

Global Lockdown: An Effective Safeguard in Responding to the Threat of COVID-19

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Abstract

Rationale, aims, and objectives: The recent outbreak of coronavirus (COVID-19) has infected around 1,560,000 individuals till 10th April 2020, which has resulted in 95,000 deaths globally. While no vaccine or anti-viral drugs for COVID-19 are available, lockdown acts as a protective public health measures to reduce human interaction and lower transmission. The study aims to explore the impact of delayed planning or lack of planning for the lockdown and inadequate implementation of the lockdown, on the transmission rate of COVID-19.

Method: Epidemiological data on the incidence and mortality of COVID-19 cases as reported by public health authorities were accessed from six countries based on total number of infected cases, viz., (United States of America (USA) and Italy (more than 100,000 cases); United Kingdom (UK), and France (50,000 to 100,000 cases), and India and Russia (6,000 to 10,000 cases). The Bayesian inferential technique was used to observe the changes (three points) in pattern of number of cases on different duration of exposure (in days) in these selected countries one month after WHO declaration about COVID-19 as a global pandemic.

Results: On comparing the pattern of transmission rates observed in these six countries at posterior estimated change points, it is found that partial implementation of lockdown (in the USA), delayed planning in lockdown (Russia, UK and France), and inadequate implementation of the lockdown (in India and Italy) were responsible to the spread of infections.

Conclusions: In order to control the spreading of COVID-19, like other national and international laws, lockdown must be implemented and enforced. It is suggested that on-time or adequate implementation of lockdown is a step towards social distancing and to control the spread of this pandemic.

Keywords: Social distancing; Posterior distribution; Marginal distribution; Credible interval.

1. INTRODUCTION

The 2019 Coronavirus(COVID-19) outbreak is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which affects the respiratory system.^{1,2} The disease was first identified in Hubei Province, People Republic of China, in late 2019 and has spread globally. The WHO declared³ it as a global pandemic on 11th March 2020;however, by then COVID-19 had already spread to over 100 countries and infected more than 100,000 people, taking over 4000 lives. By 10thApril 2020, this outbreak has affected more than 1,560,000 people across the globe (<https://ourworldindata.org/coronavirus-source-data>). The virus is primarily spread from person-to-person via close contact, either through small droplets released during sneezing, coughing, or talking.⁴

The world had already experienced a COVID-19 like pandemic situation a century ago (i.e., 1918-19), regarding H1N1 influenza (commonly known as Spanish flu).⁵ During theH1N1pandemic, some countries, particularly the United States of America (USA), tried a range of non-pharmaceutical interventions (NPIs) - measures intended to shrink the spread by avoiding person-to-person contact in the general population.⁶

For any epidemic or pandemic various national⁷ and international laws⁸⁻¹⁰ are available for slowing down the spread of any infectious disease. Laws should have been prioritised as per the requirement of the situation and supplement the other measures that to be taken in a public healthemergency^{10,11}to control the spread of the infection, whereas, law-enforcement takes the action or activity compliance with the objective stated in law, and it includes over governmental bodies like police officials, government officials or officers etc. Governmental bodies have also tried to reduce the transmission of infectious diseases through the legislative system (International Health Regulations,1981¹², 2005¹³; National Health Act, 2003¹³).^{14,15,16} Law can also contribute to the prevention of infectious diseases by improving access to vaccinations^{17,18}, facilitating screening^{12,19}, counselling, and education of those at risk of infection. Additionally, law has a responsive role, such as supporting access to treatment, empowering public health authorities to reduce contact with infectious individuals, and to exercise emergency powers in response to disease outbreaks. Essential treatment orders should restrict individual liberty only to the extent necessary to most effectively reduce risks to public health.¹² The consequences of infectious disease can also induce negative economic effects, leading to economic instability and poor socio-

economic growth.^{20,21} Governments in each country have come forward to support those who have suffered economic loss due to any infectious disease outbreak.^{22,23,24}

Globally, the core rationale for opting for lockdown was to protect human life from the COVID-19 infection by stopping the transmission of disease across the communities. The other purpose of lockdown was to provide healthcare services to those infected with COVID-19 virus as well as continuing to facilitate all other general healthcare facilities.

Governments in most of the countries have adopted lockdown and tried in all possible ways to reduce the human interaction for controlling the spread of COVID-19. However, transmission rate of COVID-19 was found to be increasing even after the implementation of lockdown. In this context, the objectives of the present study are to explore the impact of delayed planning or lack of planning for the lockdown of the country and inadequate implementation of the lockdown, on the transmission rate.

2. METHODOLOGY

In order to assess the impact of lockdown against the spread of COVID-19; a multiple change point model using the Bayesian regression technique (discussed in **Appendix**) was adopted for describing the intermittent behaviour in number of registered cases due to the infection by following the stochastic procedure. Here, a change point denotes an instance of the duration of exposure to infection where the statistical properties before and after that time differ. The change was observed in the rates of transmission, with the duration of exposure (in days). Multiple change points technique derived through Bayesian inferential procedure will provide the maximum likeness in terms of daily registered COVID-19 cases by defining the changes observed in pattern of number of cases on different duration of exposure (in days). The model (Bayesian regression based multiple change point model^{25,26}) considered for the present analysis is based on the basic assumptions that (a) number of daily registered cases due to the infection is a linear function of duration of exposure to the infection; (b) number of daily registered cases across the countries is independent. The methodological aspect of Bayesian estimation²⁷ of change occurred in the pattern of number of daily registered cases in a country due to COVID-19 and its related 95% credible interval were obtained through the posterior distribution. The simulation was performed using R software version 3.6.2.

2.1 The data

In order to study three shifts or changes in pattern of daily COVID-19 cases, the epidemiological data on the incidence and mortality of COVID-19 cases as reported by public health authorities worldwide was accessed till 11th April 2020 from the website of Our World in Data (<https://ourworldindata.org/coronavirus-source-data>). For the present study, we considered date-wise number of infected cases due to COVID-19 of six selected countries: Russia, United Kingdom (UK), India, France, Italy and USA, where country-wide lockdown was scheduled either fully, partially or not implemented. From an extensive reporting of COVID-19 data across the globe, about 50% of cases were registered from these selected countries. The criteria for selection of these countries were based on total number of infected cases, which was classified in three categories namely more than 100,000 cases (USA and Italy), 50,000 to 100,000 cases (UK and France) and 6,000 to 10,000 cases (India and Russia). Here, the first date of reporting COVID-19 cases, corresponding to each selected country, was considered as the starting day. We have also obtained the full lockdown related information about India, UK, France, and Italy from the online published news.

3. RESULTS

Table 1 summarizes posterior mean estimates of equation (1) including each change points (s_j), regression coefficients (β), standard deviation (σ), and their credible intervals (CrI) for each of the selected countries. Based on the pattern of daily registered cases of COVID-19, the shortest posterior estimate duration of exposure (95% CrI) for first change point (Cp 1) in the daily infected cases, was observed in Italy on 42nd day (40 to 44 days) of exposure followed by France on 48th day (13 to 60 days), UK on 49th day (47 to 54 days), Russia on 50th day (48-52 days) and India on 54th days (49 to 63 days). The posterior estimate duration of exposure at first changing point was highest (60th day with 95% CrI (59 to 62 days)) for the USA compared to other countries in the pattern of daily infected cases.

