

SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 4

Date: 9th June 2021

Summary

1. All modelling of taking Step 4 of the Roadmap on 21st June shows a large resurgence in infections and admissions. The scale of this resurgence is highly uncertain, and it could be either considerably smaller or larger than previous waves.
2. The key uncertainties are the growth advantage of B.1.617.2¹ (henceforth referred to as delta) compared to B.1.1.7¹ (henceforth referred to as alpha), effectiveness of vaccines against severe disease caused by the delta variant, and the extent to which behaviours and therefore transmission will change after Step 4.
3. In all scenarios modelled, even a short delay to the timing to Step 4 results in a significant drop in the number of people being admitted to hospital as more people are vaccinated and as the school summer holidays get closer. Even a two-week delay would have a significant effect, but a four-week delay is modelled as reducing the peak in hospital admissions by around a third to a half. A delay would also allow evidence to build up on the effectiveness of vaccines against delta, potentially increasing precision in future modelling scenarios.
4. Since the start of April 2021, the ratio of confirmed cases to admissions has been stable. If this continues, each doubling of cases will lead to a doubling of admissions. The number of hospital admissions that are S-gene positive (and are therefore almost certainly the delta variant) has been growing in recent weeks, however, this has been masked by a drop in those which are S-gene negative.
5. R is estimated to be 40-80% higher for delta than for alpha, although a figure higher or lower than this cannot be ruled out.
6. SPI-M-O's best estimate for R in England is between 1.2 and 1.4 and reflects the epidemiological situation approximately two weeks ago. This is substantially higher than the estimate of 1.0 to 1.1², which reflected the state of the epidemic shortly before Step 3 of the Roadmap was taken.

Key changes since the paper of 5th May:

- Models now include the delta variant, which has been seeded and become dominant in England over the past month. It is estimated that R is 40-80% higher for delta than for alpha.

¹ [The World Health Organisation recently recommended using letters of the Greek alphabet when referring to SARS-CoV-2 variants](#). Current variants of concern labelling stands as B.1.1.7 as alpha, B.1.351 as beta, P.1 as gamma, and B.1.617.2 as delta.

² R estimate for England from 26th May, published 28th May

- Evidence from Public Health England and Public Health Scotland on vaccine effectiveness against the delta variant has been incorporated. This means assumptions on vaccine-induced protection are considerably less optimistic. Preliminary estimates of a higher rate of hospitalisation of cases for the delta variant compared with the alpha variant have **not** been included in these analyses, but are considered as part of sensitivity analysis in the accompanying LSHTM paper.

Key assumptions in the central scenarios

These are for the central scenarios and relate to the delta variant. Other assumptions, including for sensitivity analyses are given in Appendix 1.

Vaccine reduction in risk of infection		AZ		Pfizer / Moderna	
		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	33%	55%	33%	85%
	LSHTM	43%	62%	47%	80%
	Warwick	34%	71%	34%	73%
Vaccine reduction in risk of onwards transmission if infected (in addition to transmission reduction from lower infection risk)		AZ		Pfizer / Moderna	
		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	33%	33%	33%	33%
	LSHTM	24%	45%	33%	56%
	Warwick	45%	45%	45%	45%
Vaccine reduction in risk of symptomatic disease		AZ		Pfizer / Moderna	
		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	33%	55%	33%	85%
	LSHTM	43%	71%	47%	84%
	Warwick	34%	82%	34%	83%
Vaccine reduction in risk of hospital admission (or severe disease)		AZ		Pfizer / Moderna	
		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	73%	85%	73%	89%
	LSHTM	69%	86%	71%	87%
	Warwick	64%	90%	64%	91%
Vaccine reduction in risk of death		AZ		Pfizer / Moderna	
		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	73%	85%	73%	89%
	LSHTM	69%	90%	71%	92%
	Warwick	60%	96%	60%	96%
Coverage achieved		Under 40-year olds	40- to 49-year olds	50- to 79-year olds	80 and over
		80%	90%	95%-99%	95%
	Imperial	80%	Per actuals	Per actuals	Per actuals
	LSHTM	80%	Per actuals	Per actuals	Per actuals
	Warwick	80%	Per actuals	Per actuals	Per actuals
Seasonality	Imperial: 20% peak (February) to trough (August) variation in transmission LSHTM: 20% peak to trough seasonality in central scenarios. Warwick: 10% peak (February) to trough (August) variation in transmission				
Transmission advantage of Delta over alpha	Imperial: Central scenarios of 50%, 65% and 80%. LSHTM: Scenarios of 30%, 50%, 70%. Warwick: Central scenario 56% (CI 34%-81%). Sensitivities for 25% to 119% transmission advantage				
Rollout speed	This is based on a scenario, provided by the Cabinet Office, that may not reflect the situation most likely to occur. An average of 2.15m doses per week in England until week commencing 25th July and 2m per week thereafter.				

A full set of assumptions is given in Appendix 1 and the respective modelling papers.

Growth advantage of the delta variant

7. Five SPI-M-O groups have continued to independently estimate the growth advantage of delta over alpha. The most recent estimates are that **R is 40-80% higher for delta, although a figure higher or lower than this cannot be ruled out.** These estimates would change if it were to become clear that the generation time (the time between primary and secondary infections) for delta is different from that of alpha.

How the delta variant could result in a large surge in admissions

8. At present, the number of COVID-19 hospital admissions remains low. They are expected, however, to rapidly increase:
 - a. Cases of delta have been doubling in the most recent weeks. This has been masked by a gradual decline in the prevalence of alpha but, as delta has come to dominate, it is now clear in the overall numbers. There is evidence of exponential growth in the epidemic in England in every age group.
 - b. This exponential growth in cases will accelerate as people have more social contact (including more riskier contacts), particularly if Step 4 is taken on 21st June. This increase will continue to quicken until either a) behaviours spontaneously change in response to the resurgence, b) policy changes or c) a build-up in immunity (acquired either through vaccination or by infection) means the epidemic starts to grow more slowly and eventually shrink.
 - c. The delta variant is highly transmissible. Whilst the precise herd immunity threshold cannot be calculated, an R_0 of 7 would require over 80% of all people (not just adults) to be immune for herd immunity to be reached and for the epidemic to begin to shrink without further measures. Younger adults play a disproportionately large role in transmission but have not yet been vaccinated.
 - d. Whilst highly effective, vaccines do not provide perfect protection against infection and so more than 80% of the population need to be either vaccinated or infected to prevent ongoing long chains of transmission. Despite the success of the vaccine rollout, without behavioural change, the growth in cases will increase for many more weeks.
 - e. The relationship between cases and hospitalisations has changed, however, it is not entirely broken. The ratio of confirmed cases to hospital admissions has been roughly stable since the start of April (Figure 1). This implies that a rapid increase in cases will lead to a rapid increase in admissions. Once the epidemic has settled to a new stable age distribution a doubling of cases will be expected to result in a doubling of admissions.

Figure 1: Hospital admissions in England per 1,000 confirmed cases 10 days earlier (data: gov.uk)



- f. Hospitalisation numbers are currently very low. As with cases two to three weeks ago, however, there has been a rapid increase in admissions with S-gene positive variants (almost certainly the delta variant). This has been masked by a decline in S-gene negative variants (Figure 2).

Figure 2 (for release): Hospital admissions in England overall (left), with detectable S-gene (centre) and with S-gene failure (right). Black line is the seven-day moving average. This analysis uses data based on admissions from emergency care; it does not include patients admitted through other routes and will therefore undercount. Patients are only counted once on a single day. S-gene data are not available for all samples. Analysis by JBC using data from NHS Digital.

