QIMR Berghofer
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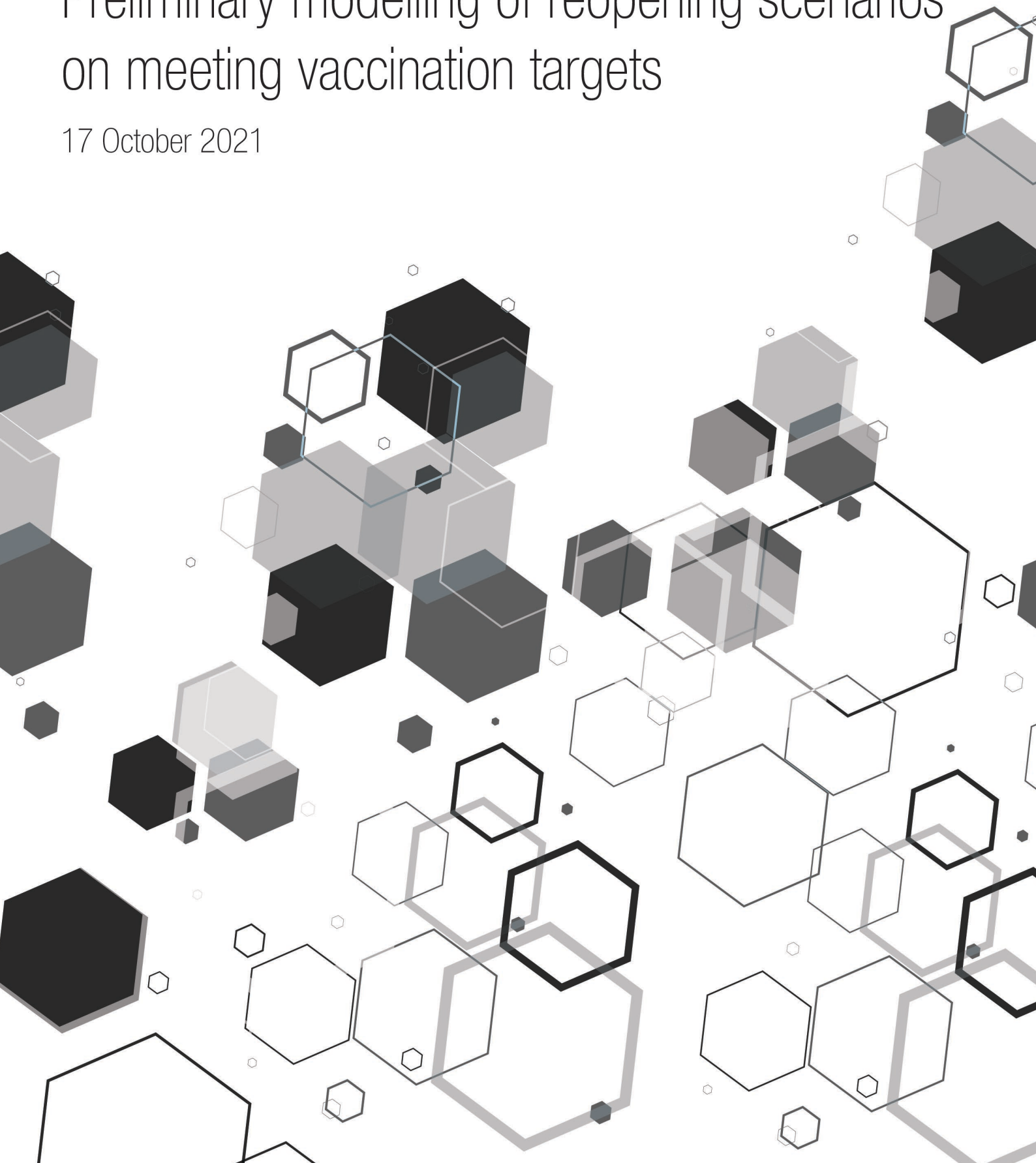
17 October 2021



Modelling COVID-19 in Queensland: Preliminary modelling of reopening scenarios on meeting vaccination targets

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(QIMR Berghofer Medical Research Institute).

