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VARIATION IN GROWTH FACTOR OF COVID-19 IN INDIA AND ITS TIMING TO APPROACH ZERO

Statistics

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ABSTRACT

COVID-19 is one of the most dreadful diseases that world has ever faced. India is also fighting efficiently against COVID-19 and facing greater challenges because of its large population and high population density. Though the government of India is taking all needful steps to prevent its spread but it is not enough to control and stop spread of the disease as of now (July, 2020), perhaps due to defiant nature of people living in India. They are not following properly, the request made by Prime Minister during the lock down period or free period. Effective measure to control this disease, medical professionals needs to know the estimated size of this pandemic and pace. In this study Logistic growth model proves its significance and enable to estimate the size and pace. It shows the behavior of growth factor converging towards the zero. On the basis of data on COVID-19 from mid march to mid July and trend of growth factor obtained by logistic curve, it has been observed that by the mid of October, the growth factor expected to reach zero i.e. no increase in COVID-19 thereafter if the present scenario remains same.

KEYWORDS

INTRODUCTION

The COVID-19 had its outbreak initially in Wuhan city of China, a deadly disease beginning at the end of 2019, becomes most devastating event in the modern world. It is an infectious disease caused by a new kind of virus causes severe respiratory illness. This virus spreads primarily through contact with an infected person mainly when they sneeze. With the rapid spread of this virus, World Health Organization has declared it as a pandemic in February 2020. Government of every country is taking various measures for prevention of spread of this disease, on the other hand scientists and experts are trying hard to develop a vaccine and also to find an effective medicine for its proper cure. It causes a serious threat to the well-being of human and also to the economy of the world. Government needs specific and precise estimates to enable the program to prevent the spread of COVID-19 as efficiently as possible. As of July 16, 2020, with the continuously increasing global risk more than 14 million confirm positive cases and more than 0.58 millions of deaths have occurred in the world. The picture of India is not so good and has more than 1 millions confirm positive cases and more than 26 thousand of deaths. Although the death rate of this pandemic is low in comparison of other pandemics and diseases but its high rate of spread and no proper cure available so far is the major concern in the present time. Right now in India only 29 districts out of 739 districts have COVID-19 case more than 4000. These districts are mainly metropolitans; if we implement preventive measures properly then spread can be under control at desired level, but due to defiant nature of people living in India, political desire and rivalry, still we India society are facing problem made by COVID-19 .

As number of cases growing day by day, in most of the countries of the world, some most populous countries like China, India, Brazil, USA, etc are badly affected by it. In this context, the crucial role of modeling, transmission dynamics and estimating development of COVID-19 are expected. The population based mathematical model especially growth model in this scenario are the most preferable techniques to understand the epidemic future trajectory. Epidemiological characteristics like propagating dynamics, severity, susceptibility, and the effects of control measures, for COVID-19 has produced a greater concern for researchers (Cowling et al., 2020; Lipsitch et al., 2020).

Since preventive measures like lock down and social distancing have immense pressure on economy of the country, quantitative estimates and predictions are necessary to learn the impact of spread that will help in plan the strategies against COVID-19. Given the paucity of such quantitative measures, the predictions on the basis of different idea given in this paper become critical and to know when the COVID-19 stops. Previous work for prediction of the spread of COVID-19 has been done using many different machines learning algorithms, including neural networks for deep learning, joinpoint regression, polynomial fitting, exponential smoothing and ARIMA (Chaurasia & Singh, 2020; Swain et al., 2020). In recent past a number of studies with various technique and tools have been carry out to understand the dynamics of propagation of disease and future course of action. For COVID 19, various models which are capable of providing worth insights for health care policy making are being continuously developed and used to explain this pandemic retrospectively as well as to project the events (Batista, 2020; Koo et al. 2020; Kucharski et al. 2020; Tuite et al. 2020 and Wu et al. 2020).

