Modelling Update of NSW Roadmap for the Delta epidemic 2021-2022

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Summary: NSW has achieved rapid and high vaccination rates in 2021. We updated our model for NSW using data from the milestones of adults 16+ being 70% and 80% fully vaccinated, using actual case data and vaccination rates for 12+ beyond the targets from these dates, and public health orders stipulated in the roadmap. The next policy question is about vaccination of children 5-11, as well as the use of other public health measures such as masks, testing and tracing. There has been some talk of ceasing QR codes (and thereby reducing contact tracing capacity when case numbers rise). In Victoria, it has been announced that infected people will have to notify their own contacts. We looked at six scenarios based on the NSW Roadmap:

1) No vaccination for 5-11 age group, 80% contact tracing

2) 5-11 age group vaccinated, 80% contact tracing

3) 5-11 age group vaccinated, 0% contact tracing

4) No vaccination for 5-11 age group, 0% contact tracing

5) No vaccination for 5-11 age group, 50% contact tracing

6) 5-11 age group vaccinated, 50% contact tracing

We assumed testing capacity always remains high, but modelled the impact of ceasing or reducing contact tracing and vaccinating children 5-11 years. If testing capacity remains high, children 5-11 are vaccinated by early 2022 at high rates, and contact tracing capacity remains high at 80%, NSW can achieve good control of COVID-19. In all scenarios, a rise in cases occurs after the December 15th milestone, with a peak between January 31 and February 21 2022. In scenarios with high rates of contact tracing and vaccination of children 5-11 years, ICU and hospital capacity will be sustainable. In scenarios where contact tracing is ceased, NSW may face code black conditions in February 2022. We did not model waning of vaccine induced immunity, which will begin to show effects by February 2022 and coincide with the epidemic peak. The best outcomes can be achieved by vaccinating

younger children as early as possible, maintain high test and trace capacity and ensuring high and timely uptake of the 3rd dose booster in NSW.

Background

NSW is planning to release all the restrictions by 15 of December at the latest or when 95% of the eligible population is fully vaccinated. There is uncertainty about the impact of lifting of restrictions on the health system. Experience shows that even in countries with high vaccination coverage such as Singapore and Denmark, when restrictions were lifted, the number of new cases per day surged. NSW has achieved high vaccination rates, with over 91.4% of all people 16 years and over, and 74.3% of 12-15 year old fully vaccinated by November 16th 2021. A recommendation for vaccination of children 5-11 years is pending. The age group <10 years is the most affected by COVID-19 currently.

During a surge in epidemic activity when case numbers are high, contact tracing capacity will be stressed. The use of digital tracing is important to ensure contact tracing can be scaled up during periods of high case numbers. The use of QR codes for contact tracing has enhanced the ability to control epidemics of COVID-19 in NSW, but there has been some discussion about removing this.

Two key current questions, therefore, are about the impact of vaccination of children 5-11 years and about the effect of potential relaxation of contact tracing efforts.

What is modelling:

Modelling is a science used to predict future outcomes under various conditions. Infectious diseases modelling is a long-established science that is helpful for informing policy decisions in public health. Each model depends on assumptions made, and contain a range of possible scenarios. The purpose of modelling is to show worst and best case scenarios, and scenarios in-between, to inform optimal decision making. A modelled output does not present a certain future – only a possible one, and usually governments act to prevent severe scenarios when informed by modelling or after early signs of health system surge. For pandemic planning, it is essential to model best and worst case scenarios, so that we know our range of options, and whether existing resources for dealing with surge capacity are adequate to protect the health system. In reality, a worst-case scenario may not occur, because once the health system starts failing, governments will re-introduce various public health measures to control the epidemic. A simulated worst-case scenario helps avoid that scenario from ever occurring. The modelling below provides worst and best case scenarios under different conditions around the NSW Roadmap to Freedom, modelled on updated vaccination rates and

Roadmap conditions, as well as uncertainties around vaccinating children 5-11 years and using digital contact tracing.

Aims:

To update the modelling of the NSW Roadmap using Roadmap conditions and vaccination rates.

To estimate the impact of high COVID-19 vaccination rates and changing public health orders on the health system in NSW, Australia.

To estimate the impact of vaccinating children 5-11 years

To estimate the impact of relaxing contact tracing

Methods

Model description

The modelling presented here uses a published, peer reviewed COVID-19 model for NSW, updated for the Delta variant of COVID-19, current public health orders and the current vaccination rollout (as of November 16 2021) in the state of NSW, Australia.

