

A new forecast model for fluctuating Pattern of Covid-19 spread in South Asia

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Received: date / Accepted: date

Abstract Exponential growths are observed in several natural phenomena, including cosmological expansion of the universe, nuclear fission, population growth, global viral spread, and financial markets fluctuations. Several deterministic and stochastic methods have been used for the modeling of dynamics of these phenomena. Global reliable data are essential to parameterise a defined model so as to enhance confidence in model outputs. Four-parameter logistic model comes out to be best forecast model for the total Covid-19 infected people in Pakistan and India. Five-parameter logistic model is best forecast model for Bangladesh. Simulation results reveal that maximum total number of cases will be about 1.0, 0.6 and 0.25 million in India, Pakistan and Bangladesh respectively. Covid-19 infected rate will be closed to 11000, 8000 and 2000 cases per day during peak period in these countries.

Keywords Covid-19 · South Asia · Viral Spread · Four- and Five-parameter logistic models · Forecast Model

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Introduction

Exponential growths are observed in several natural phenomena, including, cosmological expansion of the universe, nuclear fission, population growth, global viral spread, and financial markets fluctuations. Several deterministic and stochastic methods have been used for the modeling of dynamics of these phenomena [1]. Global reliable data are essential to parameterise a defined model so as to enhance confidence in model outputs. World Health Organization has declared this virus as pandemic due to its very high rate of increase in the world [2]. So far more than 6.8 million people have been infected and almost 0.4 million people have died due to the infection. Covid-19 has also made impact on less developed countries of South Asia where about 25% people of world population live. As reliable real data are not available, therefore, global data are used to estimate model parameters [3]. An adequate model is important for health protection planning and economic activities decision making. Initial two cases in Pakistan was reported for the Covid-19 on 26th February, 2020, whereas, India reported the first case on 30th January 2020. The first three cases of Covid-19 were reported in Bangladesh on 7th March 2020. Bhutan and Maldives have very low cases of Covid-19 [4–10].

In general Susceptible, Infectious, Recovered (SIR) model, a Markov model, of the spread of an epidemic in a population is used to model the fluctuating pattern in the area under study [11]. An extended model is SEIR, which has been used by other researchers for this purpose. Time dependent SEIR model was also used for some region [12]. Some researcher used Bessel function to predict the cumulative confirmed cases (CCC) due to Covid-19 [13]. However, we tried family of logistic and Gompertz curves to model the fluctuating patterns of

Covid-19 in South Asia. In this paper, we are going to establish a reliable forecast model for Covid-19 infected people in South Asian region. Next section elaborates the methodology used in the paper. Section 3 describes the results obtained from the fitted models. Finally, the study concludes and discusses the future research direction.

Data and Methods

The data used for the current study is freely available from European Centre for Disease Prevention and Control, with the filename "Covid-19-geographic-distribution-worldwide.xlsx". In current study, we have used the country-wise temporal data of CCC, cases to obtain adequate forecast models, which will be helpful for the policy makers and health care service providers in combating the spread of this disease. Reproduction number, R_0 , is sensitive to initial values and is time dependent [14, 15]. As discussed in section 1, the initial data in developing countries are not available with high accuracy because the number and quality of infection test centers are limited. Therefore, the values used by researchers in these countries are average of global R_0 . That is why the forecast obtained by SIR, SEIR, or other related models are either over or under estimated. We use the family of logistic and Gompertz functions to obtain forecast models.

Logistic and Gompertz differential equation models have been used to capture the fluctuating patterns of covid-19 in Iran [16].

Logistic Differential Equation:

$$\frac{dP(t)}{Pt} = aP(1 - bP) \quad (1)$$

Gompertz Differential Equation:

$$\frac{dP(t)}{Pt} = aP \ln\left(\frac{1}{bP}\right) \quad (2)$$

Where $P(t)$ represents the CCC of Covid-19 in the country.

Family of logistic and Gompertz models also seem to be appropriate for an accurate prediction of virus infected people [17–20].

Logistic model:

$$y(t) = \frac{a}{1 - e^{(b-ct)}} \quad (3)$$

4-parameter logistic model:

$$y(t) = a + \frac{d}{\left(1 - e^{\left(\frac{b-t}{c}\right)}\right)} \quad (4)$$

5-parameter logistic model:

$$y(t) = a + \frac{d}{\left(1 - e^{\left(\frac{b-t}{c}\right)^g}\right)} \quad (5)$$

Gompertz model:

$$y(t) = a \left(e^{-be^{(-ct)}} \right) \quad (6)$$

In models 3 to 6, $y(t)$ represents cumulative confirmed cases of infected people at time t . Parameters a , b , c , d , and g represent the insights of the fluctuating pattern of virus spread phenomenon. Next section explains the parameters estimation procedure.

