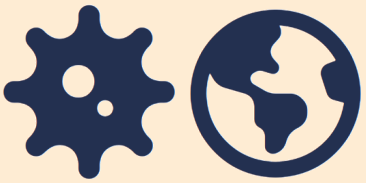

Ranking candidate trial locations:

where best for an Omicron vaccine in 2022?

An Arb Research report

Gavin Leech,
January 2022

Executive Summary

- We rank a shortlist of countries by their suitability for a May 2022 immunogenicity trial

- The keys to country suitability are 1) low expected Omicron immunity level in May and 2) low probability of an ongoing epidemic in May. A tiebreaker 3): country has multiple candidate locations with epidemiological independence: a backup centre to pivot to.

- To estimate future immunity, we fit one Neipel model per country (an SIR model with a mechanism allowing behaviour to adapt to an epidemic)

- To estimate the probability of a May epidemic, we look at past epidemics in the country, consider the course of the present Omicron epidemic, and consider the remaining public appetite for COVID restrictions

- The resulting ranking:
    1. Singapore = Australia
    3. Turkey
    4. India
    5. Egypt
    6. South Africa

- The first three score similarly. Australia has the advantage of a backup location (Tasmania) and less dependent internal epidemics (frequent closing of state borders)

- The whole analysis is based on preliminary and uncertain point estimates (see Assumptions), including low estimates of past vaccines' VE vs Omicron

- Modelling often yields sensitive (i.e. useless) results. Misha Yagudin (an elite forecaster) gave it a second pass, which resulted in no movement in the ranking

Desiderata

Of {South Africa, Turkey, Egypt, Singapore, Australia, India}:, which will be the best trial site *in May 2022*? What makes a location studyable? If our endpoint is immunogenicity:

- Low existing immunity to Omicron.
- No May Omicron wave[1]
- Multiple locations within the country with some epidemiological independence
- Tacitly: some unvaccinated people? Or booster study

Method: hybrid forecasting and modelling

We use a series of weak proxies to estimate quantities about the variant and the country (e.g. data quality, e.g. heterogeneity in future COVID waves).

A key but contentious trick: to estimate true infections (and so existing immunity), we use the confirmed deaths statistic (generally more reliable, and for which we have excess deaths ground truth) and scale it by the case-fatality ratio,
Cases = Deaths / CFR.

To predict future immunity and May wave risk we use the Neipel model as before.

Results

#	Country	Omicron immunity @ May	P(Omicron wave May)	Some degree of independence between sites	Confidence
=1	Singapore	46%	30%	N	65%
=1	Australia	26%	40%	Y	55%
3	Turkey	40%	35%	?	55%
4	India	33%	45%	Y	55%
5	Egypt	31%	45%	?	50%
6	South Africa	42%	50%	Y	60%

[1] This is the main difference between the Vaccine Effectiveness and Immunogenicity endpoints: for VE you need lots of events, which means large populations or ongoing epidemics.

Assumptions

Variants

- Omicron dominant worldwide, even when data is missing.
    - Assume ~all 2022 cases Omicron
- Most of the data is from Omicron BA.1.
- Assume that no more transmissible variant arises by May-June 2022.

Immune escape

- ~0% VE of AstraZeneca (etc) vs Omicron. [This is key. Based on a whole-population England study and a Scotland vitro study]
- Vaccine brands *injected* is generally unavailable. I infer something from the distribution and timing of shipments to that country.

Epidemiological parameters

- Using European NPI effect estimates where local estimates unavailable
- Point estimate 7 day serial interval
- Delta case fatality ratio equal across countries and throughout 2021-2
- Model results are very sensitive to the case ascertainment ratio.

South Africa

Omicron takeover date: Nov 22nd 2021

We begin here because the first Omicron wave is nearly (as of Jan 27th) run through and we can thus validate our model, particularly the key alpha (heterogeneity) parameter.

Immunity

Natural

- Prevalence of Delta immunity: 72%
- Prevalence of Omicron immunity @late January: 2%
- Projected prevalence of Omicron immunity @May: see model.

