



ANALYSING THE CORONAVIRUS EPIDEMIC IN INDIA: EXPONENTIAL VS LOGISTIC GROWTH

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Abstract: This study analyses the propagation of the coronavirus epidemic in India. The variables considered were the daily number of new cases of infection by the Covid-19 virus, the cumulative number of cases of infection, the daily number of deaths due to the infection, and the cumulative number of deaths. The study period considered was 01/03/2020 to 11/04/2020. The propagation of the coronavirus was analysed to determine whether it is exponential or logistic in nature. Also, the impact of measures taken by the government such as the lockdown on the propagation rate was analysed. The key results of the study were that the propagation of the coronavirus was logistic in nature and that there was an increase in the peak propagation rate and the limiting level of cumulative cases after 1st April, 2020. The latter result suggests that the restrictions imposed by the government in mid-March 2020 were ineffective, and strict lockdown should have been imposed in early March 2020.

Keywords: exponential, logistic, peak propagation rate, limiting level of cumulative cases.

Introduction

The coronavirus epidemic has swept across the world at an unbelievable rate. It purportedly originated in the city of Wuhan, Hubei Province in mid-November 2019 and spread quickly within Wuhan and around the Province. By the time the Chinese National Health Commission reported the matter to the World Health Organisation (WHO) on 31st December, 2019, the cumulative number of cases had already reached 266, and by the time the Chinese imposed lockdown in Wuhan city and Hubei Province on 23rd January, 2020, it had reached 830. In the intervening period, the virus was inadvertently carried to every corner of the world by travellers - including students, businessmen, and tourists - and started spreading quickly thereafter.

By 5th January, 2020, the WHO issued a preliminary report on the coronavirus outbreak in Wuhan, and by 10th January, 2020, they issued their first guidance on the novel coronavirus, urging countries to strengthen their capabilities to deal with a potential coronavirus pandemic. On 13th January, 2020, they confirmed the first case of the novel coronavirus outside China, and they called for active monitoring and preparedness in other countries. They finally declared the novel coronavirus (Covid-19) outbreak to be a Public Health Emergency of International Concern on 30th January, 2020, but by that time it had already infected 9,823 people worldwide. By 5th February, 2020, they released a US\$675 million Strategic Preparedness and Response Plan¹ aiming to protect states with weaker health systems. Only by 8th March, 2020, did they release a

¹ <https://www.who.int/docs/default-source/coronaviruse/srp-04022020.pdf>



guidance on critical preparedness, readiness, and response actions².

The first case of Covid-19 in India was reported on 30th January, 2020, but the cumulative number of cases in India remained under control until March 2020. The escalation of cases started from 4th March, 2020, brought in by foreign tourists and Indians who had travelled to some of the affected countries. The initial response, in the last week of January 2020, was thermal scanning of travellers arriving from known Covid-19 affected countries. This approach was clearly insufficient, as many travellers from non-Covid-19 affected countries were found to have carried the virus; also many critics warned that such thermal screening would not be able to detect asymptomatic, infectious persons. Only by mid-March 2020 did the central government draw up a plans to deal with the spreading pandemic, setting up additional quarantine and treatment facilities across the country. The central government also issued an advisory for social distancing measures to reduce the spread. Restrictions were imposed for travellers from abroad by mid-March 2020, including frequent health check-ups and a 14-day quarantine; however, there were many reports of violations of these restrictions. Also by mid-March, many states ordered educational institutions to close down and asked companies to facilitate work-from-home wherever possible. Inter-state travel and transportation was also restricted. Finally, the central government imposed a total lockdown (except for essential services) from 25th March, 2020 to 15th April, 2020, to reduce the spread of the coronavirus. This was further extended to 3rd May, 2020 on 14th April, 2020.

Methodology

The objective of the study was to analyse the propagation of the coronavirus in India. The variables considered for the study were the daily number of new cases of infection

by the Covid-19 virus, the cumulative number of cases of infection, the daily number of deaths due to the infection, and the cumulative number of deaths. The study period considered was 01/03/2020 to 11/04/2020. The data for the study was collected from the Worldometer website³. The data is presented in the table and figures below.

