

## Trajectory of the Pandemic in India through phases of Lockdown & Comparison with other countries

*The spread of Covid-19 in India: infection rate, death rate and recovery rate. What is the impact of lockdown and its relaxation on these?*

*Where is India compared to countries worldwide in terms of curbing the virus trajectory?*

### Introduction:

Day by day as the deadly virus takes in more and more into its grip, we want to see how the infection, death and recovery rates have progressed over time. Lockdown is considered to be an effective measure in slowing the spread of Covid-19 around the globe. India, China, France, Italy, New Zealand, Poland and the UK have implemented the world's largest and most restrictive mass quarantines. In this report we focus on **lockdown and its relaxation in India** and model the infection, death and recovery scenarios. Subsequently we also do exploratory data analysis of progression of infection rates by comparing a set of countries which have adopted contrasting approaches to that of India and in the next report we will formally evaluate the impact of various interventions and country specific characteristics on the trajectory.

### Looking at the lockdown phases of India:

- Government of India took initial measures as partial lockdown in mid March.
- On 24 March 2020, the Government of India ordered a nationwide lockdown for 21 days, limiting movement of the entire 1.3 billion population of India as a preventive measure against the COVID-19 pandemic in India.
- It was ordered after a 14-hour voluntary public curfew on 22 March, followed by enforcement of a series of regulations in the country's Covid-19 affected regions.
- The lockdown was placed when the number of confirmed positive corona virus cases in India was approximately 500.
- Following is the **detailed list of lockdown phases in India:**

PHASE & TIME PERIOD	MEASURE	COMMENTS
Phase 0: 16 March 2020 - 24 March 2020	Partial lockdown	Closure of selected public institutions such as museums (incl. Taj Mahal) until March 31 and postponement of several local elections
Phase 1: 25 March 2020 – 14 April 2020 (21 days)	Full Lockdown	Complete lockdown of entire nation for 21 days. Agriculture-Farming and allied activities exempted from Lockdown (announced 3/28)
Phase 2: 15 April 2020 – 3 May 2020 (19 days)	Partial Lockdown	On 14 April, Prime minister Narendra Modi extended the nationwide lockdown until 3 May, with a conditional relaxations after 20 April for the regions where the spread had been contained or was minimal.
Phase 3: 4 May 2020 – 17 May 2020 (14 days)	Partial Lockdown	On 1 May, the Government of India extended the nationwide lockdown further by two weeks until 17 May. The Government divided all the districts into three zones based on the spread of the virus—green, red and orange—with relaxations applied accordingly.
Phase 4: 18 May 2020 – 31 May 2020 (14 days)	Partial Lockdown	On 17 May, the lockdown was further extended till 31 May by the National Disaster Management Authority.
Phase 5 : 1 June 2020 – 30 June 2020 (30 days)	Unlock 1.0	On 30 May, it was announced that the ongoing lockdown would be further extended till 30 June in containment zones, with services resuming in a phased manner starting from 8 June. It is termed as "Unlock 1"
Phase 6 : 1 July 2020 – 31 July 2020 (31 days)	Unlock 2.0	The second phase of unlock, Unlock 2.0, was announced for the period of 1 to 31 July, with more ease in restrictions.

## Exploratory analysis of impact of the lockdown phases on the trajectory of Covid-19:

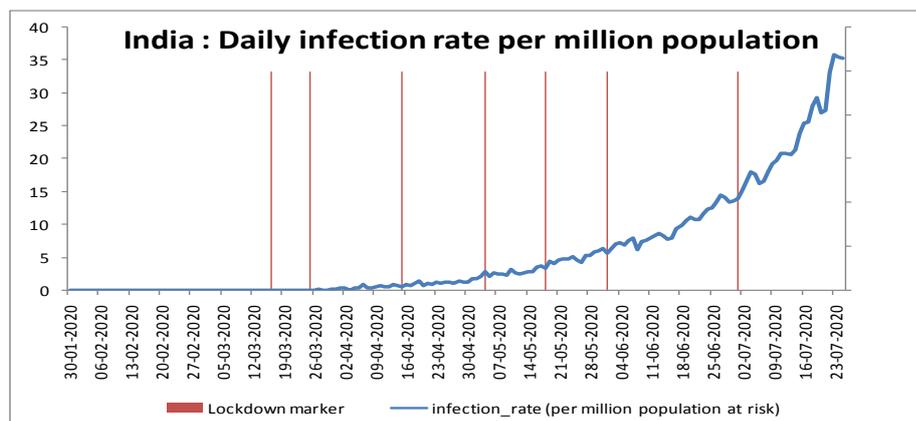
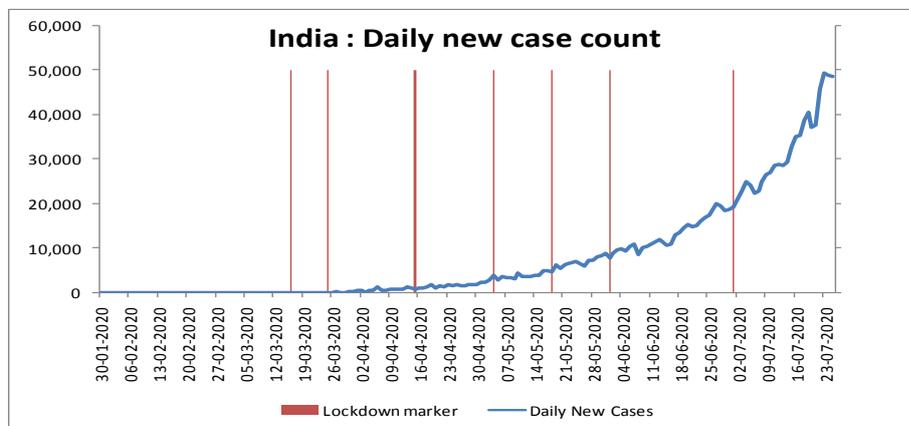
Having identified the various phases of the lockdown we try to understand the effects of these on the following trajectories –infection, death and recovery rates. It is also important to interpret these **trends with respect to relaxation of lockdown and opening up of inter-state traffic**. The first move towards this has been renewal of train operations. Some pointers on this as follows:

- On **April 29**, the government had issued an order allowing inter-state movement of stranded migrant workers, tourists, and students. However, the order had only allowed movement by buses. Trains were allowed for this purpose from May 1.
- Indian Railways had **operated its first special train for migrant workers** on **May 1** as a pilot project which started its journey to Jharkhand from Telangana, had carried around 1,200 migrants.
- State-run Indian Railways has run **Shramik Special trains** for inter-state movement of migrant workers and Uttar Pradesh and Bihar have taken in the maximum number of migrants back.
- Indian Railways decided to partially resume passenger train services from May 12 and the bookings for these special trains (travelling to major stations with selective stoppages) started from May 11.
- The Railways also began running 200 passenger trains from June 1 (in addition to earlier migrant trains).

