rate and spread of the virus will grow at an exponential rate.

2.2 Data

In this study, publicly available daily records of the confirmed cases of COVID-19 (from February 27, 2020, to December 8, 2020) was obtained from the official website of the National Centre for Disease Control (NCDC; https://covid19.ncdc.gov.ng/report/), which was used for the model forecasting operation and accuracy assessment. First of all, the daily records of the confirmed cases for the whole country were downloaded, after which data for Lagos state and the federal capital territory (FCT) were downloaded.

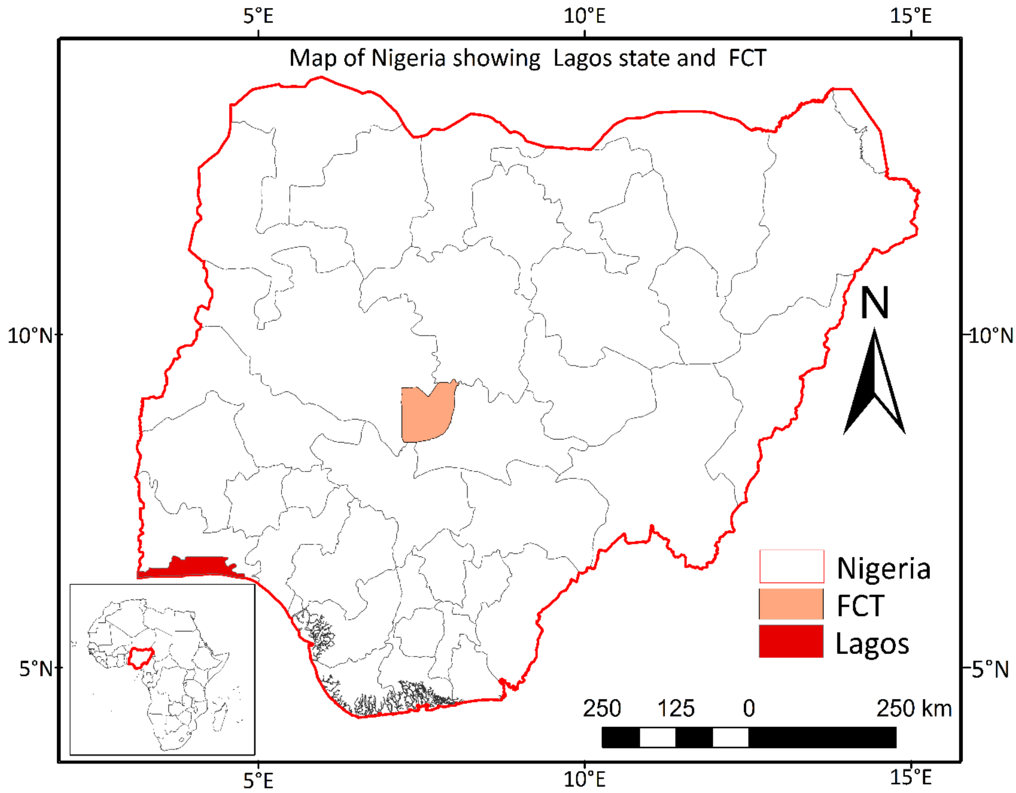

Figure 1: Map of Nigeria showing the location of FCT and Lagos state

2.3 Methods

2.3.1 The forecasting models and parameter estimations

In this study, ten forecasting models were tested and compared. This includes exponential smoothing, structural time series, Auto-Regressive Integrated Moving Average (ARIMA), cubic smoothing spline, linear regression, ARFIMA, Random walk, Bagged (also known as bootstrap aggregation), Holt's and Theta. The methods were applied on the daily confirmed cases of the COVID-19 infection in Nigeria, FCT and Lagos state. In most of the prediction literatures, single models (Ibrahim and Oladipo 2020; Petropoulos and Makridakis 2020) or only a few models (Abdulmajeed, Adeleke, and Popoola 2020) were often used for either projection or forecasting. This limits the ability to ascertain the best model that is more likely to outperform others on a consistent basis. Hence, the rationale for exploring the varieties of models in this study. Detail explanations of these models can be found in Hyndman and Athanasopoulos (2013). Bearing in mind the characteristic influence of time series data on predictability, close attention was given to the explanation offered by Hyndman and Athanasopoulos (2013) on some of the important sources of uncertainty in forecasting, using time series models. This include random error term, the parameter estimates, and the choice of model for the historical data and the continuation of the historical data generating process into the future (Hyndman and Athanasopoulos 2013). Using each model, we forecasted the daily cases of the COVID-19 for a period of about 7 months (specifically from December 9, 2020 to July 2012).

2.3.2 Accuracy assessment

Over the last few decades, a variety of measures of forecasting error for time series models were proposed due to increased interest in determining which model produce more accurate and precise estimates, as each has its advantages and drawbacks. MAE and RMSE are some the of the most popular, easy to understand and compute metrics. The Lower the value of the MAE/RMSE, the better the forecast. The models were programmed in R statistical software and each model automatically splits the time series data into 70% (as the training set dataset) and 30% (as the test dataset) for prediction and accuracy assessments respectively.

4. Results

4.1 The COVID-19 forecasts for Nigeria, FCT and Lagos state

