A comparison between one and two dose SARS-CoV-2 vaccine prioritisation in England for a fixed number of vaccine doses

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UK Research and Innovation

JUNIPER

https://maths.org/juniper/ @JuniperConsort1

Modelling response: University of Warwick involvement

Contributed to SPI-M-O (Scientific Pandemic Influenza Group on Modelling, Operational sub-group), who report to Scientific Advisory Group for Emergencies (SAGE), who in turn advise the government.

Members of SBIDER have developed multiple models for understanding SARS-CoV-2 transmission and the burden of COVID-19 in the UK: **https://tinyurl.com/sbiderCOVID19**

- Age-structured deterministic model
  - Estimate infection levels, R and incidence
  - Longer-term scenarios and planning (e.g. roadmap out of lockdown)
- Secondary school model
  - Lateral flow testing and isolation of contact bubbles
- Network models
  - Used to study transmission in universities and in **work sectors**

See Poster P5.05, Poster Session 5, Thursday 2nd December @ 11:20-13:00GMT.
"A network modelling approach to assess non-pharmaceutical disease controls against SARS-CoV-2 in a worker population"

SARS-CoV-2 vaccination: UK context

Department of Health & Social Care

Independent report

Optimising the COVID-19 vaccination programme for maximum short-term impact

Updated 26 January 2021

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Summary

- There has been a rapid increase in COVID-19 cases in the UK in December 2020
- Two vaccines now have MHRA Regulation 174 authorisation (Pfizer-BioNTech and AstraZeneca)
- Rapid delivery of the vaccines is required to protect those most vulnerable
- Short-term vaccine efficacy from the first dose of the Pfizer-BioNTech vaccine is calculated at around 90%
- Short-term vaccine efficacy from the first dose of the AstraZeneca vaccine is calculated at around 70%, with high protection against severe disease
- Given the high level of protection afforded by the first dose, models suggest that initially vaccinating a greater number of people with a single dose will prevent more deaths and hospitalisations than vaccinating a smaller number of people with 2 doses
- The second dose is still important to provide longer lasting protection and is expected to be as or more effective when delivered at an interval of 12 weeks from the first dose

URL: https://bit.ly/3kynUSn

- Urgency to achieve high levels of protection in the population.
- A key question is the appropriate interval between first and second doses - often conceptualised as prioritisation of first or second doses.

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- Parsimonious model structures may be swiftly developed and applied.
- Timely delivery of findings before a policy decision is taken can be worth more than using a more complex method and obtaining results afterwards, provided any methodological limitations are clear.

Talk outline

(1) Vaccine priority data and simulation outline

- Data on age-dependent COVID-19 mortality risk in the UK;
- Objective function: maximising deaths averted.

(2) Homogeneous vaccine allocation strategy

- For a given number of available doses and for a given relative efficacy from the first dose compared to the second, examined the question of whether to completely prioritise one dose or two doses of the vaccine.

(3) Heterogeneous vaccine allocation strategy

- Sought the optimal deployment of a mixed vaccine dose allocation scheme, where some priority groups can be targeted for two doses while others receive one.

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Priority group data

Considered two different sets of assumptions for the population size and relative risk of COVID-19 mortality of each priority group

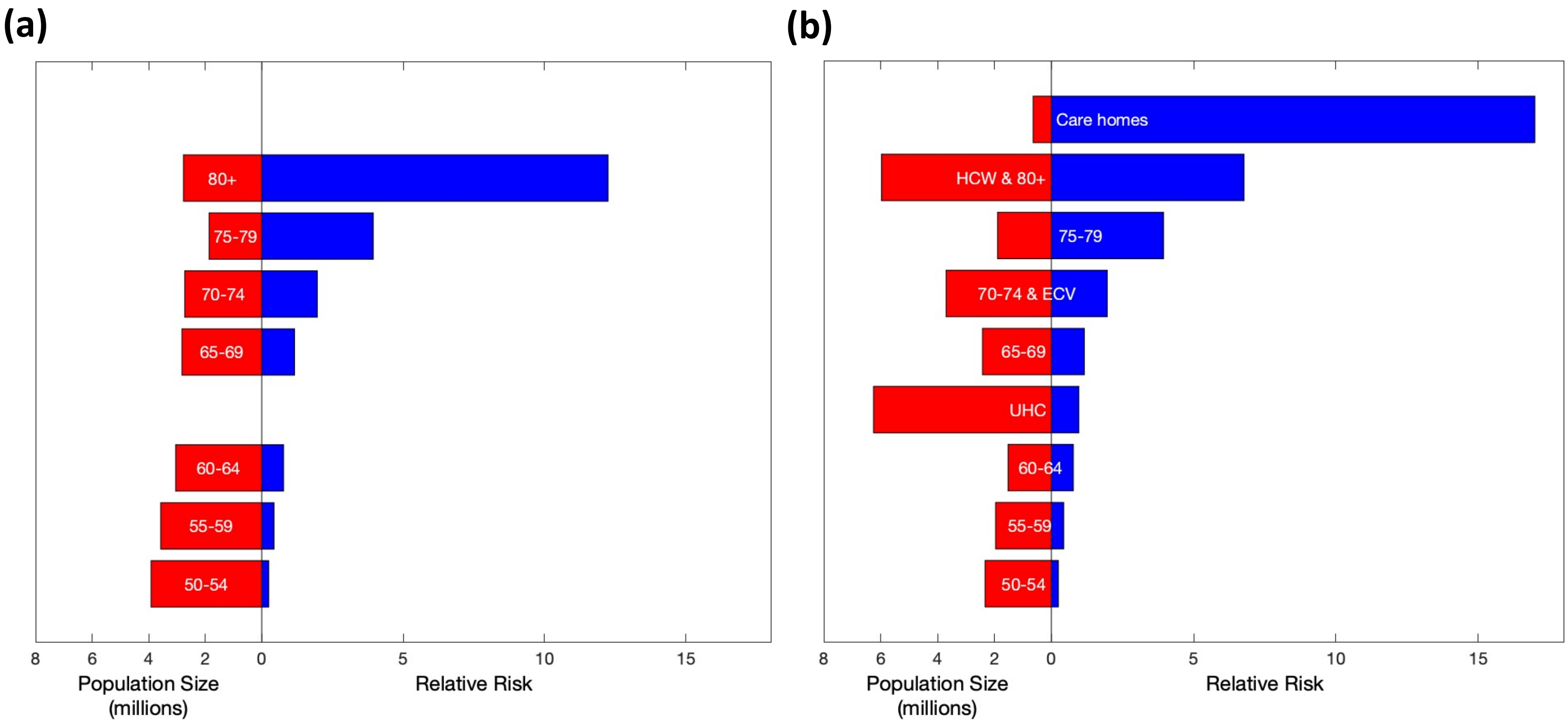
- **Age group only**
- **Priority Group estimate:** Included Joint Committee on Vaccination and Immunisation (JCVI) Phase 1 priority groups; specific groups for care homes and those with underlying health conditions.

