Strategies for gradually lifting NPIs in parallel to COVID-19 vaccine roll-out in the UK

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Commission

The following assumptions and scenarios specified by SPI-M were used for the main/central analysis:

1. **Transmissibility**: Find the level of population mixing/contact that results in:
   - R = 0.8 and
   - R = 1.1

   in February then apply that mixing until the number of UK hospital beds occupied by COVID-19 patients falls below 10,000.

   Then consider a range of scenarios in which mixing is increased (not tied to specific policies and at your own choice) over a) 3; b) 6; and c) 9 months until 75% of current NPIs have been lifted**.** We would expect that some of these result scenarios in hospital occupancy staying low and others would not.

   Note that we interpreted the above values of R as R in the presence of immunity (R_{eff}), and we have translated them into R in the absence of immunity $R_{\_excl\_immunity}$), using estimates of current immunity levels as below:

R_{eff}	$R_{\_excl\_immunity}$
0.8	1.2
1.1	1.6

   We then fix the "level of mixing" going forward by fixing $R_{\_excl\_immunity}$.

2. **Vaccine efficacy** (assuming an 80% AZ and 20% Pfizer mix): for the main analysis assume protection against risk of:
   a. Being **symptomatically infected,** we refer to this as clinical efficacy (e_{clin}) by:
      i. 88% for PF and 70% for AZ after dose 1; and
      ii. 94% for PZ and 88% for AZ after dose 2.
   b. Being **infected** (e_{inf}) by (we have used the below value for post-dose 1 efficacy similar to the previous SPI-M commissions rather than values suggested for this commission):
      i. 48% for both PF and AZ after dose 1; and
      ii. 60% for both PF and AZ after dose 2.
3. **Vaccine coverage**: We have used 85% after dose 1 and 75% after dose 2 in all groups as in previous SPI-M asks (rather than the suggested 80% or 90% coverage in JCVI groups 1-9, with 70% in others).
4. **Vaccine roll out**: an average of 2.2 million doses per week until mid-February and then 2.5 million doses per week thereafter.

Summary

- A substantial number of hospitalisations and deaths are predicted across all scenarios explored. This is particularly worrying given that in all scenarios considered, NPIs only up to 75% of current restrictions are lifted.
- In order to reduce and keep hospital occupancy as low as possible, it is critical to ensure that R_{eff} is reduced as low as possible (and below 1) before any restrictions can be eased. This should be closely monitored in the coming weeks.
- Assuming R_{eff}<1 currently, if NPIs are released on a 3-month time frame after the number of COVID-19 cases in hospital falls below 10,000 in the UK, this will then lead to a third wave of hospitalisations that breaches the 10,000 occupancy threshold nationally.
- NPIs *must* be relaxed incrementally and as cautiously as possible to prevent a large third wave. Even once R_{eff}<1 is achieved, relaxation of 75% of current restrictions over (Figure 3A and 3B):
    - 3 months (April to beginning July 2021) will lead to a third wave of hospitalisations that far exceeds the current peak occupancy across all scenarios.
    - 6 months (April to beginning November 2021) will lead to a third wave of hospitalisations with a broadly similar peak occupancy to the current wave assuming baseline transmissibility returns to high levels due to the variant of concern (Figure 3B).
    - 9 months (April 2021 to beginning January 2022) will lead to a smaller third wave of hospitalisations which will be at or above the indicative 10,000 patient threshold if baseline transmissibility is similar to the wild-type (optimistic) or the variant of concern (more likely).
- It is important to note that the speed of vaccine roll-out was fixed across all scenarios explored here (Table 1). Under the current assumed roll-out, it will take until December 2021 for 85% of the eligible population to be vaccinated with the first dose.
- *Our results show that it is critical to achieve higher uptake (>85% for dose 1 and >75% for dose 2) and faster roll-out of vaccination to the population (more than 2.2 – 2.5M doses per week) in order to be able to substantially lift NPIs before the end of 2021 while preventing a substantial third wave of hospitalisations and deaths.*
- If the recent findings of high post-dose 1 efficacy of the AZ vaccine hold true, we may expect a higher efficacy than our central assumption explored in the main analysis. Figure S4 shows how higher efficacy against infection or disease will further reduce hospitalisations and deaths as expected.
- Waiting to start lifting NPIs until a higher proportion of the population is vaccinated leads to much better outcomes in terms of hospitalisations and deaths.
- These results assume that infection and vaccine-induced immunity is life-long, does not wane, and that 31% of the UK population is currently immune due to prior infection.

Caveats and Key assumptions

- *Our results are directly dependant on the assumptions regarding vaccine efficacy.*
- Note that the reduction in the risk of being symptomatically infected (e_{clin}) is determined by both the reduction in the risk of being infected (e_{inf}) and the reduction in the risk of becoming symptomatic if infected (e_{sympt}) as follows:

  $e_{clin} = e_{inf} + (1 - e_{inf}) * e_{sympt}$

  We therefore calculated e_{sympt} as:

  $\mathbf{e_{sympt} = (e_{clin} - e_{inf}) / (1 - e_{inf})}$

- In a small number of the proposed sensitivity analyses, some combinations of parameters were not compatible (as e_{inf} must be <= e_{clin}). In those cases, we adjusted e_{inf} downwards so that $e_{clin} = e_{inf}$.
- Degree-type protection from vaccination: all vaccinees have their likelihood of acquiring infection reduced by a factor of (*1 – vaccine efficacy*). We do not model any potential additional effect on protection from severe disease or death.
- We do not model differential infectivity of susceptibility by age.
- We do not model the impact of seasonality which may have a potential impact on transmission (increased in winter, decreased in summer).
- We do not model health care workers, social workers and individuals at risk who may be prioritised for vaccination.
- We assume no dynamic replenishment of the care-home population.
- No loss of infection-induced or vaccine-induced immunity on the time horizon of the analysis.
- We assume the uptake is the same in all age groups and in care home workers and care home residents, at 85%. To mimic a potential decrease of uptake for second dose from 85% to 75%, efficacy of the second dose was adjusted downwards.
- We assume there is no correlation between vaccine uptake and population who may be more at risk of severe infections such as BAME communities. If uptake were to be lower in these groups (e.g. ethnic groups) who are also at higher risk of severe disease, our results would be too optimistic in terms of hospitalisations and deaths.
- The gradual lifting of NPIs have been modelled as a step-wise increase in R. We have not considered any potential corresponding policy changes that could reflect these changes such as reopening schools or non-essential retail.
- The scenarios modelled here only consider lifting up to 75% of current NPIs.
- When quantifying hospital capacity thresholds, this analysis is done at the national level and region-specific capacity is not considered. Moreover, we note that given the physical and mental burden on frontline workers, assuming a constantly high bed capacity threshold for a prolonged period of time is in itself optimistic.

Conditions in the commission that were not/could not be modelled:

- Efficacy against infection (e_{inf}) was assumed to be 48% for both PF and AZ after dose 1 and 60% after dose 2 rather than the specification of the commission ("scenarios of 30% and 70% reduction in risk of infection from vaccines after 1 dose and staying the same after 2 doses").

- We did not model differing vaccine uptake by age (e.g 80% dose 1 and 90% dose 2 amongst the 50+ years and 70% uptake in the <50 years).
- Step changes in transmissibility or the gradual lifting of NPIs was done in 7-day time steps (rather than discrete monthly steps as specified in the commission).

Methods

We used a stochastic compartmental model of SARS-CoV-2 transmission fitted to multiple data streams from each NHS region in the UK. The model is stratified into 17 five-year age groups (0-4, 5-9, …, 75-79, 80+), a group of care home residents (CHR) and a group of care home workers (CHW). The model has been described in detail elsewhere (https://www.medrxiv.org/content/10.1101/2021.01.11.21249564v1). The model was extended to include vaccination where each compartment in the model is further stratified to account for vaccination status. We used parameter values calibrated to data from the 29th January 2021. Note that the model was fitted with vaccination as reported since December (unlike previous iterations where we simulated a "catch up" vaccination at the start of the model simulation).