The forecasts of COVID-19 for Nigeria are shown on the appendix (Figure 2-4 respectively). This depicts the forecasting results of COVID-19 confirmed cases based on the 10 forecasting models explored, using a monthly time series data from Mid-March to early-December 2020 while the forecasts are from December 2020 to July 2021. Some models show high number of daily estimated cases while others are moderate and lower. Some of the models also provided a consistent pattern across all the three regions, while others didn't. For example, the exponential smoothing model has estimates from 476 to 1000 and the forecast has shown the COVID-19 infection for the whole country (Figure 2a). Similar model behavior was observed with daily cases ranging from 219 to 566 (Figure 3) and 142 to 257 (Figure 4) for Lagos and FCT respectively. Generally, the model shows that all cases in these places would increase exponentially. Similarly, ARIMA model indicates a future trend of the COVID-19 infection from 475 to 1000 for Nigeria (Figure c). In some methods, there is no significant variability in the daily estimated cases through the forecast period. Such model includes linear regression with an estimated daily cases from 684 to 758 for Nigeria (Figure 2e), 234 to 235 for Lagos (Figure 3e) and 96 to 115 for FCT (Figure 4e). Such type of trend shown by the linear regression model is mostly unnatural. The forecasts made by the cubic smoothing spline, random walk and Holt's model show the highest number of daily cases compared to all models with up 4000 daily cases in some of these models (Figure 2, 3, 4). While, bagged model has the moderate and lower values of the daily cases compared to all models used in this study (Figure 2, 3, 4). The accuracy assessments presented in the next section provides an insight into which model can be said to be more reliable.

4.2 The accuracy of forecasting models

Since the ultimate aim of this study is to assess the accuracy of these forecasting methods, errors of each forecasting model were assessed and are shown in Table 1. The accuracies of these forecasting methods vary. In the accuracy assessments, as expected, the RMSE recorded the highest error for all forecasts. In addition, it is not also consistent with MAE except in bagged model (Nigeria: MAE= 48.10, RMSE= 68.51, Lagos= MAE= 32.80, RMSE=

47.60 and FCT: MAE= 13.48, RMSE= 19.61). The performance of the Bagged model is consistent across all the forecasts made in this study. Bagged model is not only consistent but also indicate the highest performance with MAE of 48 for Nigeria, 32.80 for Lagos and only 13.48 for FCT. Apart from the bagged model, no other model shows unique trait based on the MAE, except linear regression which has the lowest performance in all the three forecasts. However, other performances which seem to be on a consistent basis are for exponential smoothing (Nigeria, MAE = 53.65, Lagos = 36.35, FCT = 14.83), structural time series (Nigeria, MAE = 53.62, Lagos = 34.35, FCT = 14.86), ARIMA (Nigeria, MAE = 53.64, Lagos = 36.34, FCT = 14.83), and theta models (Nigeria, MAE = 53.65, Lagos = 36.35, FCT = 14.83). Although no strong evidence of out-performance of one model over all other models on a consistent basis was observed, structural time series and ARIMA outperformed other models for Nigeria and Lagos while exponential smoothing for FCT.