With support from the Covasim team (Burnet Institute and the Institute for Disease Modeling).

Queensland Health commissioned this work.

Central question: As the vaccine rollout progresses, what might happen if borders reopen, restrictions relax, and there is an influx of cases into Queensland?

We used Covasim [1], developed by researchers at the Institute for Disease Modeling, Bill & Melinda Gates Foundation, USA, and the Burnet Institute, Melbourne. Covasim is available online [2].

We have tailored Covasim to the setting of Queensland [3], and incorporated recent insights from the Burnet Institute's modelling of the current outbreaks of the delta variant in Victoria and NSW [4-6].

We modelled four potential border reopening points, triggered by meeting double-vaccinated coverage targets:

- 70% of the 16+ population
- 80% of the 16+ population
- 85% of the 16+ population
- 90% of the 16+ population

From the simulations we estimate trajectories of cases, hospitalisations, ICU requirements, and deaths, as a function of age.

Assumptions

- Simulations were set up with immunity from the vaccine coverage (1^{st}/2^{nd} doses by brand and age) as at 10 Oct.
- The vaccine rollout proceeds from 10 Oct with first doses initially at the average daily rate of the week ending 3 Oct (week ending 10 Oct included a public holiday).
- Doses taper off toward 95% coverage for ages 60+ and 90% coverage for ages <60 (Fig. 1, corresponding to ~92% coverage overall – similar coverage was used in Victorian modelling and has been achieved in NSW). Rollout ends at 31 Dec 2021.

- Individuals receive mRNA or AstraZeneca vaccines, with the mix in each age group determined by the mix in doses delivered in the week ending 3 Oct. We treat Moderna as being equivalent to Pfizer and use Pfizer parameters for both.
- Reopening of borders will seed infections of the delta variant. We assume random (Poisson-distributed) new infections in Queensland residents at an average rate of 10 per day.
- We simulate outbreaks over the period 31 Oct 2021 – 28 Aug 2022.
- The only ongoing control measures are testing (at a rate consistent with recent Queensland daily test numbers), contact tracing (with tracing times reduced by QR code check-ins), isolation of positive cases, and quarantine of their contacts (TTIQ).
- Contact tracing has a fixed capacity of 100 cases per day.
- Effectiveness of vaccine-acquired immunity increases after delivery to a maximum, then (optionally) wans over time, as per the Covasim implementation [7] based on neutralising antibody data [8].
- We treat Queensland as a single population, neglecting geospatial variation.
- In the absence of an ongoing outbreak to calibrate to, we use our calibration to the 2020 wave; for the delta variant this corresponds to $R_0 \approx 7$.

