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QUANTITATIVE APPROACH FOR MANAGEMENT OF LOCKDOWN IN INDIA AMIDST COVID–19 PANDEMIC

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ABSTRACT

India was aware of the highly contagious nature of this disease so it took early steps for containment of this disease. Initially, School/Colleges were closed and then finally 21 days lockdown was imposed from March 25, 2020, which then further extended to May 3, 2020. Through lockdown in early stages, India successfully contained the COVID – 19 and brought down the growth rate of infections (cumulative) from exponential growth to the proportionate growth. On the other hand, the rate of growth of recoveries (cumulative) demonstrated exponential growth rate which further benefitted India. The deaths (cumulative) is also showing a proportional growth rate which is another good sign for India. The stringency level of lockdown depends upon the growth rates of infections (cumulative), recoveries (cumulative) and deaths (cumulative). We developed 64 scenarios and then determine the stringency level for each scenario based on upon Logarithmic model under certain assumptions. However, these 64 scenarios are not exhaustive and there could be more scenarios. Thus, we are able to develop a quantitative approach for management of lockdown in India amidst COVID – 19 Pandemic.

Keywords: *COVID–19, Pandemic, SARS-CoV-2, Novel Coronavirus, Outbreak, Lockdown.*

Introduction

COVID–19 is a disease that is caused by Severe Acute Respiratory Syndrome Coronavirus 2. It is highly infectious and from its origination in Wuhan, China in December 2019, the numbers of infected cases globally have crossed the mark of 1.8 million as on April 14, 2020. Since this disease is caused by a new virus, there is no specific vaccine or drug invented hitherto for the prevention and treatment of COVID–19. As this disease is highly contagious, different countries have adopted different strategies to contain the spread of COVID–19. These strategies include the closures of schools/colleges, complete lockdown, partial lockdown, selective lockdown, ban on gatherings, closure of international borders, rigorous screening program, isolation of infected persons etc. Some countries have simultaneously adopted different strategies to counter the crisis of COVID – 19 Pandemic. All these strategies are adopted to flatten the growth of COVID – 19 and some countries are more successful than others in flattening the growth of COVID – 19 Pandemic.

India was aware of the highly contagious nature of this disease so it took early steps for containment of this disease. Initially, Schools/Colleges were closed and then finally 21 days lockdown was imposed from March 25, 2020, which then further extended to May 3, 2020. Through lockdown in early stages, India successfully countered the COVID – 19 and tried to flatten out the growth of infections in the country.

In this study, we shall find out the impact of lockdown upon the growth rates of Infections (Cumulative) and whether this lockdown is effective in countering the terror of COVID–19 Pandemic.

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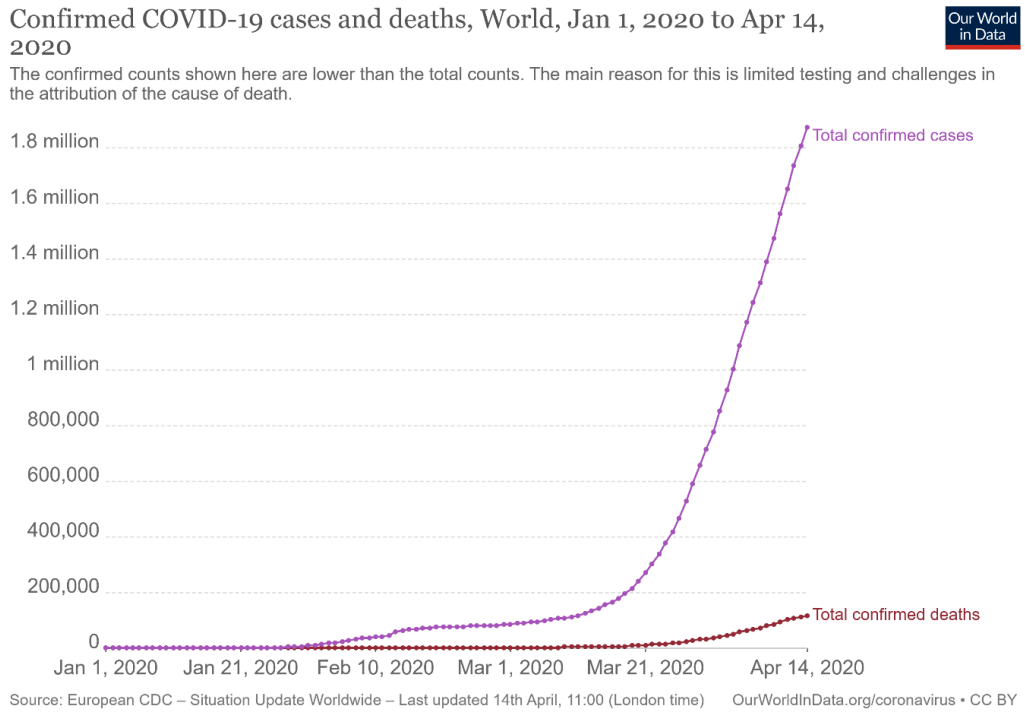
The next challenge is how to manage this lockdown. The present approaches of management of lockdown are based upon hit and trial basis and are purely qualitative. This is a very crucial time and we cannot depend upon the purely intuitive and arbitrarily methods to counter this contagious threat. Hence in this study, we shall try to develop a quantitative approach toward management of lockdown amidst COVID – 19 Pandemic.

Covid – 19

COVID–19 is a disease that is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). World Health Organization (WHO) has described this disease as COVID – 19 on February 11, 2020 (WHO, 2020). The COVID–19 originated from Wuhan area of China and then it widespread overall the world at an alarming rate. Symptoms of COVID–19 disease includes fever, dry cough, difficulty in breathing and invasion lesion on both lungs of the affected person (Zhu, Wei, & Niu, 2020). COVID–19 is a very contagious disease and it spreads through droplets, contact, aerosol, etc. It spread from humans to humans and there is no significant evidence of transmission of COVID – 19 from animals to humans. The COVID – 19 spreads in such a rapid pace that it has become pandemic in just a few days and it was declared as a pandemic by WHO on March 11, 2020. COVID – 19 can spread to the respiratory tract which may result in pneumonia. The fatality rate of COVID – 19 is not very significant but the cause of concern is the pace at which it spread.

This disease is spread by the virus which is genetically related to the Coronavirus responsible for the SARS outbreak of 2003. But this virus is different from that virus and is named as Severe Scute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) by the International Committee on Taxonomy of Viruses (WHO, 2020). Elderly people and persons with pre-existing conditions (such as high blood pressure, heart disease, lung disease, cancer or diabetes) have more chances to advance to serious stages than normal people. As this disease is spread by a new virus, therefore, the vaccine or drug for the prevention and treatment of this disease has not been invented so far and as consequence, this disease has become the cause of severe concern at the global level.

