Modeling Covid-19

Complexities and Conundrums

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www.insight.co.za/2020/08/12/covid-19-conundrums-and-considerations/

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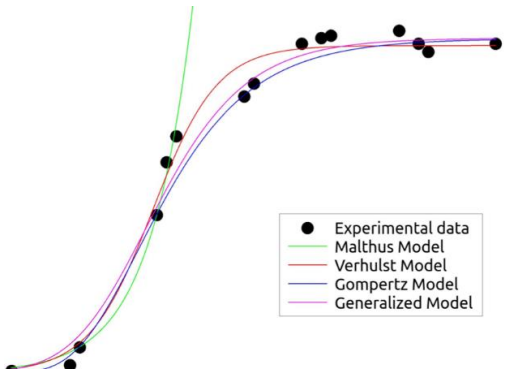
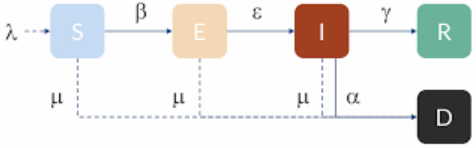
Primarily 3 model choices

Curve fitting

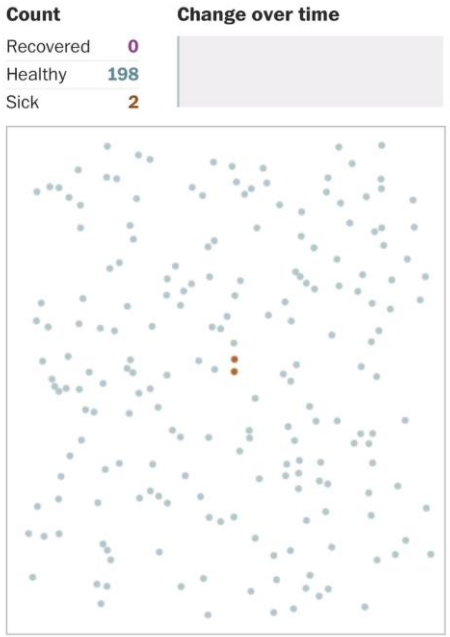


Susceptible, Exposed, Infected, Removed

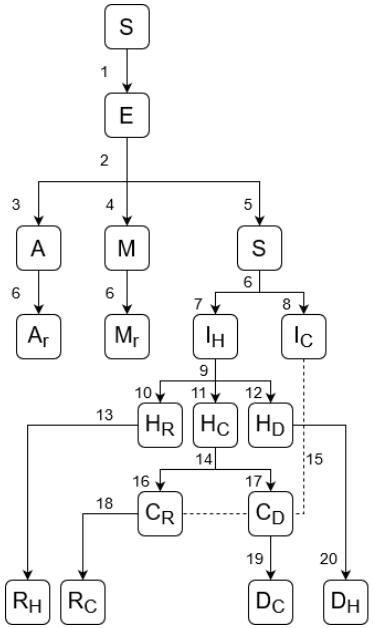


$$
\begin{aligned}
\frac{dS}{dt} &= \mu(N-S) - \beta\frac{SI}{N} - \nu S \\
\frac{dE}{dt} &= \beta\frac{SI}{N} - (\mu+\sigma)E \\
\frac{dI}{dt} &= \sigma E - (\mu+\gamma)I \\
\frac{dR}{dt} &= \gamma I - \mu R + \nu S \\
N &= S + E + I + R
\end{aligned}
$$

Agent Based Model



ASSA Model V2



1. Infection rate
2. Incubation rate
3. Asymptomatic proportion
4. Mild proportion
5. Severe proportion
6. Infectious period
7. Proportion severe to be hospitalised
8. Proportion severe to be critical
9. Average rate of hospitalisation
10. Proportion hospitalised to recover
11. Proportion hospitalised to ICU
12. Proportion hospitalised to decease
13. Ave rate of hospital recovery
14. Ave rate to ICU from hospital
15. Ave rate to ICU from severe
16. Proportion critical to recover
17. Proportion critical to decease
18. Ave rate of critical recovery
19. Ave critical mortality rate
20. Ave hospitalised mortality rate

Compartmental model.