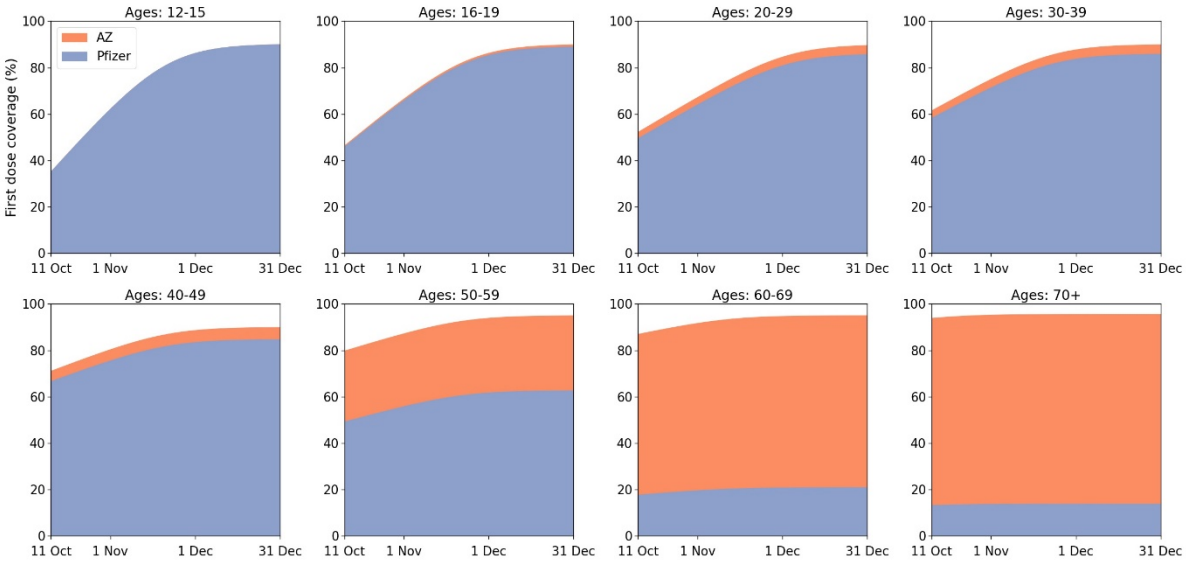

Fig. 1: Assumed rollout of first dose coverage during the simulations. True eventual rollout may be faster or slower.

Inputs

- ABS population demographics by age for Queensland as at 30 June 2020.
- Vaccine coverage as at 10 Oct 2021, by age, brand, and number of doses.
- Average daily rate of vaccination by age in the week ending 3 Oct 2021.
- Mix of vaccine brand doses delivered in the week ending 3 Oct 2021.
- Individual agents interact with one another across 14 contact networks: homes, schools, workplaces, public transport, cafes/restaurants, pubs/bars, entertainment, places of worship, community sport, professional sport, large events, parks, social settings, and other community settings.

- Vaccine parameters:

	Protection against infection	Protection against symptomatic covid	Protection against severe covid
Pfizer 1	65%	77%	86%
Pfizer 2	92%	95%	98%
AstraZeneca 1	47%	61%	77%
AstraZeneca 2	55%	67%	79%

Table 1: Parameters for the peak effectiveness of the Pfizer and AZ vaccines against the Delta variant. Cohen et al. (2021) medRxiv https://www.medrxiv.org/content/10.1101/2021.05.31.21258018v2.full

- Parameters of the delta variant:

Age bracket	Relative susceptibility	Pr(symptomatic)	Pr(severe)	Pr(critical)	Pr(hospital)	Pr(ICU)	Pr(death)
0-4	0.34	0.55	0.0020	0.00006	0.0020	0.00006	0.00004
5-9	0.34	0.55	0.0020	0.00006	0.0009	0.00006	0.00004
10-14	0.34	0.55	0.0032	0.00010	0.0032	0.00010	0.00004
15-19	1	0.65	0.0050	0.00017	0.0050	0.00017	0.00004
20-24	1	0.77	0.0190	0.00075	0.0190	0.00075	0.00021
25-29	1	0.77	0.0190	0.00075	0.0190	0.00075	0.00021
30-34	1	0.79	0.0540	0.00216	0.0504	0.00216	0.00067
35-39	1	0.79	0.0540	0.00216	0.0539	0.00216	0.00067
40-44	1	0.79	0.0870	0.00448	0.0597	0.00448	0.00204
45-49	1	0.79	0.0870	0.00448	0.0870	0.00448	0.00204
50-54	1	0.8	0.1840	0.01921	0.1581	0.01921	0.00550
55-59	1	0.8	0.1840	0.01921	0.1840	0.01921	0.00550
60-64	1.24	0.8	0.3020	0.07283	0.2657	0.06932	0.01580
65-69	1.24	0.8	0.3020	0.07283	0.3020	0.07283	0.01580
70-74	1.47	0.85	0.4130	0.16928	0.4130	0.12262	0.04943
75-79	1.47	0.85	0.4130	0.16928	0.4130	0.11996	0.04943
80-89	1.47	0.9	0.4490	0.30496	0.4490	0.03097	0.15830
90+	1.47	0.9	0.4490	0.30496	0.4490	0.03097	0.28663

Table 2: Age-specific susceptibility, disease progression and mortality risks for unvaccinated people. Parameters from Covasim Victorian modelling, https://www.premier.vic.gov.au/sites/default/files/2021-09/210919%20-%20Burnet%20Institute%20-%20Vic%20Roadmap.pdf

