SPI-M-O: Summary of modelling on scenarios for easing restrictions

Date: 7th February 2021

1. This document is a summary of modelling by University of Warwick and Imperial College London. It is an update to a paper presented at SAGE on 4th February and has been signed off by SPI-M-O's chairs on behalf of the committee.

Summary

2. Four scenarios have been modelled that differ in the speed of easing restrictions from current levels to minimal measures. **All four scenarios modelled lead to a substantial resurgence in hospital admissions and deaths.**

3. The scale and timing of these resurgences are critically dependent on *very uncertain modelled assumptions*, including real world vaccine effectiveness against severe disease and infection; vaccine coverage and rollout speed; behavioural factors; and the extent to which baseline measures (which could be voluntary) continue to reduce transmission once restrictions are lifted. Given this uncertainty, **it would be inadvisable to tie changes in policy to dates instead of data.**

4. Unless vaccine efficacy is *significantly* better than assumed here, it is **highly likely that hospital occupancy would be higher than that seen in January 2021, if all restrictions are lifted by the start of May**, even under the optimistic vaccine rollout scenario modelled here of 4m doses per week from the end of March 2021.

5. As restrictions are relaxed virus transmission will increase. The more slowly restrictions are relaxed, the greater the number of hospitalisations and deaths prevented by vaccination and hence it would be less likely that restrictions would need to be reimposed later to avoid hospitals being put under extreme pressure. Rapid relaxation results in a very large wave of hospitalisations and deaths.

6. A resurgence occurs because there are still many people in vulnerable groups who do not have protection; neither directly (either because they have not been vaccinated, or because their vaccination has not prevented them from becoming infected then ill) nor indirectly from wider population immunity (because many younger age groups have not yet been vaccinated or infected).

7. **It would take several weeks after lifting one set of restrictions to determine whether it is safe to take the next step.**

8. **Maintaining baseline measures to reduce transmission once restrictions are lifted is almost certain to save many lives and minimise the threat to hospital capacity**. These could include voluntary measures as well as effective Test, Trace and Isolate.

9. Relaxation of current restrictions would be safer the lower the prevalence and hospital occupancy reached before any relaxations commence. This would give a longer time window to respond if it becomes apparent that the relaxation of measures is leading to an unsustainable rise in hospital admissions. Lower prevalence of infection will also reduce the risk of the evolution of new variants. Hospital occupancy is still very high and will remain so for a significant length of time. SPI-M-O's medium-term projection of hospital occupancy in England on 8th March is between 5,600 and 12,100[1].

Key changes since the paper of 4th February:

- The scenarios being modelled are those commissioned by Cabinet Office and cover England only (see Appendix 1 for details). Both groups assume a significant baseline reduction in transmission due to measures (voluntary or otherwise) after the Tiers system is lifted.
- Rollout assumptions are *significantly* quicker than previously modelled (a large increase from current rates to 4m doses per week from the final week in March).
- Coverage assumptions are significantly more optimistic (including 95% in over 80s).

Key assumptions

Rollout speed	Per current plan until 22nd March, then 4m per week in England		
Compliance	The same in each Tier as in Autumn		
Vaccine reduction in risk of infection		Central	Pessimistic
	First dose	48%	24%
	Second dose	60%	30%
Vaccine reduction in risk of hospital admission or death		Central	Pessimistic
	First dose	70%	56%
	Second dose	88%	70%
Coverage achieved		Central (Warwick)	Pessimistic (Warwick) Single scenario (Imperial)
	Over 80s	95%	95%
	50-80 year old	85%	85%
	Under 50s	85%	75%

10. Models assume a significant increase in vaccine rollout speed, to 4m per week in England from 22nd March. Both groups considered two scenarios (named "central" and

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[1] Interquartile range of the distribution given.

"pessimistic") for vaccine efficacy based on data from trials, and two or three scenarios for transmission under baseline measures once Tiers have been lifted. Warwick considered two scenarios for vaccine coverage. Efficacy assumptions given here are those used by Warwick; those used by Imperial were slightly different. A full set of assumptions is given in Appendix 2.