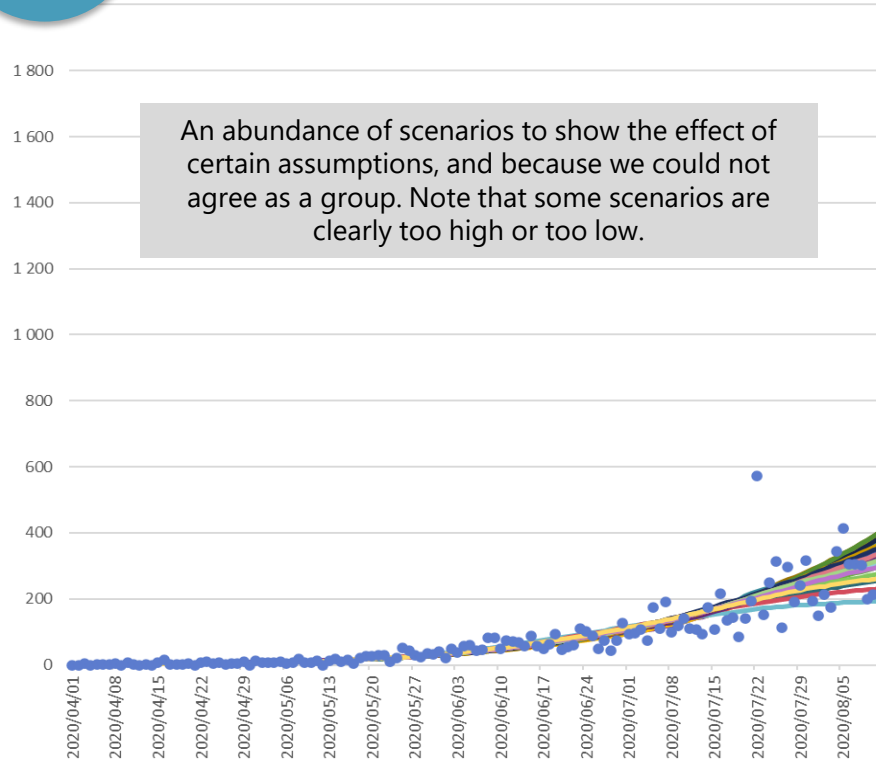
Have to estimate transition rates between states, length of time in each state, all managed by differential equations. Estimates based on early studies and literature, but fitted to observed mortality data.

Significant risk of over complicating things, violating parsimony, and increasing model risk.

Mainly trying to model key metrics such as hospital bed and ICU usage, and mortality.

Key assumptions with greatest uncertainty are level of asymptomatic cases, presence of innate or cross immunity, and level of population heterogeneity.