- Parameters on the effects of testing, tracing, isolation & quarantine (TTIQ)

Contact network	Assumed contact tracing probability	Assumed contact tracing delay [days]	Assumed effectiveness of quarantine on network	Assumed effectiveness of isolation on network
House	1	1	0.00	0.80
School	0.95	1	0.99	0.99
Work	0.95	1	0.90	0.90
Community (general)	0.1	7	0.80	0.80
Places of worship	0.5	2	0.99	0.99
Community sport	0.5	2	1.00	1.00
Professional sport	0.5	2	1.00	1.00
Entertainment	0.5	2	1.00	1.00
Cafe/restaurant	0.5	2	1.00	1.00
Pub/bar	0.5	7	1.00	1.00
Public transport	0.1	14	0.99	0.99
Public parks	0.1	14	1.00	1.00
Social	0.75	1	0.50	0.80

Table 3: Parameters on the effects of testing, tracing, isolation & quarantine (TTIQ). Adapted from Covasim Victorian modelling.

Results I: Effect of reopening on infection numbers

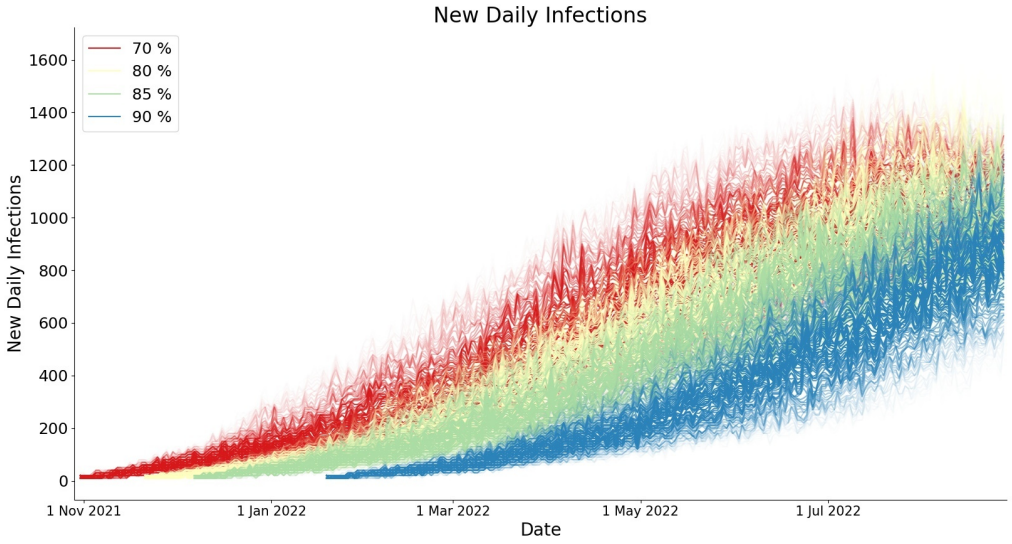

Fig. 2: New daily infections for four reopening scenarios on meeting age 16+ double-dose coverage targets: 70% (red), 80% (yellow), 85% (green), and 90% (blue). Each reopening scenario is an ensemble of 100 simulations, and assumes no waning of vaccine-derived immunity.

Interpretation:

- Herd immunity is not reached, outbreaks occur.