Till April 15, 2020, the cumulative cases of COVID – 19 has crossed 1.8 million at Global Level and it started in Wuhan, China in December 2019. The chart for the increases in the cases of COVID – 19 and death due to COVID – 19 at the global level is given in the chart given below for the period between January 1, 2020, to April 14, 2020.



From the chart given above, it can be seen that the numbers of COVID – 19 is increasing at a rapid pace daily and this is a matter of great concern since medical facilities in any country to counter the terror of COVID – 19 will simply get overburdened in few days and will collapse which may cause a substantial loss in terms of human lives in the country.

As there is no vaccine or drug for the prevention and treatment of COVID – 19, therefore, this situation has raised the alarm at the Global Level. Self-isolation and social distancing emerge as effective tools to counter the terror of COVID–19 at an individual level. However, different countries have adopted different strategies to counter the challenge of COVID – 19 and some of the countries due to their strategies are successful in restricting the growth of COVID – 19 cases. These different strategies are the closure of schools/colleges, complete lockdown, partial lockdown, selective lockdown, bans on gatherings, closures of international borders, rigorous screening programs, isolation of infected persons etc. Some countries have simultaneously adopted different strategies to counter the crisis of COVID – 19 Pandemic. All these strategies are adopted to flatten the growth of COVID – 19 and some countries are more successful than others in flattening the growth of COVID – 19 Pandemic (Hjelmgaard, 2020).

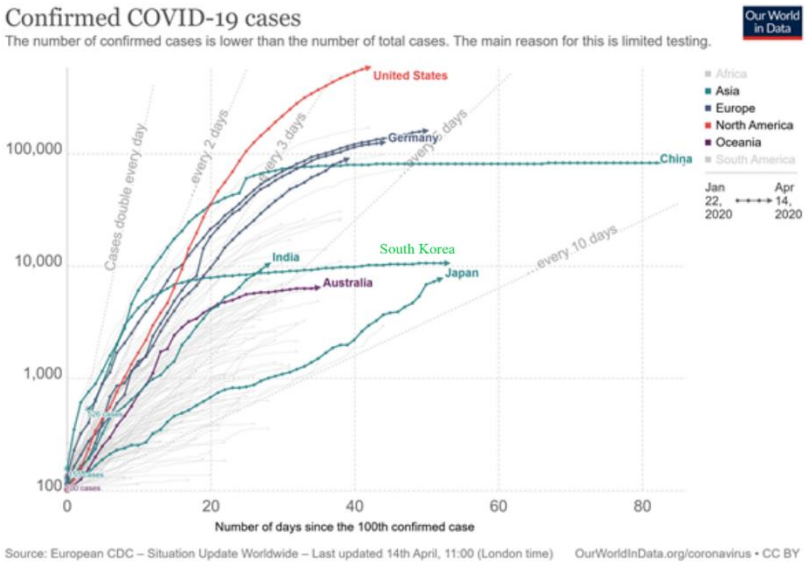
The chart below, list out the different strategies to contain the COVID – 19 Pandemic to flatten the growth of COVID – 19 Pandemic by some countries.

How countries responded to coronavirus

Nation	Travel restrictions	Social distancing encouraged	Restaurants/bars officially closed	Widespread testing	Lockdown
Italy	✔	✔	✔	✔	✔
Spain	✔	✔	✔	✖	✔
China	✔	✔	✖	✖	✔
South Korea	✔	✔	✖	✔	✖
Singapore	✔	✔	✖	✔	✖
U.S.	✔	✔	✔	✖	✖
France	✔	✔	✔	✖	✖
Germany	✔	✔	✔	✖	✖
U.K.	✔	✔	✖	✖	✖
Japan	✔	✔	✖	✖	✖
Australia	✔	✖	✖	✖	✖
Iran	✔	✖	✖	✖	✖

NOTE In U.S., restaurants and bars closed In some states; In U.K., theaters and music venues were closed and public was advised not to visit restaurants and pubs; SOURCE USA TODAY reporting and research; GRAPHIC George Petras/USA TODAY

The graph showing the growth rate of COVID – 19 cases in some selective countries is given below:



This chart vindicates the fact that some countries are doing better from other countries. South Korea and Australia have flattened the growth of COVID – 19 patients. China is now able to flatten the growth of COVID – 19 patients after a severe outbreak. But the USA is performing worst for containment of COVID – 19 and it is not hitherto able to flatten the growth of COVID–19 patients.

COVID – 19 and its Prognosis in India

The rate of spread of COVID – 19 is very alarming and on the other hand, there is no vaccine or drug for the prevention and treatment of COVID – 19, therefore, this situation has raised the alarm at very early stages in India. Even the medical infrastructure in India is not so strong in comparison with the medical infrastructure of some developed countries and still, those developed countries have collapsed due to COVID – 19. As a consequence, India desperately needed a quick reaction to COVID – 19.

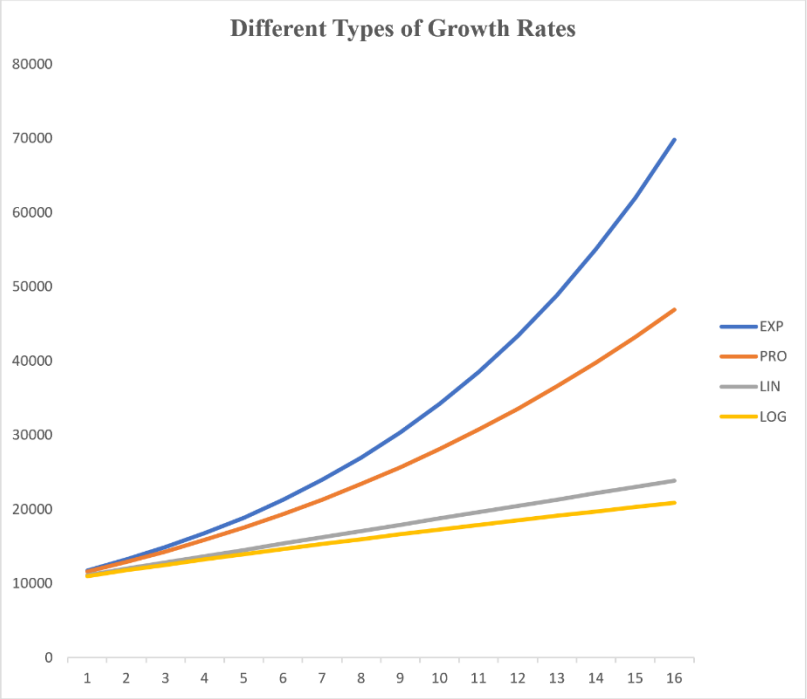
This disease is characterized by four stages in India. Indian Council of Medical Research has recognised these four stages as Imported Cases, Local Transmission, Community Transmission and Epidemic. During the first stage (i.e. Imported Cases), this disease is not originated domestically but from the persons coming from foreign countries. Thereafter these imported cases put the country to the second stage (i.e. local transmission) when imported cases come in contact with local people and spread this disease among the local people. During this stage, the source of transmission of infection to an infected person is easily traceable. After the second stage, this disease advances to the third stage. At this stage, the source of infection to an infected person cannot be traced. Finally, this disease enters into the fourth stage (i.e. Epidemic) and in this stage, the disease is so widely spread among the people of a country that it has to declare a state of a public health emergency (Sutaria, 2020).