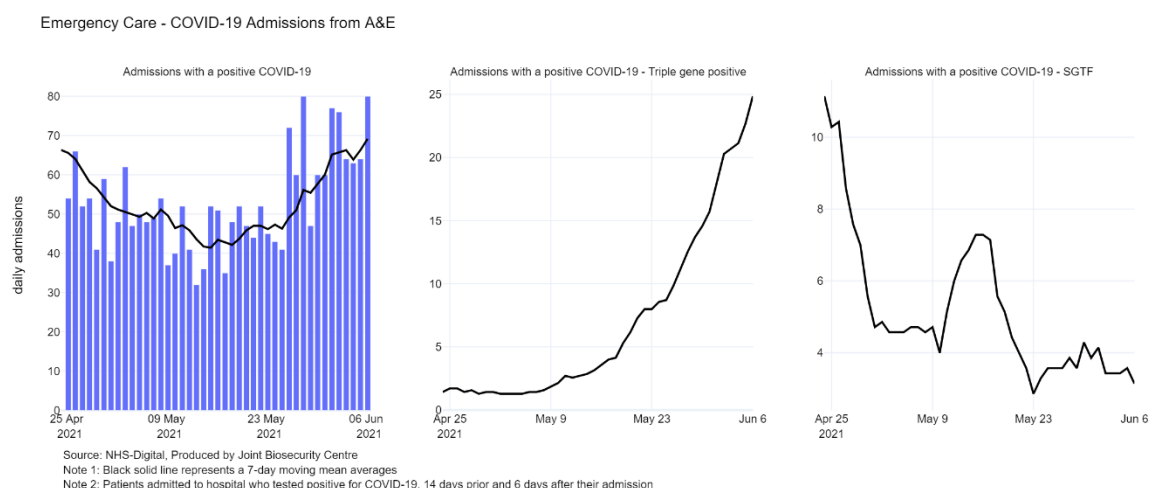
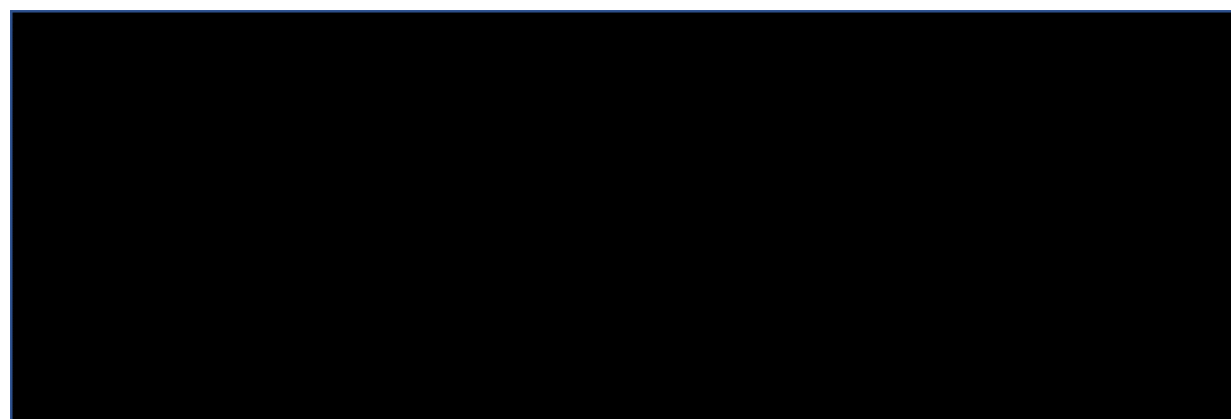


Figure 2 (redacted): Hospital admissions in England overall (left), with detectable S-gene (centre) and with S-gene failure (right). Black line is the seven-day moving average. Data in the shaded grey area are incomplete and will be revised upwards. There may be further minor revisions in the non-shaded

area to account for those with the longest hospital stay. S-gene data are not available for all samples. Analysis by JBC using data from NHS Digital.³



- g. The last 18 months have demonstrated that exponential growth does not appear to be problematic at first, but this rapidly changes. On 6th June, there were 121 hospital admissions in England. While low, this is only around five doublings from the peak in January 2021. It is highly likely that at least one doubling of admissions will occur within the next two weeks as the result of the recent doubling in cases.

Current epidemic estimates

9. SPI-M-O's best estimate for R in England is between 1.2 and 1.4 and the growth rate is between +3% and +6% per day, based on data available up to 7th June. Estimates for NHS England regions are given in Appendix 2. R is a lagging indicator, reflecting the state of the epidemic approximately two weeks ago when a smaller proportion of cases were caused by the delta variant. This estimate is significantly higher than an R of 1.0 to 1.1 (and a growth rate of 0% to +3% per day)⁴, which reflected the state of the epidemic shortly before Step 3 of the Roadmap was taken.
10. The local hotspots have coalesced into wider regional patterns. On the current trajectory, high growth areas are expected to expand further. The epidemic remains highly heterogeneous.

Medium term projections and scenarios

11. Each week, SPI-M-O combine estimates from several independent models to project the trajectory of the epidemic **if no further changes in behaviour or policy take place**. They represent what the trajectory might be if the epidemic continued to follow the trends seen in the latest available data up to 7th June. **They are neither forecasts nor predictions**

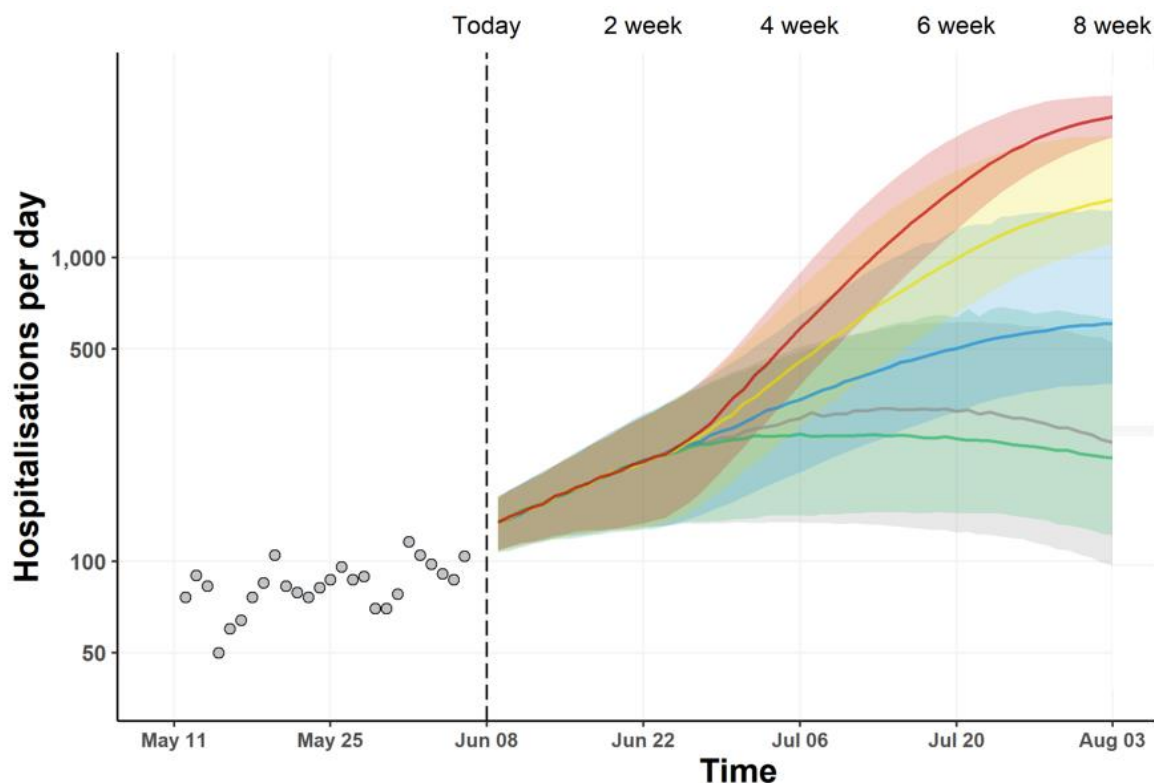
³ Footnote added for release: A redaction has been made to remove Figure 2 as originally presented to SAGE, as it contains statistically disclosive / identifiable data. An alternative Figure 2 has been provided for release that conveys a similar point.