Date	New Cases	Cumulative Cases	Deaths	Cumulative Deaths
01-03-2020	0	3	0	0
02-03-2020	3	6	0	0
03-03-2020	1	7	0	0
04-03-2020	22	29	0	0
05-03-2020	1	30	0	0
06-03-2020	1	31	0	0
07-03-2020	3	34	0	0
08-03-2020	6	40	0	0
09-03-2020	7	47	0	0
10-03-2020	15	62	0	0
11-03-2020	0	62	0	0
12-03-2020	12	74	1	1
13-03-2020	8	82	1	2
14-03-2020	18	100	0	2
15-03-2020	14	114	0	2
16-03-2020	15	129	0	2
17-03-2020	14	143	1	3
18-03-2020	26	169	0	3
19-03-2020	25	194	1	4
20-03-2020	55	249	1	5
21-03-2020	83	332	0	5
22-03-2020	64	396	2	7
23-03-2020	103	499	3	10
24-03-2020	37	536	0	10
25-03-2020	121	657	2	12
26-03-2020	70	727	8	20
27-03-2020	160	887	0	20
28-03-2020	100	987	4	24
29-03-2020	37	1024	3	27
30-03-2020	227	1251	5	32
31-03-2020	146	1397	3	35
01-04-2020	601	1998	23	58
02-04-2020	545	2543	14	72
03-04-2020	516	3059	14	86
04-04-2020	529	3588	13	99
05-04-2020	701	4289	19	118

² <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance>

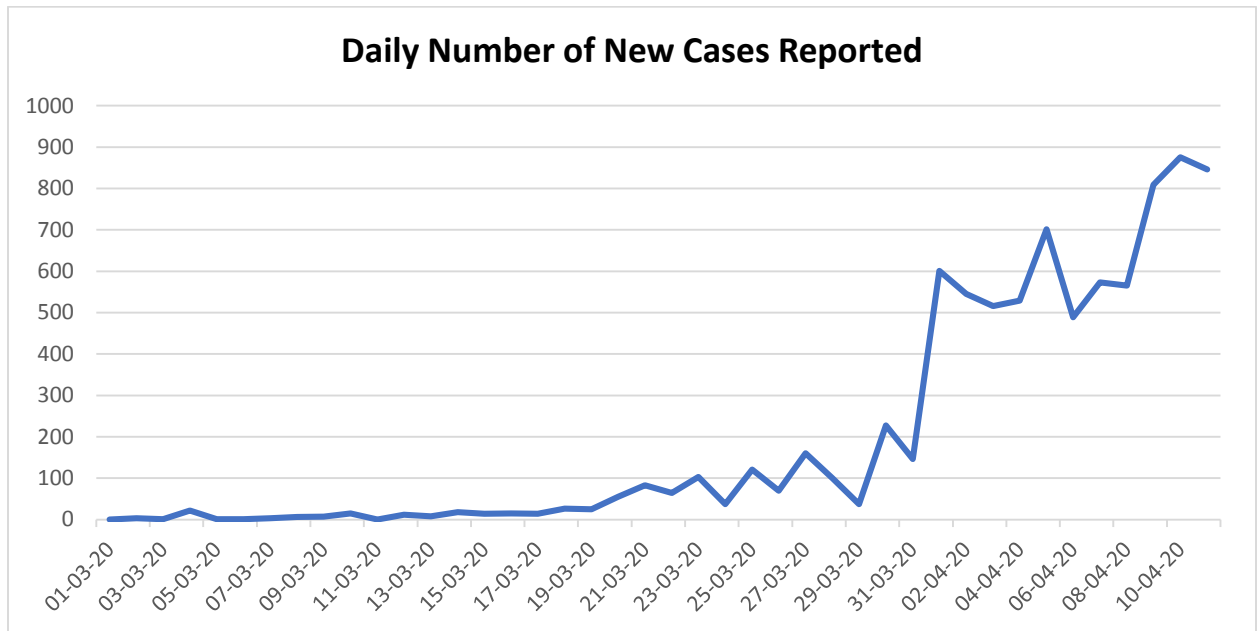
³ <https://www.worldometers.info/coronavirus/country/india/>

