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Modeling COVID -19 Epidemic of India and Brazil

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ABSTRACT

India has recorded the second-highest infected cases of the Covid-19 in Asia and also the highest in South Asia, Brazil is the second-highest infected cases reported globally after the USA. The growing trend in daily cases of both countries could gain negative consequences on society. Booming of daily cases generate outnumbered of health care facilities and other medical supplies. Therefore, the aim of the study was to forecast the number of infected cases within India and Brazil. The daily confirmed cases of COVID-19 of the two countries for the period of 22nd January 2020 to 1st June 2020 were obtained from the WHO database. The Auto-Regressive Integrated Moving Average (ARIMA) model, Autoregressive Distributed Lag Model (ADLM) Double Exponential Smoothing (DES) techniques, Liner trend model, Quadratic trend model, Growth Curve (GC) model, and Pearl — Reed Logistic model were tested. Anderson Darling test, Auto-Correlation Function (ACF), and Ljung-Box Q (LBQ)-test were used as the goodness of fit tests in model validation. The Best-fitting model was selected by comparing relative and absolute measurements of errors. The ARIMA and ADLM did not satisfy the model validation criterion for any of the countries, but the GC and DES did. It's concluded that DES is the best model for forecasting India and Brazil. The results of this study could be used to combat the epidemic.

Keywords: COVID -19, Growth Curve, DES.

1. INTRODUCTION

At the center of the year 2020, the new coronavirus (COVID-19) spread widely in globally. The sizable amount for people became infected. The virus originated in China in December 2019. At present, the outbreak in China has been satisfactorily controlled, but outside of China is becoming the worst daily. India is the second-highest populated country within the world, booming with over 180,000 infected cases, and suffered from over 8000 deaths because of the dark epidemic. As per the World Health Organization (WHO) reports, India has recorded the second-highest infected cases in Asia and also the highest in South Asia. Brazil is the sixth-highest populated country within the world, booming with nearly 500,000 infected cases, and suffered from over 28,000 deaths at the present. Among the Latin American countries, Brazil is the highest infected. Consistent with WHO, Brazil has reported 7350 cases per day on the average from 31st March to 28th May 2020. At present, both India and Brazil are in a rapid climb of COVID- 19.

1.2 Research Problem

An increasing number of infected cases generates outnumbered of health care facilities and other medical supplies (Konarasinghe, 2020). The healthcare and medical resources are the requirements for the powered health system of a rustic. If the confirmed cases outnumbered the health care and medical resources, the health system would be paralyzed. An anticipating of resources results in saving the human lives of a country. Forecasting infected cases would play a vital role to figure out the need for health care and medical resources to combat the epidemic. Therefore finding suitable models for forecasting is extremely important to beat the epidemic difficulties.

1.3 Objective of the Study

The objective of the study is to forecast the number of infected cases of COVID -19 in India and Brazil.

1.4 Significance of the Study

The results of this study would be a tool to be proactive and protect the country from the epidemic. They would be useful to work out health care and medical resources with minimum waste. The authorities can decide the lockdown schedules and impose the supply delivery systems to attenuate the movement of the general public. The business can develop e-commerce activities and confirm the sleek run of their business by maintaining social distance and avoid gatherings to satisfy their internal and external stakeholders. Decisions of the manufacturing volume of Personal Protective Equipment (PPE) kits and other medical equipment would be another significance of the study. This would be a pathfinder to attenuate the damage to human lives. The results of this study could be used to impose a new mandate to control COVID- 19 spread in India and Brazil.