As far as posterior estimate of second change point (Cp 2) is concerned, the pattern of daily infected cases shifted with respect to first change point within 5 days in Russia, 6 days in the USA, 7 days in UK and Italy, and highest was 9 days in India and France. If we compare the posterior estimate of third change point (Cp 3) with respect to second change point, shift in the pattern of daily

infected cases were observed within 4 days in France, 5 days in India, 6 days in Russia, UK and USA, and 11 days in Italy.

The six selected countries (Russia, United Kingdom, India, France, Italy, and USA), reported 50% of world's COVID-19 infection cases till 10/04/2020. The posterior estimates of the parameters (in Table 1), β , σ , s_j , of Bayesian regression based multiple change point model. Non-informative choice of priors for β and σ provided an apparently good fit to the number daily registered cases. The 95% credible interval of their posterior estimates of β and σ are showing a narrow interval. As our parameters of interest are the point in duration of exposure, where there were shifts in pattern of number of daily registered cases, the 95% credible interval of their posterior estimates for each of the change points were showing a narrow interval and consistent pattern with posterior density as depicted in Figure S1 of Appendix.

In order to understand the impact of delaying lockdown and whether its implementation was effective on the number of daily registered cases of COVID-19 in each of the selected country, two-way comparisons are presented in the Table 2. Firstly, we compared posterior estimate of point for first change with the lockdown, which will answer the question whether the lockdown was on time. Secondly, we compared the posterior estimates of consecutive change points to review whether the lockdown was properly implemented. Here, reported days refer to days where COVID-19 cases were registered; therefore, it is different from the length of time interval.

Table 2 presents the date of first COVID-19 infected cases for each of the selected countries, their duration of exposure experienced (days), and number of infected cases reported on dated 11/03/2020, when WHO declared COVID-19 outbreak as a pandemic. Corresponding to each of the selected countries, duration of exposure experienced (days), and number of infected cases reported on the date scheduled for lockdown, was also presented. In order to visualize the shift in pattern of daily infected cases, for each country, the number of infected cases reported on the posterior estimate of change points, first (Cp 1), second (Cp 2) and third (Cp 3), were also reported. The pattern of daily infected cases and its posterior densities corresponding to each country and their change point were depicted pictorially in Figure S1 of Appendix. The pattern of cumulative COVID-19 cases and its associated deaths was presented in Figure S2 of Appendix.

The country wise change trend for reporting COVID-19 cases are described as follows:

In Russia, the first case of COVID-19 was registered on 31/01/2020, with the first change in trend for reporting COVID-19 cases was posterior estimated as 50th day with 95% CrI (48 to 52 days), on that day, there was a total of 658 cases registered. Lockdown was scheduled in Russia on the 55th day of reporting, on 31/03/2020, which was the second change point posterior estimate with 95% CrI(54 to 56 days). The posterior estimate of third change point was observed on 61st days having 95% CrI (60 to 62 days) with 5389 cases of COVID-19.

In United Kingdom (UK), the first case of COVID-19 was registered on 31/01/2020 and the first change in trend for reporting of COVID-19 cases was posterior estimated as the 49th day with 95% CrI (47to 54 days), on that day, there was a total of 2,630 cases registered. Lockdown was scheduled in the UK on 53rd day of reporting cases, on 23/03/2020, The second occasion of change point posterior estimate was on the 56th days (95%CrI, 55 to 57days) with reporting of 9,529 COVID-19 cases in the country. The posterior estimate of third change point was observed on 62nd days having 95% CrI (61 to 63 days) with 25,150 cases of COVID-19.

In India, the first case of COVID-19 was registered on 30/01/2020 and the first change in trend for reporting of COVID-19 cases was posterior estimated as 54th day with 95% CrI (49to 63 days), on that day, there was a total of 492 cases registered. Lockdown was scheduled in India on same posterior estimated first change point 54th day of reporting on 24/03/2020. The second occasion of posterior estimated change point was on 63rd day with 95% CrI (62-68 days) with reporting of 1397 COVID-19 cases. The posterior estimate of third change point was attained on 68th day having 95% CrI (64 to 69 days) with 4421 cases of COVID-19.

In France, the first case of COVID-19 was registered on 21/01/2020 and the first change in trend for reporting of COVID-19 cases was posterior estimated as 48th day with 95% CrI (13to 60 days), on that day, there was a total of 2281 cases registered. Lockdown was scheduled in France on the 52nd day of reporting on 16/03/2020. The second occasion of change point posterior estimate was on 59th day (95% CrI, 48 to 77days) with reporting of 16,018 COVID-19 cases in the country. The posterior estimate of third change point was observed on 64th day having 95% CrI(59 to 70 days) with 32,964 cases of COVID-19.

In Italy, the first case of COVID-19 was registered on 31/01/2020 and the first change in trend for reporting of COVID-19 cases was posterior estimated as 42th day with 95% CrI (42to 44 days),

on that day, there was a total of 12462 cases registered. Lockdown was scheduled in Italy on 40th day of reporting on 10/03/2020, which was 2 days earlier as per the posterior estimate for the first change point on 42nd day. The second occasion of change point posterior estimate was on 49th day (95% CrI, 48 to 50 days) with reports of 35,713 COVID-19 cases in the country. The posterior estimate of third change point was observed on 60th day having 95% CrI(59 to 61 days) with 97,689 cases of COVID-19.

In the USA, the first case of COVID-19 was registered on 21/01/2020 and the first change in trend for reporting of COVID-19 cases was posterior estimated as 60th day with 95% CrI (59to 62 days), on that day, there was a total of 14,250 cases registered. No complete lockdown was declared in USA, as a result on 66th day, the second change point posterior estimate with 95% CrI(65 to 67 days). The posterior estimate of third change point was observed on 72 days having 95% CrI(71 to 73 days) with 164,620 cases of COVID-19.

4. DISCUSSIONS

The World Health Organization (WHO) on March 11, 2020, had declared the COVID-19 outbreak a global pandemic, pointing to over 100,000 cases of coronavirus and spread across 100 countries and territories around the world. Following the declaration, in a bid to control the spreading of COVID-19 infection, most of the countries implemented lockdown and applied various prohibitions. Lockdown was at the forefront of these restrictions as an emergency protocol that was implemented by the authorities to prevent transmission.

Among the six selected countries, Russia, UK and France have delayed in implementing the lockdown, which resulted in increase of infection rate by three, two, and more than two folds, respectively, on the date of declaring lockdown. On comparing the change in pattern of infection rate observed at second point with the first one, it was found that the rate increased by more than three and half, and seven folds in UK and France, respectively. In context of Russia, the second change point and lockdown declaration dates were same. If we compare the third change point in pattern of spreading, then it shows that the infection rates were increase to eight, more than nine and half, and fourteen and half folds, in Russia, UK and France, respectively.

The countries India and Italy were scheduled lockdown either on time or before. Comparing the change in pattern of infection rate observed in these countries at second point with the first one, it

was found that the rate increased by about three folds, which was comparatively very less than those who delayed. If we compare the third change point in pattern of spreading in these countries, it shows that the infection rates were increased to nine and eight folds, respectively, which was again found to be comparatively less. Even on time implementation of lockdown could not help in the virus spreading in both of the countries. Correlating the events^{28, 29} that occurred during the lockdown in India, the reason for this sudden rise in COVID-19 cases were predominately due to unexpected crowding of migrants in various regions. During that time, individuals in particular religious groups and low earning labourers did not follow the restricted measures imposed by the Government in India. The infection might have spread further due to lack of coordination or implementation of lockdown by the concerned authorities to ban public gatherings or individual failure, where infected people unintentionally spread the infection. Similar event³⁰ occurred in Italy during lockdown and the reason for the rise in COVID-19 cases were mostly due to media leakage of the lockdown on 7th March 2020, which lead to the mass exodus of hundreds of people out of Milan, similar to what was seen in India. The lack of coordination in implementation by the concerned authorities to ban public gatherings and discourage mass movement resulted in a raise in the infection rate.