Table: Estimates of priority group population size and relative mortality risk.

	age groups only		priority group estimate	
priority group, p	size, P_p (millions)	relative risk, RR_p	size, P_p (millions)	relative risk, RR_p
1. care homes	—	—	0.7	17.0
2. ≥80 years & HCW	2.8	12.3	6.0	6.8
3. 75–79 years	1.9	3.9	1.9	3.9
4. 70–74 years & CEV	2.7	2.0	3.7	2.0
5. 65–69 years	2.8	1.2	2.4	1.2
6. UHC	—	—	6.2	1.0
7. 60–64 years	3.0	0.77	1.5	0.77
8. 55–59 years	3.6	0.43	2.0	0.43
9. 50–54 years	3.9	0.25	2.3	0.25
0–49 years	35.3	0.035	29.3	0.035

Priority group data

Figure 1: Estimated population size (red) and the relative risk of mortality from COVID-19 (blue) of each priority group. **(a)** Age group only estimates. **(b)** Priority Group estimates. Vertical spacing of the two graphs is such that the groups of similar ages match.



Objective and vaccination assumptions

- **Objective:** *relative* number of deaths averted by the proportion receiving one dose (v_p^1) or two doses (v_p^2), for fixed amount of total doses.

$$\text{Deaths averted} \propto \sum_p (v_p^1 VE_1 + v_p^2 VE_2) P_p RR_p$$

$$\propto \sum_p (v_p^1 VE_R + v_p^2) P_p RR_p,$$

P_p - population size (priority group p)

RR_p - relative COVID-19 mortality risk

$$VE_R = \frac{VE_1}{VE_2}$$

VE_1 Vacc. eff. after one dose

VE_2 Vacc. eff. after two doses

- **Strategy for dose allocation:** Two types of dose allocation strategy, which we describe as: (i) homogeneous strategy and (ii) heterogeneous strategy.

- **Vaccine uptake:** In all scenarios we assumed 90% vaccine uptake, independent of age and priority group.

- **Limitations:** Static model, instantaneous vaccine benefit, ignored the impact of transmission blocking, only considered one outcome measure…

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(3) Heterogeneous vaccine allocation strategy

- Sought the optimal deployment of a mixed vaccine dose allocation scheme, where some priority groups can be targeted for two doses while others receive one.

Homogeneous allocation strategy

More people one dose vs **fewer people two doses**

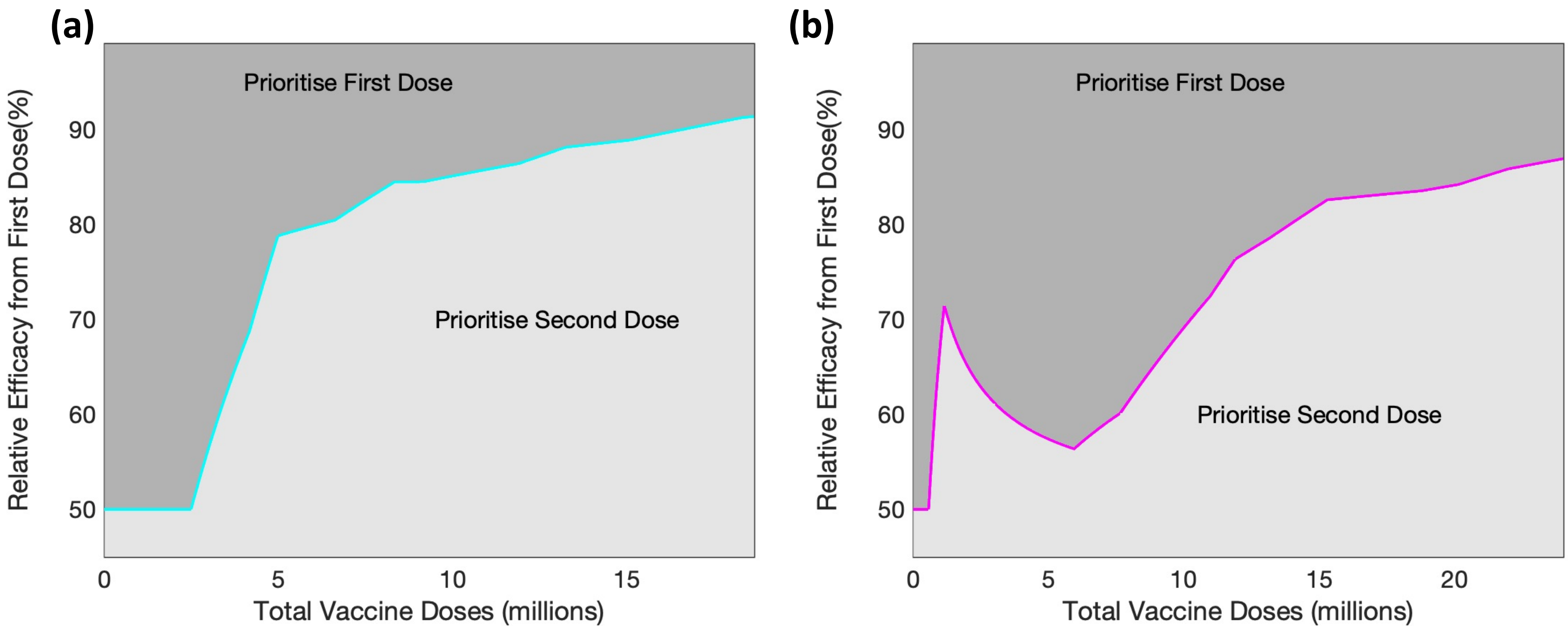
$$\text{deaths averted}_1 \propto \sum_p v_p^1 VE_R P_p RR_p \qquad \text{deaths averted}_2 \propto \sum_p v_p^2 P_p RR_p$$