Table 1 details the scenarios explored with respect to doses administered per week and vaccine efficacy.

Table 1: Vaccination roll-out scenarios. In all scenarios, we assume vaccine roll-out of 1st doses as reported in data received from PHE and DHSC via SPI-M up to 29 Jan 2021 in the UK.*

Roll-out scenario	**Total doses per week**	**Efficacy (first / second dose)**
Central	• First doses as reported up to 29 Jan 2021 • Average of 2.2M per week until mid-February and then 2.5M per week thereafter	Against being symptomatically infected (e_{clin}) *Pfizer* = 88% / 94% *Astra-Zeneca* = 70% / 88% Against being infected (e_{inf}) 48% / 60%

**if the latest vaccination dose data were not available, we assumed that the mean number of doses over the previous 7-day period were administered each day.*

1st dose vaccine roll-out

We assume first doses were delivered in the UK between 8th December 2020 and 29th January 2021 as reported in data received from PHE and DHSC via SPI-M. We then assume a vaccine dose roll out as in Table 1. To account for second doses, we assumed that the number of available first doses on a given day is given by the total available doses on that day and subtract the number of first doses administered 84 days (12 weeks) prior. If the resulting value was negative, this was set to 0. From 30th January onwards, we assumed first doses are split between NHS regions in proportion of their population size. We assumed a mixture of 20% of Pfizer and 80% of AstraZeneca vaccine doses are distributed, with no difference between age groups or care home workers and residents being modelled.

We assume doses are distributed in priority order to:

1. Care home workers and residents
2. Individuals 50 or over by decreasing 5-year age band priority
3. Individuals under 50

Children under 18 years are not vaccinated. As our model is stratified using 5-year age classes, we model the vaccination of individuals aged 18-19 by assuming the uptake in the 15-19 age group is 2/5 of the uptake in other groups under 50 years old.

2nd dose vaccine roll out and vaccine efficacy after each dose

For each compartment in the model, 4 successive vaccination stages (duration of each stage and efficacy of vaccine in each stage are shown on Figure 1):

- Unvaccinated
- Vaccinated with 1st dose before onset of vaccine efficacy
- Vaccinated with 1st dose with full efficacy from 1st dose – this includes individuals having received the second dose before the onset of efficacy of the second dose
- Vaccinated with 2nd dose with full efficacy from 2nd dose

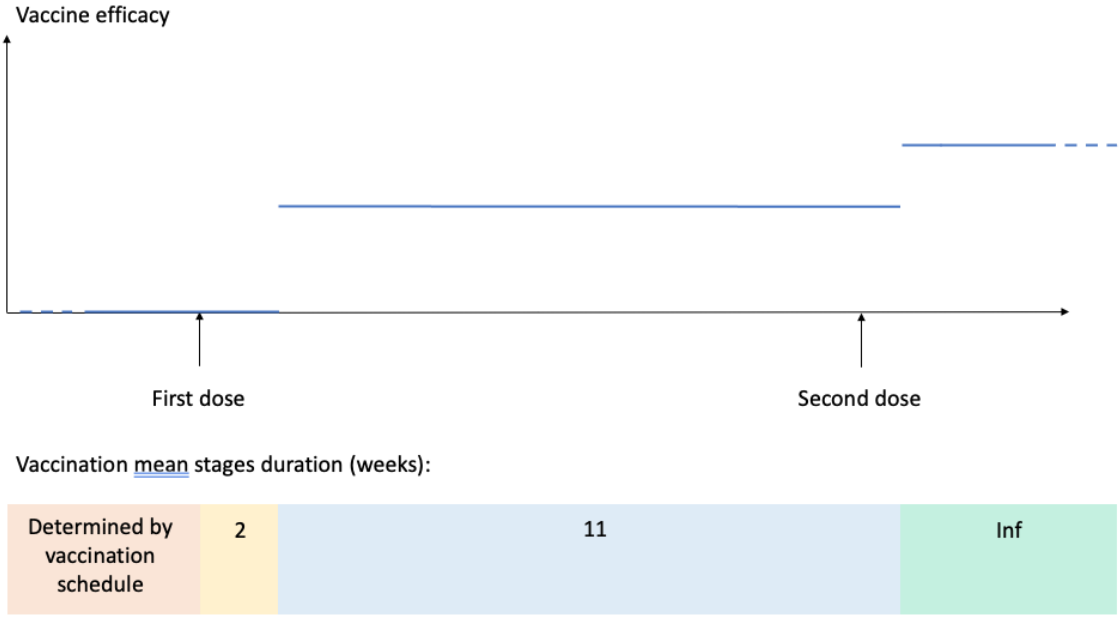

Figure 1: Vaccination stage duration and associated vaccine efficacy. The lower panel depicts mean duration of vaccination stages in weeks (numbers denote number of weeks in each stage). The top panel shows the associated vaccine efficacy and delays to protection over time.

Vaccine efficacy after first and second dose was varied across scenarios (see below and Table 1) but we assume:

- No efficacy in the 14 days following the first dose
- No efficacy of the second dose for the 7 days following dose 2

Phase 2 PF and AZ vaccine trial results indicated substantial increase in immunogenicity only after 14 days post-dose 1, and 7-days post-dose 2[1,2]. We therefore assumed a 14-day

[1] Mulligan et al. (2020). https://www.nature.com/articles/s41586-020-2639-4
[2] Ramasamy et al. (2020). https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)32466-1/fulltext

(respectively 7-day) delay between receiving the first (respectively second) dose and the onset of dose-specific efficacy.

Vaccine efficacy

Against being symptomatically infected (e_{clin})

Efficacy against being symptomatically infected (defined as the relative reduction in the probability that a vaccinated individual becomes symptomatic if infected, compared to an unvaccinated) was assumed to be:

- First dose efficacy: 88% for PF and 70% for AZ
- Second dose efficacy: 94% for PF and 88% for AZ

with no heterogeneity by age.

Against being infected (e_{inf})

Efficacy against being infected (defined as the relative reduction in the probability of becoming infected when exposed of a vaccinated individual, compared to an unvaccinated) was assumed to be:

- First dose efficacy: 48% for both PF and AZ
- Second dose efficacy: 60% for both PF and AZ

with no heterogeneity by age.

Note that the reduction in the risk of being symptomatically infected (e_{clin}) is determined by both the reduction in the risk of being infected (e_{inf}) and the reduction in the risk of becoming symptomatic if infected (e_{sympt}) as follows:

$$e_{clin} = e_{inf} + (1 - e_{inf}) * e_{sympt}$$

We therefore calculated e_{sympt} as:

$$\boldsymbol{e_{sympt} = (e_{clin} - e_{inf}) / (1 - e_{inf})}$$

We considered the above in our main analyses, and also considered as a sensitivity analysis (labelled f) a more pessimistic efficacy of 66% of the vaccine efficacy assumed against being symptomatically infected in the main analysis. This was only run for the central daily doses scenario. We also considered as sensitivity analyses (labelled h, I and j) different impacts on transmission blocking:

h. Assume above but **transmission blocked** (acquisition of infection blocked) at **dose 1 is 32% and dose 2 is 40%**
i. Assume above but **transmission blocked** (acquisition of infection blocked) at **dose 1 is 60% and dose 2 is 75%**
j. Assume above but with **0% of transmission blocked** (acquisition of infection blocked).

Vaccine uptake

We assume the uptake is the same in all age groups and in care home workers and care home residents, at 85%. To mimic a potential decrease of uptake for second dose from 85% to 75%, we adjusted the efficacy of the second dose downwards.