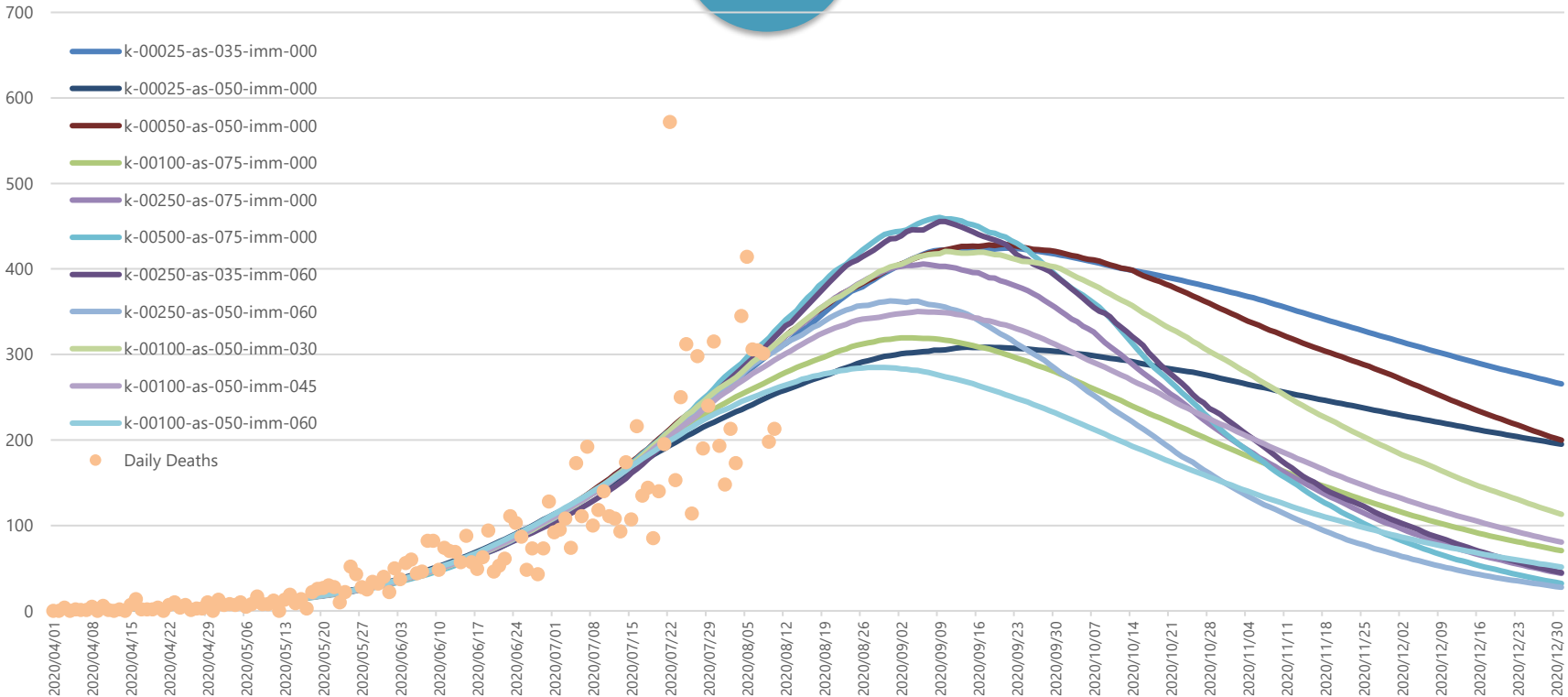
Daily death short term fitting

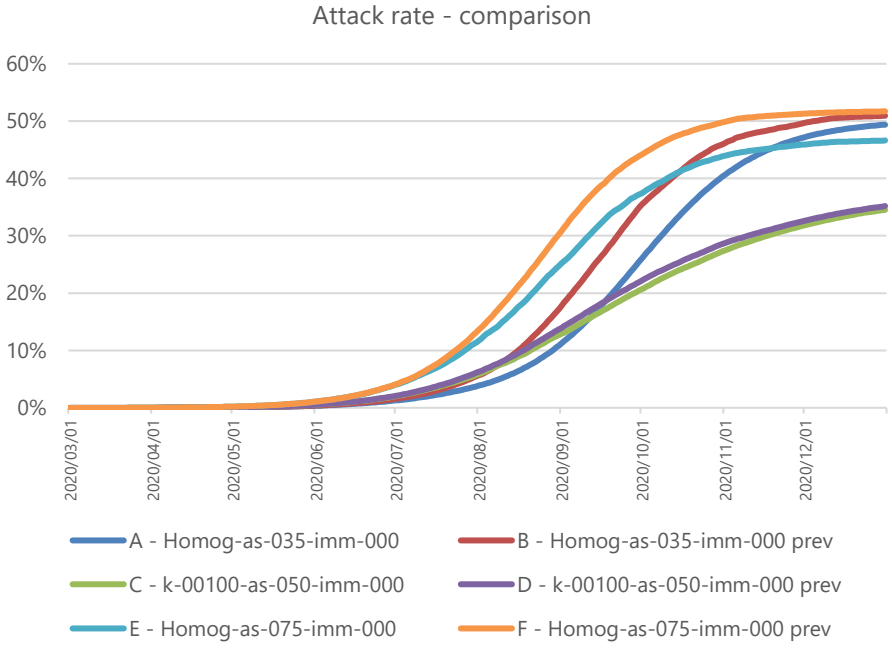


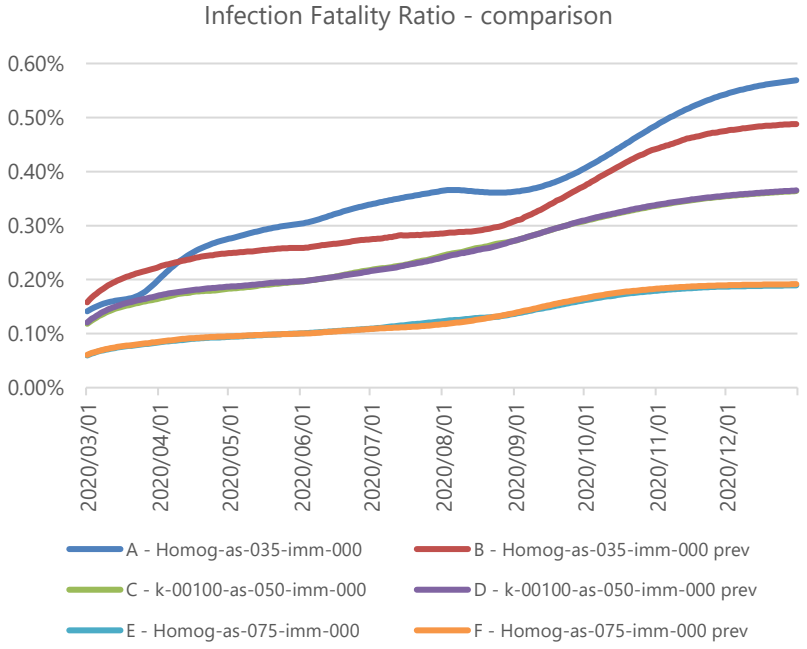
An abundance of scenarios to show the effect of certain assumptions, and because we could not agree as a group. Note that some scenarios are clearly too high or too low.

Daily death long term projections

Daily death long term projections, narrower range of scenarios







Higher non-susceptibility reduces the attack rate
Lower K value (higher heterogeneity reduces the attack rate)

Higher asymptomatic rates lower the IFR
For reference, SA population age adjusted IFR from:
Verity = 0.44%
France study + Diamond Princess = 0.24%

Some sense checking from Western Cape data so far

Reminder of current international stats: (Worldometers.info)

#	Country, Other	Total Cases	New Cases	Total Deaths	New Deaths	Total Recovered	Active Cases	Serious, Critical	Tot Cases/ 1M pop	Deaths/ 1M pop
1	San Marino	699		42		657	0		20,596	1,238
