Using R for mathematical modelling of SARS-CoV-2

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UNSW SYDNEY

But first…some intro to R

- What is R? A free software for analysing data and performing statistical analysis
- The basic functionality is in “base R” but there are thousands of additional packages that you install and load to do different, specialised things (we will use some packages today)
- Data, results, functions, etc in R are all named “objects”

Throughout the pandemic, ongoing questions about who should be prioritised for vaccine delivery, e.g.:

- Within countries (e.g. healthcare workers, the elderly, working-age, priority groups)?
- Equitable and efficient global distribution of doses?
- How to allocate doses once program is underway?

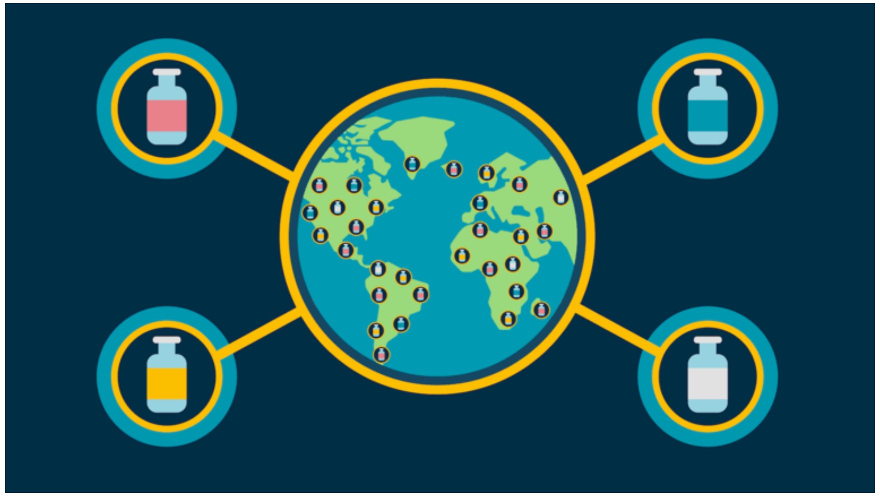
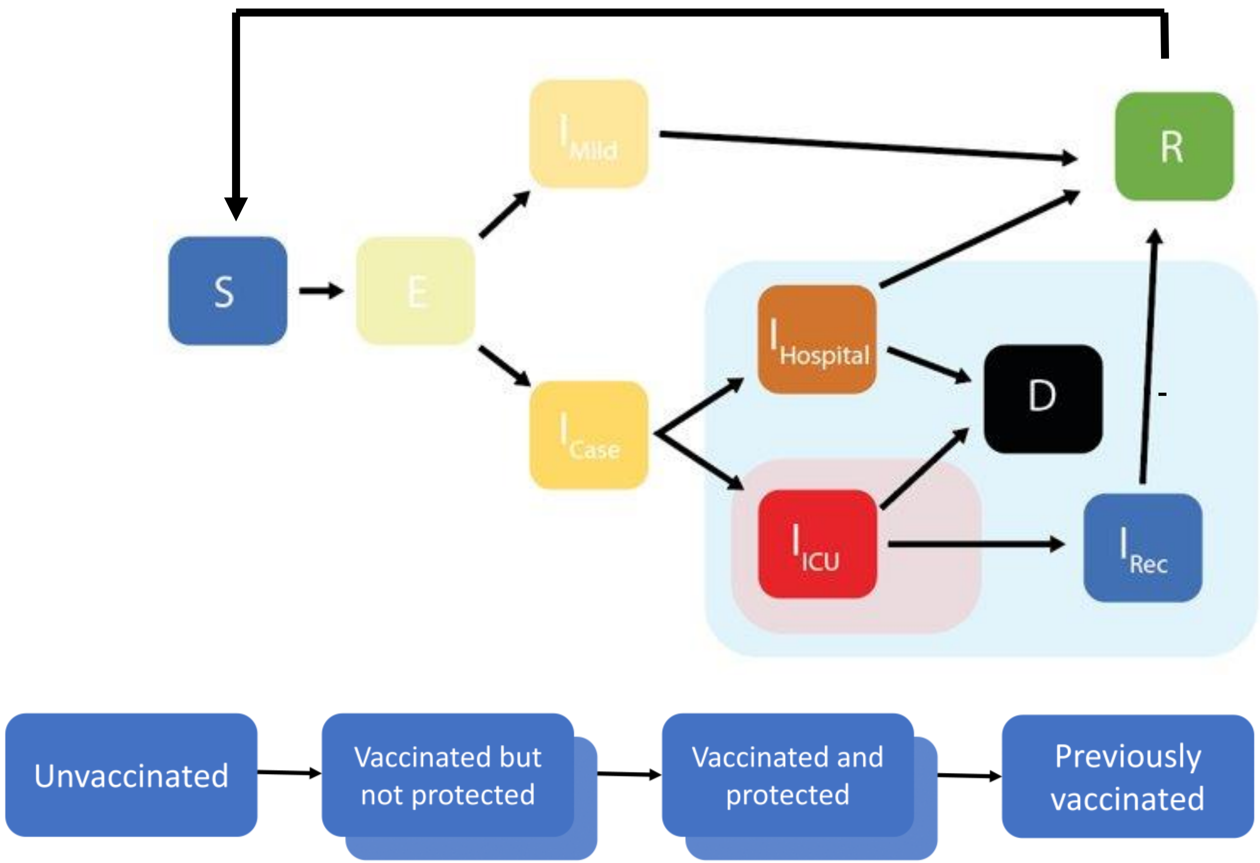