⁴ R estimate for England from 26th May, published 28th May

and cannot fully reflect recent changes in transmission that have not yet filtered through into surveillance data. They are published separately as SPI-M-O medium-term projections.

12. Three of these same models have further been used to explore the potential impact of a range of scenarios following changes in transmission. These scenarios assume R changes to 1.2, 1.5, 1.8, or 2.1 on 21st June⁵, and run for a further six weeks. These scenarios are shown **on a logarithmic scale** in Figure 3 ($R=1.2$ – green; 1.5 – blue; 1.8 – yellow; 2.1 – red) for England's hospital admissions alongside the latest medium-term projection of current trends (grey) for comparison.
13. A doubling time in infections of around one week is consistent with growth in hospitalisations akin to the blue line ($R=1.5$) in Figure 3. Faster growth in infections will cause faster growth in hospitalisations a few weeks later.
14. Figure 3 shows that the ongoing vaccine rollout programme means that a period with R around 1.2 would result in a very small increase in hospital admissions. An increase of R to 1.5 or 1.8 would result in substantial number of hospital admissions.

Figure 3: Eight-week scenarios for daily hospital admissions in England over a range of R values (1.2 – green; 1.5 – blue; 1.8 – yellow; 2.1 – red) reflecting the possible impact of the easements from 21st June. The grey line is SPI-M-O's medium-term projection of current trends. All scenarios show interquartile ranges of model combinations as the shaded band. Note the logarithmic scale.



⁵ In each of these scenarios, R drops over time as vaccination and infection reduce the number of people who remain susceptible.

15. Similar scenarios, published in SPI-M-O's Step 3 roadmap modelling, assumed a step change in transmission happened on 17th May. In reality, in addition to a change in behaviour from that date, there were gradual increases in transmission in different parts of the country at different times as the delta variant spread. This means that hospital admissions have not yet settled down to a consistent trajectory across the country.

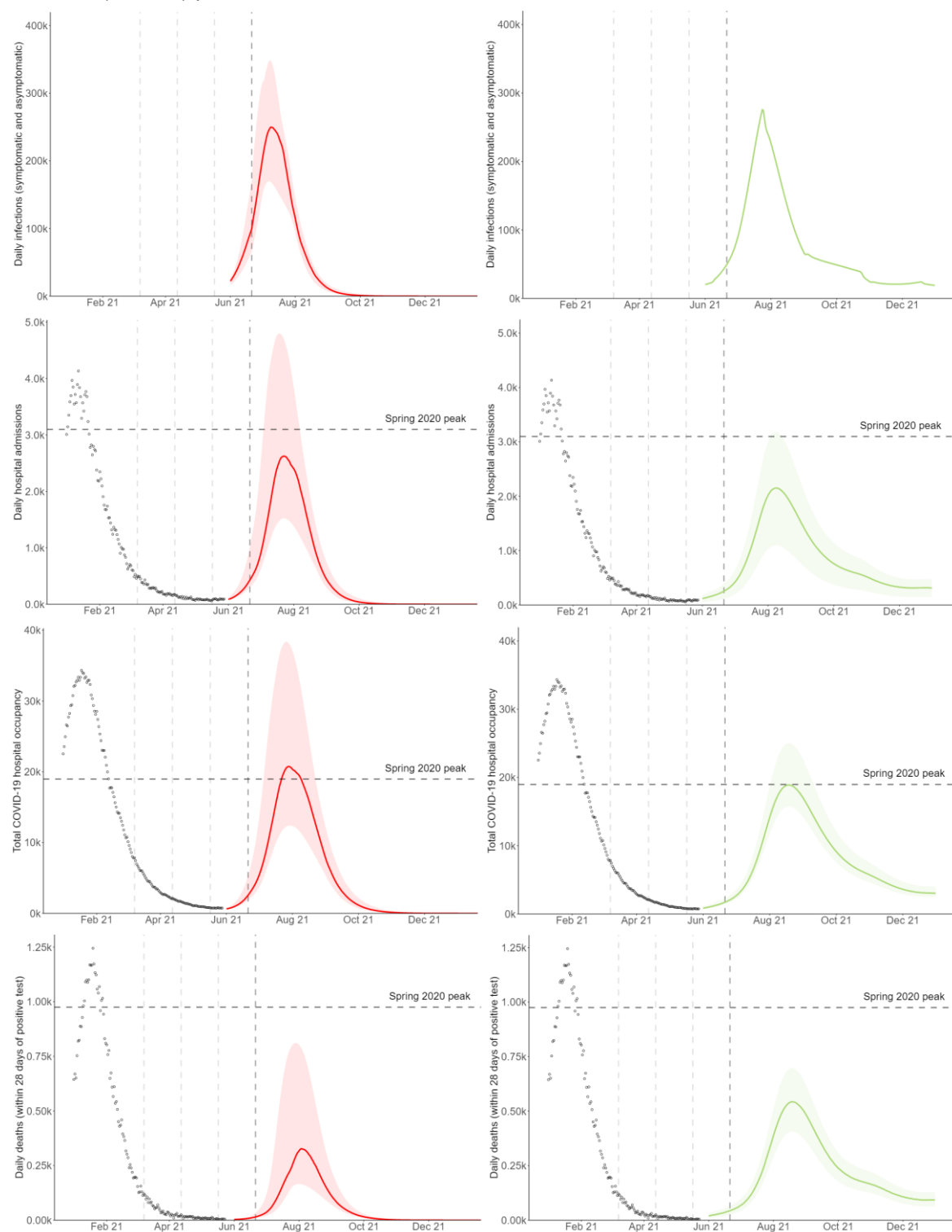
Modelling Step 4 of the Roadmap

16. SPI-M-O has considered the results from two academic groups that have independently modelled taking Step 4 of the Roadmap at the earliest possible date, 21st June. These groups have made assumptions in the central scenarios that include:
- a. Delta is the dominant strain, with increased transmissibility and decreased vaccine effectiveness compared to alpha. Increased risk of admission given infection is **not** included;
 - b. There is a step change in behaviour on 21st June, but that transmission reduction remains as a result of baseline measures and behaviour change after Step 4;
 - c. Once removed, social distancing measures are never re-imposed.
17. **All results are highly sensitive to the modelling assumptions, and extensive sensitivity analyses have been performed.** The key uncertainties are laid out in this summary; full details are given in the accompanying modelling papers.
18. Imperial's modelling is not described in detail in this paper but has results which are consistent with the other two groups. A full description is given their accompanying paper.
19. Every commissioned scenario from the two groups shows another substantial wave of hospital admissions. These waves are larger than those seen in SPI-M-O's modelling at Step 3 of the Roadmap⁶ due to the recent emergence and now dominance of the delta variant, with its increased growth advantage and decreased vaccine effectiveness compared to the alpha variant.
20. Figure 4 shows the results of the groups' **central scenarios**⁷. In all instances, the confidence intervals indicate that under **these particular sets of assumptions**, a peak in hospital admissions that is either higher or lower than that of January 2021 is plausible.