2	Belgium	74,620	+468	9,879	+7	17,792	46,949	73	6,435	852
3	UK	312,789	+1,148	46,526		N/A	N/A	67	4,605	685
4	Andorra	963		52		839	72	1	12,461	673
5	Peru	483,133		21,276		329,404	132,453	1,484	14,631	644
6	Spain	373,692	+3,632	28,581	+5	N/A	N/A	617	7,992	611
7	Italy	251,237	+412	35,215	+6	202,461	13,561	49	4,156	583
8	Sweden	83,126		5,770	+5	N/A	N/A	35	8,225	571
9	Chile	376,616	+1,572	10,178	+39	349,541	16,897	1,268	19,683	532
10	USA	5,272,367	+20,921	166,886	+694	2,719,695	2,385,786	17,589	15,918	504
11	Brazil	3,068,138	+10,668	102,034	+177	2,163,812	802,292	8,318	14,423	480
12	France	204,172	+1,397	30,340		82,836	90,996	383	3,127	465
13	Mexico	485,836	+5,558	53,003	+705	327,993	104,840	3,683	3,764	411
14	Sint Maarten	205	+16	17		93	95	3	4,775	396
15	Panama	75,394		1,664		49,510	24,220	157	17,444	385

3,843 WC deaths as at 27 August
= 557 deaths per million *so far*

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Some sense checking from WC data so far

