Modelling methods, Bhutan application

May 24, 2022

1 Model Structure

1.1 General features

Our COVID-19 model is a series of compartments representing transitions between states relevant to infection with SARS-CoV-2 and onward transmission of this virus. Unlike previous iterations of this model (including our past publications on the epidemics in the Philippines, Malaysia and Victoria, Australia), our current model considers only states relevant to transmission. Hospitalisation, admission to ICU and death are no longer represented as explicit model states, but are now calculated from model outputs through a convolution process. The rationale for this approach is that the explicitly modelled states are reserved to represent considerations relevant to epidemic transmission dynamics only. The other outcomes can be calculated from the quantities that are tracked during the process of numerically solving the dynamic system ("derived outputs"). It should be noted that this is done after each model realisation, such that these quantities can still be compared to empirically observed outcomes and so used for calibration.

1.2 Compartments

Model compartments represent sequential progressions through the processes of infection with, progression through and recovery from the phases of SARS-CoV-2. Reinfection is permitted in our model code structure, which is represented as transition from the recovered compartments back to the first infected compartment. The following compartments are implemented:

- Susceptible
  - Persons never previously infected with SARS-CoV-2 during the model simulation period
- Latent
  - Persons recently infected with SARS-CoV-2, but not yet infectious
  - This compartment is divided into two sequential phases

- Infectious
  - Persons with active COVID-19 who are potentially infectious to others
  - This compartment is divided into two sequential phases
  - The second of these two sequential compartments includes any persons who are identified through the health system and asked to isolate
  - The infectiousness of the second compartment will be reduced to capture the effect of case isolation
- Recovered
  - Persons recovered from COVID-19 during the model simulation period
  - This compartment is divided into two sequential phases
  - Reinfection from these compartments is permitted and will occur at a different rate for the two sequential phases
  - This compartment retains the stratification by strain (or variant of concern ("VoC")), with the strain of the last infection episode used for classification

2 Case detection and isolation

2.1 Determining the proportion of cases detected

We calculate a time-varying case detection rate, being the proportion of all symptomatic cases (clinical strata 2 to 5) that are detected (clinical strata 3 to 5). This proportion is informed by the number of tests performed using the following formula:

$$CDR(time) = 1 - e^{-shape \times tests(time)}$$

time is the time in days from the 31st December 2019 and *tests(time)* is the number of tests per capita done on that date. To determine the value of the shape parameter, we solve this equation based on the assumption that a certain daily testing rate *tests(t)* is associated with a certain *CDR(t)*. Solving for *shape* yields:

$$shape = \frac{-log(1 - CDR(t))}{tests(t)}$$

That is, if it is assumed that a certain daily per capita testing rate is associated with a certain proportion of symptomatic cases detected, we can determine *shape*. As this relationship is not well understood and unlikely to be consistent across all settings, we vary the *CDR* that is associated with a certain per capita

testing rate during uncertainty/calibration. Given that the *CDR* value can be varied widely, the purpose of this is to incorporate changes in the case detection rate that reflect the historical profile of changes in testing capacity over time.

The proportion of persons entering clinical stratum 3 is calculated once the *CDR* is known, along with the proportion of all incident cases hospitalised (strata 4 and 5).

2.2 Isolation of detected cases

As described in the Section **??** above, as infected persons progress from the early to the late stage of active COVID-19, infectiousness is reduced for those in the detected strata (3 to 5) to reflect case isolation.

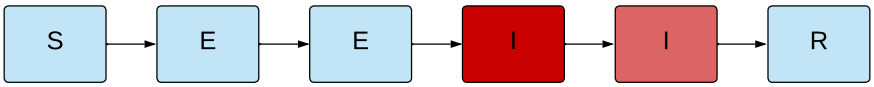

Figure 1: Unstratified compartmental model structure. S = susceptible, E = exposed, I = active, R = recovered/removed. Depth of pink/red shading indicates the infectiousness of the compartment.