The lockdown was not completely implemented in the USA, as a result the infection rate increased to five and twelve folds, at second and third point, respectively, which was significantly higher than other countries except France.

One of the significant aspects of lockdown was to reduce the burden on health services and arrange proper medical facilities and related infrastructures, to prevent further spread of COVID-19. It was observed from Figure S2 of Appendix that if the initiative of lockdown was on time and properly maintained then it will not only reduce the spread of COVID-19, but also control its associated deaths by building-up of the medical facilities in time. The impact of Government initiatives and policies, and the effect of failures to control this pandemic can be visualized from the quantum of the severity and time elapsed to death.³¹

5. CONCLUSIONS

Lockdown is a step towards social distancing to control the spread of this pandemic until availability of any vaccine or anti-viral drugs against COVID-19. The pattern of posterior estimates of change point were compared among six selected countries where lockdown implemented either before (in Italy), or on the day (in India) or after (in Russia, UK, and France) or not implemented (in the USA). We also explored the reason for the increase in number of daily infected cases of COVID-19 by giving insight into the spread of infections even after lockdown. We correlated the real-life incidences that occurred in the selected countries with the shift or change in pattern of rates of transmission with the duration of exposure. The study suggested that 3 out of 6 countries, Russia, UK, and France had one of the important reasons for rates of transmission were due to delay in implementing the lockdown. In the study, we also observed that COVID-19 infected cases were increasing in countries where either lockdown was scheduled earlier (Italy) or on the same day (India) to the first change in pattern of rates of transmission observed was most likely due to the system (legislative) failure or individuals' failure or both. In order to control the spreading of COVID-19, lockdown, like other national and international laws, must be obeyed and implemented, which is considered to be a good and safe practice for current outbreak.

The result suggests that on-time decision of lockdown delayed the spreading as observed in the context of India, whereas no lockdown accelerated the infection rate in the USA. Those countries (viz., Russia, UK, and France) who delayed in implementing lockdown saw their infection cases increased. In order to make effective and protective policy, the researchers' and policy-makers must discuss the importance and impact of lockdown to safeguard human life from COVID-19 infection, which can be achieved by following the social distancing and restricting human interaction.

The analysis is no doubt confounded by several variables and has a couple of limitations. The study analyzed up to the third change in pattern of transmission rate, and could not be taken into account the changes thereafter. Second, due to the unavailability of information on factors that can explain exposure in private and public, government preparedness and policy actions towards the lockdown, exploration of their association and direct comparison among countries remain unexplored.

ACKNOWLEDGMENTS

The authors are very grateful to both of the anonymous referees, Editor-in-chief Prof. Mathew Mercuri and the editorial board for their constructive and valuable comments, which helped to improve the contents of the paper.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

CONFLICT OF INTEREST STATEMENTS: No potential conflict of interest was reported by the authors.

ETHICS APPROVAL: The database considered for the present study does not contain any individual identifiable information. Due to the unidentified nature of the dataset and no human subject were directly involved in the present study; therefore, this study was exempt from any ethical or Institutional Review Board clearance.

FUNDING: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Liu, Y., Gayle, A. A., Wilder-Smith, A., & Rocklöv, J.. The reproductive number of COVID-19 is higher compared to SARS coronavirus. *Journal of travel medicine*. 2020.
2. Peeri NC, Shrestha N, Rahman MS, Zaki R, Tan Z, Bibi S, Baghbanzadeh M, Aghamohammadi N, Zhang W, Haque U. The SARS, MERS and novel coronavirus (COVID-19) epidemics, the newest and biggest global health threats: what lessons have we learned?. *International journal of epidemiology*. 2020.
3. WHO | Q&A on coronaviruses (COVID-19) [Internet]. World Health Organization [cited 2020 April 12] <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-coronaviruses>

4. CDC | How COVID-19 Spreads.[Internet] Centers for Disease Control and Prevention (CDC). [cited 2020 April 12]. <https://www.cdc.gov/coronavirus/2019-ncov/faq.html#How-COVID-19-Spreads>
5. CDC | 1918 Pandemic (H1N1 virus).[Internet] Centers for Disease Control and Prevention (CDC). [cited 2020 April 13].<https://www.cdc.gov/flu/pandemic-resources/1918-pandemic-h1n1.html>
6. Ferguson NM, Laydon D, Nedjati-Gilani G, Imai N, Ainslie K, Baguelin M, Bhatia S, Boonyasiri A, Cucunubá Z, Cuomo-Dannenburg G, Dighe A. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. 2020. DOI. 16;10:77482.
7. Kidambi, P. ‘An infection of locality’: plague, pythogenesis and the poor in Bombay, c. 1896–1905. *Urban History*. 2004; 31(2); 249-267.
8. Fidler, D. P. Globalization, international law, and emerging infectious diseases. *Emerging infectious diseases*. 1996; 2(2); 77.
9. Stoeva P. International norm development and change: can international law play a meaningful role in curbing the lifestyle disease pandemic?. *BMC International Health and Human Rights*. 2020;20(1):1-3.
10. Gostin, L. O. Influenza A (H1N1) and pandemic preparedness under the rule of international law. *JAMA*. 2009;301(22); 2376-2378.
11. Rakesh, P. S. The epidemic diseases act of 1897: public health relevance in the current scenario. *Indian J. Med. Ethics*. 2016;1.
12. Aginam O. International law and communicable diseases. *Bulletin of the World Health Organization*. 2002;80:946-51.
13. Magnusson R. Advancing the right to health: the vital role of law. *Advancing the Right to Health: The Vital Role of Law, World Health Organization, Switzerland*. 2017.
14. Parmet WE, Sinha MS. Covid-19—the law and limits of quarantine. *New England Journal of Medicine*. 2020;382(15):e28.
15. Gostin LO, Berkman BE. Pandemic influenza: ethics, law, and the public's health. *Admin. L. Rev.*. 2007;59:121.