Results II: Effect of reopening on hospital bed and ICU numbers

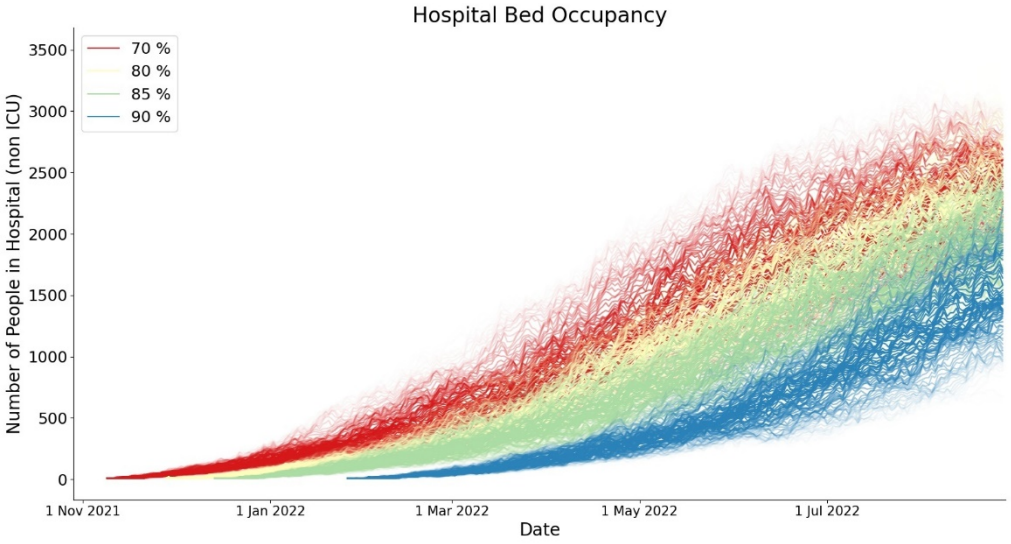

Fig. 3: Number of people in hospital (but not ICU) with COVID-19 for four reopening scenarios on meeting age 16+ double-dose coverage targets: 70% (red), 80% (yellow), 85% (green), and 90% (blue). Each reopening scenario is an ensemble of 100 simulations, and assumes no waning of vaccine-derived immunity.

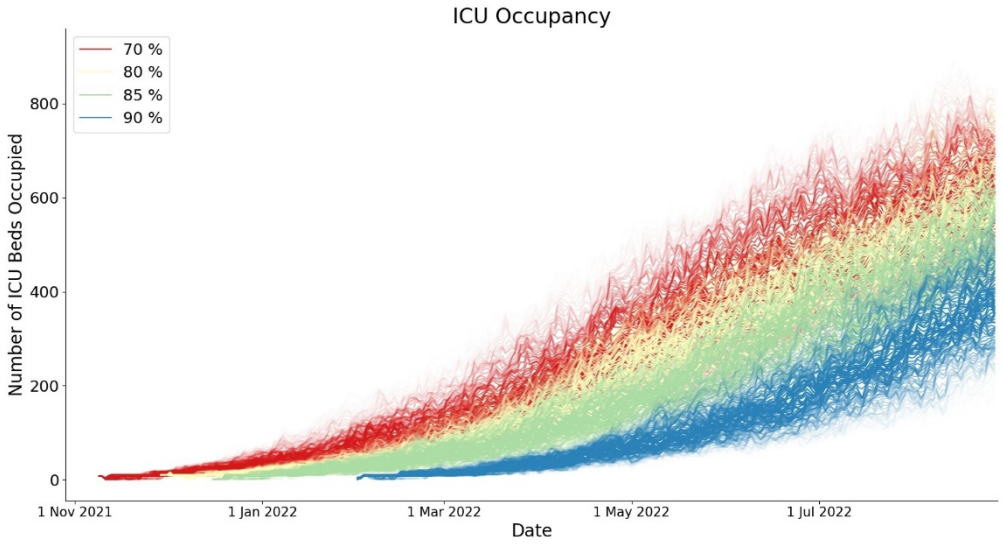

Fig. 4: Number of people in ICU with COVID-19 for four reopening scenarios on meeting age 16+ double-dose coverage targets: 70% (red), 80% (yellow), 85% (green), and 90% (blue). Each reopening scenario is an ensemble of 100 simulations, and assumes no waning of vaccine-derived immunity.

Interpretation:

- ICU and hospital resources may come under severe pressure but not catastrophically so before control measures can be enacted.