Table 1: Error measurement of forecasting models for the total confirmed cases for the whole country (Nigeria), Lagos State and the Federal Capital Territory (Abuja)

Models	**Nigeria**		**Lagos**		**Abuja (FCT)**	
	MAE	**RMSE**	**MAE**	**RMSE**	**MAE**	**RMSE**
Exponential Smo	***53.65***	***76.86***	***36.35***	***52.68***	***14.83***	***21.60***
Structural TS	***53.62***	***76.82***	***36.34***	*52.68*	*14.86*	***21.55***
ARIMA	***53.64***	***76.86***	***36.34***	*52.68*	***14.83***	***21.60***
Cubic Smo Sp	55.97	*80.38*	41.26	*60.73*	*15.18*	*21.79*
Linear regre.	166.72	*198.95*	58.87	*75.22*	*22.30*	*28.99*
ARFIMA	53.96	*76.81*	36.46	*52.22*	15.01	*21.60*
Random walk	64.54	*93.03*	41.11	*64.28*	18.24	*26.69*
Bagged	***48.10***	***68.51***	***32.80***	***47.60***	***13.48***	***19.61***
Holt's	54.27	*76.91*	36.45	***52.67***	**14.86**	***21.54***
Theta	***53.65***	*76.86*	*36.35*	*52.68*	***14.83***	***21.60***

5. Discussion

The present study was designed to forecast the number of populations that are anticipated to contract the COVID-19 epidemic as well as to compare the accuracy of the forecasting models based on the MAE and RMSE estimated from the remaining 30% of the daily confirmed cases of the Coronavirus in Nigeria. Forecasting the number of populations that would be infected by this disease, as accurately as possible, is necessary for an effective decision-making process (e.g. healthcare demand overtime), but quantifiably, it is more important to evaluate the most accurate forecasting model since a good decision making lies with getting the most effective results. The choice of method for forecasting the future trends must therefore be driven by its ability to perform but the evaluation of model performance is even more challenging.

In this study, compared to MAE, the error measurements from the RMSE are high. MAE show better model performance. This was highlighted by Willmott and Matsuura (2005), who compare the applicability of RMSE and MAE and suggest that MAE is a better metric for this purpose (Willmott and Matsuura 2005; Weron 2014). Even though our forecasting results vary significantly with models, the most interesting finding was that bagged model outperformed all other models on a consistent basis and across all scenarios (MAE = 48 (Nigeria), 32.80 (Lagos) and 13.48 (FCT). These results are consistent with those of other studies. This finding corroborates the ideas of Bergmeir, Hyndman, and Benítez (2016) and Dantas and Cyrino Oliveira (2018) who suggested that bagging should be used in combination with other forecasting models such as bootstrap aggregation of exponential smoothing methods and clusters (Bergmeir, Hyndman, and Benítez 2016; Dantas and Cyrino Oliveira 2018). This is simply because bagging is a machine learning ensemble meta-algorithm designed mainly to improve the accuracy of machine learning algorithms. It helps to get a better measure of forecast uncertainty, and secondly, it provides a way of improving point forecasts (i.e. it reduces variance and helps to avoid overfitting) (Hyndman and Athanasopoulos 2013).

