The Curve is Certainly Flattening in Maharashtra:

The Saga of Covid-19 Infections

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Abstract:

Using daily state wise and district level data on the number of confirmed Corona infection cases, this paper argues on the basis of accepted techniques from epidemiology that contrary to public perception, the epidemic trajectory is slowly but surely flattening out in Maharashtra and Mumbai. It also places Maharashtra in a comparative perspective vis-à-vis other states. The paper also examines the progress of the various districts in Maharashtra. The paper ends with policy prescriptions for revamping urban housing policies that currently make our cities mega tinder boxes for epidemics.

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The Curve is Certainly Flattening in Maharashtra

India is now one of the worst Covid-19 affected countries in the world, with 1,25,101 cumulative cases as on 23rd May 2020. India is now only behind USA, Russia and Brazil as far as countries with active covid infections are concerned. Within India, the states of Maharashtra, Gujarat, Tamil Nadu, Delhi and Madhya Pradesh account for 73% of all cumulative infections. In particular, Maharashtra alone accounts for almost 36% of all cases in India at the time of writing. Hence, it becomes pertinent too do some deep dive into the big five states, and in particular Maharashtra. The country has been through three lock down stages, and has now entered the fourth lock down stage. The first three lockdowns in particular have been regarded as one of the world's most stringent. It becomes imperative to understand how the trajectory of Covid-19 infections has been influenced by these measures. India went into the first lock down on March 25, when many states had not experienced any substantive number of infections. We have restricted our analysis from the dates on which the respective states had at least 10 infections. Most states in our analysis did not have as many infections at the beginning of the first lock down. Due to this, we are unable to do a pre and post comparison for the first lock down. However, this did not remain a consideration later on, and we can analyze things well for lockdown phase 2 and later. We examine whether the trajectory of corona infections has been flattening for the five states. Given the large significance of Maharashtra, we also examine the sub regional, i.e. district level experience. Section 1 explains our methodology for deciding whether the curve has flattened. Section 2 examines the five states, and places them in comparative perspective with other states. Section 3 looks at what is happening at the district level in Maharashtra. Section 4 concludes the paper.

Section 1: Determining if the curve has indeed "flattened"

A lot of discussion has centered around the issue of whether the trajectory of corona infections has flattened. Most of the times, the phase is used rather loosely, without defining the exact meaning of the term. We start by defining the terms. We argue that infections like the corona virus spread through the community in an S shaped formation. That is, in the first phase, infection

growth rates are slow, accelerating subsequently, and finally slowing down till the growth stops. The following graph illustrates this:

Section 1:

We have been tracking the time series of infections in all countries in the world, on a daily basis for the last one month and more. We scrape all possible information, and build daily predictions models for various countries. These predictions are available at www.mu.ac.in/covid19lab. We also generate forecasts for the next three days for all major Indian states. Inn that process, we found that in countries which had stopped reporting new infections (Australia, Thailand, South Korea, New Zealand, China etc.), the time path of cumulative reported Covid-19 positive cases followed as S shaped curve. This is shown by the following figure:

Figure 1

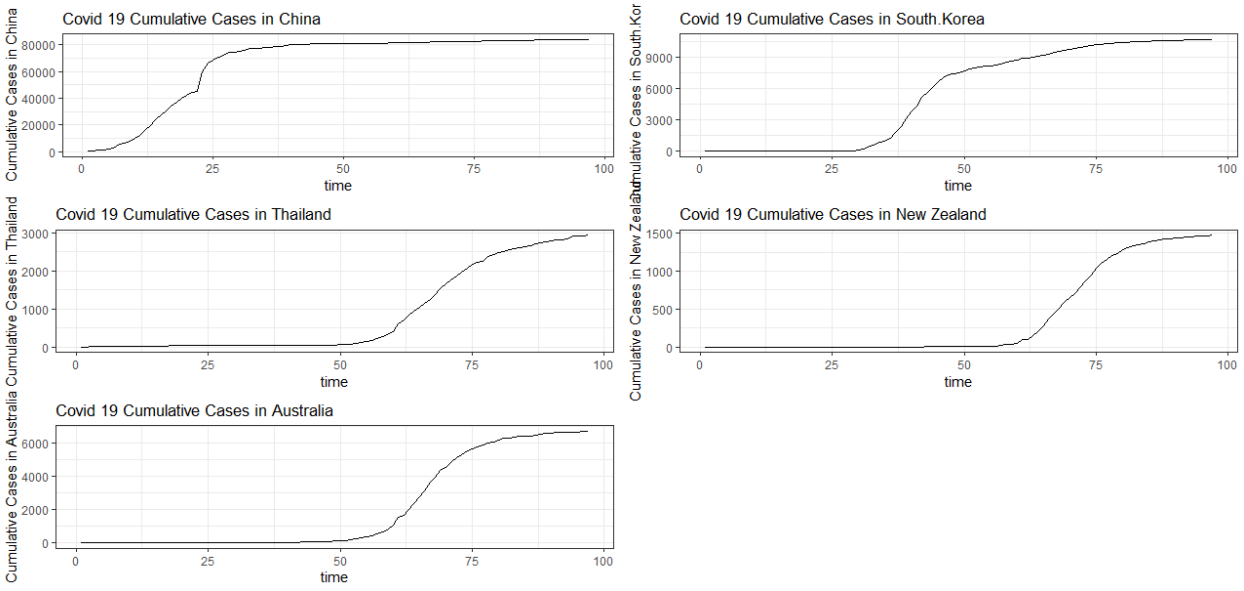


Figure 1 clearly indicates an "S" shaped curve, as countries reach their plateau, when new cases stop coming. This is very similar to the manner in which colonies of microorganisms grow in a limited environment. Assume we introduce a few bacteria into a bowl of milk. Initially, the rate of growth of new organisms will be small, then will explode very fast, and finally, given the limited resources, will eventually cease. At that time, the population of the organisms will stabilize, at a level called the "carrying capacity". We have used this model to estimate the eventual size of the

infected population in each state. Think of each state as a bowl of milk, and think of an infected person as a microorganism. The number of infected people will mimic the growth of the microorganism in the bowl of milk, and finally cease growing at a limit. This limit will be biological, but will also be set by the policies of social distancing, testing, contact tracing and quarantine. By limiting the spread, the final size of the population gets controlled.

The growth of the corona infections therefore, is not always 'exponential". It is exponential only in a phase, which invariably slows down. That is why the so called "doubling period" of infections growth keeps on lengthening. Mathematically, this model is described as the logistic curve, with the following equation:

$$N_t = \frac{K}{1 + \left(\frac{K - K_0}{N_0}\right) e^{-rt}}$$

Where N_t is the size of the infected population and time t, K is the carrying capacity, and r is the growth rate that would have been observed had there been no limitation on growth. The carrying capacity for a particular colony of organisms can be estimated through fitting a model through non-linear least squares.

The essential point is that growth rates for any closed region will have three distinct phases:

Phase 1: When the growth rate of cumulative infections is lower than the exponential growth rate, and is rising towards the exponential growth rate

Phase 2: When the growth rate of cumulative infections is higher than the exponential growth rate

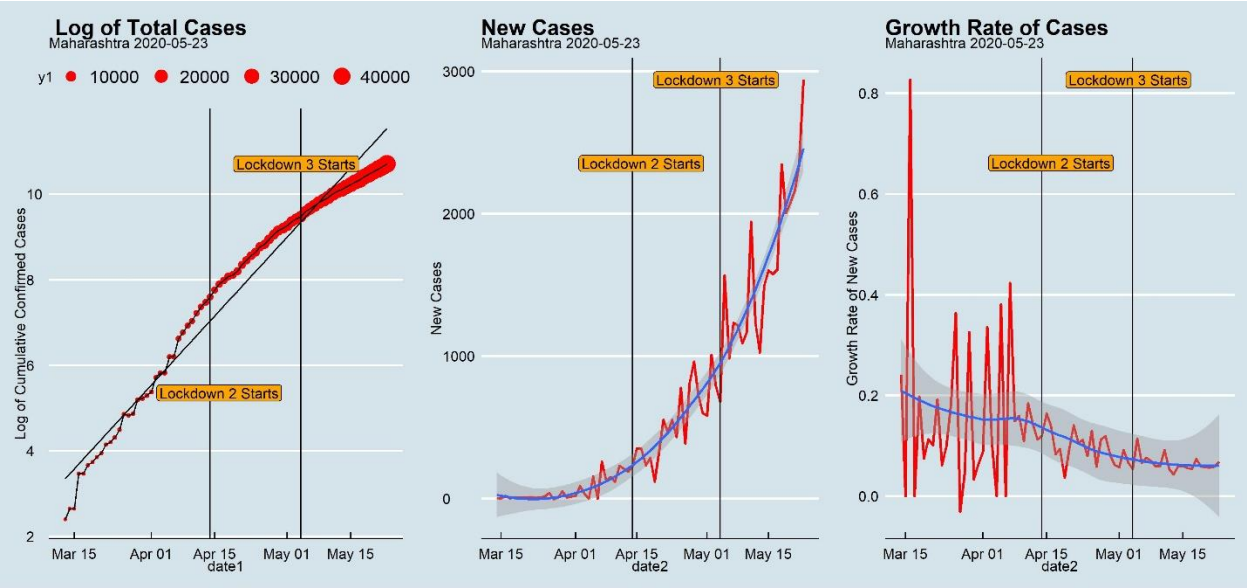
Phase 3: When the growth rate of cumulative infections is lower than the exponential growth rate and keeps on falling further finally going to zero.

We say that the trajectory of corona infections has started to flatten out when the trajectory goes from phase 2 to phase3. Section 2 examines the experience of Maharashtra in the light of this definition. It also places this experience in a comparative perspective with other states.

Section 2: What is happening to corona trajectory in Maharashtra?

Figure 1 captures the experience of Maharashtra. It examines the trajectory of the logarithm of cumulative cases, the time path of new cases and the time path of the rate of growth of new cases in Maharashtra from 12th March 2020 to 22nd May 2020.

Figure 1:

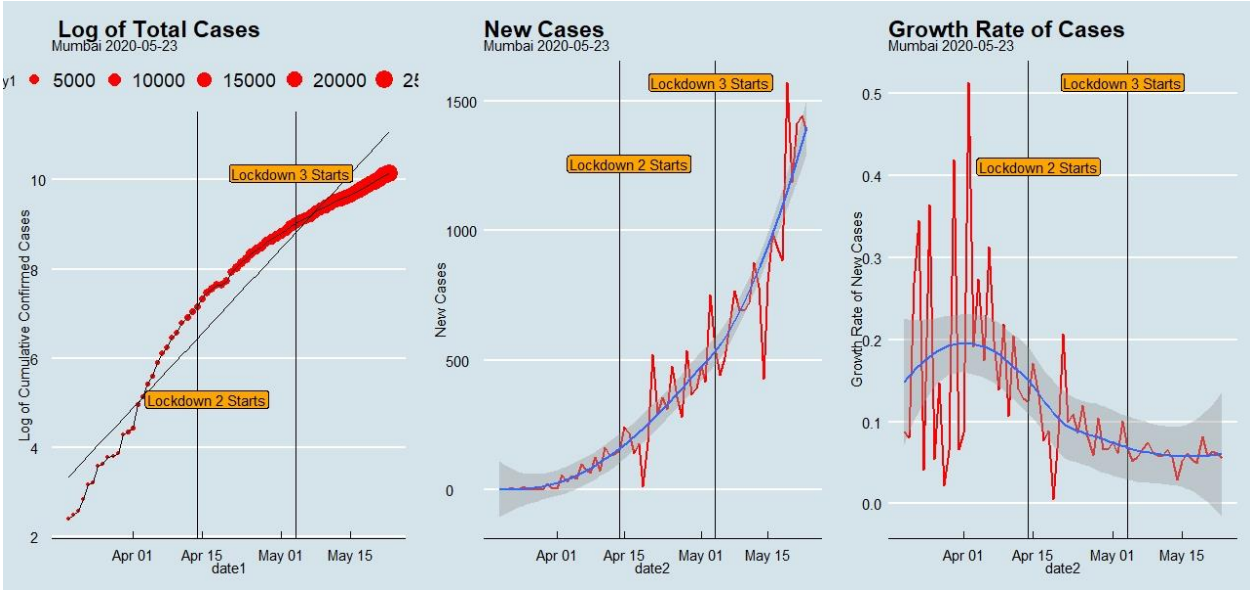


In this figure, the first panel shows the logarithm of the cumulative cases., represented by the red dots and the tin black line running through the red dots. The slope of the red dots at any point of time shows the growth rate at that point of time. The size of the red dots is proportional to the actual number of cases as shown by the key on top of panel 1. The diagonal straight line shows the exponential rate of growth for the whole data set. Imagine drawing a tangent to the red balls line at any point. If the slope of the tangent is greater than the slope of the black line, we are in phase 2. If the slope falls to less than the slope of the diagonal line, we are in phase 3. As one can see, from the beginning of April to the first week of May, corona cases I Maharashtra were growing at a rate faster than the exponential rate of growth. However, from the end of April, the rate of growth has fallen below the exponential rate of growth. The state has transited from phase 2 to phase 3. That of course does not mean that the absolute number of new cases

will decline. Maharashtra already has 40000+ cases on 22nd May 2020. A growth rate of 5% will bring 2000 cases daily on this base. Suppose Maharashtra's growth rate falls as low as 1%, but the base is 60000. That would mean that about 600 new cases will arrive daily, despite the rapid decline in the growth rate. Indeed, as one can see from panels 2 and 3, the number of new cases has been increasing, despite the decrease in the growth rate of cases.

The key to observing a large number of new cases in Maharashtra lies in the very large base of cumulative cases. More than 95% of the cases in Maharashtra are to be found in the 25 municipal areas of the state. In particular, the area under the Mumbai Municipal corporation accounts for 61% of the cases. Hence, what is happening in Mumbai is a key determinant of the progress in the state. Figure 2 examines this for Mumbai.

Figure 2:



As can be seen from figure 2, Mumbai is a major driver of what is happening inn the state. Since the first week of May, the curve has flattened. The experience of the state more or less reflects what is happening in Mumbai. Yet, the number of new cases is indeed staggering and is bound to put substantial pressure on the health infrastructure. A major reason why Mumbai is seeing

such a large number of cases is because of its high population density, coupled with a lot of informal housing in cramped , overcrowded spaces without much infrastructural facilities. In particular, 42% of the city's population occupies only 9.5% of its space given that housing has become unaffordable by a mix of physical features and poor policy (Kulshreshta (2019))[2]. In the highly overcrowded slum environments, rapid spread of virulent infections is inevitable, as has been the case inn Mumbai. That Mumbai will record a large number of covid-19 infections was an inevitability, given the situation that has built up over many years.

This argument is strengthened by examining the trends in the doubling periods as well as the daily R0 (the average number of individuals that an infected individual eventually infects). The doubling periods are estimated using the Maximum Entropy Boot Strapping method developed by Vinod(2009)[3]. Figure 3 shows the daily estimates for the doubling period in the state. The size of the balls in the figure is proportional to the actual doubling period. The doubling period for Maharashtra has steadily gone up during the period under consideration.

Figure 3:

[2]Kulshrestha I (2019): "The Proliferation of Slums inn Mumbai: An Analysis of City's Exclusionary Urbanisation", South Asia, July 1 , 2019.

[3]Vinod H.D. and Lopez-de-Lacalle (2009): "Maximum Entropy Bootstrap for Time Series : The meboot R Package" Journal of Statistical software, Volume 29, issue 5.

