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Short Essay

Understanding COVID-19 Situation in India from Inequality Study

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Abstract

In this article I have studied the inequality in the state-wise number of COVID-19 infected people in India from various aspects. Inequality was measured usingthe Gini index. The time period of this study is from March 2020 to July 2022. In this study, the temporal variation of the Gini index for inequalities in state-wise number of new COVID-19 infected people per 5 days shows oscillatory in nature. This clearly indicates that inequality has some realistic upper and lower limits. This is different from the theoretical upper and lower limit of the Gini index which are 1 and 0 respectively. Comparing this sinusoidal curve with temporal variation of COVID-19 infected people in every 5 days, one can also predict the coming situation of COVID-19 in India.

Keywords: *Inequality, Lorenz curve, Gini index, COVID-19 infection, temporal variation.*

1. Introduction

Inequality and socioeconomic issues are inseparable. From the beginning of human civilization, we have noticed disparities in income, wealth, and opportunity often lead to serious societal problems. These issues are multifaceted, encircling income inequality, wealth concentration, access to education and healthcare, and various forms of social and political inequality [1,2]. Spatial inequality is also observed in the spread of infectious diseases [3, 4, 5]. With time they change the epicenters. Recent impact of COVID-19 pandemic has forced researchers to explore this field in more detail. As spreading of an infectious disease affects people and society directly, policy making becomes a vital issue to protect society from all odds related to an epidemic situation [6, 7]. Various models have been invented to understand the spreading nature of infectious diseases [8, 9]. However, till now, studying a pandemic from the spatial inequality in spreading rate is yet to be explored in the literature.

In this article, I have studied inequalities in the state-wise number of people infected with COVID-19 in India. COVID-19 hit India around March 2020. Like any other infectious disease, the spread of COVID-19 is also dependent on various aspects like weather condition, social status, health and hygiene of people, economic conditions and so on[10, 11]. However, the spreading nature is the same anywhere.Infections spread exponentially at first, then, follows a power law. At the end, infection flattens until successive waves impact [12, 13, 14]. State-wise daily data of COVID-19 infected people in Indiaare available in the various websites [15, 16, 17, 18]. I have considered data of COVID-19 cases in India from March 2020 to July 2022 for the present study.

In the following section, I have briefly discussedhow to measure inequality mathematically using the Gini index. In section 3, I have shown how COVID-19 infection rate varies with time. Section 4 deals with spatial variation of infection rate. In section 5, I have shown both temporal and spatial variation of this infectious disease. Section 6 depicts the amazing outcome of the present study. This article ends with section 7, where I have summarized my findings.

2. Mathematical formulation of Inequality

Mathematical presentation of inequality starts with Pareto's 80/20 law, which states that, 20% of causes are related to 80% of consequences [19]. Graphically inequality is expressed by the Lorenz curve [20].I shalldescribe the procedure to plot the Lorenz curve through a function,$L(x) = x^n$, where, n is any natural number. One can consider x is the normalized cumulative fraction of population while $L(x)$ is the normalized cumulative fraction of wealth/income possessed by them. When $n = 1$, all the values of $L(x)$ are the same as$x$. So, distribution of $L(x)$ with$x$is perfectly equal. As n increases,$L(x)$ becomes more and more unequal relative to the corresponding values of x. Thus, $n$represents inequality in distribution of $L(x)$ with x.