Results

11. The left-hand column of Figure 1 shows the number of hospital admissions, hospital occupancy, and deaths in each of the four scenarios from the Imperial model under the most optimistic set of assumptions (i.e. this is the best plausible outcome in terms of epidemic progression). Warwick's model shows qualitatively similar results, and are in remarkable quantitative agreement about hospital admissions, using the central estimates for vaccine efficacy[2].

12. Even with these optimistic set of assumptions, including 4m doses per week from 22nd March and the long-term retention of measures to reduce transmission, under scenario 1 (purple lines), there is another wave comparable in size to January 2021, resulting in a further 62,000 to 107,000 deaths in England[3].

13. Under the more pessimistic efficacy assumptions (right-hand column), this wave is significantly larger still, with 102,000 to 176,000 further deaths in England.

14. Taking a careful approach to relaxing NPIs is likely to save many lives. Under the central assumptions, unlocking between March and 5th July (scenario 3 – red lines) leads to approximately 10,000 fewer deaths than the same measures happening around a month more quickly (scenario 2 – blue lines).

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[2] In some scenarios, there will be some differences, particularly with more pessimistic assumptions around vaccine efficacy. This is for several reasons including: Warwick estimating that a smaller proportion of the population are already immune as a result of being infected; Warwick estimating that infection hospitalisation rates and infection fatality rates are higher; and differences in model structure. Such variation between models is normal. Both sets of assumptions are valid and fall within the range of consensus views considered by SPI-M.

[3] These estimates, and others given in this document, cover the period from 1st February 2021 to June 2022.