⁶ [SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 3](#); SAGE 88 5th May 2021

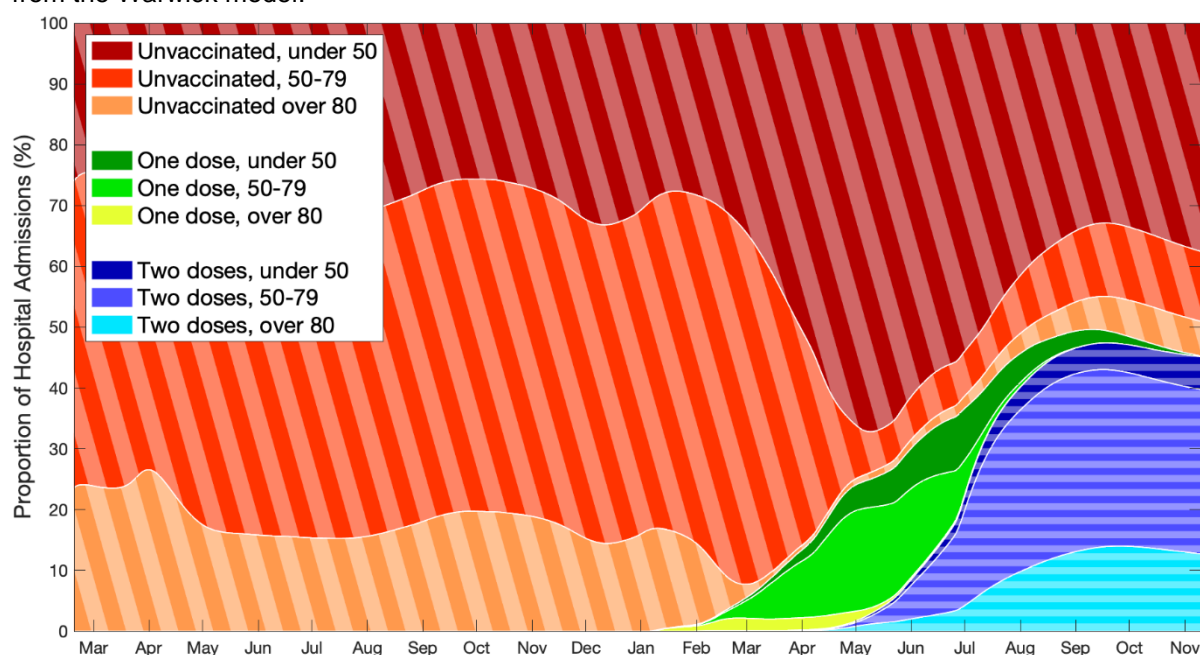
⁷ No single central scenario is provided in the accompanying LSHTM paper. The scenario relating to medium mobility, low immune escape and delta being 50% more transmissible is shown here to aid comparability across the groups.

Figure 4: England infections (top), hospital admissions (second row), hospital occupancy (third row) and deaths within 28 days of a positive test (bottom) in the Warwick (left – red) and LSHTM (right – green) models, assuming central assumptions if Step 4 is taken on 21st June including delta being 56% (Warwick) and 50% (LSHTM) more transmissible, two dose vaccine effectiveness against admission of 90-91% (Warwick) and 90% (LSHTM). Peaks in occupancy and daily deaths from January 2021 and levels seen in Spring 2020 are shown by past data points and dashed horizontal line. Vertical dashed lines show the dates at which each Roadmap step is taken. Shaded regions show the 95% (Warwick) and 90% (LSHTM) prediction/credible intervals and lines indicate the medians of the distributions.



21. There is some variation in the modelled age and vaccine status of those being admitted to hospital during the peak of the next wave. In the middle of June for each model, almost all admissions to hospital are from non- or partially vaccinated people. Models are also consistent in predicting that the proportion of admissions from vaccinated people will rise over time but disagree as to how far. This will depend on a complex mix of factors including vaccine uptake, effectiveness, and timing of the peak. Figure 5 shows the proportion of admissions split by age and vaccine status in Warwick's central scenario. LSHTM project a smaller proportion of admissions being in vaccinated people whereas Imperial project a higher proportion.
22. This is broadly in line with SPI-M-O's modelling of Step 2 of the Roadmap⁸, although in this iteration of modelling, a slightly smaller proportion of admissions are from vaccinated groups. The latest modelling assumes a slightly lower uptake in under 50-year olds than that previously modelled (then 80% to 85% in those under 30 and approx. 90% in those aged 30 to 49, now in line with doses given to date in those aged 40 to 49 and 80% in those aged 18 to 39).

Figure 5: Admissions in England, split by age group and vaccination status (unvaccinated – red with diagonal hashing; one dose – solid green; two doses – blue with horizontal hashing). Central scenario from the Warwick model.



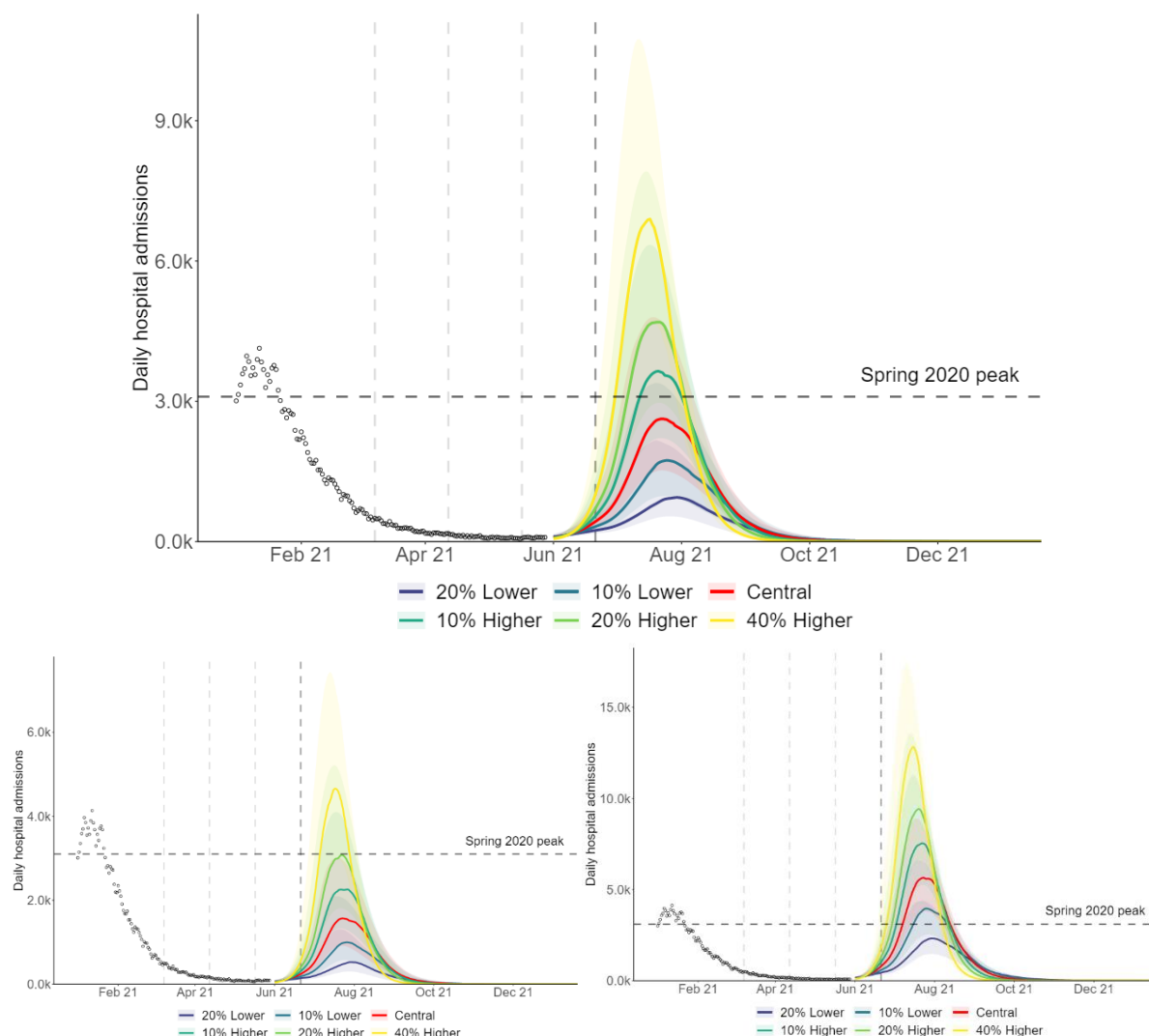
⁸ [SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 2](#); SAGE 85 31st March 2021