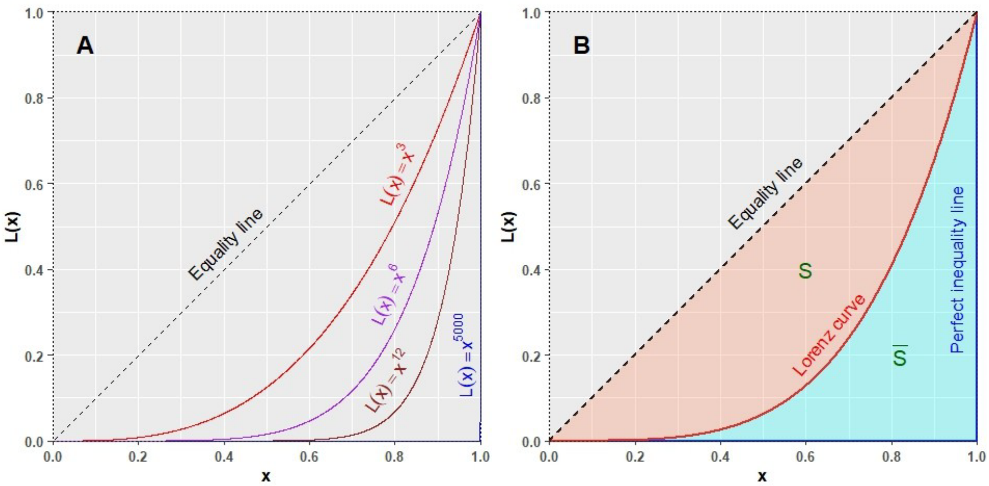


Figure 1A: - Lorenz plots with different inequalities. As inequality increases Lorenz plot bends towards perfect inequality line.

Figure 1B: Measurement of the Gini Index from a Lorenz plot. Gini index, g = S/(S+$\bar{S}$)

In case of Lorenz plot, the parameters which represent x and y–axis are arranged in a specific manner. For this, one has to arrange thevalues of x $(x_0, x_1, x_2, \ldots, x_k)$ in an ascending order $(x_i < x_{i+1})$along the x-axis such that, $x_0 = 0$ and $x_k = 1$, where k is the end point. So, the values of x should be normalized and in ascending order. The same is true for y-axis also. Here, the values of $L(x)$ should be arranged in ascending order such that, $L(0) = 0$ and $L(1) = 1$.

In Fig. 1A, Lorenz curves with different inequality have been shown.When $n = 1$, The $L(x)$ is equally distributed among x and the corresponding graph is known as the "Equality line" (black dotted line). With increasing n, L gradually bends towards the border line.When $n \to \infty$, the Lorenz curve overlaps with the boundary line (denoted by blue line) and is known as the "perfect inequality line".In this case, $L(x) = 0$ if $x \neq 1$ and $L(x) = 1$ if $x = 1$.

Gini indexis estimated from the Lorenz curve. I have shown a particular Lorenz curve for a certain n in Fig.1B. Gini index is measured as, $g = \frac{S}{S+\bar{S}}$ where, S is the pink shaded area between the Equality line and the Lorenz curve, while $\bar{S}$ is the cyan shaded area between the Lorenz curve and the perfect equality line. In this case $S + \bar{S} = \frac{1}{2}$ and $g = 2S$.So, g is 0 for perfect equality (as $S = 0$) and 1 (as $S = \frac{1}{2}$) for perfect inequality. However, these two values are for ideal cases.

In reality, perfect equality or perfect inequality is never achieved. In reality, g lies between two certain values which are not one or zero and they are the effective upper and lower limits. Now let us concentrate on our present topic, i.e. inequality in COVID-19 infection rate in India. Like any other infectious disease, COVID-19 should also change its epicenters with time. In the next section, I have explained this topic.

3. Temporal variation of COVID-19 infection rate

In Fig. 2, I have shown how the spreading rate of COVID-19 infection in India varies with time. I have already told that time span of my study is from March 2020 to July 2022. Here the plot depicts the number of COVID-19 infected people detected in each 5 days. I have chosen 5 days because sometimes infected population data of some states were uploaded after a gap of 2-3 days. So, choosing 5-day gap is safer for analyzing the data.Fig.2 revels that spreading rate of infection is different at different time. This is obvious characteristics of any infectious disease.

From March 2020 to July 2022, rate of spreading of infection varied from nearly zero to maximum 2 lakh infection/5 days. After first detection of COVID-19 in March 2020, spreading rate of infection increased till October, 2020. Then it decreased till February 2021. This indicates that during this period, i.e. from March 2020 to February 2021, rate of spreading was maximum around October 2020. One may consider this as the first peak.After this, infection rate again increased and it gained a peak around May 2021. This time number of COVID-19 infected people in 5 days was around 2 million. Then it decreased till December 2021. However, during this period, i.e. from March 2021 to December 2021, apart from major peak around May 2021, many local maxima and minima can be found in the plot. One may consider these as local fluctuations.