Model parameters and assumptions

The COVID-19 model uses the Delta variant estimated parameters, including an R0 of 6 and an incubation period of 5 days. Where available, parameters and rates used are age specific.

Hospitalization and ICU rates were taken from Australian data, with 11% hospitalisation rate and 3% ICU admission overall, and age specific rates used per age group. Age-specific deaths rates were calculated using age specific case incidence and case fatality data from NSW. Median length of hospital stay and ICU stay was taken from a systematic review, which estimated a mean length of stay in ICU of 7 days, and 5 days of hospitalization. This is an optimistic scenario, based on reports from NSW that intubated patients have a considerably longer length of stay.

Vaccine effectiveness against Delta is assumed to be 31% following one dose for both vaccines, and 88% and 67% for Pfizer and AZ respectively after two doses based on recent published data. The vaccine effectiveness against hospitalization, ICU and death is assumed to be >90% for both vaccines. The vaccine roll out is built in the model following the increased percentage of age specific people fully vaccinated over time from 20 June, data on vaccine rollout were taken from the

Australian Department of Health, and forecasted to reach 95% of 12+ fully vaccinated by 15 of December. We tested the addition of vaccination in the age group 5-11 years old starting on the 7th of January 2022. For this age group the gap between dose 1 and 2 is considered to be 6 weeks.

The outbreak response built into the model comprises testing, contact tracing, quarantine of contacts, cases isolation, masks use and movement/contact reduction according to the NSW public health orders. Contact tracing is considered effective if done within 24-48 hours after the infected case is identified. Contact tracing which occurs later than this is considered ineffective, because of the high probability contacts will already be infected if identified late.

While symptomatic isolation is kept constant at 90%, the contact tracing, the lockdown effect on contacts and the masks use percentage are estimated fitting the model output to the notification data from 20 June 2021 to 6 November 2021. The fitting was done considering all the different levels of restrictions and masks use (indoor/universal) in the NSW Public Health Orders, while the contact tracing capacity depends on the number of new cases per day and decreases when case numbers increase. We used the NSW notification data to estimate the reduction in movement from lockdowns, proportion of people wearing masks and proportion of contacts traced (and capacity to contact trace by case numbers). Assumptions on face masks effectiveness were taken from a published, peer reviewed study of masks effectiveness and use during the Victorian second wave.

For health system capacity, "Code Black" is defined in NSW as the point when ICU occupancy (of COVID and non-COVID patients) is over ~900 cases on a single day. We allowed for 300 non-COVID-19 patients a day requiring ICU admission, which means Code Black would be reached when there are 600 COVID-19 patients requiring ICU per day. This is the point when ICU capacity is exceeded and alternative models of care (such as using operating theatres) are required. The modelling uses conservative estimates to model different possible scenarios in the NSW Roadmap to Freedom. It does not include rising case fatality rate, which would be expected if ICU capacity is exceeded. Data from 2020 shows that case fatality rises as availability of ICU beds declines.

We started the outbreak from June 20 2021 with 7 infected as reported from NSW data and one latent untraced infected. The model runs to June 2022. The scenarios considered follow the NSW Roadmap schedule of relaxation of restrictions at 70, 80 and 95% vaccination of 16+. The conditions for the period after December 15th are shown in Table 2.

Scenarios considered:

All scenarios projected the epidemic after lifting of restrictions on December the 15th 2021

1) No vaccination for 5-11 age group, 80% contact tracing

2) 5-11 age group vaccinated, 80% contact tracing

3) 5-11 age group vaccinated, 0% contact tracing

4) No vaccination for 5-11 age group, 0% contact tracing

5) No vaccination for 5-11 age group, 50% contact tracing

6) 5-11 age group vaccinated, 50% contact tracing

Results

Figure 1 shows the modelled output fitted to data from 20/6 to 6/11, 2021. Table 1 shows the estimated value of those parameters for each time period, and the increased percentage of people fully vaccinated during the Australian vaccine rollout.