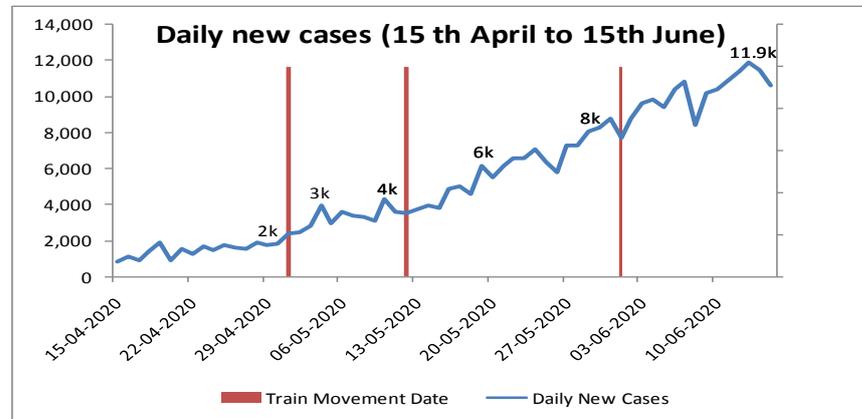
## Modelling trajectory of the pandemic with respect to lockdown phases:

### 1. Daily new infection rate per million population at risk with respect to lockdown/unlock phases:

Following are views of daily infection count and rate in India from 30<sup>th</sup> Jan with days where there was an intervention relating to lockdown is taken marked in bars:



- The daily new case counts in India is increasing at a fast pace. As of 25<sup>th</sup> July daily case mark is in 40k as in the unlock 2.0 phase.
- When the first partial lockdown was introduced the daily case count was below 50 and before full lockdown was introduced, the daily case count had just touched a little more than 100.
- The new infection rate per million populations at risk is currently around 30 as of July 25<sup>th</sup>.



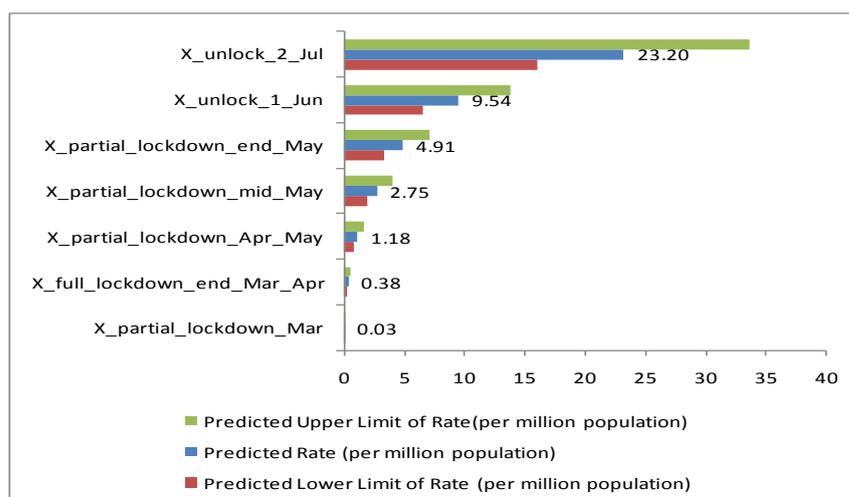
- After migrant trains and passenger trains started running in addition to lockdown relaxations from May there have been spikes in daily cases. Looking at the above picture, there is a shift in daily cases after first train movement on 1st May with two peaks before 12<sup>th</sup> May when passenger trains started running. After that there have not been sudden peaks but case counts reached 8k and after more trains started running from June case counts reach almost 12k.
- We fit a Poisson regression of the daily new confirmed Covid-19 cases in India on the following dummies:

Dummy Variable	Start	End
X_partial_lockdown_Mar	16-Mar	24-Mar
X_full_lockdown_end_Mar_Apr	25-Mar	14-Apr
X_partial_lockdown_Apr_May	15-Apr	03-May
X_partial_lockdown_mid_May	04-May	17-May
X_partial_lockdown_end_May	18-May	31-May
X_unlock_1_Jun	01-Jun	30-Jun
X_unlock_2_Jul	01-Jul	31-Jul

We use as offset, the population currently at risk (defined as India's population minus the recoveries and deaths up to that point). This leads to the following results:

Phase-wise Regression Model Output for infection rate			
Dummy Variable/ Phase	Predicted Rate (per million population)	Predicted Lower Limit of Rate (per million population)	Predicted Upper Limit of Rate(per million population)
X_partial_lockdown_Mar	0.03	0.02	0.05
X_full_lockdown_end_Mar_Apr	0.38	0.26	0.55
X_partial_lockdown_Apr_May	1.18	0.82	1.71
X_partial_lockdown_mid_May	2.75	1.90	3.98
X_partial_lockdown_end_May	4.91	3.40	7.11
X_unlock_1_Jun	9.54	6.59	13.80
X_unlock_2_Jul	23.20	16.04	33.56

**Insights:** The following is a pictorial view of the table before:



- The predicted infection rate per phase is constant as we have used phase-wise constant value of regressor from dummy variables. Comparing consecutive phases, infection rate per million populations is always non-decreasing.
- In terms of % increase between phases the highest is in the month of March i.e. from March mid March phase to full lockdown.
- As of end July, in the unlock 2.0 phase, the predicted infection rate is 23 per million population.

