https://github.com/philomaths-org/covid-19/blob/master/conditional_immunity_v1.pdf.
git-tag: immunity-v1. This study has not been peer reviewed.

Technical Note: CD-3
Notes on Conditional Immunity.

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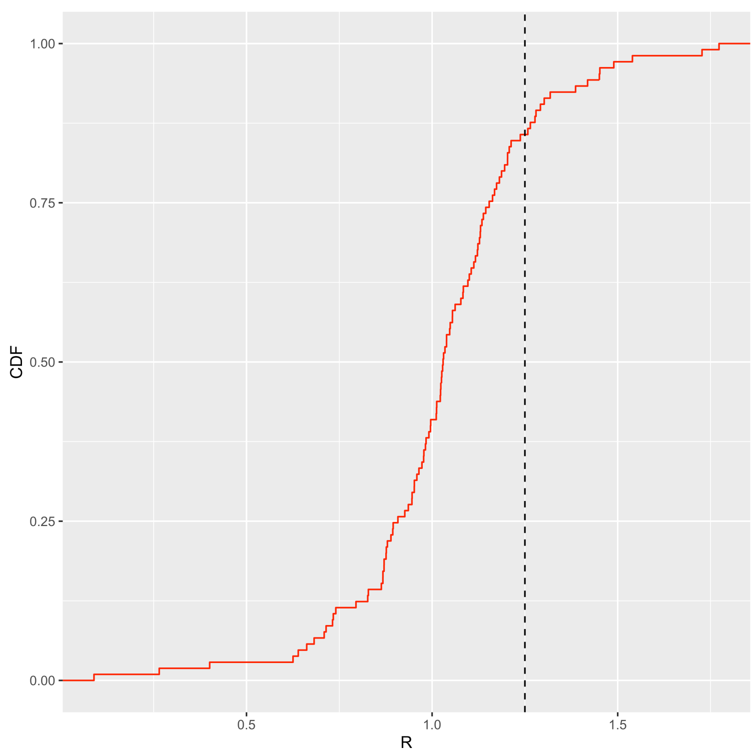
1 Conditional Immunity

The basic reproduction number, R_0 for COVID-19 is estimated to be 2.5 [1]. Herd immunity is reached when $1 - \frac{1}{R_0}$ have been infected. For an R_0 of 2.5, this is reached with 60% of the population. With the COVID-19 epidemic, governments and the population are varying their behaviours so that the value of R is considerably less than 2.5. This raises the prospect of a population reaching herd immunity with a much smaller percentage infected. This would be conditional herd immunity as it would be conditional on the government and the population maintaining the lower value of R even after the number of infections starts to drop.

We generated the empirical Cumulative Distribution Function (CDF) of the R value for all countries with a tight confidence interval (0.1) for the estimates of R. There were 105 such countries. This data was generated on July 29, 2020, using information from the Johns Hopkins University COVID-19 website [2]. Countries with a tight confidence interval for R generally have a significant incidence of the disease, so it excludes most countries that are in a successful lock-down. It can be seen that the very large majority of countries are maintaining a value of R well below 2.5.

Examining the Wikipedia entry for National Responses to the COVID-19 pandemic [3], it identifies 86 countries that carried out lock-downs, of which, as at July 28, 2020, only 11 were still in lock-downs. An archive of this

Figure 1: CDF of R values



wikipedia page on this date is stored on the Philomaths github site [4]. The Wikipedia page defines lockdowns as 'a requirement for people to stay where they are'. Although a more details analysis could be carried out, it seems that the large majority of the 105 countries that are analysed in Figure 1 are not under tight lock-down, but are probably under some degree of restriction.

Accordingly the major of countries are able to maintain much lower value of R without a severe lock-down. Indeed almost 90% of countries have a value of R less than 1.25. Accordingly, it seems reasonable that a target R of 1.25 is achievable without drastic lock-downs. A value of 1.25 means that conditional herd immunity would be reached when 20% of the population have been infected.

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2 SIRS model

It seems immunity from the COVID-19 disease does last a reasonable length of time. The advice from the Australian Government [5] is that 'There have been reports of apparent re-infection in a small number of cases. However, most of these describe patients having tested positive within 7-14 days after apparent recovery.' In addition the CDC Planning Scenarios [1] do not include any parameters for reinfection. However, little is known about the long term chances of reinfection. Accordingly, we examined the sensitivity to this issue using a modeling approach.

The Susceptible Infected Recovered Susceptible (SIRS) model [6] allows for an epidemic where immunity is lost over time, so that some recovered individuals return to the Susceptible population. This requires an addition to the standard SIR model, where the recovered individuals re-enter the susceptible population at a rate γ. Accordingly the equations become

$$\begin{cases} \frac{dS(t)}{dt} = -\beta S(t)I(t) + \gamma R(t) \\ \frac{dI(t)}{dt} = \beta S(t)I(t) \ - \ \alpha I(t), \\ \frac{dR(t)}{dt} = \alpha I(t) \quad - \quad \gamma R(t) \end{cases}$$

where γ is the reinfection rate. Note it is still a closed three compartment model so we have

$$S(t) + I(t) + R(t) = N \tag{1}$$

We built a computer simulation of these equations

To be continued...

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