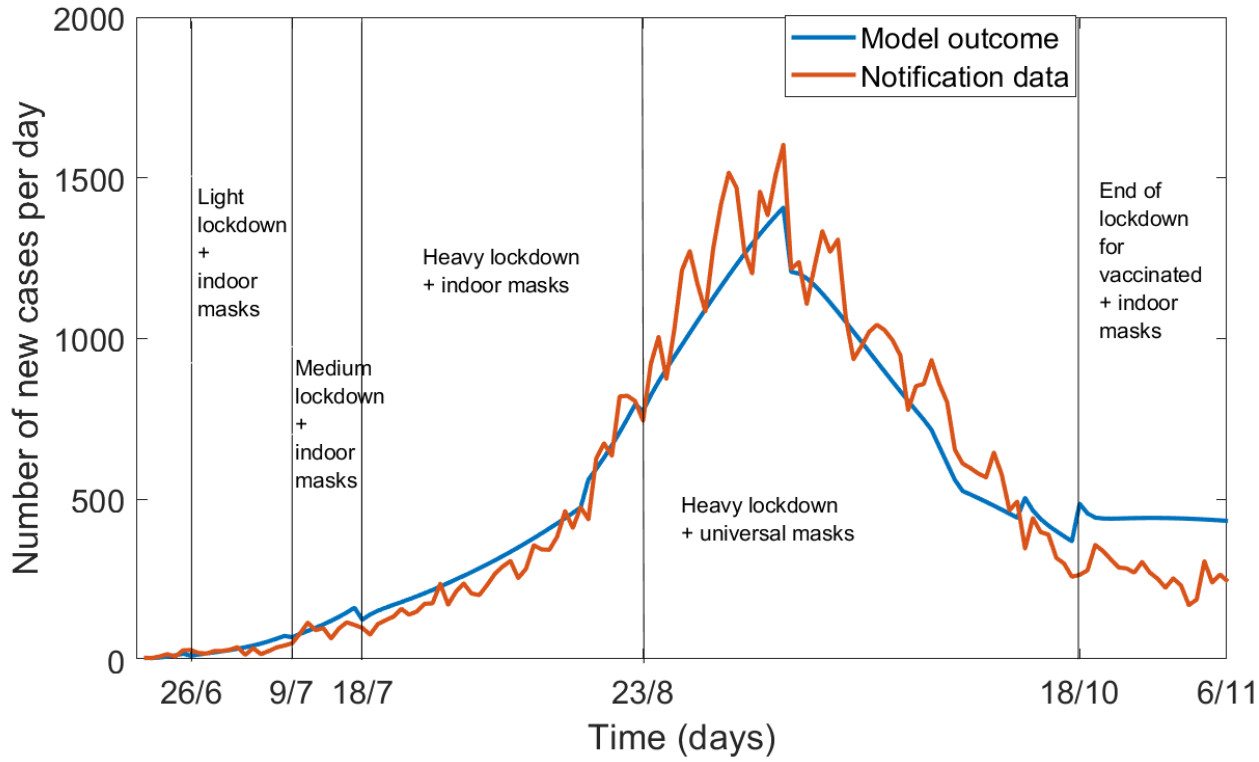

Figure 1: Fitting the model output to notification data from 20-June to 6 November, values estimated for different response effectiveness in each period are listed in Table 1

Table 2 shows the estimated movement reduction, mask use and contact tracing during the NSW epidemic of 2021. Effective contact tracing (within 24-48 hours) was estimated to vary from 80% (during low incidence periods) to 10% (at the peak in notified cases), masks use was estimated to be 50% when the indoor mask mandate was in effect and between 70-80% when the universal mask mandate (indoors and outdoors) was used. Movement was reduced by 40% in the first light lockdown, 50% in the medium lockdown and between 60-65% in the heaviest lockdown period. The estimates from December 15th onward (Table 2) are used to model the scenarios – which is that 95% of people aged 12+ will be vaccinated, there will be a 15% reduction in movement and mixing, there

will be 10% mask wearing, and 80% of contacts will be traced and quarantined within 24-48 hours of the infected case being identified.

Table 2: Estimated parameters from fitting model output to notification data from 20/6 to 6/11.

DATE	DESCRIPTION	VACCINE % (16+ fully vacc)	MOVEMENT REDUCTION	MASK USE	CONTACT TRACING
20/6 TO 25/6	Start of outbreak		0%	0%	80%
26/6 TO 8/7	Light lock down + indoor masks		40%	50%	80%
9/7 TO 17/7	Medium lock down + indoor masks	10%	50%	50%	70%
18/7 TO 15/8	Heavy lock down + indoor masks	13%	65%	50%	40%
16/8 TO 22/8	Heavy lock down + indoor masks	27%	60%	50%	20%
23/8 TO 10/9 (peak)	Heavy lock down + universal masks	31%	60%	70%	10%
11/9 TO 10/10	Heavy lock down + universal masks	46%	65%	80%	30%
11/10 TO 17/10	Slightly relaxed heavy lock down + universal masks	16+, 74% 12-15, 18%	59%	80%	30%
18/10 TO 7/11	Lockdown ended for vaccinated with some restriction and indoor masks	16+, 80% 12-15, 35%	45%	50%	80%
8/11 TO 14/12	Vaccinated are free to move around and indoor masks retained	16+, 90% 12-15, 70%	30%	50%	80%
15/12 ONGOING	Vaccinated and unvaccinated have the same freedoms. Masks on public transport and front house hospitality, 1 person per 2 square meters	12+, 95%	15%	10%	80%