16. Quinn TC, Wawer MJ, Sewankambo N, Serwadda D, Li C, Wabwire-Mangen F, Meehan MO, Lutalo T, Gray RH. Viral load and heterosexual transmission of human immunodeficiency virus type 1. *New England journal of medicine*.2000;342(13):921-9.
17. Gentile L, Cuda A, Dallagiacomma G, Provenzano S, Santangelo OE, Navaro M, D'Aloisio F, Gianfredi V. Opinion, knowledge and attitude of public health residents towards the new mandatory vaccination law in Italy. *Journal of Public Health*. 2020;1-1.
18. Phelan AL, Katz R, Gostin LO. The novel coronavirus originating in Wuhan, China: challenges for global health governance. *Jama*.2020;323(8):709-10.
19. Gostin LO, Hodge JG. US emergency legal responses to novel coronavirus: Balancing public health and civil liberties. *Jama*.2020;323(12):1131-2.
20. Suhrcke M, Stuckler D, Suk JE, Desai M, Senek M, McKee M, Tsoлова S, Basu S, Abubakar I, Hunter P, Rechel B. The impact of economic crises on communicable disease transmission and control: a systematic review of the evidence. *PloS one*.2011;6(6).
21. Semenza JC, Tsoлова S, Lim TA. Economic crisis and infectious disease control: a public health predicament. *The European Journal of Public Health*.2012;22(1):5-6.
22. Press Information Bureau Government of India | Central teams being sent to States to support in COVID-19 Management. [Internet] [cited 2020 April 22] <https://pib.gov.in/PressReleasePage.aspx?PRID=1616985>; [cited 2020 April 9] <https://pib.gov.in/Press>
23. Fernandes N. Economic effects of coronavirus outbreak (COVID-19) on the world economy. Available at SSRN 3557504. 2020
24. Smith KM, Machalaba CC, Seifman R, Feferholtz Y, Karesh WB. Infectious disease and economics: The case for considering multi-sectoral impacts. *One Health*.2019; 7:100080.
25. Fearnhead P. Exact and efficient Bayesian inference for multiple changepoint problems. *Statistics and computing*.2006;16(2):203-13.
26. Lai TL, Xing H. A simple Bayesian approach to multiple change-points. *Statistica Sinica*. 2011;539-69.
27. Rasmussen P. Bayesian estimation of change points using the general linear model. *Water Resources Research*.2001;37(11):2723-31.
28. The Hindu | Coronavirus | Nearly 4,300 cases were linked to Tablighi Jamaat event, says Health Ministry. [Internet] [cited 2020 April 25]

<https://www.thehindu.com/news/national/coronavirus-nearly-4300-cases-were-linked-to-tablighi-jamaat-event-says-health-ministry/article31376202.ece>

29. The Economic Times | Migrant workers crowd AnandVihar bus terminus to return to their villages. [cited 2020 April 25] <https://economictimes.indiatimes.com/news/politics-and-nation/migrant-workers-crowd-anand-vihar-bus-terminus-to-return-to-their-villages/articleshow/74863940.cms>
30. The Guardian | Leaked coronavirus plan to quarantine 16m sparks chaos in Italy. [cited 2020 April 25] <https://www.theguardian.com/world/2020/mar/08/leaked-coronavirus-plan-to-quarantine-16m-sparks-chaos-in-italy>
31. Verma V., Vishwakarma RK., Verma A., NathDC., Khan H.T.A. Time-to-Death approach in revealing Chronicity and Severity of COVID-19 across the World. *PloS one*. 2020; 15(5): e0233074. <https://doi.org/10.1371/journal.pone.0233074>

Appendix

A change point considered here is the shift occurred due to duration of exposure, such that the number daily registered cases in a country due to COVID-19 follows different distribution before and after that shift. For a given series of COVID-19 daily registered cases in a country till the ‘d’ days of exposure, denoted as Y_1, Y_2, \dots, Y_d a shift or change in point occurs if there exist a ‘s’ such that $s \in [1, d - 1]$, such that the distributional pattern of $[Y_1, Y_2, \dots, Y_s]$ and $[Y_{s+1}, Y_{s+2}, \dots, Y_d]$ are different in context of certain criteria. The criteria chosen is based on duration of exposure, say X_t and error, ε_t denotes the random error, which is assumed to follow normal distribution with mean zero and variance σ^2 such that

$$y_t = \begin{cases} \beta_1 + \beta_2 x_t + \varepsilon_t & 1 < t \leq s_j \\ \beta_3 + \beta_4 x_t + \varepsilon_t; & s_j + 1 \leq t \leq d \end{cases} ; \beta_1 \neq \beta_3, \beta_2 \neq \beta_4 \dots (1)$$

The likelihood function based on normal distribution assumption based on the suggested model of equation (1) will be

$$\begin{aligned} L(\mathbf{y}|\mathbf{x}, \boldsymbol{\beta}, \sigma, s) &= \prod_{t=1}^d f(y_t|\mathbf{x}, \boldsymbol{\beta}, \sigma, s_j) \\ &= \prod_{t=1}^{s_j} (\sqrt{2\pi}\sigma)^{-1} e^{-\frac{(y_t - \beta_1 - \beta_2 x_t)^2}{2\pi\sigma^2}} \prod_{t=s_j+1}^d (\sqrt{2\pi}\sigma)^{-1} e^{-\frac{(y_t - \beta_3 - \beta_4 x_t)^2}{2\pi\sigma^2}} \dots (2) \end{aligned}$$

Under the Bayesian paradigm, the analysis, and characterization of any parameter starts with prior specification corresponding to each of the unknown model parameters. In absence of any prior information about the chosen model parameters, $(\boldsymbol{\beta}, \sigma, s_j)$, where $\boldsymbol{\beta} = \{\beta_1, \beta_2, \beta_3, \beta_4\}$, Non-informative priors were suggested. The prior distribution for each of the model parameters are as follows

$$g(\boldsymbol{\beta}) \propto \text{Constant}; \quad \dots \quad (3)$$

$$\tau(s_j) \propto t - \text{distribution} \left(\mu = 0, \sigma = \frac{1}{j-1}, df = j-2 \right) \dots \quad (4)$$

$$h(\sigma) \propto \frac{1}{\sigma} \dots \quad (5)$$

where, s_j denotes, j^{th} of numbers of shifts or change points. For the model simplicity and better understanding of the country-wise variation, we fixed $j = 3$, i.e., study focused upto the third change in the pattern of daily registered cases. The joint posterior distribution for the parameters based on the likelihood and prior distributions were derived using equation (2) and (3-5) will be

$$\begin{aligned} \varphi(\boldsymbol{\beta}, \sigma, s_j | \mathbf{y}, \mathbf{x}) &\propto L(\mathbf{y} | \mathbf{x}, \boldsymbol{\beta}, \sigma, s) g(\boldsymbol{\beta}) \tau(s_j) h(\sigma) \\ &\propto \sigma^{-d} \exp \left[- \sum_{t=1}^s \frac{(y_t - \beta_1 - \beta_2 x_t)^2}{2\pi\sigma^2} - \sum_{t=s+1}^d \frac{(y_t - \beta_3 - \beta_4 x_t)^2}{2\pi\sigma^2} \right] \dots \quad (6) \end{aligned}$$

The marginal posterior distribution of the parameters and its related summaries are obtained through the Markov Chain Monte Carlo simulation procedure²⁵ using following equations

$$\varphi(\beta_k | \mathbf{y}, \mathbf{x}) \propto \int \varphi(\boldsymbol{\beta}, \sigma, s_j | \mathbf{y}, \mathbf{x}) \prod_l d\beta_l d\sigma ds_j ; l \neq k \dots \dots \quad (7)$$

$$\varphi(\sigma | \mathbf{y}, \mathbf{x}) \propto \int \varphi(\boldsymbol{\beta}, \sigma, s_j | \mathbf{y}, \mathbf{x}) d\boldsymbol{\beta} ds_j \dots \dots \dots \quad (8)$$

$$\varphi(s_j | \mathbf{y}, \mathbf{x}) \propto \int \varphi(\boldsymbol{\beta}, \sigma, s_j | \mathbf{y}, \mathbf{x}) d\boldsymbol{\beta} d\sigma \dots \dots \quad (9)$$

Table 1: Posterior summaries of mean duration of exposure and the highest density intervals for each change point and other parameters corresponding to each selected country.