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2. LITERATURE REVIEW

The review of the study was focused on modeling epidemics for various destinations. The researchers have used mathematical and statistical models for the aim. Zhang, et al., (2020) have estimated daily COVID-19 cases within the ship-Diamond Princess Cruise Liner, by using Gamma distribution. The Susceptible- Exposed-Infectious-Recovered (SEIR) predictive model has utilized by Hamzah, et al., (2020) to Predict and forecast COVID- 19 cases, deaths, and recoveries within and out of doors of China. The Moving Average (MA), Weighted Moving Average (WMA), and Single Exponential Smoothing (SES) are the time series models utilized by Elmousalami & Hassanien (2020) to forecast COVID-19 affected cases in China and out of doors the mainland of China. Bastos & Cajueiro (2020) have forecasted the first evolution of the Covid-19 pandemic in Brazil by Susceptible-Infected- Recovered (SIR) model. The study of David, et al.,(2020) have used an epidemiologic-based (susceptible, infected, recovered) SIR model to forecast active, death, and total cases of COVID 19 within the Philippines. Roosa, et al., (2020) have used the Logistic growth model to get short-term forecasts of cumulative reported COVID 19 cases in Guangdong and Zhejiang, China. The study of Gupta & Pal (2020) was focused to forecast and assess the trends of the COVID-19 outbreak in India by utilizing the Auto-Regressive Integrated Moving Average (ARIMA) and Exponential smoothing. Kumar, et al., (2020) have done 30 days forecast, the dynamics of cumulative confirmed death and recovery of cases in India by utilizing the ARIMA outperformed Richard model. The SEIR model was utilized by Wu, et al., (2020) to forecast numbers of infections in China and out of doors. Konarasinghe (2020) has modeled the epidemic of the USA, UK, and Russia by utilizing the ARIMA, Auto Regressive Distributed Lag Model (ADLM), and Double Exponential Smoothing (DES).

Hence, the SEIR and SIR were the commonly applied mathematical models within the epidemic. Besides, Gamma distribution, ARIMA, ADLM, DES, MA, WMA, SES, and Logistic growth models have utilized by researches. The reliability of a fitted model depends on the validation and verification, but, most of the researchers have paid the smallest amount of interest in it. China was the focus of many of the researchers, but the least attention has paid to the South Asian, Latin American, and Southeast Asian countries.

3. METHODOLOGY

The daily confirmed cases of COVID-19 of the India and Brazil for the period of 22nd January 2020 to 1st June 2020 were obtained from the World Health Organization (WHO) database. Pattern recognition of a data series paves the path for model selections. It gives an insight into the trends, seasonal variations, cyclical variations, and volatility within the precise period of time (Konarasinghe, 2020). Therefore, time series plots, Auto Correlation Functions (ACF), and Partial Auto Correlation Functions (PACF) were used for the aim, as done by Konarasinghe & Abeynayake (2014). Supported by the pattern recognition, the Auto-Regressive Integrated Moving Average (ARIMA) model, Autoregressive Distributed Lag Model (ADLM), Double Exponential Smoothing (DES)

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techniques, Liner trend model, Quadratic trend model, Growth Curve (GC) model, and Pearl - Reed Logistic model were tested to forecast the pandemic of India and Brazil. The Anderson Darling test, ACF, and Ljung-Box Q (LBQ)-test were used to test the validation criterion and fit the model. The forecasting ability of the models was assessed by three measurements of errors; Mean Absolute Percentage Error (MAPE), Mean Square Error (MSE), and Mean Absolute Deviation (MAD) in both model fitting and verification process, as per Konarasinghe, et al. (2015).

3.1 Trend analysis

Trend analysis fits a general trend model to time series data and provides forecasts. This study followed the procedure of Konarasinghe (2015) to choose among the Linear, Quadratic, Growth Curve or decay, and Pearl - Reed Logistic models. A formula of GC trend model is;

$$\ln Y_t = \alpha(\beta^t) + \varepsilon \tag{1}$$

3.2 Double Exponential Smoothing Model

Double Exponential Smoothing (DES) provides short-term forecasts. This technique works well when a trend is present, but it also is a general smoothing method (Konarasinghe, 2016). This method is found using two dynamic estimates, α and β; with values between 0 and 1 (Konarasinghe, 2016). They represent level and trend respectively. Formulae of DES technique (Holt' method) are;

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1}) \tag{2-1}$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1} \tag{2-2}$$

$$\hat{Y}_t = L_{t-1} + T_{t-1} \tag{2-3}$$

$$F_{t+m} = L_t + mT_t \tag{2-4}$$

Where,

L_t : is the level at the end of period t , α is the weight of level, T_t = is the estimated trend at the end of period t, β is the weight of trend, m = is the forecast horizon.