In this study, the bagged model, exponential smoothing, ARIMA and structural time series models recorded good performance. These models were reported to have good performance in the various literature by a number of researchers and in forecasting the trend of COVID-19 infection across the globe (Petropoulos and Makridakis 2020; Ceylan 2020; Haushofer and Metcalf 2020). Ceylan (2020) applied ARIMA models to forecast the epidemiological trend of COVID-19 prevalence in Italy, Spain, and France using a two-month (21 Feb to 15 April 2020) data acquired from WHO. Various ARIMA models were tested and results show that ARIMA (0,2,1), ARIMA (1,2,0), and ARIMA (0,2,1) models have the lowest MAPE values (4.7520, 5.8486, and 5.6335) for Italy, Spain, and France, respectively (Ceylan 2020). The author attributes the accuracies of these models to simplicity and systematic structure and acceptable forecasting performance of the ARIMA model.

Another recent study by Petropoulos and Makridakis (2020) used models from the exponential smoothing family to forecast daily cumulative cases covering the period from 22 January 2020 to 11 March 2020 to forecast confirmed cases, deaths and recoveries (10 day ahead) from the COVID-19 infection at a global scale. The analyses were conducted in four segments, starting with a very few data points (10 points) and kept increasing the points in the subsequent phases as the time series data became available. The largest error was observed in the first round (absolute percentage error= 338%). In the second round, the accuracy of the forecasting model had increased substantially (an absolute percentage error of 7.7%). In the third round, an underestimation was recorded with an absolute error of 6.2%. Similarly, in the fourth round, the absolute forecast error at the end was 12.1% (underestimated) which the authors attributed to the exponential increase of the confirmed cases mostly in Europe, Iran and the US (Petropoulos and Makridakis 2020).

Our results show that combining different approaches is of great value to forecasting modelling. Therefore, our choice to approaches in forecasting require special attention and need experimentation as most of the best forecasting outcomes result from a scenario-based analyses, hence, they may have a severe negative implications to decision making if treated otherwise.

6. Conclusion

In this study, the potential of forecasting models for predicting the COVID-19' s future trend in Nigeria was explored. The main findings were as follows:

1. Bagging was found to be the most accurate model for predicting the COVID-19 future trends in Nigeria with the least MAE of 48 for Nigeria, 32.80 for Lagos and only 13.48 for FCT.
2. The study found that the MAE of the bagged model is lower when the records daily time series data were lower (MAE=13.48 for Abuja) and vice-versa (48 for Nigeria). This means that, even though dense time series is useful for understanding the trend, uncertainty increases with increasing time series observations.
3. Three other models (exponential smoothing, structural time series and ARIMA) alongside bagging applied in this study, are undeniably useful for the purpose of disease forecasting and public policy.
4. Our study shows that the modelling performance of forecasting approaches vary significantly, thus, policy framework that are designed based on these quantitative models need to be treated with caution despite the need for urgent decision making, especially in the recent COVID-19 pandemic

Acknowledgement
We acknowledge the R Core team for making various library packages available for the data analyses.

Funding Statement
Not applicable

Ethics Approval and Consent to Participate Statement
Not applicable.

Author Contributions
SI: Conceptualization; **SI, AR**; Data curation, Formal analysis; Methodology; **AR, SI**; Visualization; **SI**; Writing - original draft; **SI**, **AR**, **MSO**, **BA**; Writing - review & editing.

Conflict of Interest Statement
The authors declare no conflicts of interests.