where there is a strict limit on the number of available vaccine doses:
$\sum_p v_p^1 P_p = V$ or $\sum_p 2v_p^2 P_p = V$

- Calculated the optimal deployment of vaccine across all priority groups without having to perform an exhaustive combinatorial search.
- The relative risk of COVID-19 mortality (RR_p) decreases monotonically between risk groups, meaning it is optimal to maximally vaccinate the higher-risk groups before preceding to lower-risk ones.
- Solutions of form: $(v_1^1, \ldots, v_{q-1}^1, v_q^1, v_{q+1}^1, \ldots, v_1^1) = (0.9, \ldots, 0.9, v_1^1, 0, \ldots, 0)$

Homogeneous allocation strategy

Figure 2: Optimization of homogeneous dosing strategy with respect to the number of vaccine doses and the relative efficacy of the first dose compared to the second dose. **(a)** Age group only estimate. **(b)** Priority Group estimate.



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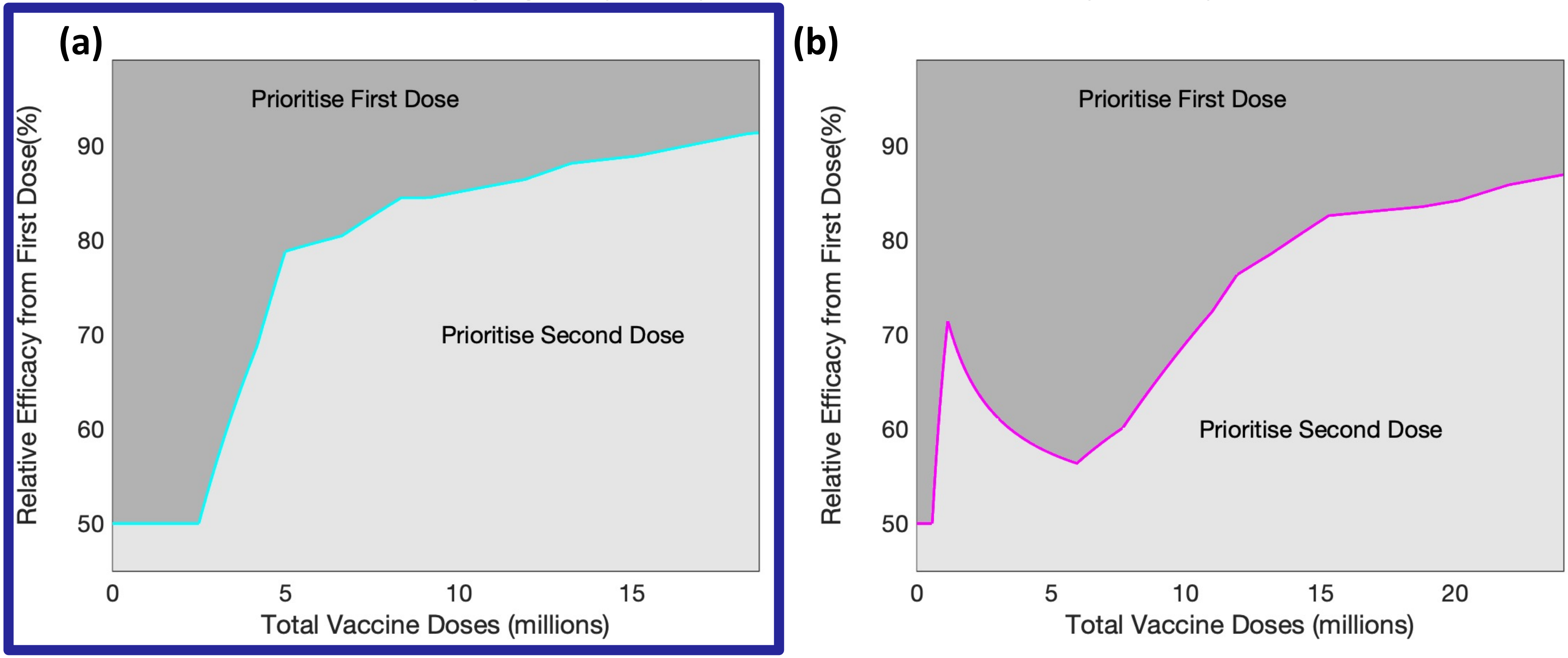

- For the age only estimate, the separation between prioritising first dose or second dose was relatively smooth.