Vaccinations

- 28% fully vax. **22% mRNA**
- <1% boosted

Hotspots (regions to maybe avoid)

- Western Cape (cases 50% above per capita expectation),
- Northern Cape (+39%),
- Gauteng (+25%)

Neipel model

See appendix for model description and global parameter values.

The following parameters are estimated for 26th December 2021, to allow for outcome and reporting delays.

Population size (N). 58,775,020

Variants. B.1.1.529 (Omicron) is already prevalent, 99% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in South Africa, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 8,036,151 people in the resistant compartment as of 2021-12-26.

- 20% of the SA population were fully vaccinated with mRNA, approximately 0.8% of which with boosters. Unboosted Pfizer perhaps 10-20% VE. Boosted looks like 50-63% VE.
    - The expected resistant population from vaccines is thus very approximately 1,763,251.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, SA reported 62,729 deaths with COVID.
    - Given a Delta CFR of 0.19% [zhao], this implies 33,015,263 past infections.
    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 6,272,900.

Infected population (I). We estimate 2,109,240 active cases as of 26 December 2021 (15,066 mean daily confirmed cases in the preceding week, and an under-reporting factor of at least[2] 3.7 but potentially as high as 50x [2020 estimate]). We chose 20x, as the mid estimate from the paper assuming that SA testing has improved over the last year. While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in South Africa. As of the 26th December 2021, SA had a mask mandate [oxcgrt]. Using NPI effectiveness estimates from [sharma], these measures may have reduced R0 by 12%, resulting in an effective R of 1.67.

[2] We are using (excess deaths / reported COVID deaths) as a proxy for the case ascertainment. Deaths are much more carefully recorded, so this is a lower bound on case undercounting.

Projected Omicron immunity, May: 38%

Running the above model gets us 20% Omicron extra immunity at convergence in May. We add this to the existing immunity of 18%.

In this case, the first Omicron wave has passed, so we can validate the model right away:

Omicron immunity after first wave, actual: 42% (32% - 76%)

- 0.67m cases since Nov 26.
- Case undercount: call it 20x
    - 2020 estimate: 11x to 50x
- 0.67m * 20 = 13.4m
    - 0.67m * 11 = 7.37m
    - 0.67m * 50 = 33.5m
- = 23% of population
    - + 14% effectively immune from vaccine and past natural infection
    - + 4% ongoing infections Feb-May. In past inter-epidemic periods this was ~0.1m confirmed, or 2m infections.
    - + 1% for current wave not quite over

P(Omicron wave May): 55%

- Initial Omicron takeover (50%) date: Nov 22nd 2021.
- Peak of first Omicron wave: 16th Dec 2021
- Mean time between waves in this country: 6 months reliably
- Discrete waves: Yes
- peak-to-peak times imply June or July for Omicron wave #2 (under business-as-usual).
- Given the above (weak) projection and SA's track record, a second Omicron wave is likely in July and so moderately likely in May.

Subnational variation: very high

- 67% urban. (Proportions further from 50% imply less variation. Urbanised populations also more similar.)
- 63% Gini (world average 39%)
- Hotspots: Western Cape (50% above per cap), Northern Cape (+39%), Gauteng (+25%)

Locations with some spatial independence

- *Islands:* all too small.

- *Distinct state politics / cultures?*

    - Eastern Cape is 79% Xhosa
    - KwaZulu-Natal is 77% Zulu
    - North West is 70% Tswana
    - Free State is 62% Sotho

    - Regional NPIs?

Misc

PR considerations

- 6 successful trials, including AstraZeneca. Why do people keep doing this? Because the fairly extreme vaccine hesitancy means that there's a large unvaccinated population to recruit from? Previously (2021) also many seronegative people.
- Frequent riots and unrest

Confidence: 60%

Very bad data, very chaotic situation. But at least we don't have to rely on the model projection.

Data Quality

- Deaths undercounting factor: 2.1x to 2.6x (global average: 3x)

Turkey

Omicron takeover date: Jan 10th 2022

Immunity

Natural

- Prevalence of Delta: 19% given a 2.3x undercount.
    - But CFR method below implies 39%.
- Prevalence of Omicron @late January: 1.5%
- Projected prevalence of Omicron @May: see model

Vaccinations

- 62% fully vax, or **50%+ mRNA**
- 38% boosted (maybe 10% Turkovac)
    - 24% as of 26th December 2021

Hotspots (regions to maybe avoid)

- Gümüşhane
- Amasya

Neipel model

See appendix for model description and global parameter values.