Background levels of transmission

Phase 1: We considered that current levels of restrictions would be maintained until the number of COVID-19 patients in hospital in the UK dropped below 10,000 (Phase 1). For that phase, we assume two levels of initial mixing, consistent with an initial effective reproduction number (including immunity) of 0.8 (main analyses) or 1.1 (worst case). We used our current regional estimates of immunity levels in the population to translate these into values of R in the absence of immunity ($R_{\_excl\_immunity}$) which were fixed for the rest of Phase 1.

Phase 2: After phase 1, we assumed gradual relaxation of NPIs up to a level where 75% of NPIs have been lifted. We considered two scenarios for $R_{\_excl\_immunity}$ in the absence of NPIs: 4.5 (consistent with central estimates of transmissibility of B.1.1.7) and 3.5 (optimistic assumption). We computed the overall reduction in R due to NPIs, δ_R, as the difference between these $R_{\_excl\_immunity}$ values ("without NPIs") and the values of $R_{\_excl\_immunity}$ used in Phase 1 ("with NPIs"). We assumed that during phase 2, $R_{\_excl\_immunity}$ increased from $R_{\_excl\_immunity}$*(Phase 1)* to $R_{\_excl\_immunity}$*(Phase 1)* + *0.75* * δ_R, with step changes every 7 days. The size of the step-wise increases were calculated to reach 75% NPI lifted 3, 6 or 9 months after the start of Phase 2. Overall, with 2 levels of initial mixing, 2 values of $R_{\_excl\_immunity}$ after 75% NPIs have been lifted, and 3 durations for phase 2, we explored a total of 12 scenarios for the changing levels of transmissibility whilst the vaccine 1st doses are being rolled out.

Results

The figures below (Figures 2-4) show results through to 30th June 2022. The sensitivity analyses are only shown for the scenario where transmissibility gradually increases from the lowest $R_{\_excl\_immunity}$ in phase 1 (corresponding to R_{eff} of 0.8) to the highest $R_{\_excl\_immunity}$ at the end of phase 2 (corresponding to R0 = 4.5) as R is unlikely to be >1 currently and to account for the increased transmissibility of the variant of concern.

We found that under the current vaccine roll out assumed (Table 1), and if the current effective reproduction number is R_{eff} = 0.8, Figure 3A and B), the number of individuals in hospital is likely to stay above 10,000 until at least late March/early April 2021. If the current effective reproduction number is higher (R_{eff} = 1.1) then our results suggest the current levels of NPIs will lead to a prolonged second wave of infections, hospitalisations and deaths, with hospital occupancy remaining above 10,000 until at least June 2021 (Figure 3C and D).

Under the assumption that R_{eff} is currently 0.8, our results suggest that gradually lifting 75% of current NPIs could lead to a large third wave of infections, hospitalisations and deaths, if done too quickly. Our model predicts that, lifting 75% of NPI over 3 months (respectively 6 and 9 months) would result in a third wave of hospitalisations with a peak hospital occupancy much larger (respectively similar and smaller) than that in the current wave.

All scenarios we considered led to a substantial number of additional deaths, between 67,100 and 224,400.

As we model a two-phased approach where relaxation of NPIs is not initiated until the hospital occupancy is below 10,000, the cumulative number of deaths is lower in the scenario where transmissibility ($R_{\_excl\_immunity}$) increases from 1.6 to 3.5 compared to increases from 1.2 to 3.5 (Figure 2A, 2C and Table 2). This is due to the additional ~2 months of current lockdown levels that must be maintained to achieve this level of hospital occupancy during which time vaccines can be distributed to a greater number of individuals.

These results highlight that waiting to start lifting NPIs until a higher proportion of the population is vaccinated leads to much better outcomes in terms of hospitalisations and deaths.

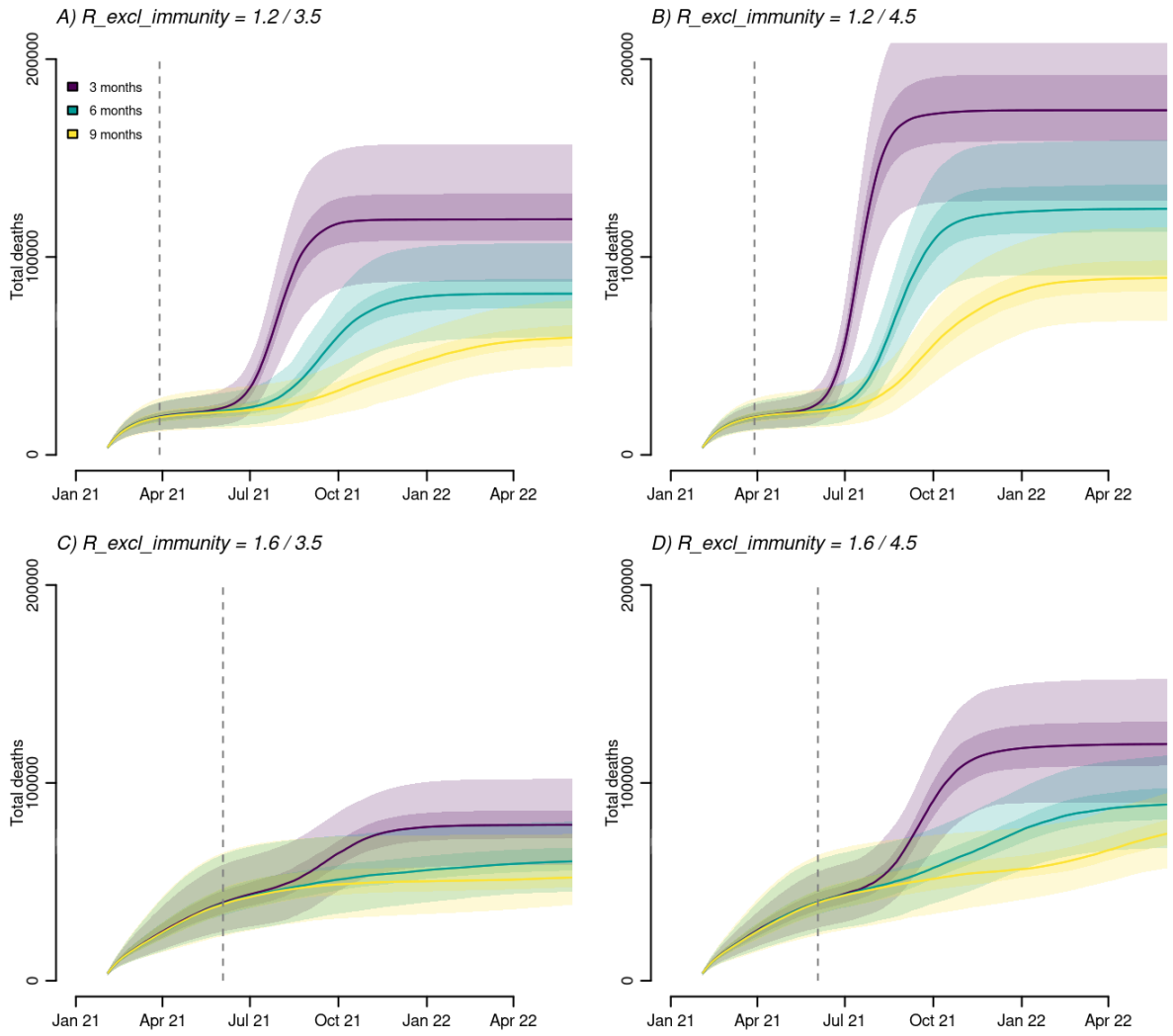

Figure 2: Cumulative UK COVID-19 deaths assuming gradual relaxation of NPIs (removing 75% of current restrictions) over 3 months (purple), 6 months (blue) or 9 months (yellow) after the number of COVID-19 patients in hospital in the UK has fallen below 10,000, under the vaccine roll-out and efficacy assumptions as described in Table 1. Each panel shows the impact of vaccination according to different levels of NPI relaxation translating to a gradual increase in the transmissibility ($R_{excl\_immunity}$) with stepwise changes every 7 days during the 3-, 6-, or 9-month relaxation period considered. $R_{excl\_immunity}$ A) increasing from 1.2 (corresponding to current effective R = 0.8) to 3 (assuming R0 of 3.5); B) increasing from 1.2 to 3.75 (assuming R0 of 4.5); C) increasing from 1.6 (corresponding to current effective R = 1.1) to 3.15 (assuming R0 of 3.5); and D) increasing from 1.6 to 3.9 (assuming R0 of 4.5). Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.