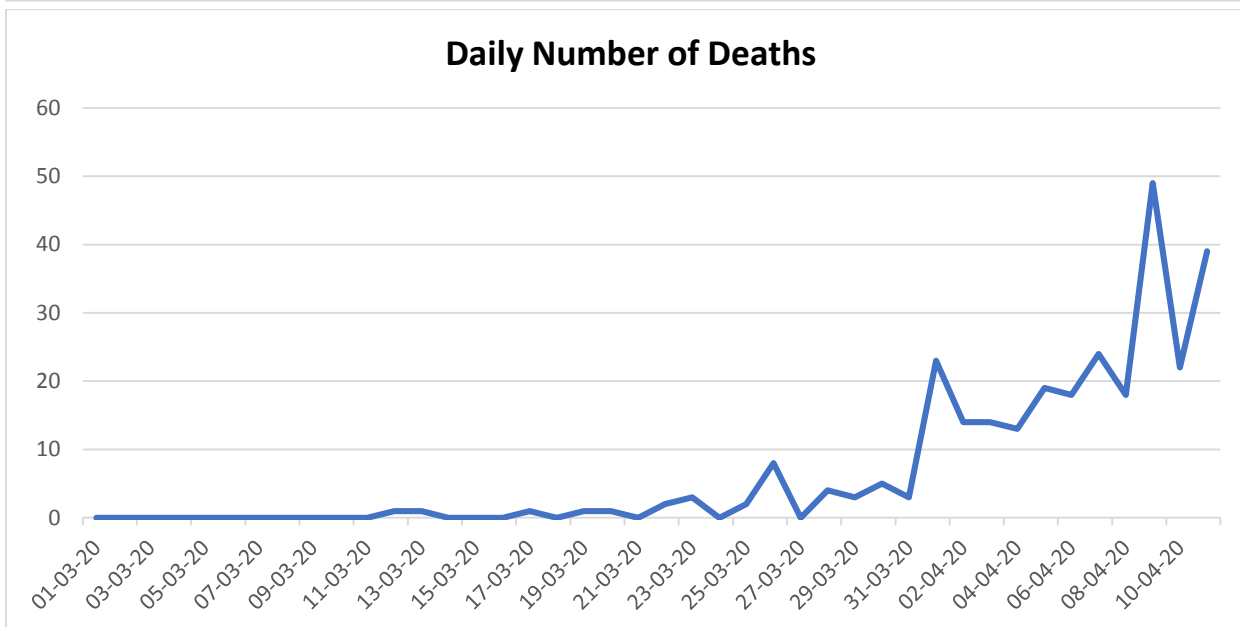
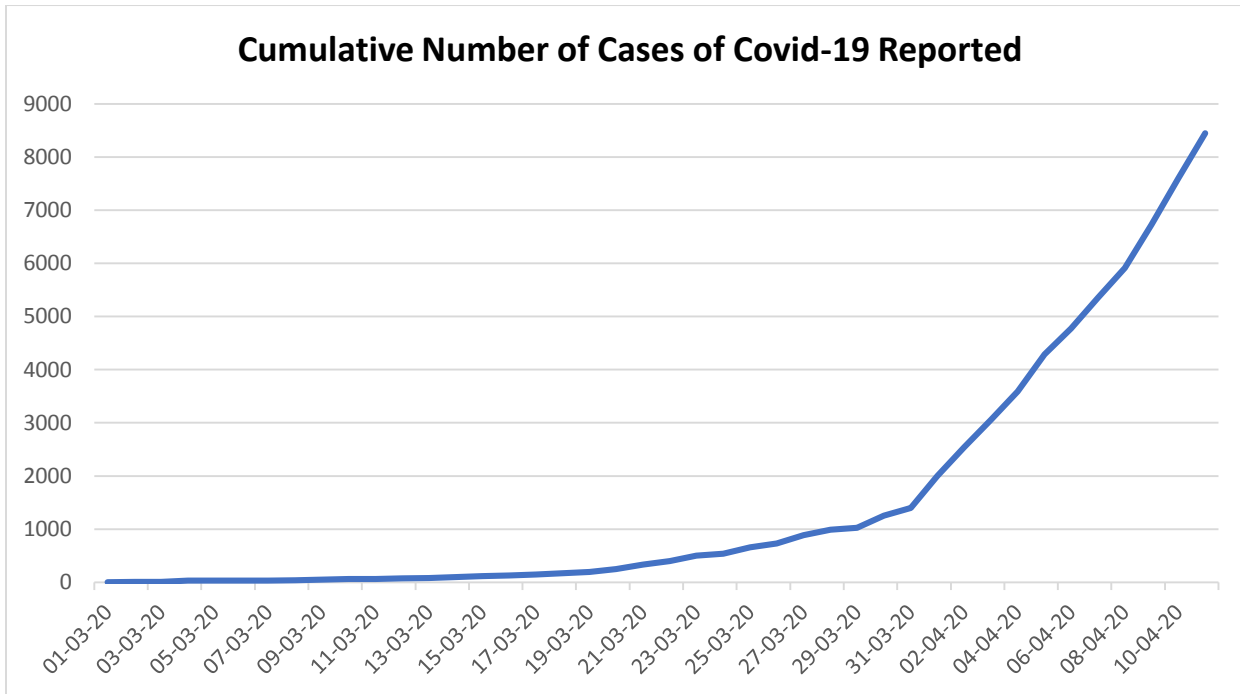