Population size (N). 84,340,000

Variants. B.1.1.529 (Omicron) is already prevalent, 84% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in Turkey, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 18,946,480 people in the resistant compartment as of 2021-12-26.

- Approximately 50% of the Turkish population were fully vaccinated with mRNA, approximately 22% with Pfizer boosters. Unboosted Pfizer perhaps 10-20% VE, boosted perhaps 50-63%.
    - The expected resistant population from vaccines is thus very approximately 12,819,680.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, Turkey reported 61,268 deaths with COVID, mostly Delta.
    - This is probably pretty accurate: maybe 1.2x undercount
    - Given Delta CFR of 0.19% [zhao], this implies 32,246,316 past infections.

    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 6,126,800.

Infected population (I). We estimate at least 312,807 active cases as of 26 December 2021 (19,429 mean daily confirmed cases in the preceding week, and an under-reporting factor of at least 2.3 [irons]). While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in Turkey. As of the 26th December 2021, Turkey had closed some workplaces, cancelled public events, restricted internal movement, and imposed a strict mask mandate [oxcgrt]. Using NPI effectiveness estimates from [sharma], together these measures may have reduced R0 by (10% + 15% + 12%) = 37%, resulting in an effective R of 1.2.

Projected Omicron immunity in May: 40%

23% existing immunity and 17% modelled as acquired in first Omicron wave

P(Omicron wave May): 35%

- Initial Omicron takeover (50%) date: Jan 10th 2022
- Current wave ends: maybe beginning of March
- Time between waves in this country: Varies
- Discrete waves: Mostly
- Current wave is not under control, but probably won't last 3 months

Subnational variation: medium

- 76% urban
- 42% Gini (world average 39%)
- Hotspots:

Locations with some spatial independence

- Islands?
- Tribes?
- Regional NPIs?

Misc

Very helpful regional map of vaccinations here

PR considerations

Confidence: 55%

Turkish government is still willing to impose fairly strict NPIs.

Egypt

Omicron takeover date: *maybe* Jan 9th 2022

Immunity

Natural

- Prevalence of Delta: "3%". Naive CFR estimate (below) gives 95%.
    - This low even *after* an infamous death undercount factor of 13x
- Prevalence of Omicron @late January: >1%
- Projected prevalence of Omicron @May: see model

Vaccinations

- 25% fully (mostly Sinopharm and AZ until Oct 21), maybe **12% mRNA**
- Negligible boosted

Hotspots (regions to maybe avoid)

Neipel model

See appendix for model description and global parameter values.

Population size (N). 102,300,000

Variants. No data. But B.1.1.529 (Omicron) is extremely likely to be already dominant, ~95% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in Egypt, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 20,287,500 people in the resistant compartment as of 2021-12-26.

- I guess that 12% of the Egyptian population were fully vaccinated with mRNA, <1% of which with boosters. Unboosted Pfizer perhaps 10-20% VE.

    - The expected Omicron-resistant population from vaccines is thus very approximately 1,841,400.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, Egypt reported 14,081 deaths with COVID.
    - Apply an undercounting factor of 13 → 184,461 deaths
    - Given a Delta CFR of 0.19% [zhao], this implies 97,084,736 past infections, or 95% of a majority-rural population. This is obviously very high.
        - I am inclined to think this isn't insane.
        - Egypt seropositivity rates:
            - October 2020: 30% of all hosp admissions
            - December 2020: 46% in HCWs
        - And the area of the subsequent epidemic curves are easily 2.5x the first.
        - Still, assume that the underreporting has eased to a mere 9x via institutional development
            -
    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 18,446,100.

Infected population (I). We estimate 36,078 active cases as of 26 December 2021 (859 mean daily confirmed cases in the preceding week, and an under-reporting factor of 6-13x). While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in Egypt. As of the 26th December 2021, these were strict restrictions on gatherings, and a strict mask mandate [oxcgrt]. Using NPI effectiveness estimates from [sharma], together these measures may have reduced R0 by (8% + 12%) = 20%, resulting in an effective R of 1.5.