Parameters		Posterior Mean (95% Credible Interval)					
		Russia	United Kingdom	India	France	Italy	United States
Change points	Cp 1	50 (48-52)	49(47-54)	54(49-63)	48(13-60)	42(40-44)	60 (59-62)
	Cp 2	55(54-56)	56(55-57)	63(62-68)	59(48-70)	49(48-50)	66(65-67)
	Cp 3	61(60-62)	62(61-63)	68(64-69)	64(59-70)	60(59-61)	72(71-73)
β_1		-17.2 (-56.06-21.1)	-81 (-286-118)	-11.29 (-45.07-22)	-160 (-628-338)	-350 (-627--54)	-345 (-1181.8-517)
β_2		230.9 (159.08-296.4)	992.1 (648.1-1382)	154.65 (66.55-531)	1757.7 (-169-4388)	3176 (2825-3504)	8065 (6276.7-10122)
β_3		595.8 (531.49-651.1)	2601 (2329.1-2887)	492.1 (297.85-771)	3349 (829-8277)	5618 (5342-5906)	18641 (17014.6-20569)
β_4		1186.4 (119.85-1256.2)	4437.2 (4227.2-4652)	646.41 (559.55-714)	3918.2 (3491-4393)	4186 (3910-4456)	30248 (29176.7-31364)
σ		64.5 (52.55-77.1)	325.5 (271.4-387)	50.06 (41.13-60)	649.6 (503-787)	455 (375-538)	1600 (1347.9-1875)

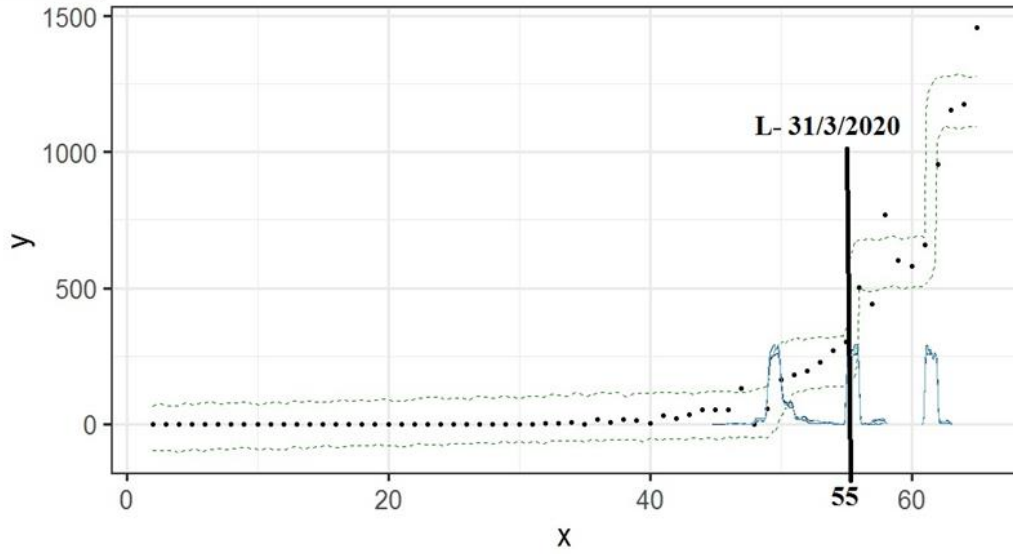
Table 2: Total numbers of registered COVID-19 cases till the date of lockdown based on duration of exposure and on posterior estimated change point day corresponding to each selected country.

Variables		Total number of registered cases of COVID-19					
		Russia	United Kingdom	India	France	Italy	United States
Date of first case reported		31/01/2020	31/01/2020	30/01/2020	21/01/2020	31/01/2020	21/01/2020
WHO declaration	Cases (day) (11/03/2020)	10 (35)	373 (41)	50 (41)	1784 (47)	10149 (41)	1025 (51)
Lockdown	Date	31/03/2020	23/03/2020	24/03/2020	16/03/2020	10/03/2020	NA
	Day	55	53	54	52	40	NA
	Cases	1836	5683	492	5423	9172	NA
Posterior estimate d change point	Cp 1 (days)	658(50)	2630 (49)	492 (54)	2281 (48)	12462 (42)	14250 (60)
	Cp 2 (days)	1836(55)	9529 (56)	1397 (63)	16018 (59)	35713 (49)	69194 (66)
	Cp 3 (days)	5389(61)	25150 (62)	4421 (68)	32964 (64)	97689 (60)	164620 (72)

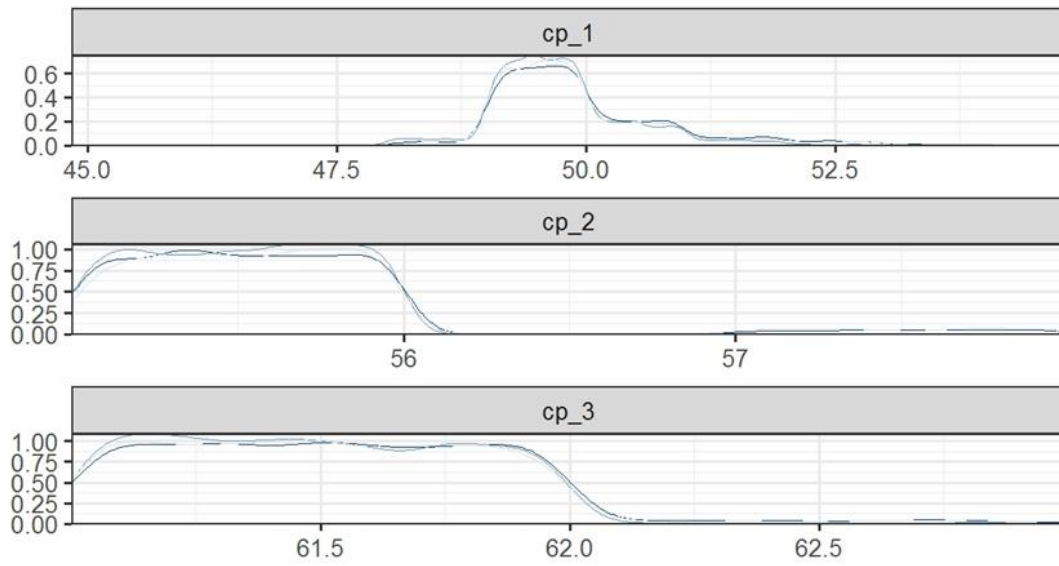
NA= No complete lockdown was declared in USA