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Appendix

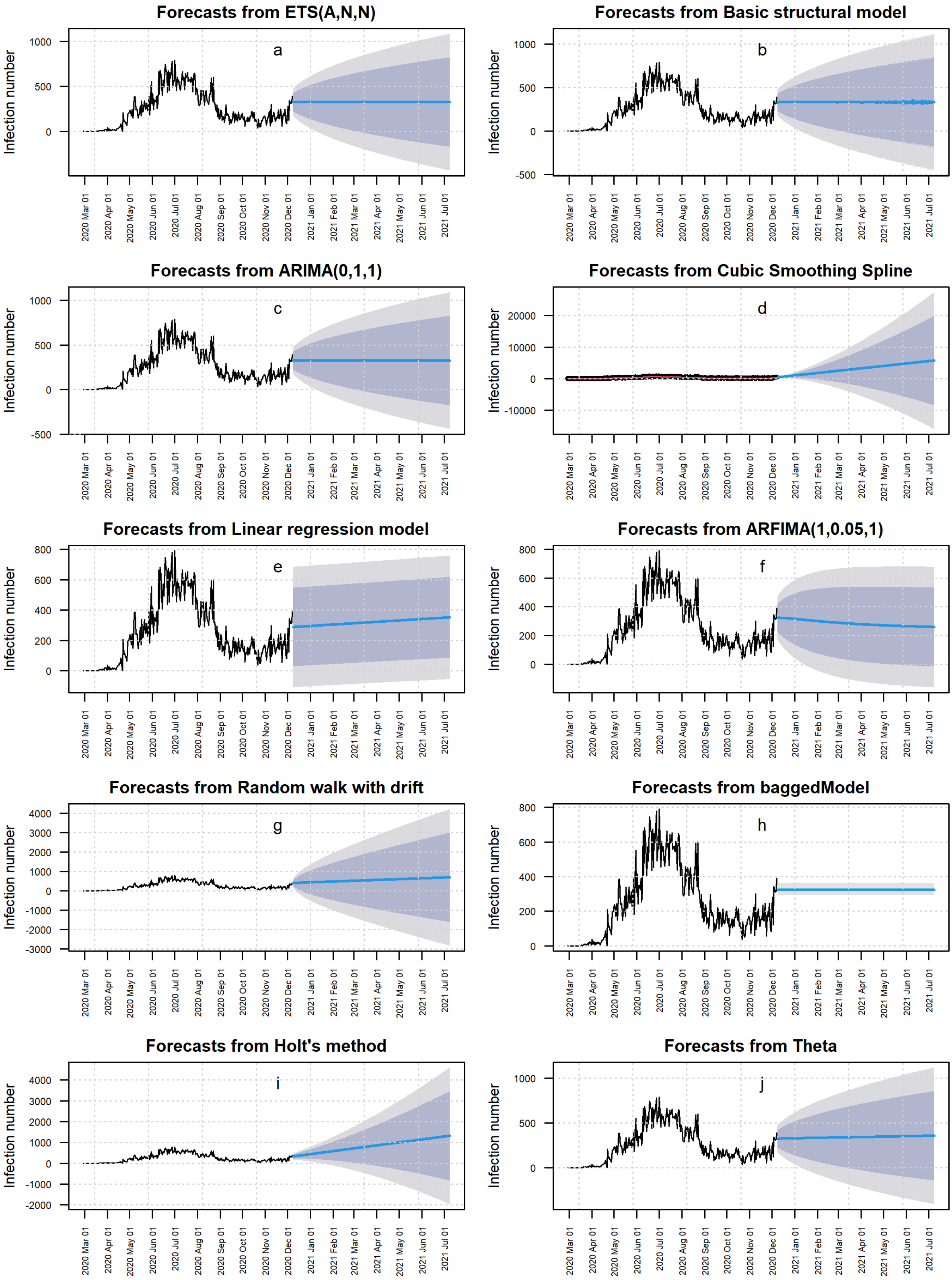

Figure 2: Forecasting Covid-19 infection in the next seven months in Nigeria,
(a) Exponential Smoothing (b) Structural time series (c) ARIMA (d) Cubic smoothing spline
(e) Linear regression (f) ARFIMA (g) Random walk (h) Bagged (i) Holt's (j) Theta.