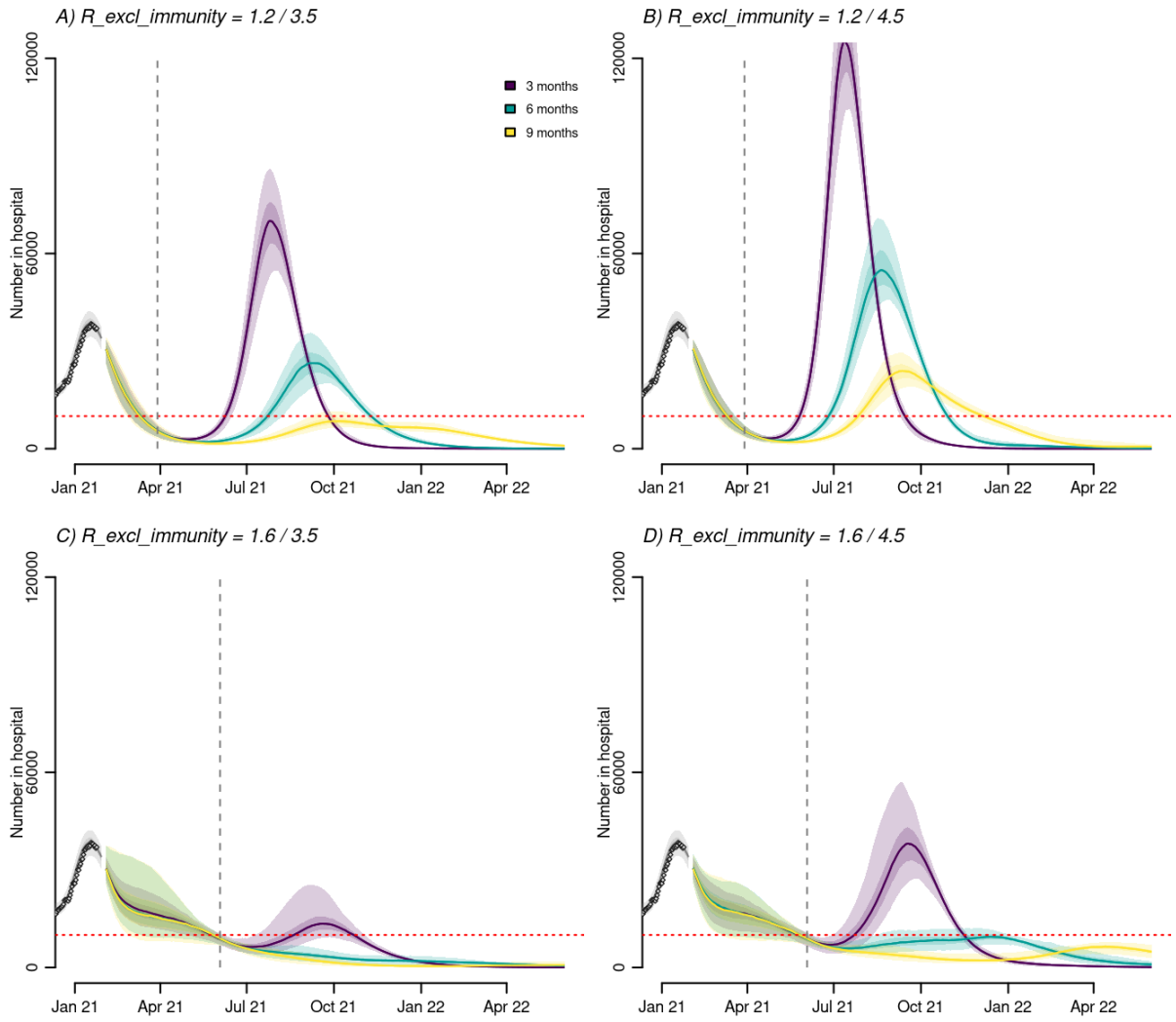

Figure 3: UK COVID-19 hospital occupancy (general wards and ICU) assuming gradual relaxation of NPIs (removing 75% of current restrictions) over 3 months (purple), 6 months (blue) or 9 months (yellow) after the number of COVID-19 patients in hospital in the UK has fallen below 10,000, under the vaccine roll-out and efficacy as described in Table 1. Each panel shows the impact of vaccination according to different levels of NPI relaxation translating to a gradual increase in the transmissibility ($R_{\_excl\_immunity}$) with stepwise changes every 7 days during the 3-, 6-, or 9-month relaxation period considered. $R_{\_excl\_immunity}$ A) increasing from 1.2 (corresponding to current effective R = 0.8) to 3 (assuming R0 of 3.5); B) increasing from 1.2 to 3.75 (assuming R0 of 4.5); C) increasing from 1.6 (corresponding to current effective R = 1.1) to 3.15 (assuming R0 of 3.5); and D) increasing from 1.6 to 3.9 (assuming R0 of 4.5). The horizontal red dashed line denotes a threshold of 10,000 beds in the UK. Points at the start of the graph (Jan 2021) show the recent hospital occupancy data. Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.