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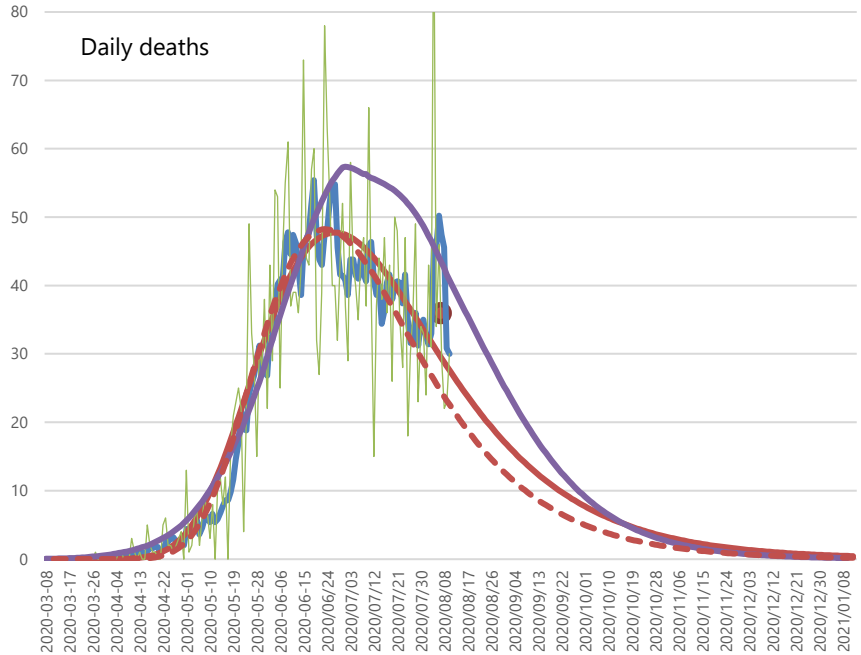
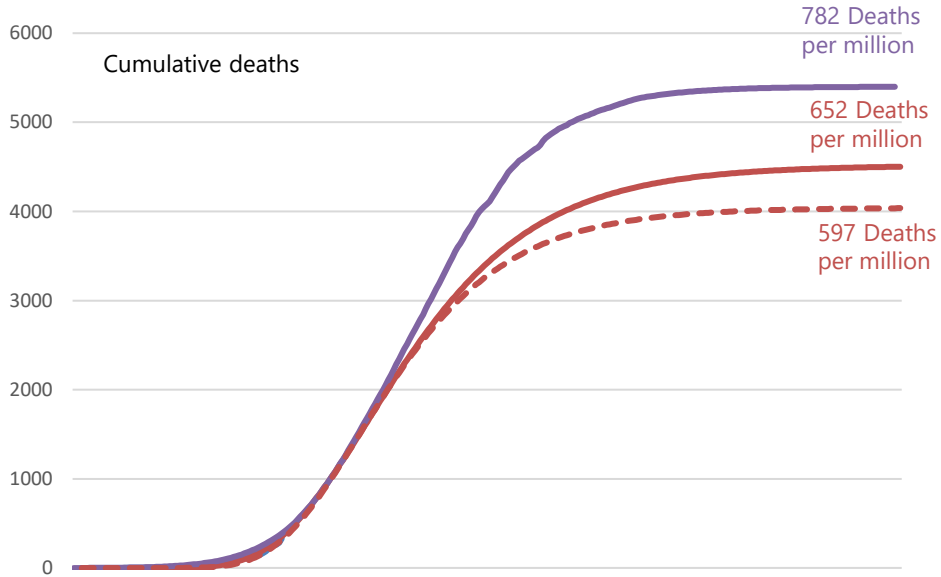
ASSA model with K = 0.01, 50% asymptomatic, 65% immune, fitted 12 July
Gompertz, fitted (min SS) 11 August (dotted line 31 July)





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782 Deaths per million

652 Deaths per million

579 Deaths per million

All depends on how each province goes through their disease progression. Rural provinces likely much lighter. KZN, Gauteng and EC may be similar to WC. Which would put EOY SA mortality at
~ 34,000 – 46,000

IF other provinces improve their mortality reporting. Overall national reported deaths likely to be lower. Excess reported mortality likely to be higher.

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Another check on mortality so far – SAMRC excess deaths

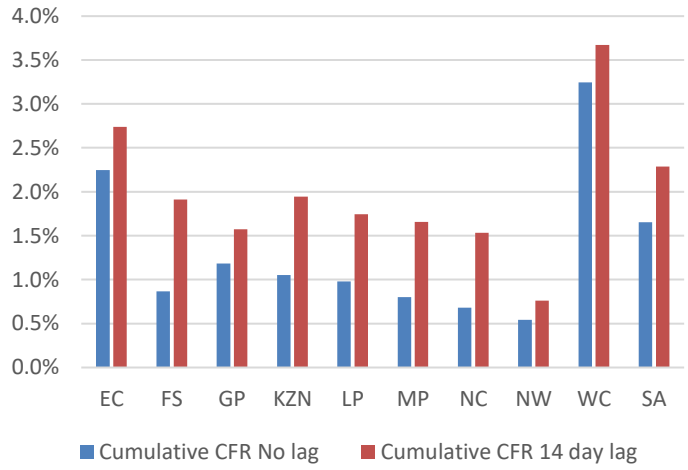
Table 1: Number of excess **natural** deaths of persons 1+ years by province and metro relative to revised predicted number based on the observed drop during lockdown, South Africa 2020