At the last stage of the period under study, infection rate again increases from January 2022 and gains a peak around February 2022. Then again decreases and flattens around March 2022. So, during the period of study, there are three major peaks. The spreading rate of infection is approximately 4.3 Lakh/5 days around the 1-st peak, 20 Lakh/ 5 days around 2-nd peak and 16 Lakh/ 5 days around the third peak. Again, another important characteristic of the plot is that the width of the peaks gradually decreases from 1-st to 3-rd peak. In the next section I shall discuss the spatial variation of infection rate.

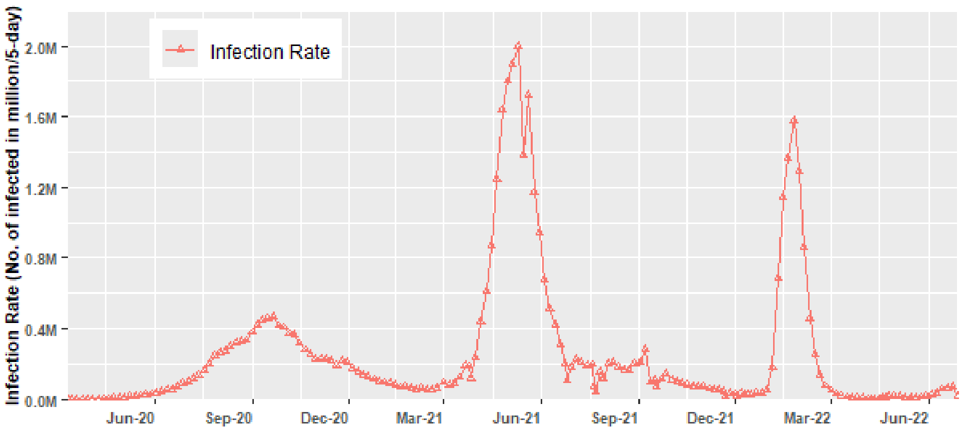


Figure 2: Number of infected people in million due to COVID-19 in each 5 days within India.

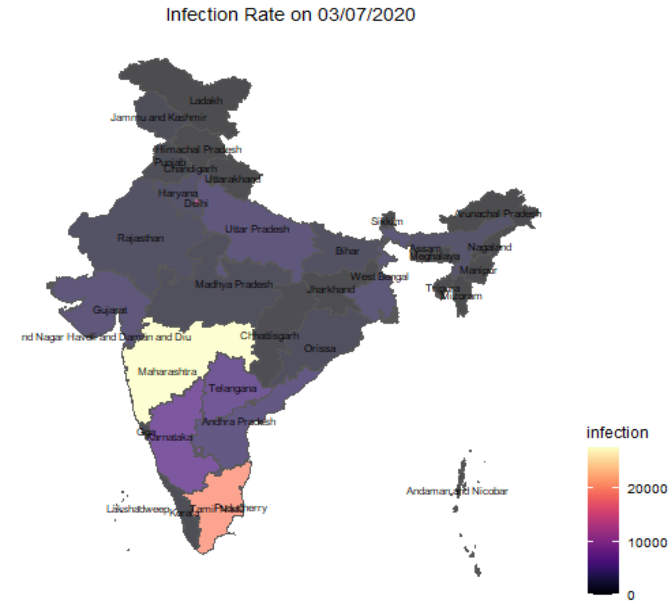
4. State-wise variation of COVID-19 infection rate