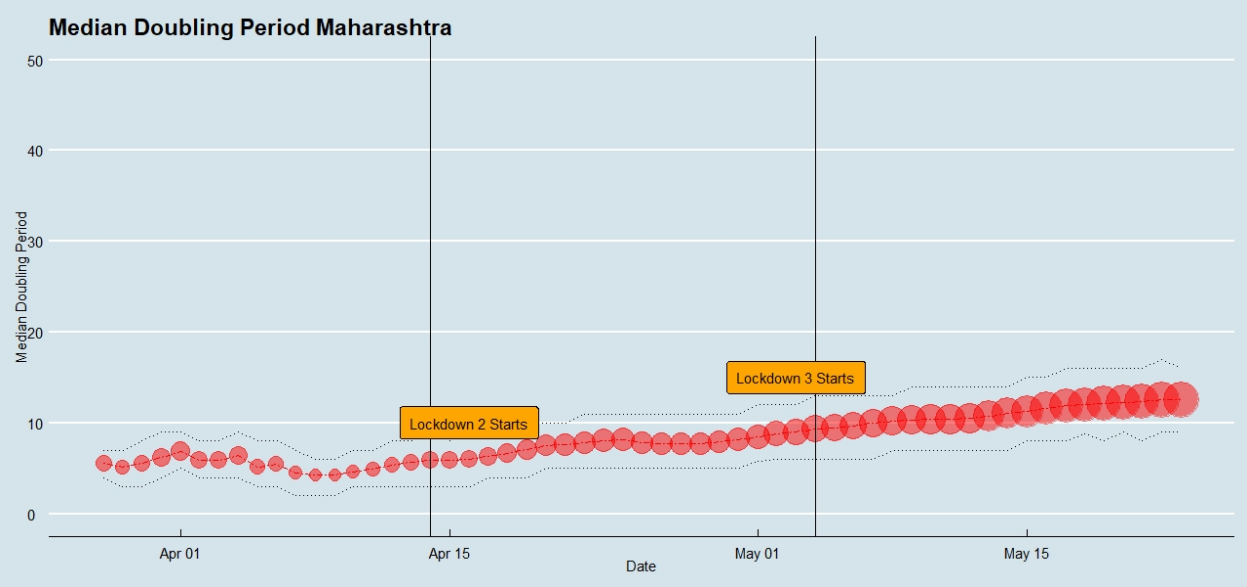


Figure 4 shows the daily estimates of R0 calculated using the method in Cori (2013) [4]and Thompson et al (2019)[5]. We have used the R package EpiEstim, following Churches (2020)[6].

Figure 4:

[4] Anne Cori(2013), Neil Fergusson,Christophe Fraser and simon Cauchemez, American journal of Epidemiology 2013,Nov1;178(9):1505-1512. Using the package epiEstim

[5] R.N.Thompson, J.E.Stockwin, R.D.Van Gaalen, J.A. Polonsky, Z. N. Kamvar,P.A. Demarsh,E.Dahlqwist,S. Li, E. Miguel,T.Jombart,J.Lessler, S. Cauchemez, A Cori, Epidemics, vol 29 ,Dec 2019.

[6]

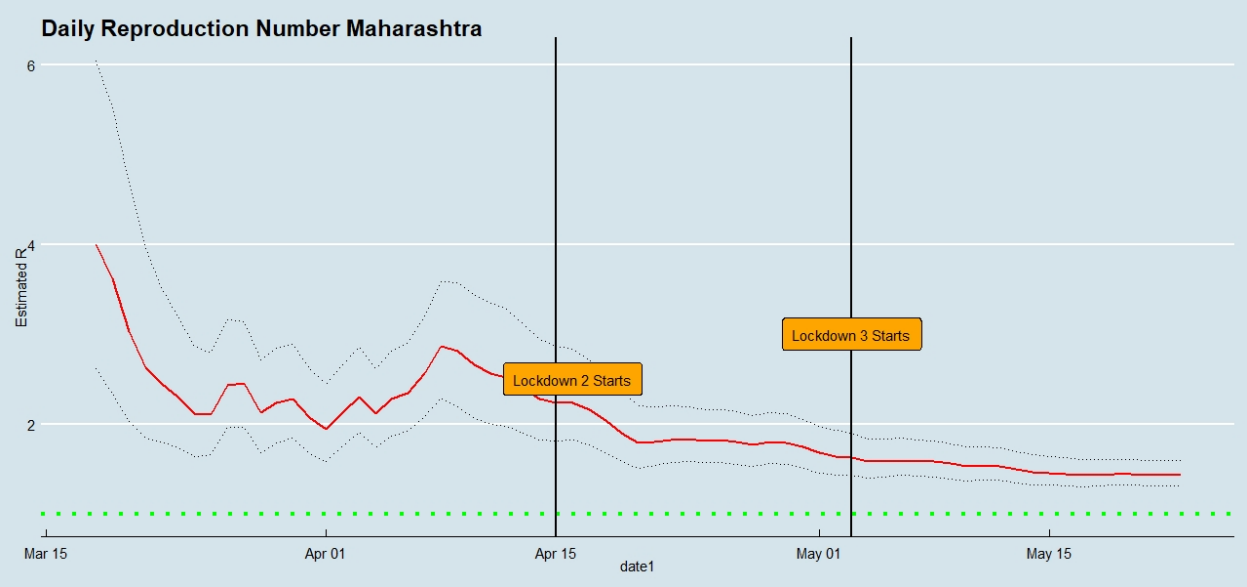


Figure 4 clearly shows that the daily R0 has been declining consistently over the period. It has not yet crossed the magic figure of 1, but more importantly, it has not shown an upward movement. Of course, our analysis is based on reported infections and not actual infections, as should ideally have been the case. Also, the reported infections give us the time from which the infection was reported, rather than from the actual onset. The latter, we do not have any data on, and we must work with whatever we have. The former objection will be dealt with below.

There can be several objections to our position that the curve is indeed flattening. They can be as follows:

1.**We are missing all the asymptomatic cases**: It is well known that a large number of Corona infected persons are asymptomatic and do not seek medical attention. But they can still serve as carriers. The counts of actually diagnosed cases are a huge under estimation of the actual numbers. This is indeed true, but we are concerned with the trends. As long as the ratio of undetected to detected cases does not increase over time, our conclusions of a decline in the actual numbers continues to be valid. We have no clear reason to believe that this ratio has indeed increased over time. Hence, on this count, our argument of a decline in the actual number of infections (as against their levels) holds true.

2.**We might be missing out on false negatives**: We can safely rule out the argument that we are not testing enough, the rate of testing in Maharashtra has in fact gone up over time, and if at all,

the increased rate could be at least partially due to increased testing. Increased testing cannot lead to a slower rate of increase in cases. But tests for corona virus are highly specific. If a test is positive, the clinician can be reasonably sure that the patient indeed is positive. But not all tests are sensitive. Depending upon the sample tested and timing, we could get false negatives. But in our case, the issue is not how many genuine cases have been missed out, but whether they could be missed out because of an increase inn false negative. Again, at the time of writing, there is no evidence that the rate of false negatives has gone up.

Figures 5, 6,7,8 show the situation for Gujarat, Tamil Nadu, Delhi and Madhya Pradesh respectively.

Figure 5:

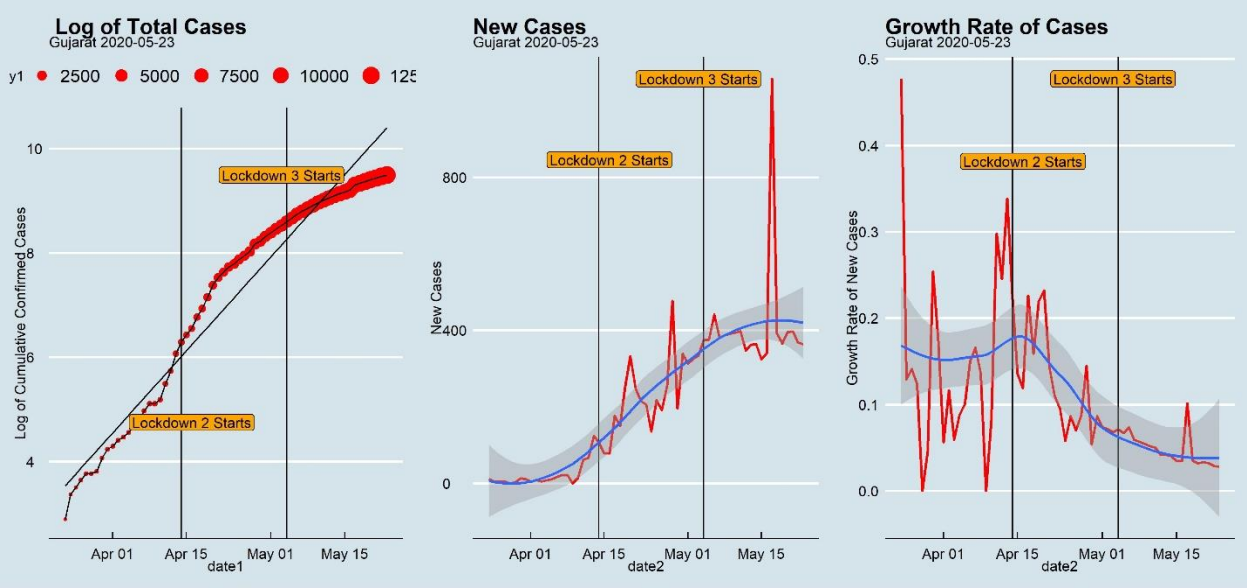


Figure 6:

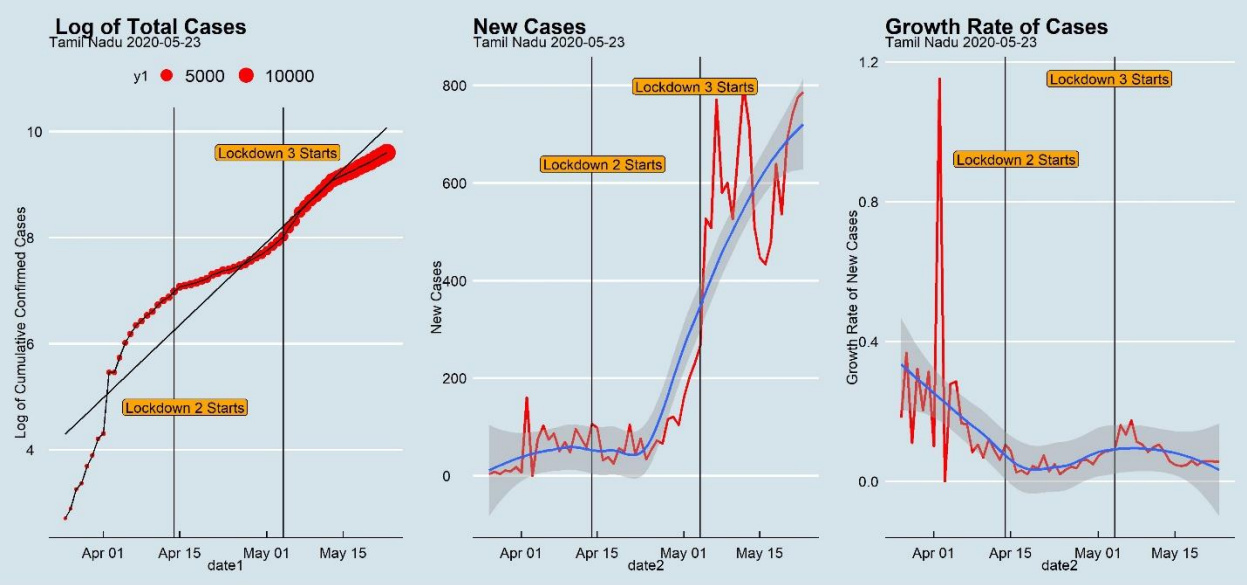


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Figure 7:

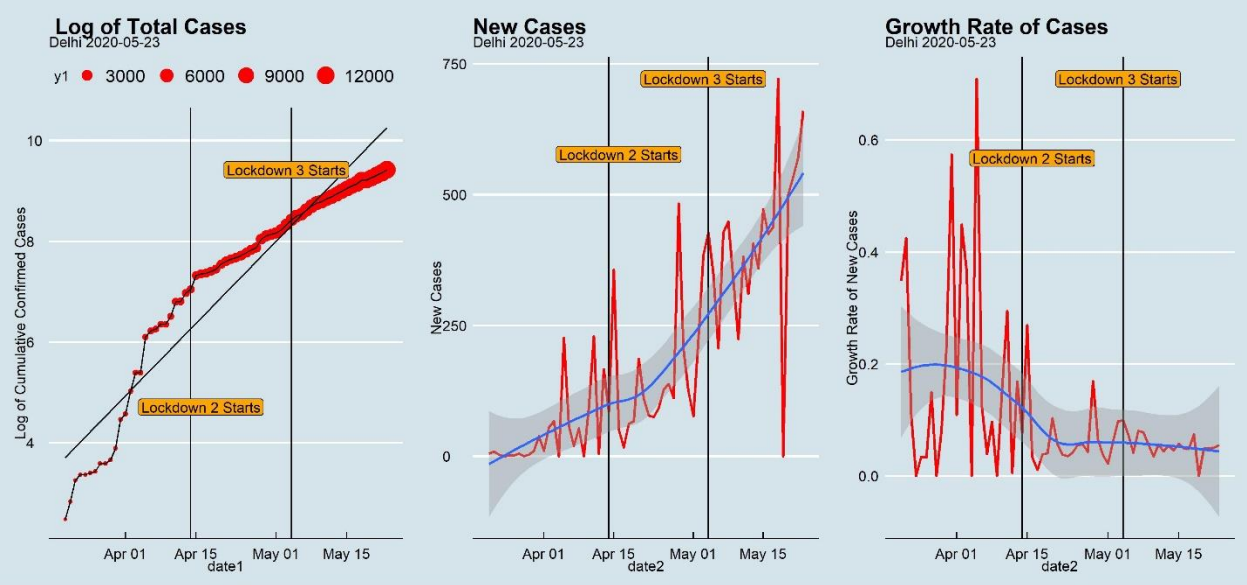
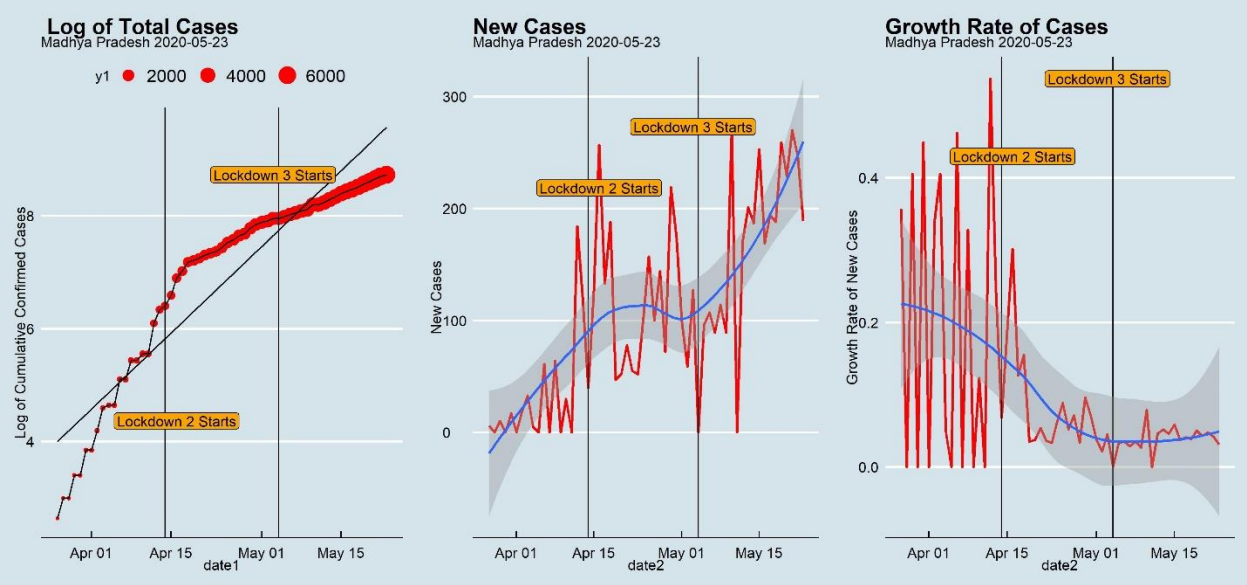


Figure 8:

[7] Churches (2020, Feb. 18). Tim Churches Health Data Science Blog: Analysing COVID-19 (2019-nCoV) outbreak data with R - part 1. Retrieved from https://timchurches.github.io/blog/posts/2020-02-18-analysing-covid-19-2019-ncov-outbreak-data-with-r-part-1/



As you can see, all the five states have entered into phase 3 at different times between lock down 2 and lock down 3. Gujarat, Delhi and Tamil Nadu, like Mumbai, have registered a large number of cases coming mostly from the highly congested cities.