**Did lockdown significantly change the rate or did unlock phase increase rate and if so how much?**

Phase Rate Ratio	Exponential of difference between phase estimates	Exponential of difference between LCL	Exponential of difference between UCL
"FL_end_Mar_Apr" vs "PL_Mar"	1.4	1.3	1.6
"PL_Apr_May" vs "FL_end_Mar_Apr"	2.2	1.7	3.2
"PL_mid_May" vs "PL_Apr_May"	4.8	3.0	9.7
"PL_end_May" vs "PL_mid_May"	8.7	4.5	22.7
"Unlock_1" vs "PL_end_May"	102.2	24.5	805.7
"Unlock_2" vs "Unlock_1"	8,59,126.9	12,662.7	3830,85,944.6

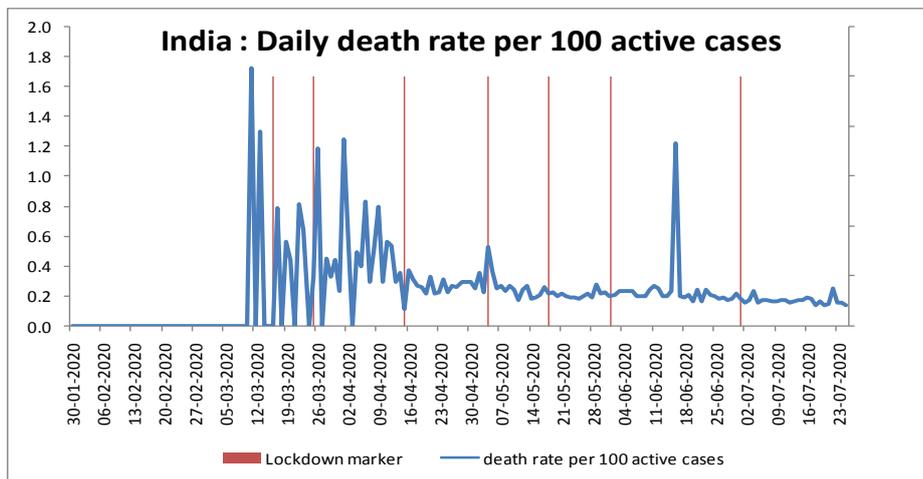
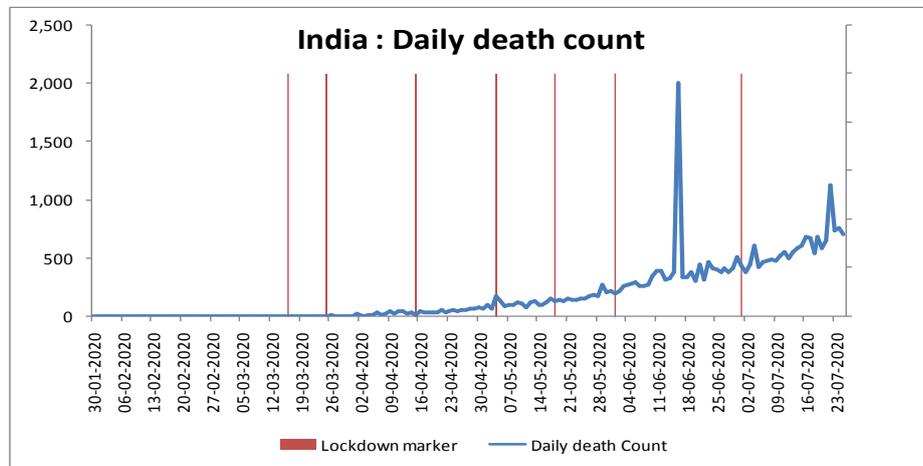
For ease of viewing partial lockdown and full lockdown are abbreviated as PL and FL respectively.

Numbers are obtained from estimates of infection rate per million populations in previous table.

For all the consecutive phase comparisons there is an increasing trend. In the comparison of lockdown phases, be partial or full, the difference in the exponential of phase estimates or CIs is not that high as compared to that in the unlock phases. The jump from Unlock 1 to Unlock 2 is really high indicating huge increase in infection rate in the second instalment of unlocking.

## 2. Daily death rate per 100 active cases with respect to lockdown/unlock phases of India:

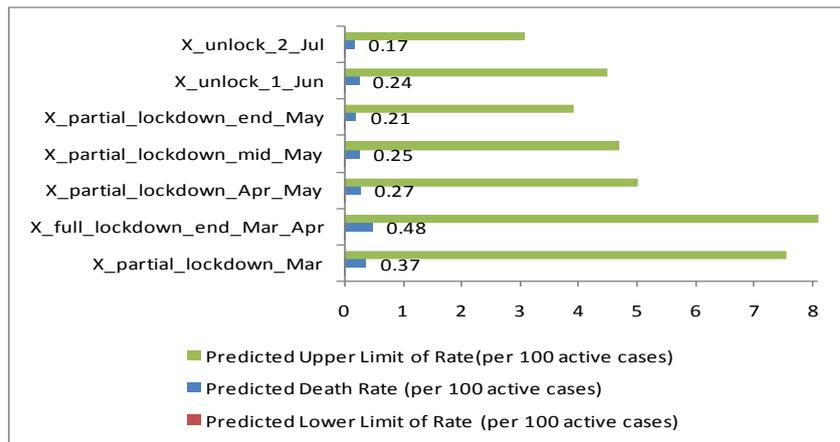
Following are views of daily death count and death rate due to Covid-19 in India from 11<sup>th</sup> Mar i.e. the day of the first death, with days where there was an intervention relating to lockdown is taken marked in bars:



- The daily death counts in India are on the rise strictly from end April with sharp peak is seen in the beginning of May and end of May.
- In unlock 1 phase in June the situation got worse with death toll in 400s and there is a huge spike of over 2,000 deaths on 16<sup>th</sup> June.
- The death rate per 100 active cases in the unlock 2 phase is on an average 0.16, better than unlock 1.
- A similar Poisson regression leads to the following results:

Phase-wise Regression Model Output for death rate			
Dummy Variable/ Phase	Predicted Death Rate (per 100 active cases)	Predicted Lower Limit of Rate (per 100 active cases)	Predicted Upper Limit of Rate (per 100 active cases)
X_partial_lockdown_Mar	0.37	0.02	7.56
X_full_lockdown_end_Mar_Apr	0.48	0.03	8.84
X_partial_lockdown_Apr_May	0.27	0.01	5.03
X_partial_lockdown_mid_May	0.25	0.01	4.69
X_partial_lockdown_end_May	0.21	0.01	3.91
X_unlock_1_Jun	0.24	0.01	4.48
X_unlock_2_Jul	0.17	0.01	3.09

**Insights:** The following is a pictorial view of the above table:



➤ The predicted death rate increased initially then after full lockdown decreased continuously (except that in unlock 1) with predicted rate being 0.17 out of 100 active cases in unlock 2 phase.