Results III: Health outcomes at 90 days after reopening

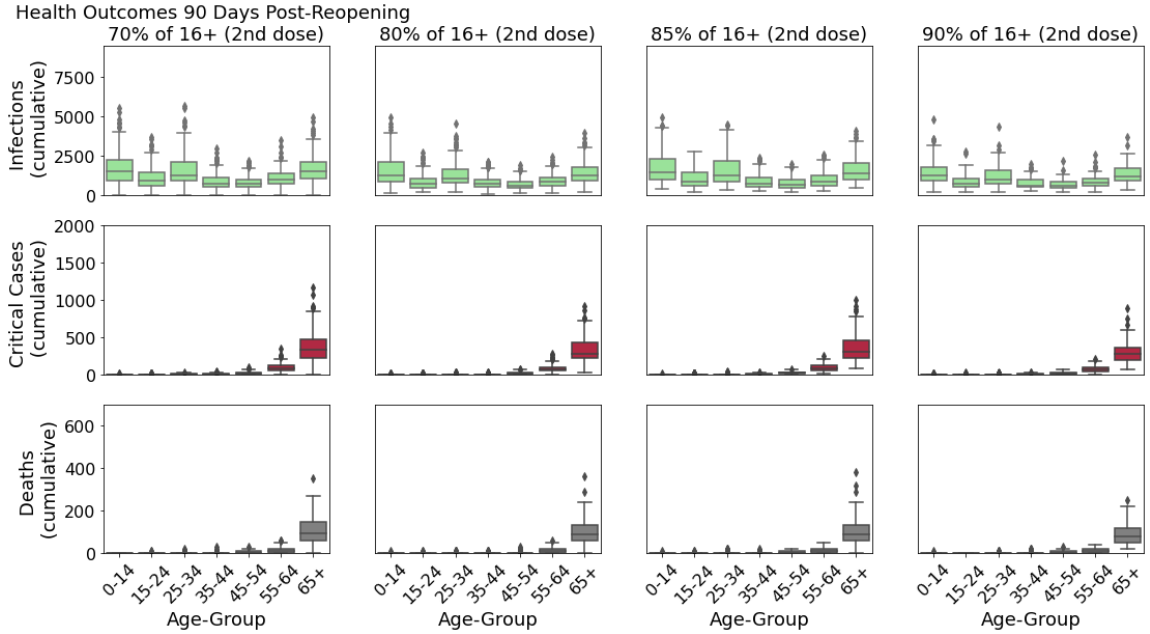

Fig. 5: Health outcomes by age, cumulative at 90 days after reopening. Simulations assume no waning of vaccine-derived immunity. Box plots summarise ensembles of 100 simulations.

Interpretation:

- Infections concentrate on the young and old, but severe outcomes concentrate even more heavily on the old.

Results IV: Effects of waning immunity

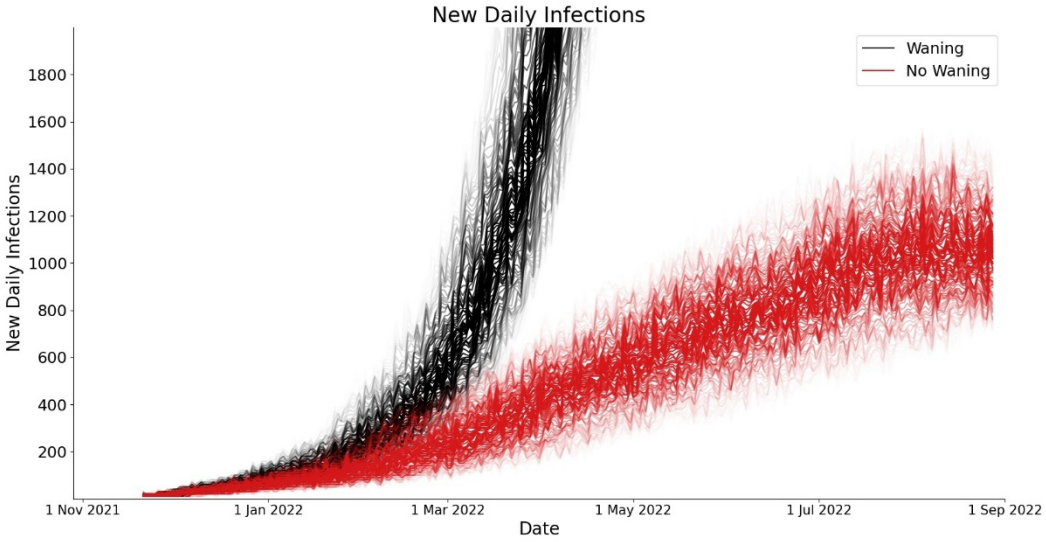

Fig. 6: Daily new infections with and without waning of vaccine-derived immunity. Scenarios are for a reopening target of 80% double-dose coverage, showing ensembles of 100 simulations.