In all these states, there has been a flattening of the curve after the first week of May. Some other states too have achieved this flattening, but at different rates. Andhra Pradesh, Haryana, Jammu and Kashmir, Punjab, Telangana, Uttar Pradesh, Kerala, Karnataka and West Bengal have been able to do this, as can be seen in the following figures:

Figure9

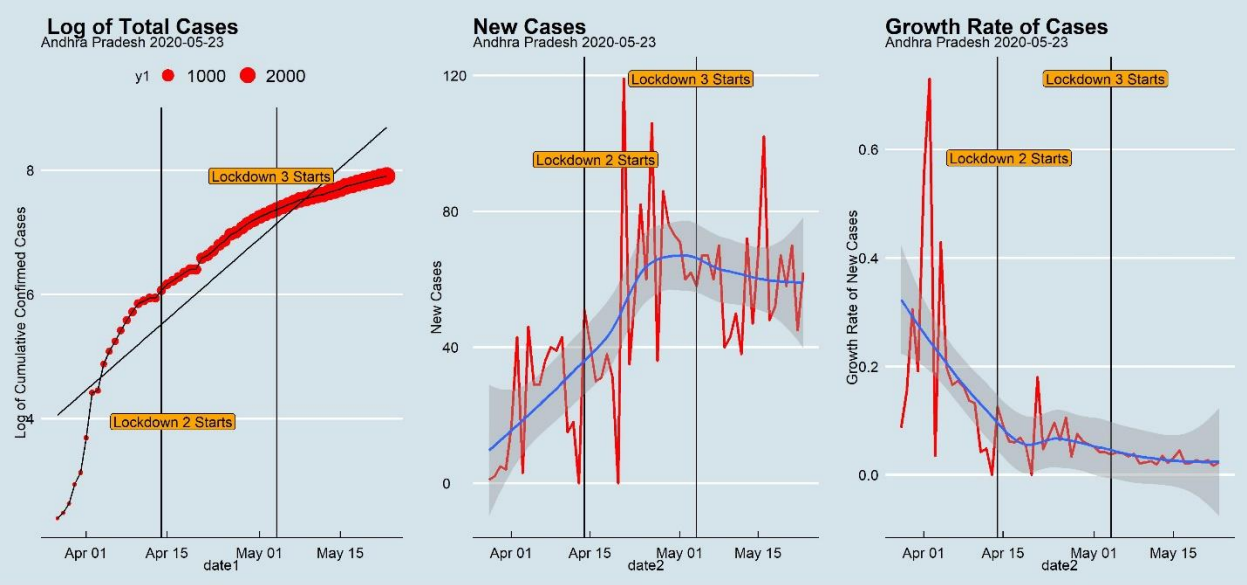


Figure 10:

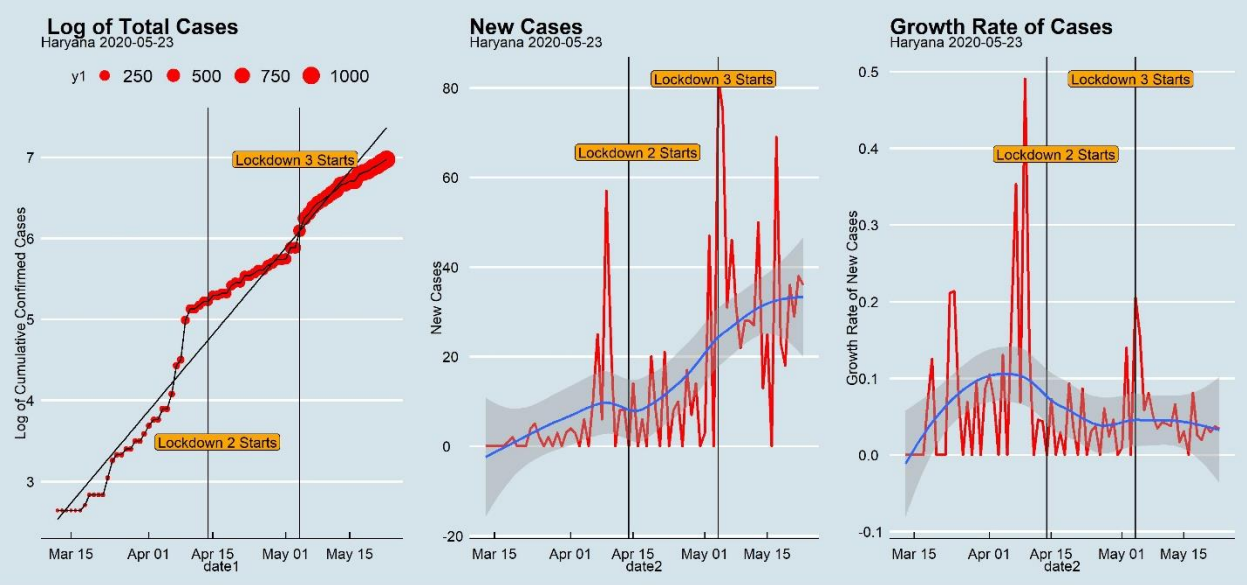


Figure 11:

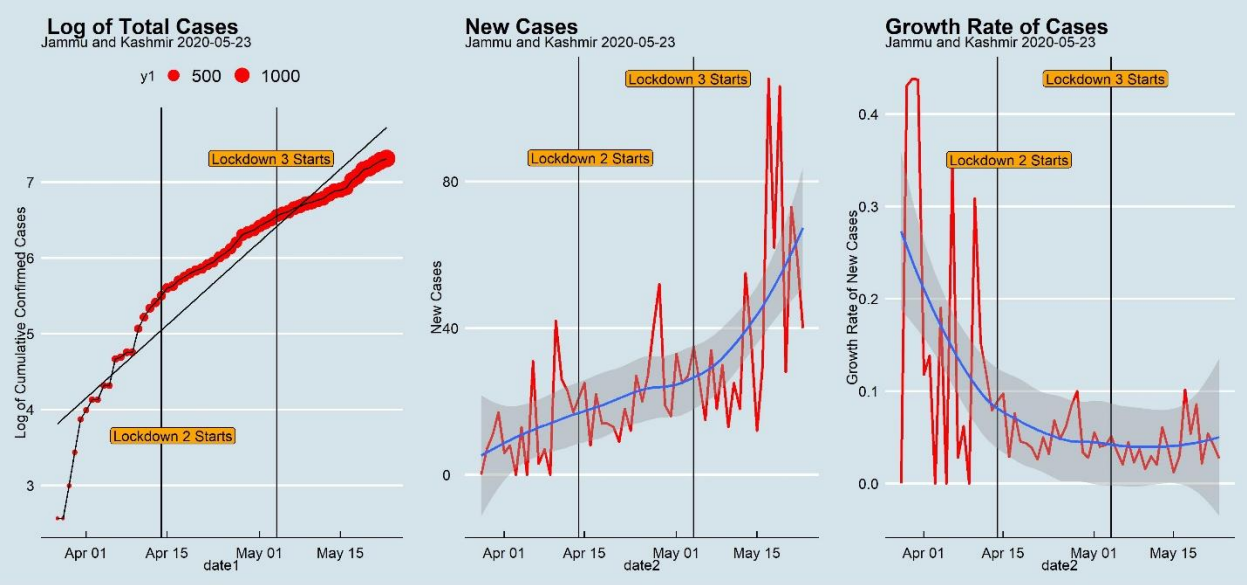

Log of Total Cases
Jammu and Kashmir 2020-05-23
y1 500 1000
Lockdown 3 Starts
Lockdown 2 Starts
Log of Cumulative Confirmed Cases
7
6
5
4
3
Apr 01
Apr 15
May 01
May 15
date1
New Cases
Jammu and Kashmir 2020-05-23
Lockdown 3 Starts
Lockdown 2 Starts
80
40
0
Apr 01
Apr 15
May 01
May 15
date2
Growth Rate of Cases
Jammu and Kashmir 2020-05-23
Lockdown 3 Starts
Lockdown 2 Starts
Growth Rate of New Cases
0.4
0.3
0.2
0.1
0.0
Apr 01
Apr 15
May 01
May 15
date2

Figure 12:

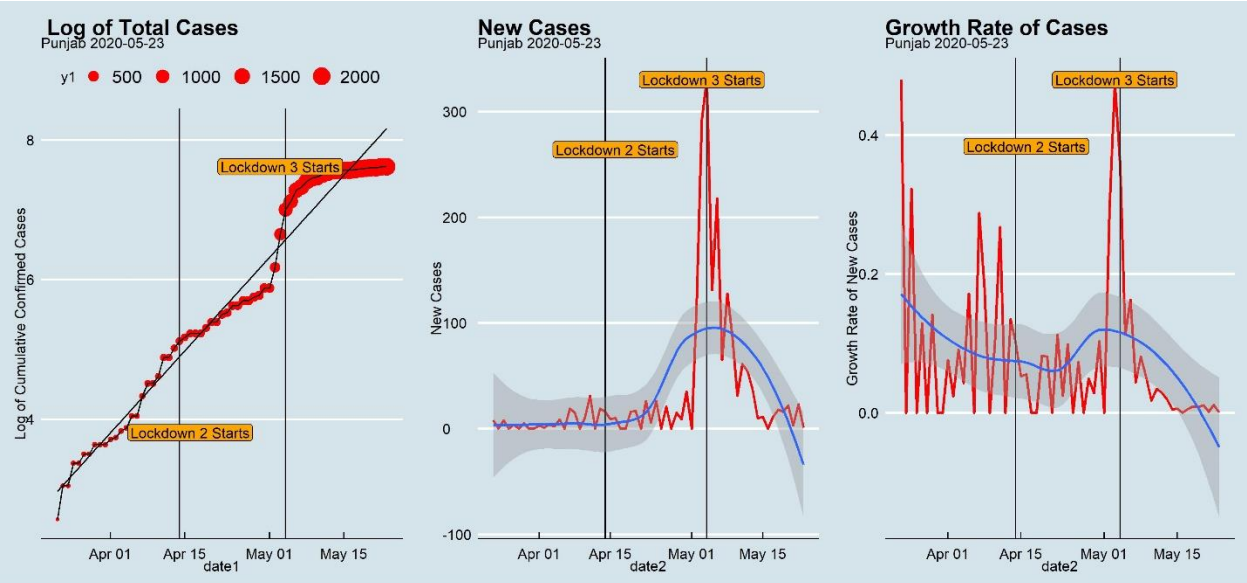

Log of Total Cases
Punjab 2020-05-23
y1 500 1000 1500 2000
Lockdown 3 Starts
Lockdown 2 Starts
Log of Cumulative Confirmed Cases
8
6
4
Apr 01
Apr 15
May 01
May 15
date1
New Cases
Punjab 2020-05-23
Lockdown 3 Starts
Lockdown 2 Starts
300
200
100
0
-100
Apr 01
Apr 15
May 01
May 15
date2
Growth Rate of Cases
Punjab 2020-05-23
Lockdown 3 Starts
Lockdown 2 Starts
Growth Rate of New Cases
0.4
0.2
0.0
Apr 01
Apr 15
May 01
May 15
date2

Figure 13:

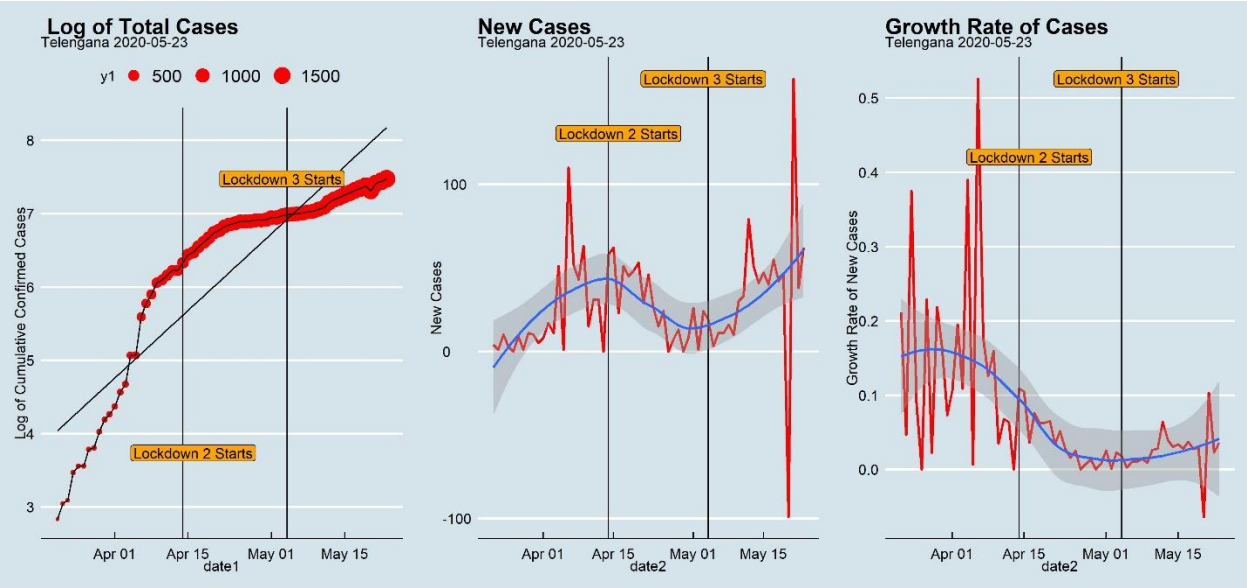


Figure 14:

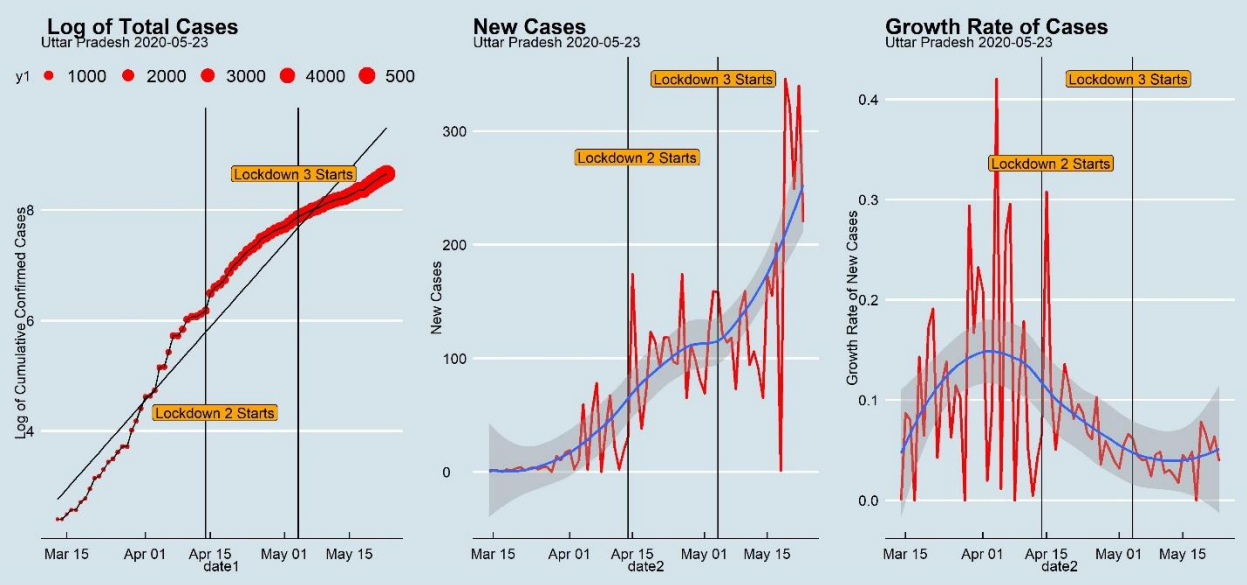


Figure 15:

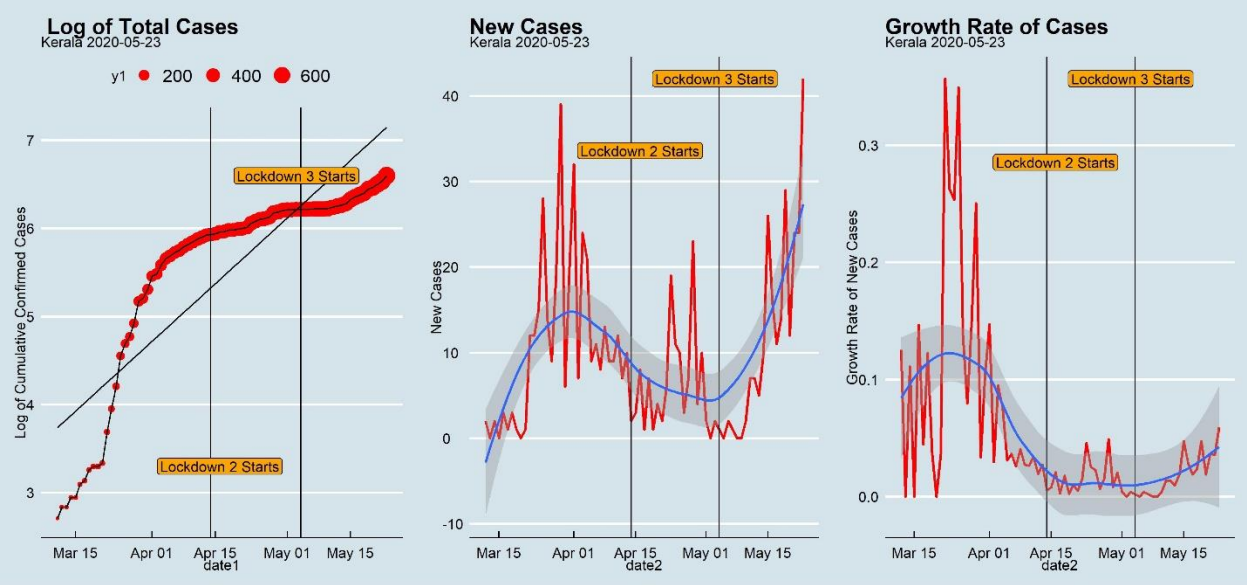


Figure 16:

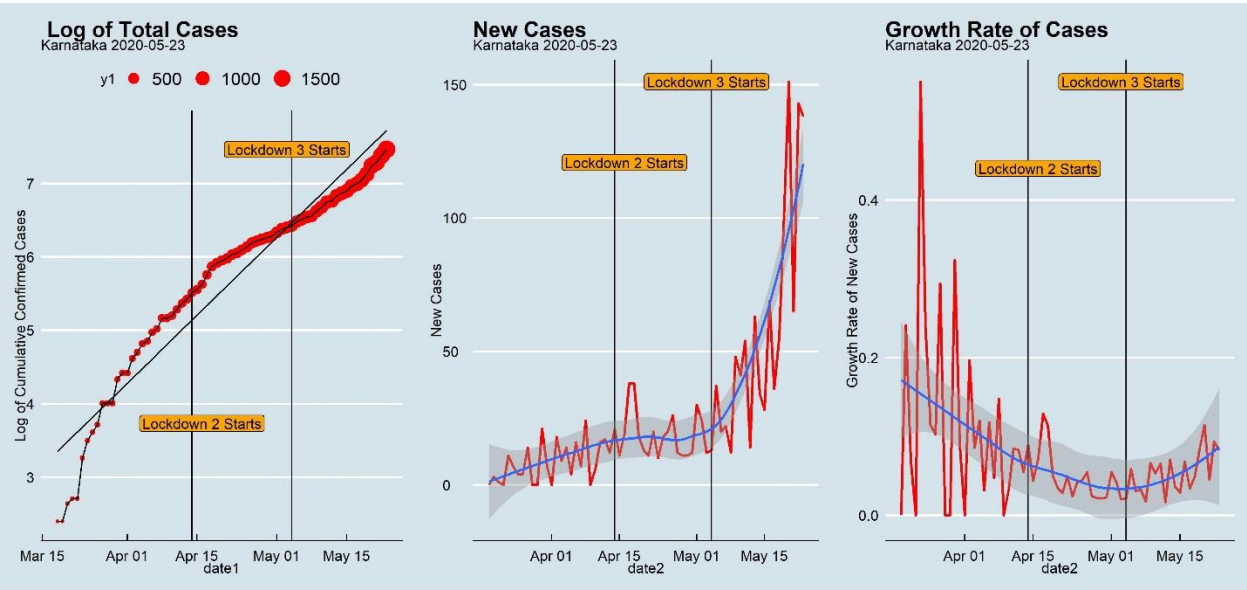
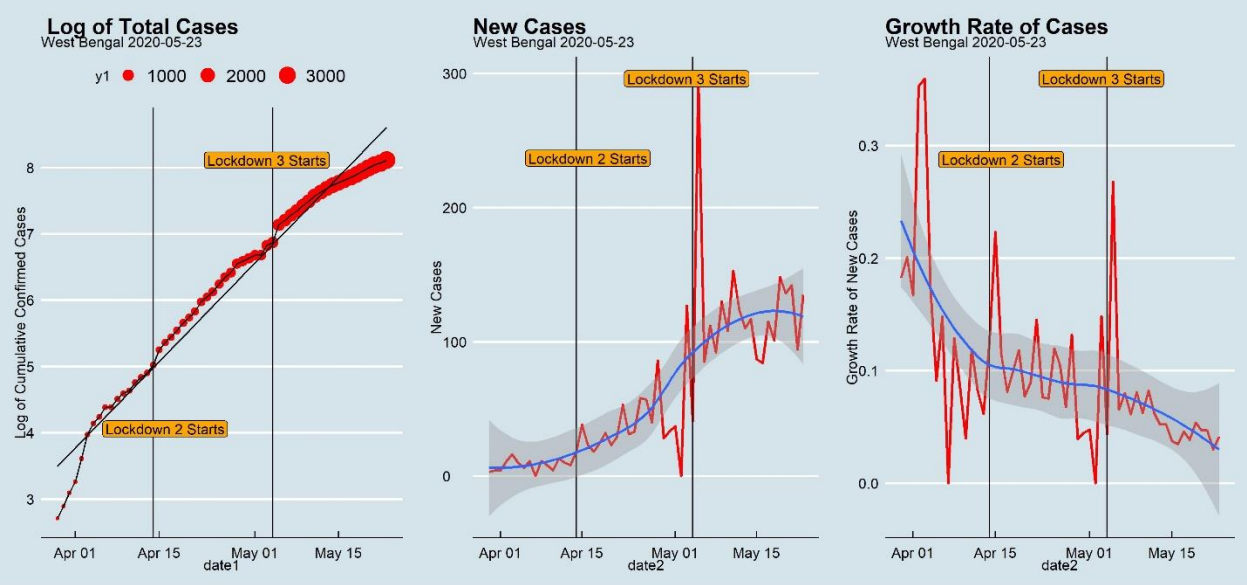


Figure 17:



As one can see, all these states have made the transition to phase 3. But there are significant differences in their trajectories. For example, Punjab's phase 2 came much later than most states, and the curve has completely flattened out in Punjab. Both, new cases and the growth of new cases has fallen to zero. While the overall experience has been satisfactory, we need to worry about states like Kerala and Karnataka, which have recently shown an uptake in their corona trajectories. Is this a second wave of infections? Only time can tell. There is the final group of states where the situation is not that rosy.

In states like Assam, Bihar, Himachal Pradesh, Odisha and Uttarakhand the situation is one of concern.

Figure 18:

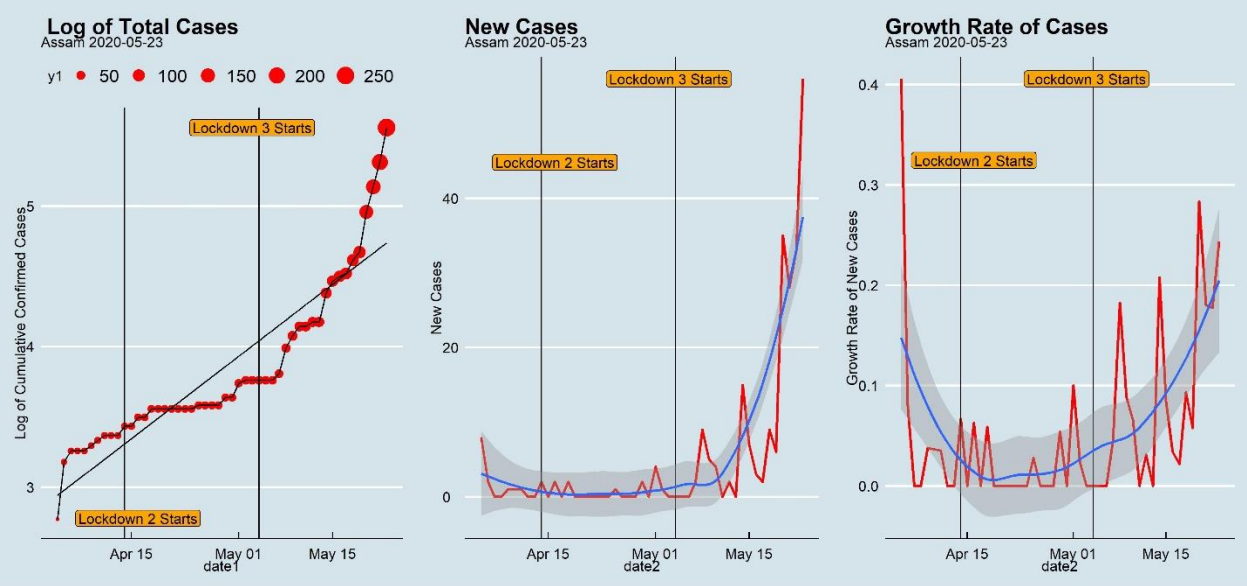


Figure 19:

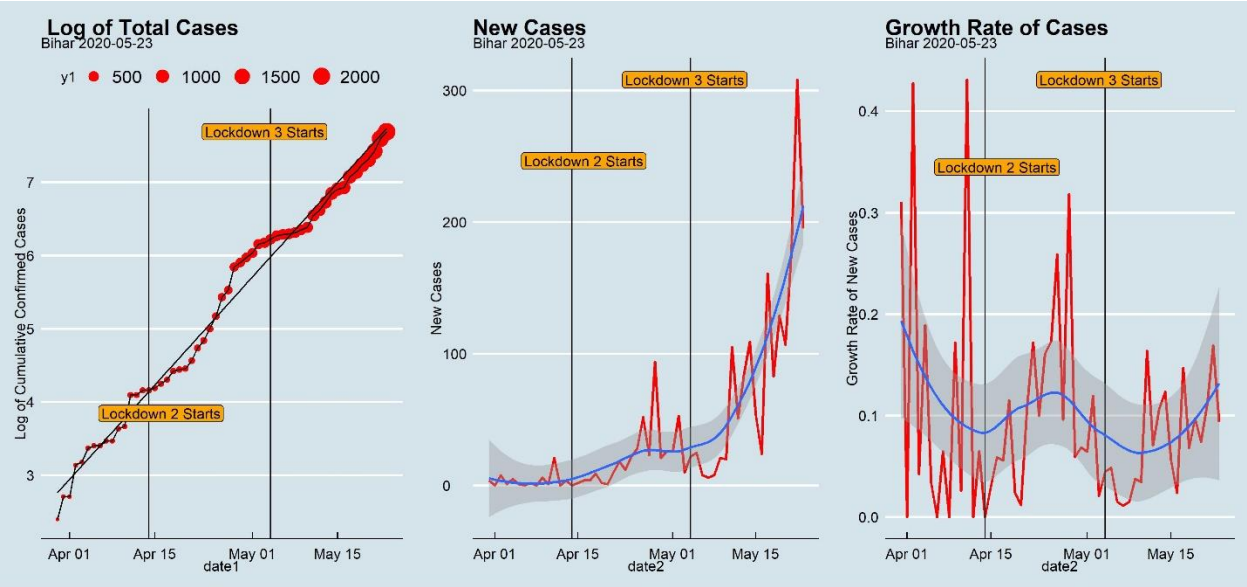


Figure 20:

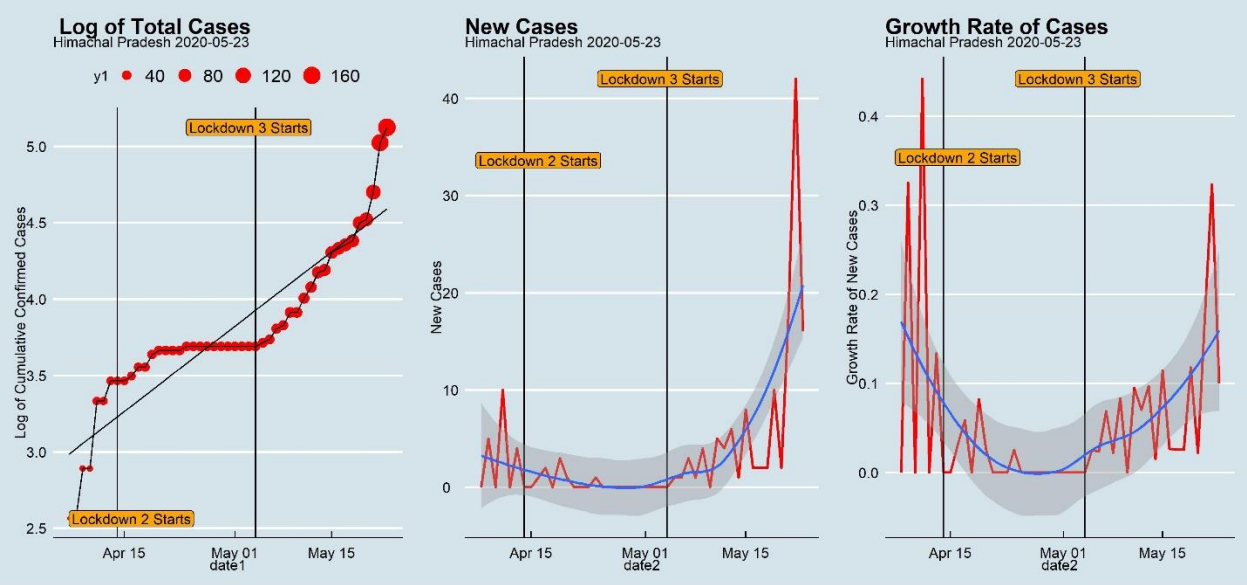


Figure 21:

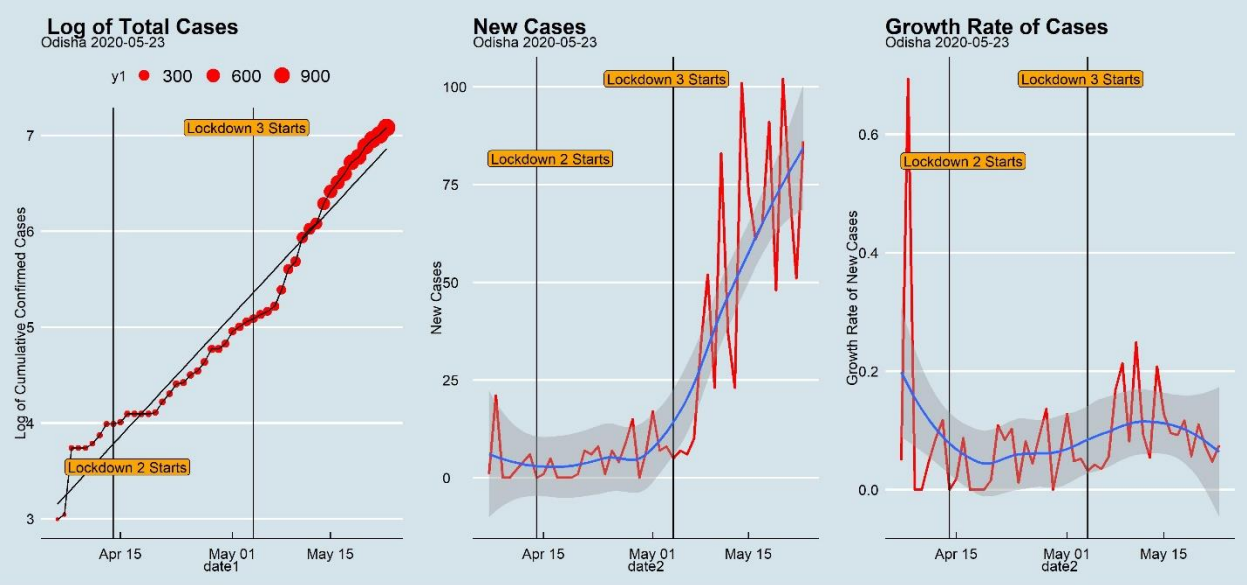
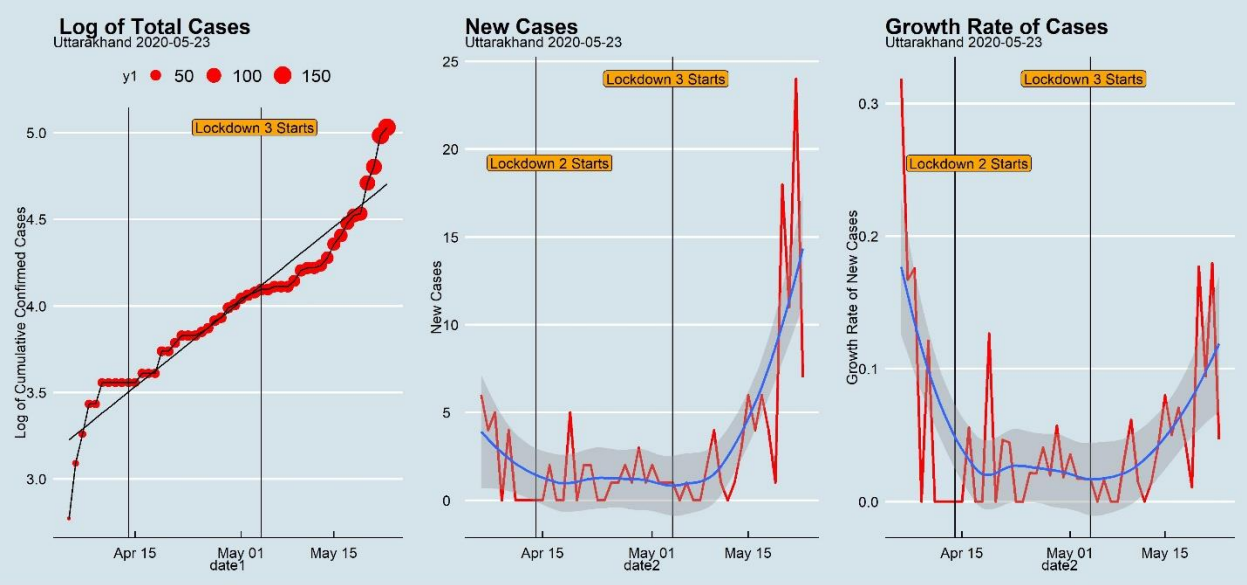


Figure 22:



As one can see from the graphs above that the curve has started rising above the exponential growth rate curve after the third lock down started. Is it due to migrants returning to their native places from cities? this question needs to be examined.

Section : 3 District Wise Situation in Maharashtra

Now, let us consider the District wise cases in Maharashtra.