Projected Omicron immunity in May: 31%

18% existing immunity and 13% modelled as acquired in first Omicron wave

P(Omicron wave May): 45%

- Initial Omicron takeover (50%) date: maybe ~Jan 9th 2022
- Time between waves in this country: Irregular, 4-7 months
- Discrete waves: Mostly double dips.
- Could happen: model implies 48% total Omicron immunity from priors and the first O wave. Current wave hasn't peaked yet, and 4 months peak to peak isn't uncommon.

Subnational variation: **High**.

- 43% urban
- 31% Gini (world average 39%)
- Hotspots:

Locations with some spatial independence

- Islands?
- Tribes?
- Federation?

Misc

Truly vast Delta immunity, given some strong assumptions about CFR.

PR considerations

Lots of unrest including covid-related protests

Confidence: 50%

Data Quality

- Deaths undercounting factor: 13x (prior: 3x). Absolutely appalling

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Singapore

Omicron takeover date: ~27 December 2021

Immunity

Natural

- Prevalence of Delta: 4%
- Prevalence of Omicron @late January: 1%?
- Projected prevalence of Omicron @May: see model.

Vaccinations

- 83% fully, **79% mRNA**
- 50% boosted (37% on 26th December)

Hotspots (regions to maybe avoid)

N/A

Neipel model

See appendix for model description and global parameter values.

Population size (N). 5,686,000

Variants. B.1.1.529 (Omicron) is already prevalent, 94% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in Singapore, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 1,549,731 people in the resistant compartment as of 2021-12-26.

- 86% of the Singaporean population were fully vaccinated with mRNA, approximately 37% of which with boosters. Unboosted Pfizer perhaps 10-20% VE, boosted perhaps 50-63%.
    - The expected resistant population from vaccines is thus very approximately 1,469,831.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, Singapore reported 799 deaths with COVID.
    - Approximately 0 undercounting
    - Given a Delta CFR of 0.19% [zhao], this implies 420,526 past infections.
    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 79,900.

Infected population (I). We estimate at least 4589 active cases as of 26 December 2021 (285 mean daily confirmed cases in the preceding week, and an under-reporting factor of at least 2.3 [irons]). While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in Singapore. As of the 26th December 2021, there were intense restrictions on gatherings larger than 2 people, and a strict mask mandate [oxcgrt]. Using NPI effectiveness estimates from [sharma], together these measures may have reduced R0 by (23% + 12%) = 35%, resulting in an effective R of 1.24.

Omicron immunity in May: 46%

27% existing immunity and 19% modelled as acquired in first Omicron wave

P(Omicron wave May): 30%

- Initial Omicron takeover (50%) date: ~25th December 2021
- Hasn't peaked yet
- Time between waves in this country: either 3 months or a year
- Discrete waves: Yes
- Intense state capacity and public submission means I can't see this lasting for three months

Subnational variation: **minimal**.

- 100% urban
- 35% Gini (world average 39%)
- Hotspots: N/A

Locations with some spatial independence

Islands: No. (Sentosa, but pop 1500.)

Misc

PR considerations

?

Confidence: 65%

Data Quality

- Deaths undercounting factor: None, 1x (prior: 3x)

Australia

Omicron takeover date: ~20th December 2021

Immunity

Natural

- Prevalence of Delta: 1%
- Prevalence of Omicron @late January: 8%
- Projected prevalence of Omicron @May: see model.

Vaccinations

- 79% fully, **40%?? mRNA**
- 27% boosted

Hotspots (regions to maybe avoid)

Neipel model

See appendix for model description and global parameter values.

Population size (N). 25,690,000

Variants. B.1.1.529 (Omicron) is already prevalent, 97% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in Australia, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 2,318,050 people in the resistant compartment as of 2021-12-26.