Wu et al. (2020) has been done to analyzing the pace of virus transmissibility through estimating the value of R_0 with the help of stochastic Markov Chain Monte Carlo method. Another analysis with mathematical incidence decay and exponential adjustment is performed (Majumdar & Mandl, 2020). Further to explain growth behavior of Corona virus a statistical exponential growth model adopting the serial interval from Severe Acute Respiratory Syndrome is applied by Zhao et al. 2020. A three-parameter logistic growth function is applied and predicted for China as well as some other countries is found very satisfying (Shen, 2020). In the context of India, an early study of COVID-19 (when it started spreading in India) done by Singh and Adhikari (2020) rightly believed that countrywide lockdown on March 24 for 21 days may be insufficient for controlling the COVID-19 pandemic. Malhotra et al. (2020) tried to forecast the endpoints to explain the progression of COVID-19 in Indian States, using SIR and Logistic Growth Models and found the endpoint of COVID-19 in India is in 23 July, 2020. Singh (2020) found exponential model is suitable in the initial phase however, logistic curve under log transformation is provided encouraging estimate for the future pandemic, also significant effect of lockdown on spread of COVID-19 has been found.

Data and Method

Exponential curve fit the epidemic at the beginning but the logistic growth curve is S-type curve and has two asymptotes therefore it explains better an epidemic than exponential curve. We know that at some point, recovered people will not spread the virus anymore and when someone is or has been infected, the growth will stop. Logistic Growth is characterized by increasing growth in the beginning period, but a decreasing growth after point of inflexion. For example in the COVID-19 case, the maximum limit would be the total number of exposed people in India because when everybody is infected, the growth will be stopped. After that the increasing rate of curve starts to decline and reach to the minimum. In exponential growth curve, the rate of growth of y per unit of time is directly proportional to y but in practice the rate of growth cannot be in the same proportion always. The logistic curve will continue up to certain level, called the level of saturation, sometimes called the carrying capacity, after reaching carrying capacity it starts declining. A system far below its carrying capacity will at first grow almost exponentially however, this growth gradually slows as the system expands, finally bringing it to a halt specifically at the carrying capacity. This phenomenon is taken care by logistic growth model which is given by Verhulst (1838). When the population of y reaches k, this leads to slow of rate of growth to zero, which is similar to symmetrical S-shaped curve. A particular form of symmetric Logistic curve, also known as Pearl-Reed curve is given by

$$y_t = \frac{k}{1+e^{a+bt}}; \qquad b<0$$

Where b is the growth factor, which decide the growth of a disease, a is the location parameter and k is carrying capacity. The curve consists of a point of inflexion at half of the carrying capacity k. It is worthwhile to mention here that in the logistic curve b should be negative. This study is based on the data taken from the website www.covid19india.org. It is used as series of the cumulative number of daily Corona positive cases from March 14, 2020 to July 16, 2020. Logistic curve is applied on the data to check the dynamics of growth factor. A fortnight data with a gap of two days is taken for the study. Here we use method of three selected points to estimate the value growth factor (given in Table 1).

Further, the growth factor have been analyzed and found its pattern follows logarithmic function which is given bellow

$$Growth\,Factor = [0.059 \times Ln(time\,segment)] - 0.27$$

The model summary and analysis of variance tables are reveals that the logarithmic model is a suitable model for prediction of the pattern of growth factor in India. Analysis of variance table shows that the model is significant, the F value is very high and p value is 0.000. The value of adjusted R^2 is 0.83 that is quite satisfactory. This means the natural log of time segment has 83 percent capacity to explain growth factor (b). Also the estimate of coefficient of natural log of time segment is statistically significant indicates the idea of predicting growth factor (b) with logarithmic model is appropriate.