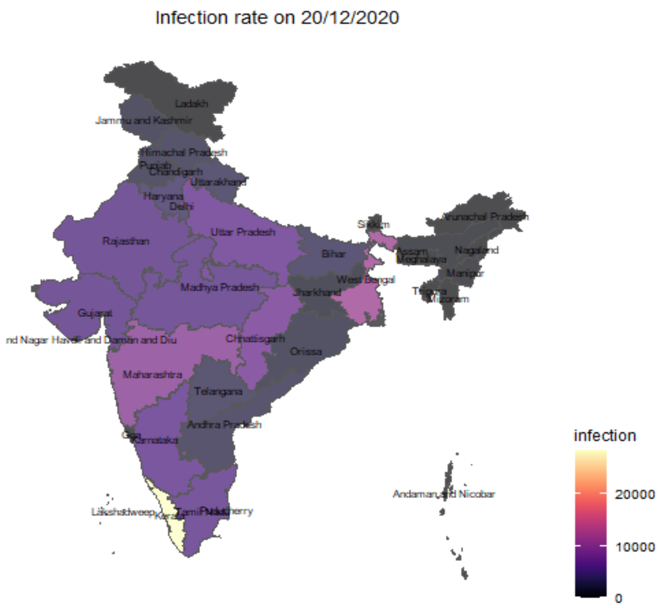
Fig. 2 does not provide any information about inequality in state-wise infection rate at a certain time. It only shows how infection rate of COVID-19 changes with time. Now, I shall concentrate on spatial variation of the rate of infection of COVID-19. India consists of 28 states and 8 Union Territories (UT). Spatial variation of COVID-19 means, on a certain date, spreading rate of COVID-19 should be different in different states and UTs. To visualize this, I have taken the help of choropleth map. In Fig. 3, I have shown 6 choropleth map of India showing number of people infected in each 5-day state-wise on six different dates.

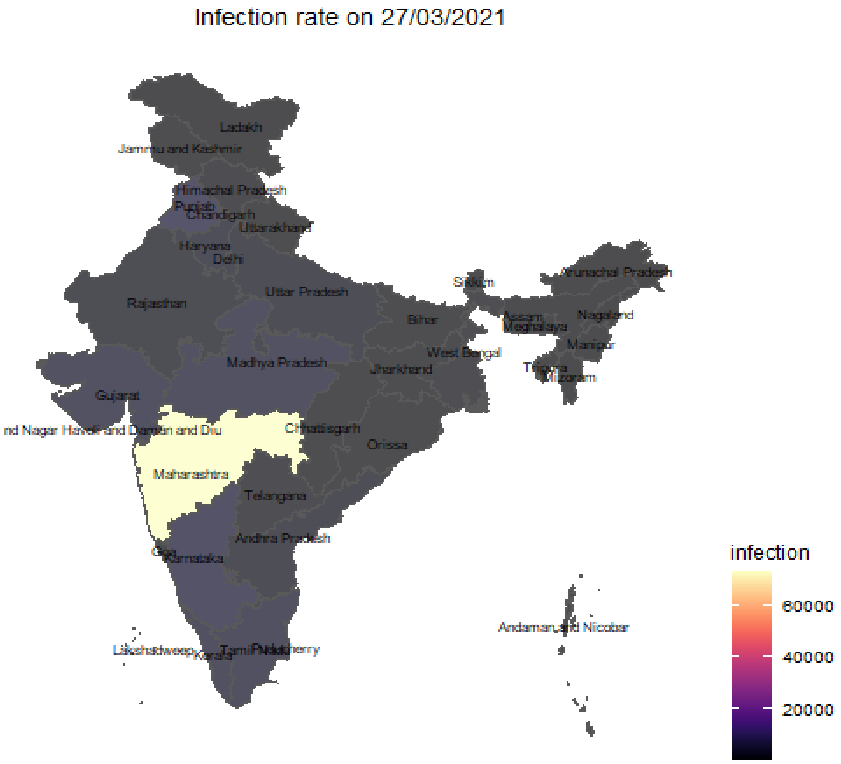
Fig. 2 suggests that temporal variation of infection rate has three major peaks. So, I have chosen 6 different dates for choropleth map to show that spatial inequality exists all the time throughout the time span under study. The first two dates in the upper row of Fig. 3 are 03/07/2020 and 20/12/2020. These two dates have been chosen because they are on two opposite sides of 1-st major peak which was observed around October