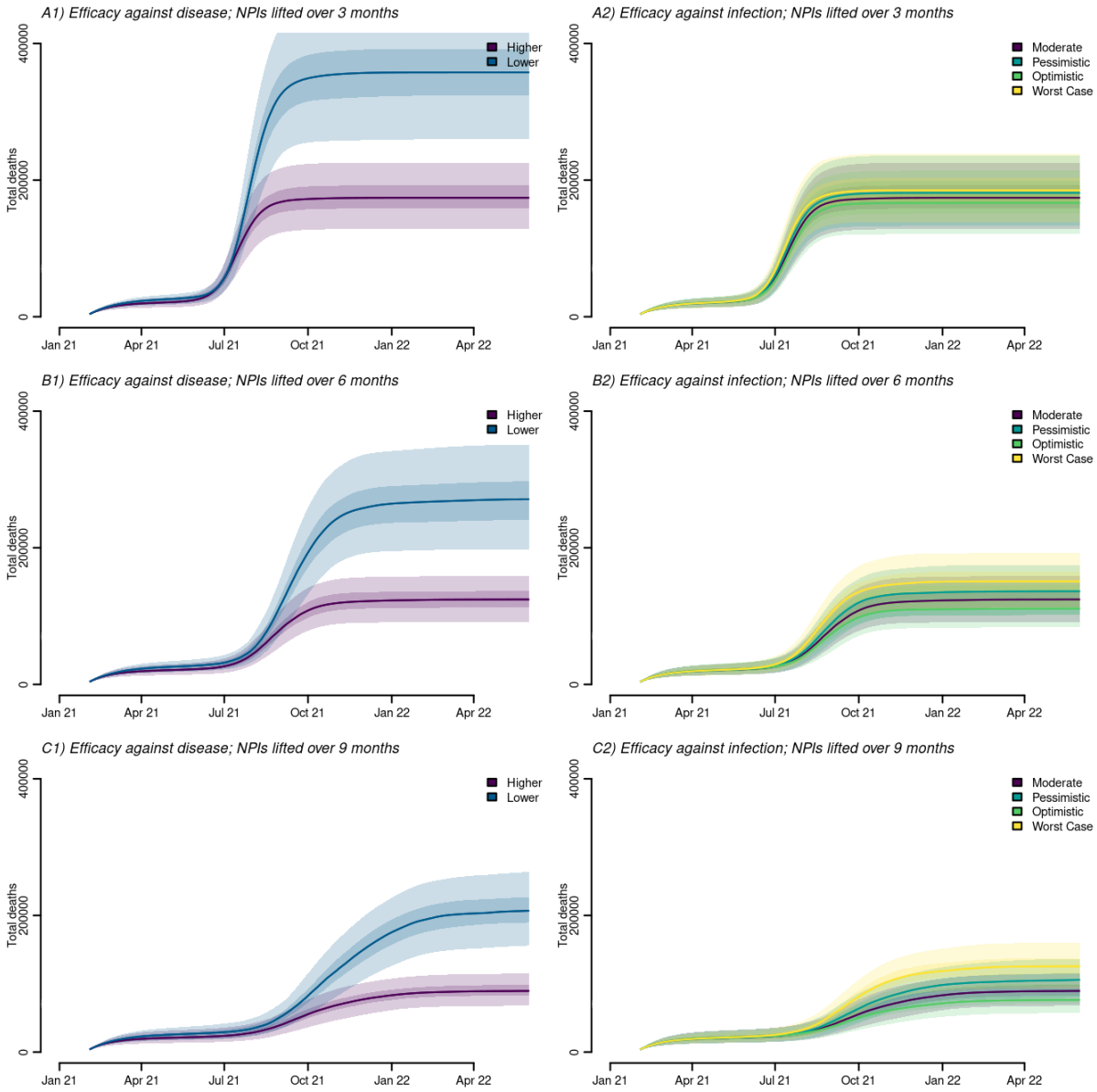

Figure 4: Cumulative UK COVID-19 deaths under different assumptions of vaccine efficacy against (left panel) symptomatic disease and (right panel) acquisition of infection. [Left panels] Purple shows the higher vaccine efficacy against symptomatic disease (first dose efficacy: 88% for PF and 70% for AZ, second dose efficacy: 94% for PF and 88% for AZ) and blue a more pessimistic efficacy of 66% of the vaccine efficacy assumed in main analysis. [Right panels] Purple shows the moderate/central vaccination efficacy (first dose/second dose) against acquisition of infection of 48% / 60% for both PF and AZ, blue the pessimistic where efficacy is 32% / 40%; green the optimistic where efficacy is 60% / 75%; and yellow a worst-case efficacy of 0% / 0%. We assume levels of NPI relaxation (lifting up to 75% of current restrictions) translating to a gradual increase in the transmissibility ($R_{\_excl\_immunity}$) from 1.2 (corresponding to current effective R = 0.8) to 3.75 (assuming R0 of 4.5), with stepwise changes every 7 days over 3 (top), 6 (middle) and 9 (bottom) months after number of COVID-19 patients in hospital have fallen below 10,000, and a central vaccine roll-out scenario as described in Table 1.

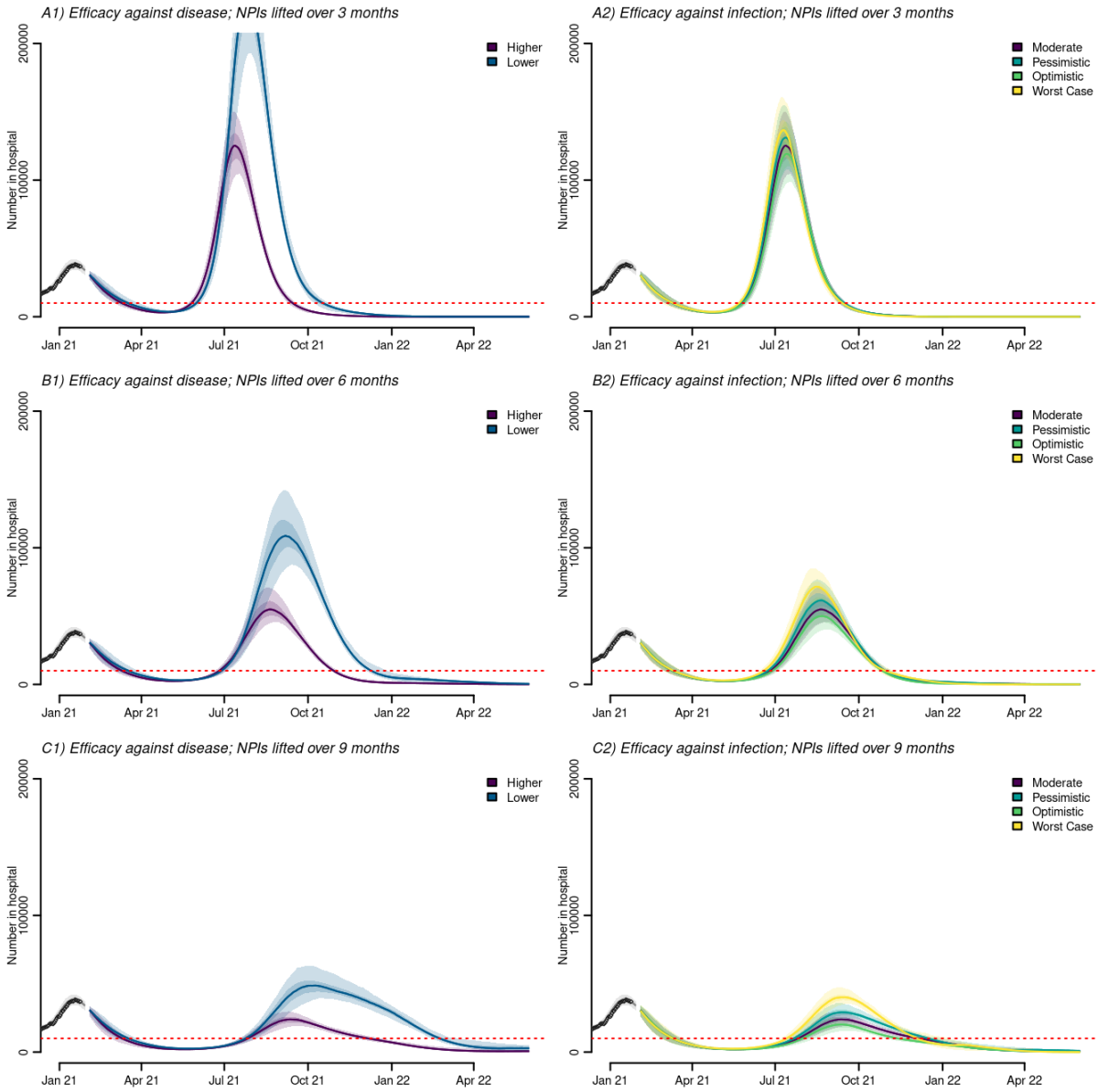

Figure 5: UK COVID-19 hospital occupancy (general wards and ICU) under different assumptions of vaccine efficacy against (left panel) symptomatic disease and (right panel) acquisition of infection. [Left panel] Purple shows the higher vaccine efficacy against symptomatic disease (first dose efficacy: 88% for PF and 70% for AZ, second dose efficacy: 94% for PF and 88% for AZ) and blue a more pessimistic efficacy of 66% of the vaccine efficacy assumed in the main analysis. [Right panel] Purple shows the moderate/central vaccination efficacy (first dose/second dose) against acquisition of infection of 48% / 60% for both PF and AZ, blue the pessimistic where efficacy is 32% / 40%; green the optimistic where efficacy is 60% / 75%; and yellow a worst-case efficacy of 0% / 0%. We assume levels of NPI relaxation (lifting up to 75% of current restrictions) translating to a gradual increase in the transmissibility ($R_{\_excl\_immunity}$) from 1.2 (corresponding to current effective R = 0.8) to 3.75 (assuming R0 of 4.5), with stepwise changes every 7 days over 3 (top), 6 (middle) and 9 (bottom) months after number of COVID-19 patients in hospital have fallen below 10,000, and a central vaccine roll-out scenario as described in Table 1. Points at the start of the graph (Jan 2021) show the recent hospital occupancy data.