Region	Excess deaths 6 May - 18 August	
South Africa	39,087	12,264 (31%)
Province		
Eastern Cape	9,354	2.633 (28%)
Free State	2,664	537 (20%)
Gauteng	10,860	3,018 (28%)
KwaZulu-Natal	6,396	1,743 (27%)
Limpopo	1,349	159 (12%)
Mpumalanga	1,982	214 (11%)
Northern Cape	596	100 (17%)
North West	1,546	214 (14%)
Western Cape	4,933	3,646 (74%)

Confirmed Covid fatalities

Not all excess deaths will be due to Covid, and reporting remains problematic in some areas, but there does appear to be material undercounting, especially in EC and Gauteng

Case fatality rates per province appear to corroborate the under reporting by province



Covid-19 fatalities as at 18 August would be 28,924 if all provinces had the same ratio of reported Covid-19 deaths to excess deaths as the WC (~2,5 times confirmed deaths).

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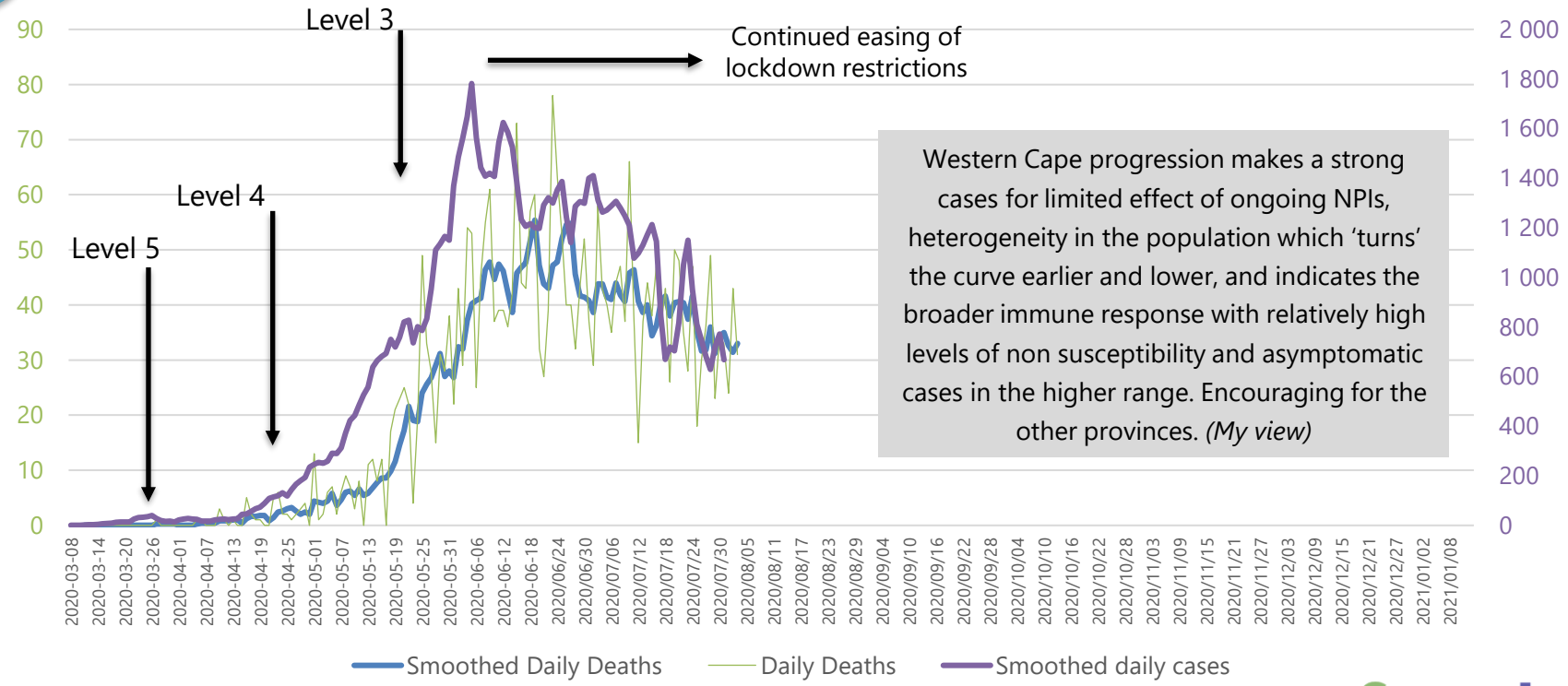
Western Cape story