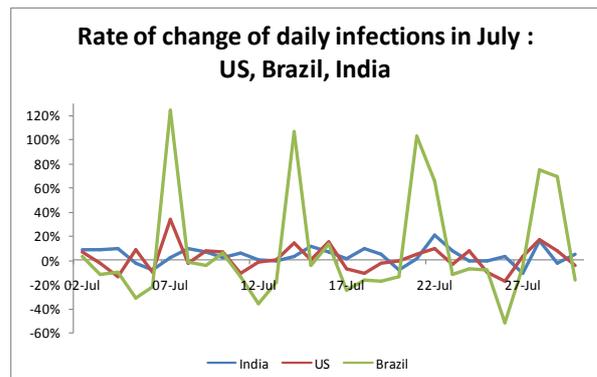
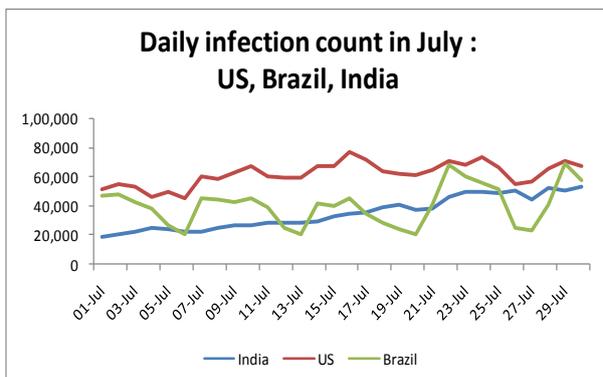
**Did lockdown significantly change the rate or did unlock phase increase rate and if so how much?**

Phase Rate Ratio	Exponential of difference between phase estimates	Exponential of difference between LCL	Exponential of difference between UCL
"FL_end_Mar_Apr" vs "PL_Mar"	1.11	1.01	3.58
"PL_Apr_May" vs "FL_end_Mar_Apr"	0.82	0.99	0.02
"PL_mid_May" vs "PL_Apr_May"	0.98	1.00	0.72
"PL_end_May" vs "PL_mid_May"	0.96	1.00	0.46
"Unlock_1" vs "PL_end_May"	1.03	1.00	1.77
"Unlock_2" vs "Unlock_1"	0.93	1.00	0.25

For all the consecutive phase comparisons of rate ratios there is no significantly large change. From the rate ratio of pre full lockdown to full lockdown there is highest change implying significant drop in death rate after lockdown and subsequently all the exponentials are around 0.9.

**Comparison of India with other countries:**

While India has traversed through numerous lockdown and unlock phases since March, there are countries that have not followed others in locking down their residents and countries that have mostly relied on improved healthcare, adopted measures like mass testing and rigorous tracking of the virus. As of July end, India is at the 3<sup>rd</sup> position in the world in terms of total cases and the daily infections in India is increasing at a very fast pace. In comparison with the two countries above India in the list (USA and Brazil) following is the view at rate of increase of daily infections:



7 day moving average of growth rate of daily infections			
Date Range	USA	Brazil	India
03 Jul - 09 Jul	3.1%	6.0%	6.5%
10 Jul - 16 Jul	3.3%	7.6%	2.3%
17 Jul - 23 Jul	-1.4%	11.9%	5.5%
24 Jul - 30 Jul	0.4%	8.0%	0.4%

- Rate of change of daily infection are higher for Brazil than India and US.
- Looking at the 7 day moving averages in the table above, at the last week of July India is at par with USA as compared to the position in the beginning of July where India's value was 6.5 and that of USA was 3.1.
- Looking at India itself, there is quite a decrease in the last week of July that the week before from 5.5% average rate of change in daily infections to that of 0.4%.

## What are the broad types of responses from countries worldwide?

To get a comparative view of the pandemic trajectories in different countries, we categorise them as follows:

### 1. Early and full lockdown

**China:** The origin of the virus being Wuhan and also, with the world's largest population of 1.4 billion, China was totally unprepared at first, but imposed strict lockdown later with quarantine in Wuhan City and later extended it to 15 other cities. Here's a look at timelines of how the pandemic started and evolved:

- **Early infections of Covid-19 in China: December, 2019**  
In Dec 2019 Govt in Wuhan confirmed that the health authorities were treating dozens of cases of pneumonia of unknown cause, detected in Wuhan City, Hubei Province of China.
- **Isolation of the virus: 7<sup>th</sup> January 2020**  
The Chinese authorities identified a new type of corona virus and shared the genetic sequence of the novel corona virus for countries to use in developing specific diagnostic kits.
- **First death in China: 11<sup>th</sup> January**  
The 61-year-old man W.H.O. died was a regular customer at the market in Wuhan. The report of his death came just before one of China's biggest holidays, when hundreds of millions of people travel across the country.
- **Other countries confirmed cases: 20<sup>th</sup> January**  
The first confirmed cases outside mainland China occurred in Japan, South Korea and Thailand, according to the W.H.O.'s first situation report.
- **Lockdown in Wuhan: 23<sup>rd</sup> January (total cases 830)**  
The Chinese authorities closed off Wuhan, a city of more than 11 million, by cancelling planes and trains leaving the city, and suspending buses, subways and ferries within it.
- **Declaration of global health emergency by W.H.O.: 30<sup>th</sup> January**  
Amid thousands of new cases in China, a "public health emergency of international concern" was declared officially by the W.H.O.
- **First death outside China: 2<sup>nd</sup> February**  
A 44-year-old man in the Philippines died after being infected, reported by officials as the first death outside China.
- **The disease the virus corona virus causes was named Covid-19 by W.H.O. on 11<sup>th</sup> February 2020.**

**India:** With a huge population (1.3 billion) and high population density, India acted early with airport screening as early as mid January followed by several phases of full and partial lockdown:

- **First infection: 29<sup>th</sup> January**
- **Partial lockdown (institutional closure) started: 16<sup>th</sup> March (total cases 129)**
- **Full lockdown started: 25<sup>th</sup> March (total cases 500-600)**

However, the testing rate was initially really low and as per W.H.O. 13k per million population as of end July.

**Vietnam:** Although a developing country with 97million population and bordered by China, Vietnam's government was able to create a success story in fighting the pandemic mainly due to early awareness generation and the following numbers (as of end July) reflect these:

- **Total Covid-19 cases: 509**
- **Total Deaths: 1**
- **Total Recovered: 373**

## 2. Locked down at an intermediate stage

**Italy:** Even after country saw surge in cases there was late government response in terms of measures to isolate affected areas and limit the movement of the broader population. One factor affecting the country's death rate may be the age of its population as Italy has the oldest population in Europe - Population ages 65 and above (% of total) in Italy was reported at 22.75 % in 2018, according to the World Bank collection of development indicators, compiled from officially recognized sources.

- **First infection: 30<sup>th</sup> January**
- **Lockdown started: 8<sup>th</sup> March (total cases 7,380)**

**France:** France was slow in imposing lockdown, sluggish in building up its testing capacities and responding to shortages of face masks and other personal protective equipment but later improved and as of July end testing rate is 45 thousand per million populations as per W.H.O.

- **First infection: 24<sup>th</sup> January**
- **Lockdown started: 17<sup>th</sup> March (total cases 7,730)**

**UK:** Initially UK counted on herd immunity (letting a large percentage of the healthy population be infected in order to prevent it from spreading to the most vulnerable) as a response to the pandemic but later took lockdown measures as total infections went up and the death toll started rising.