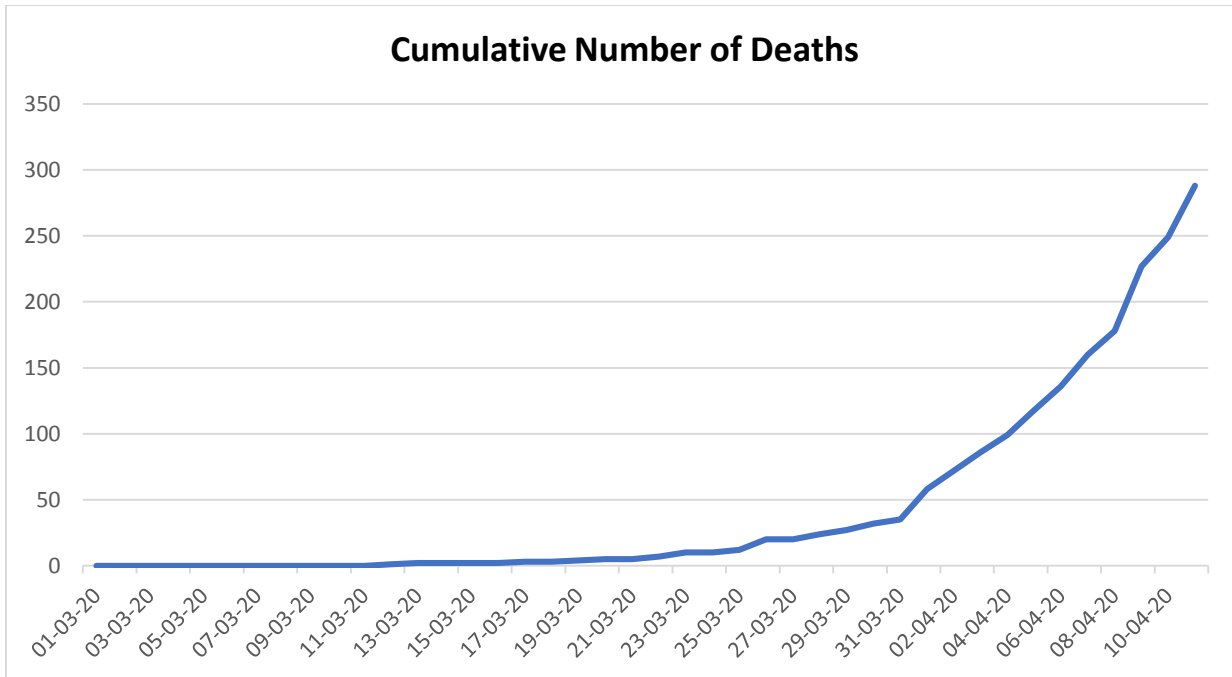
06-04-2020	489	4778	18	136
07-04-2020	573	5351	24	160
08-04-2020	565	5916	18	178
09-04-2020	809	6725	49	227