Figure 2 shows the outbreak following the 15th of December for each scenario considered. Stopping or relaxing contact tracing will have an adverse impact on the incidence of cases while extending vaccination to 5-11 years produces better epidemic control. The worst outcome is if contact tracing (including QR code use to identify contacts) is ceased and children 5-11 years remain unvaccinated (purple line). There is a large difference between the best and worst-case scenarios. The best-case scenario, where children 5-11 years are vaccinated and high levels of timely contact tracing are maintained, results in excellent epidemic control and a small surge in cases which does not exceed health system capacity.

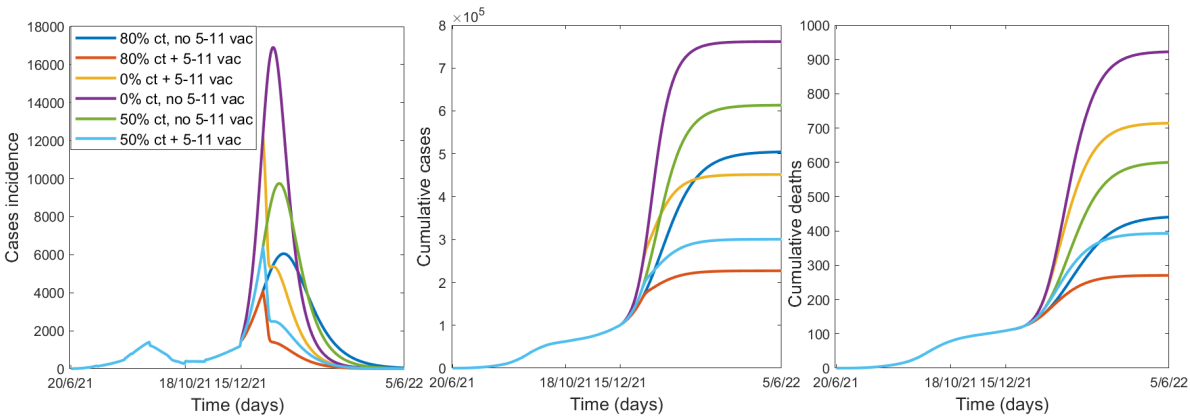

Figure 2: From left to right, cases incidence, cumulative cases and deaths for each scenario to June 2022.

When looking at hospitalization and ICU beds occupied over time (Figure 3-4), the code black threshold for ICU is exceeded in both scenarios where contact tracing is stopped, and worst if children 5-11 remain unvaccinated.