Sensitivity to growth advantage of, and vaccine effectiveness against the delta variant

23. As mentioned in paragraph 7, whilst information is accruing about the transmission advantage of the delta variant, a wide range of estimates remain plausible. There is also very little data available so far on the protection given by vaccines against hospital admission and death with the delta variant. SPI-M-O has previously modelled the emergence of and possible impacts of variants with different properties, showing the sensitivity of results to the assumptions used⁹.
24. Figure 6 demonstrates the sensitivity to each of these factors. The three different plots show admissions in the Warwick model with vaccine effectiveness assumptions that are central (top; 90-91% against admission after two doses), optimistic (bottom left, 95%) or cautious (bottom right, 86%). Within each plot, different colours represent a different assumption about the transmission advantage of delta, ranging from 20% lower (blue) to 40% higher (yellow) compared to the central scenario (red), where the central assumption is that delta has a 56% transmission advantage over alpha.
25. This shows that, while there is a significant resurgence in admissions in all scenarios, **the scale of that resurgence is highly uncertain and ranges from considerably smaller than January 2021 to considerably higher**. The difference between the optimistic and cautious effectiveness assumptions leads to a factor of three difference in the peak height; between 20% additional and 20% less transmission advantage leads to a factor of five difference.
26. **As results are so sensitive to these assumptions, SPI-M-O cannot determine with confidence whether taking Step 4 of the Roadmap on 21st June would result in a peak that might put unsustainable pressure on the NHS.**

⁹ [SPI-M-O: Consensus statement on COVID-19](#); SAGE 80, 11 February 2021; [SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 2](#); SAGE 85 31 March 2021; [SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 3](#); SAGE 88 5th May 2021

Figure 6: Impact of assuming various levels of transmission of the delta variant, on the number of daily hospitalisations in England for the default vaccine efficacy assumptions (top), optimistic vaccine assumptions (bottom left), and cautious vaccine assumptions (bottom right) in the Warwick model. Each line and shaded area represent transmission of delta compared to the default (red) – either 20% lower (purple), 10% lower (blue), 10% higher (dark green), 20% higher (light green), or 40% higher (yellow). Dashed line represents the peak from spring 2020 and dots represent actual data, including the January 2021 peak. Shaded regions show the 95% prediction intervals and lines indicate the medians of the distributions.



27. The epidemic is at a particularly uncertain point in time and models have struggled to reconcile the rapid growth in delta cases with what appear to be currently flat hospitalisations. This may be due to reasons outlined above in paragraph 8, however, this has made it more difficult for models to successfully fit to all data streams. Delaying Step 4 would enable more time to resolve these data interpretation issues, accrue more information on the delta variant's transmission and hospitalisation rates and observe the

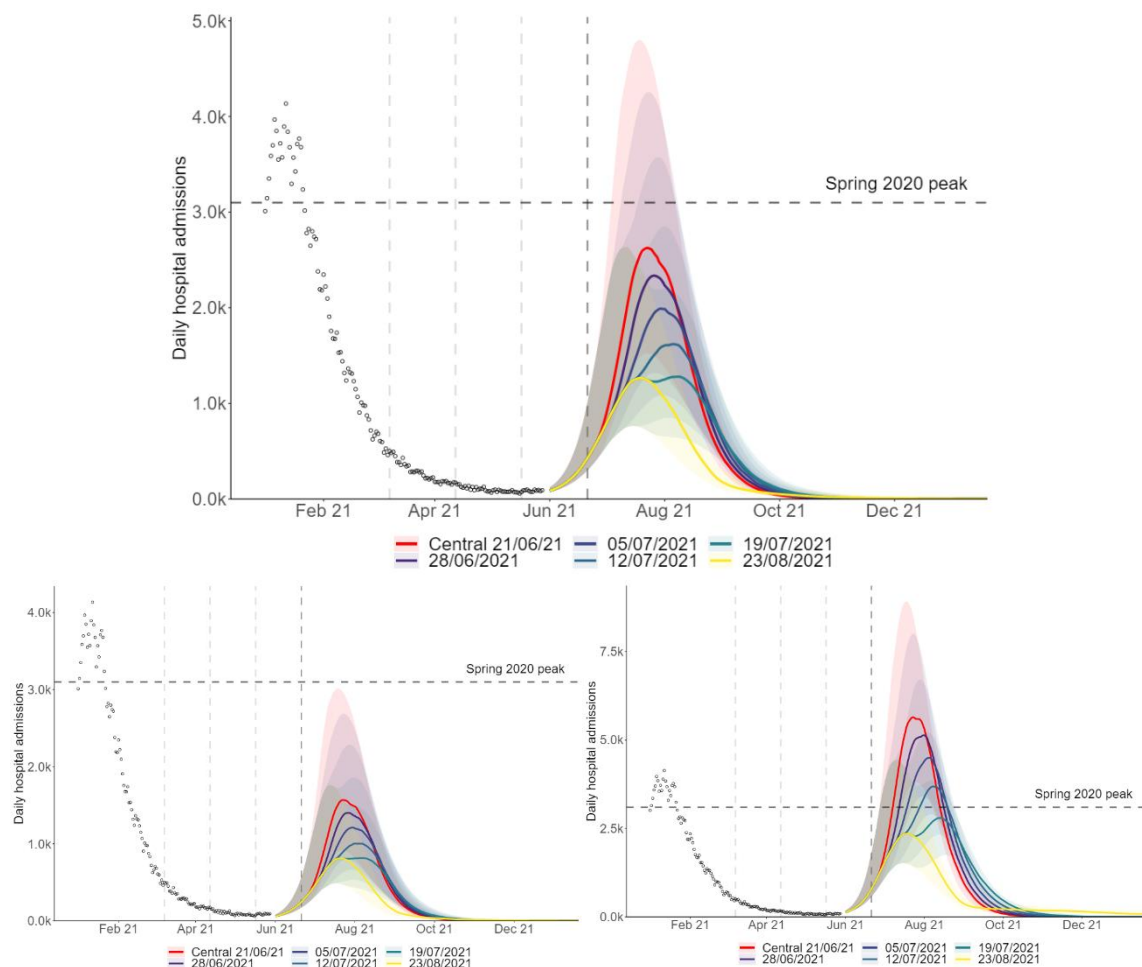
progression of the new delta variant epidemic before adding even faster transmission as a result of further relaxations.

