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PREDICTION THE DAILY NUMBER OF CONFIRMED CASES OF COVID-19 IN SUDAN WITH ARIMA AND HOLT WINTER EXPONENTIAL SMOOTHING

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ABSTRACT

This paper compares the performance of ARIMA and Holt linear exponential smoothing models in the perdition of covid-19 confirmed cases in Sudan, daily readings of Covid-2019 confirmed cases data covered the period 24th March 2020 until 10th June 2020 obtained from federal ministry of health- Sudan are used in the analysis of this paper.ARIMA and Holt linear exponential smoothing models were applied to the data, the empirical analysis results indicated that the ARIM(2, 1,2) is an appropriate to represents ARIMA model. ARIM(2,1,2) as well as Holt linear exponential smoothing models are compared through examining the goodness of fit of each model using certain criteria. Based on AIC and BIC accuracy measurementsthe ARIMA model was chosen as an appropriate model rather than Holt exponential smoothing models, this finding suggests that ARIMA is highly recommended.

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INTRODUCTION

Sudan - like most countries in the world - breathes under the impact of the Corona pandemic, which entered the country and the first case of the disease was discovered in Sudan on 3/13/2020 after the death of the patient and the injury was number two for a foreigner on 20/3/2020 [http://www.fmoh.gov.sd/]. In particular, COVID-19 is an infectious viral disease that is transmitted through the spray either directly. While coughing or sneezing the patient or indirectly; by contact, touch the surfaces contaminated with the stool containing the virus. The virus finds its way into the human body through the mucous membranes of the mouth, nose, and eyes [WHO, 2020; WHO, 2020; WHO, 2019]. Recently, many different research studies have been proposedMathematical prediction models and machine learningEstimate the spread of the disease and determine its effect [Mahalle, 2020] Globally [Petropoulos, 2020] and specific countries such as the United States of America [Liu, 2020] and China[Al-qaness, 2020] Italy [Perone, 2004], Spain [Monllor, 2020], France [Fanelli, 2020], India [Gupta, 2020], Japan [Sugishita, 2020] and Saudi Arabia[Forecasting the spread of the COVID-19] are among. Others. To our knowledge, there have been no previous studiesIt was conducted to predict the prevalence of COVID-19 in Sudan as the number of daily cumulative cases continuesTo grow significantly, it increased to more than 4 thousand cases in total [Brown, 1962] and from that the precautionary measures began to close The airport followed by the appearance of a few numerical cases, and after the exception of opening the airport and borders for the stuck Sudanese to enter Sudan and receiving news of their failure to submit to the quarantine period necessary to examine the disease and prevent its spread, the disease began to spread more broadly, which driven the authorities to increase precautionary measures and prevent travel between states and prohibit partial roaming in all states.After the cases increased dramatically in the state of Khartoum, the authorities adopted a policy of complete prohibition and closure to prevent

further outbreaks, without pursuing societal investigations or identifying regional hotspots, which led to public discontent among them and failure to adhere to these measures, which resulted in the increase in cases, and some states also adopted measures.
It is proportional to its epidemiological situation, which is much less than the state of Khartoum and is totally absent in some states.Recently, there has been a promising rise in the number of registered recoveries, which makes the curve of injuries and recovery nearly equal in its daily form, indicating that the precautionary measures adopted will soon be relaxed, when this pattern will continue to increase with those recovering without injuries.In this study, two prediction methods are employed to prediction the number of covid-19 confirmed cases in Sudan, namely, ARIMA and Holt-Winters Exponential smoothing [Gilchrist, 1976; Muhammad, 2020; Chatfield, 1984]. Different statistical criteria were computed to assess the precision and the reliability of the proposed models, which used to forecast the future covid-19 confirmed cases.

ARIMA Models: The Box-Jenkins methodology was described in a highly advantaged book [Gilchrist, 1976]. They effectively put together in a comprehensive manner, the relevant information required to understand and use univariate time series ARIMA models [Holt, 1957; Jonathan, 2008]. The ultimate objective is to arrive at a model that appropriately describes a time series under consideration. Their approach to construct ARIMA models consists of four phases: model identification, model estimation, model diagnostic checking and forecasting. Nemours models have been used to represent a time series depending on the underline process assumed to operate on the series.