- **First infection: 31<sup>st</sup> January**
- **Lockdown started: 23<sup>rd</sup> March (total cases 6,030)**

## 3. Adoption of mass testing policies and improved healthcare measures:

**South Korea:** With a population of 51million, South Korea relied on widespread data collection, efficient and effective contact tracing, ramping up testing and surveillance to fight the spread of the virus.

- **First infection : 20<sup>th</sup> January**
- **No lockdown**
- **Testing rate per million population: 30 thousand (July end as per W.H.O.)**
- **Total confirmed cases as of July end : 14 thousand**

**UAE:** With a population of 9.8 million, the UAE has a very high testing rate. The UAE strategy of taking early steps to contain the virus, including rigorous testing and contact tracing of cases along with lockdown measures, has been praised internationally. As early as end January, the Dubai Health Authority (DHA) directed all DHA-licensed hospitals to consider all suspected and confirmed cases as emergencies and **patients are to be treated free of charge**, including those without insurance.

- **Health screening at airports (Abu Dhabi, Dubai International): 23<sup>rd</sup> January**
- **First infection : 29<sup>th</sup> January**
- **Lockdown started: 26<sup>th</sup> March (total cases 333)**
- **Testing rate per million population: 317 thousand (July end as per W.H.O.)**

**Germany:** With really good and properly funded health-care system and being home to many laboratories that can test for the virus, Germany has been well appreciated in its response to the pandemic. Germany has a common **National Pandemic Plan** with three stages: **Containment** (circumstances of dedicated cases and clusters), **Protection**

(circumstances of further spreading infections and unknown sources of infections) and **Mitigation** (circumstances of widespread infections).

- **First infection : 27<sup>th</sup> January**
- **Awareness health campaign : 6<sup>th</sup> February**
- **Lockdown started: 21<sup>th</sup> March (total cases 22 thousand)**
- **Testing rate per million population: 95 thousand (July end as per W.H.O.)**

#### **4. Advantages of very small population and/or able to declare Covid-19 free (at least once)**

**New Zealand:** With a very small population of 5m, New Zealand adopted high testing rates and responded well to the crisis and are still maintaining border closures. The country was declared Covid-19 free on 1<sup>st</sup> June 2020.

- **First infection : 28<sup>th</sup> February**
- **As of July end: Total cases 1.5 thousand and total deaths 22.**
- **Testing rate per million population: 92 thousand (July end as per W.H.O.)**

**Estonia, Iceland, Malta and Mauritius:** These countries have high testing rates but also their very small population sizes which have given them an added advantages of containing the spread. Other small countries to declare virus free at least once are Monaco (French), Montenegro (European), Eritrea (East African), Papua New Guinea (Pacific nation), Seychelles (East Africa), Holy See (Rome), Saint Kitts and Nevis (West Indies nation), Fiji, East Timor (south-east Asia) etc.

#### **5. Late response to the pandemic and/or no lockdown**

**USA:** As of July end, the USA remains the country with the most confirmed cases. Response to the pandemic varied from state to state and was famously characterized by an explosion of cases in the state of New York before lockdown was imposed. Several states did not impose lockdown and internal travel was generally unrestricted.

- **First infection : 20<sup>th</sup> January**
- **Health screening at airports: 14<sup>th</sup> March**
- **Partial lockdown in some states started: 23<sup>rd</sup> March (total cases 44 thousand)**
- **Death toll reaches highest in the world, surpasses Italy: 11<sup>th</sup> April (total deaths >20 thousand)**
- **Total confirmed cases surpassed 1 million : 28<sup>th</sup> April**

**Brazil:** South America's largest country with death toll surpassing that of Italy had a very late and un-coordinated government response to the pandemic fearing economic downfall and reached the second highest number of confirmed cases in the world in June.

- **First infection: 26<sup>th</sup> February**
- **Partial lockdown: 7<sup>th</sup> May (total cases 135 thousand)**
- Several cities in the northern states of Amazonas and Pará began issuing lockdown measures in order to curb the spread of the virus.
- **Total confirmed cases surpassed 1 million: 19<sup>th</sup> June**

**Sweden:** Swedish government has not imposed any lockdown in the country and tried to focus efforts on encouraging the right behaviour and creating social norms rather than mandatory restrictions.

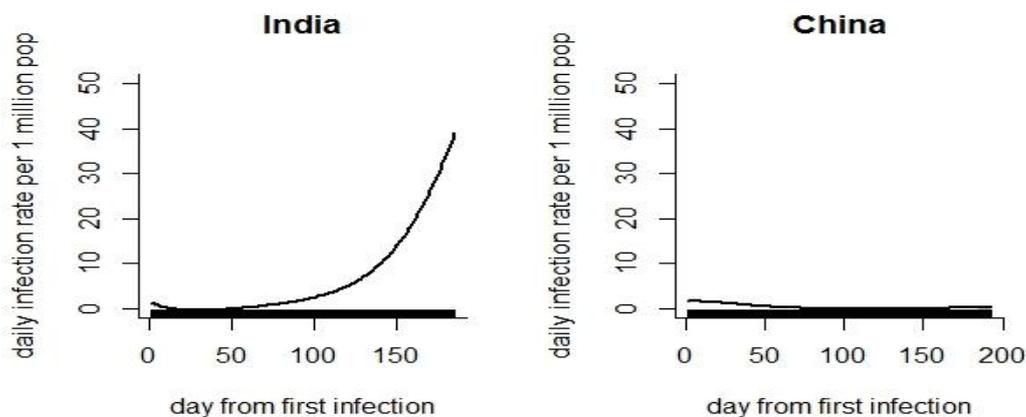
- **First infection: 31<sup>st</sup> January**
- **No lockdown**
- **Social distancing for people aged > 70 : 16<sup>th</sup> March (total cases : 1 thousand)**
- **Highest daily case count : 24<sup>th</sup> June (1.8 thousand)**
- **Testing rate per million population: 80 thousand (July end as per W.H.O.)**