Table 1: Growth Factor (*b*) of different Segment in India

S. No.	Time Segment		Growth Factor	S. No.	Time Segment		Growth Factor
	From	To	(*b*)		From	To	(*b*)
1	14-Mar-20	28-Mar-20	-0.21877	29	09-May-20	23-May-20	-0.05055
2	16-Mar-20	30-Mar-20	-0.22928	30	11-May-20	25-May-20	-0.04359
3	18-Mar-20	01-Apr-20	-0.20412	31	13-May-20	27-May-20	-0.05856
4	20-Mar-20	03-Apr-20	-0.17664	32	15-May-20	29-May-20	-0.06832
5	22-Mar-20	05-Apr-20	-0.13119	33	17-May-20	31-May-20	-0.07045
6	24-Mar-20	07-Apr-20	-0.14257	34	19-May-20	02-Jun-20	-0.06101
7	26-Mar-20	09-Apr-20	-0.20022	35	21-May-20	04-Jun-20	-0.05532
8	28-Mar-20	11-Apr-20	-0.21719	36	23-May-20	06-Jun-20	-0.05423
9	30-Mar-20	13-Apr-20	-0.22388	37	25-May-20	08-Jun-20	-0.05301
10	01-Apr-20	15-Apr-20	-0.18249	38	27-May-20	10-Jun-20	-0.0597
11	03-Apr-20	17-Apr-20	-0.16045	39	29-May-20	12-Jun-20	-0.06021
12	05-Apr-20	19-Apr-20	-0.12793	40	31-May-20	14-Jun-20	-0.06217
13	07-Apr-20	21-Apr-20	-0.14079	41	02-Jun-20	16-Jun-20	-0.0584
14	09-Apr-20	23-Apr-20	-0.12445	42	04-Jun-20	18-Jun-20	-0.05337
15	11-Apr-20	25-Apr-20	-0.1088	43	06-Jun-20	20-Jun-20	-0.04708
16	13-Apr-20	27-Apr-20	-0.10523	44	08-Jun-20	22-Jun-20	-0.03858
17	15-Apr-20	29-Apr-20	-0.1031	45	10-Jun-20	24-Jun-20	-0.03166
18	17-Apr-20	01-May-20	-0.10219	46	12-Jun-20	26-Jun-20	-0.03176
19	19-Apr-20	03-May-20	-0.08056	47	14-Jun-20	28-Jun-20	-0.03365
20	21-Apr-20	05-May-20	-0.06148	48	16-Jun-20	30-Jun-20	-0.03753
21	23-Apr-20	07-May-20	-0.04249	49	18-Jun-20	02-Jul-20	-0.04101
22	25-Apr-20	09-May-20	-0.04869	50	20-Jun-20	04-Jul-20	-0.04142
23	27-Apr-20	11-May-20	-0.07378	51	22-Jun-20	06-Jul-20	-0.04393
24	29-Apr-20	13-May-20	-0.09015	52	24-Jun-20	08-Jul-20	-0.03884
25	01-May-20	15-May-20	-0.09722	53	26-Jun-20	10-Jul-20	-0.0389
26	03-May-20	17-May-20	-0.09271	54	28-Jun-20	12-Jul-20	-0.03865
27	05-May-20	19-May-20	-0.07334	55	30-Jun-20	14-Jul-20	-0.03754
28	07-May-20	21-May-20	-0.05699	56	02-Jul-20	16-Jul-20	-0.03476

Model Summary

R	R^2	Adjusted R^2	SE of the Estimate
0.912	0.833	0.830	0.024

Analysis of Variance

Source	Sum of Squares	Degree of freedom	Mean Square	F	p value
Regression	0.155	1	0.155	268.605	0.000
Error	0.031	54	0.001		
Total	0.186	55			

Coefficients

Character	Coefficients	SE	$\|t\|$	p value
ln(time)	0.059	0.004	16.389	0.000
Constant	-0.270	0.012	23.399	0.000

RESULTS AND DISCUSSION

In the table 1, we have growth factor (b) estimated using logistic curve for the different segment of time. Fifteen days data with a gap of two days have been used to estimate growth factor (b), thus a total of 56 different growth factors (b) are used for understating the pattern and prediction of growth factor. Table 1 clearly shown than first growth factor initially increasing some days after 14 March, 2020 but from the end of March it is decreasing up to first week of April. This is the time of tablighi issue; perhaps this may be the possible reason for this decrease in growth factor. It is worthwhile mention here that for lower value of growth factor, the spread will faster and vice versa. During the second week of April through last week of April, we found steady increase in the growth factor but a slight decrease has been observed from 27 April, 2020 to 5 May, 2020. This time migrant laborers are forced to move their own home town, the reason of their movement is not known, but people can move only in the situation from the destination places, if they faces lot of problem like food, electricity and security etc. This politically induced disturbance again mitigated the faster growth of COVID-19. If these two down falls were not present in the data, India must have achieved asymptotic population of COVID-19 positive cases earlier.