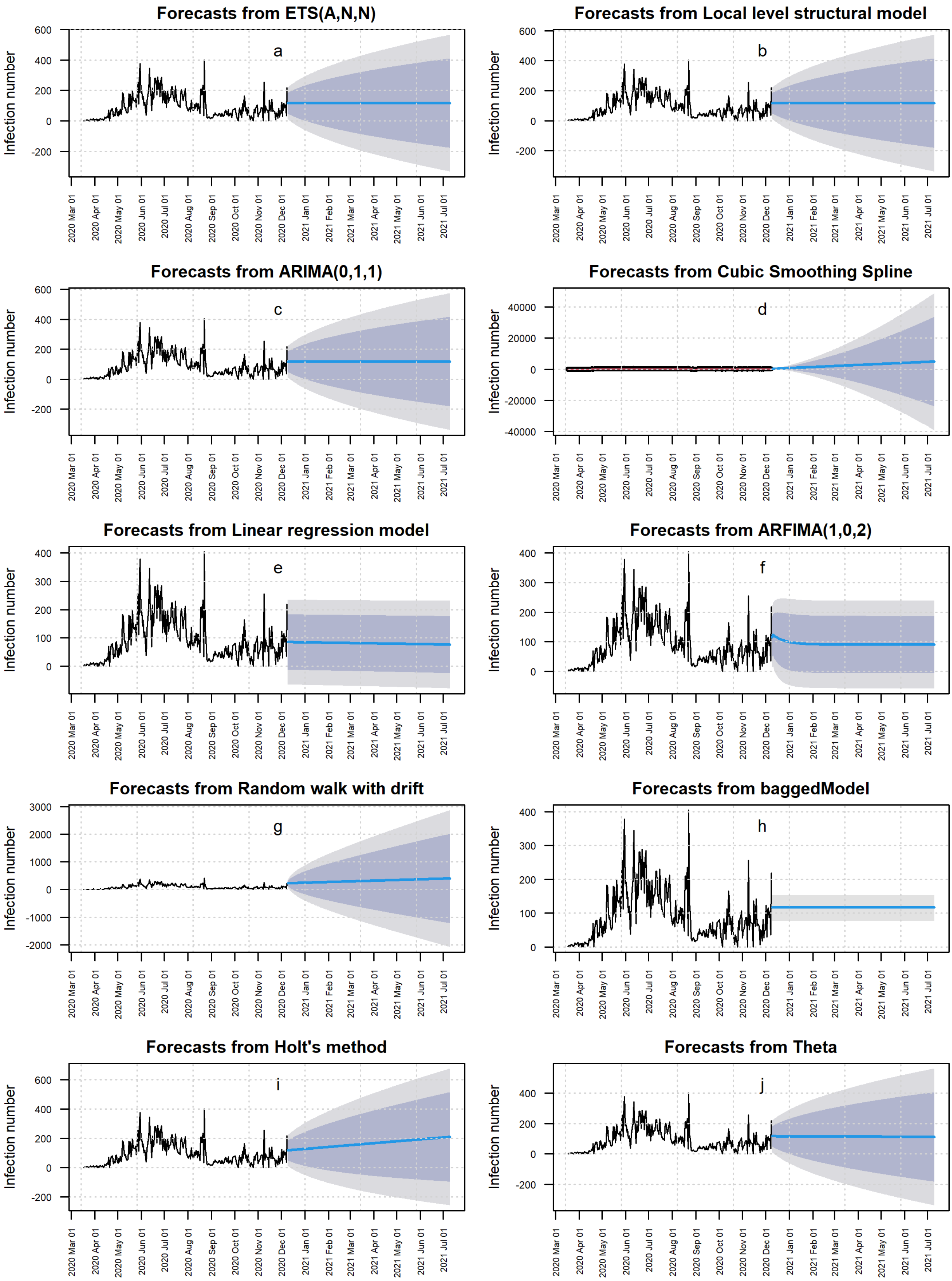

Figure 3: Forecasting Covid-19 infection in the next seven months in Lagos in Nigeria, (a) Exponential Smoothing (b) Structural time series (c) ARIMA (d) Cubic smoothing spline (e) Linear regression (f) ARFIMA (g) Random walk (h) Bagged (i) Holt's (j) Theta

