Mathematical modelling of Australian COVID-19 response: A PhD student perspective

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It has been a little over 12 months since COVID-19 became a regular headline in the Australian media, but I would not be alone in saying it has definitely felt longer. At the time I was entering the third year of my PhD in mathematics and epidemiology, so when news broke of the new virus in late 2019, I was certainly paying attention. Little did I know it would affect not only my life as a researcher in the field, but everyone across the world.

Although COVID-19 restrictions have disrupted my study and research like many other HDR students, I have been fortunate that my work in modelling COVID-19 made progress towards my thesis.

In late February 2020 I was asked if I could help in the modelling effort, and at first this was supporting Dr Andrew Black and Dr James Walker in examining Australia's pandemic preparedness and border closures. This modelling work by Andrew and James formed part of the advice on closing the international border. It was a frantic period of time, with a rapidly evolving situation. Seeing this body of work influence policy was the first of many instances

It wasn't long after that my supervisor Prof. Joshua V. Ross asked if I was interested in developing and providing a forecast of COVID-19 cases to the COVID-19 response. I would be lying if I didn't say Imposter Syndrome didn't tell me to run the other way. Fortunately, and with encouragement from my supervisors and the wider COVID-19 modelling group, I didn't give in and dived into the work.

To better describe our model, I will briefly introduce some important epidemiological concepts. An important epidemiological parameter is the effective reproduction number R_{eff}, which can be defined as the average secondary number of infections from an infectious individual. This can vary through time, as behaviour changes through the epidemic, through social distancing and public health policy changes.

R_{eff} can be retrospectively estimated through examining the number of cases over time, but to forecast cases using a mechanistic model, it must incorporate some estimate of the future transmission potential and/or arrival of infected cases. The relatively low number of cases in Australia also creates difficulties in utilising methods that rely on historical case incidence. Measures of mobility of each Australian jurisdiction provided by Google and survey results of the public's behaviour in adhering to personal distancing measures provides the ability to link these indicators to an estimate of the effective reproduction number. This allows for a mechanistic model to forecast cases.

We estimated R_{eff} using historical case incidence and an established method from the literature. To forecast R_{eff} forward, we calibrated a model that links social mobility and personal distancing measures to these estimates of R_{eff}.

Within Australia, there have been jurisdictional level differences in policy and response to social distancing, but the underlying culture and mobility patterns may have commonalities. As such, we employed a hierarchical model to partially pool information between jurisdictions, while allowing for inferred differences where they may occur.

After calibrating the model and using Bayesian inference to learn the parameters, we then forecast the social mobility and distancing metrics using a random walk with drift in each jurisdiction. The model then gives a posterior predictive distribution on the R_{eff} over time.

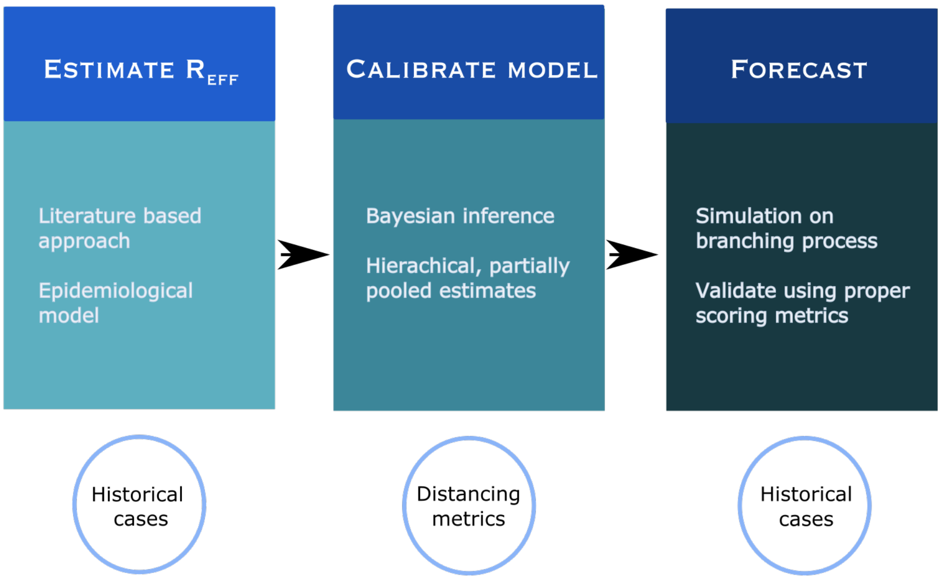

Figure 1: A schematic of the probabilistic COVID-19 forecasting model.

The relatively few cases of local transmission in Australia, in conjunction with strict border control measures internationally and domestically, makes it natural to forecast the number of cases in each jurisdiction using a stochastic branching model. This generative model, using estimates from the literature for epidemiological parameters, can be paired with the time varying effective reproduction number to forecast COVID-19 cases in Australian jurisdictions. This framework adapts to changing public health policies and responses to the ongoing pandemic, particularly during small outbreaks and the irregular but frequent responses to outbreaks seen in Australia.

This forecasting model was run every week, and the results contributed to an ensemble forecast that was provided to various bodies in the Australian Government. This ensemble forecast was often considered by Chief Health Officers in determining the appropriate course of action, and was even shown a few times at media press conferences.

As mathematicians, it is rare that we get to personally observe the impacts of our research, let alone at my level as a PhD candidate. While the pressure and high stakes definitely gave me some sleepless nights, to see policy and action consider my work was incredibly fulfilling, and I highly recommend any HDR student take any opportunity to work on research with direct and immediate impacts like the COVID-19 response. Don't let your Imposter Syndrome dissuade you from contributing, as every effort, however minor, helps. Your unique perspective will always be valuable in discussions, and you will almost certainly be supported by an amazing and dedicated team as well as your supervisors, as I did in my work!