Sensitivity to timing of taking Step 4

28. In the scenarios modelled by both groups, a short delay to the date at which Step 4 is taken significantly reduces both the height of the next peak and the total number of deaths and admissions that occur over the duration of the wave. Even a two-week delay would have a significant effect, but a four-week delay is modelled as reducing the peak in hospital admissions by around a third to a half.

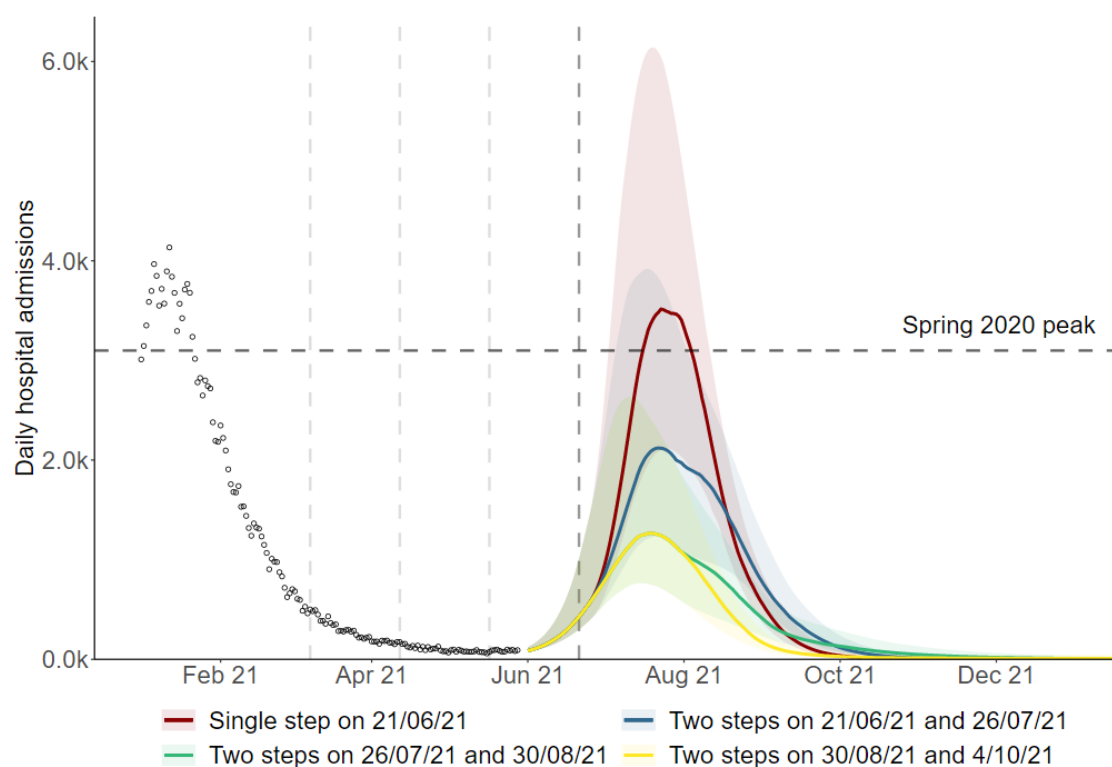
29. This is illustrated by Figure 7, showing the Warwick model with the central (top), optimistic (bottom left) and pessimistic (bottom right) vaccine effectiveness assumptions. The proportional impact is similar in each scenario, even though the scale is very different. Models assume that transmission will be significantly reduced during the school summer holidays and so a delay of four weeks that moves further relaxations into this time period has a particularly large effect.

Figure 7: Admissions in England in Warwick’s central (top), optimistic (bottom left) and cautious (bottom right) scenarios, if Step 4 is taken on 21st June (red) or with a delay of one to four weeks (purple to green lines) or a delay of nine weeks (yellow). Shaded regions show the 95% prediction intervals and lines indicate the medians of the distributions.



30. In addition to allowing many more people to be protected by vaccination (thus reducing the risk of severe outcomes and the likelihood of unsustainable pressure on hospitals), a short delay to progressing to Step 4 would allow for greater clarity about the transmission advantage of delta and the extent to which vaccines offer protection against severe disease caused by it. This would provide greater certainty about the risk of taking Step 4 before it happens.
31. In *some* of the LSHTM scenarios, lower transmission over summer and waning immunity results in a second peak in the autumn, or an extended period of a high prevalence. This, however, does not account for either revaccination or the emergence of other variants.
32. As previously modelled by SPI-M-O¹⁰, a two-stage process in which restrictions are partially lifted on 21st June before being removed slightly later can also significantly reduce the peak of the next wave. This is illustrated by Figure 8, showing a return to pre-pandemic behaviour on 21st June (red) or a two-stage process with partial relaxation on that date and a full relaxation five weeks later (blue).

Figure 8: Admissions in England in the Warwick model for default vaccine efficacy assumptions if there were a return to pre-pandemic behaviours on 21st June (dark red) or if there is a partial relaxation on that date followed by a return to pre-pandemic behaviour five weeks later (26th July, blue); a two-step relaxation with first stage on 26th July and second step five weeks later (30th August, green); or first stage on 30th August and second step five weeks later (4th October, yellow). *Please note, this single step scenario is not the same as the other central scenarios from Warwick modelling due to assuming a return to pre-pandemic levels of contacts.*

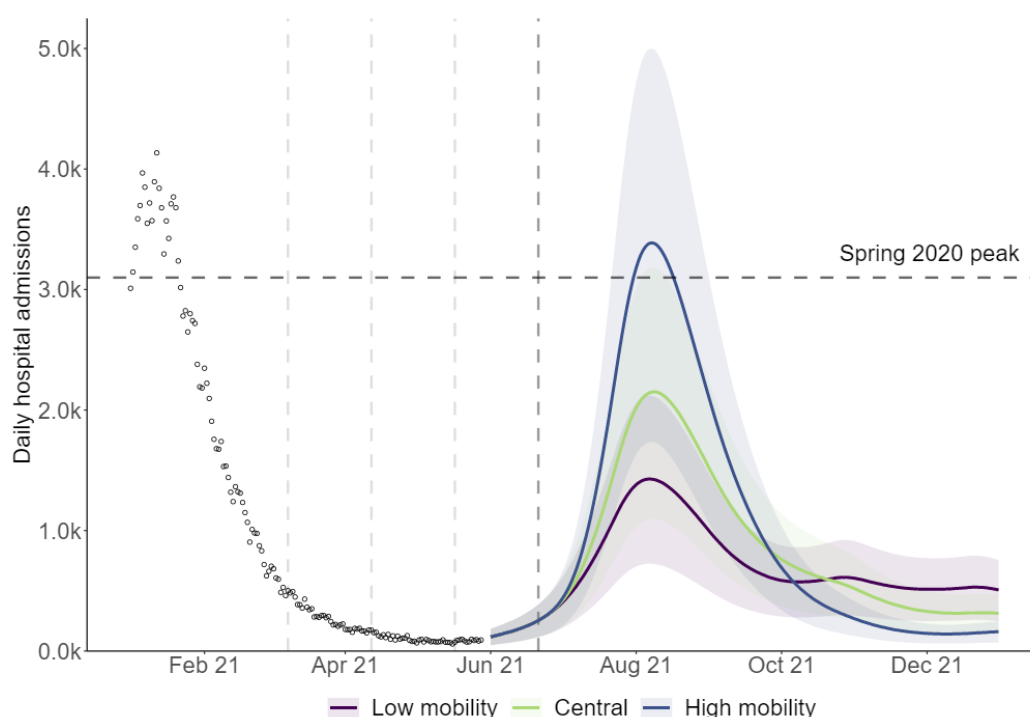


¹⁰ [SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 3](#); SAGE 88 5th May 2021

Sensitivity to transmission once all restrictions are lifted after Step 4 is taken

33. SPI-M-O have previously advised that an important unknowable factor is the extent to which behaviours will change after Step 4 compared to pre-pandemic, and how much baseline measures will reduce transmission.
34. Figure 9 shows the central scenario¹¹ in the LSHTM model with high, medium, and low transmission after Step 4, represented by high, medium or low mobility, **in addition** to a 30-40% transmission reduction from baseline measures. For this set of assumptions about the delta variant, the high mobility scenario results in a resurgence of a similar size to January 2020, but the low mobility scenario is half this size.