Image credit: wellcome.org

SARS-CoV-2 transmission model

- Age-structured deterministic SEIRS model (17 five-year age groups) with expanded healthcare component
- Age-dependent disease severity
- Setting-specific healthcare capacity, contact patterns, and demography
- Vaccination incorporated by replicating compartments across vaccine states
- Vaccines:
    - modes of action (infection, disease, and transmission)
    - age-targeting and prioritisation
- Fully open source as an R package



https://github.com/mrc-ide/nimue

Package developers: Oliver Watson, Patrick Walker, Charlie Whittaker, Peter Winskill, Giovanni Charles

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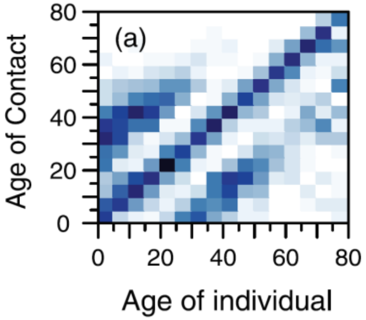
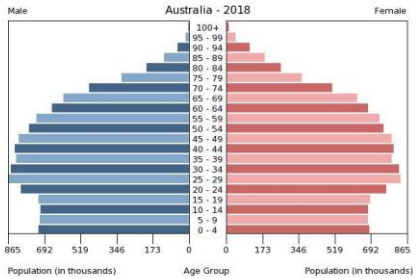
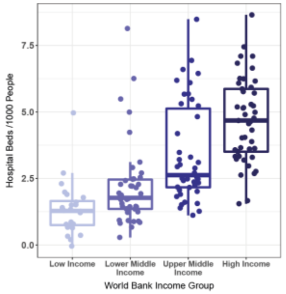
Imperial College London



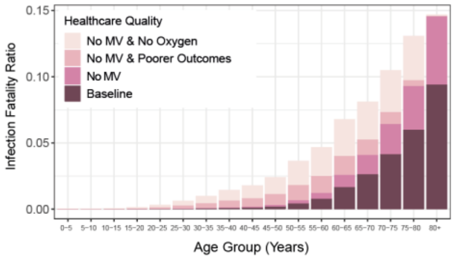
Patterns of mixing between age-groups.