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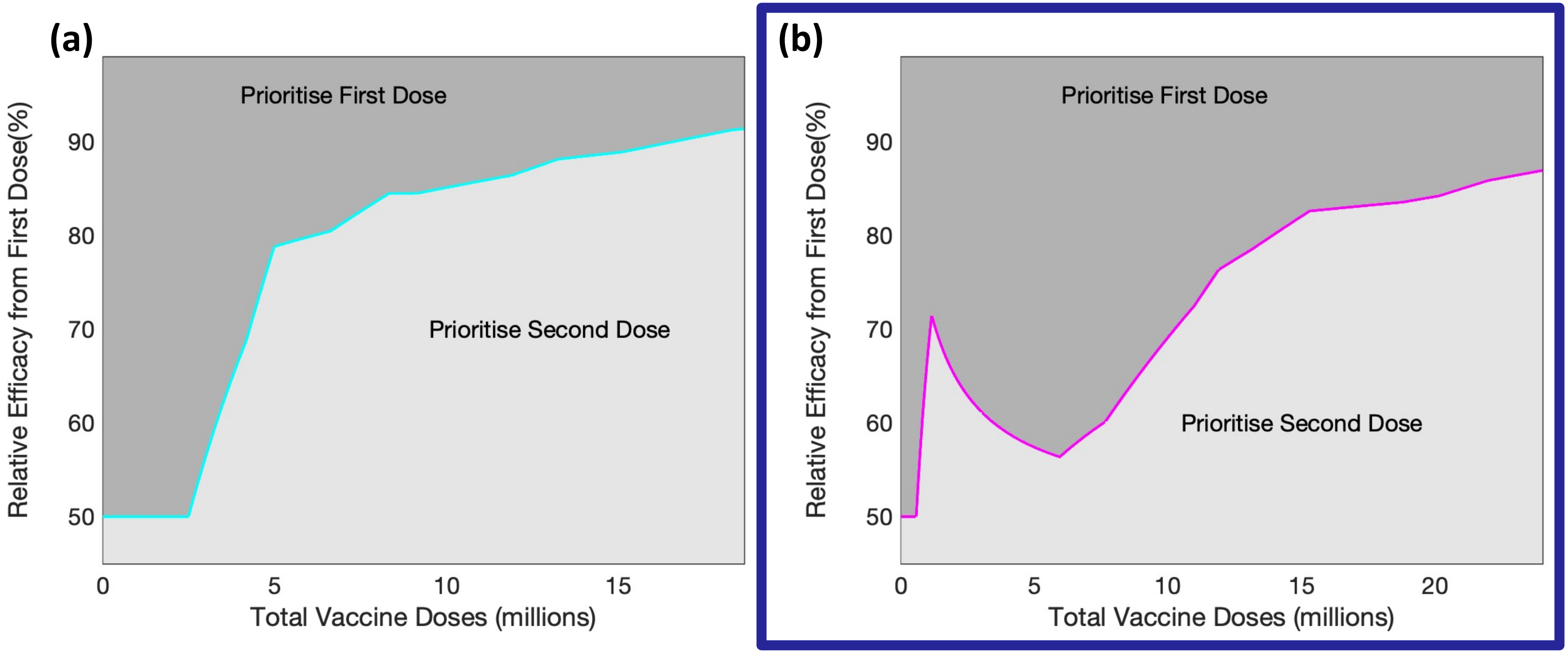

- For a low number of doses and a low relative efficacy, it can be optimal to prioritise giving two doses to the care home group (priority group 1).

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Heterogeneous allocation strategy

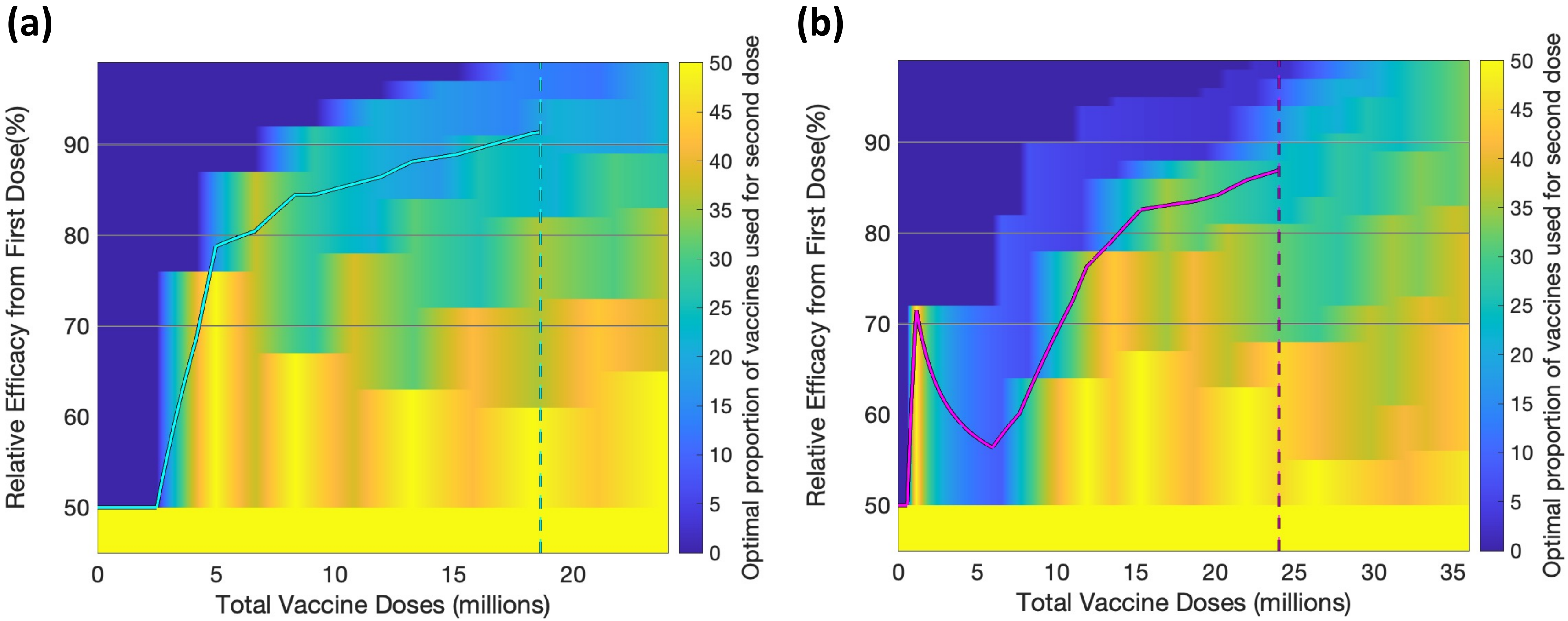
$$\text{maximize}(\text{deaths averted}) \propto \sum_p (v_p^1 VE_R + v_p^2) P_p RR_p$$