Appendix

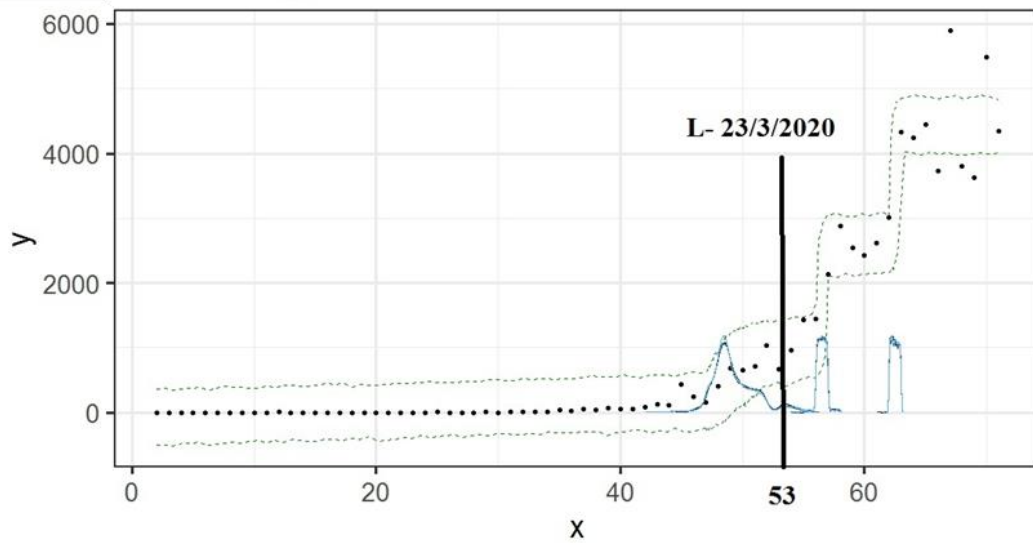
(A) Russia



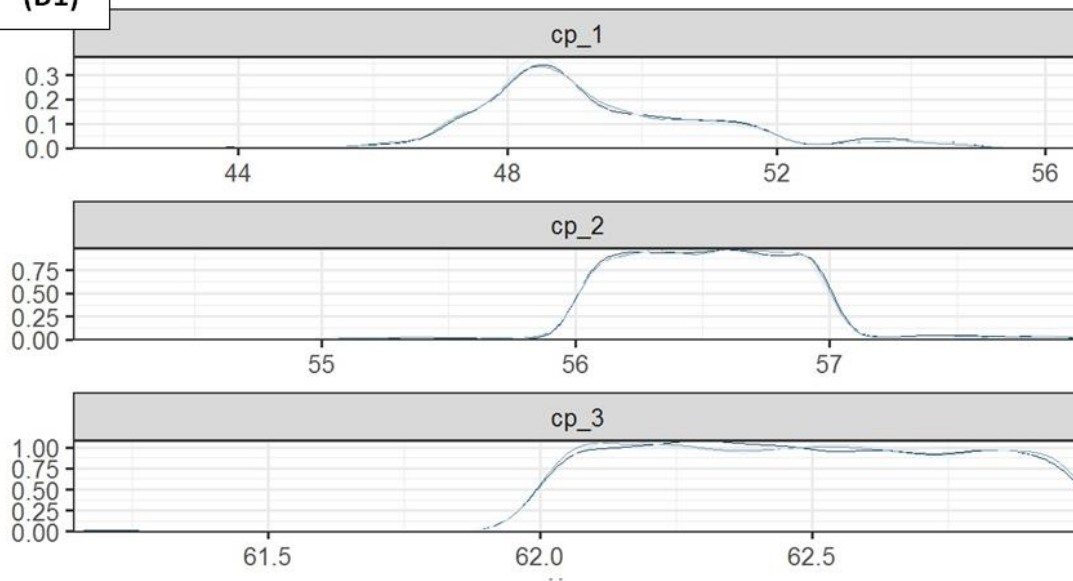
(A1)



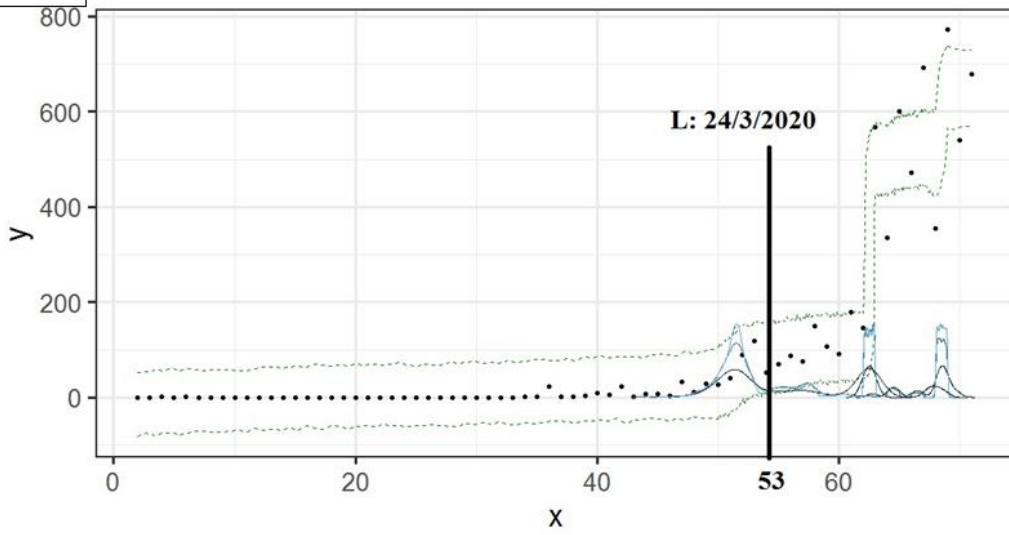
(B) United Kingdom



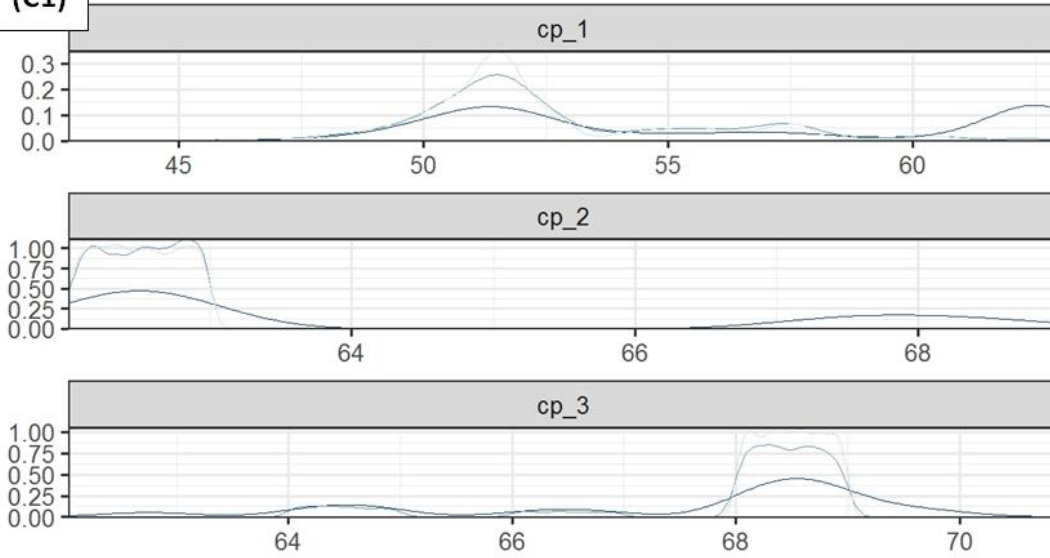
(B1)