Table 2: Cumulative deaths between 1st February 2021 and 30th June 2022 under different vaccination scenarios considered. Values shown are mean (95% CrI) and are all rounded to the nearest hundred.

Analysis type	**NPI lifting period**	**Background transmissibility** $R_{\_excl\_immunity}$ *	**Vaccine efficacy against disease**	**Vaccine efficacy against infection**	**Cumulative number of deaths by 30 June 2022 (95% CrI)**
Main analysis	3 months	1.2 to 4.5	Higher	Moderate	174,500 (127,700 - 224,400)
	6 months				124,300 (90,100 - 158,300)
	9 months				89,500 (67,100 - 114,000)
Varying background transmissibility	3 months	1.6 to 4.5	Higher	Moderate	119,100 (89,500 - 151,400)
		1.2 to 3.5			119,800 (87,100 - 156,100)
		1.6 to 3.5			78,500 (58,000 - 101,000)
	6 months	1.6 to 4.5			88,800 (66,500 - 112,800)
		1.2 to 3.5			80,900 (59,000 - 105,800)
		1.6 to 3.5			60,700 (44,300 - 79,500)
	9 months	1.6 to 4.5			74,200 (56,200 - 93,900)
		1.2 to 3.5			59,300 (44,200 - 77,000)
		1.6 to 3.5			53,000 (37,800 - 73,100)
Varying vaccine efficacy against disease	3 months	1.2 to 4.5	Lower	Moderate	358,400 (259,300 - 464,000)
	6 months				269,400 (197,100 - 350,100)
	9 months				207,400 (155,300 - 262,900)
Varying vaccine efficacy against infection	3 months	1.2 to 4.5	Higher	Pessimistic	181,300 (132,600 - 235,100)
	6 months				137,100 (101,100 - 173,800)
	9 months				105,400 (79,200 - 135,200)
	3 months			Optimistic	166,700 (120,400 - 212,900)
	6 months				112,000 (83,000 - 144,300)
	9 months				76,100 (56,400 - 99,100)
	3 months			Worst case	185,800 (138,200 - 237,900)
	6 months				150,700 (111,300 - 190,900)
	9 months				125,400 (93,200 - 158,600)

* The first value indicates the value of $R_{\_excl\_immunity}$ used in the first phase of the simulation (see text for details); the second value indicates the assumed basic reproduction number. In the second phase of the simulation 75% of NPIs are assumed to be gradually lifted, so that $R_{\_excl\_immunity}$ never reaches the full R0 value (see text for detail).

Supplementary Results

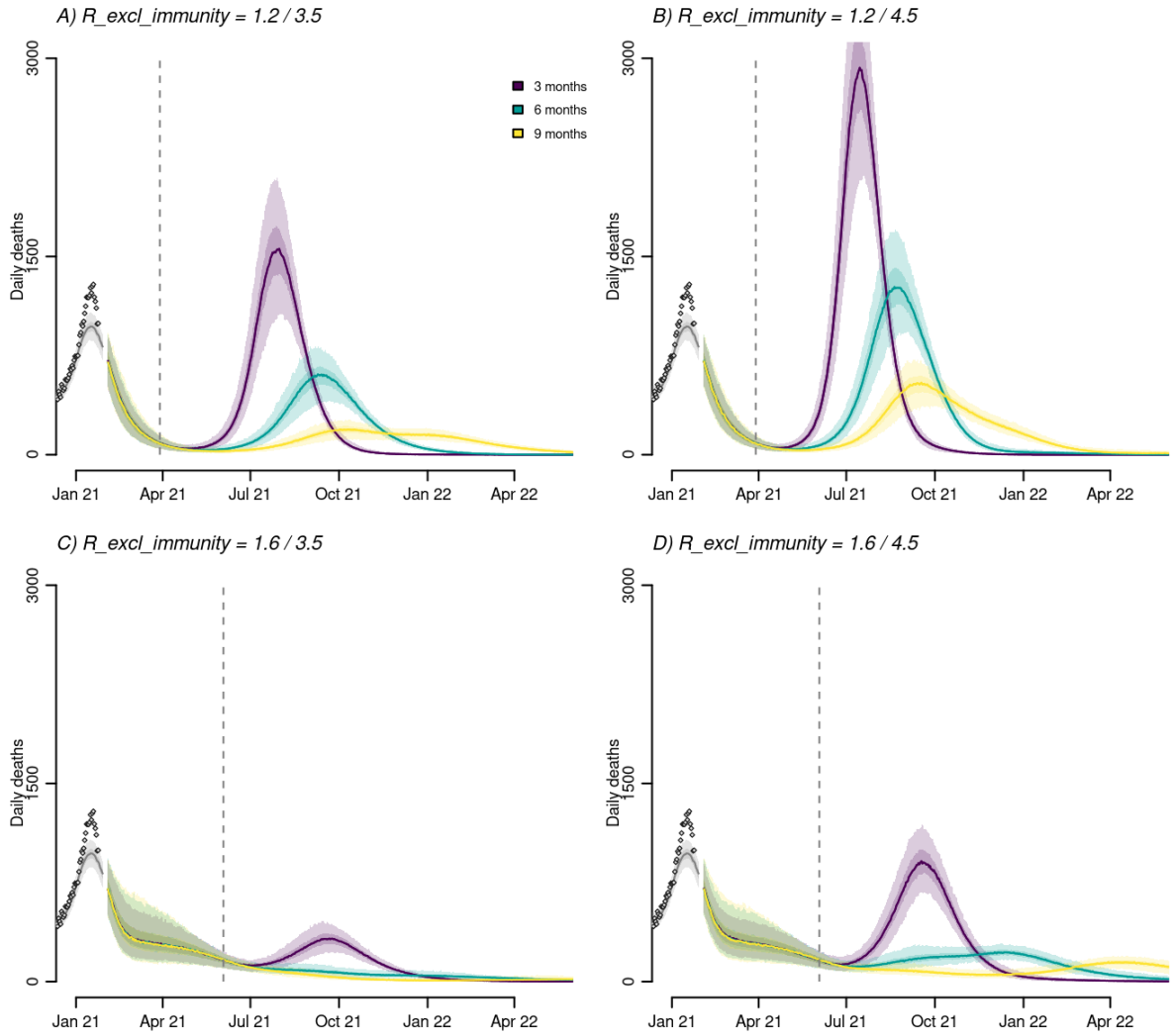

Figure S1: UK daily COVID-19 deaths assuming gradual relaxation of NPIs (removing 75% of current restrictions) over 3 months (purple), 6 months (blue) or 9 months (yellow) after the number of COVID-19 patients in hospital in the UK has fallen below 10,000, under the vaccine roll-out and efficacy assumptions as described in Table 1. Each panel shows the impact of vaccination according to different levels of NPI relaxation translating to a gradual increase in the transmissibility ($R_{excl\_immunity}$) with stepwise changes every 7 days during the 3-, 6-, or 9-month relaxation period considered. $R_{excl\_immunity}$ A) increasing from 1.2 (corresponding to current effective R = 0.8) to 3 (assuming R0 of 3.5); B) increasing from 1.2 to 3.75 (assuming R0 of 4.5); C) increasing from 1.6 (corresponding to current effective R = 1.1) to 3.15 (assuming R0 of 3.5); and D) increasing from 1.6 to 3.9 (assuming R0 of 4.5). Grey line at the start of the graph (Jan 2021) show the recent death data. Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.