10-04-2020	875	7600	22	249
11-04-2020	846	8446	39	288

Source: Worldometer







There are three noticeable ‘jumps’ in the number of new cases: a small jump from single digits to double digits at around 13th/14th March, another small jump from double to triple digits at around 25th March, and a larger jump from the low hundreds to the middle hundreds at around 1st April. The first two jumps coincide with the imposition of lockdowns partially at the state levels in the former case, and totally at the national level in the latter case. The last jump is far more serious and indicates that the epidemic is spreading much quicker than expected.

Of particular interest is whether the propagation of the coronavirus is exponential or logistic in nature (Batista, 2020; Dash, 2020; Jia et al, 2020; Wu et al, 2020). To examine this question, linear and quadratic regression were compared. Exponential growth is given by the differential equation $\frac{dy}{dt} = ry$, which for simplicity is estimated by a linear regression (through the origin) of the daily number of new cases (x_t) on the cumulative number of cases (y_{t-1}):

$$x_t = ry_{t-1} + \epsilon_t,$$

On the other hand, logistic growth is given by the differential equation $\frac{dy}{dt} = ry(M - y)$, which for simplicity is estimated by a quadratic regression (through the origin) of the daily number of new cases (x_t) on the cumulative number of cases (y_{t-1}):

$$x_t = ry_{t-1} - r/M y_{t-1}^2 + \epsilon_t,$$

It is also of interest to determine whether the propagation rate has been effectively decreased due to measures taken by the government such as the lockdown. To examine this question, the dummy variables D_1 (for the period from 14th March) and D_2 (for the period from 1st April) were introduced. The linear regression models was of the form:

$$x_t = by_{t-1} + b_1D_1y_{t-1} + b_2D_2y_{t-1} + \epsilon_t$$

While the quadratic regression model was of the form:



$$x_t = by_{t-1} + b_1D_1y_{t-1} + b_2D_2y_{t-1} + cy_{t-1}^2 + c_1D_1y_{t-1}^2 + c_2D_2y_{t-1}^2 + \epsilon_t$$

Analysis

The overall linear and quadratic regression results are presented below.

Panel A: Linear regression

	<i>Coeff</i>	<i>Std Error</i>	<i>t Stat</i>	<i>p-value</i>
cumulative cases(-1)	0.133537	0.006564	20.34485	0.0000

adj R² = 88.55%, F Stat = 413.91, p-value = 0.0000

Panel B: Quadratic regression

	<i>Coeff</i>	<i>Std Error</i>	<i>t Stat</i>	<i>p-value</i>
cumulative cases(-1)	0.212493	0.018521	11.47323	0.0000
cumulative cases(-1)**2	-0.000014	0.000003	-4.45915	0.0000

adj R² = 91.33%, F Stat = 312.22, p-value = 0.0000

According to the exponential model, the overall growth rate in the daily number of new cases was 13.35%, whereas, according to the logistic model, the overall growth rate in the daily number of new cases was 21.25%. Also, the logistic model yields a projection for the limiting level of cumulative cases of 15,131.80. Further, the logistic model was found to be a better fit, with a higher adjusted R².

Applying the logistic model (via quadratic regression) to the daily number of deaths and cumulative number of deaths, the following results are obtained.