Figure:24

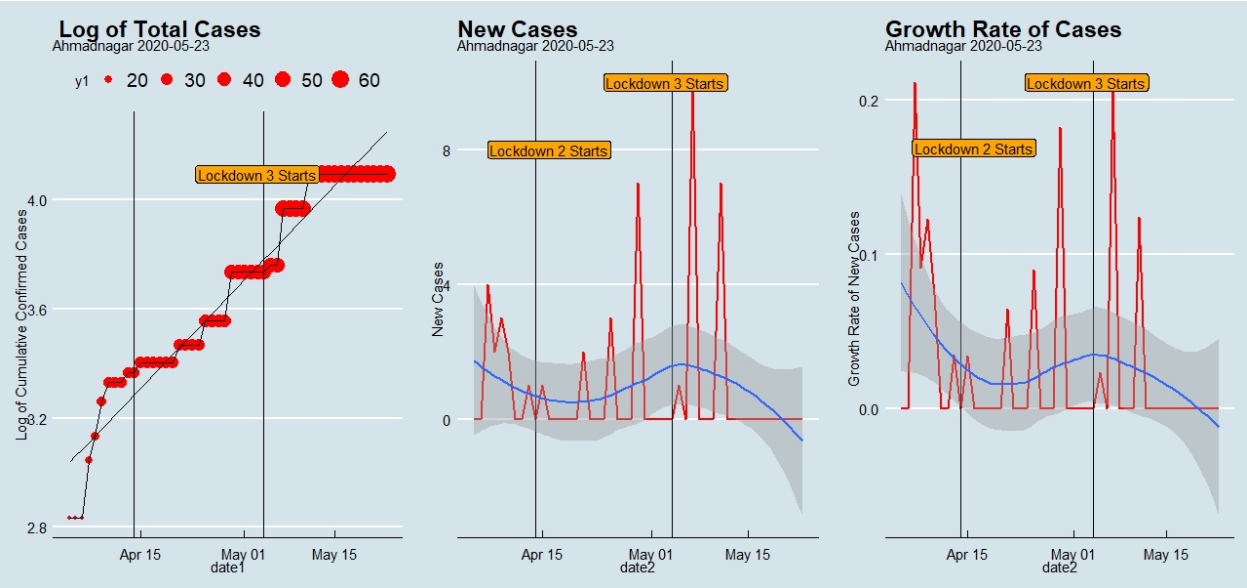


Figure: 25

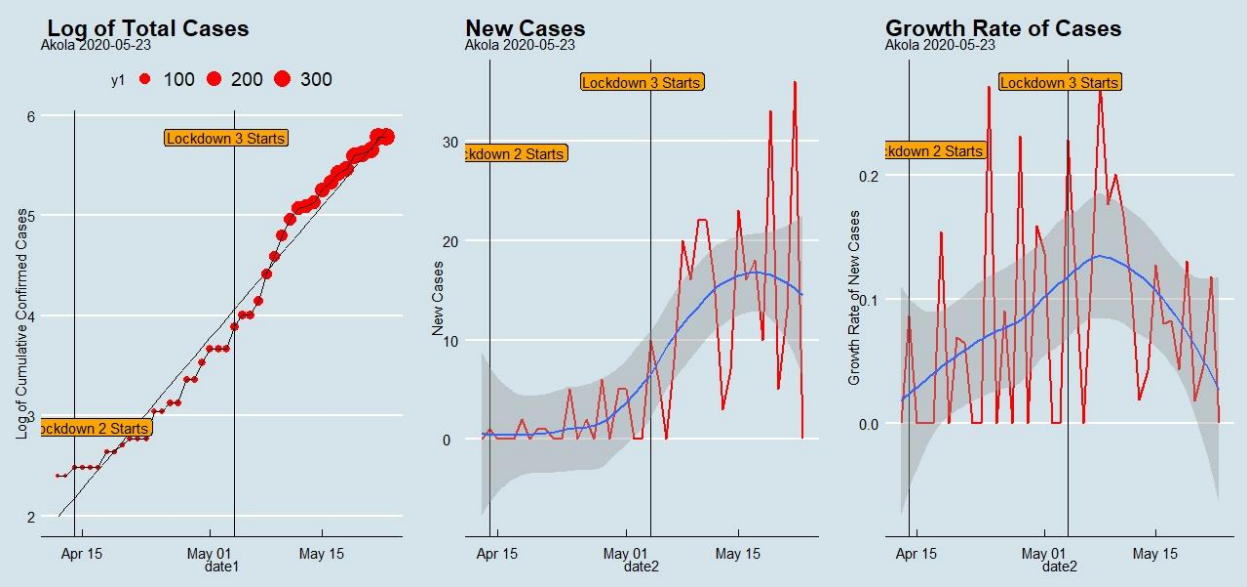


Figure : 26

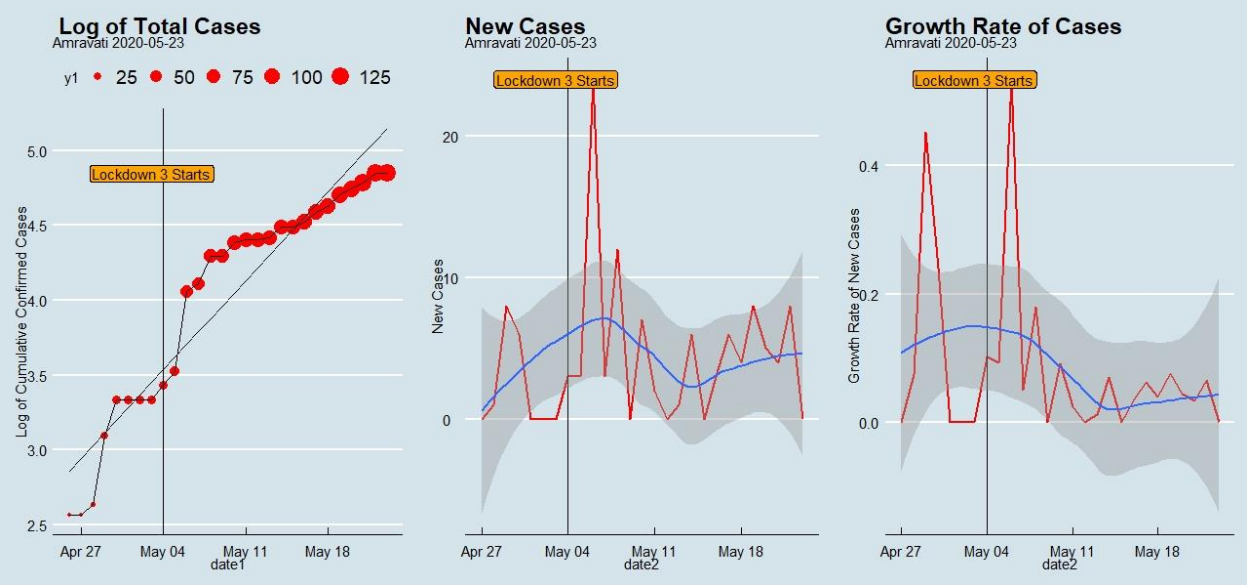


Figure : 27

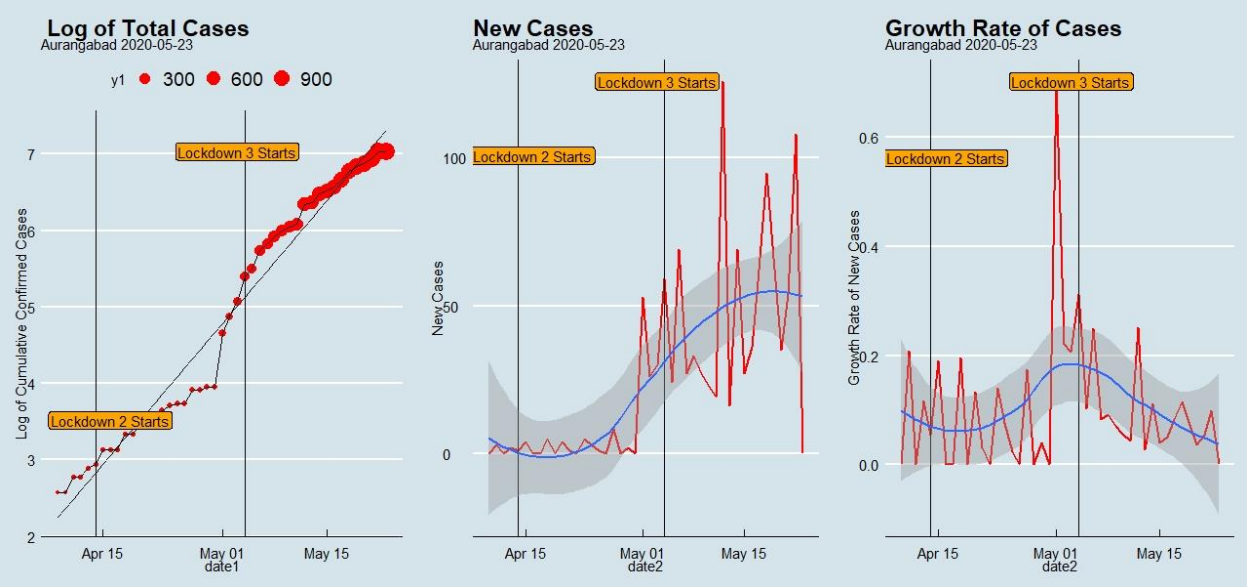


Figure : 28

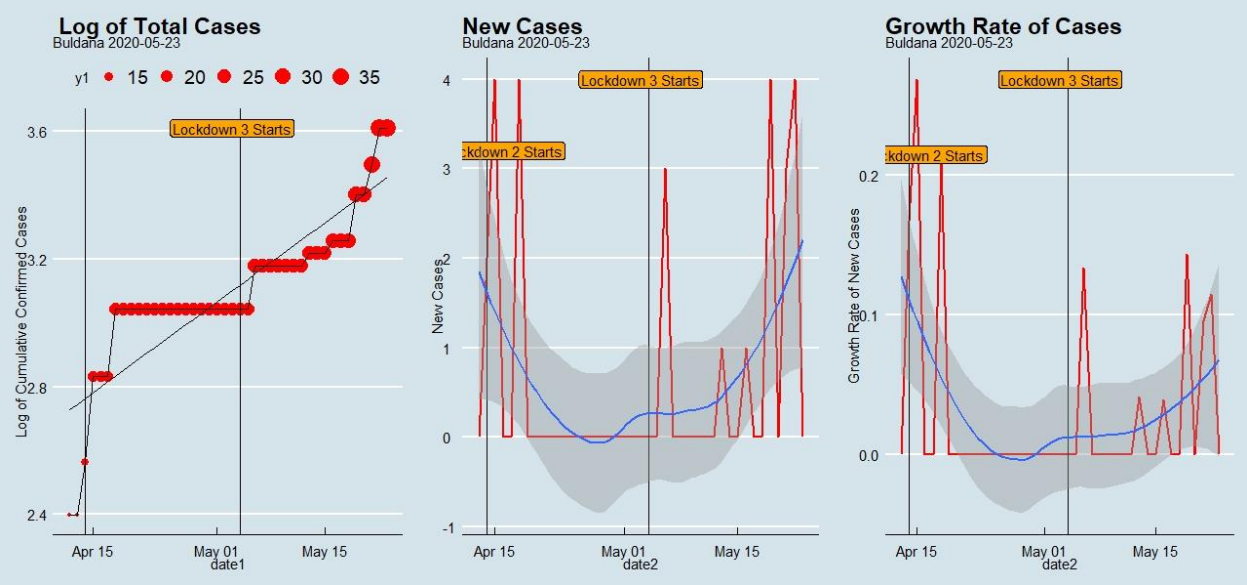


Figure : 29

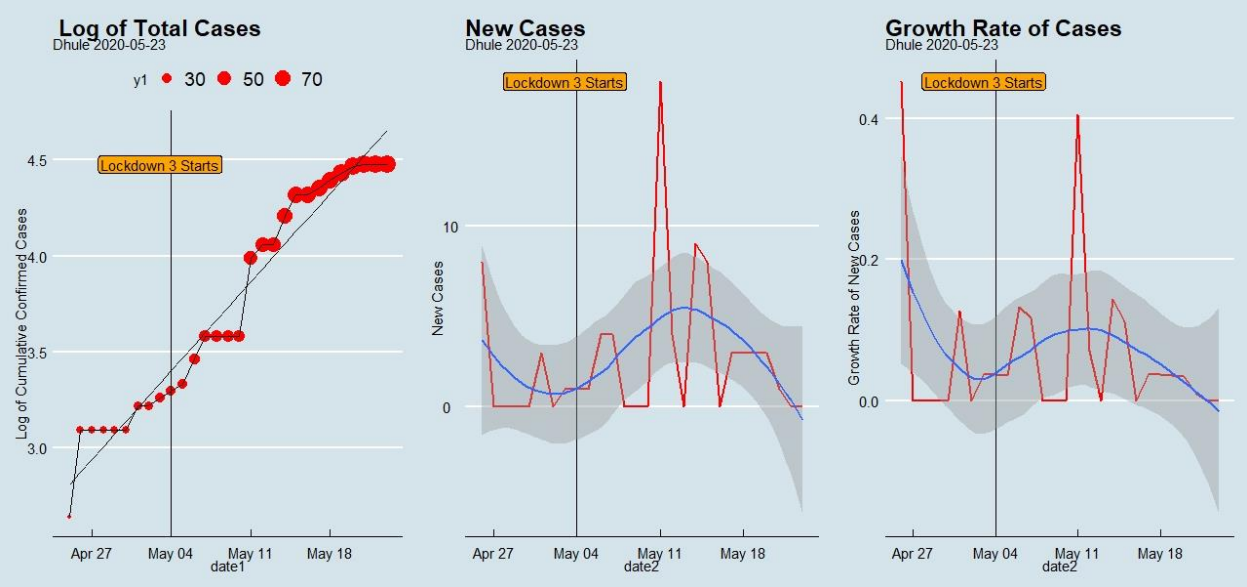


Figure : 30

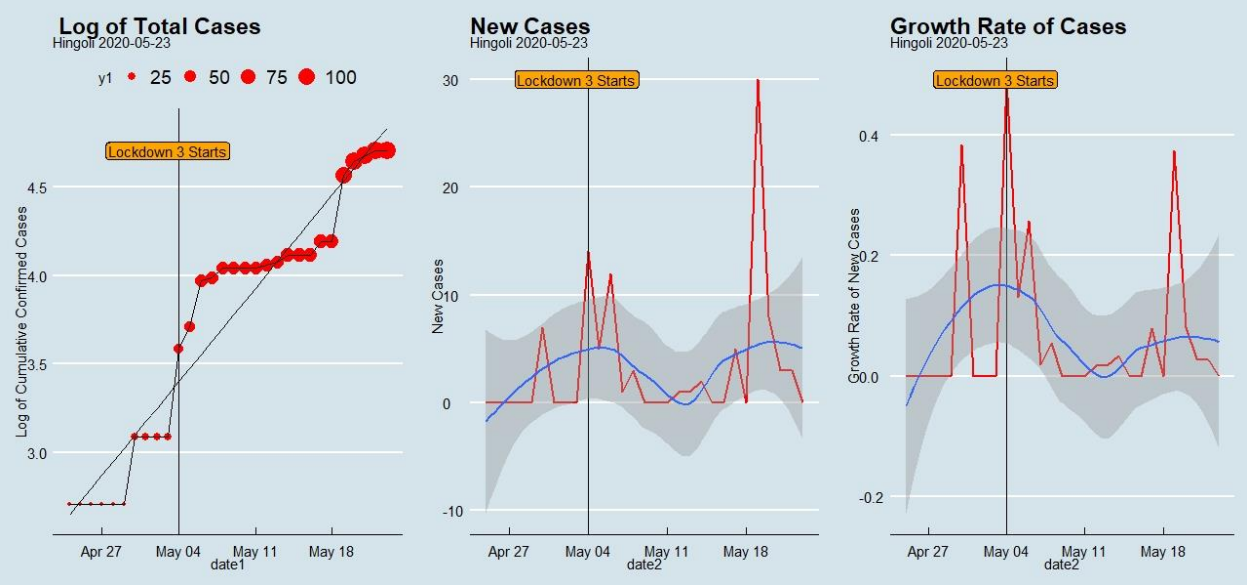
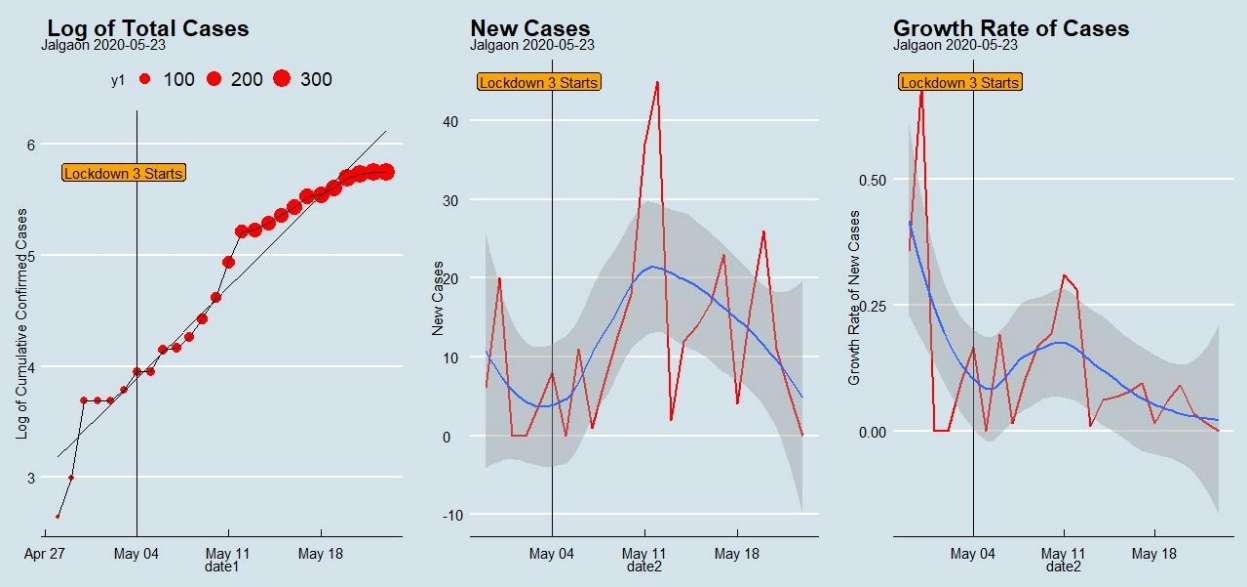


Figure : 31



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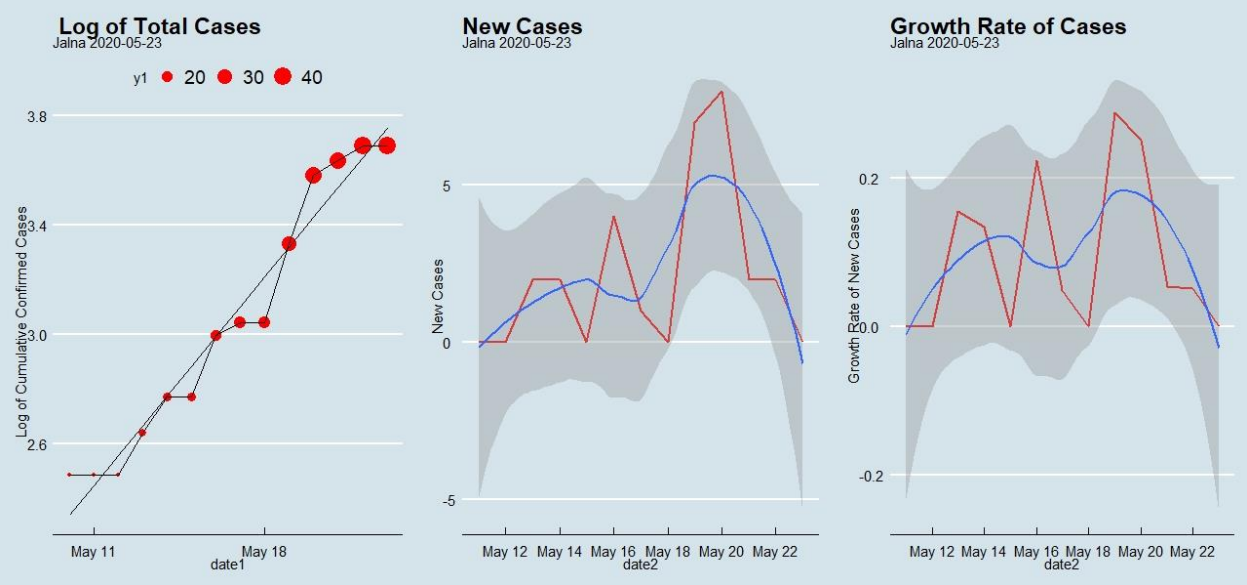

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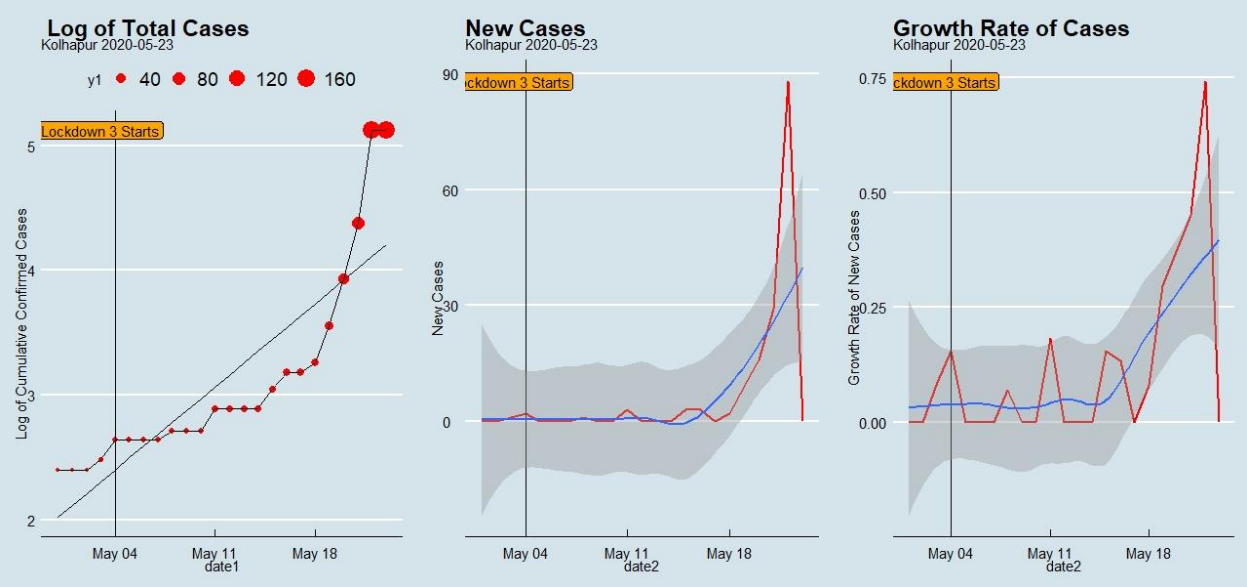

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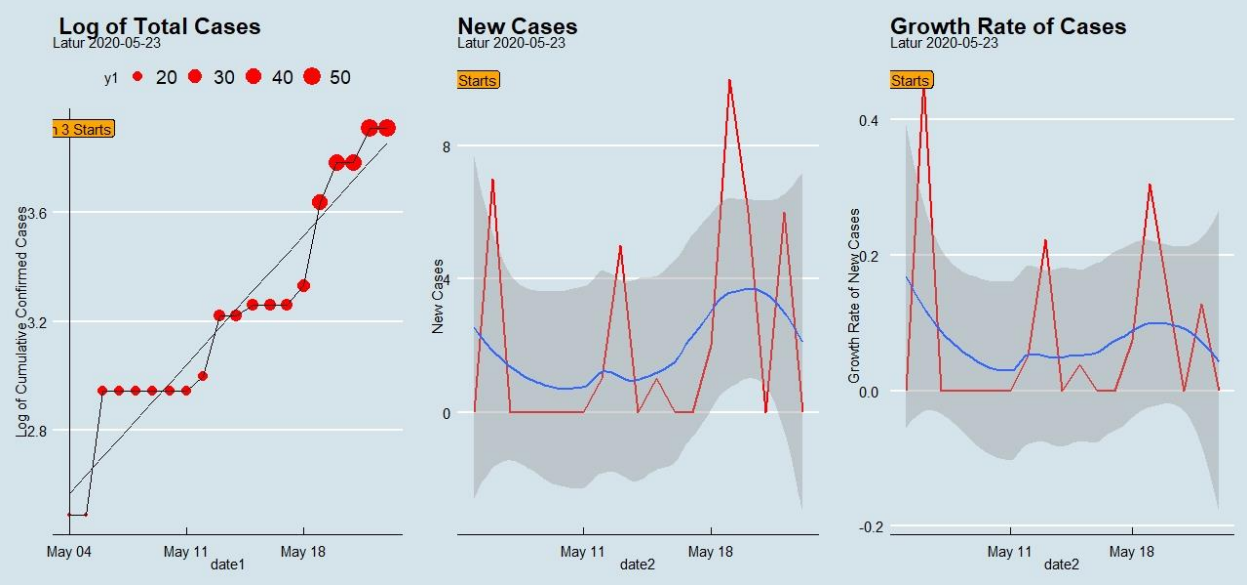