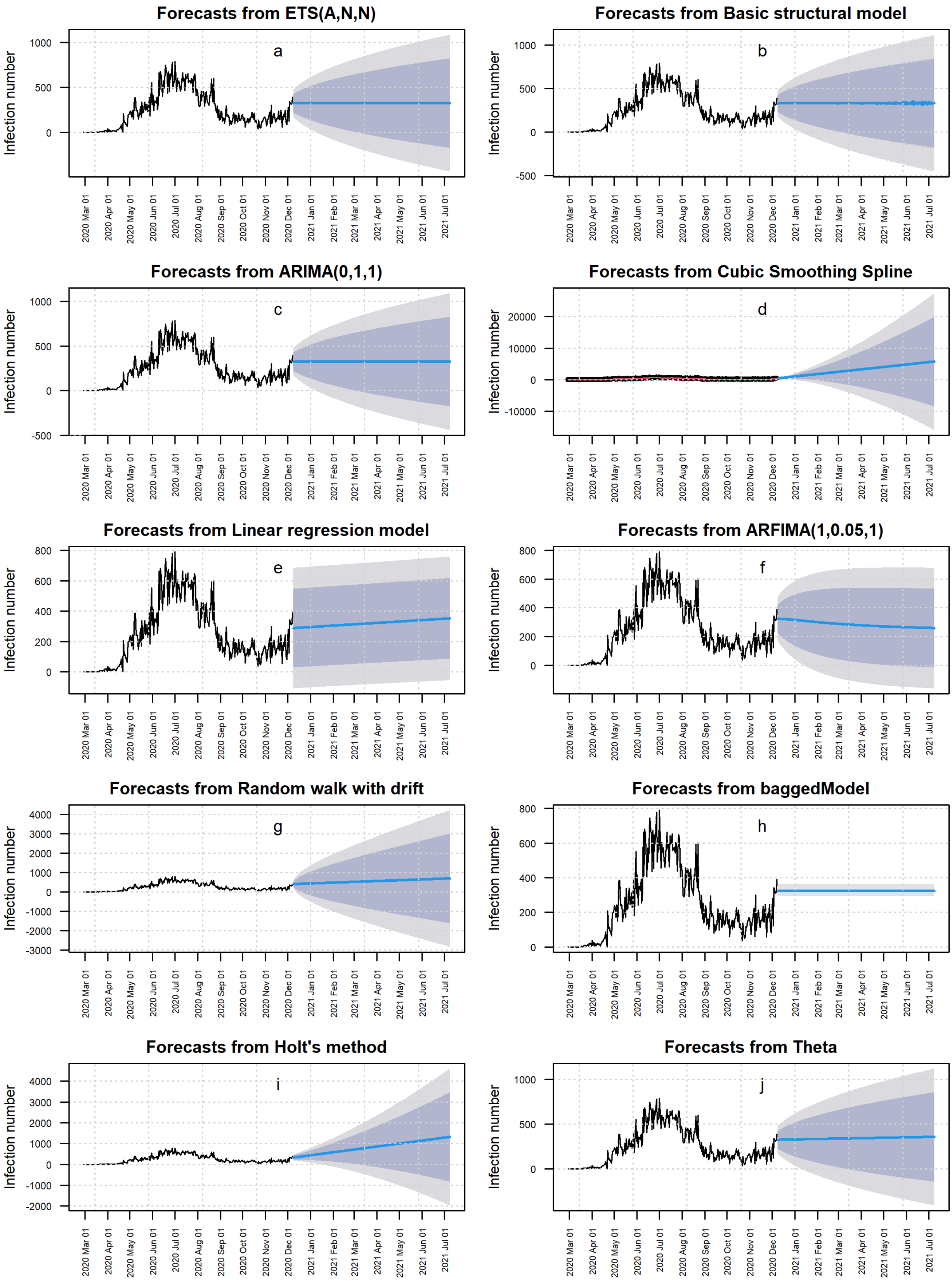

Figure 4: Forecasting Covid-19 infection in the next seven months in FCT in Nigeria, (a) Exponential smoothing (b) Structural time series (c) ARIMA (d) Cubic smoothing spline (e) Linear regression (f) ARFIMA (g) Random walk (h) Bagged (i) Holt's (j) Theta

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