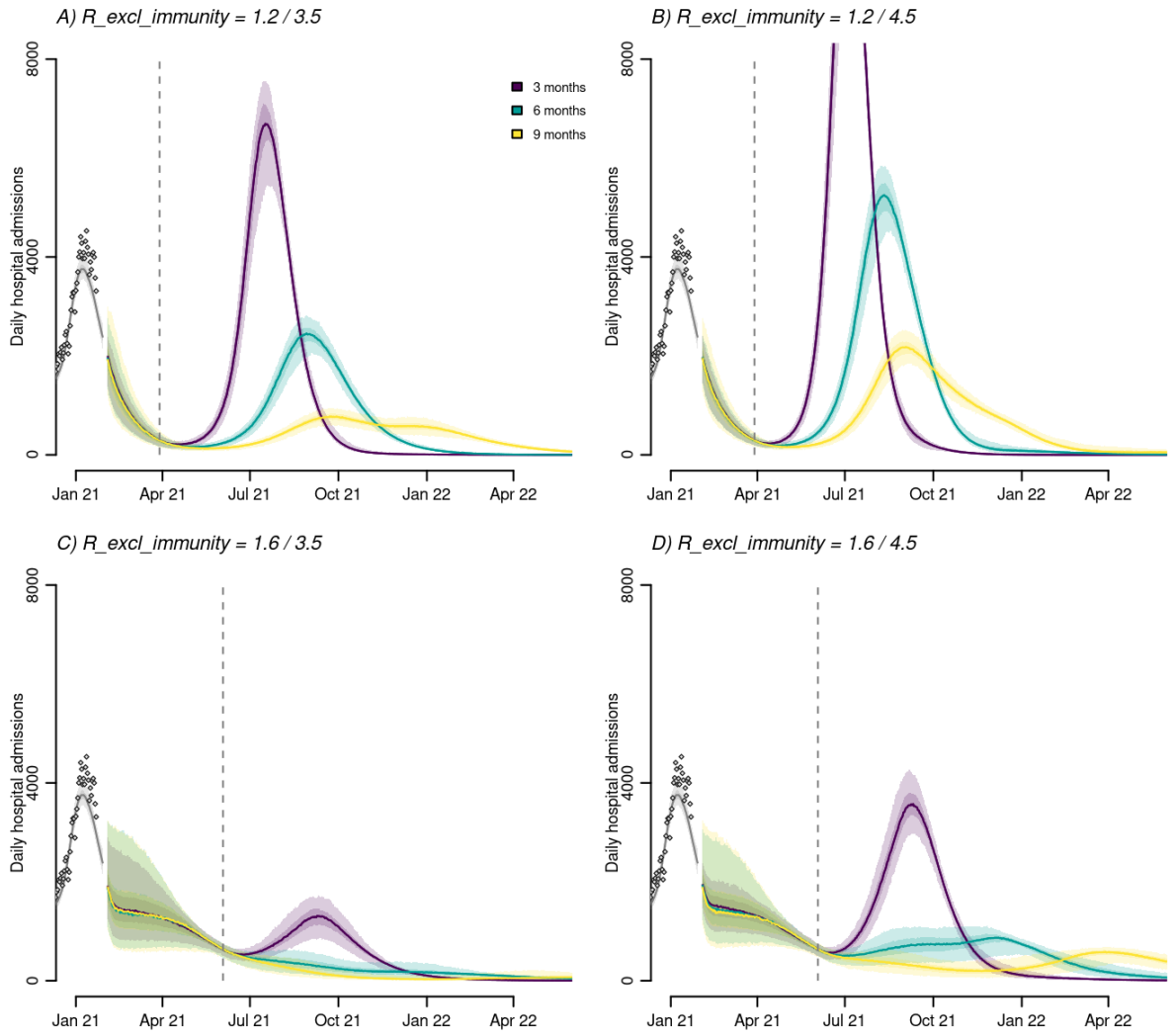

Figure S2: UK daily COVID-19 hospital admissions assuming gradual relaxation of NPIs (removing 75% of current restrictions) over 3 months (purple), 6 months (blue) or 9 months (yellow) after the number of COVID-19 patients in hospital in the UK has fallen below 10,000, under the vaccine roll-out and efficacy assumptions as described in Table 1. Each panel shows the impact of vaccination according to different levels of NPI relaxation translating to a gradual increase in the transmissibility ($R_{\_excl\_immunity}$) with stepwise changes every 7 days during the 3-, 6-, or 9-month relaxation period considered. $R_{\_excl\_immunity}$ A) increasing from 1.2 (corresponding to current effective R = 0.8) to 3 (assuming R0 of 3.5); B) increasing from 1.2 to 3.75 (assuming R0 of 4.5); C) increasing from 1.6 (corresponding to current effective R = 1.1) to 3.15 (assuming R0 of 3.5); and D) increasing from 1.6 to 3.9 (assuming R0 of 4.5). Grey lines at the start of the graph (Jan 2021) show the recent hospital occupancy data. Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.