$$\text{such that } \sum_p (v_p^1 + 2v_p^2) P_p = V.$$

- Due to the monotonicity of the relative risk of mortality, we can again insist on a simple ordering of vaccination.
- Expect to maximally vaccinate higher risk groups before moving to lower risk groups.

Heterogeneous allocation strategy

Figure 3: Optimal distribution of a given number of vaccine doses between first and second dose. Solid lines show the boundary associated with the homogeneous strategies. **(a)** Age group only estimate. **(b)** Priority Group estimate.



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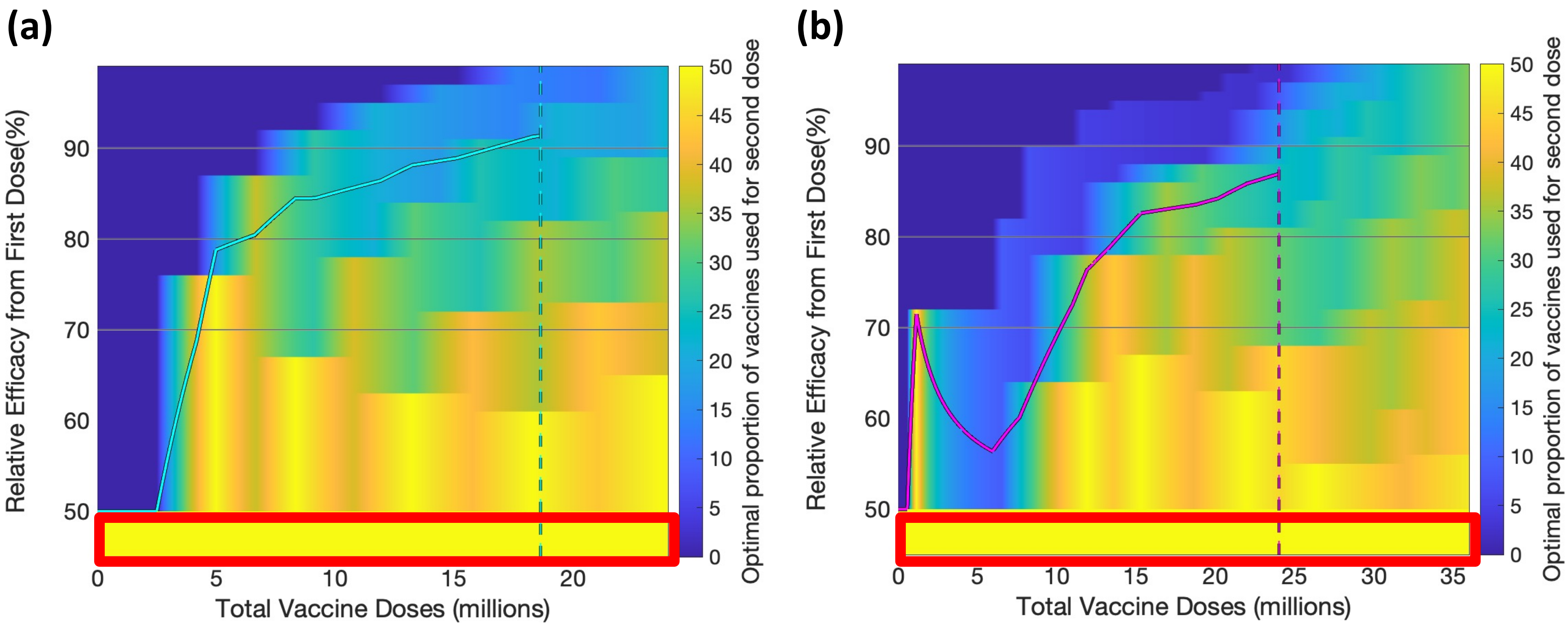

- Given a relative efficacy for the first dose of below 50%, the optimal strategy is to use half of the available vaccine for second doses.