The initial step taken by India was immediate closure of school and colleges to curb the outbreak of COVID – 19 from March 16, 2020. However, as there was a festival of Holi going on in India at that time, so school and colleges effectively closed down before March 16, 2020. But as the COVID–19 cases were increasing at an alarming rate, therefore, India decided to impose complete lockdown from March 25, 2020, for 21 days which was scheduled to end on April 14, 2020. However, on April 14, 2020, the lockdown was extended till May 3, 2020.

The main issue in COVID – 19 is to analyse the growth rate of Infections, Recoveries and Deaths on a cumulative basis. The control and management of growth rates in respect of all these three variables (i.e. infections, recoveries and deaths) is the only way to contain the COVID – 19 and India adopt the strategies of social distancing and lockdown to control these variables.

There are four kinds of growth rates i.e. Exponential, Proportionate, Linear and Logarithmic. Since we are concerned with the growth of COVID – 19 with respect to time so, therefore, it is pertinent to elaborate these four kinds of growth rate before proceeding further.

These different kinds of growth rates behave differently. This is illustrated by a graph given below:



The legends used in this graph are as follows:

- EXP : Exponential
- PRO : Proportionate
- LIN : Liner
- LOG : Logarithmic

From the above chart, it is quite clear that Exponential growth is the fastest growth rate, then followed by Proportionate growth, thereafter Linear Growth and slowest growth rate is Logarithmic growth. Therefore, Exponential growth, increase the variables at an alarming rate but in contrast Logarithmic growth flattens the actual growth of any variable.

We have collected data from March 2, 2020, to April 13, 2020, daily in India in respect of three variables (i.e. Infections, Recoveries and Deaths) on a cumulative basis. We in our study has collected the data from the website of India COVID-19 Tracker - A Crowdsourced Initiative (https://www.covid19india.org/)

- **Growth Rates of Infections on Cumulative Basis**

The Data collected in respect of Infection on a cumulative basis is first analysed for exponential growth. For this purpose, we estimated the following equation:

INF = e^{a_0} x $e^{a_1 TME}$

Whereas:

INF = Total Number of Infections on a cumulative basis

TME = Time

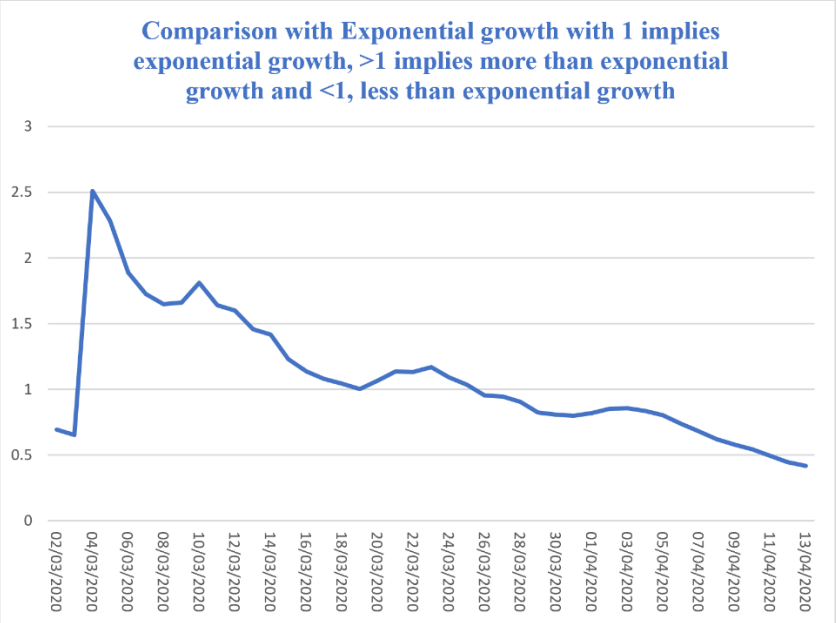
a_0 = The value of the constant

a_1 = The value of the exponential parameter associated with time.

With the help of this estimated equation, we calculated the value of a_0 and a_1 through Regression Analysis using Econometric Views (EViews) software and adopting the Generalised Method of Moments (GMM) methodology and the results are as follows:

Date	Constant		Time		r^2
	Value (a_0)	P-Value	Value (a_1)	P-Value	
02/03/2020					
03/03/2020					
04/03/2020					
05/03/2020	0.9215	0.0597	0.6383	0.0174	0.8501
06/03/2020	1.1346	0.0345	0.5066	0.0136	0.7969
07/03/2020	1.3817	0.0174	0.3956	0.0105	0.7482
08/03/2020	1.5662	0.0104	0.3295	0.0080	0.7294
09/03/2020	1.6987	0.0059	0.2914	0.0048	0.7416
10/03/2020	1.7789	0.0030	0.2726	0.0020	0.7747
11/03/2020	1.8806	0.0015	0.2517	0.0011	0.7938
12/03/2020	1.9746	0.0007	0.2347	0.0006	0.8110
13/03/2020	2.0768	0.0003	0.2180	0.0004	0.8212
14/03/2020	2.1630	0.0001	0.2052	0.0002	0.8323
15/03/2020	2.2645	0.0000	0.1911	0.0001	0.8348
16/03/2020	2.3550	0.0000	0.1794	0.0001	0.8373
17/03/2020	2.4464	0.0000	0.1687	0.0000	0.8438
18/03/2020	2.4849	0.0000	0.1639	0.0000	0.8499
19/03/2020	2.5279	0.0000	0.1592	0.0000	0.8591
20/03/2020	2.5397	0.0000	0.1583	0.0000	0.8739
21/03/2020	2.5319	0.0000	0.1596	0.0000	0.8899
22/03/2020	2.5223	0.0000	0.1610	0.0000	0.9038
23/03/2020	2.5062	0.0000	0.1630	0.0000	0.9163
24/03/2020	2.5000	0.0000	0.1639	0.0000	0.9260
25/03/2020	2.4989	0.0000	0.1642	0.0000	0.9339
26/03/2020	2.5035	0.0000	0.1640	0.0000	0.9413
27/03/2020	2.5080	0.0000	0.1638	0.0000	0.9458
28/03/2020	2.5121	0.0000	0.1636	0.0000	0.9507
29/03/2020	2.4923	0.0000	0.1643	0.0000	0.9558
30/03/2020	2.5019	0.0000	0.1637	0.0000	0.9593
31/03/2020	2.5077	0.0000	0.1633	0.0000	0.9626
01/04/2020	2.5070	0.0000	0.1635	0.0000	0.9658
02/04/2020	2.5002	0.0000	0.1641	0.0000	0.9690
03/04/2020	2.4914	0.0000	0.1648	0.0000	0.9718
04/04/2020	2.4839	0.0000	0.1654	0.0000	0.9743
05/04/2020	2.4784	0.0000	0.1658	0.0000	0.9764
06/04/2020	2.4787	0.0000	0.1659	0.0000	0.9782
07/04/2020	2.4835	0.0000	0.1656	0.0000	0.9797
08/04/2020	2.4932	0.0000	0.1651	0.0000	0.9809
09/04/2020	2.5046	0.0000	0.1644	0.0000	0.9818
10/04/2020	2.5180	0.0000	0.1637	0.0000	0.9826
11/04/2020	2.5342	0.0000	0.1628	0.0000	0.9832
12/04/2020	2.5543	0.0000	0.1618	0.0000	0.9835
13/04/2020	2.5743	0.0000	0.1607	0.0000	0.9838