In the present study, growth factor of logistic curve has been preferred to use rather than an empirical, descriptive or data motivated characteristics under certain assumptions. This approach of growth function of logistic curve displays probable behavior of reaching toward the asymptote i.e. x-axis and value tends to zero. When it reaches zero the model becomes constant and hence there will be no new cases further. In the given figure we can observe that growth factor (b) is approaching to zero and it seems to be asymptotic to x-axis in near future. Table 2 provides the observed value of growth factor (b), predicted growth factor using logarithmic model and 95 percent confidence interval. The mean square error is 0.00056 and correlation between observed and predicted is 0.91. The predicted value is almost equal to zero for the 97th time segment and become positive for the 98th segment, but b should negative. This indicates that by the mid October the spread become constant and no new COVID-19 case further provided the present scenario remains same and all preventive measures will take place effectively. Figure 1 shows the trends of the estimated values along with confidence intervals for easy understanding.

Table 2: Prediction of Growth Factor (*b*) and Confidence Interval for Various Time Segments

S. No.	Growth Factor (*b*)	Predicted	95% Confidence Limit		S. No.	Growth Factor (*b*)	Predicted	95% Confidence Limit	
			Lower	Upper				Lower	Upper
1	-0.21877	-0.27000	-0.28269	-0.25731	50	-0.04142	-0.03919	-0.04989	-0.02849
2	-0.22928	-0.22910	-0.24145	-0.21676	51	-0.04393	-0.03802	-0.04904	-0.02700
3	-0.20412	-0.20518	-0.21719	-0.19317	52	-0.03884	-0.03688	-0.04822	-0.02553
4	-0.17664	-0.18821	-0.19988	-0.17653	53	-0.03890	-0.03575	-0.04743	-0.02408
5	-0.13119	-0.17504	-0.18639	-0.16370	54	-0.03865	-0.03465	-0.04666	-0.02264
6	-0.14257	-0.16429	-0.17531	-0.15327	55	-0.03754	-0.03357	-0.04592	-0.02122
7	-0.20022	-0.15519	-0.16589	-0.14449	56	-0.03476	-0.03250	-0.04519	-0.01981
8	-0.21719	-0.14731	-0.15770	-0.13693	57		-0.03146	-0.04449	-0.01843
9	-0.22388	-0.14036	-0.15044	-0.13029	58		-0.03043	-0.04382	-0.01705
10	-0.18249	-0.13415	-0.14392	-0.12437	59		-0.02943	-0.04316	-0.01569
11	-0.16045	-0.12852	-0.13800	-0.11905	60		-0.02843	-0.04252	-0.01435
12	-0.12793	-0.12339	-0.13258	-0.11420	61		-0.02746	-0.04190	-0.01302
13	-0.14079	-0.11867	-0.12758	-0.10976	62		-0.02650	-0.04130	-0.01170
14	-0.12445	-0.11430	-0.12293	-0.10566	63		-0.02556	-0.04071	-0.01040
15	-0.1088	-0.11023	-0.11860	-0.10185	64		-0.02463	-0.04014	-0.00911
16	-0.10523	-0.10642	-0.11455	-0.09829	65		-0.02371	-0.03959	-0.00783
17	-0.1031	-0.10284	-0.11073	-0.09495	66		-0.02281	-0.03906	-0.00657
18	-0.10219	-0.09947	-0.10714	-0.09180	67		-0.02192	-0.03853	-0.00531
19	-0.08056	-0.09628	-0.10374	-0.08882	68		-0.02105	-0.03803	-0.00407
20	-0.06148	-0.09325	-0.10052	-0.08599	69		-0.02019	-0.03753	-0.00284
21	-0.04249	-0.09037	-0.09746	-0.08328	70		-0.01934	-0.03706	-0.00162
22	-0.04869	-0.08763	-0.09456	-0.08070	71		-0.0185	-0.03659	-0.00041
23	-0.07378	-0.08501	-0.09180	-0.07821	72		-0.01768	-0.03614	0.00078
24	-0.09015	-0.08249	-0.08917	-0.07582	73		-0.01686	-0.03570	0.00197
25	-0.09722	-0.08009	-0.08667	-0.07351	74		-0.01606	-0.03527	0.00315
26	-0.09271	-0.07777	-0.08428	-0.07127	75		-0.01527	-0.03485	0.00432
27	-0.07334	-0.07555	-0.08200	-0.06909	76		-0.01449	-0.03445	0.00547
28	-0.05699	-0.07340	-0.07983	-0.06697	77		-0.01372	-0.03405	0.00662
29	-0.05055	-0.07133	-0.07776	-0.06490	78		-0.01295	-0.03367	0.00776
30	-0.04359	-0.06933	-0.07579	-0.06287	79		-0.01220	-0.03330	0.00889
31	-0.05856	-0.06739	-0.07390	-0.06089	80		-0.01146	-0.03293	0.01001
32	-0.06832	-0.06552	-0.07210	-0.05894	81		-0.01073	-0.03258	0.01112
33	-0.07045	-0.06371	-0.07038	-0.05703	82		-0.01000	-0.03224	0.01223
34	-0.06101	-0.06194	-0.06874	-0.05515	83		-0.00929	-0.03190	0.01333
35	-0.05532	-0.06023	-0.06716	-0.05330	84		-0.00858	-0.03158	0.01441
36	-0.05423	-0.05857	-0.06566	-0.05148	85		-0.00788	-0.03126	0.01549
37	-0.05301	-0.05696	-0.06422	-0.04969	86		-0.00719	-0.03095	0.01657
38	-0.0597	-0.05538	-0.06284	-0.04792	87		-0.00651	-0.03066	0.01763
39	-0.06021	-0.05385	-0.06152	-0.04618	88		-0.00584	-0.03036	0.01869
40	-0.06217	-0.05236	-0.06025	-0.04446	89		-0.00517	-0.03008	0.01974
41	-0.0584	-0.05090	-0.05903	-0.04277	90		-0.00451	-0.02981	0.02079
42	-0.05337	-0.04948	-0.05786	-0.04110	91		-0.00386	-0.02954	0.02182
43	-0.04708	-0.04809	-0.05673	-0.03945	92		-0.00321	-0.02928	0.02285
44	-0.03858	-0.04673	-0.05564	-0.03782	93		-0.00258	-0.02903	0.02388
45	-0.03166	-0.04541	-0.05460	-0.03622	94		-0.00195	-0.02878	0.02489
46	-0.03176	-0.04411	-0.05359	-0.03463	95		-0.00132	-0.02855	0.02590
47	-0.03365	-0.04284	-0.05261	-0.03307	96		-0.00070	-0.02831	0.02691
48	-0.03753	-0.04160	-0.05167	-0.03152	97		-9.2E-05	-0.02809	0.02791
49	-0.04101	-0.04038	-0.05077	-0.03000	98		**0.000513**	**-0.02787**	**0.02890**