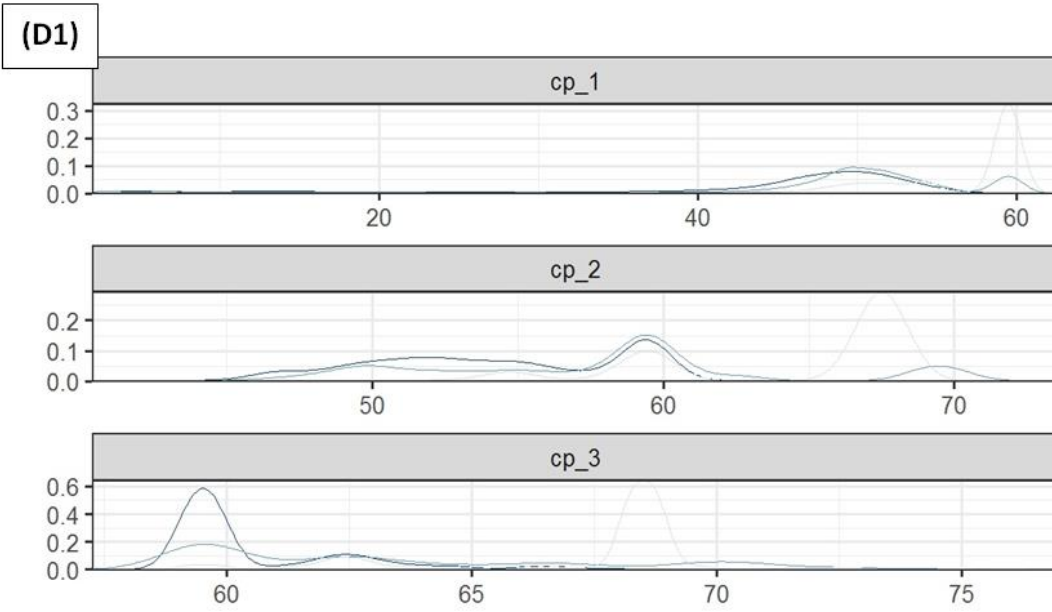
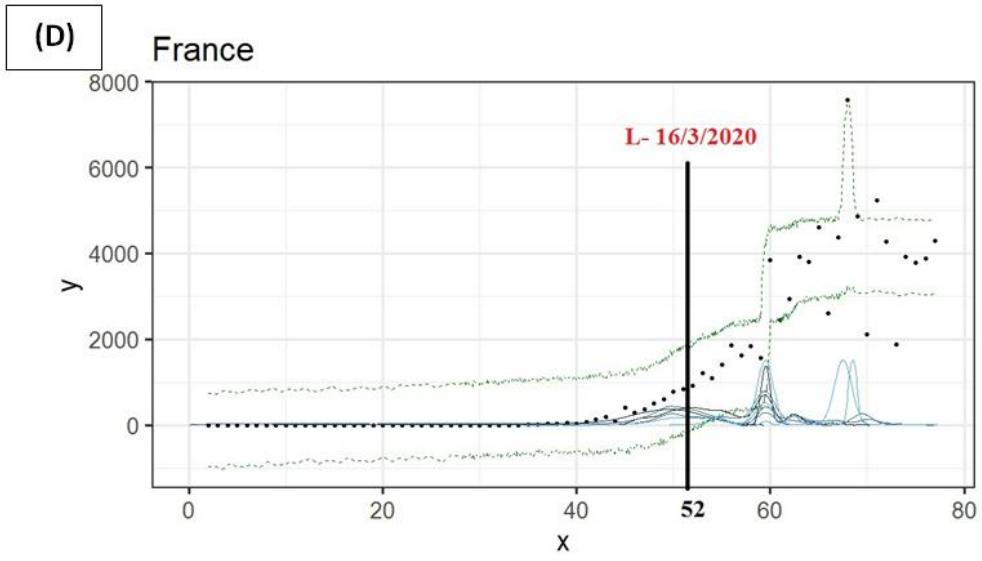


(C) India

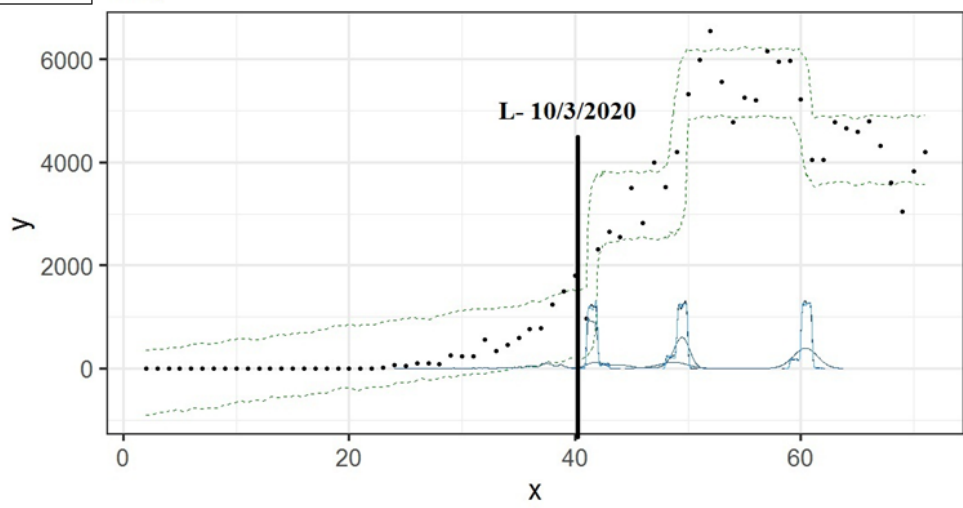


(C1)

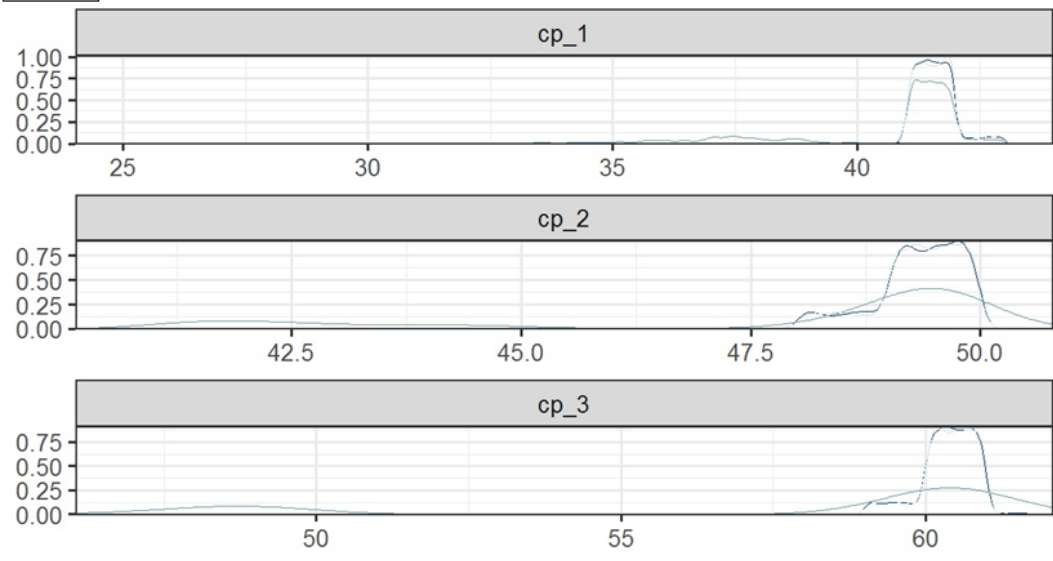




(E) Italy



(E1)