- ~~38% of the Australian population were fully vaccinated with mRNA, approximately 8% of which with boosters. Unboosted Pfizer perhaps 10-20% VE, boosted perhaps 50-63%.
    - The expected resistant population from vaccines is thus very approximately 2,183,650.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, Australia reported 1,344 deaths with COVID.
    - Zero undercounting apparent
    - Given a Delta CFR of 0.19% [zhao], this implies 707,368 past infections.
    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 134,400.

Infected population (I). We estimate at least 128,317 active cases as of 26 December 2021 (7970 mean daily confirmed cases in the preceding week, and an under-reporting factor of at least 2.3 [irons]). While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in Australia. As of the 26th December 2021, there were very few *nationally enforced* policies in place, but many strict policies in many regions [oxcgrt]. Using NPI effectiveness estimates from [sharma], together these measures may have reduced R0 by 20%, resulting in an effective R of 1.52.

Projected Omicron immunity in May: 26%

9% existing immunity and 17% modelled as acquired in first Omicron wave

P(Omicron wave May): 40%

- Initial Omicron takeover (50%) date: ~20th December 2021
- Time between waves in this country: N/A
- Discrete waves: yes
- Current wave is ending mid-Feb.
- Early Winter
- National appetite for restrictions is incredibly high. Assume Christmas was the anomalous cause of this wave.

Subnational variation: Very low.

- 86% urban.
- 34% gini. (world average 39%)

Locations with some spatial independence

- Tasmania
- Frequent state border closures.
    - Victoria is the strictest and so most independent.

Misc

PR considerations

Vaccines are heavily politicised, but pro-vax is completely dominant.

Confidence: 65%

Only one wave to base this off. Their death toll is not as scary as other initial waves, so far. Model implies that this Omicron wave will be vast: 40% infected. On priors this seems too large.

The surprising national appetite for harsh restrictions makes this evaluation a bit safer.

Data Quality

- Deaths undercounting factor: None (prior: 3x)

India

Omicron takeover date: ~3rd Jan 2021

Immunity

Natural

- Prevalence of Delta: "12%" given 7x undercount. Naive CFR estimate = 75%
- Prevalence of Omicron @late January: 3%
- Projected prevalence of Omicron @May: see model.

Vaccinations

- 50% fully, **1%?? mRNA** / DNA
    - People claim Covaxin is 90% effective vs Omicron…
    - ZyCoV-D negligible at the moment: zero full courses
    - Sputnik seems ok so I'll count it: **~7%? Sputnik**
- <1% boosted

Hotspots (regions to maybe avoid)

- Madhya Pradesh (79https://www.bbc.com/news/world-asia-india-57885663% seropositivity)
- Rajasthan (76%)
- Bihar (76%)

Neipel model

See appendix for model description and global parameter values.

Population size (N). 1,401,235,640

Variants. B.1.1.529 (Omicron) is already prevalent, 94% of cases. The following parameters are thus based on Omicron evidence. We do not have data on the BA.1 vs BA.2 mixture in India, so the following is the usual latent mixture of the two.

Resistant population (R). We estimate 208,463,108 people in the resistant compartment as of 2021-12-26.

- 6.4% of the Indian population were fully vaccinated with mRNA / DNA / Sputnik, <1% of which with boosters. Unboosted Pfizer perhaps 10-20% VE. Sputnik perhaps 10% VE (high uncertainty).
    - The expected resistant population from vaccines is thus very approximately 8,967,908.
- Given strong under-reporting of cases, we can estimate true past infections using the more reliable confirmed deaths statistics and the estimated case-fatality ratio (CFR).
    - In 2021, India reported 332,492 deaths with COVID.
    - Undercount of 11.5x → 3,823,658
        - This checks out
    - Given a Delta CFR of 0.19% [zhao], this implies 1,049,974,737 past infections, or 75% of the country. This is confirmed in sero studies.
    - Past Delta infection maybe 19% protective against Omicron [ferguson]
    - The estimated population resistant from past infection is then 199,495,200.

Infected population (I). We estimate 464,940 active cases as of 26 December 2021 (6642 mean daily confirmed cases in the preceding week, and an under-reporting factor of 11.5). While this estimate is highly uncertain, our results are only mildly sensitive to it, due to the exponential growth nature of the wave.