Western Cape progression makes a strong cases for limited effect of ongoing NPIs, heterogeneity in the population which 'turns' the curve earlier and lower, and indicates the broader immune response with relatively high levels of non susceptibility and asymptomatic cases in the higher range. Encouraging for the other provinces. *(My view)*

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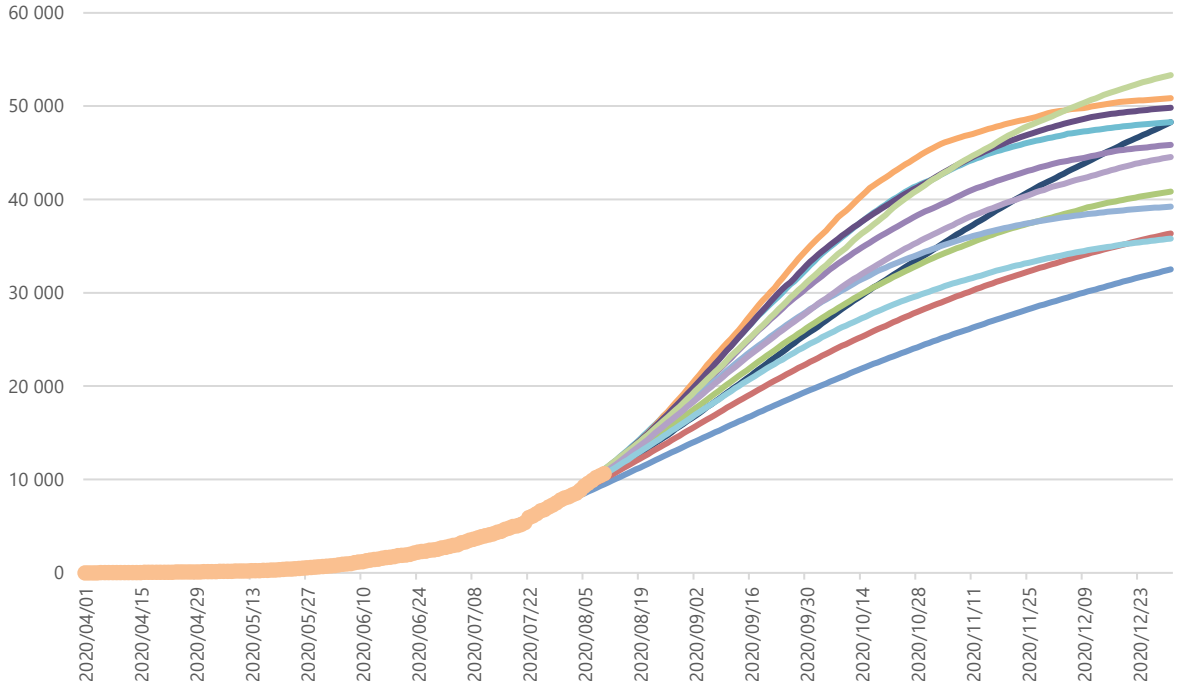
My view



My median view would be around 35,000 deaths by year end.

After the fact, we will debate for some time where the true count is, between the official count and excess mortality. I suspect the confirmed Covid fatalities to be lower than 30,000 and the excess mortality to be above 40,000

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Some closing notes

On immunity

Characterised by complexity – Drs, immunologists and virologists we spoke to had mixed views on whether T-cell confer immunity (innate or cross-reactive), or merely means lower disease severity. Antibody tests can show wide range of infections in small communities but tend to level out at lower levels across broader communities. Antibody tests have a threshold. Biology is not as black & white as the states we would like to model.