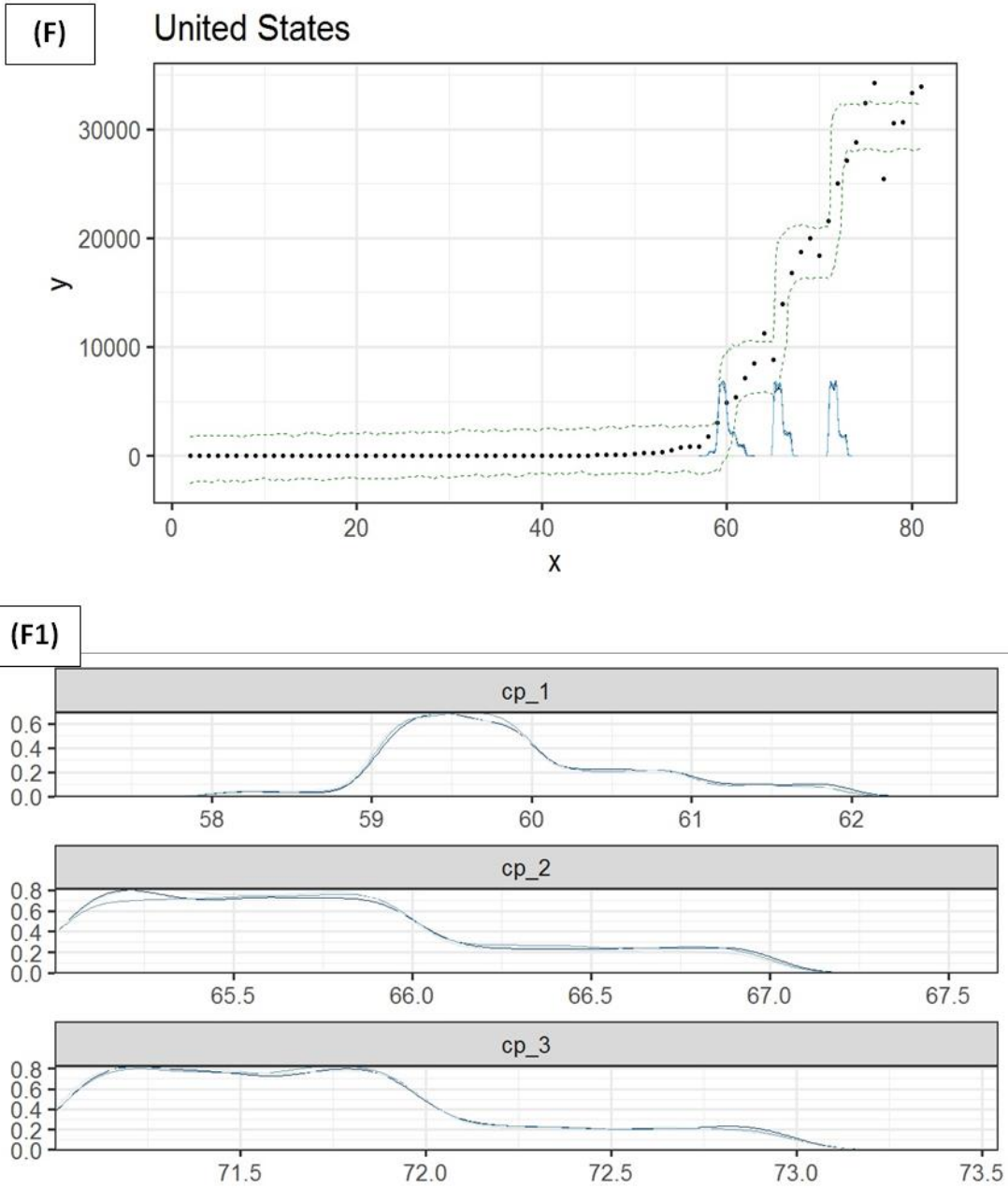


Figure S1: (A-F) Pattern of COVID-19 cases with duration of exposure and their 95% highest density intervals with their lockdown (L) and (A1-F1) the posterior distribution each change points corresponding to each selected countries.

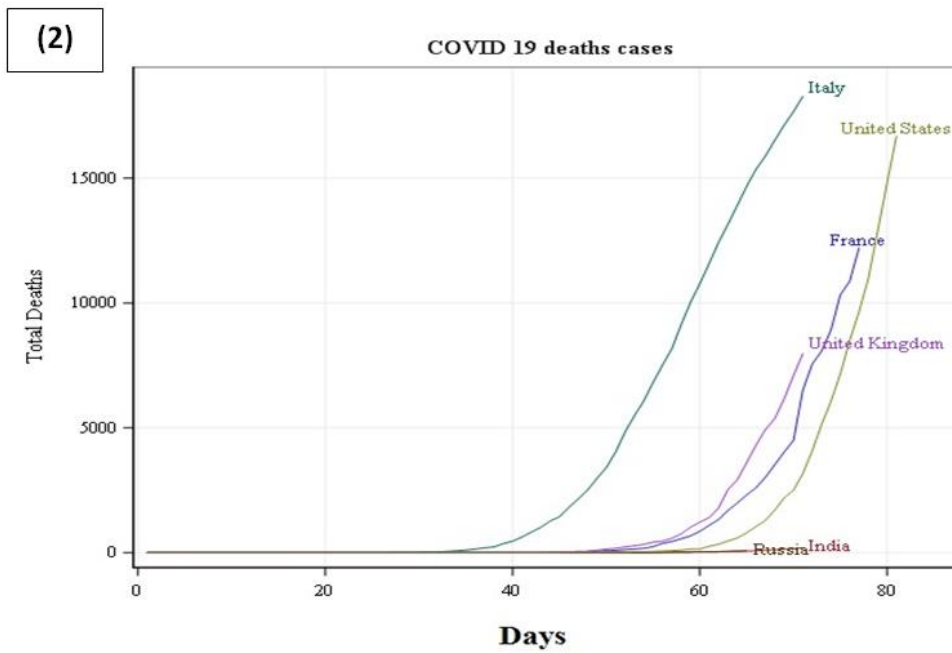
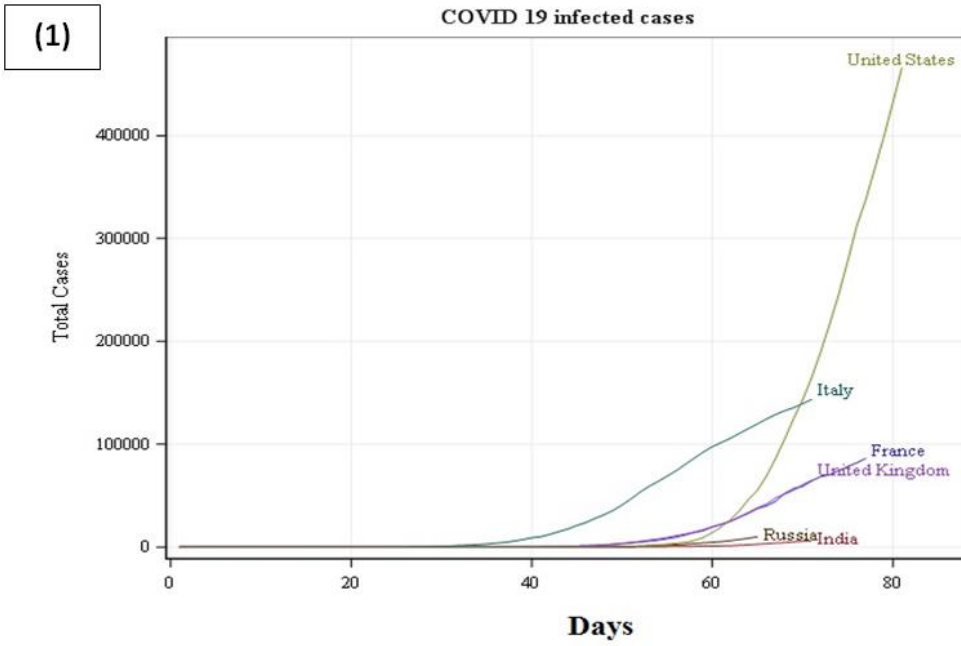


Figure S2: The pattern of cumulative number of COVID-19 (1) cases and (2) deaths occurred corresponding to each selected countries