4. RESULTS

The analysis contains two main parts:

4.1 Pattern recognition and forecasting pandemic of India
4.2 Pattern recognition and forecasting pandemic of Brazil

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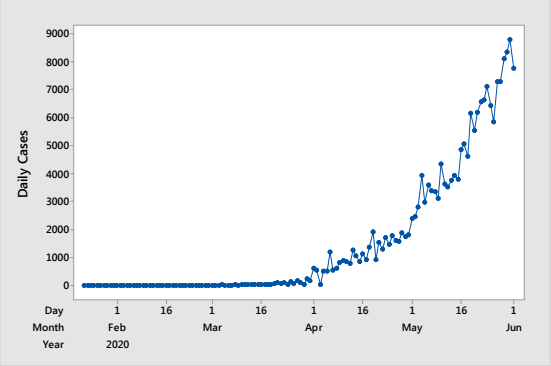
Log transformed data were used for the analysis. Initially, pattern recognition of the data series of India and Brazil was done, then ARIMA, ADLM, DES, Linear, Quadratic, Growth Curve, and Pearl - Reed Logistic models were tested for forecasting.

4.1 Pattern Recognition and Forecasting Pandemic of India

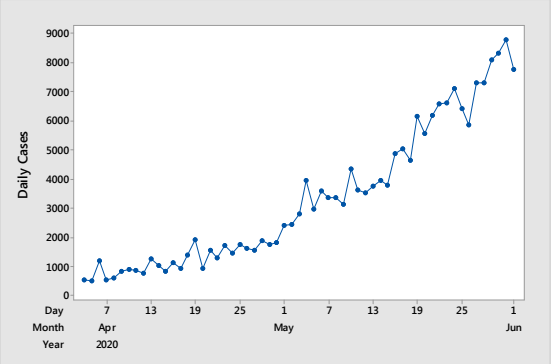
Time series plot of confirmed cases of India for the period of 22nd January 2020 to 1st June 2020 (Figure 1). The first confirmed case reported from India on 30th January 2020. The number of cases was low up to 4th April 2020 and shows a rapid climb afterward.

Figure 1: Time Series Plot of India



Hence, the data set for the period of 4th April to 1st June 2020 was used to forecast India.

Figure 2: Time Series Plot of Growth of India



The behavior of the daily confirmed cases for the chosen period was further examined. Figure 2 is that the time series plot of confirmed cases for the period of 4th April to 1st June 2020. There is a rapid climb with high irregular fluctuation from 4th April to 1st June 2020. The ACF and PACF of the series are shown in Figures 3 and 4;

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Figure 3: ACF of Daily Cases

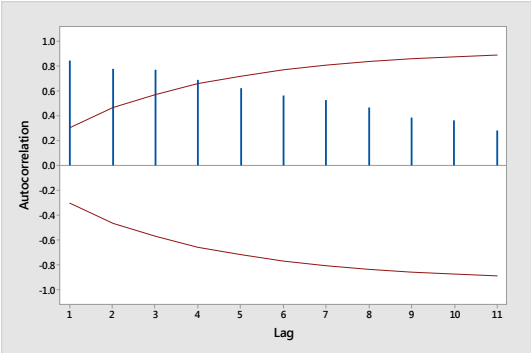
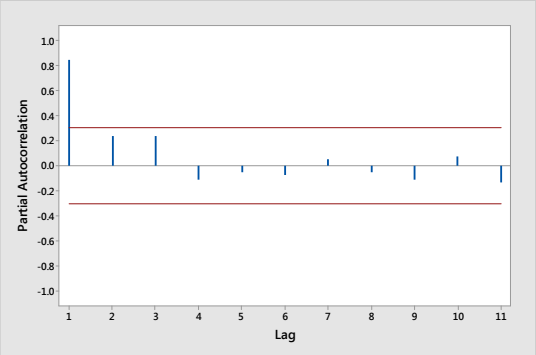