Figure 1: England daily hospital admissions (top row), daily deaths (middle row) and hospital bed occupancy (bottom row) with central assumptions (left column); low baseline of reduction in transmission kept in place (central column); and pessimistic efficacy assumptions (right column). Colours represent the four scenarios (purple = 1, blue= 2, red= 3, yellow =4). Assumed 4m doses per week from 22nd March, coverage of 95% (over 80s), 85% (50-80 year olds) and 75% (under 50s). From the Imperial College model.
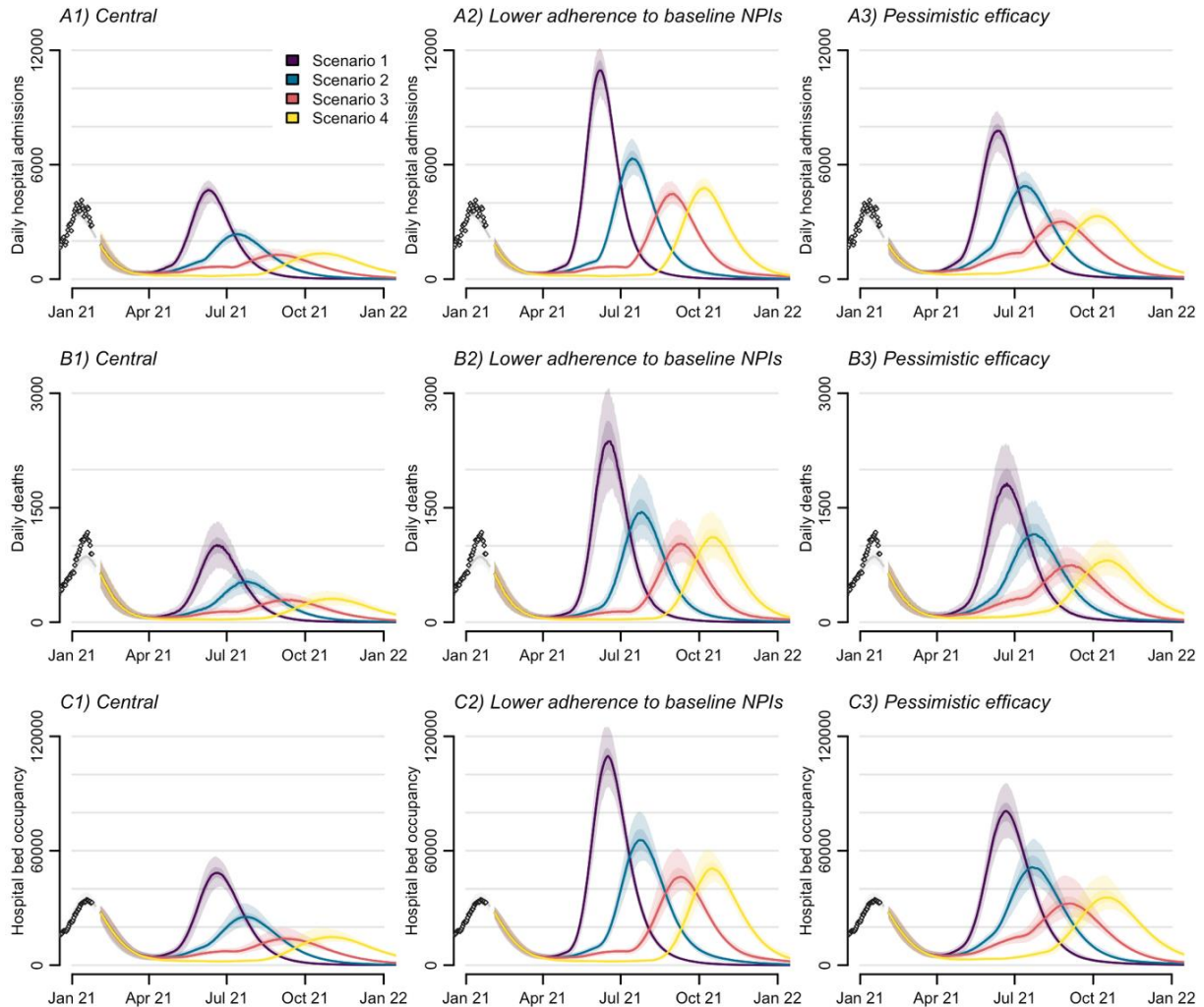
15. The resurgence is lower in the scenarios where measures are lifted more slowly (blue, red, and yellow lines). In the most optimistic set of scenarios (left-hand column), these peaks are all very high but lower than in January 2021.

16. **Under more pessimistic vaccine efficacy assumptions** (right-hand column), however, **scenario 2 (blue) exceeds the size of the January 2021 peak** and scenarios 3 and 4 approach it. Under both sets of assumptions, the height of the peaks in scenarios 3 (red) and 4 (yellow) are similar because the optimistic vaccine rollout assumptions mean a large proportion of vulnerable people in both scenarios have had two doses before leaving Tier

1[4]. **If the rollout were slower than 4m per week, scenario 3 would result in a higher number of deaths and admissions than scenario 4**.

17. Clinical trials are not sufficiently powered to fully test efficacy of vaccines against severe disease, hospitalisation, or death. To illustrate the effect of higher protection against severe disease, sensitivity analysis has been performed by the University of Warwick to show what effect 99% protection from the vaccine might have on the subsequent waves under each scenario (see Appendix 3). Even when baseline measures of NPIs are retained and assumed to lead to moderate levels of transmission in the final stage of easing, there is the potential for resurgences comparable to those seen in November 2021.

18. In the central column of scenarios in Figure 1, the more optimistic vaccine efficacy assumptions are used but, once Tiers are lifted, behaviour is closer to that seen pre-COVID-19 instead of maintaining more significant baseline measures to reduce transmission. In each scenario, **the peak is approximately twice as high when there is little transmission reduction on exiting Tiers**. Under these conditions, the numbers of further deaths range from 100,000 to 171,000 in scenario 1 to 82,000 to 134,000 in scenario 4.