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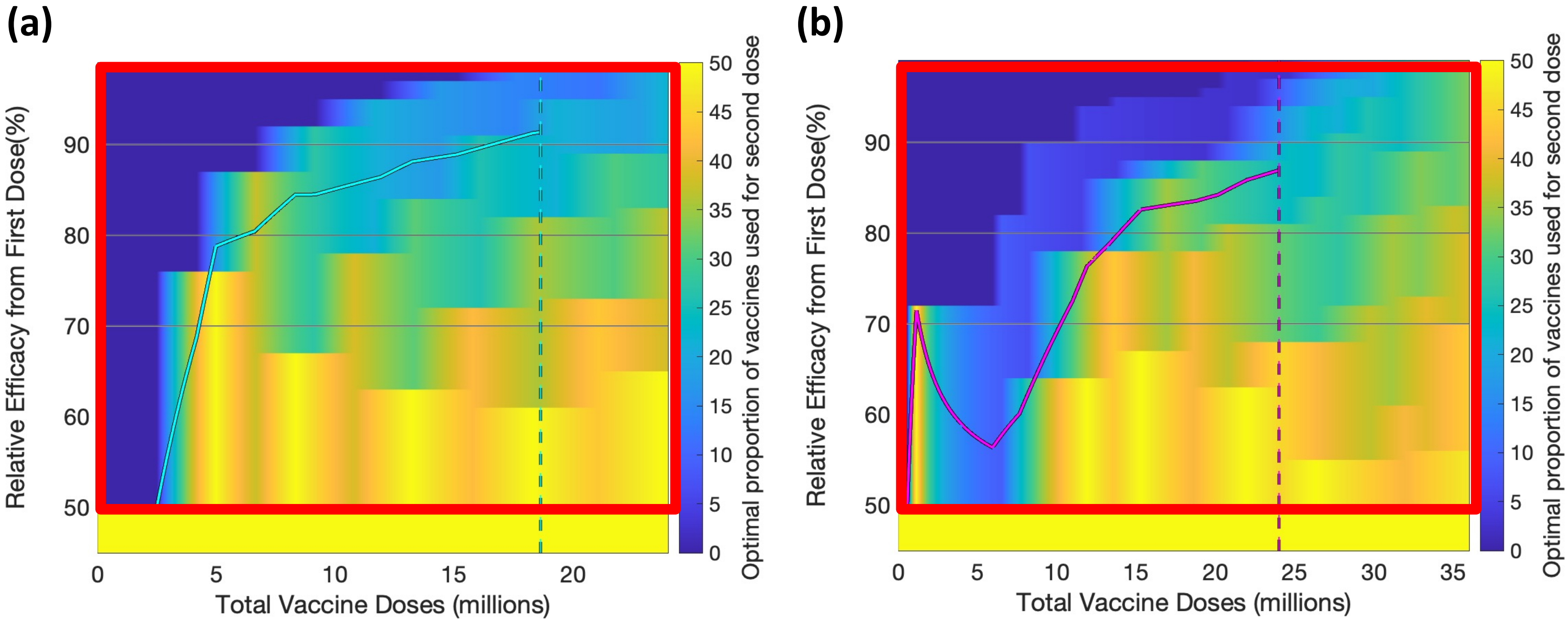
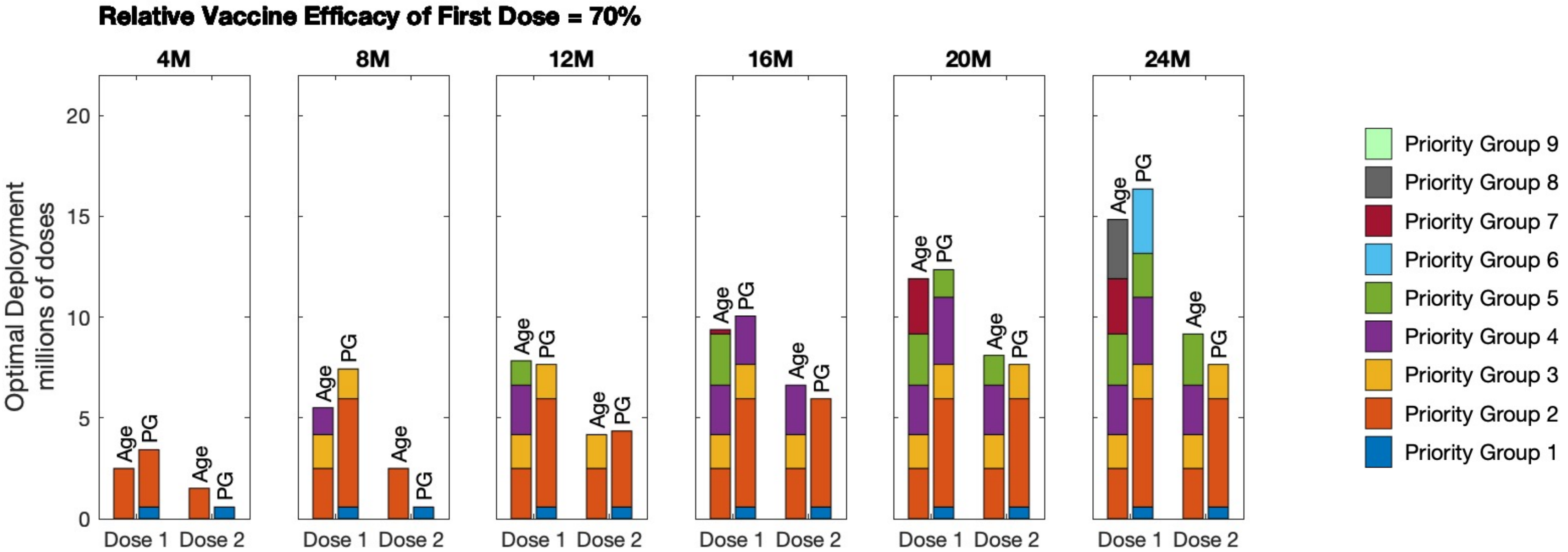


- We found a smaller region of parameter space where the optimal strategy is to only give one dose (dark blue shading), and only for a low number of doses or very high levels of relative efficacy of the first dose.