Figure 4: PACF of Daily Cases



The ACF has an exponential decline with four significant lags. The PACF has one significant spike. The series suggests the stationary criteria, and differenced series confirmed. Hence, the ARIMA was tested, but it has not satisfied the model validation criteria. The ADLM also was not successful. Then all four trend models namely; Liner, Quadratic, Growth Curve, and Pearl - Reed Logistic models were tested. Among them, the GC model is the only trend model that satisfied the model validation criterion. Finally, the DES was tested. The summaries of the GC and DES models are given in Table 1;

Table 1: Summary of Model Fittings and Verifications of Growth Curve and DES

Model	Model Fitting		Model Verification	
$\ln Y_t = 6.2991 + 0.05463t - 0.000114t^2$	MAPE	2.05421	MAPE	3.19180
	MAD	0.15039	MAD	0.28335
	MSE	0.03622	MSE	0.10311
	Normality	P = 0.108		
	Independence of Residuals	Yes		
α (level) 0.358 ϒ (trend) 0.160	MAPE	2.34969	MAPE	0.928224
	MAD	0.17143	MAD	0.081913
	MSE	0.04833	MSE	0.008988
	Normality	P=0.051		
	Independence of Residuals	Yes		

The Anderson Darling test confirmed the normality of residuals. The ACF of the residuals and LBQ test confirmed the independence of residuals of both models. The

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relative and absolute measurements of errors are very low under the fitting and verifications of DES than the GC model. Both models were satisfied with the model validation criterion, but the relative and absolute measurements of errors of DES were lower than the GC model. The actual fits, and forecast of GC and actual, fits, and forecast of DES are in Figures 5 and 6. Actual vs. Fits of DES are closer to each other than Actual vs. Fits of GC model.

Figure 5: Actual, Fits & Forecast of GC

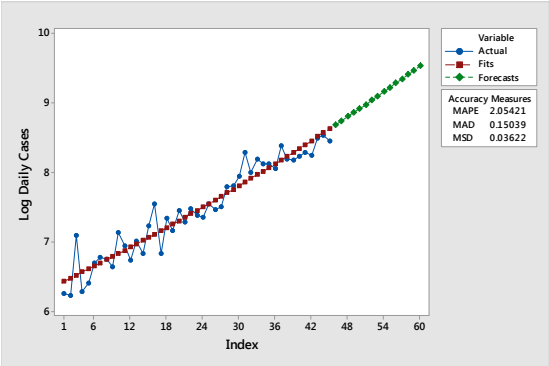
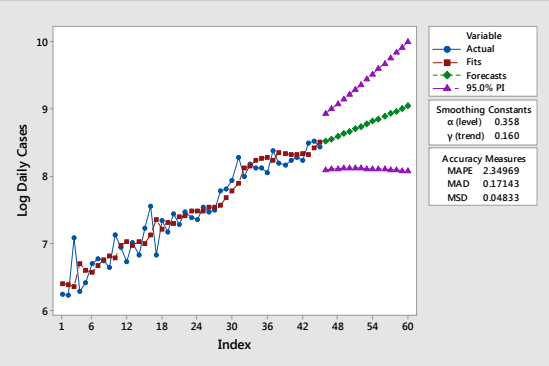