19. It is impossible to precisely predict how specific policies (especially any baseline measures retained after Tiers are lifted) will change transmission. As these results show, there is *considerable uncertainty* whether scenarios 2, 3, and 4 can avoid putting hospitals under similar levels of pressure to those seen in January 2021. For that reason, **it would be inadvisable to tie changes in policy to dates instead of data.**

20. It is much less likely that restrictions would need to be reimposed if an approach were taken in which each step was followed by a careful evaluation of data before any further unlocking was allowed. **Several weeks between steps are required to determine if that change has significantly increased transmission**.

21. There is greater uncertainty about vaccine efficacy and coverage during the earlier steps of relaxation; although later steps have the potential for causing larger increases in transmission, there will be more data and understanding on the real-world impact of vaccination.

Why are the resurgences so high in these scenarios, even if 4m people per week are vaccinated from 22nd March?

22. There are still many people in vulnerable groups who do not have protection; neither directly (either because they have not been vaccinated or because their vaccination has

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[4] The peak of the resurgence in scenario 4 is slightly higher than in scenario 3 as, in the latter, a larger proportion have been infected before all measures are lifted.

not prevented them from becoming infected then ill) nor indirectly from wider population immunity (because many younger age groups have not yet been vaccinated or infected).

23. This is illustrated by Figure 2, where the green area shows the proportion of the population who have been protected against disease through vaccination (dark green) and those who have had the vaccine but who have not received protection (light green). The grey areas are unvaccinated. The coloured lines shows how R (excluding the effects of immunity) changes in each of the four scenarios.

Figure 2: Increase in mixing (measured as equivalent R in the absence of immunity, left axis) under different release strategies over time, and proportion of the population in England protected against disease through vaccination over time (dark green shading, right axis) and vaccinated (having received one dose) over time (light green shading, right axis). The grey shaded areas show the proportion of the population ineligible for vaccination (i.e. <18 years, light grey, right axis) and those who are vaccine hesitant and not taking the vaccine (dark grey, right axis).
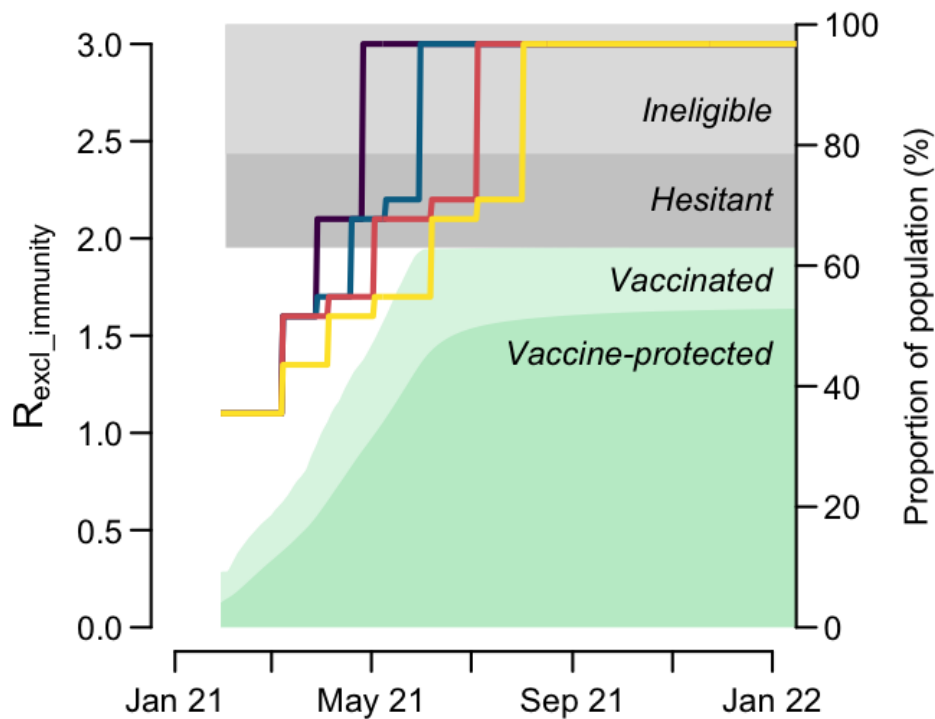
24. A large proportion of adults remain who are not directly protected by vaccination; in this case:

Proportion of adults directly protected against severe disease =
85% vaccine efficacy against severe disease x 79% final coverage = 67%

25. Only around 79% of the population are adults, which means population level protection is lower, at 53% (dark green in Figure 2). In addition, protection against infection is likely to be lower than that against disease. **As a result, herd immunity is not reached without a large resurgence of transmission**.

26. Figure 2 also demonstrates that, under the 4m per week rollout assumption, **the levels of protection are very similar in scenarios 3 and 4 at the point of exiting to Tier 1**. At this point in either scenario 3 or 4, a comparable number of people from JCVI cohorts 1 to 9 have already been protected through vaccination, thus leading to subsequent resurgences with similar magnitudes.

Efficacy versus effectiveness.

27. It is usually observed that the impact of a vaccination when applied in the community is less than that measured under trial conditions. This difference is captured in the two words efficacy (measured under trial conditions) and effectiveness (observed in communities)[5]. The central assumptions used here are from vaccine efficacy trials data and are therefore optimistic estimates for effectiveness in the community.

Implications of uneven vaccine coverage

28. These models do not account for vaccination coverage being different in different communities. Early evidence suggests that coverage has, so far, been lower in some minority ethnic groups. As a result, even if vaccination successfully drives down mortality and morbidity overall, it is highly likely that outbreaks will still happen in some communities.

Seasonality

29. The extent of any seasonal patterns in transmission (either intrinsic to SARS-CoV-2 or as a result of behavioural factors) is not yet clear and so is not included in these models. If transmission is slower in warmer months there would be potential for slightly quicker reopening than these models suggest, but a further resurgence could happen later in the year. This could be particularly acute if waning immunity becomes a factor.

Emergence of vaccine escape mutants

30. These models assume that the field efficacy of vaccines will remain high. Emergence of vaccine escape mutants would lead to decreasing efficacy. Whilst new vaccines can be developed, this will take many months.

Waning immunity

31. These models assume that neither naturally acquired nor vaccine induced immunity wane. Immunity to other coronaviruses is known to wane.

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[5] https://www.gavi.org/vaccineswork/what-difference-between-efficacy-and-effectiveness

Spatial heterogeneity

32. These models have focussed on the national average. There is the possibility of significant divergence regionally, if the epidemic grows as observed in early autumn 2020. It is possible to have, what appears to be a controlled national scenario alongside a large regional epidemic.

Appendix 1: Scenarios Modelled

	Stage 1	Stage 2	Stage 3	Stage 4	Baseline measures
	Schools open	Tier 3	Tier 2	Tier 1	Baseline measures
Scenario 1	8 March	29 March (merged)		n/a	26 April
Scenario 2	8 March	29 March	19 April	10 May	31 May
Scenario 3	8 March	5 April	3 May	7 June	5 July
Scenario 4	8 March (primary) 5 April (all)	3 May	7 June	5 July	2 Aug