Panel B: Quadratic regression

	<i>Coeff</i>	<i>Std Error</i>	<i>t Stat</i>	<i>p-value</i>
cumulative deaths(-1)	0.230036	0.039401	5.83834	0.0000
cumulative deaths(-1)**2	-0.000368	0.000202	-1.81891	0.0796

adj R² = 82.39%, F Stat = 89.27, p-value = 0.0000

The key insight from the above quadratic regression was the a projection for the limiting level of cumulative deaths of 625.77. Expressing this as a ratio of the limiting level of cumulative cases gives a ‘limiting mortality rate’ of just 0.45%.

The results of the dummy variable linear and quadratic regressions are presented below.

Panel A: Linear regression

	<i>Coeff</i>	<i>Std Error</i>	<i>t Stat</i>	<i>p-value</i>
cumulative cases(-1)	0.135951	0.733422	0.18537	0.8539
D1*cumulative cases(-1)	0.005158	0.734633	0.00702	0.9944
D2*cumulative cases(-1)	-0.007770	0.042714	-0.18192	0.8566

adj R² = 87.97%, F Stat = 131.36, p-value = 0.0000

Panel B: Quadratic regression

	<i>Coeff</i>	<i>Std Error</i>	<i>t Stat</i>	<i>p-value</i>
cumulative case(-1)	0.265193	2.164813	0.12250	0.9032
D1*cumulative case(-1)	0.049150	2.167824	0.02270	0.9820
D2*cumulative case(-1)	0.015066	0.116111	0.12976	0.8975
cumulative case(-1)**2	0.002310	0.037235	0.06206	0.9509
D1*cumulative case(-1)**2	0.002229	0.037235	0.05985	0.9526
D2*cumulative case(-1)**2	0.000065	0.000120	0.54481	0.5892

adj R² = 91.07%, F Stat = 105.05, p-value = 0.0000

Again, the logistic model was found to be a better fit, with a higher adjusted R². The logistic model indicates that the growth rate in the daily number of new cases was initially 26.52%; after 14th March, it decreased to 21.60%; and after 1st April, it increased slightly to 23.11%. On the other hand, the limiting level of cumulative cases was initially 114.76; after 14th March, it increased to 2,627.34; and after 1st April, it increased to 13,582.18.

Discussion

The results of the study suggest that the propagation of the coronavirus is logistic in nature. This implies that, the rate of propagation of the coronavirus starts low, initially increases rapidly with increasing cumulative number of cases, reaches a peak when the cumulative number of cases reaches ½M, and then decreases asymptotically to zero as the cumulative number of cases gets closer to the limiting upper bound M.

The peak propagation rate of the coronavirus was estimated to be 17.51% - 25.06% with 95% confidence,



and the projected limiting level of cumulative cases was estimated to be 12,246.65 - 22,800.33 with 95% confidence. This is much less than the extent of spread of the coronavirus in the US and most of Europe. It would be imperative to understand how India has managed to contain the spread of the coronavirus, against all odds.

The results of the study suggest that there was an increase in the peak propagation rate and the limiting level of cumulative cases after 1st April, 2020. As the incubation period of the virus is estimated to be 14 days, this means that there was an acceleration in the spread of the coronavirus in mid-March 2020. Thus, the restrictions imposed in mid-March 2020 were clearly ineffective, and strict lockdown should have been imposed in early/mid-March 2020. Another factor that may have contributed to the increase in spread of the coronavirus was the mass exodus of migrant labourers from many Indian metropolitan cities, just days after the lockdown, due to its serious economic implications.

There are several limitations inherent in the study. The study period is short, just forty-two days, which is why some dummy variable regression results failed to be statistically significant. Further, the data on reported new cases are affected by many sources of variation, including the incubation period of the virus in different patients, the time taken for different patients to exhibit symptoms, the time taken for different patients to come forward for testing, and the time for the test results to be available. The most serious limitation is that the official number of reported cases and deaths are gross under-estimates of the true numbers, as only a small fraction of the population has been tested. There is a lack of adequate testing facilities in cities, leave aside rural areas. This must be urgently addressed, as the South Korean experience had shown that testing and isolation are the key to successful containment of the coronavirus (Balilla, 2020; Potluri and Lavu, 2020).

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