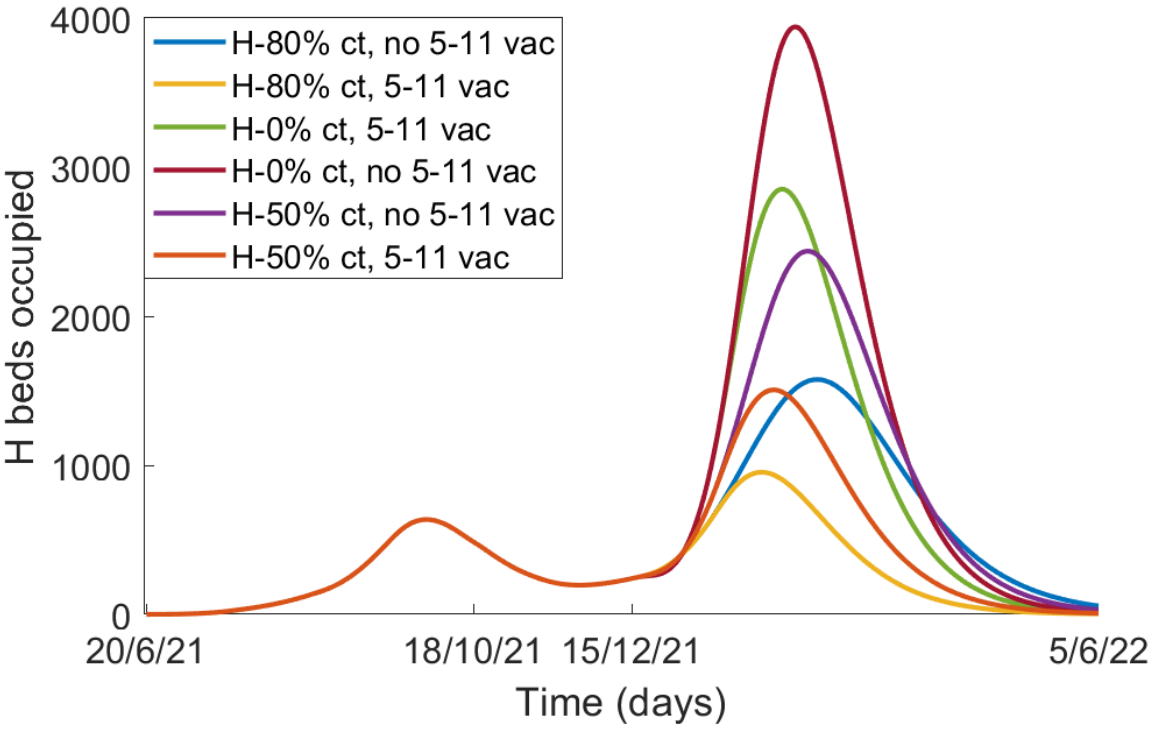

Figure 3: Hospitalization bed needed each day for all six scenarios.

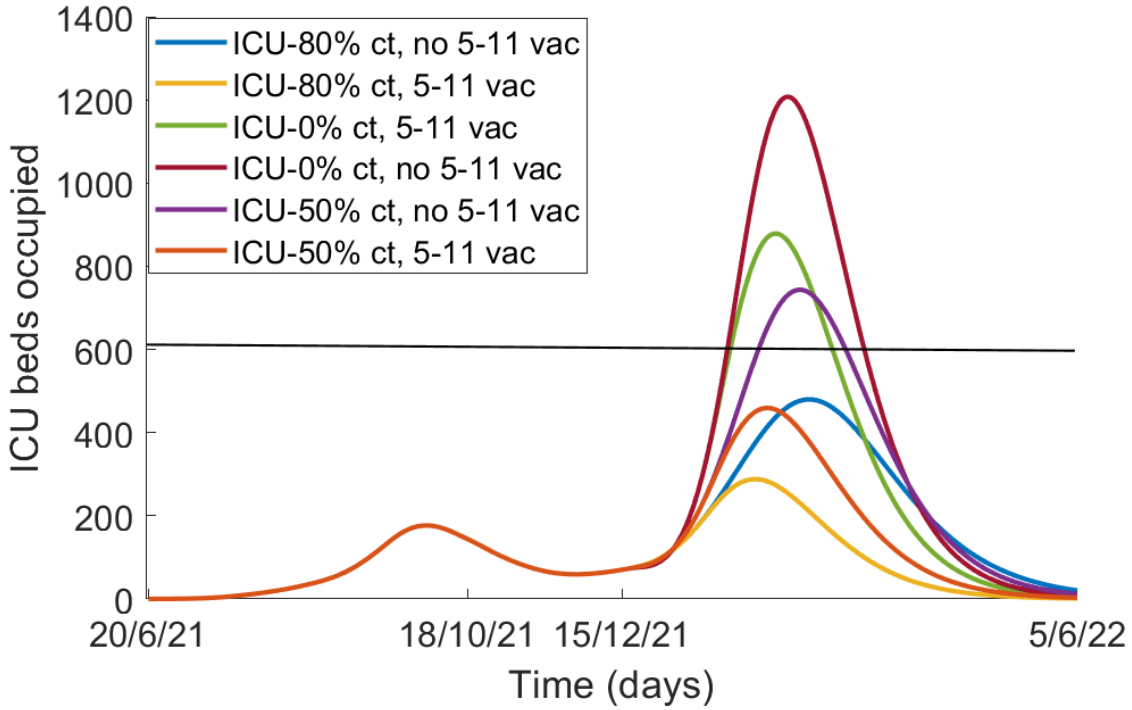

Figure 4: ICU beds needed each day for all five scenarios (black line is the code black threshold of 600 COVID-19 ICU beds a day required).

Table 2 shows the total cases and deaths for each scenario, and the date and size of the expected peak in hospitalization and ICU bed requirements.