Results and Discussions

As government officials in South Asia have started putting serious efforts towards data collection two months back due to shortage of testing kits, medical supplies, and personal protective equipment therefore, data for analysis were taken from April 01, 2020. For the estimation of model parameters Mathematica command, *NonlinearModelFit*, was used, which produced the model parameters using quasi-Newton method [21]. Estimation results produced the following forecast models for three thickly populated countries, Pakistan, India, and Bangladesh, of this region. Nepal, Srilanka, Bhotan, and Maldives, so far, have been following about linear models with respect to increase in cumulative infected people in these countries

Forecast model for Covid-19 infected people in Pakistan:

$$y(t) = 770361.698 - \frac{771456.671}{1 + e^{-0.058(95.240-t)}} \quad ;$$

$$R^2 = 0.9997$$

Forecast model for India:

$$y(t) = -5938.738 + \frac{511953.107}{1 + e^{0.060(71.105-t)}} \quad ;$$

$$R^2 = 0.9999$$

Forecast model for Bangladesh:

$$y(t) = -738.12 + \frac{226534.82}{\left(1 + e^{0.023(-65.23-t)}\right)^{32.04}} \quad ;$$

$$R^2 = 0.9998$$

Use of above models will provide information in time to the public for any pandemic situation. It will also help the authorities in these countries to help improve the health care facilities to combat Covid-19 spread. Figure 1 shows that highest total infected people in India and lowest in Bhutan. Figures 2 and 3 reveal the maximum total deaths and infection rate are in India whereas, it is minimum in Bhutan (almost zero). It is not mentioned in the graph. Second lowest rate is for Sri Lanka.

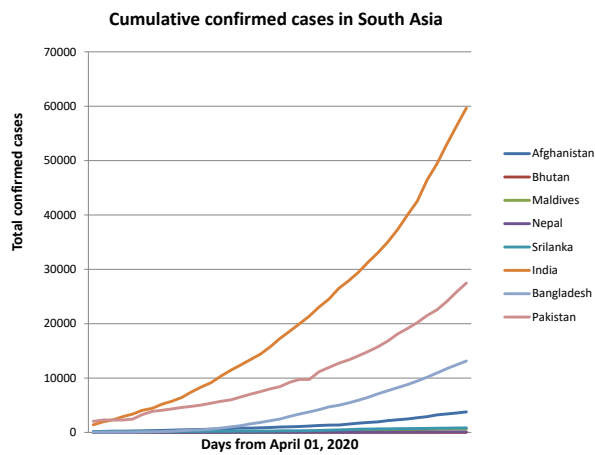


Fig. 1 Covid-19 cumulative cases from April 01 to May 09, 2020 in South Asian countries.

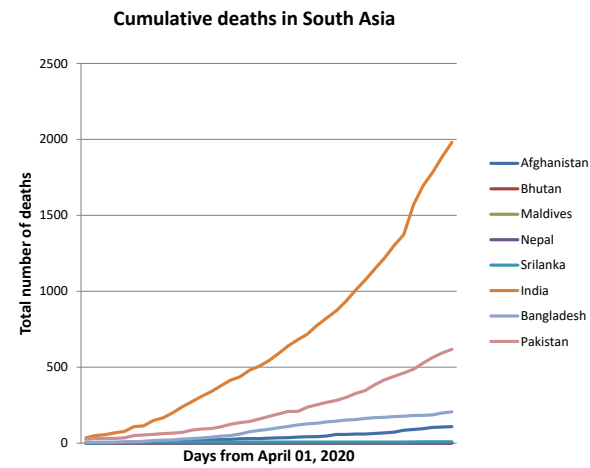


Fig. 2 Covid -19 cumulative death cases from April 01 to May 09, 2020 in the region.

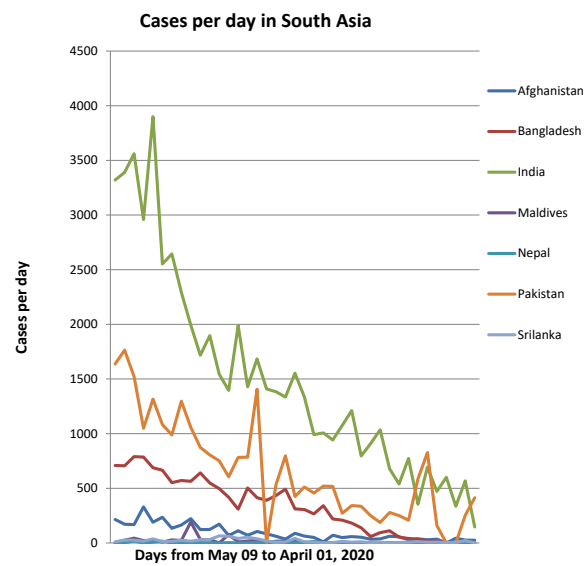


Fig. 3 Covid -19 per day cases from May 09, 2020 to April 01 in South Asia region.