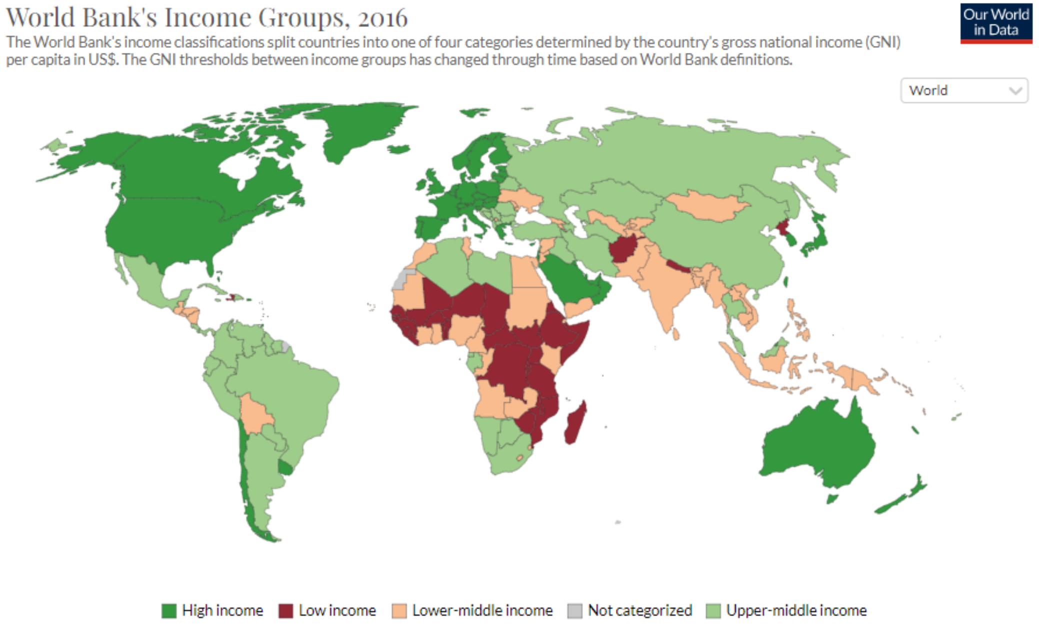
Age structure (UN World Population Prospects)

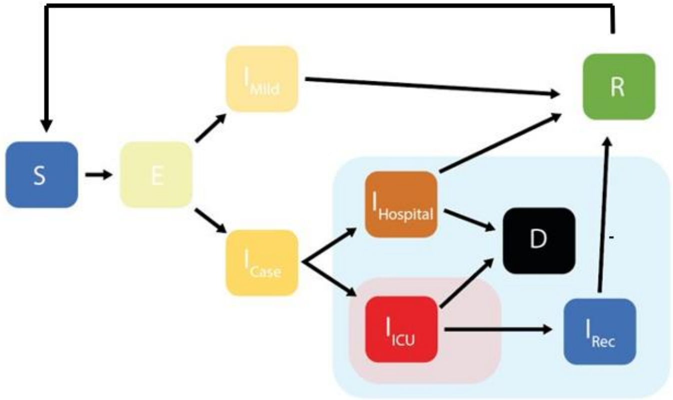


Setting specific healthcare capacity –for both general hospital and ICU beds.