On uncertainty

There remains considerable variation between country experiences, some getting off very lightly and some severely. Some have neat distribution fitting curves and some do not.

On second waves (my view)

Countries and regions where spread is significant seem to have much lower if any second waves. There also appears to be a strong seasonal effect.

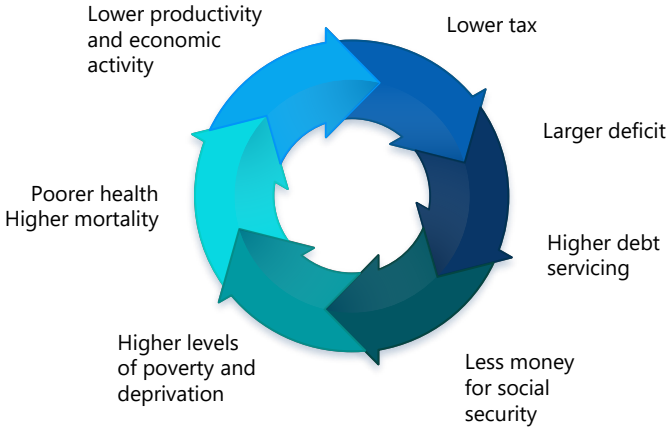
Negatively reinforcing economic cycle will require significant stimulus

Prior situation

Significant budgeted deficit
Slow GDP growth
High unemployment
Narrow tax base
High dependency on social security

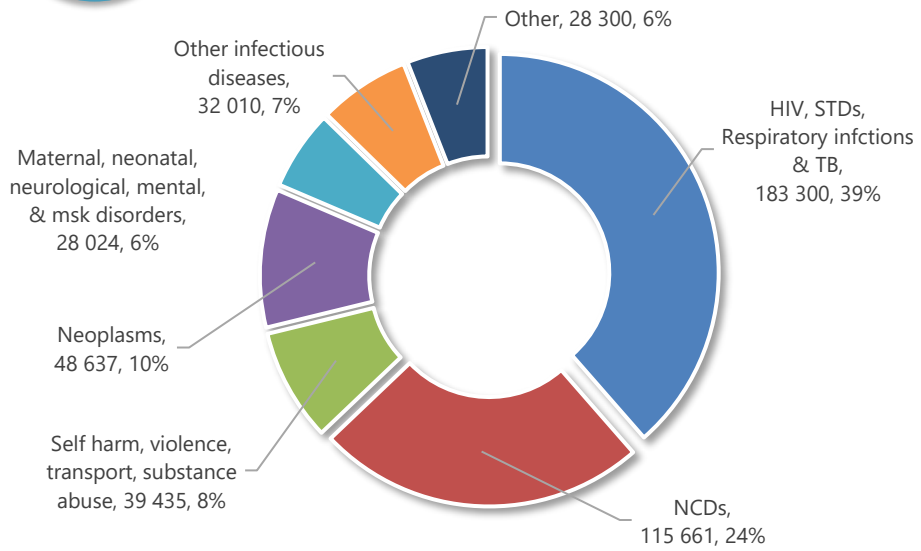
External shock

	Moderate recovery	Slow recovery
	-10% GDP	-15% GDP
	-2.8m jobs	-3.3m jobs
	-R290bn tax	-R330bn tax



Not a new problem for South Africa, but concern that the cycle is aggravated

Proportionality



2017 Deaths

Global health data exchange

~ 1,300 deaths a day

Significant concern that management of other conditions fall by the way side due to focus on Covid-19

"In high burden settings, HIV, TB and malaria related deaths over 5 years may be increased by up to 10%, 20% and 36%, respectively, compared to if there were no COVID-19 epidemic. We estimate the greatest impact on HIV to be from interruption to ART, which may occur during a period of high or extremely high health system demand; for TB, we estimate the greatest impact is from reductions in timely diagnosis and treatment of new cases, which may result from a long period of COVID-19 suppression interventions"

Report 19 - The Potential Impact of the COVID-19 Epidemic on HIV, TB and Malaria in Low- and Middle-Income Countries, Imperial college London