Figure 9: Admissions in England in LSHTM's high (blue), medium (green), and low (purple) mobility scenarios if Step 4 is taken on 21st June, assuming 50% increased transmissibility relative to alpha and two dose vaccine effectiveness against admission of 90%. Shaded regions show the 90% credible intervals and lines indicate the medians of the distributions.



Sensitivity to other factors

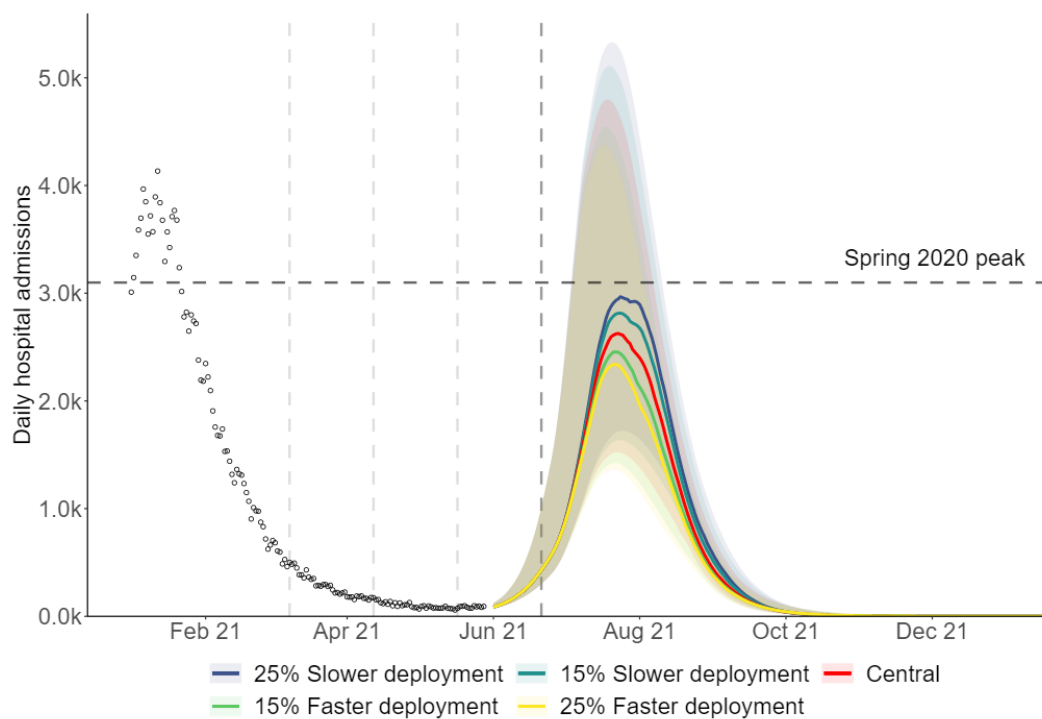
35. Other sensitivity analyses are given in the respective full modelling papers, including considering the effect of overall vaccine uptake.
36. As expected, a more rapid rollout of first vaccine doses would somewhat reduce the size of the next resurgence (Figure 10). The effect is smaller than in previous iterations of SPI-M-O modelling as first doses have been rolled out more widely, and models assumed that

¹¹ No single central scenario is provided in the accompanying LSHTM paper. The scenario relating to medium mobility, low immune escape and delta being 50% more transmissible is used for consistency with Figure 4.

the time between doses is fixed (at eight weeks for those aged 50 and over, and 11 weeks for under 50-year olds).

37. Although there are good data on the number of vaccines administered to date, estimates of the total population, and therefore the number of unvaccinated people, vary considerably. This could mean the scale of the next wave is being under- or overestimated in these scenarios for some parts of the country.

Figure 10: Admissions in England in the Warwick's central scenario with total vaccine rollout ranging from 25% faster (yellow) to 25% slower (blue). Shaded regions show the 95% prediction intervals and lines indicate the medians of the distributions.



Appendix 1: Model assumptions

Parameter values for B.1.1.7 are given in the respective modelling papers, alongside further details of the models. Given the dominance of B.1.617.2, the results are less sensitive to assumptions about B.1.1.7 than previously.

Parameter	Imperial College				LSHTM				Warwick			
Vaccine reduction in risk of infection (Delta variant)		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic
	AZ	33%	20%	45%	AZ 1 dose	43%	38%	48%	AZ 1 dose	34%	33%	45%
	1 dose				dose				AZ 2 dose	71%	58%	84%
	AZ	55%	30%	60%	AZ 2 dose	62%	60%	63%	PF/MD 1 dose	34%	30%	45%
	2 dose				dose				PF/MD 2 dose	73%	58%	84%
	PF/MD	33%	20%	40%	PF/MD 1 dose	47%	43%	52%				
	1 dose				PF/MD 2 dose	80%	79%	81%				
	PF/MD	85%	78%	86%								
	2 dose											
Vaccine reduction in risk of onward transmission if infected (Delta variant) (additional to transmission reduction due to reduced infection risk)		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic
	AZ	33%	20%	45%	AZ 1 dose	24%	22%	27%	AZ 1 dose	45%	40%	50%
	1 dose				dose				AZ 2 dose	45%	40%	50%
	AZ	33%	20%	45%	AZ 2 dose	45%	44%	46%	PF/MD 1 dose	45%	40%	50%
	2 dose				dose				PF/MD 2 dose	45%	40%	50%
	PF/MD	33%	20%	45%	PF/MD 1 dose	33%	30%	36%				
	1 dose				PF/MD 2 dose	56%	56%	57%				
	PF/MD	33%	20%	45%								
	2 dose											
Vaccine reduction in risk of symptomatic disease (Delta variant)		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic
	AZ 1 dose	33%	20%	45%	AZ 1 dose	43%	38%	48%	AZ 1 dose	34%	27%	45%
	AZ 2 dose	55%	30%	60%	AZ 2 dose	71%	69%	72%	AZ 2 dose	82%	64%	84%
	PF/MD 1 dose	33%	20%	40%	PF/MD 1 dose	47%	43%	52%	PF/MD 1 dose	34%	24%	45%
	PF/MD 2 dose	85%	78%	86%	PF/MD 2 dose	84%	83%	85%	PF/MD 2 dose	83%	64%	84%