Age- and healthcare-capacity-dependent COVID-19 mortality



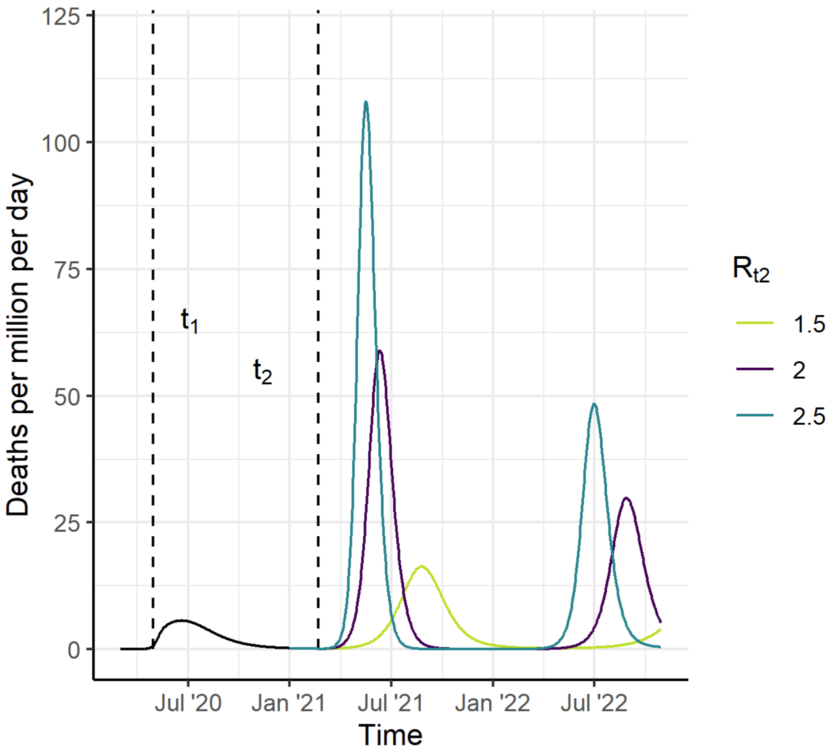


Walker, Whittaker, Watson *et al*. Science, 2020

User inputs

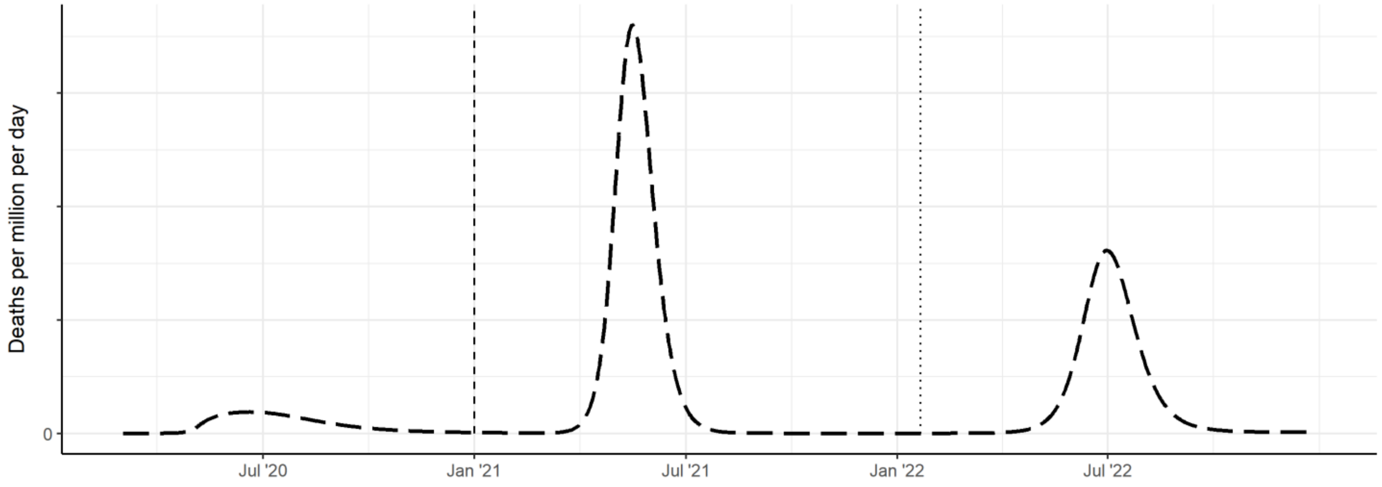
- Level of transmission each day (the daily Reproduction Number)
- The setting (a few ways to do this: can specify country or income setting)
- Vaccine doses available each day (if any)
- Vaccine uptake in each age group
- Who gets prioritised for the vaccine
- Vaccine characteristics (e.g. efficacy)