Heterogeneous allocation strategy

Figure 4: Optimal deployment of vaccine for the two different priority group estimates and a 70% relative vaccine efficacy of first dose. Left bars correspond to age group only estimate and right bars correspond to Priority Group estimates.



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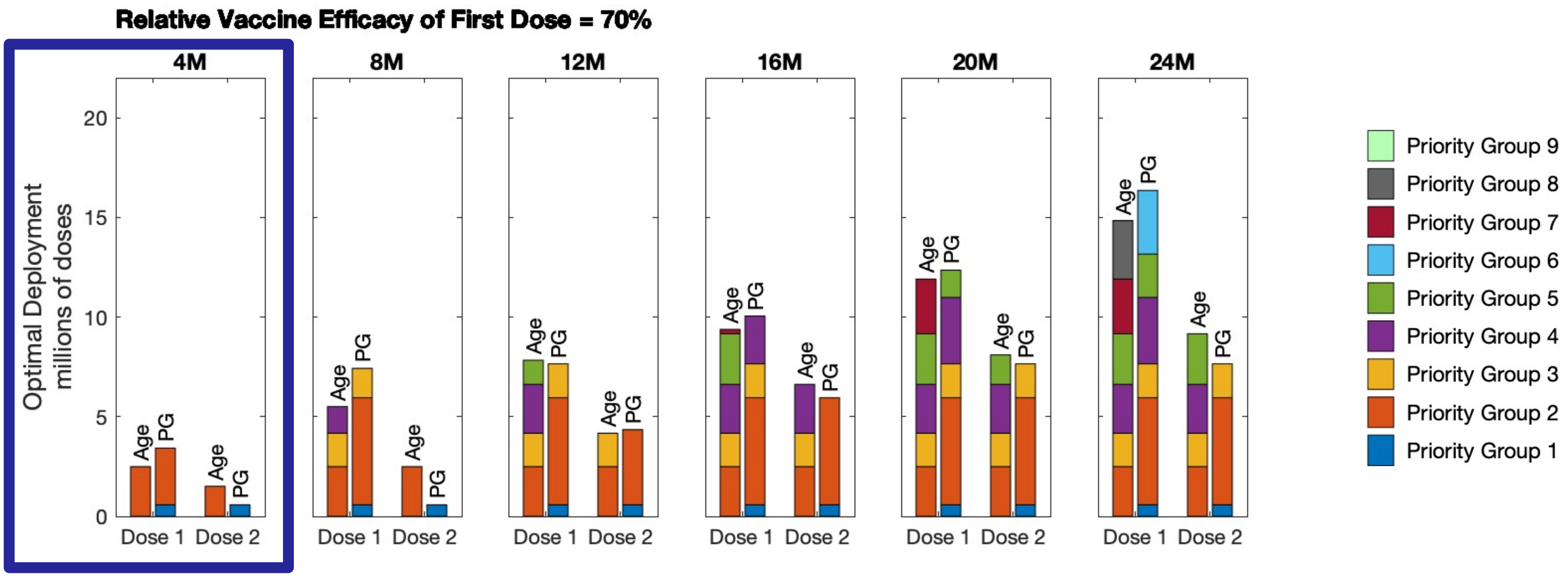

- At 70% relative vaccine efficacy of first dose, we observe a strong tendency to offer second doses shortly after the first.