Figure 6: Actual, Fits & Forecast of DES

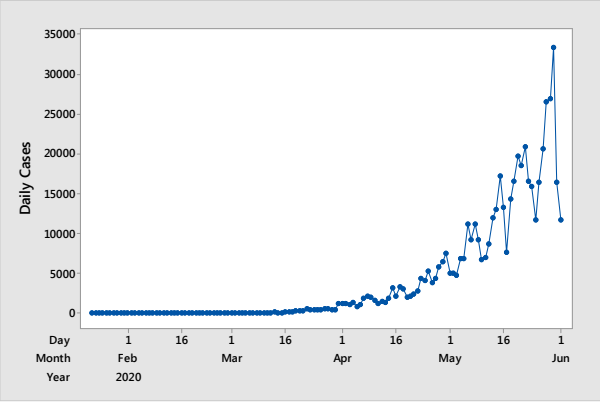


Hence, DES is the most suitable model to forecast COVID -19 of India.

4.2 Pattern Recognition and Forecasting Pandemic of Brazil

The pattern recognition of confirmed cases of Brazil was examined. The time series plot of confirmed cases was obtained for the period of 22nd January 2020 to 1st June 2020. Figure 7 is the time series plot of confirmed cases.

Figure 7: Time Series Plot of Brazil



The first confirmed case was reported on 26th February 2020. The number of cases was low up to 31st March and rapid climb afterward. Hence, the data set for the period of 31st March to 1st June 2020 used to forecast confirm cases of Brazil.

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Figure 8: Time Series Plot of Growth of Brazil

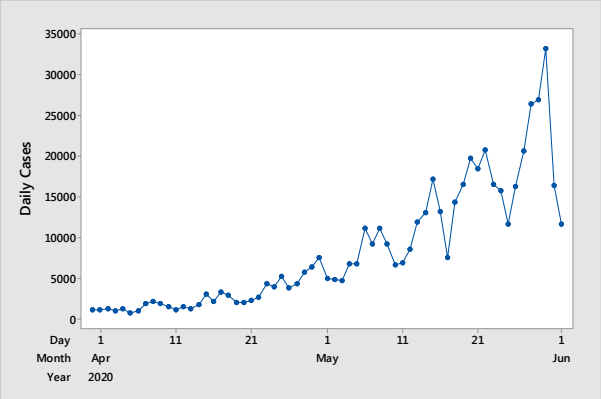


Figure 8 is the time series plot of daily confirmed cases for the period of 31st March to 1st June 2020. There is a rapid climb with a high irregular fluctuation of daily cases on 5th May 2020 afterward. The ACF and Partial Auto Correlation Function (PACF) of the series are shown in Figures 9 and 10.

Figure 9: ACF of Daily Cases

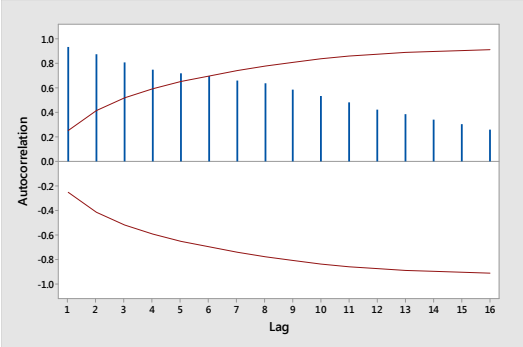
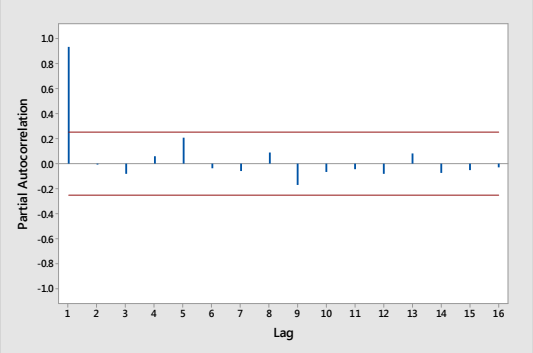


Figure 10: PACF of Daily Cases



The ACF has an exponential decline with five significant lags. The PACF has a single significant spike. The series does not confirm the stationary criteria; hence, the ADLM and ARIMA were not tested. Then all four trend models were tested, but they were not satisfied with the model validation criterion. The DES was tested with log-transformed data for different α and γ values. Model Summary in Table 2 shows the outputs at the best levels.