The General Box-Jenkins model [Brown, 1956]:

The general ARIMA model of orders $(p,d,q)(P,D.Q)^s$ can be written as:

$$\emptyset(\mathrm{B})\Phi(B^s)\Delta_d\Delta_s^D x_t = \theta(\mathrm{B})\Theta(B^s)e_t \quad (1.1)$$

Where:

$(1-B)^d$is the d[th] order difference)
$(p,d,q)$is the nonseasonal part of the model.
$(P,D.Q)^s$is the seasonal part of the model.
$S$is the seasonal Length.

Double Exponential Smoothing Holts two – parameters [Frederick; Ruets, 2005]: Extended simple exponential smoothing to permitpredicting of data with a trend. Holt's linear double exponential smoothing method is hinge on two smoothed constant namely alpha α and gamma γ such that their values lies between zero and one i.e: $0 < \alpha, \gamma < 1$ .Holt's linear double exponential smoothing method was concentrated on the following equations:

$$S_t = \alpha x_t + (1-\alpha)(S_{t-1} + b_{t-1}) \quad , \quad 0 < \alpha < 1 \quad (1.2)$$

$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1} \quad , \quad 0 < \gamma < 1 \quad (1.3)$$

$$F_{t+m} = b_t + b_t m$$

whereS_t is smoothed value, b_t is the trend smoothed value and m is a forecast period ahead.

Triple Exponential Smoothing (Winter's Method): Triple exponential smoothing method is smoothing technique used when the series exhibit seasonal variations, i.e the method allow seasonality. Triple exponential smoothing method depend on three parameters that's are alpha α gamma γ and beta β their values lies between zero and one i.e $0 < \alpha, \gamma, \beta < 1$.

Triple exponential smoothing method depends on the following equations [Gupta, 2020; Sugishita et al., 2020; Forecasting the spread of the COVID-19]:

Over all smoothing: $S_t = \alpha \frac{x_t}{I_{t-L}} + (1-\alpha)(S_{t-1} + b_{t-1}) \quad , \; 0 < \alpha < 1 \quad (1.4)$

Trend smoothing: $b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1} \quad , \; 0 < \gamma < 1 \quad (1.5)$

Seasonal smoothing: $I_t = \beta \frac{x_t}{S_t} + (1-\beta)I_{t-L} \quad , \; 0 < \beta < 1 \quad (1.6)$

Forecasting equation: $F_{t+m} = (S_t + b_t m)I_{t-L+m} \quad (1.7)$

And the trend $\beta = \frac{1}{L}\left[\left(\frac{x_{L+1}-x_1}{L}\right) + \left(\frac{x_{L+2}-x_2}{L}\right) + \cdots + \left(\frac{x_{L+L}-x_L}{L}\right)\right] \quad (1.8)$

Where L is the length of seasonality,β is the trend parameter component,I is the seasonal adjustment factor and F_{t+m} is the m period ahead forecast.

Empirical Results: This section brieflyinvestigate the empirical results for application oftwoprediction methods Box-Jenkins and Holt-Winters Exponential smoothing methodsto data representing COVID-2019 confirmed cases in the Sudan.

The Data: Daily readings of COVID-2019 confirmed cases data in the Sudan covered the period 24thMarch 2020until 10thJune 2020 are used in the analysis of this paper. The data are obtained from federal ministry of health- Sudan [http://www.fmoh.gov.sd/].

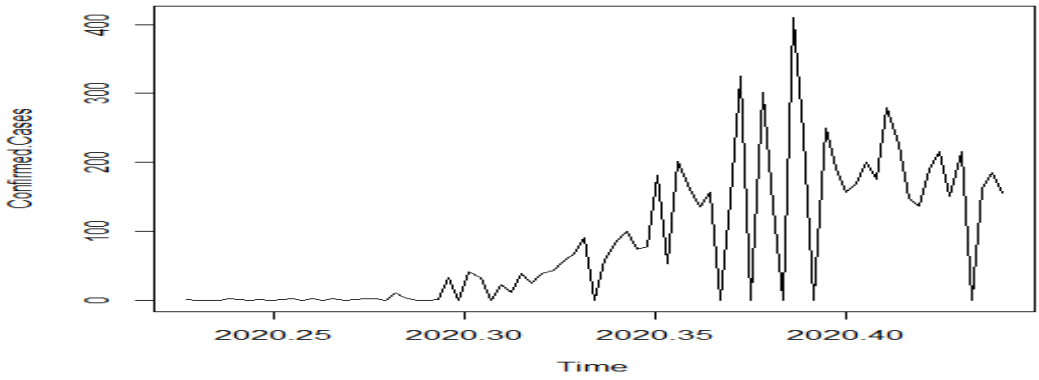

Figure1. The daily COVID-2019 confirmed cases in Sudan period 24March 2020 – 10June 2020 data

Figure1.Above shows the sequence chart of daily readings forCOVID-2019 confirmed cases data in the Sudan covered the period 24thMarch 2020 – 10thJune 2020.It can be shown that COVID-2019 confirmed cases in the Sudan fluctuate between 1 and 2 confirmed cases before it steadily increase till the mid of April, then itshows slightly increase till the 1st week of June, before it sharply decrease till the end of July 2020, at the end of study period the confirmed cases goes to decrease.