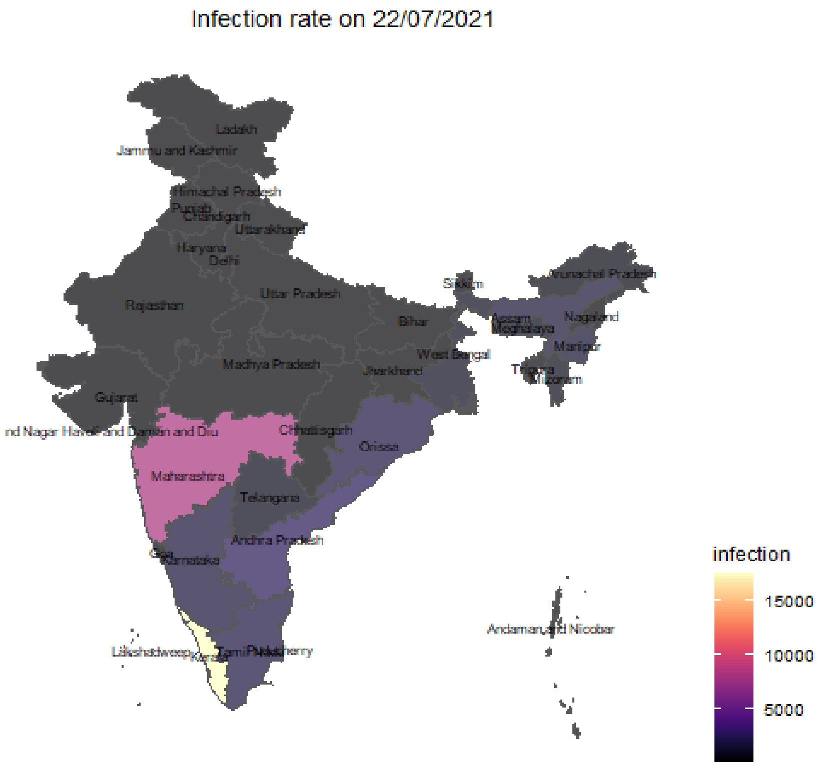
2020. In the same manner the two dates (27/03/2021 and 22/07/2021) in the middle row lie on opposite direction of the time when 2-nd major peak which was observed around May 2021. In the same process, the two dates in the lower row, 05/01/2022 and 06/03/2022 are in opposite sides of third major peak which was observed around February 2022.

Now let us concentrate on the two choropleth maps of the upper row in Fig. 3. The left one among these two plots is based upon data on 03/07/2020. This map depictsstate-wise spreading rate of COVID-19 on this particular date.






Infection rate on 27/03/2021
Ladakh
Jammu and Kashmir
Himachal Pradesh
Punjab
Chandigarh
Uttarakhand
Haryana
Delhi
Rajasthan
Uttar Pradesh
Sikkim
Arunachal Pradesh
Bihar
Assam
Meghalaya
Nagaland
Madhya Pradesh
West Bengal
Manipur
Jharkhand
Tripura
Mizoram
Gujarat
Chhattisgarh
Orissa
Maharashtra
Telangana
Andhra Pradesh
Goa
Karnataka
Lakshadweep
Andaman and Nicobar
infection
60000
40000
20000


Infection rate on 22/07/2021
Ladakh
Jammu and Kashmir
Himachal Pradesh
Punjab
Chandigarh
Uttarakhand
Haryana
Delhi
Rajasthan
Uttar Pradesh
Sikkim
Arunachal Pradesh
Bihar
Assam
Meghalaya
Nagaland
Madhya Pradesh
West Bengal
Manipur
Jharkhand
Tripura
Mizoram
Gujarat
Chhattisgarh
Orissa
Maharashtra
Telangana
Andhra Pradesh
Goa
Karnataka
Lakshadweep
Andaman and Nicobar
infection
15000
10000
5000