## Comparisons with India:

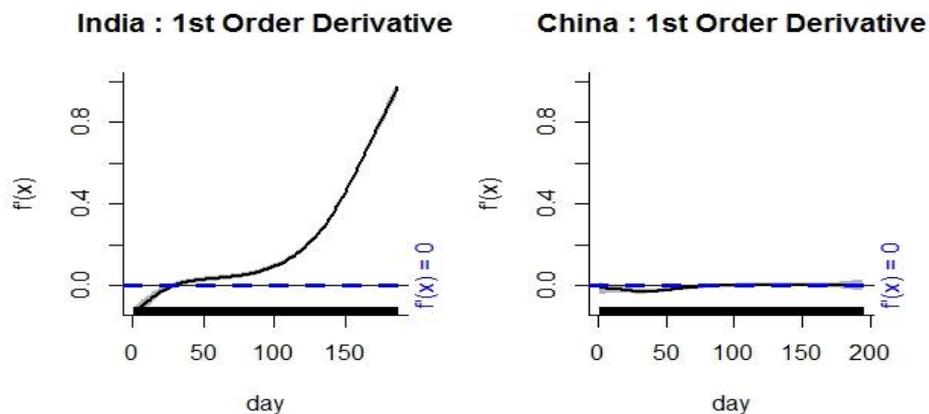
In this section, we use semi-parametric regression to model the **daily infection rate per million population** over time (starting from the day of first infection) and compare the results for India and some selected countries in terms of the estimated trajectories as well as the estimated first and second derivatives. The semi-parametric model allows us to test point-wise for the statistical significance of the first and second derivatives and hence to infer about significant changes in the infection rate. We use penalized splines of degree 5 to model the trajectories and a mixed model approach to smoothing using R package “SemiPar”.

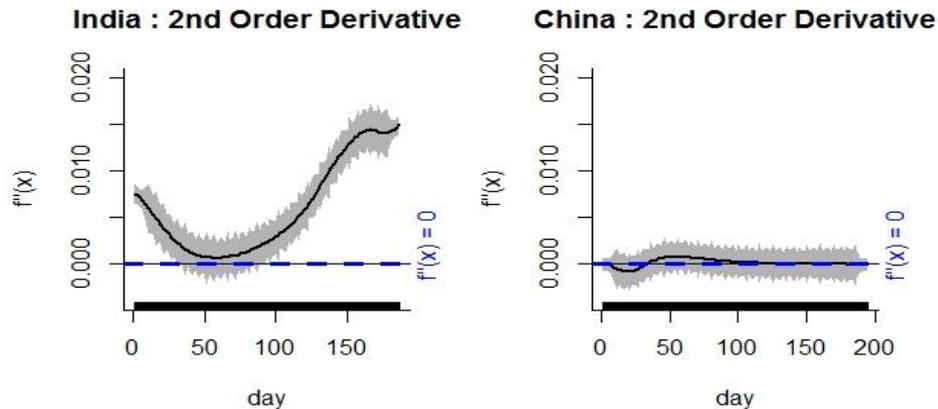
### India vs. China

The following plot shows the estimated trajectories of the daily infection rate per 1 million population for India and China together with point-wise prediction intervals.



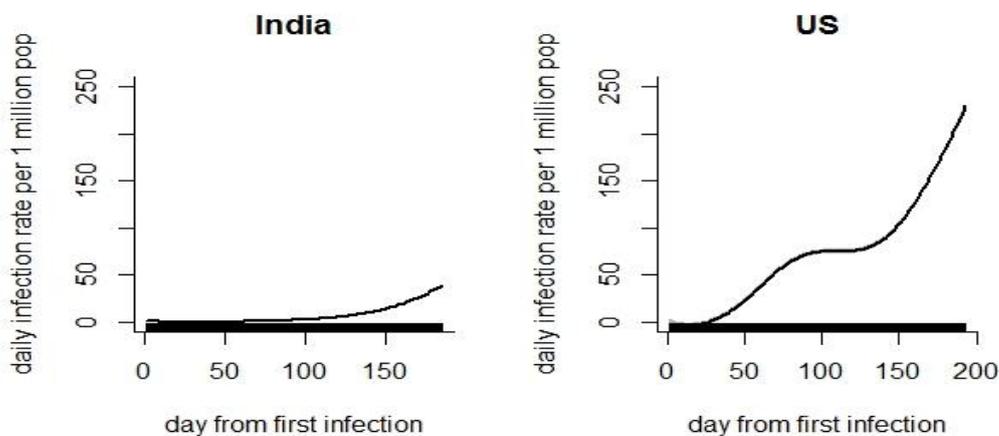
- India and China are the two countries of the world to have population in excess of 1 billion.
- Corresponding average population densities are 153 persons for China and 464 persons for India per square kilometre (as per worldometer population 2020).
- Both countries implemented total lockdown early in the course of the pandemic.
- The results suggest that while the infection rate for China reached the peak within a few days of the first confirmed infection and plateau-ed quickly, for India the infection rate has continued to rise.
- As of end July, the estimated infection rate per million is around 40 for India while for China since middle of March it's not significantly different from zero (with approximately less than 1 infection per million).
- The estimated infection rate for China is always less than 2 infections per million.





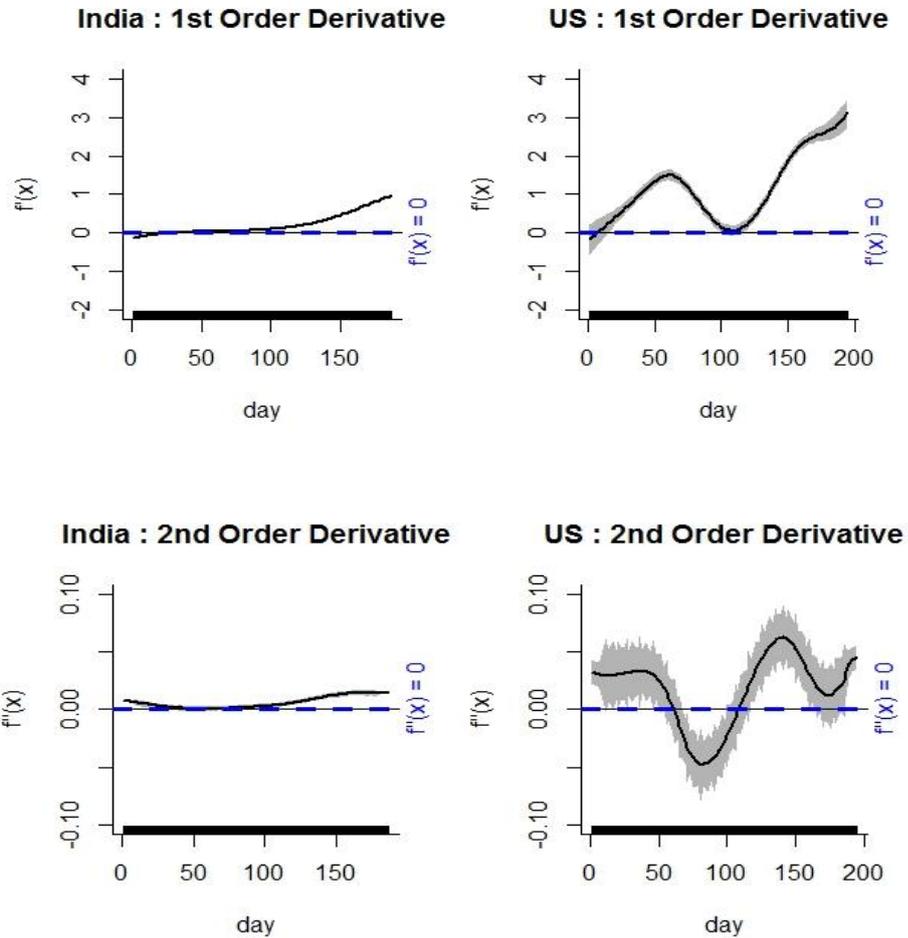
- For India, the estimated first order derivative becomes significantly different from zero at around day 49 (which was just before full lockdown around 18<sup>th</sup> March when partial movement restrictions were imposed) while for China, it remains insignificant throughout the course of the pandemic.
- The estimated second derivative for India remains significantly positive from about day 70 indicating that the growth rate has been increasing ever since. For China, the estimated second derivative is not significantly different from zero at any point indicating that the growth rate has effectively remained at zero from very early on in the course of the pandemic.