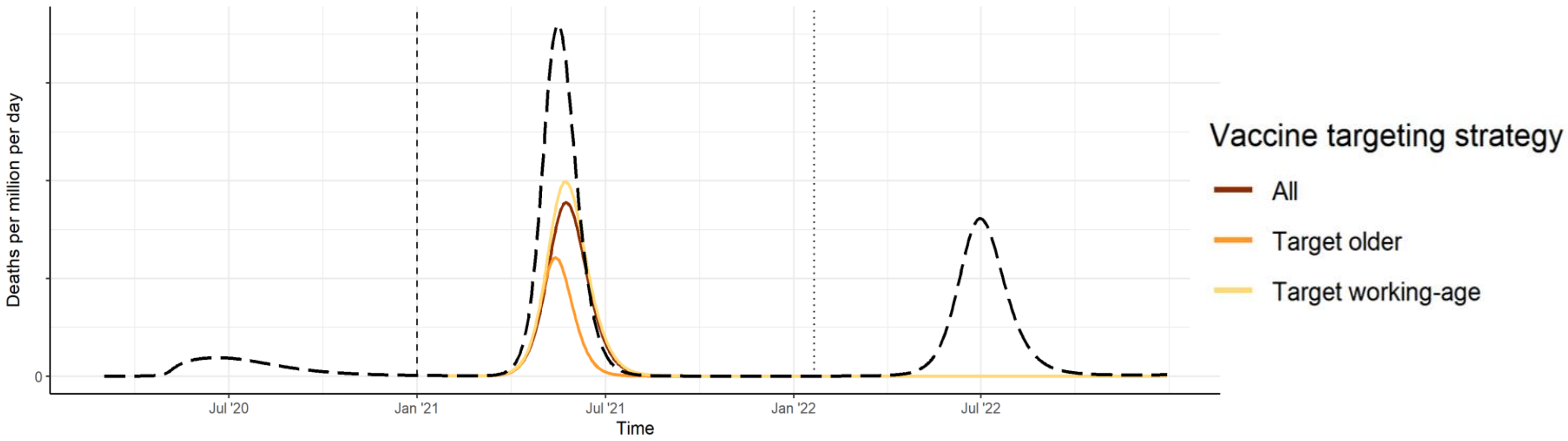
Example model outputs



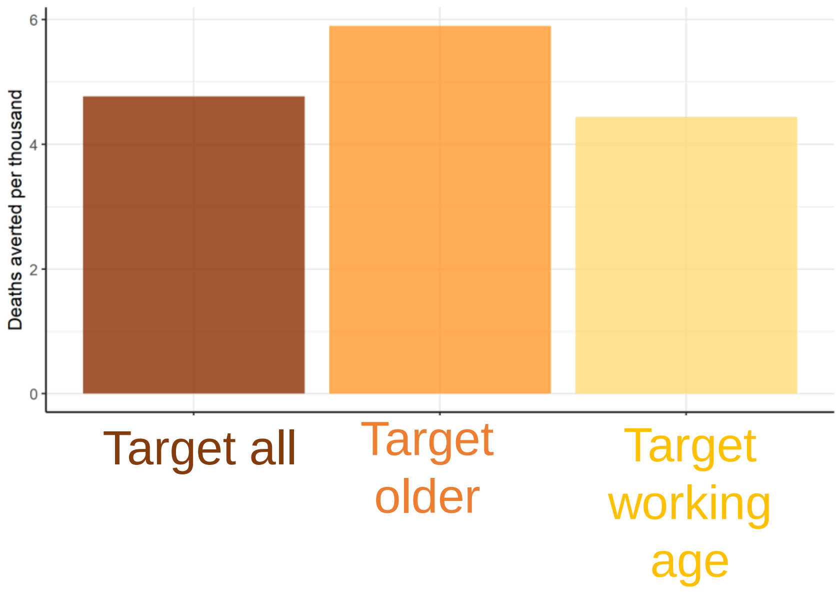
Example model outputs

Daily deaths



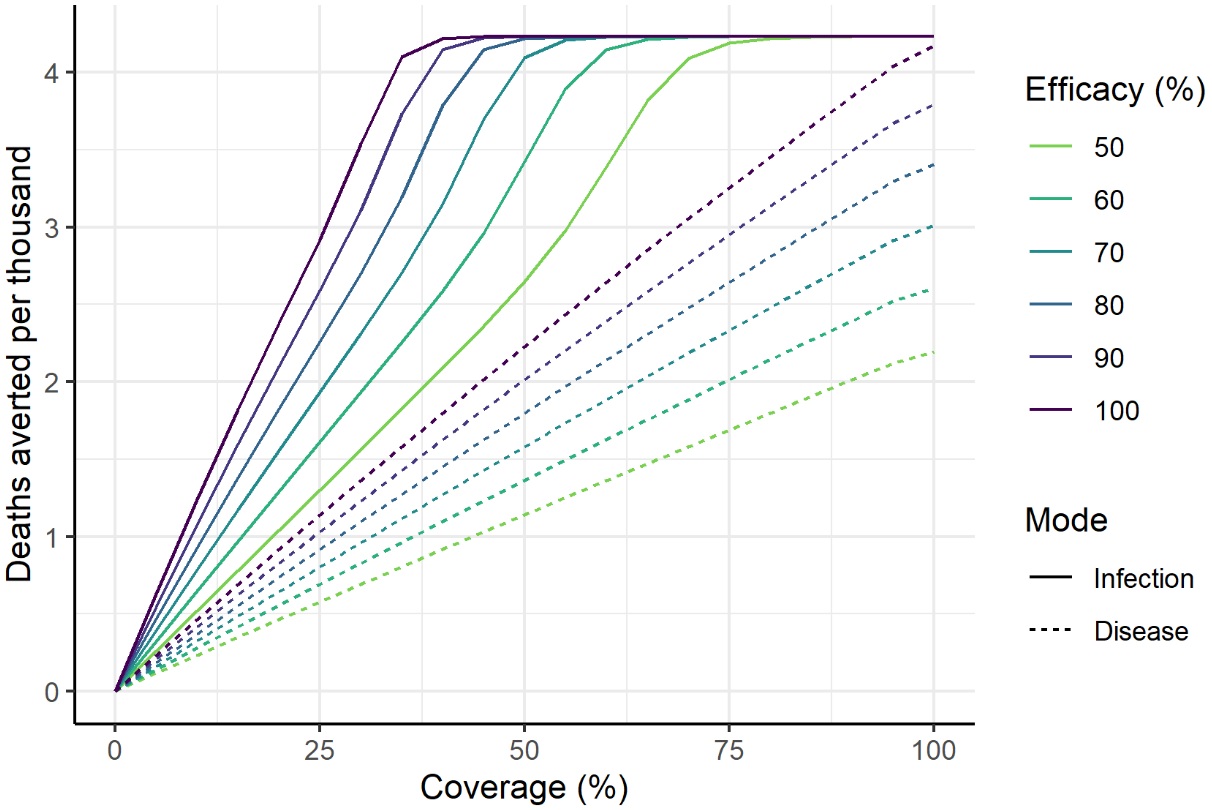


Deaths averted

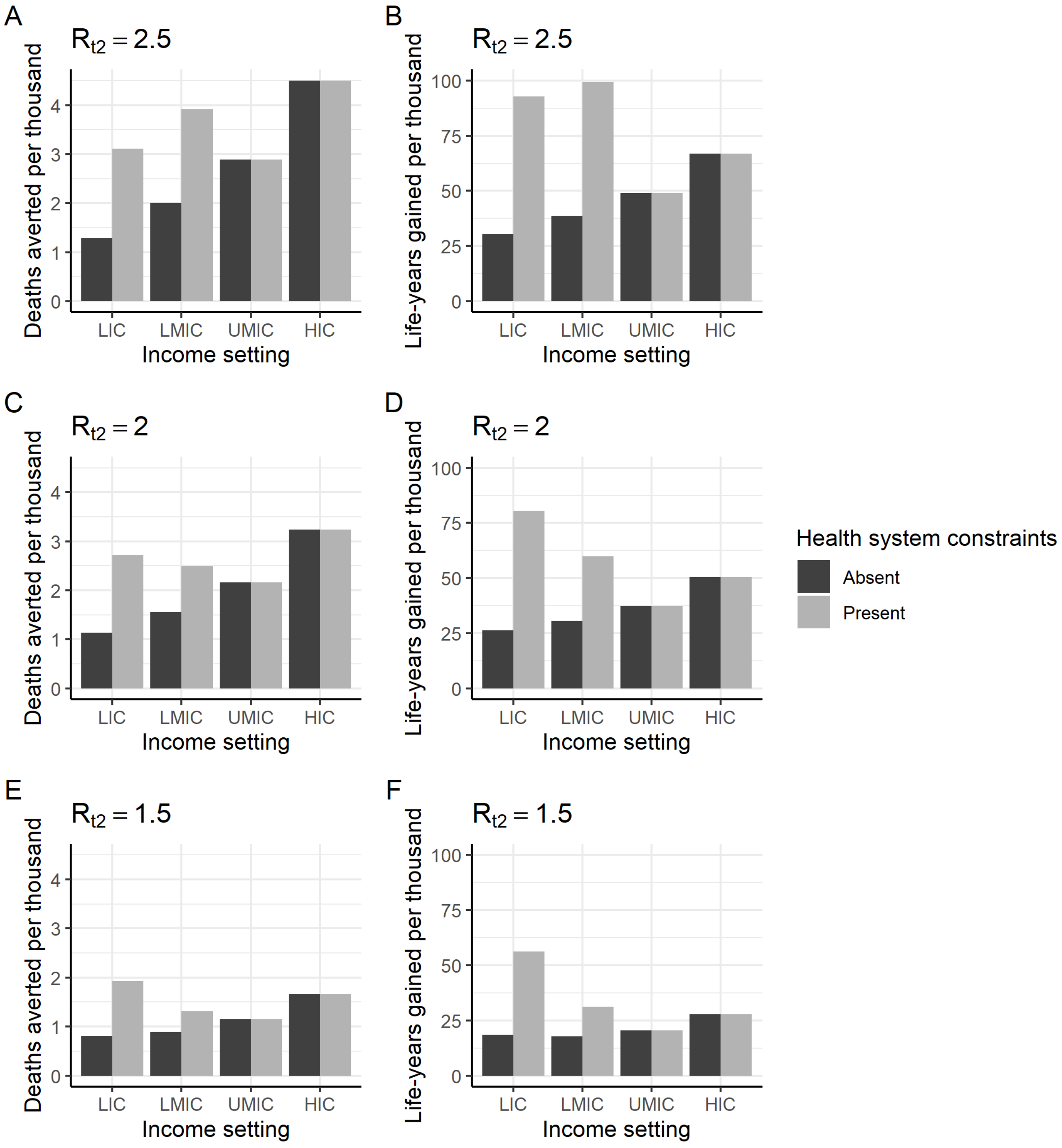


Hogan & Winskill et al, Vaccine 39 (2021) 2995-3006

Example model outputs



Example model outputs



Vaccine 39 (2021) 2995–3006

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Within-country age-based