Parameter	Imperial College				LSHTM				Warwick			
Vaccine reduction in risk of hospitalisation admission (Delta variant)		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic
	AZ 1 dose	73%	68%	78%	AZ 1 dose	69%	54%	85%	AZ 1 dose	64%	60%	85%
	AZ 2 dose	85%	77%	87%	AZ 2 dose	86%	81%	90%	AZ 2 dose	90%	86%	95%
	PF/MD 1 dose	73%	68%	76%	PF/MD 1 dose	71%	57%	85%	PF/MD 1 dose	64%	58%	85%
	PF/MD 2 dose	89%	84%	90%	PF/MD 2 dose	87%	85%	90%	PF/MD 2 dose	91%	86%	95%
Vaccine reduction in risk of death (Delta variant)		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic		Central	Pessimistic	Optimistic
	AZ 1 dose	73%	68%	78%	AZ 1 dose	69%	54%	85%	AZ 1 dose	60%	60%	80%
	AZ 2 dose	85%	77%	87%	AZ 2 dose	90%	86%	95%	AZ 2 dose	96%	93%	99%
	PF/MD 1 dose	73%	68%	76%	PF/MD 1 dose	71%	57%	85%	PF/MD 1 dose	60%	58%	80%
	PF/MD 2 dose	89%	84%	90%	PF/MD 2 dose	92%	89%	95%	PF/MD 2 dose	96%	93%	99%
Rollout speed (England basis)	Per Cabinet Office scenario: An average of 2.15m doses per week in England until week commencing 25 th July and 2m per week thereafter. Sensitivities of 15% and 25% faster and slower rollout are explored by Warwick. 8 weeks between doses for over 50s and 11-week period between doses for under 50s (LSHTM and Warwick); 11-week period between doses (Imperial).											
Time to full vaccine protection	3 weeks (dose 1); 1 week (dose 2)				4 weeks (dose 1); 2 weeks (dose 2)				2 weeks (dose 1); 2 weeks (dose 2)			
Coverage achieved (all ages)	80 and over	Central			40+	Central			40+	Central		
	50-79	95%				Per actuals (ONS 2018 population estimates)				Per actuals (ONS 2019 population estimates)		
	40-49	95%-99%			18-39	80%			18-39	80%		
	<40	90%										
	Care home residents	80%										
	Care home workers	95%										
		86%										

Parameter	Imperial College	LSHTM	Warwick																				
R excluding the effect of immunity after step 4 of easing	<p>In terms of B.1.1.7 R excl. immunity: With schools open:</p> <ul style="list-style-type: none"> (central; higher impact from measures): 3.0 (95% CI 2.33 to 3.8) (lower impact from measures): 4.5 (95% CI 3.81 to 5.28) <p>With schools closed:</p> <ul style="list-style-type: none"> (central; higher impact from measures): 2.7 (95% CI 2.04 to 3.51) (lower impact from measures): 4.2 (95% CI 3.51 to 4.98) <p>B.1.617.2 assumed to have between 1.5-fold and 2-fold increase in R excluding the effect of immunity over B.1.1.7.</p>	<p>30-40% reduction in R from baseline measures plus additional reduction using mobility data (relative to baseline mobility in early 2020, pre-epidemic)</p> <table> <tr> <th></th><th>Low</th><th>Medium</th><th>High</th></tr> <tr> <td>Grocery and pharmacy</td><td>105%</td><td>105%</td><td>105%</td></tr> <tr> <td>Retail and recreation</td><td>Aug 2020</td><td>95%</td><td>105%</td></tr> <tr> <td>Transit</td><td>Sept 2020</td><td>80%</td><td>90%</td></tr> <tr> <td>Workplace</td><td>80%</td><td>85%</td><td>90%</td></tr> </table> <p>R (excluding immunity) reduced by 0.2 to 0.3 during school holidays in all scenarios.</p>		Low	Medium	High	Grocery and pharmacy	105%	105%	105%	Retail and recreation	Aug 2020	95%	105%	Transit	Sept 2020	80%	90%	Workplace	80%	85%	90%	<p>Central: 5.66 (95% CI 5.4 to 5.95)</p> <p>Additional sensitivities for transmission reduction from baseline controls after Step 4 considered, ranging from R excl. immunity = 3.51 to 6.68.</p> <p>School holidays modelled by changing the mixing patterns for school-aged children.</p>
	Low	Medium	High																				
Grocery and pharmacy	105%	105%	105%																				
Retail and recreation	Aug 2020	95%	105%																				
Transit	Sept 2020	80%	90%																				
Workplace	80%	85%	90%																				
Transmission advantage of Delta over Alpha	<p>Scenarios of 50%, 65% and 80% transmission advantage over alpha (central immune escape/vaccine effectiveness).</p> <p>Additional sensitivities of 50%, 70% and 90% (low escape) and 40%, 55% and 70% (high escape).</p>	<p>Scenarios of 30%, 50% and 70% transmission advantage over alpha.</p>	<p>Central scenario 56% (CI 34%-81%) transmission advantage over alpha.</p> <p>Sensitivities for 20% or 10% lower, and 10%, 20% or 40% higher advantage <i>relative to the central scenario</i> of 56% - corresponding to between 25% and 119% transmission advantage.</p>																				
Seasonality	<p>20% peak (February) to trough (August) in central scenario.</p>	<p>20% peak to trough seasonality in central scenarios.</p>	<p>10% peak (February) to trough (August) in central scenario. Other scenarios included in accompanying paper</p>																				
Waning immunity	<p>Exponential decay in infection-induced immunity with an average of 3 years</p>	<p>Waning of natural and vaccine-induced immunity by 15% over six months. Sensitivity analysis with no waning also included.</p>	<p>None over the timescale modelled</p>																				

Appendix 2: Regional estimates of R and growth rates

Table 1: Combined estimates of R values and growth rates in England, and NHS England regions (90% confidence interval)¹². These estimates represent the transmission of COVID-19 two to three weeks ago, due to the time delay between someone being infected, developing symptoms, and needing healthcare.

Nation	R	Growth rate per day	Doubling time ¹³
England	1.2 to 1.4	+3% to +6%	13 to 21 days
NHS England region	R	Growth rate per day	Doubling time
East of England	1.1 to 1.4	+2% to +6%	12 to 26 days
London	1.1 to 1.4	+2% to +6%	12 to 26 days
Midlands	1.1 to 1.3	+1% to +5%	Flat to 15 days
North East and Yorkshire	1.0 to 1.2	0% to +4%	Flat to 21 days
North West	1.3 to 1.5	+4% to +8%	9 to 14 days
South East	1.1 to 1.4	+1% to +6%	Flat to 12 days
South West ¹⁴	1.0 to 1.3	0% to +6%	Flat to 13 days

Appendix 3: Regional estimates of R and growth rates

Full details of the Roadmap for England are available¹⁵. A summary is given here.

Step 1a: 8th March

- Schools and colleges return
- Higher education on practical courses return
- Recreation and exercise outdoors with household or support bubble, or with one person from outside their household
- Care home residents allowed one regular visitor

Step 1b: 29th March

- Outdoor sport and leisure facilities
- Rule of 6 or two households outside

Step 2: 12th April

- Non-essential retail
- Personal care
- Indoor leisure facilities
- Outdoor attractions
- Outdoor hospitality

Step 3: 17th May

- Indoor hospitality, entertainment and leisure
- 30-person limit outside
- Rule of 6 or two households advised inside
- Return to face-to-face teaching for all higher education
- Large events (outdoor 50% capacity, limit 4,000; indoor 50% capacity, limit 1,000)

Step 4: Not earlier than 21st June

Full unlock with long-term mitigations and guidance

¹² The estimated intervals for R and growth rate may not exactly correspond to each other due to the submission of different independent estimates and rounding in presentation.

¹³ Footnote added for release: Figures amended for rounding; previously England 12 to 20 and London 11 to 26.

¹⁴ Particular care should be taken when interpreting these estimates as they are based on low numbers of cases, hospitalisations, or deaths and / or are dominated by clustered outbreaks and so should not be treated as robust enough to inform policy decisions alone.

¹⁵ Further details can also be found at [COVID-19 Response – Spring 2021 \(Summary\)](#)