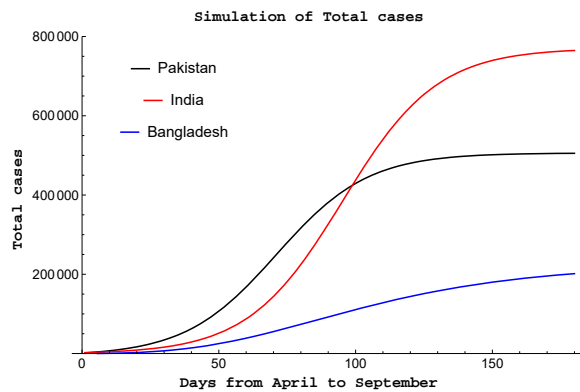


Fig. 4 Simulation of total number of infected people from April to September in South Asia.

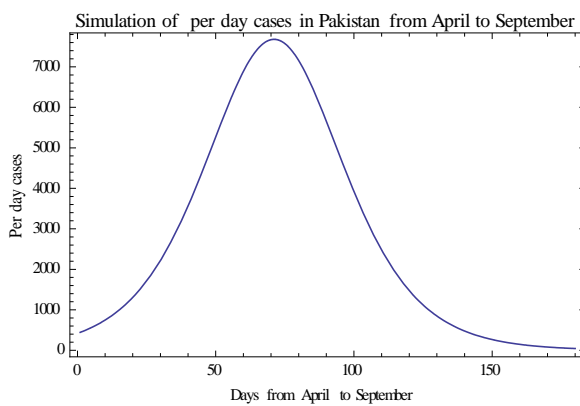


Fig. 5 Simulation of per day infected people in Pakistan from April to September.

Simulation of above models are depicted in Figure 4 that the peak of total infected people in India, Pakistan, and Bangladesh will appear in July or August, 2020. Maximum total number of cases will be about 1.0, 0.6 and 0.25 million in India, Pakistan and Bangladesh respectively. Figures 5-7 depict the Covid-19 infected rate will be closed to 8000, 11000 and 2000 cases per day during peak period in Pakistan, India and Bangladesh respectively. These graphs will help to understand the three-month projection of the evolution of the epidemic curve.

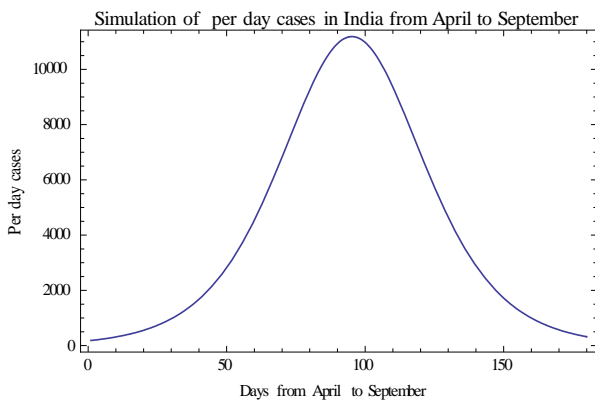


Fig. 6 Simulation of per day infected people in India from April to September.

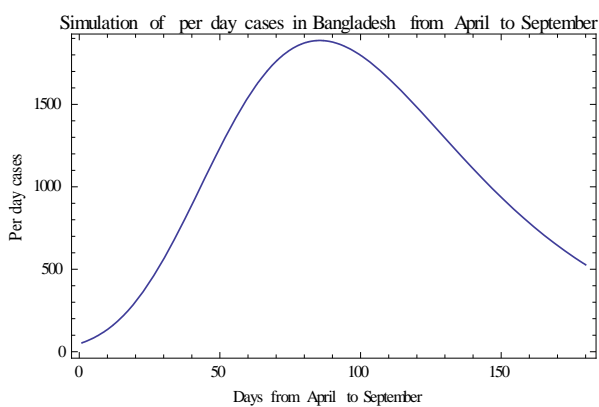


Fig. 7 Simulation of per day infected people in Bangladesh from April to September.

Conclusion

We studied the recent spread of Covid-19 in South Asian countries and estimated important parameters of its dynamics. We projected the cumulative incidences in three countries of the region. Simulation of developed models show occurrence of Maximum increasing rate would be about 2000, 8000 and 11000 cases per day during peak period in these countries. Death rate is highest in India (2.87%) and lowest (almost zero %) in Bhutan. Countries in the region support the WHO recommendations to “push down the epidemic curve.

Most of the countries are now lifting lockdowns, which may be very risky for the war against Covid-19. The current situation accentuates the need for more clinical investigation so as to prevent human beings from incalculable loss from Covid-19 spread. Government officials in the region have already directed the health care authorities to prepare awareness campaign among people about the symptoms and prevention of Covid-19. So, its analysis is extremely important as it is highly probable that it will reappear in near future with

more damaging effects. To cover this scenario, our next paper will be prepared with title “World with Covid-19 one year after.

Acknowledgements The authors would like to thank European Centre for Disease Prevention and Control, for the online data availability of “Covid-19-geographic-distribution-worldwide.xlsx.

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