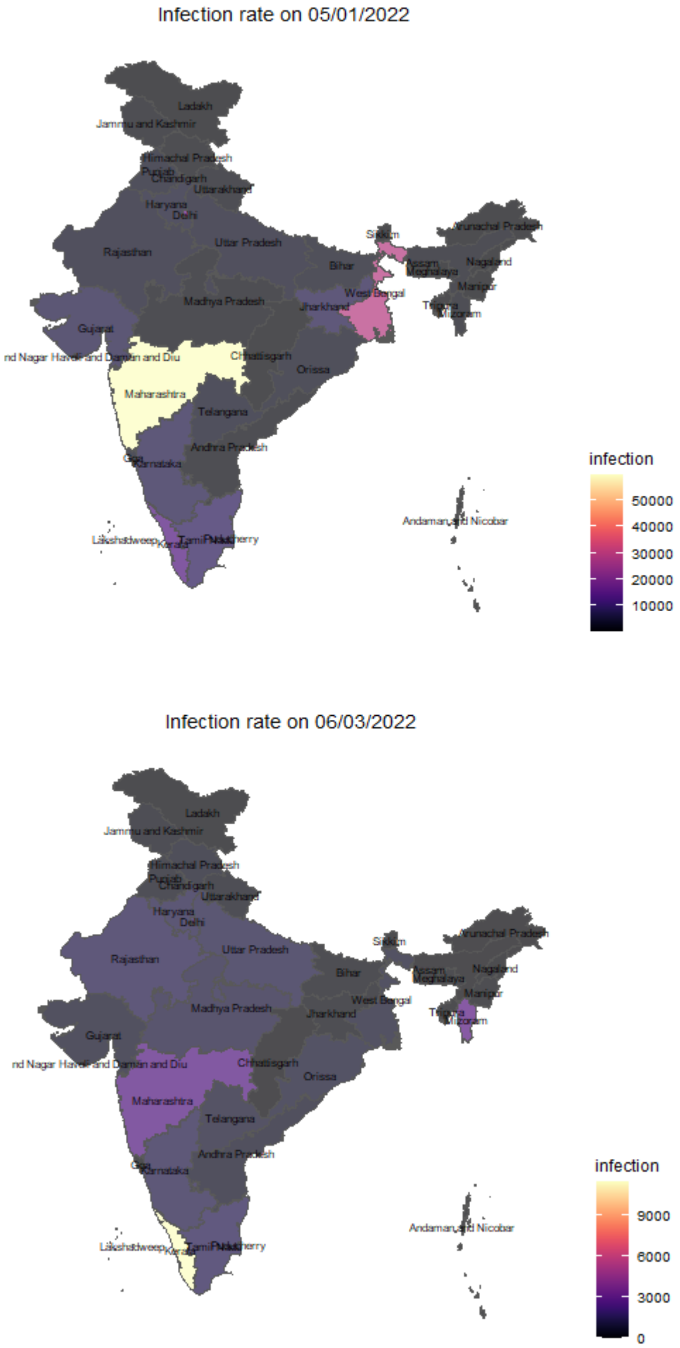


Figure 3: Choropleth Map showing state-wise number of infected people/ 5 day on different dates. The upper left plot indicates spreading rate on 03/07/2020 and upper right on 20/12/2020. The middle left plot shows information of spreading rate on 27/03/2021 and middle right on 22/07/2021 while the lower left on 05/01/2022 and lower right on 06/03/2022.

Here, Maharashtra has the highest infection rate followed by Tamilnadu and Karnataka. Most of the northern states have very low infection rate. Now let us observe the right choropleth map of the upper row. This map has been prepared on the basis of infection rate on 20/12/2020, i.e. after the 1-st peak. Here Kerala has the highest infection rate. Most of the northern and southern states display significant infection rate. Both these two choropleth maps show huge inequality in state-wise infection rate of COVID-19. Although, with time rate of infection changes in each state, however inequality in infection rate among the states always remains.

The left choropleth map of middle row reflects infection rate in different states of India on 27/03/2021 while the right one on 22/07/2021. The left choropleth map reflects that at the beginning of 2-nd peak, on 27/03/2021, only Maharashtra shows significant infection rate while other states have very low rate. This indicates presence of strong inequality in infection rate among the states. The right choropleth map of middle row reveals that Kerala has highest infection rate followed by Maharashtra, Andhra Pradesh and Orissa. Others states have low infection rate.