The correlogram of the daily readings for COVID-2019 confirmed cases series level is shown bellow in figure 2 and 3. The autocorrelation functions in figure 3 shows large positive peak decays exponentially to zero after lag 4 figure 2 whereas the partial autocorrelation function cut off to zero after lag of 10 figure 3, therefore the COVID-19 confirmed data seems to follow an autoregressive model since ACF decay exponentially to zero.

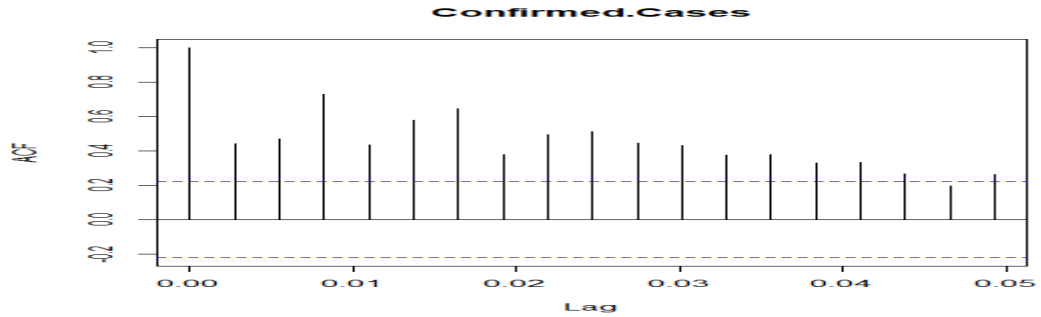

Figure 2. ACF of COVID-2019 confirmed cases in Sudan period 24March 2020 – 10June 202 data

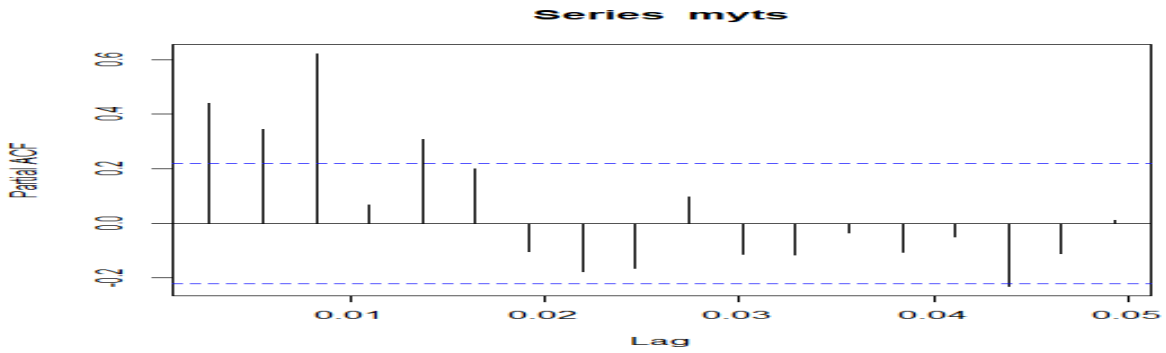

Figure 3. PACF of COVID-2019 confirmed cases in Sudan period 24March 2020 – 10June 202 data

Augmented dickey fuller ADF test was applied toCOVID-2019 confirmed cases series level, the empirical results indicate that ADF test value in absolute terms (−1.9) with probability of (*0.58*) whereas, the application of ADF test on the first difference series reveals that ADF test value in absolute terms (-8.127) with probability of (*0.01*), these finding confirmed thatCOVID-2019 confirmed cases series level is non-stationary while the first difference of the series is stationary.

Modeling Covid-19 Confirmed Cases in the SudanUsing Exponential Smoothing Models: This section provides the performance of Holt Exponential Smoothing Methodon COVID-2019 confirmed cases data in the Sudan from the period 24thMarch 2020 – 10thJune 2020.