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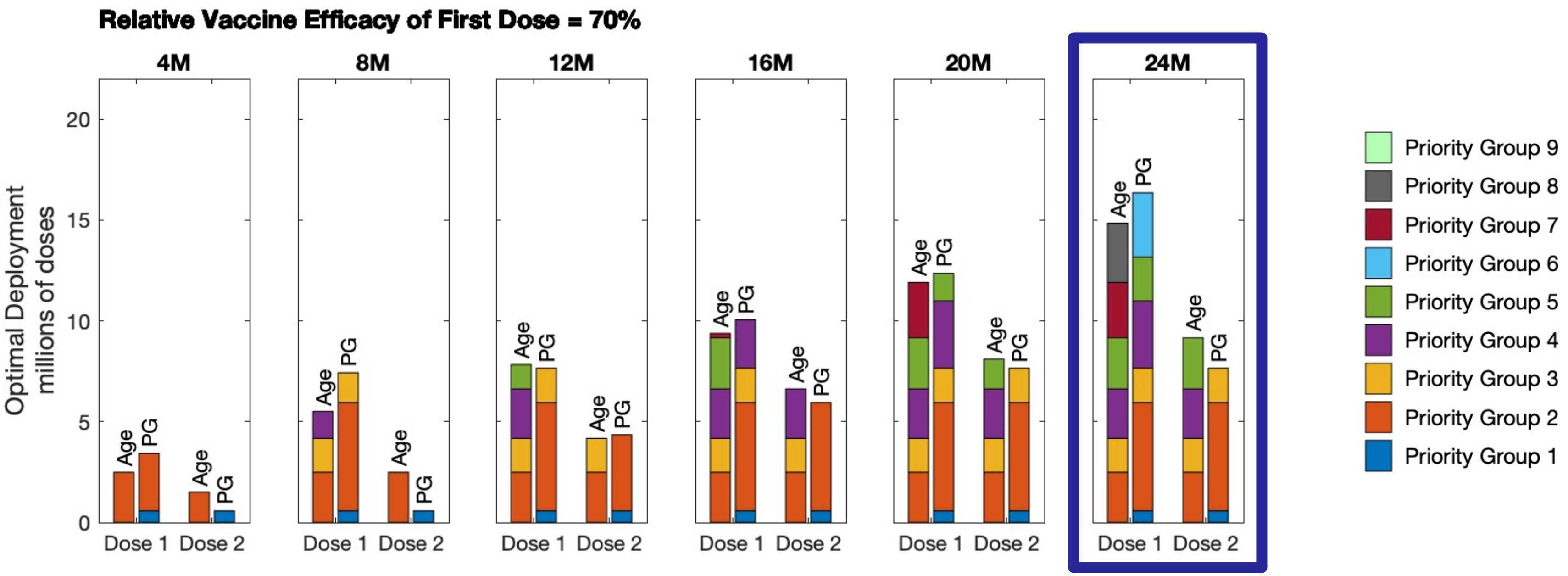
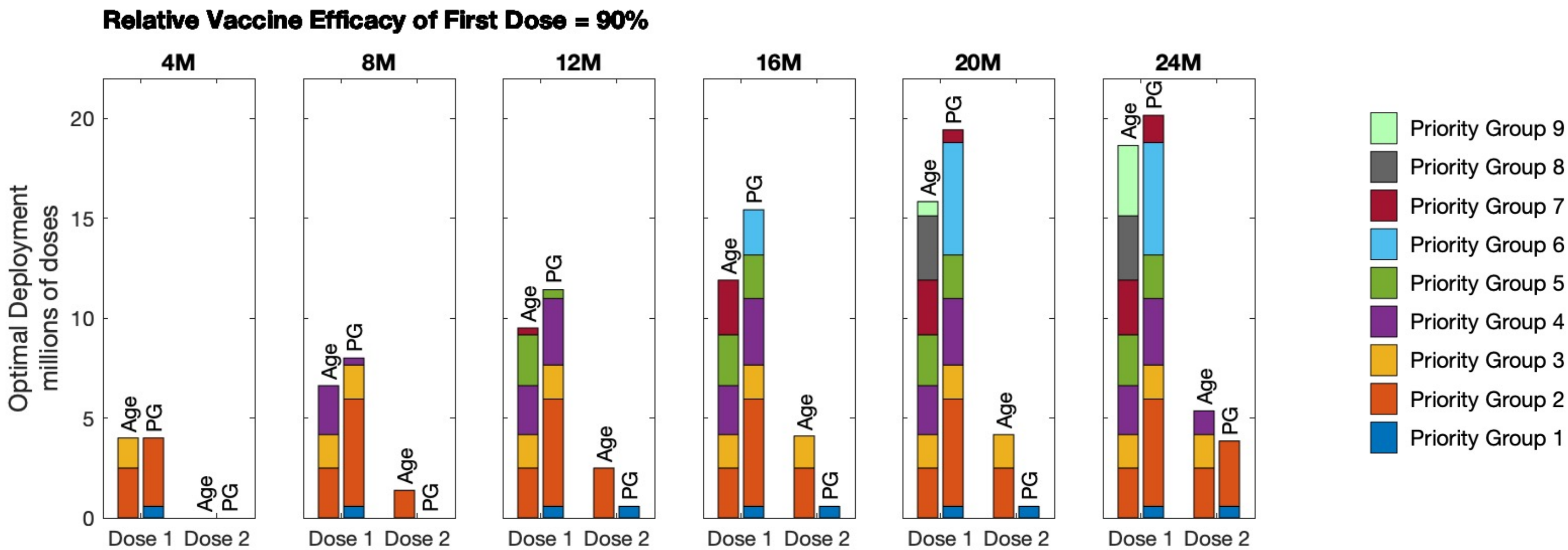


- ➢ At 70% relative vaccine efficacy of first dose, we observe a strong tendency to offer second doses shortly after the first.

Heterogeneous allocation strategy

Figure 5: Optimal deployment of vaccine for the two different priority group estimates and a 90% relative vaccine efficacy of first dose. Left bars correspond to age group only estimate and right bars correspond to Priority Group estimates.



➢ For a higher relative first dose efficacy (90% presented here), there is more of a delay before it becomes optimal to give second vaccine doses.

Summary

(1) Vaccine priority data and simulation outline

- Produced two sets of population and priority group COVID-19 mortality risk estimates for England;
- Focused on COVID-19 mortality using the relative risk of infection followed by death for each of the nine JCVI priority groups.

(2) Homogeneous vaccine allocation strategy

- Prioritising two doses preferred for a low relative efficacy from first dose and with greater availability of doses.

(3) Heterogeneous vaccine allocation strategy

- For relatively high protection from the first dose (compared to the efficacy derived from two doses), a substantial number of first doses should be administered before attention switches to second doses.

Limitations and further work

- A lack of a dynamic perspective means with this model we cannot address questions that relate to the precise timing of vaccination.

- The prioritisation of first doses compared to second doses, for a given relative efficacy, may differ under an alternative metric(s).
  - We anticipate an objective of minimising life-years lost or COVID-19 morbidity to increase the prioritisation of first doses over second doses, with second doses in older individuals not generating the greatest benefit until a larger proportion of the population have been given first doses.

- Our analysis has been carried out using data corresponding to the population of England. These findings will not necessarily directly translate to other settings, in particular where the population structure and mortality rates are vastly different.

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- Zeeman Institute: SBIDER (for research by the group as part of the COVID-19 pandemic modelling response, see **https://tinyurl.com/sbiderCOVID19)**

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