Appendix 2: Model assumptions

Parameter	Imperial College			Warwick		
Vaccine reduction in risk of infection (all ages)		Central	Pessimistic		Central	Cautious
	AZ 1 dose	48%	24%	1 dose	48%	24%
	AZ 2 dose	60%	30%	2 dose	60%	30%
	PF 1 dose	48%	48%	Based on a weighted average of the two vaccines		
	PF 2 dose	60%	60%			
Vaccine reduction in risk of hospital admission or death (all ages)		Central	Pessimistic		Central	Cautious
	AZ 1 dose	70%	56%	First dose	70%	56%
	AZ 2 dose	82.4%	70%	Second dose	88%	70%
	PF 1 dose	88%	88%	Based on a weighted average of the two vaccines		
	PF 2 dose	94%	94%			
Time to full vaccine protection	2 weeks (dose 1), 1 week (dose 2)			2 weeks		
Rollout speed (England basis)	Per current plan until 22nd March, then 4m per week			Per current plan until 22nd March, then 4m per week		
Vaccine prioritisation	Per JCVI ordering			Per JCVI ordering		
Coverage achieved (all ages)	Over 80s		95%		Central	Cautious
	50-80 year old		85%	Over 80s	95%	95%
	Under 50s		75%	50-80 year old	85%	85%
	Care home residents		95%	Under 50s	85%	75%
	Care home workers		85%			
Variants	No impact of novel variants other than B.1.1.7			No impact of novel variants other than B.1.1.7		
R until easing	0.8 (as of start of February 2021)			0.79 (as of start of February 2021)		
Seasonality	None			None		
Waning immunity	None over the timescale modelled			None over the timescale modelled		
School holidays	Not modelled			Modelled		
Effect of Tiers	Estimated from data. Assumed to be the same as in Autumn with no changes in behaviour. $R_{excl\_immunity}$ is an estimate of what R would be today in the absence of any immunity			Stage 1: As today, but with mixing of school Contacts of pupils increase to 80% of pre-COVID-19 levels. Stage 2: Similar to Tier 3. Mixing equivalent to 70% of Stage 1 and 30% of Stage 4. Stage 3: Similar to Tier 2. Mixing equivalent to 30% of Stage 1 and 70% of Stage 4. Stage 4: Similar to Tier 1. Fitted to mid-September levels of control.		
Effect of long-term baseline measures to reduce transmission	Low transmission scenario: $R_{excl\_immunity} = 3$ High transmission scenario: $R_{excl\_immunity} = 4$			Low transmission scenario: $R_{excl\_immunity} \sim 3$ Medium transmission scenario: $R_{excl\_immunity} \sim 3.6$ High transmission: $R_{excl\_immunity} \sim 4$ This compares to an unmitigated R_0 (equivalent to $R_{excl\_immunity}$ with pre-COVID-19 behaviour) of around 4.5.		

Within the Effect of Tiers cell (Imperial College):