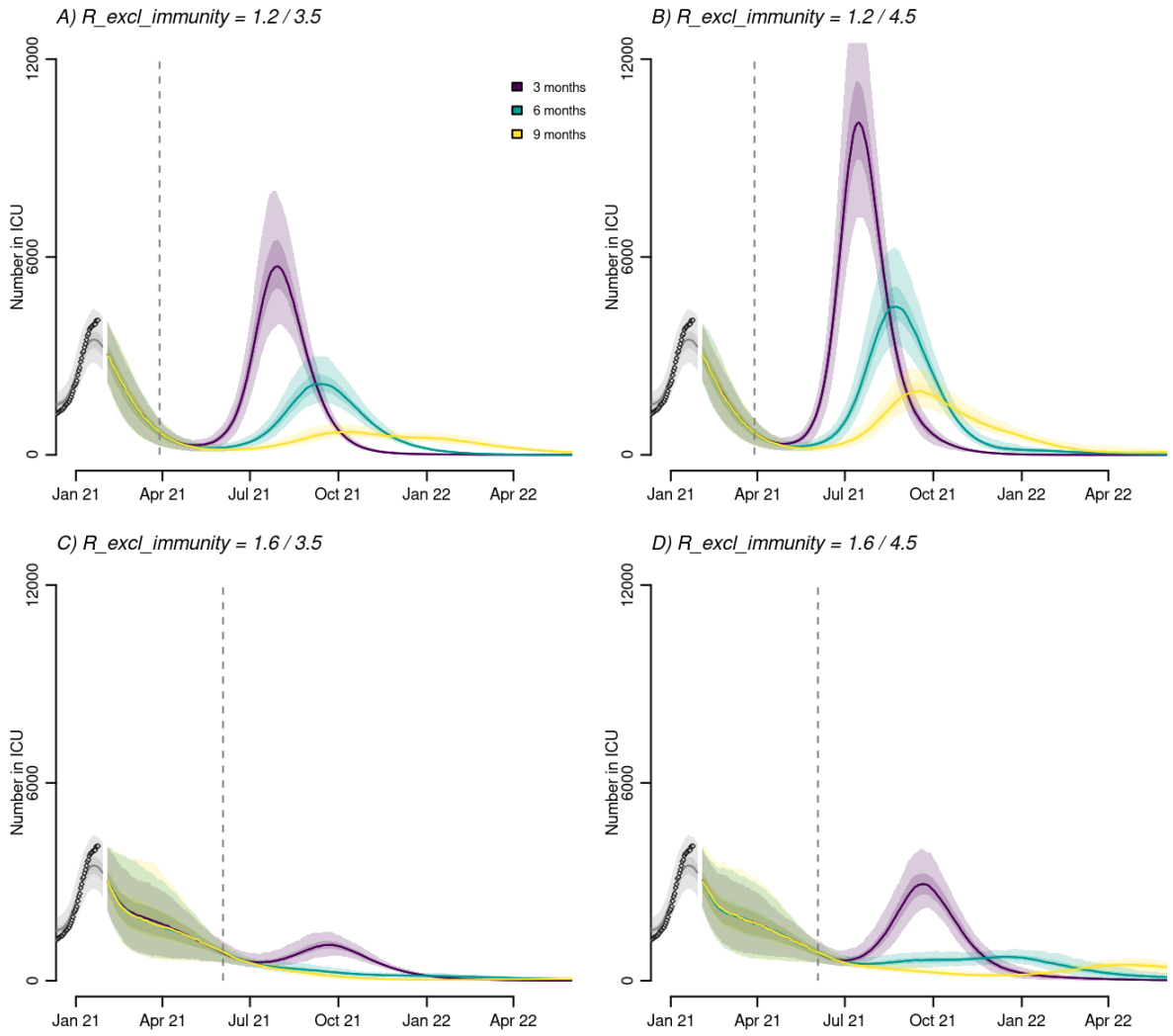

Figure S3: UK COVID-19 ICU occupancy assuming gradual relaxation of NPIs (removing 75% of current restrictions) over 3 months (purple), 6 months (blue) or 9 months (yellow) after the number of COVID-19 patients in hospital in the UK has fallen below 10,000, under the vaccine roll-out and efficacy assumptions as described in Table 1. Each panel shows the impact of vaccination according to different levels of NPI relaxation translating to a gradual increase in the transmissibility ($R_{excl\_immunity}$) with stepwise changes every 7 days during the 3-, 6-, or 9-month relaxation period considered. $R_{excl\_immunity}$ A) increasing from 1.2 (corresponding to current effective R = 0.8) to 3 (assuming R0 of 3.5); B) increasing from 1.2 to 3.75 (assuming R0 of 4.5); C) increasing from 1.6 (corresponding to current effective R = 1.1) to 3.15 (assuming R0 of 3.5); and D) increasing from 1.6 to 3.9 (assuming R0 of 4.5). Grey line at the start of the graph (Jan 2021) shows the recent ICU occupancy data. Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.

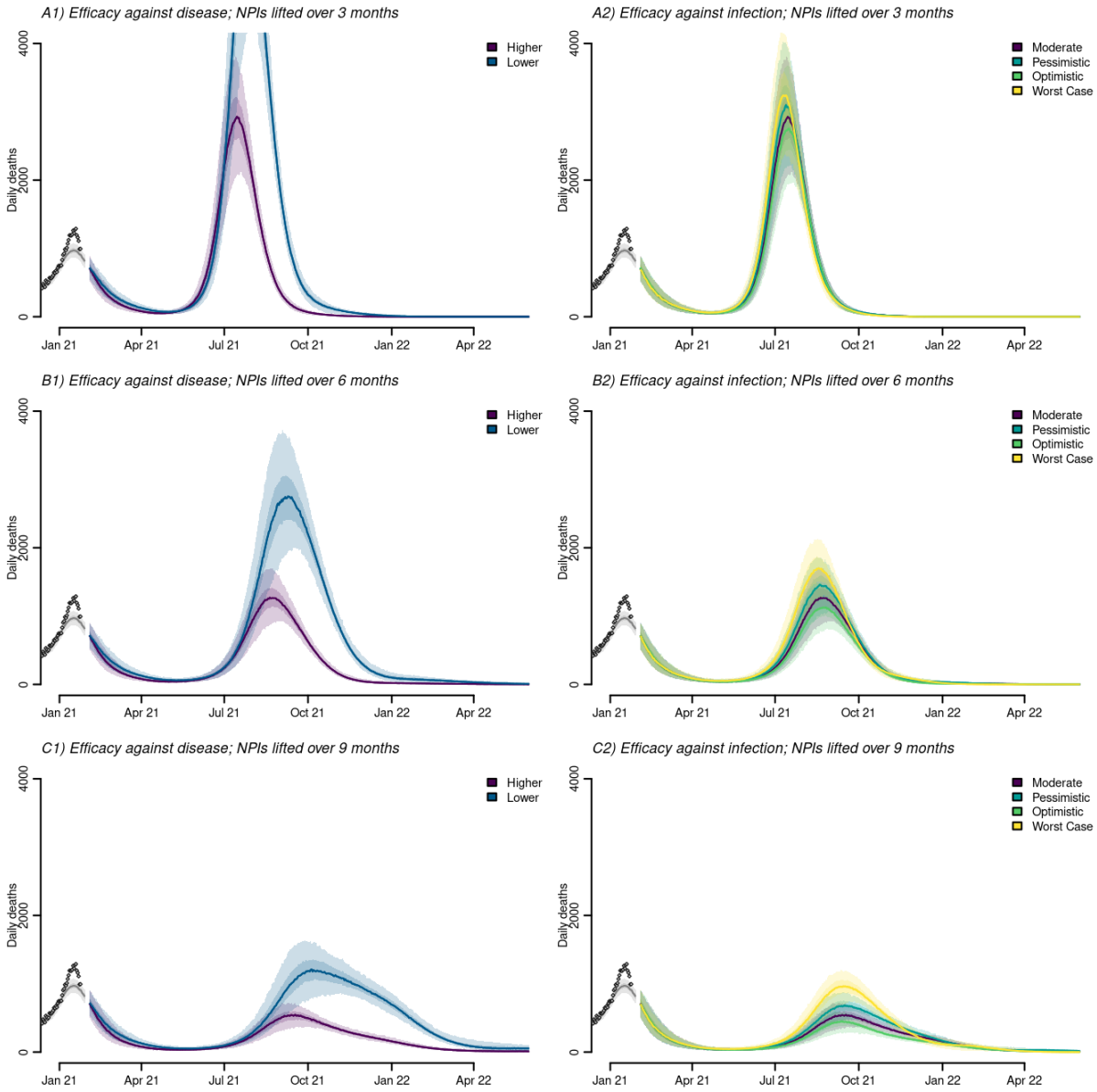

Figure S4: UK daily COVID-19 deaths under different assumptions of vaccine efficacy against (left panel) symptomatic disease and (right panel) acquisition of infection. [Left panel] Purple shows the higher vaccine efficacy against symptomatic disease (first dose efficacy: 88% for PF and 70% for AZ, second dose efficacy: 94% for PF and 88% for AZ) and blue a more pessimistic efficacy of 66% of the vaccine efficacy assumed in the main analysis. [Right panel] Purple shows the moderate/central vaccination efficacy (first dose/second dose) against acquisition of infection of 48% / 60% for both PF and AZ, blue the pessimistic where efficacy is 32% / 40%; green the optimistic where efficacy is 60% / 75%; and yellow a worst-case efficacy of 0% / 0%. We assume levels of NPI relaxation (lifting up to 75% of current restrictions) translating to a gradual increase in the transmissibility ($R_{excl\_immunity}$) from 1.2 (corresponding to current effective R = 0.8) to 3.75 (assuming R0 of 4.5), with stepwise changes every 7 days over 3 (top), 6 (middle) and 9 (bottom) months after number of COVID-19 patients in hospital have fallen below 10,000, and a central vaccine roll-out scenario as described in Table 1. Grey line at the start of the graph (Jan 2021) shows the recent death data. Vertical lines denote the date at which hospital bed occupancy below the threshold of 10,000 and NPIs can begin to be lifted in each scenario.