After calculating the value of a_0 and a_1 daily, we found the geometric mean of these different values of a_0 and $a_1$to obtain the robust value of a_0 and a_1. Thereafter, we estimated the values of infections on a cumulative basis and then we divide actual values of infections (cumulative) with estimated values of infections (cumulative). Thereafter these results are adjusted for unity. Afterwards, we plot the results on the graph from March 2, 2020, to April 13, 2020, and the graph is given below



The results are quite interesting since India was on the path of exponential growth till March 24, 2020, but thereafter there is a decline from exponential growth. This clearly shows that lockdown imposed in India is working effectively and it has reduced the exponential growth of infections on a cumulative basis in India. Certain breaks can also be observed in this graph. These breaks are:

Breaks	Reasons for Break
10/03/2020	School/College Break
25/03/2020	Lockdown
30/03/2020	Special Operations due to Tablighi Jammat
04/04/2020	Any other reason

As from the graph, it is quite clear that Infections (Cumulative) in India is not on the path of exponential growth hence it is necessary to analyse the growth rate of infections (Cumulative) in terms of other types of growth rate. Hence we proceed to analyse the growth rate of infections (Cumulative) on a proportionate basis. For this purpose, we estimated the following equation:

INF = a_0 x TME^{a_1}

INF = Total Number of Infections on a cumulative basis

TME = Time

a_0 = The value of the constant

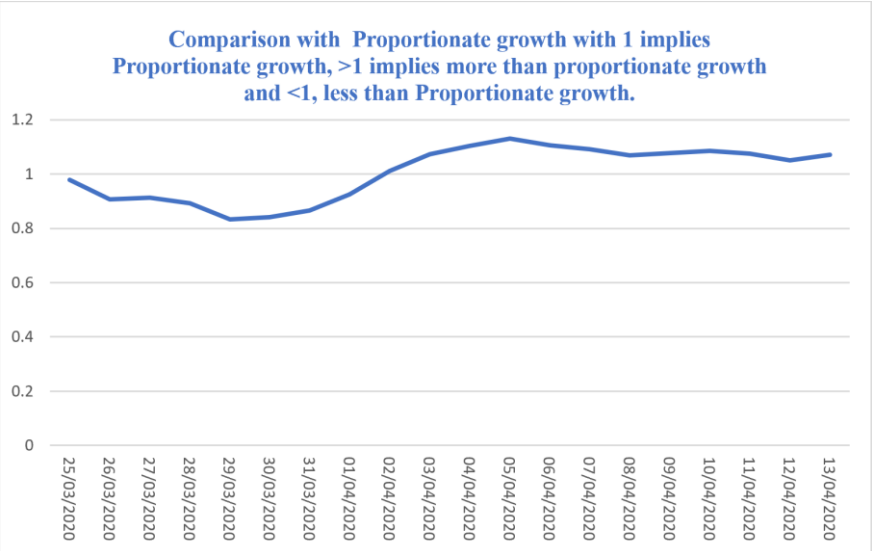
a_1 = The value of the proportional parameter associated with time.

With the help of this estimated equation, we calculated the value of a_0 and a_1 from March 25, 2020, to April 13, 2020, through Regression Analysis using EViews software and adopting the GMM methodology and the results are as follows:

Date	Constant		Time		r^2
	Value (a_0)	P-Value	Value (a_1)	P-Value	
25/03/2020					
26/03/2020					
27/03/2020	-5.3696	0.1538	3.7282	0.0699	0.9751
28/03/2020	-5.9873	0.0106	3.9207	0.0024	0.9890
29/03/2020	-5.1458	0.0007	3.6587	0.0001	0.9912
30/03/2020	-5.6085	0.0000	3.8020	0.0000	0.9943
31/03/2020	-6.2019	0.0000	3.9853	0.0000	0.9926
01/04/2020	-6.8997	0.0001	4.2007	0.0000	0.9863

02/04/2020	-7.7739	0.0001	4.4698	0.0000	0.9794
03/04/2020	-8.7344	0.0000	4.7644	0.0000	0.9780
04/04/2020	-9.5301	0.0000	5.0072	0.0000	0.9797
05/04/2020	-10.0587	0.0000	5.1676	0.0000	0.9821
06/04/2020	-10.1943	0.0000	5.2084	0.0000	0.9853
07/04/2020	-10.1281	0.0000	5.1884	0.0000	0.9880
08/04/2020	-9.9222	0.0000	5.1269	0.0000	0.9898
09/04/2020	-9.7720	0.0000	5.0821	0.0000	0.9912
10/04/2020	-9.6534	0.0000	5.0469	0.0000	0.9923
11/04/2020	-9.5225	0.0000	5.0082	0.0000	0.9931
12/04/2020	-9.3641	0.0000	4.9614	0.0000	0.9935
13/04/2020	-9.2738	0.0000	4.9347	0.0000	0.9941

After calculating the value of a_0 and a_1 daily, we found the geometric mean of these different values of a_0 and $a_1$to obtain the robust value of a_0 and a_1. Thereafter, we estimated the values of infections on a cumulative basis and then we divide actual values of infections (cumulative) with estimated values of infections (cumulative). Thereafter these results are adjusted for unity. Afterwards, we plot the results on the graph from March 25, 2020, to April 13, 2020, and the graph is given below