	$R_{excl\_immunity}$
Stage 1	1.6
Tier 3	1.7
Tier 2	2.1
Tier 1	2.2

Appendix 3: Extremely optimistic vaccine efficacy sensitivity analysis

Figure 3: England hospital admissions (top panel) and occupancy (bottom panel) assuming vaccine prevents 99% of all severe disease. Colours represent the four scenarios (purple = 1, blue = 2, red =3, yellow = 4) Assumed 4m doses per week from 22nd March, coverage of 95% (over 80s), 85% (50-80 year olds; and under 50s in the optimistic scenario) and 75% (under 50s in the pessimistic scenario). Levels of transmission for the final phase – low = $R_{excl\_immunity} \sim 3$; medium = $R_{excl\_immunity} \sim 3.6$; and high = $R_{excl\_immunity} \sim 4$. From the Warwick model.
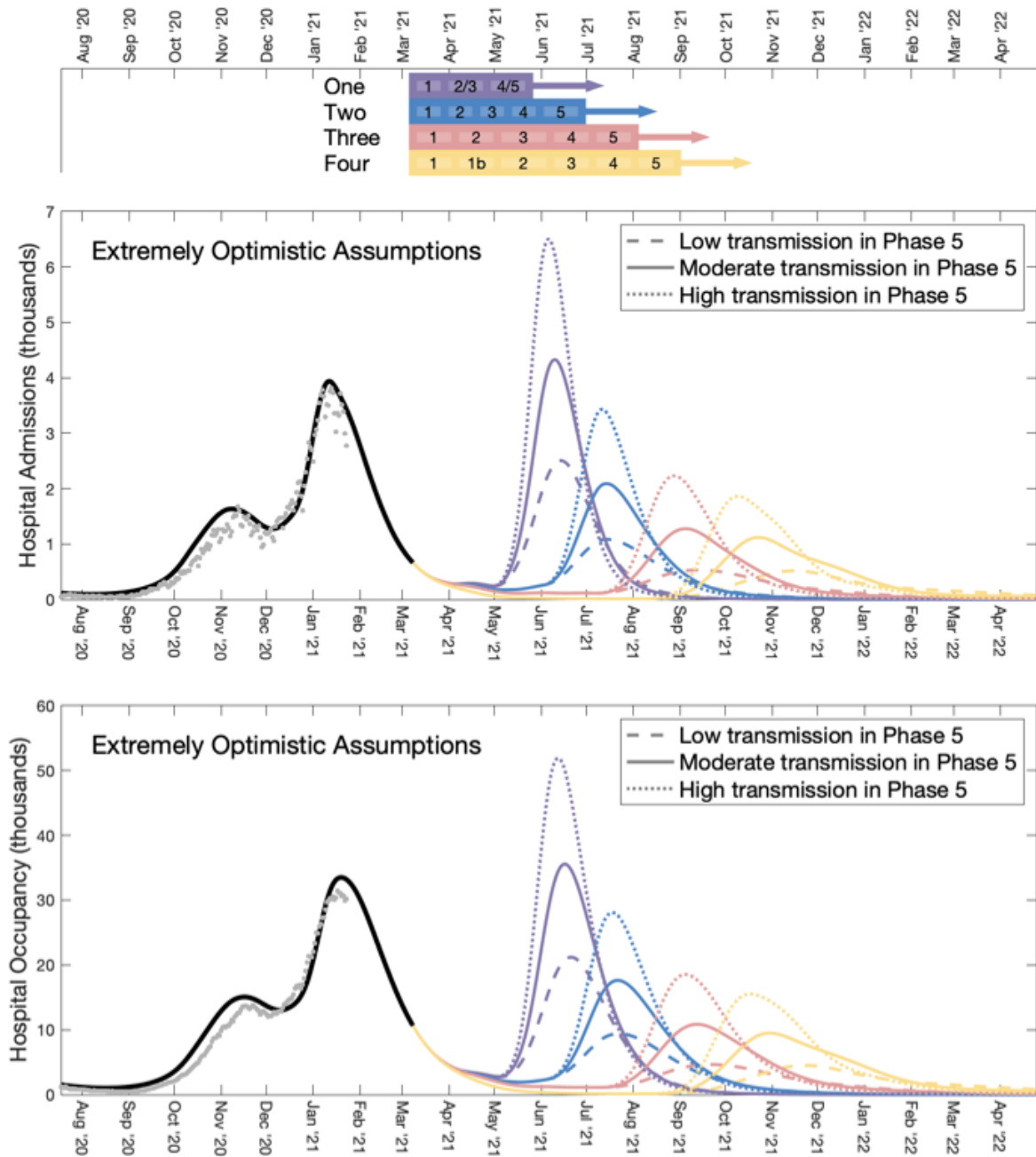
Appendix 4: Comparison of the University of Warwick's Results