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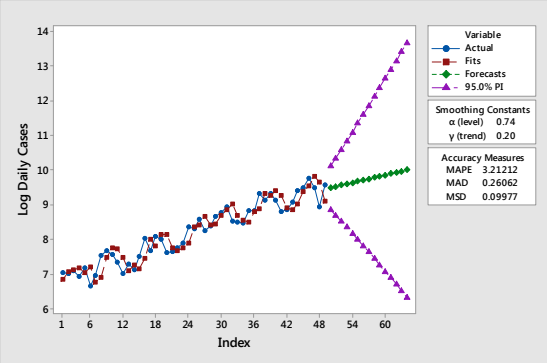
Table 2: Summary of Model Fittings and Verifications of DES

Model	Model Fitting		Model Verification	
α (level) 0.74 γ (trend) 0.20	MAPE	3.21212	MAPE	2.73726
	MAD	0.26062	MAD	0.26903
	MSE	0.09977	MSE	0.09947
	Normality	P= 0.799		
	Independence of Residuals	Yes		

Among all, the DES with $\alpha = 0.74$ and $\gamma = 0.20$ had the least relative and absolute measurement of errors during the model fitting and verifications. The residuals were normally distributed and independent. Figure 11 is the plot of actual, fits, and forecast of daily confirmed cases.

Figure 11: Actual, Fits and Forecast of Brazil



The fits and the forecast followed a similar pattern of actual confirm cases. The deviation between actual values fits, and the forecast is less. Therefore, the DES ($\alpha = 0.74$ and $\gamma = 0.20$) is the suitable model for forecasting infected cases of Brazil.

5. CONCLUSION AND RECOMMANDATION

It is concluded that DES is the best-suited model in forecasting pandemic in India and Brazil. The forecasting ability of DES was very high compared with the GC trend model.

The behaviors of the pandemic of India and Brazil have an upward trend. It's not favorable to the society and economy of both countries. The Authorities of Brazil and India should impose non-pharmaceutical practices, like personal protection, social distancing, and restrict movements of the overall public and monitor them strictly. They need to implement doorstep delivery systems of some essential services to attenuate movements. Authorities of India and Brazil should actively promote and monitor strictly

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the personal responsibility for slowing the spread of infection through proper hand hygiene, respiratory etiquette, and other personal hygiene in all settings and at all times. To defeat the epidemic, the utilization of disinfectant hand soaps and alcohol-based rubs should even be encouraged and make it compulsory in places occupied by the general public. It is important to increase the capacity and developing the potential for rapid viral diagnosis systems. The medical staff, health care officers, security providers, and other essential service providers need to use, proper protective equipment. The media of both countries need to play a key role to teach the general public on non-pharmaceutical and immunization practices to defeat the pandemic. Due to the absence of antiviral drugs for COVID-19, the effective implementation of immunization practices such as; consume suitable food and beverages (Natural Food), avoid bad habits like smoking and alcohol consumption, use warm water, steaming, etc. are important (Konarasinghe,2020). Authorities need to take steps to prepare a conducive environment to enhance immunization practices. They need to limit smoking, and alcohol consumption, artificial food, and beverages, etc. India features a rich culture of its indigenous medicine; hence there might be better practices to defeat pandemic situations. Medical authorities of both Western and Indigenous need to sit on one table and share their competencies and publish to the society would be one in all the most effective investments to the whole world. It is recommended to continue further studies as patterns of daily cases are under rapid change.

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