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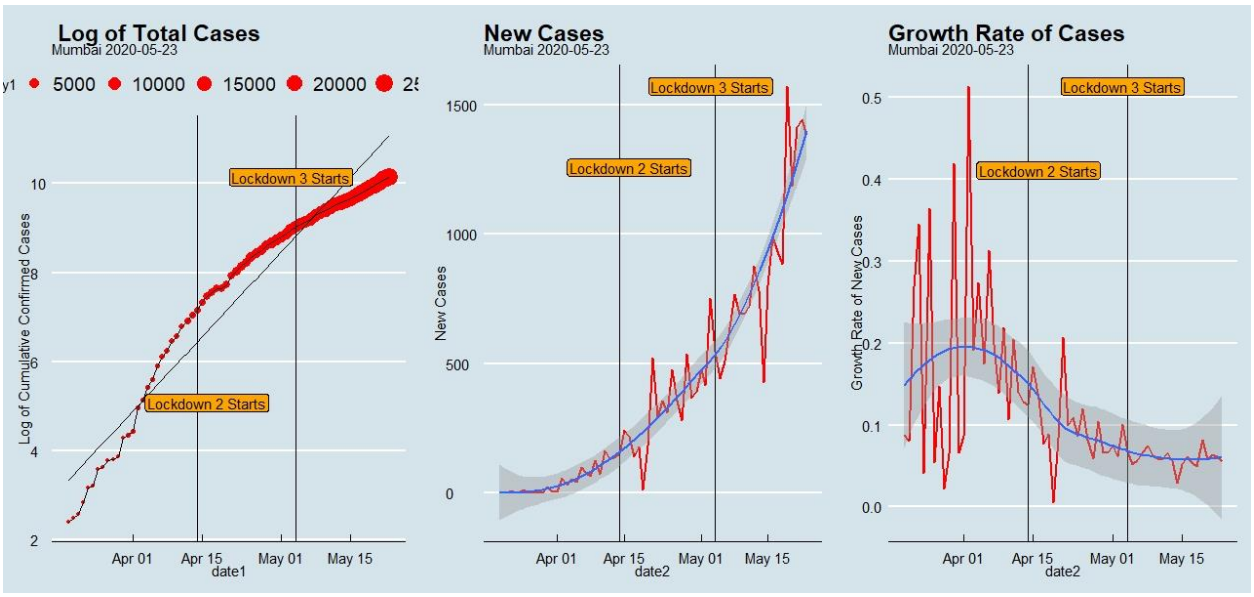

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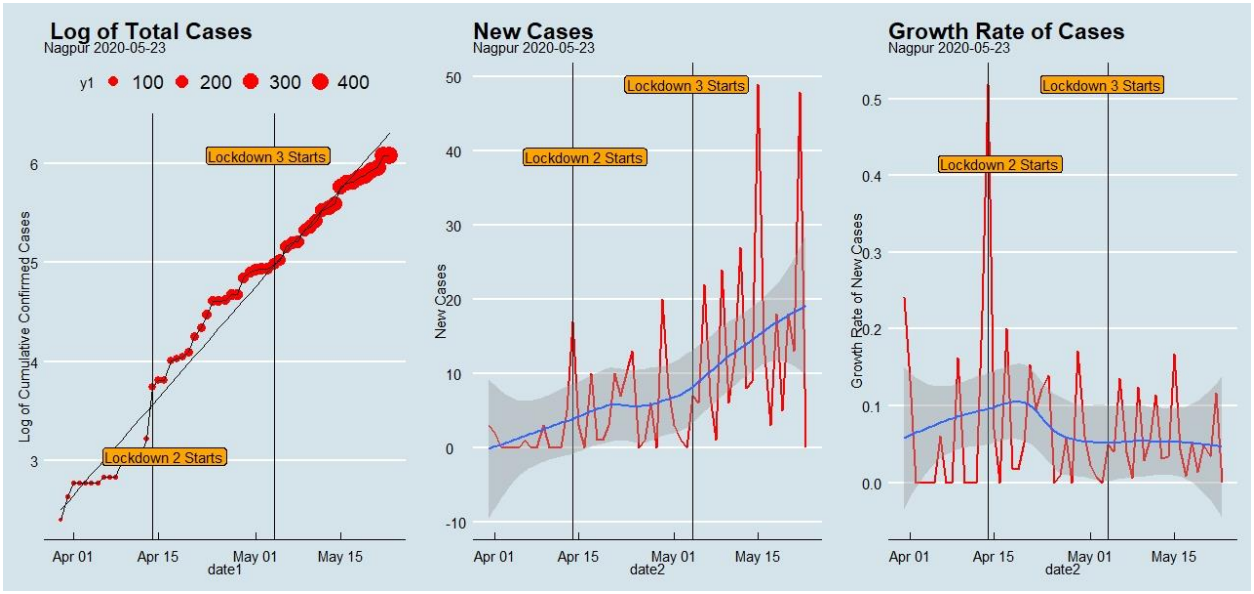

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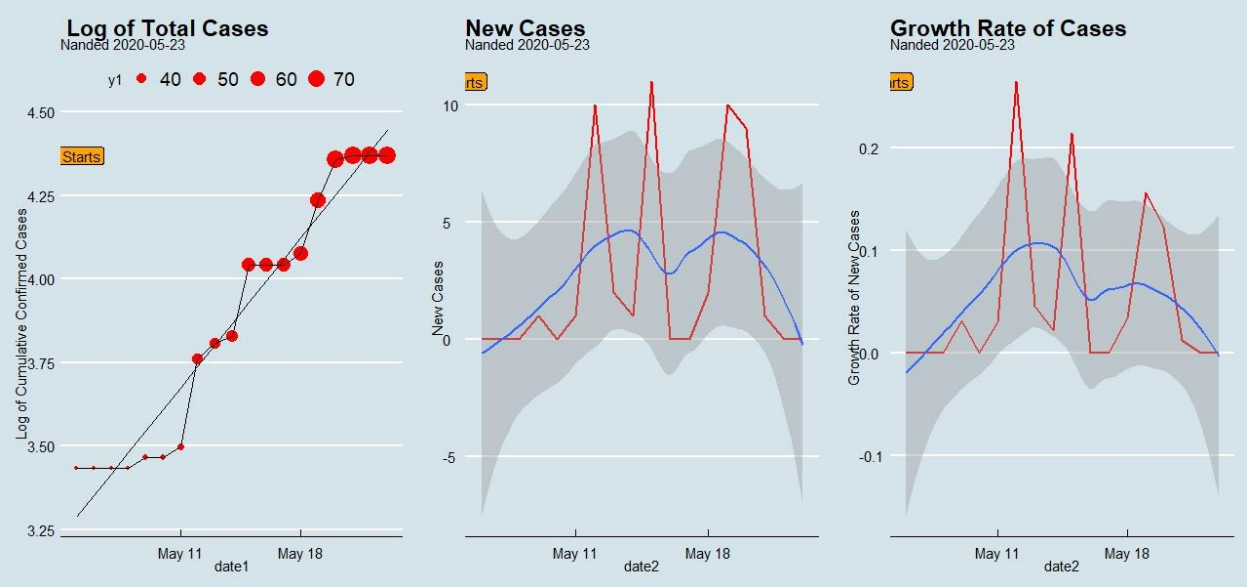

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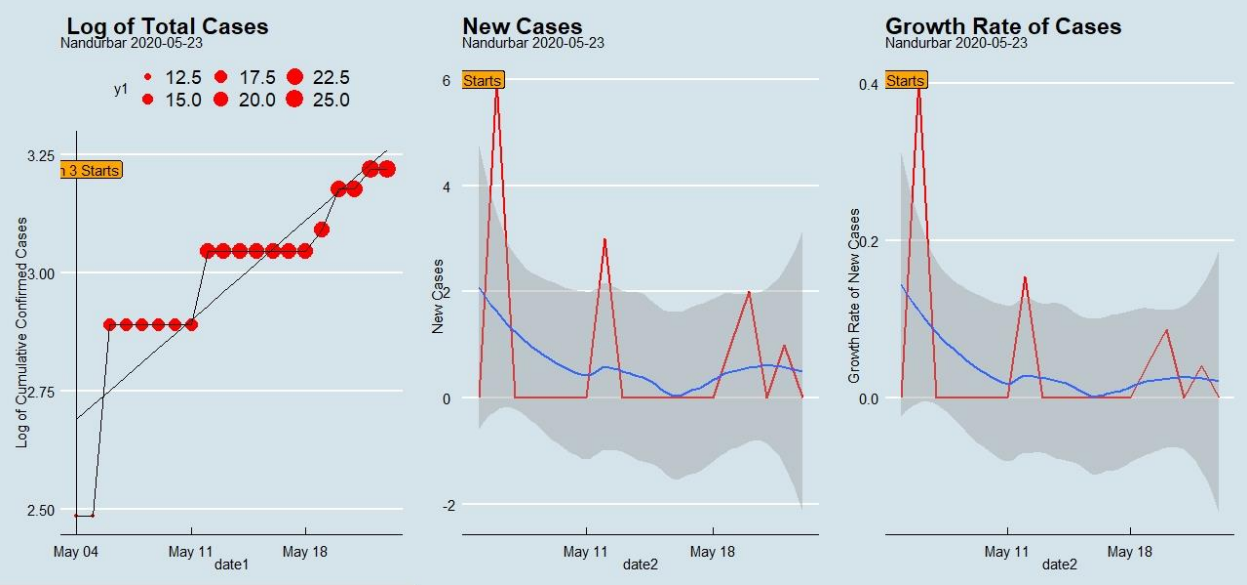

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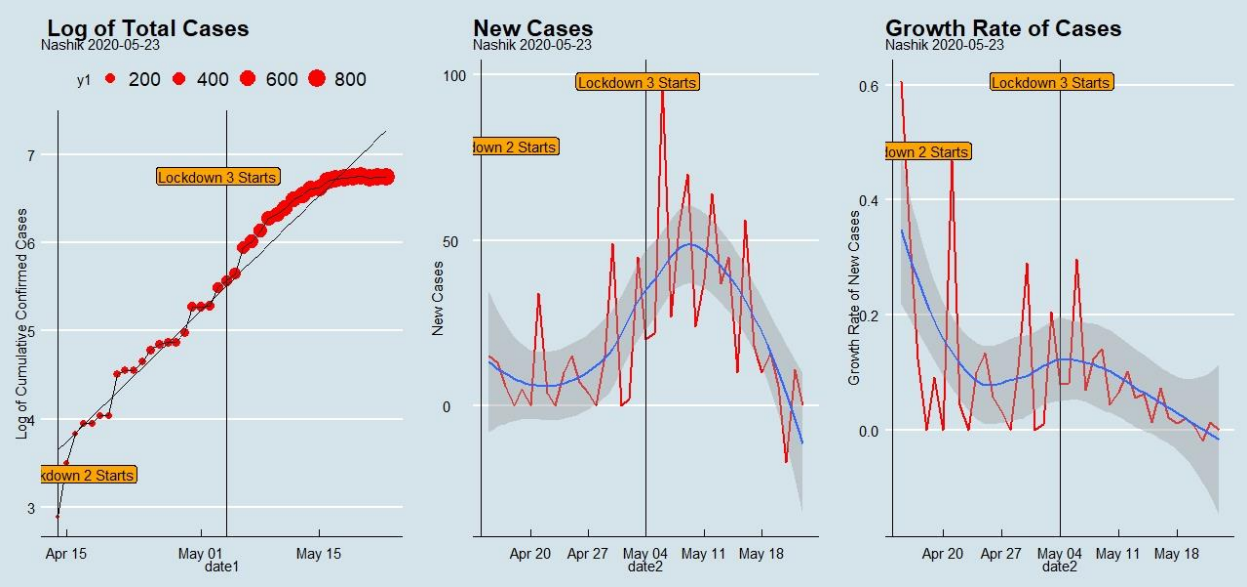

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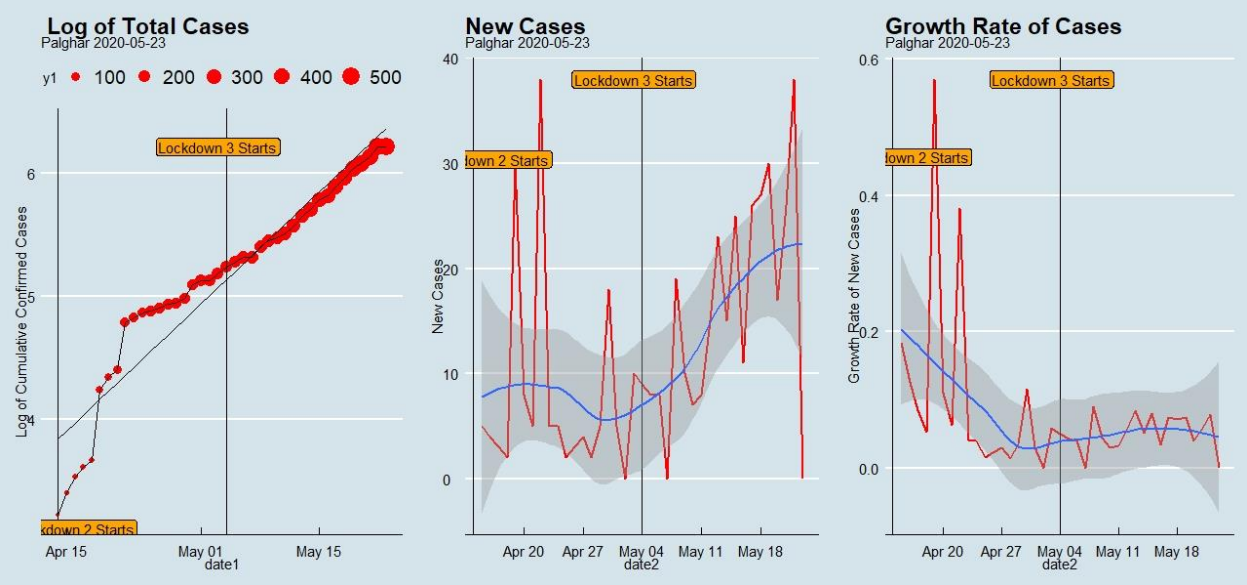
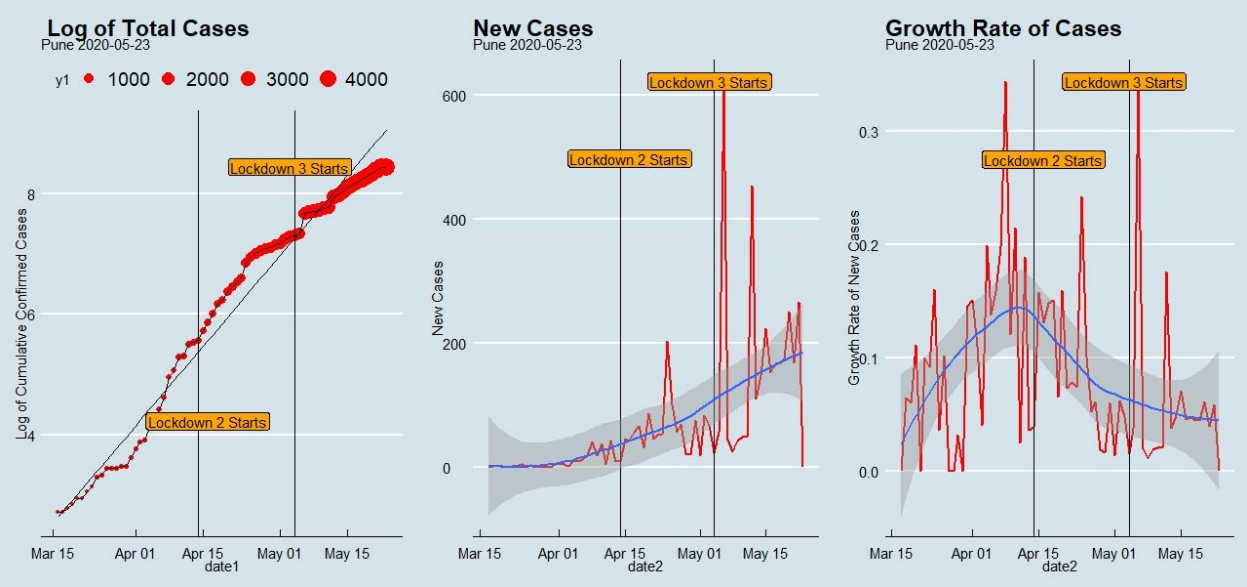