The left and right choropleth maps of the last row reflects infection rate on 05/01/2022 and 06/03/2022. The left one show Kerala has highest infection rate, followed by Maharashtra and Mizoram. Other states has low infection rate. Whereas the right map informs Maharashtra plays the leading role followed by West Bengal and Kerala. Other states have low infection rates.

In a nutshell, all of these six choropleth maps suggest presence of very strong spatial inequality in COVID-19 infection rate all the time. In the next section, I shall concentrate on the temporal variation of this spatial inequality for the whole period of study.

5. Temporal variation of spatial inequality of infection rate of COVID-19

To study temporal variation ofspatial inequalities of infection rates among Indian states,I have calculated date-wise Gini index. The Gini index on a particular date depicts spatial inequality of infection rate on that day. For this, I have considered “state-wise number of people infected for last 5 days on a particular date” as the y-variable and “the number of states” as the x-variable. Then following the process depicted in section 2, I have plotted Lorenz curve for that particular date. From this Lorenz plot, I calculated Gini Index. The value of Gini index depicts the amount of spatial inequality in infection rate of COVID-19 in India on that particular date. In the same manner, starting from March 2020 to July 2022, I have calculated Gini index for each 5-day interval and plotted in Fig. 4. This plot depicts temporal variation of spatial inequality of COVID-19 infection rate for the whole period of study.

Ignoring initial fluctuations, one can observe that Fig. 4 shows oscillatory nature with maxima around 0.87 and minima around 0.63. This may be considered as the realistic limits of inequality in this particular case. Actually, in reality many external factors affect the system under study which try to mitigate inequality. As for example, when inequality becomes too high, the states with high infection rate imposes many mitigation measures very strictly and people also obey them. So, infection rate decreases and inequality also decreases. Again, when infection rate in a state becomes too low, people starts to ignore mitigation measures strictly and infection increases with new epicenters. In the process inequality also increases. Thus, one should not expect presence of perfect equality or perfect inequality in real social issues like COVID-19. In the process, Gini index never shows 1 or 0, but some other maxima and minima.

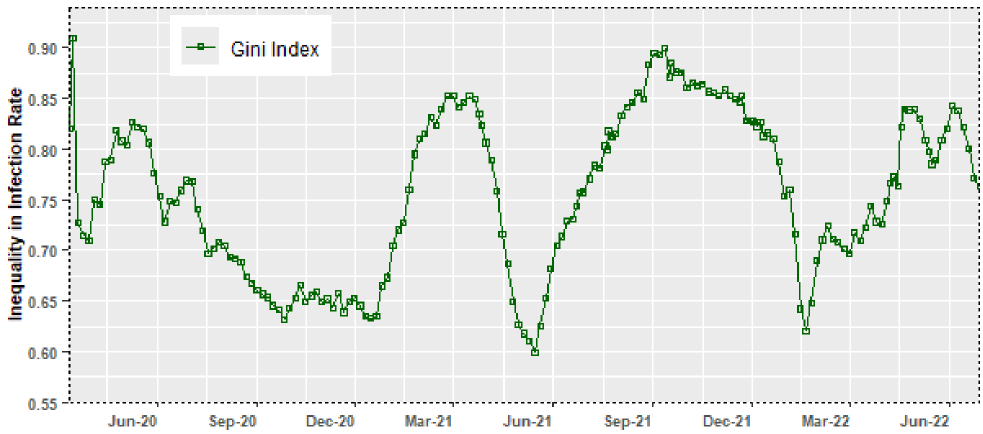


Fig. 4: Temporal variation of spatial inequality of COVID-19 infection rate in India

In the next section, I have described one important outcome of the present study.

5. Future estimation of situation of COVID-19 infection

In Fig. 5, I have compared Fig. 2 with Fig. 4 considering the same x- axis, i.e. date range. Here, one can observe that when the Gini index touches the minima, overall infection rate (number of COVID-19 infected people in each 5 days for whole country) touches maxima. Vice versa, when the Gini index attains maxima infection rate is around minima. In this case, The Gini index represents spatial inequality of infection rate. It informs when infection rate is at peak, i.e. all the states shows steep rise in infection rate due to a certain wave, no new epicenters are generated. As a consequence, for some time the total number of infected people rises but the spatial inequality decreases. After a certain time, in absence of new epicenters infection rate of all the states starts decreasing. This indicates end of a certain wave. During this time a new wave hits and COVID-19 finds some new epicenters. In the process inequality again rises.

