**eSIR lockdown modeling**

**Goal**

To estimate the impact of a lockdown on the number of reported cases and deaths during the second wave of the COVID-19 pandemic in India

**Methods**

We implement a modified version of the traditional susceptible-infected-recovered (SIR) model, called extended SIR (or eSIR), which allows for a time-varying effective reproduction number (Rt). This model was developed by Wang et al. [[CITE](https://jds-online.org/journal/JDS/article/28/info)] to model the COVID-19 outbreak in China and was made available in the eSIR R package [[CITE](https://github.com/lilywang1988/eSIR)]. We allow the model to run and estimate Rt using observed data and then implement the effect of a lockdown. That is, we impose a time-varying schedule , which represents the proportion of Rt under a lockdown scenario.

The primary challenge for obtaining a realistic lockdown intervention is, of course, the choice of the schedule. Thankfully, we have two real-world examples from the COVID-19 pandemic in India on which to draw such a schedule: the national lockdown beginning in March 2020 in response to the first wave and the Maharashtra lockdown beginning in April 2021 in response to the second wave. We calculate the respective schedules as the ratio of the Rt following the lockdown over the Rt the day the lockdown started. We begin the India lockdown schedule on March 27, 2020, and the Maharashtra lockdown schedule on April 14, 2021. The nationwide lockdown was swift and had relatively strong immediate and long-term reductions in Rt and represents a best-case or optimistic scenario. The Maharashtra lockdown had a more subdued impact on Rt relative to the national lockdown the previous year and represents what we consider to be a moderate scenario.

Using these schedules and the tvt.eSIR function from the eSIR R package, we are able to impose lockdowns at various timepoints to assess the impact of a lockdown had it been implemented. Because Rt first rose above 1 in mid-February, an early warning sign of a forthcoming surge in cases, we assess lockdowns had they been implemented on March 1, March 15, March 30, April 15, and April 30, 2021.

We can also estimate the number of deaths under these lockdown scenarios. To do this, we apply a case-fatality rate (CFR) schedule, which was calculated as the observed, trailing 7-day average CFR (i.e., ratio of daily deaths to daily cases) for India, for Maharashtra, and for Kerala through May 15. We include the Kerala CFR schedule because of their relatively low COVID-19 CFR and their robust healthcare system, which can be interpreted as a best-case scenario. We then multiply the projected case counts by the CFR schedule to obtain an estimate of the number of COVID-19 deaths.

**Results**

We project each scenario out to May 15 and compare the forecasted results to observed, reported counts. The results for the India lockdown schedule are shown in **Figure 1** and for the Maharashtra lockdown schedule in **Figure 2**. We can estimate the number of cases that could have been avoided had the lockdown been implemented on these dates. The projected case counts, and potential cases averted are under these schedules are enumerated in **Table 1**.

The results for the India CFR schedule are shown in **Figure 3**, for the Maharashtra CFR schedule in **Figure 4**, and for the Kerala CFR schedule in **Figure 5**. Like the cases, we can estimate the number of deaths that could have been avoided. The projected death counts, and potential deaths averted are under these schedules are enumerated in **Table 2**.

**Figures**



**Figure 1**. Observed and predicted daily cases under lockdown scenarios starting on different dates using the India lockdown schedule from February 15 to May 15, 2021.



**Figure 2**. Observed and predicted daily cases under lockdown scenarios starting on different dates using the Maharashtra lockdown schedule from February 15 to May 15, 2021.



**Figure 3**. Observed and predicted daily deaths under lockdown scenarios starting on different dates using the India lockdown and case-fatality rate schedules from February 15 to May 15, 2021.



**Figure 4**. Observed and predicted daily deaths under lockdown scenarios starting on different dates using the Maharashtra lockdown and case-fatality rate schedules from February 15 to May 15, 2021.



**Figure 5**. Observed and predicted daily deaths under lockdown scenarios starting on different dates using the India (**panel A**) and Maharashtra (**panel B**) lockdown and Kerala case-fatality rate schedules from February 15 to May 15, 2021.

**Tables**

Table 1. [CASE PROJECTION TABLE]

Table 2. [DEATH PROJECTION TABLE]