Table 1. ADF test of Covid-2019 confirmed cases in Sudan

Unit Root Test Results of COVID -2019 confirmed cases data				
Test Type	Level		1st Difference	
	Test Value	Prb	Test Value	Prb
ADF. Test	−1.9888	0.5802	−8.1277	−8.1277

Table 2. Holt-Winters exponential smoothing model of COVID-2019 confirmed cases in Sudan

Holt-Winters exponential smoothing model of Covid-2019 confirmed cases in Sudan						
Coefficients	α	β	a	b	AIC	BIC
Estimate	0.03865291	1	143.862472	-7.658429	1013.411	1025.258

Table 3. Holt-Winter exponential smoothing forecasts values and lower and upper forecasts confidence limits

Day	11/6	12/ 6	13/6	14/6	15/6	16/6	17/6	18/6	19/6	20/6
Forecast values	136	128	120	112	103	95	87	79	71	63

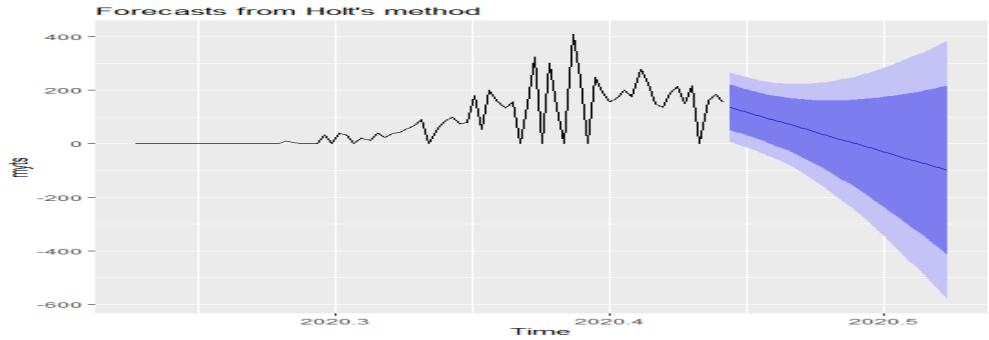

Figure 5. Prediction of COVID-2019 confirmed cases in Sudan for the period 11th Jun 2020 to 10thJuly 202

Table 4. The estimation parameters of the ARIMA (2,1,2) with drift model of COVID-2019 confirmed cases data

ARIMA(2,1,2) with drift model of COVID-2019 confirmed cases data							
Coefficients.	$\emptyset_1$	$\emptyset_2$	θ_1	θ_2	$drift$	AIC	BIC
Estimate	−0.9229	−0.5865	−0.2045	−0.3712	2.1674	865.75	879.89

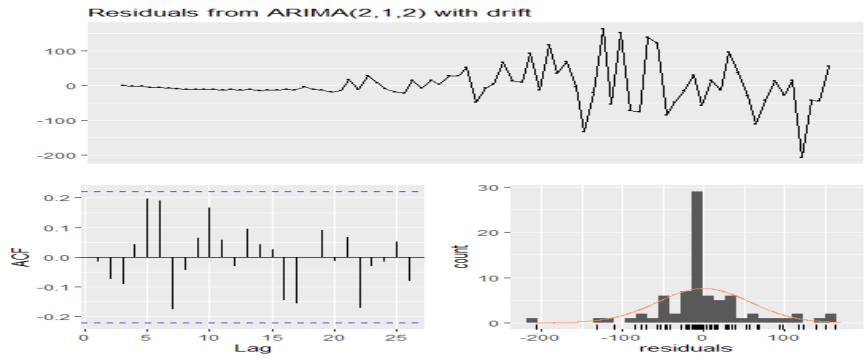

Figure 5. Residuals from COVID-2019 confirmed cases in Sudan period 24thMarch 2020 – 10thJune 202 data

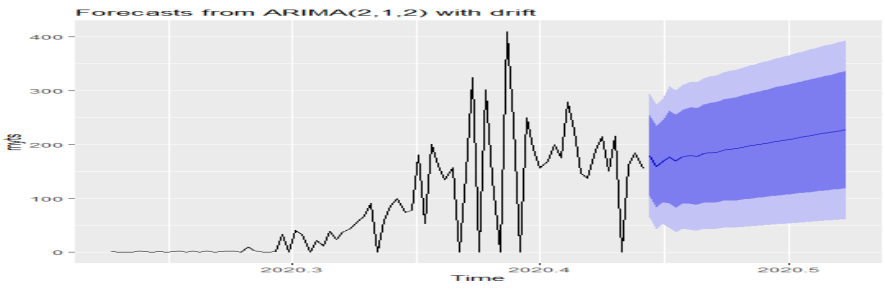

Figure 6. Predictionof COVID-2019 confirmed cases in Sudanfrom the ARIMA (2, 1, 2) with drift model