The results vindicate that India is on the path which is more than proportionate growth but less than exponential growth from March 25, 2020, onwards. As India is on the path which is more than proportionate growth, therefore, there is no need of analysing other paths i.e. linear and logarithmic since both of these growth rates are lesser than proportionate growth and if the growth of infections (cumulative) is more than proportionate growth then it would also be higher than linear and logarithmic growths. Certain breaks are also be observed in this graph. These breaks are:

Breaks	Reasons for Break
30/03/2020	Special Operations due to Tablighi Jammat
04/04/2020	Any other reason
08/04/2020	Any other reason
12/04/2020	Any other reason

As the growth of infections (cumulative) is more than proportionate growth but less than exponential growth, therefore, we estimated the value of infections (cumulative) from April 15, 2020, to May 03, 2020, with the help of breaks identified in both of the above graphs and the Geometric Mean of exponential and proportionate growth where exponential growth has been given the weightage of 0.5 and proportionate growth has been given the weightage of 1.1. The values of associated parameters are found out through regression analysis using EViews software and adopting GMM methodology. Our estimations for infections (cumulative) are as follows:

Date	Estimated Infections (Cumulative) with overall Lockdown (data till 13/04/2020)
15/04/2020	12,346
16/04/2020	13,432
17/04/2020	14,569
18/04/2020	15,761
19/04/2020	17,010
20/04/2020	18,319
21/04/2020	19,692
22/04/2020	21,132
23/04/2020	22,642
24/04/2020	24,225
25/04/2020	25,886
26/04/2020	27,628
27/04/2020	29,455
28/04/2020	31,371
29/04/2020	33,380
30/04/2020	35,487
01/05/2020	37,696
02/05/2020	40,012
03/05/2020	42,440

Infections Cumulative with Overall Lockdown (data till 13/04/2020)	
R-squared	0.99985
Adjusted R-squared	0.99985
S.E. of regression	38.70674
R	0.99993

The confidence level of estimated values depend on the value of R and in the present case, the R is almost approaching to unity and therefore these estimated values are highly reliable.

- **Growth Rates of Recoveries on Cumulative Basis**

Recoveries (Cumulative) of the infected persons from COVID–19 disease are also following different growth paths in different countries. This is also one of the most important variables since if recoveries (cumulative) are increasing at an exponential growth then a country can come back to normalcy within a short time. However, if recoveries (cumulative) are increasing at a logarithmic growth then it is a cause of concern and country cannot come back to normalcy even after a long period.

There can also be simultaneity between death (cumulative) and recoveries (cumulative) but through econometric methods, we found out that recoveries (cumulative) are dependent upon death (cumulative) but it is not true vice versa.

We analysed recoveries (cumulative) for exponential growth and we estimated the following equation:

REC = e^{a_0} x $e^{a_1 TME}$

Whereas:

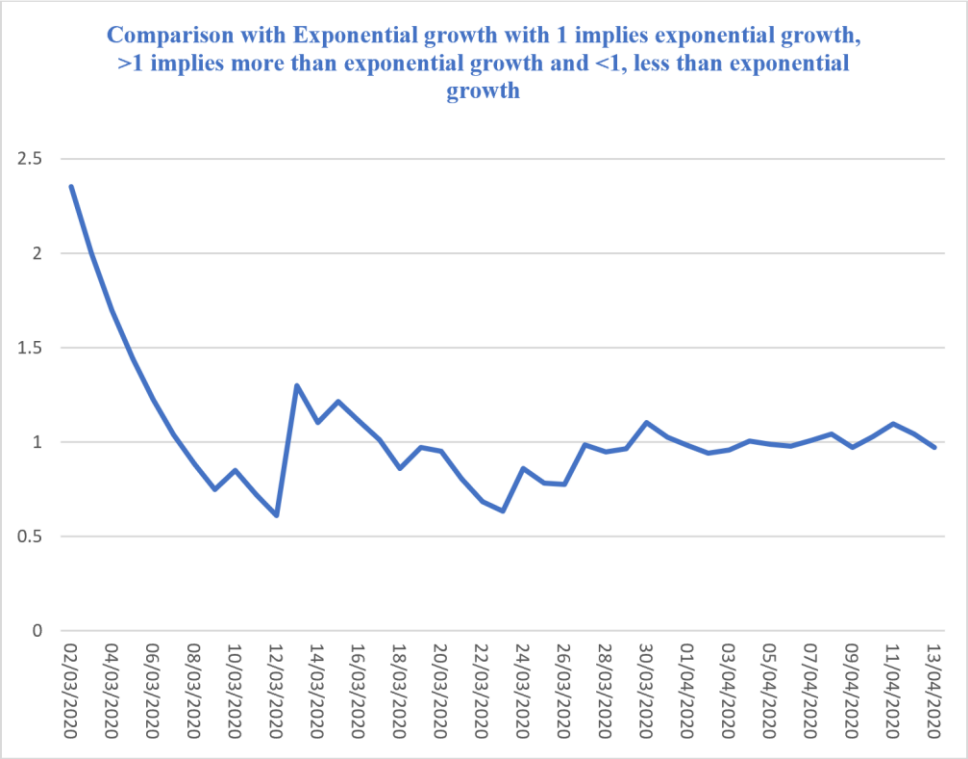
REC = Total Number of Recoveries on a cumulative basis

TME = Time

a_0 = The value of the constant

a_1 = The value of the exponential parameter associated with time.

With the help of this estimated equation, we calculated the value of a_0 and a_1 using EViews software and adopting GMM methodology and thereafter, we estimated the values of recoveries on a cumulative basis and then we divide the actual value of recoveries (cumulative) with estimated values of recoveries (cumulative). Thereafter these results are adjusted for unity. Afterwards, we plot the results on the graph from March 2, 2020, to April 13, 2020, and the graph is given below:



This chart indicates that recoveries (cumulative) are increasing at the exponential rate from March 27, 2020. Thus in terms of recoveries (cumulative), India is performing well and due to this exponential growth of recoveries (cumulative), India can regain normalcy in a short time. We estimated recoveries (cumulative) based on exponential growth and also taking into account the deaths (cumulative). The values of associated parameters are found out through regression analysis using EViews software and adopting the GMM methodology. Our estimations for recoveries (cumulative) are as follows:

Date	Estimated Recoveries (Cumulative) with overall lockdown (data till 13/04/2020)
15/04/2020	1,575
16/04/2020	1,820
17/04/2020	2,103
18/04/2020	2,431
19/04/2020	2,808
20/04/2020	3,244
21/04/2020	3,747
22/04/2020	4,327
23/04/2020	4,997
24/04/2020	5,770
25/04/2020	6,663
26/04/2020	7,692
27/04/2020	8,880
28/04/2020	10,251
29/04/2020	11,833
30/04/2020	13,658
01/05/2020	15,763
02/05/2020	18,193
03/05/2020	20,996

Recoveries Cumulative with overall Lockdown (Data till 13/04/2020)	
R-squared	0.99387
Adjusted R-squared	0.99372
S.E. of regression	24.58332
R	0.99693

The confidence level of estimated values depend on the value of R and in the present case, the R is almost approaching to unity and therefore these estimated values are highly reliable.