Thus, a careful study of temporal variation of spatial inequality hints when COVID-19 infection will rise and when it will fall. By simply studying inequality, one can predict the future trend of COVID-19 infection. This has a deep impact in epidemiology. It will help the policymakers to take necessary action.

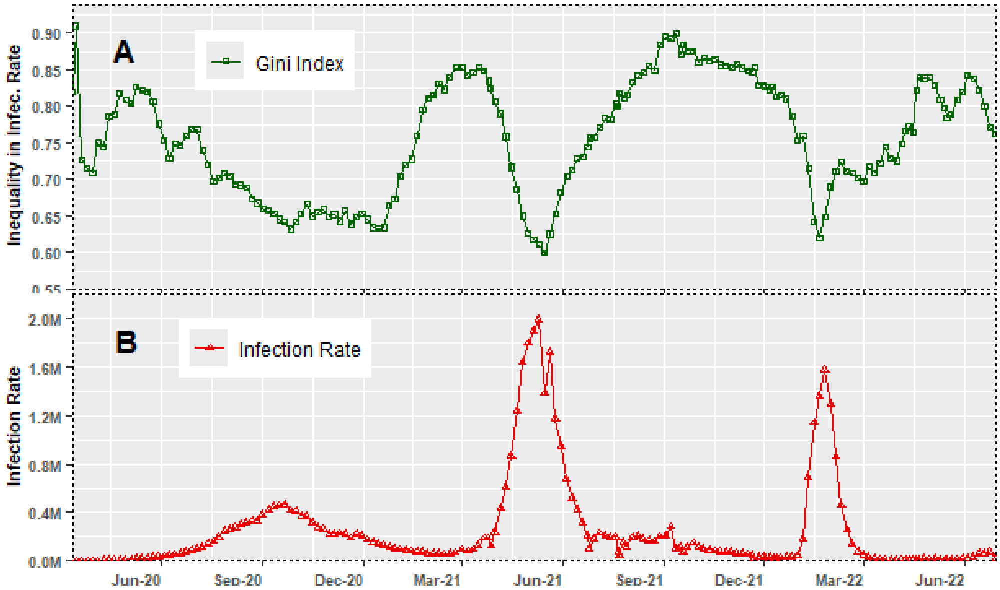


Fig. 5: Comparison of the temporal variation of Gini index (Indicating spatial inequality in state-wise infection rate) with the temporal variation of infection rate for whole India for same date range. The Gini index is represented by dark green line with square points and COVID-19 cases in each 5-day, i.e. COVID-19 infection rate is represented by red line with triangular points.

7. Summary and Discussion

The article deals with temporal variation of spatial inequalities in state-wise infection rate due to COVID-19 pandemic. Here inequality has been measured in terms of the Gini index. Some important outcomes of the present study are:

Like many social phenomena, infection rate of a disease also shows spatial inequality. Although with time, epicenter of the disease changes, but overall spatial inequality always remains. Again, spatial inequality is minimum when average infection rate all over the country is low and maximum when average infection rate is high. Spatial inequality varies sinusoidally with time with a certain upper and lower limit.

The Gini Index for a particular social issue have upper limit 1 and lower limit 0 for ideal cases. Gini index 1 represents perfect inequality and 0 represents perfect equality. However, in reality, both perfect equality and perfect inequality do not exist. For, realistic social issues the Gini index also varies between two certain values which are not 0 or 1. These are called realistic upper limit and lower limit. In this particular case maximum value of Gini index is around 0.87 and minimum value is around 0.63.

Studying temporal variation of inequality in state-wise infection rate one can predict whether overall number of COVID-19 infected people in India will increase or decrease in near future. It proves that studying inequality is an important aspect for policy making as it can predict future trend of an infectious disease.

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