Table 5. Forecasts of COVID-2019 confirmed cases in Sudan period 24March 2020 – 5June 202 data using ARIMA(2,1,2) with drift model

Day	11/6	12/ 6	13/6	14/6	15/6	16/6	17/6	18/6	19/6	20/6
Forecast values	179	159	168	177	169	177	179	178	183	184

In this section we establish the application of Holt-winter exponential smoothing method to data representing COVID-2019 confirmed cases data in the Sudan covered the period 24thMarch 2020 – 10thJune 2020, the estimation results that the values of α and γ are 0.038 and 1 respectively. Table (3) illustrates forecast values ofCOVID-2019 confirmed cases for the next 10 periods using Holt winter exponential smoothing model.

Modeling Covid-19 Confirmed Cases in the Sudan Using ARIMA Models: This section provides the application of ARIMA model to data representing COVID-2019 confirmed cases data in the Sudan covered the period 24thMarch 2020 – 10thJune 2020, through model identification, estimation and diagnostic checking.Both ADF and correlogram tests result confirmed thatCOVID-2019 confirmed cases series level is non-stationary however, the first difference is stationary. Furthermore the ACF in figure (2) decays exponentially and the PACF figure (3) cut off to zero after lag of 10 this result confirmed that an autoregressive model of order (2,1,2) with drift is an appropriate model for modeling COVID-2019 confirmed cases data in the Sudan.Table (4) bellow shows the estimation results of ARIMA(2,1,2) model onCOVID-2019 confirmed cases data in the Sudan covered the period 24thMarch 2020 – 10thJune 2020.

After a tentative COVID-2019 confirmed cases data in the Sudan model has been identified and its parameters has been estimated, diagnostic checking is then applied to the fitted model to see whether the model is adequate to fit the data. The Ljung-Box test was applied to residuals from an ARIMA (2,1,2) with drift model, the test results indicate that Q* = 14.082, df = 10, p-value = 0.1693, this results confirmed that the residuals are random.From Figure4 it can be seen that the residuals from the fitted model lies between upper and lower confidence limits, moreover residuals also follow histogram with normal curve. This result confirmed that ARIMA (2,1,2) with drift model is adequate, therefore it can be used for predictingCOVID-2019 confirmed cases data in the Sudan. The figures (5) shows the Forecasts of COVID-2019 confirmed cases in Sudan generated from the ARIMA(2,1,2) with drift model. Table (3) illustrates forecast values ofCOVID-2019 confirmed cases for the next 10 periods using ARIMA(2, 1,2) with drift

Evaluation Exponential Smoothing and ARIMA Methods: In This section Holt-Winter exponential smoothing and ARIMA methodswere compare for modeling and forecasting daily COVID-2019 confirmed cases in the Sudan.

The comparison is achieved through examining the goodness of fit of each model using certain criteria. Itshould be pointed out that saying one model is better than the other should not be understood as being better in all circumstances, it only happened to be better with respect to this particular type of data. Table (**6**) below reports the evaluation results of two forecasting methods using AIC and BIC accuracy measurements. It can be seen that the ARIMA model, therefore it could be chosen as an appropriate model, this findingsuggeststhat ARIMA is highly recommended in forecastingdaily COVID-2019 confirmed cases in the Sudan.

Table 6. Evaluation of the two forecasting methods

Forecasting Method	Accuracy Measurements	
	AIC	*BIC*
Exponential Smoothing	1013.411	1025.258
ARIMA (2,1,2) with drift	865.75	879.89

Conclusion

This studycompared the performance of Exponential Smoothing and ARIMA method in modeling and forecasting dailyCOVID-2019 confirmed cases in the Sudan covered the period 24thMarch 2020 until 10thJune 2020,the empirical findings revealed that the sequence chart of the data shown a secular trend. ADF test result confirmed that COVID -2019 confirmed cases series level is non-stationary while the first difference of the series is stationary. ARIM(2,1,2) with drift is an appropriate to represents ARIMA model. ARIM(2,1,2) with drift as well as Holt linear exponential smoothing models are compared through examining the goodness of fit of each model using certain criteria. Based on AIC and BIC accuracy measurementsthe ARIMA model was chosen as an appropriate model rather than Holt exponential smoothing models, this finding suggests that ARIMA is highly recommended.

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