Figure 4: England hospital occupancy assuming baseline measures reduce transmission remain the equivalent of Tier 1, with cautious assumptions (top panel) and optimistic assumptions (bottom panel).Colours represent the four scenarios (purple = 1, blue = 2, red = 3, yellow = 4) Assumed 4m doses per week from 22nd March, coverage of 95% (over 80s), 85% (50-80 year olds; and under 50s in the optimistic scenario) and 75% (under 50s in the pessimistic scenario). From the Warwick model.
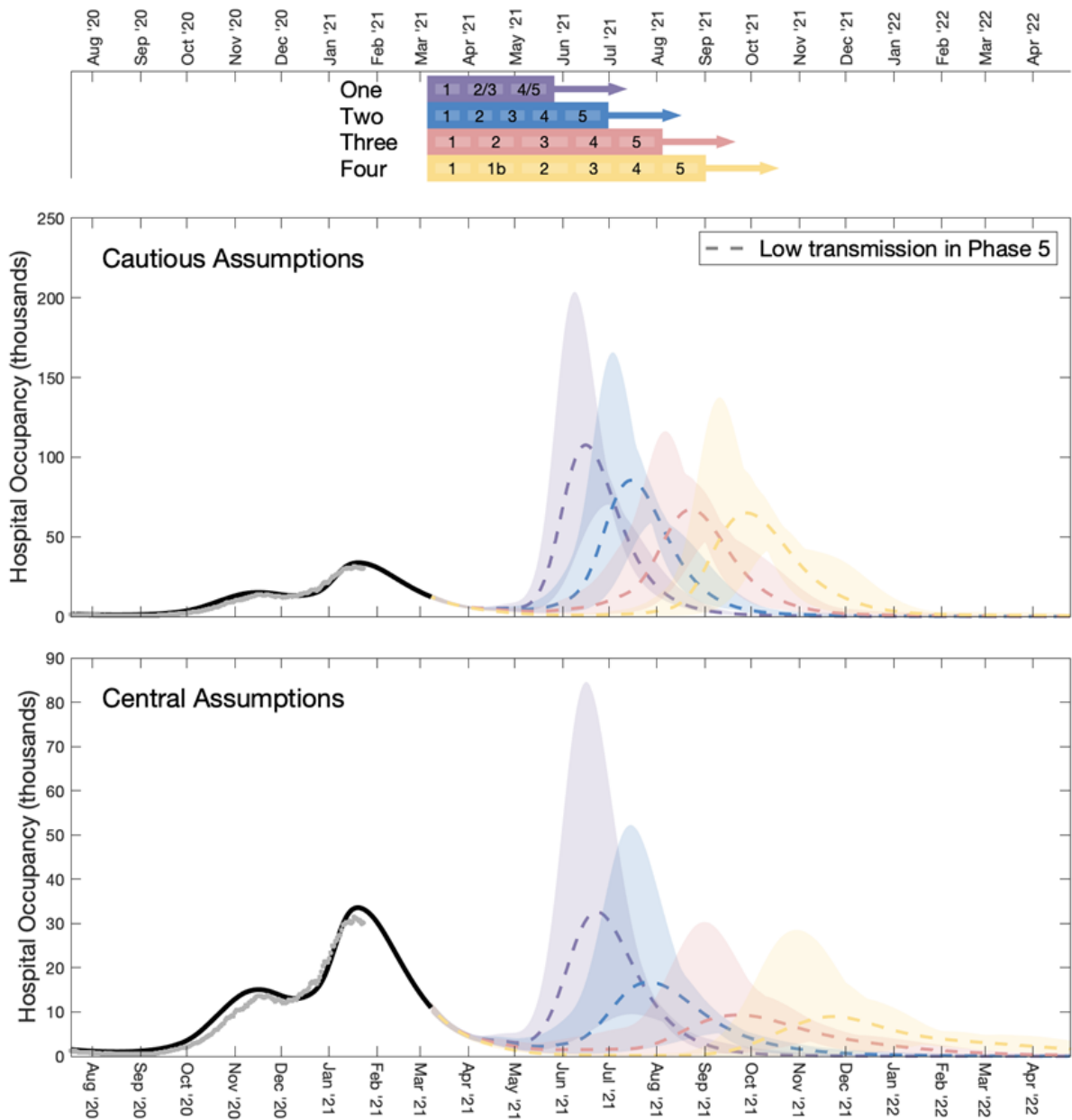
Figure 5: England hospital admissions assuming no baseline measures, with cautious assumptions (top panel) and optimistic assumptions (bottom panel).Colours represent the four scenarios (purple = 1, blue = 2, red = 3, yellow = 4) Assumed 4m doses per week from 22nd March, coverage of 95% (over 80s), 85% (50-80 year olds; and under 50s in the optimistic scenario) and 75% (under 50s in the pessimistic scenario). From the Warwick model.