Initial reproduction number. The basic reproduction number of Omicron is estimated at 1.90 (95% Credible Interval: 1.50–2.43) [kim]. We can adjust this raw estimate according to the non-pharmaceutical interventions active in India. As of the 26th December 2021, there were mild restrictions on gatherings and a mild mask mandate [oxcgrt]. Using NPI effectiveness estimates from [sharma], together these measures may have reduced R0 by (10% + 6%) = 16%, resulting in an effective R of 1.6.

Projected Omicron immunity in May: 33%

15% existing immunity, 8% modelled as acquired in first Omicron wave, 10% subjective estimate of the long tail of inter-epidemic (Feb-May) cases there.

P(Omicron wave May): 45%

- Initial Omicron takeover (50%) date: ~3rd Jan 2021
- Time between waves in this country: 8 months like clockwork
- Discrete waves: Yes (but at this subcontinental level)
- Current wave should be over by end of March. Recrudescence is unlikely at national level (but who cares about national level here?)

Subnational variation: **Very high**.

- It's a subcontinent, 30 latitude degrees.
- 35% urban.
- 36% gini (world average 39%)
- Dedicated study at state level:

Locations with some spatial independence

Islands?
Tribes?
Federation?

Misc

PR considerations

?

Confidence: 55%

If we go with India we absolutely must redo this analysis with the constituent states. I know the people who wrote a lot of the Indian covid stats software.

Data Quality

- Deaths undercounting factor: 7x (prior: 3x)

Appendix: Omicron parameters

Studies with an unspecified BA.1/2 mixture (but mostly BA.1)

Estimates of unboosted vaccine effectiveness against Omicron infection range from ~0% AstraZeneca (AZ) [ferguson,willett] to 19% Pfizer (PF) [ferguson].

Appendix: the Neipel model,
adding heterogeneous susceptibility

To predict expected infections, we use the modified SIR model of [neipel] with epidemiological parameters estimated for each possible location.

Neipel et al go beyond the standard SIR model in incorporating heterogeneity in the degree of susceptibility to infection, and are thus able to capture deviations from SIR that characterize many COVID-19 epidemics (for instance, earlier peaks in case curves) [grossmann, moein].

Let x be the degree of susceptibility to infection of an individual. This is intended to cover any cause of infection risk, from immunological factors to personal social distancing, rate of interpersonal contacts, and hygiene. When all individuals have equal and constant susceptibility $x = 1$, we obtain the standard SIR model.

The initial susceptibility distribution $s_0(x)$ is gamma-distributed with exponent α representing the homogeneity of the population:

$$s_0(x) \sim x^{-1+\alpha} e^{-\alpha x}$$

They define the epidemic completion as $\cdot\tau = \frac{\beta I}{N}$, with infection rate β, current infectious compartment size I and total population S. Then given initial infections I_0 and for a given point in the epidemic τ, the number of susceptible individuals is

$$S(\tau) = \int_0^\infty s_0(x)\, e^{-\tau x}\, dx = \frac{N - I_0}{(1 + \tau/\alpha)^\alpha}$$

Moreover, average susceptibility $\bar{x}$ decreases throughout the epidemic (e.g. as higher-degree nodes in the social network become resistant, and as society learns safety measures), dampening the epidemic curve:

$$\bar{x} = \frac{1}{1 + \tau/\alpha}$$

We next assume that individual susceptibility x strongly correlates with the number of contacts in a physical contact network. The distribution parameters of these networks are generally difficult to estimate precisely due to lack of available data as well as the high variance of the estimators [clauset].

Generation interval (GI). Two preliminary studies find a mean generation interval for Omicron of 2.2 days [abbott, kim]. Note that both studies estimate proxies of GI: either the test-to-test distribution [abbott] or the serial interval [kim].

We use the same SIR and heterogeneity values for each country:
$\gamma = \frac{1}{GI} = 0.45$ [vazquez] and $\beta = R_0\gamma = 0.7$ [beckley].

Population heterogeneity exponent α. Our choice of $\alpha = 1.5$ is consistent with physical contact networks as well as the Barabasi-Albert model commonly used to model contact networks.

The extra model complexity is richly rewarded. One/two extra parameters, and in return you get something like humans instead of infectable rocks.

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