Interpretation:

- Waning immunity may pose a serious threat in the absence of additional control measures or boosters.

Conclusions

- Reopening in the absence of restrictions beyond TTIQ is likely to trigger an outbreak.
- Our projections suggest the health system would be strained but not to breaking point.
- The precise location of an outbreak may have a large effect on health system impacts, due to Queensland's heavily decentralised geography – an outbreak in Regional Queensland may hit capacity limits far sooner than in Brisbane.
- The young and old age groups carry most of the infections, but the severe health outcomes load heavily on the old.
- Waning of vaccine-derived immunity may mean the above is optimistic, and boosters and/or vaccinating more of the population may be needed.
- Extending the rollout to younger children (e.g. aged 5-11) may help reduce case numbers, though there are not yet vaccines approved for those ages.

Limitations

- This work is preliminary and ongoing, and will be updated as more information comes to hand.
- Results are based on model inputs up to 10 October 2021, and assumptions on the future trajectory of the rollout, including its timing and endpoint.

- If hesitancy prevents Queensland reaching ~92% coverage of age 16+, results may be optimistic.
- Potential adding of ages 5-11 to the vaccine schedule may significantly reduce cases, including in older age groups.
- We did not model (re-)implementation of public health measures to control outbreaks; additional control measures would reduce cases and health system impacts.
- Using a fixed random rate of new infections due to border reopening does not account for different infection rates in other states, territories, and countries.
- We did not model vaccine mandates nor differing restrictions for the vaccinated and unvaccinated.
- We assumed there was no ongoing outbreak at the time of reopening, results could change if infections are seeded on an already high background level.
- Although we modelled finite TTIQ capacity, our results do not include reduced compliance with TTIQ measures over time. Our assumed rate of testing may be low for a large outbreak, though high vaccination rates may also dramatically reduce the population's willingness to test and isolate. Likewise vaccinated people may be less compliant with QR sign in or responding to public notices of exposure sites.
- There is uncertainty in the average length of stay in hospital and ICU, and this would impact estimates of peak hospital and ICU demand.
- There is considerable uncertainty around waning of vaccine-derived immunity, information on waning is still emerging. We modelled past vaccinations (up to 10 Oct) as still being at peak immunity on 10 Oct, it is likely that people early in the rollout already have waning immunity.
- Results do not include seasonal effects on behaviour or incursion rates.
- The model does not include geospatial information and so does not capture Queensland's unique distributed geography, nor spatial clustering of vaccination rates or infections (e.g., LGAs of concern).
- The model does not account for socioeconomic status, comorbidities, and risk factors (other than age) and so cannot account for differences in transmission risks, TTIQ adherence, or disease outcomes for different population subgroups.

References

[1] Kerr et al. (2021) PLOS Comput Biol 17:e1009149

[2] https://github.com/InstituteforDiseaseModeling/covasim

[3] Sanz-Leon et al. (2021) medRxiv https://doi.org/10.1101/2021.06.08.21258599

[4] https://www.premier.vic.gov.au/sites/default/files/2021-09/210919%20-%20Burnet%20Institute%20-%20Vic%20Roadmap.pdf

[5] https://www.burnet.edu.au/system/asset/file/4899/SydneyModelling_COVASIM_Explainer_FINAL.pdf

[6] https://www.burnet.edu.au/projects/467_covasim_modelling_covid_19

[7] Cohen et al. (2021) medRxiv https://www.medrxiv.org/content/10.1101/2021.05.31.21258018v1.full

[8] Khoury et al. (2021) Nature Medicine 27:1205–1211