- **Growth Rates of Deaths on Cumulative Basis**

Even deaths (cumulative) are an important variable for the determination of the severity of COVID–19 Pandemic in any country. If deaths (cumulative) are increasing at an exponential growth rate then this can result in large numbers of fatalities due to COVID–19.

We analysed deaths (cumulative) for exponential and proportionate growth and we estimated the following equation:

For Exponential Growth

DEA = e^{a_0} x $e^{a_1 TME}$

Whereas:

DEA = Total Number of Deaths on a cumulative basis

TME = Time

a_0 = The value of the constant

a_1 = The value of the exponential parameter associated with time.

For Proportionate Growth

DEA = a_0 x TME^{a_1}

Whereas

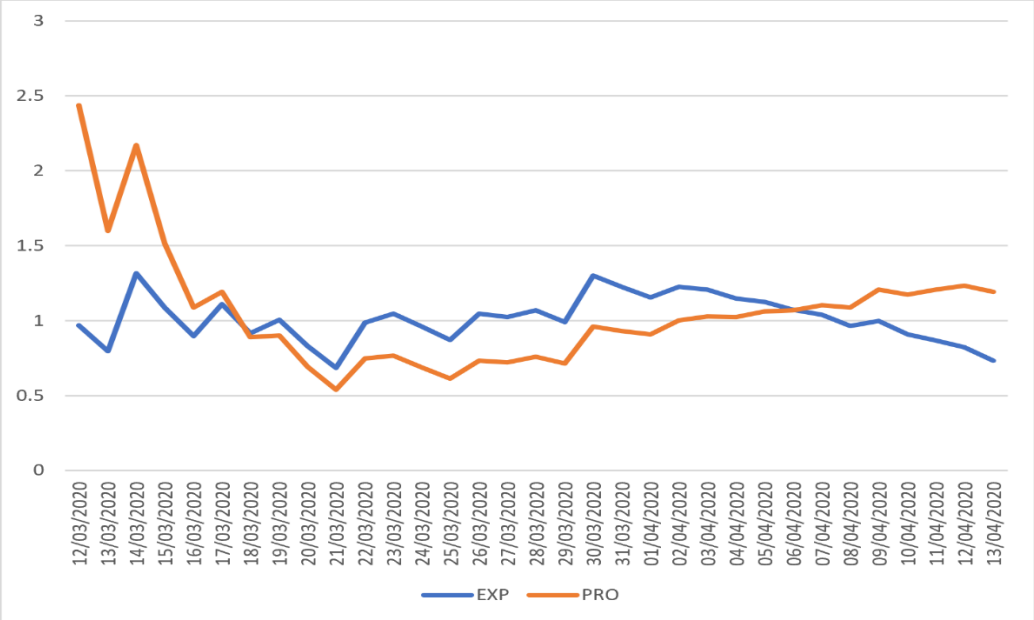
DEA = Total Number of Deaths on a cumulative basis

TME = Time

a_0 = The value of the constant

a_1 = The value of the proportional parameter associated with time.

With the help of these estimated equations, we calculated the value of a_0 and a_1 using EViews software and adopting the GMM methodology and thereafter, we estimated the values of deaths on a cumulative basis and then we divide the actual value of deaths (cumulative) with estimated values of death (cumulative). Thereafter these results are adjusted for unity. Afterwards, we plot the results on the graph from March 12, 2020, to April 13, 2020, and the graph is given below



The legends used in this graph are as follows:

Legend	Interpretation
EXP	Exponential growth rate for deaths (cumulative) with 1 implies exponential growth, >1 implies more than exponential growth and <1, less than exponential growth
PRO	Proportionate growth rate for deaths (cumulative) with 1 implies Proportionate, >1 implies more than Proportionate growth and <1, less than Proportionate growth

From the above graph, it is evident that March 30, 2020, onwards, the exponential growth of deaths (cumulative) are decreasing but on the other hand, the proportionate growth of deaths (cumulative) are increasing.

Based on this graph, we estimated the value of deaths (cumulative) from April 15, 2020, to May 03, 2020, with the help of Geometric Mean of exponential and proportionate growth where exponential growth has been given the weightage of 0.6 and proportionate growth has been given the weightage of 1.25. The values of associated parameters are found out through regression analysis using EViews software and adopting the GMM methodology.

Date	Estimated Deaths (Cumulative) with Overall Lockdown (Data till 13/04/2020)
15/04/2020	442
16/04/2020	495
17/04/2020	553
18/04/2020	617
19/04/2020	687
20/04/2020	764
21/04/2020	848
22/04/2020	940
23/04/2020	1,040
24/04/2020	1,150
25/04/2020	1,270
26/04/2020	1,401
27/04/2020	1,544
28/04/2020	1,699
29/04/2020	1,868
30/04/2020	2,052
01/05/2020	2,251
02/05/2020	2,468
03/05/2020	2,703

Recoveries Cumulative with overall lockdown (data till 13/04/2020)	
R-squared	0.99307
Adjusted R-squared	0.99281
S.E. of regression	9.12350
R	0.99653