Figure: 41



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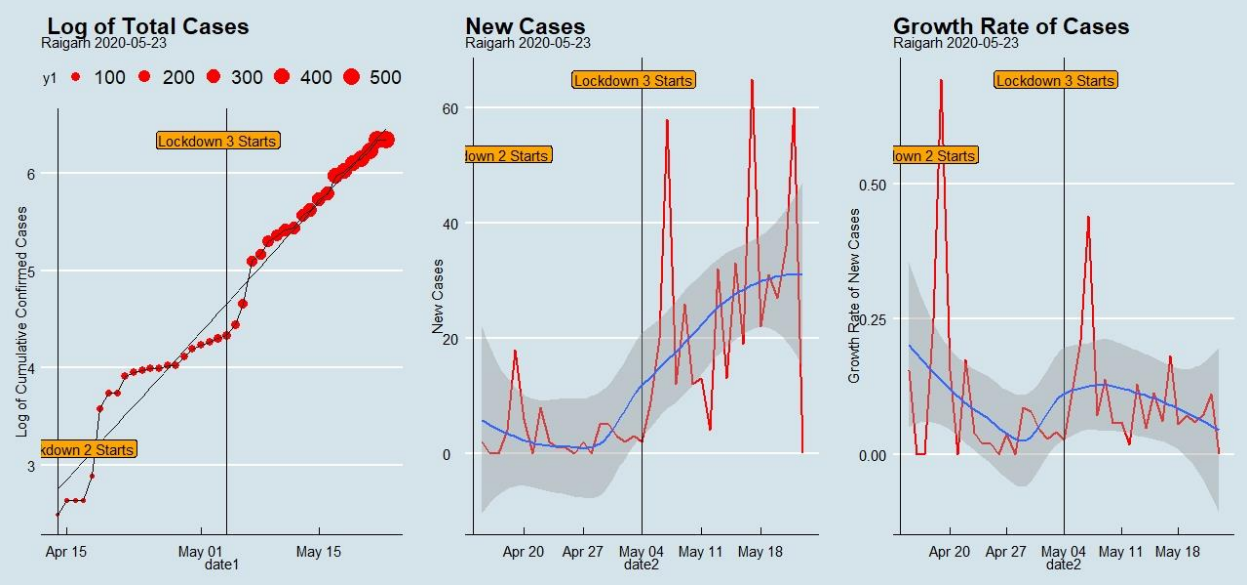

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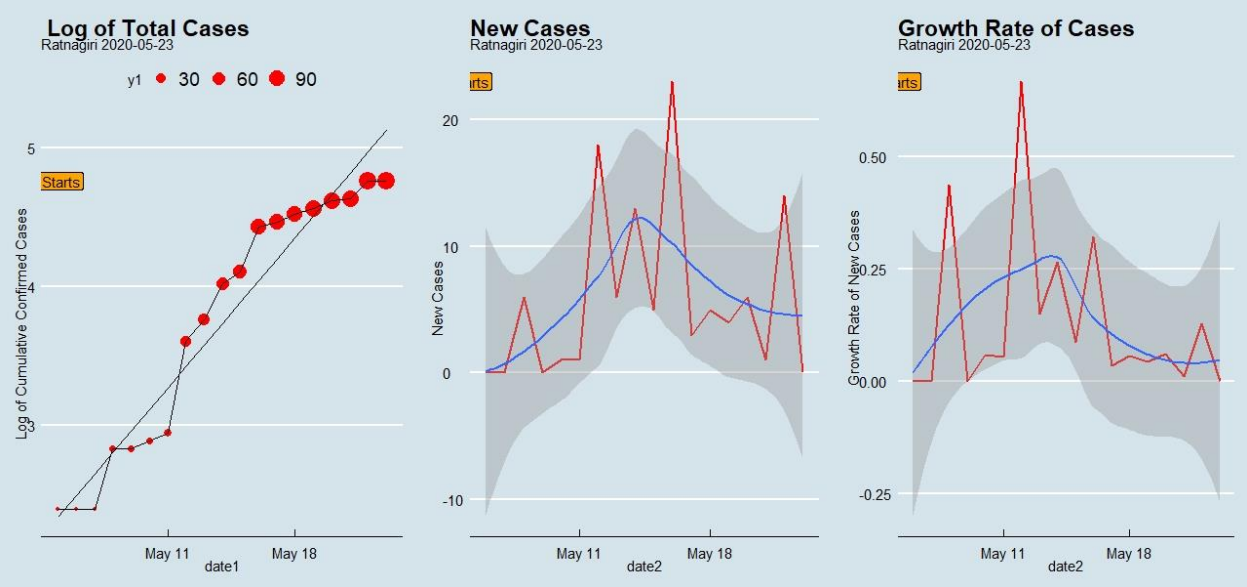

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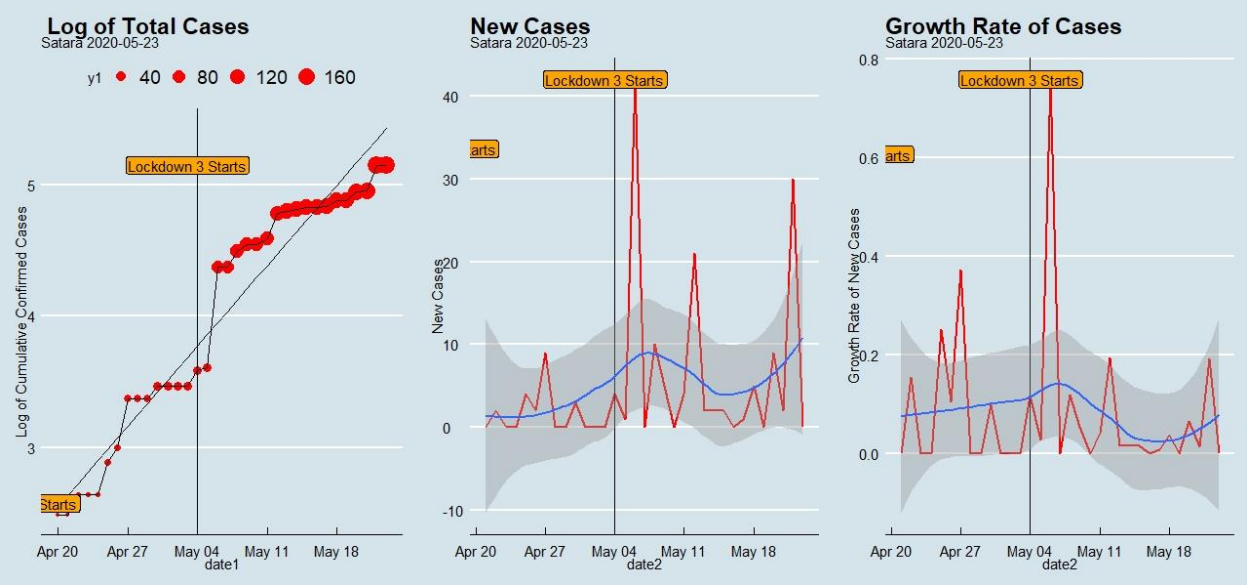

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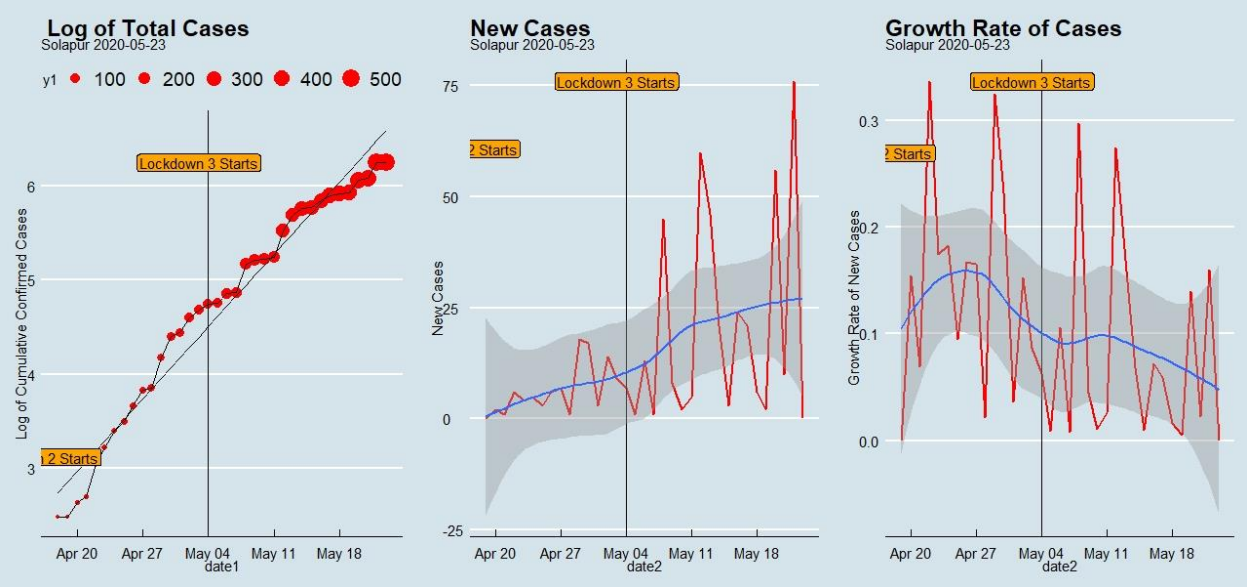

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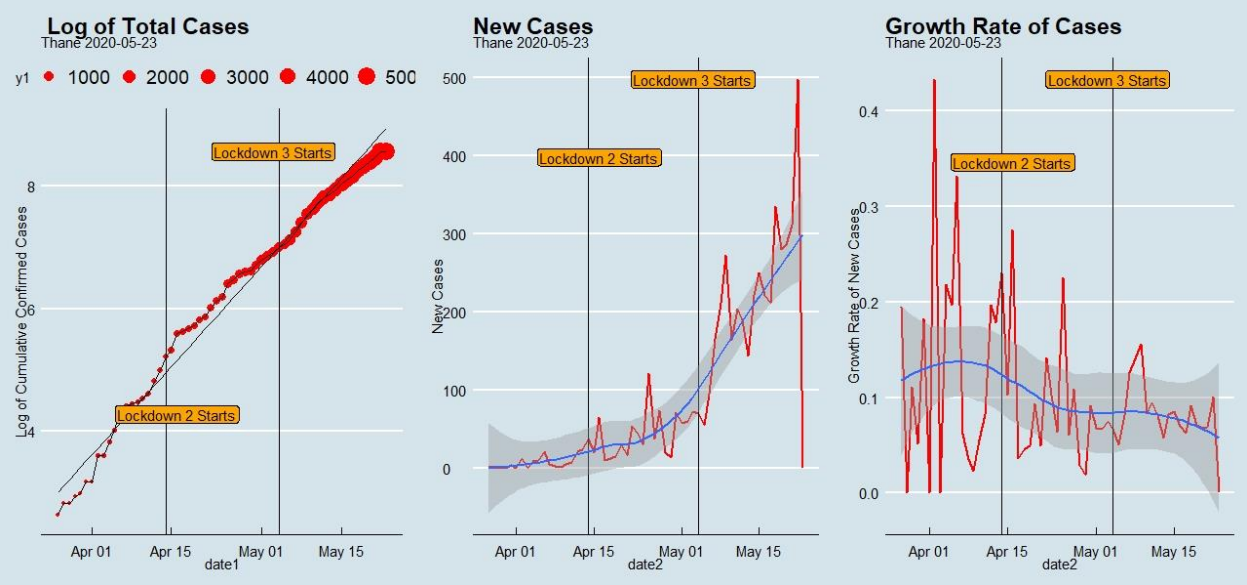
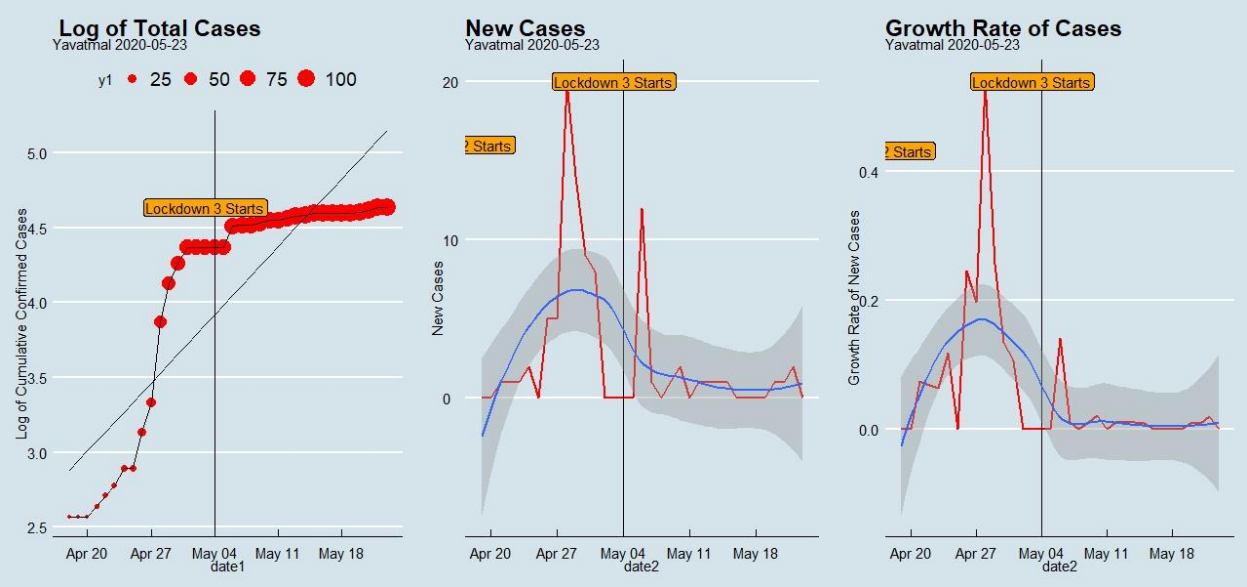


Figure: 47



As can be easily seen from the graphs that districts like Ahmadnagar, Hingoli, Latur, Mumbai, Nanded, Nandurbar, Ratnagiri, Solapur, Thane, Dhule and Yavatmal are showing flattening of the curve. This has happened at varying rates between lock down 2 and 3.Akola,Amaravati,Buldhana, Kolhapu r,Satara, Sangli and Palghar are the districts of some concern where the growth rate has actually picked up post lockdown 3.Aurangabad,Nagpur,Pune,Raigarh,Jalgaon,Jalna show slow but steady decline in the growth rate.

Conclusion:

Although we can see that the total number of cases of Covid-19 cases is increasing day-by-day inn Maharashtra and in Mumbai things are actually improving. The ground level evidence does not paint such a grim picture. The statistics in this paper help one see clearly through the dust of the media reports, untimely politics and popular sentiments. What one sees should allow a degree of cautious reassurance that things are far from being out of hand. Se need to be particularly concerned about states like Assam, Himachal Pradesh , Odisha which have shown no signs of slowing down despite lockdowns, or states like Karnataka or Kerala that are showing an uptake. Unfortunately, it is the mega cities and their huge numbers that are hogging all the media lime light.

As a postscript, we would like to highlight another issue. The experience of Mumbai, Delhi, Ahmedabad has shown us what tinder boxes of cities we are sitting on as far as the effects of

large pandemics are concerned. India is one of the world's fastest growing economies and its rapid growth attracts poor people from the countryside to its cities in hordes. But minus appropriate policy mixes that would ensure affordable housing, the poor are forced to live in jam packed surroundings with next to no infrastructural facilities or basic amenities. This is a situation ripe enough for epidemic spread. So far, epidemics have been proliferating in the slum neighborhoods of cities, but have not had a large impact on the non slum dwelling non -poor. Ciovod-19, and the lock down associated with it is perhaps one rare instance when the privileged and the middle classes have borne the brunt. We sincerely hope that a realization would dawn on the policy makers that rapid growth needs to be accompanied by policies that will support the lives of the poor who drive the growth. The gridlock of badly designed urban housing policy needs to be broken and broken fast.