**India (early and complete lockdown) vs. US (late and partial lockdown):**



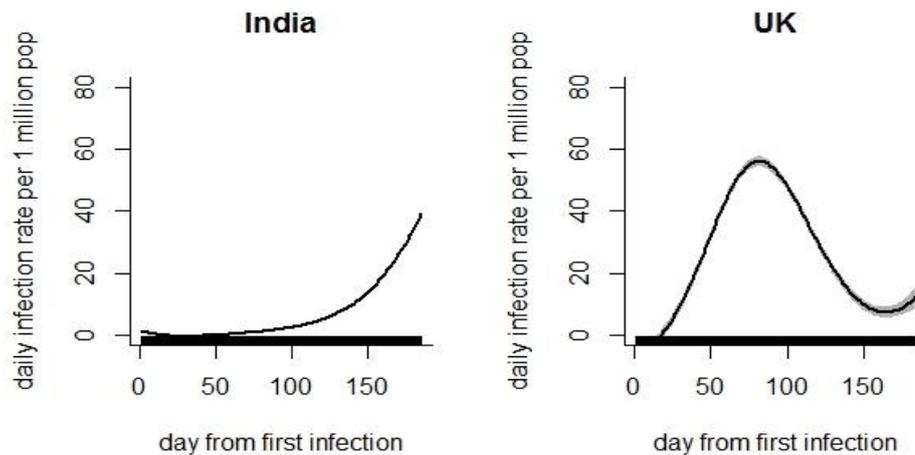
- The daily infection rate for both India and US are both on the rise.
- However, while the infection rate for India increases consistently to 14.4 cases per million on day 150 from first infection, the same for the US increases sharply to about 95.3 in the same period, a seven fold increase over India.
- The infection rate for the US is in fact higher than for any other country in the world.
- The estimated trajectory for the US appears to plateau between days 100-150 but subsequently explodes afterwards from end June.
- More than two third of the states which had gone on lockdown from end March started lifting lockdown restrictions after mid May and within a month from that explosion in daily infection rate is observed.
- **Although if we compare death rate, for India as of last week of July the daily death rate is on an average 13 out of 10 thousand active cases whereas that of US is 4 out of 10 thousand active cases.**
- **The above is because for India although the daily death in absolute numbers are lower but the denominator i.e. active population is a lot lower than that of US (around 600 thousand for India and around 4 million for US which is 7 times of India as of July).**

- The daily death rate started decreasing from May end for US (and became below 10 deaths per 10,000 active cases) while for India from end June death rate started decreasing (and became below 20 deaths per 10,000 active cases).
- In terms of total death rate (i.e. total deaths/total confirmed) as of July end for India it is 2.2% and for US it is 3.5%.



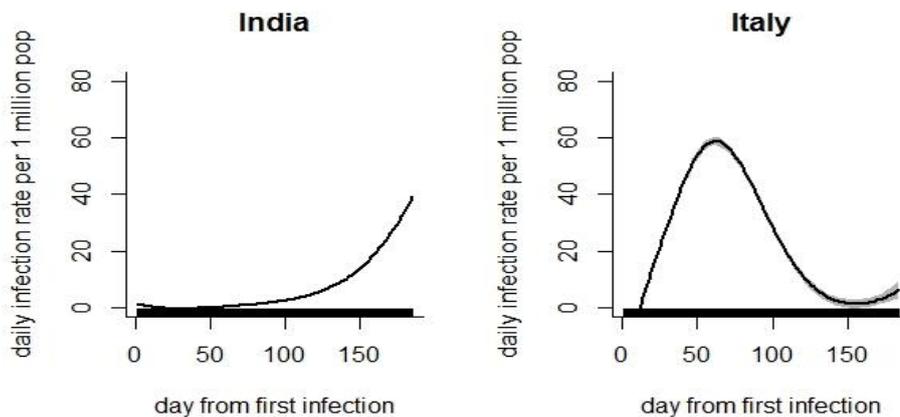
- The initial increase in rates followed by a decrease and a subsequent rapid increase is statistically significant as confirmed by the estimated first derivative.
- The estimated second derivative confirms that the rate at which the number of cases per million is increasing in the US is rapid and unchecked.

**India (early lockdown) vs. UK (initial approach of herd immunity then later lockdown):**



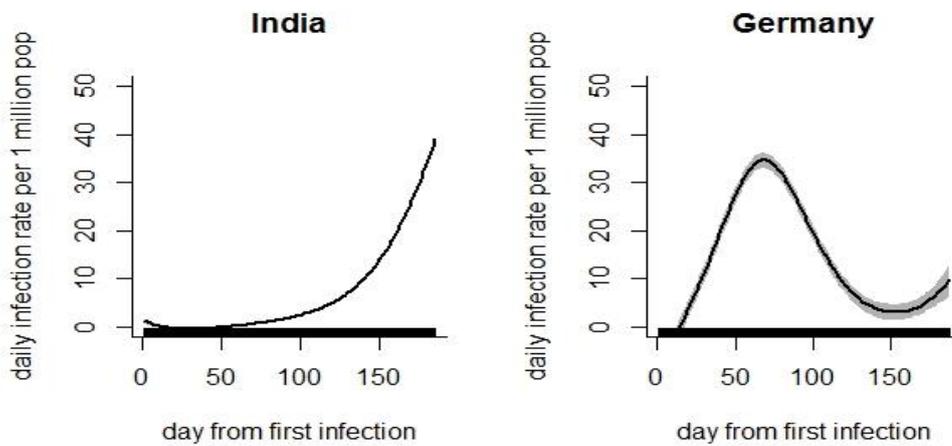
- For UK the infection rate is higher than India until about day 120.
- For the UK, the estimated infection rate reaches a high of about 60 per million population at around day 80.
- While the rate for India continues to increase, the rate for the UK decreases after around day 80. Note that the UK switched to the lockdown strategy from about 53.
- The current rate for the UK (as of end July) is as low as 11 per million population.
- The estimated first derivative is significantly negative for the UK after day 80. It remains negative subsequently but starts increasing after day 120. This increase is statistically significant as the estimated second derivative is significantly positive post day 120.