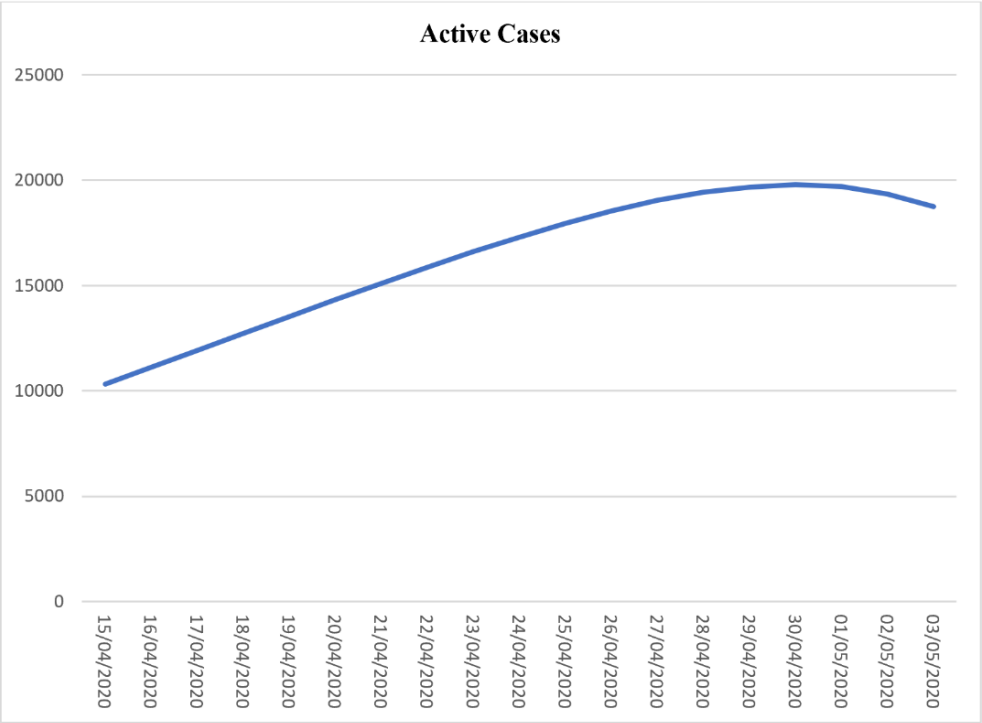
The confidence level of estimated values depends on the value of R and in the present case, the R is almost approaching to unity and therefore these estimated values are highly reliable.

Strategies for Easing of Lockdown

The lockdown and social distancing strategy adopted by India is working effectively since it is having restricted the exponential path of growth of COVID – 19 Pandemic and now it is more inclined toward proportionate growth. On the other hand, the growth of recoveries (cumulative) is following exponential growth and as consequence rate of growth of recoveries (cumulative) is more than the rate of growth of infections (cumulative) and if such trend continues then it is expected that within a short frame of time, the active cases of infections would start declining. The estimation in respect of active cases of COVID – 19 from April 15, 2020, to May 3, 2020, is as follows:

Date	Estimations based on the Data Available till April 13, 2020.			
	Infections (Cumulative)	Recoveries (Cumulative)	Deaths (Cumulative)	Active number of the cases
	A	B	C	D = A – B – C
15/04/2020	12,346	1,575	442	10,329
16/04/2020	13,432	1,820	495	11,117
17/04/2020	14,569	2,103	553	11,913
18/04/2020	15,761	2,431	617	12,713
19/04/2020	17,010	2,808	687	13,515
20/04/2020	18,319	3,244	764	14,311
21/04/2020	19,692	3,747	848	15,097
22/04/2020	21,132	4,327	940	15,865
23/04/2020	22,642	4,997	1,040	16,605
24/04/2020	24,225	5,770	1,150	17,305
25/04/2020	25,886	6,663	1,270	17,953
26/04/2020	27,628	7,692	1,401	18,535
27/04/2020	29,455	8,880	1,544	19,031
28/04/2020	31,371	10,251	1,699	19,421
29/04/2020	33,380	11,833	1,868	19,679
30/04/2020	35,487	13,658	2,052	19,777
01/05/2020	37,696	15,763	2,251	19,682
02/05/2020	40,012	18,193	2,468	19,351
03/05/2020	42,440	20,996	2,703	18,741

The graph of active numbers of cases is given below:



The graph above clearly indicates that under given conditions and circumstances, the active cases shall be maximum on April 30, 2020, and thereafter the active cases shall start declining.

However, if India had not imposed a lockdown on March 25, 2020, then the conditions would have been very miserable with infections (cumulative) been increasing at exponential growth rate. In such a case, the infections (cumulative) would have crossed 2 lakhs by April 01, 2020.

- **Stringency Level of Lockdown**

The stringency level of lockdown will differ depending upon the condition of the growth rate of infections (cumulative), recoveries (cumulative) and deaths (cumulative). As there are four types of growth rates (i.e. Exponential, Proportionate, Linear and Logarithmic) and 3 variables i.e. infections (cumulative), recoveries (cumulative) and deaths (cumulative) there are at least 64 scenarios (i.e. 4^3). Stringency level of lockdown ranges from 0% to 100% where 0% implies zero lockdown situation and 100% implies complete lockdown without any exemptions.

The table given below shows the stringency level of Lockdown required to be imposed under different 64 scenarios.

Scenario	Rate of Growth of Infections	Rate of Growth of Recovery	Rate of Growth of Death	Stringency in Lockdown (in %)
1	Exponential	Logarithmic	Exponential	100.00
2	Exponential	Logarithmic	Proportionate	93.28
3	Exponential	Logarithmic	Linear	83.80
4	Exponential	Logarithmic	Logarithmic	67.60
5	Exponential	Linear	Exponential	90.02
6	Exponential	Linear	Proportionate	83.30
7	Exponential	Linear	Linear	73.82
8	Exponential	Linear	Logarithmic	57.62
9	Exponential	Proportionate	Exponential	84.19
10	Exponential	Proportionate	Proportionate	77.47
11	Exponential	Proportionate	Linear	67.99
12	Exponential	Proportionate	Logarithmic	51.79
13	Exponential	Exponential	Exponential	80.05
14	Exponential	Exponential	Proportionate	73.33
15	Exponential	Exponential	Linear	63.85
16	Exponential	Exponential	Logarithmic	47.65
17	Proportionate	Logarithmic	Exponential	93.57
18	Proportionate	Logarithmic	Proportionate	86.84
19	Proportionate	Logarithmic	Linear	77.37
20	Proportionate	Logarithmic	Logarithmic	61.17
21	Proportionate	Linear	Exponential	83.59
22	Proportionate	Linear	Proportionate	76.87
23	Proportionate	Linear	Linear	67.39
24	Proportionate	Linear	Logarithmic	51.19
25	Proportionate	Proportionate	Exponential	77.76
26	Proportionate	Proportionate	Proportionate	71.03
27	Proportionate	Proportionate	Linear	61.56
28	Proportionate	Proportionate	Logarithmic	45.36
29	Proportionate	Exponential	Exponential	73.62
30	Proportionate	Exponential	Proportionate	66.89
31	Proportionate	Exponential	Linear	57.42
32	Proportionate	Exponential	Logarithmic	41.22
33	Linear	Logarithmic	Exponential	84.50
34	Linear	Logarithmic	Proportionate	77.78
35	Linear	Logarithmic	Linear	68.30
36	Linear	Logarithmic	Logarithmic	52.10
37	Linear	Linear	Exponential	74.53
38	Linear	Linear	Proportionate	67.80
39	Linear	Linear	Linear	58.33
40	Linear	Linear	Logarithmic	42.13
41	Linear	Proportionate	Exponential	68.69
42	Linear	Proportionate	Proportionate	61.97
43	Linear	Proportionate	Linear	52.49
44	Linear	Proportionate	Logarithmic	36.29