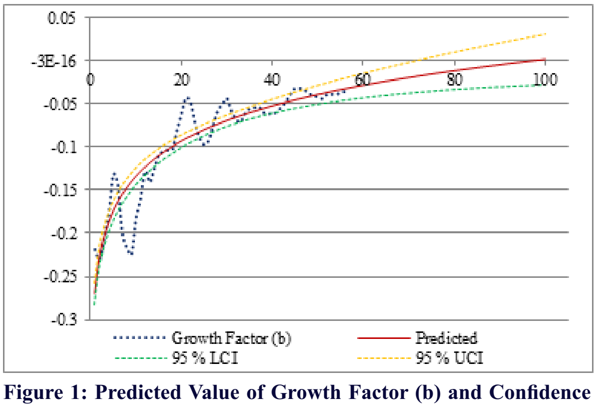

Figure 1: Predicted Value of Growth Factor (b) and Confidence Interval

CONCLUSION

At present, COVID-19 is a serious disaster concern for the outbreak situation for our society. The virus is spreading in a huge number of populations as well. However, considering the huge population of India, the limited resources are not enough to face this outbreak. For this reason, it is most important to know when the effect of COVID-19 is going to start decline and its effect will be negligible. In this context, this study tries to propose a model for the prediction of the expected time when its effect will be negligible. To know the nature of graph of the study, end time of spreading corona virus, Indian people should follow WHO guidelines and maintaining social distancing, mask use as well as hand wash after sometimes. People should have the responsibility to make their home as a quarantine place that could decrease spreading the virus rapidly. This strategy can control faster from spreading the virus and protect human being. This study can help health professionals and policy maker to make appropriate policy. Finally, it should be accepted that the above findings are a data based observations of the COVID-19 pandemic and the estimates are calculated from a mathematical model. If several protective measures will not be taken, then this rate may be changed. However, the government of India has already taken various protective measures such as lockdown in several areas, make possible quarantine facility to reduce the rate of COVID-19, thus we may hopefully conclude that, India will be successful to reduce the risk of this pandemic.

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