**India (young population, early lockdown) vs. Italy (ageing population, relatively late lockdown):**



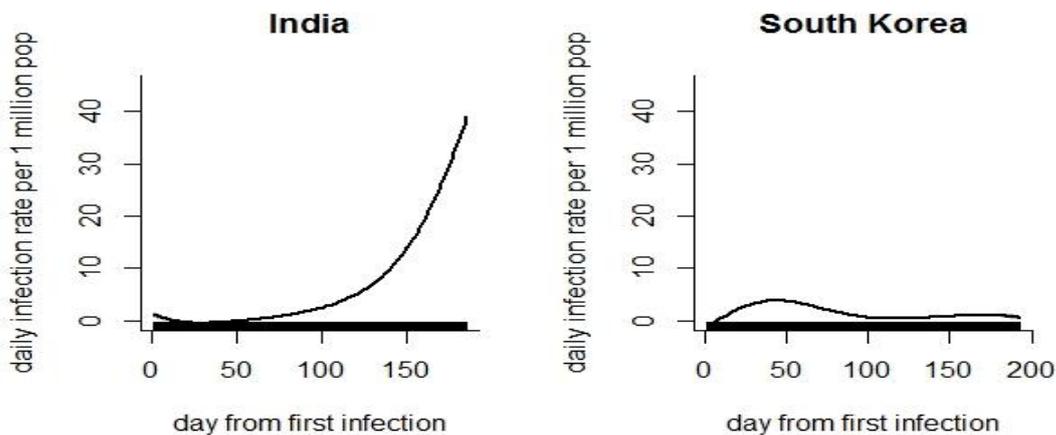
- The conclusions for the infection rate are similar as for the UK.
- **Looking at daily death rate of India vs. Italy, as of last week of July on an average for Italy there are 5 deaths out of 10 thousand active cases and that for India is 13.**
- **While infection rate was fast increasing and at the peak for Italy the daily death rate was more than 100 deaths per 10 thousand active cases, whereas since lockdown average daily death rate for India has been high in April (40 deaths on an average out of 10 thousand active cases) which then decreased in May and June (to around 20) and further decreased in July.**
- **In terms of total death rate, for India it is at 2.2% at July end, while that for Italy is 14%.**

**India (early intervention but initially limited healthcare and testing) vs. Germany (mass testing and a strong healthcare system):**



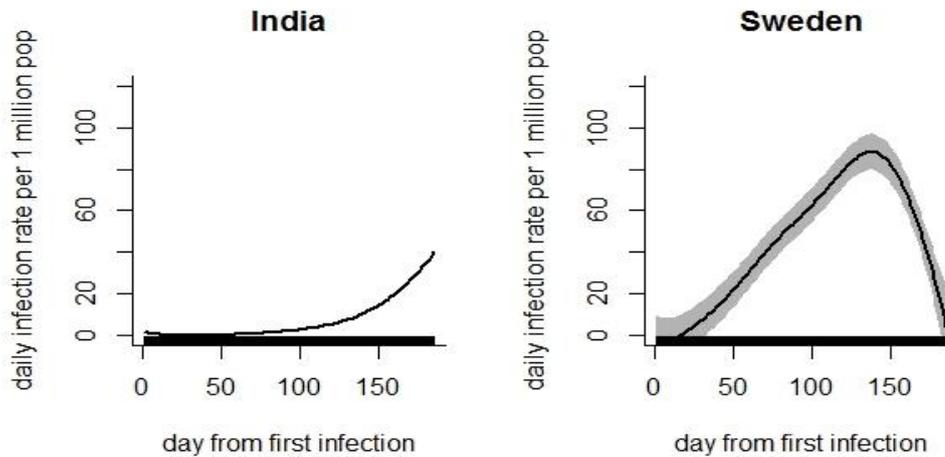
- The estimated infection rate for Germany is higher than for India until about day 100 indicating that India’s early action had an impact.
- However, the estimated first derivative for Germany indicates that the rate has been checked at around day 80 and has been significantly decreasing since then to a value of about 8 per million at day 120. There is however, some suggestion of a local increase towards the tail end which could either be due to a “tail effect” on estimation or due to the effect of relaxation of lockdown.

**India (early lockdown) vs. South Korea (mass testing but no lockdown):**



- The South Korean rate increases up to day 40 but shows a consistent and significant decline ever since.
- After day 100 which is after 1<sup>st</sup> week of May there is again an increase in infection rate, though not a sharp one, which remains more or less constant then starts to go down after day 190.
- Throughout, the estimated infection rate is never more than 5 per million population even without any lockdown strategies in place.
- **Comparing death rate, for South Korea daily death rate as of last week of July is on an average 4 out of 10 thousand active cases whereas that for India is 13.**
- **Total death rate for India and South Korea are similar at 2% at the same time.**

### India (early lockdown) vs. Sweden (no lockdown):



- Sweden did not adopt a lockdown policy but relied on social distancing.
- The infection rate for Sweden increased significantly throughout the pandemic until day 130. Beyond this, there is a decrease but not accompanied by a significantly negative first derivative.
- The estimated per million daily infection rate for Sweden is much higher as compared to that for India and reaches a peak of about 100 cases per million at day 130.
- **Looking at daily death rate, for Sweden the daily death rate at the end of July stands at an average of 1 death per 10 thousand active cases whereas that for India is 13 deaths.**
- **During the peak infection time for Sweden (end June to early July), the daily death rate stayed around 20 deaths per 10 thousand active cases.**
- **If we check the total death rate it is at 2% for India as compared to 7% for Sweden at the end of July.**

**Conclusion:** The pair-wise comparisons of India with seven other countries generally indicate the effectiveness of lockdown and early action as well as that of aggressive testing and contact tracing. In the next section, we will develop multivariate models to model the joint impact of various interventions on the infection and death trajectories.

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