45	Linear	Exponential	Exponential	64.55
46	Linear	Exponential	Proportionate	57.83
47	Linear	Exponential	Linear	48.35
48	Linear	Exponential	Logarithmic	32.15
49	Logarithmic	Logarithmic	Exponential	69.00
50	Logarithmic	Logarithmic	Proportionate	62.28
51	Logarithmic	Logarithmic	Linear	52.80
52	Logarithmic	Logarithmic	Logarithmic	36.60
53	Logarithmic	Linear	Exponential	59.03
54	Logarithmic	Linear	Proportionate	52.30
55	Logarithmic	Linear	Linear	42.83
56	Logarithmic	Linear	Logarithmic	26.63
57	Logarithmic	Proportionate	Exponential	53.19
58	Logarithmic	Proportionate	Proportionate	46.47
59	Logarithmic	Proportionate	Linear	36.99
60	Logarithmic	Proportionate	Logarithmic	20.79
61	Logarithmic	Exponential	Exponential	49.05
62	Logarithmic	Exponential	Proportionate	42.33
63	Logarithmic	Exponential	Linear	32.85
64	Logarithmic	Exponential	Logarithmic	16.65

These stringency levels for different 64 scenarios are based upon Logarithmic model under certain assumptions. However, as per this table, the easing of stringency level should not be as per lobbying and influence but strictly by observing and monitoring the growth rates of infections (cumulative), recoveries (cumulative) and deaths (cumulative). The relevant Government officials should monitor the growth rates of all these 3 variables daily and project it into the future. If there are significant deviations in these projections then the Government should again strengthen the stringency level of lockdown if it has been eased earlier.

India should decide on the stringency level of lockdown on an ex-ante basis that is projecting the growth rate of infections (cumulative), recoveries (cumulative) and deaths (cumulative) from the past data and then deciding as per projections. If India decides it on an ex-post basis i.e. only based on the availability of data and not projecting it into the future then all past efforts may go in vain. India during this emergent time should not be influenced by mass public opinions and lobbyist and must decide on the rational and logical basis

With the help of the logarithmic equation, we are able to prescribe a quantitative approach for the management of lockdown in India. We have focused on the stringency level of lockdown which ranges from 0% to 100%. This quantitative approach, when combined with other qualitative approaches, can produce favourable outcomes. Secondly, the quantitative approach will result in more rationality amidst this crisis and is more beneficial and reliable amidst this crisis.

Conclusion

COVID–19 is a disease that is caused by SARS-CoV-2 virus. It is highly contagious and it originated in Wuhan, China in December 2019 but now the number of cases globally has crossed the mark of 1.8 million as on April 14, 2020. Since this disease is caused by new virus i.e. SARS-CoV-2, there is no specific vaccine or drug invented hitherto for the prevention and treatment of COVID–19. As this disease is highly contagious, different countries have adopted different strategies to contain the spread of COVID–19. These strategies include the closure of schools/colleges, complete lockdown, partial lockdown, selective lockdown, bans on gatherings, closures of international borders, rigorous screening programs, isolation of infected persons etc. Some countries have simultaneously adopted different strategies to counter the crisis of COVID – 19 Pandemic. All these strategies are adopted to flatten the growth of COVID – 19 and some countries are more successful than others in flattening the growth of COVID – 19 Pandemic.

India was aware of the highly contagious nature of this disease so it took early steps for containment of this disease. Initially, Schools/Colleges were closed and then finally 21 days lockdown was imposed from March 25, 2020, which then further extended to May 3, 2020. Through lockdown in early stages, India successfully contained the COVID – 19 and brought down the growth rate of infections (cumulative) from exponential growth to the proportionate growth. On the other hand, the rate of growth

of recoveries (cumulative) demonstrated exponential growth rate which further benefitted India. The deaths (cumulative) is also showing a proportional growth rate which is another good sign for India. We also estimated infections (cumulative), recoveries (cumulative) and deaths (cumulative) through regression analysis in Eviews software by adopting GMM methodology.

The stringency level of lockdown depends upon the growth rates of infections (cumulative), recoveries (cumulative) and deaths (cumulative). We developed 64 scenarios and then determine the stringency level for each scenario based on upon Logarithmic model under certain assumptions. However, these 64 scenarios are not exhaustive and there could be more scenarios.

Findings of the Study

The findings of our study are as follows:

- The growth rate of infections can be controlled effectively by imposing lockdown.
- We have been able to prove that lockdown can control the growth rate of infections (cumulative) with the help of robust econometric frameworks.
- We identify different breaks through the study of graphs and thereafter these breaks help us in estimating the values of infections (cumulative), recoveries (cumulative) and deaths (cumulative) on a highly reliable basis.
- We found out at least 64 different scenarios for COVID – 19 Pandemic.
- We also determined the stringency level of lockdown required under these 64 different scenarios using quantitative approach.
- However, these 64 different scenarios are not exhaustive and there can be more scenarios than these 64 scenarios.

Contributions of the Study

The main contributions of this study are as follows:

- We used robust econometric framework such as regression analysis with GMM methodology to determine the growth rates of infections (cumulative), recoveries (cumulative) and deaths (cumulative).
- We used almost all types of equations that is Log-Lin, Double Log, Linear and Lin-Log for estimating the values of infections (cumulative), recoveries (cumulative) and deaths (cumulative).
- We developed a quantitative approach towards management of Lockdown amidst COVID – 19 Pandemic.
- Our quantitative approach towards management of Lockdown amidst COVID – 19 Pandemic is based upon Logarithmic model and is more reliable than pure qualitative approaches.

Policy Recommendations of the Study

The policy recommendations of this study are as follows:

- As the present crisis of COVID – 19 is very severe, therefore relevant authorities must focus on the quantitative approach developed in this study to supplement its decision making in respect of the management of lockdown amidst of COVID – 19.
- This quantitative approach is ex-ante. Hence the relevant authorities must project the infections (cumulative), recoveries (cumulative) and deaths (cumulative) into future daily and if there is a significant difference between the present and previous projections then immediate action must be taken to decide stringency level of lockdown as per quantitative approach developed in this study.
- It is time to act in a highly rational manner. Quantitative approaches are more rational than Qualitative approach. Thus with the help of this quantitative approach, the relevant authorities can tackle the present situation more logically and reliably.
- If relevant authorities are working as per public opinions and persuasion of lobbyist then it is highly probable that COVID – 19 Pandemic can increase in India at very high alarming rate thereby wasting our past efforts also.

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