Table 2: Cases, deaths, health system surge and date of the expected peak in hospitalization and ICU bed requirements

Scenario after lifting of restrictions on December 15 2021	**Total cases from June 2021 to June 2022**	**Total deaths from June 2021 to June 2022**	**Daily hospital bed requirements at the peak (date of peak)**	**Daily ICU bed requirements at the peak (date of peak)**
1) No vaccination for 5-11 age group, 80% contact tracing	504,528	440	1575 (21/2/22)	479 (23/2/22)

2) 5-11 age group vaccinated, 80% contact tracing	227,076	270	953 (31/1/22)	288 (3/2/22)
3) 5-11 age group vaccinated, 0% contact tracing	451,613	714	2852 (8/2/22)	878 (11/2/22)
4) 5-11 age group unvaccinated, 0% contact tracing	761,733	922	3,941 (13/2/22)	1,207 (15/2/22)
5) 5-11 age group unvaccinated, 50% contact tracing	613,449	600	2,436 (17/2/22)	743 (21/2/22)
6) 5-11 age group vaccinated, 50% contact tracing	300,666	393	1,505 (5/2/22)	459 (8/2/22)

Discussion

Excellent prospects

NSW has achieved control of the 2021 epidemic and extremely high vaccination rates, which places it in a strong position for epidemic control in 2022. The modelling shows that ongoing excellent control of COVID-19 can be achieved by vaccinating children 5-11 years as early as possible and by maintaining high testing and tracing capacity. A subsequent increase in cases is likely to occur after December, peaking in February 2022 because of increased mixing and movement, but in the best scenarios the health system capacity will not be exceeded.

Vaccination and timing is key

It would be beneficial if children 5-11 years are fully vaccinated before schools re-open in February 2022. The peak community vaccination in NSW was around August 2022, so waning of immunity following 2 doses will become apparent on a population level 6 months later, by February 2022, which coincides with a peak in infection. We did not factor in waning immunity in the model, so the model presents best-case outputs. To avoid a surge in cases due to waning immunity, we should ensure high and timely uptake of the 3rd dose by all eligible people.

Contact tracing is essential

The purpose of modelling variations in contact tracing is to show how influential it is in epidemic control, acknowledging that NSW Health has always had a strong testing and tracing program. However, reports from NSW of ceasing QR code use, and from Victoria of expecting infected people to notify their own contacts, are cause for concern. Certainly, QR codes can be scaled up and down depending on case incidence, as long as the infrastructure is retained and enhanced to enable rapid scaling up at times of high epidemic activity. Contact tracing remains central to COVID-19 control, even in the era of vaccination, because of vaccine breakthrough infection that may be highly transmissible. The investment in QR codes and the culture of use of digital technology should be continued and strengthened, because if case numbers rise to high levels, manual tracing will not be sufficient.

Recommendations for the best control of COVID-19 into the future:

- Ensure high levels of vaccination in children 5-11 years before schools re-open in 2022.
- Timely communication campaigns between December and January to ensure high uptake of the 3rd dose booster for people 18 years and over, so that epidemic control remains good.
- The messaging around “fully vaccinated” for adults equating to “double jabbed” needs to be reframed as “triple jabbed”.
- Maintain and strengthen digital contact tracing infrastructure, including QR codes to ensure contact tracing can be scaled up during periods of high epidemic activity. All states and territories should scale up digital tracing capacity.

- These results are applicable to any Australian setting. We urge Victoria to maintain contact tracing as a public health capability.
- Maintain high testing rates and wide accessibility to testing, and reduce the pricing of home tests for community and businesses for long term sustainability of high testing rates.

Caveats

We did not model waning of vaccine induced immunity, which will begin to show population-wide effects by February 2022. The best outcomes can be achieved by vaccinating younger children as early as possible, maintain high test and trace capacity and ensuring high and timely uptake of the 3rd dose booster in NSW.

The period December-January is the school holidays in NSW. School re-opening would increase the incidence of infection, especially in unvaccinated children. We did not model any interventions in pre-school aged children, but this would be the group that will be most at risk of outbreaks into 2022.

We were able to estimate the changing degree of mask use and movement restriction through the 2021 epidemic by fitting the model to observed case data. The fit of the model to observed data is close but the model predicts a slightly higher number of cases following the end of the lockdown, from the 18th of October. This discrepancy could be because the model shows total cases (including 35% of cases which are asymptomatic) while the notification data are only a subgroup of those.