COVID Risk Estimation Methodology

August 22, 2021

Github link to notebook

Binder link to notebook

Estimating T

For our model of risk of catching covid-19, we will first need to estimate T, the probability of becoming infected with COVID-19 given an hour of contact. We can derive T from R_0 since

$$R_0 = \bar{h}T\tau$$

Where $\bar{h}$ is the average total contact hours per day and τ is the infectious period for a person with COVID-19.

For the original strain of COVID-19, R_0 was estimated to be 2.87.

As for τ, according to the CDC adults with COVID-19 remain infectious likely remain infectious for no longer than 10 days for mild to moderate cases or 20 days for sever cases after symptom onset. However Australian Department of Health also reports that "Pre symptomatic transmission can occur 1-3 days before symptom onset." Therefore, we will set τ to be around 14 days.

Now for $\bar{h}$, a study of 1,149 Hong Kongnese participants found a average total contact hours of 11.46 hours.

Of course all of these parameters can, and will be changed later, for now we will quickly define a function for calculating T given R_0, $\bar{c}$, and τ.

Estimating Probability Of Contracting COVID-19

With our estimate of T we can also estimate the probability of a person with c contacts contracting covid every day P_c

$$P_c = 1 - \prod_{i=1}^{c} \left(1 - P_I \left(1 - (1-T)^{h_i}\right)\right)$$

Where P_I is the probability that a given person has COVID-19 and h_i is the number of hours spent interacting with the ith contact. Assuming that the number of hours spent interacting with each contact (ie $h_i = h$ for any i) is constant, this becomes

$$P_c = 1 - \left(1 - P_I \left(1 - (1-T)^{h}\right)\right)^c$$

Mitigation Methods

For this notebook we will assume that mitigation methods would change T, the probability of becoming infected with COVID-19 given an hour of contact. To be specific, given n mitigation methods:

$$T_m = T \prod_{i=1}^{n} (1 - r_i)$$

Where r_i is the reduction in risk due to the ith mitigation method

Masks

Masks have been proven to significantly reduce COVID-19 infection. A study of the outbreak on board USS Theodore Roosevelt (CVN-71) found that face coverings was associated with "a 70For now we will set $r_{mask} = 0.7$

Vaccines

Currently there are three approved vaccines in the United Sates, the Pfizer-BioNTech vaccine, the Moderna vaccine, and the Johnson & Johnson vaccine. Against the original strain of COVID-19, they have 95%, 90% and 72% efficacy. So, for now we will set $r_{pfizer} = 0.95$, $r_{moderna} = 0.9$, and $r_{JJ} = 0.72$

COVID Variants

Now we can introduce different variants of COVID-19, these variants have higher R_0 (so as a result higher T). In particular, we will consider two variants:

- **Alpha Variant** This variant, first detected in Britian, has a R_0 of between 4-5 (for now we will set $R_0 = 4.5$)
- **Delta Variant** This variant, first detected in India, has a R_0 of between 5-8 (for now we will set $R_0 = 6.5$)

Vaccine effectivness Against Delta

There are some concerning Data regarding to the effectiveness of Vaccines (in particular the Pfizer vaccine) against Delta. For instance one preprint study found that the Pfizer and Moderna vaccines were only 42% and 76% effective against infection in July, when the Delta variant was dominant.

Three Dose Vaccine for the Delta Variant

On August 18th 2021, the Biden administration anounced a plan to "begin offering Covid-19 boosters shots to all American adults starting Sept. 20" (per Politico). Israel has already been administering a third doses, according Reuters in initial results from an Israeli healthcare provider was the a third does of the Pfizer vaccine was found to be 86% effective in people aged 60 and older.

Probability of Contracting COVID over a Longer Time Period

Up till now, we have been consider the probability of contracting covid in a day. However, what if we want to consider the risk of contracting COVID in a year, not a day? If the probability of Contracting COVID in a day is p_d, the probability of contracting COVID over a longer period of t days is:

$$p_t = 1 - (1 - p_d)^t$$