prioritisation, global allocation, and public health impact of a vaccine against SARS-CoV-2: A mathematical modelling analysis

Alexandra B. Hogan [a,1,*], Peter Winskill [a,1], Oliver J. Watson [a], Patrick G.T. Walker [a], Charles Whittaker [a], Marc Baguelin [a,c], Nicholas F. Brazeau [a], Giovanni D. Charles [a], Katy A.M. Gaythorpe [a], Arran Hamlet [a], Edward Knock [a], Daniel J. Laydon [a], John A. Lees [a], Alessandra Løchen [a], Robert Verity [a], Lilith K. Whittles [a], Farzana Muhib [b], Katharina Hauck [a], Neil M. Ferguson [a], Azra C. Ghani [a]

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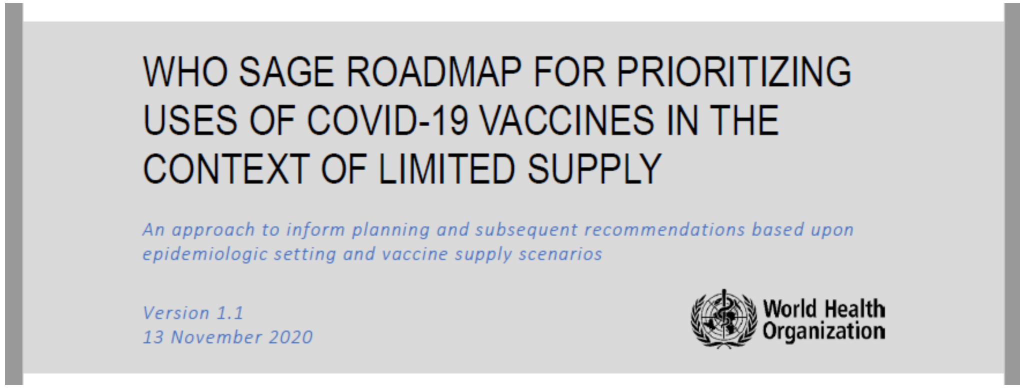
ABSTRACT

The worldwide endeavour to develop safe and effective COVID-19 vaccines has been extraordinary, and vaccination is now underway in many countries. However, the doses available in 2021 are likely to be limited. We extend a mathematical model of SARS-CoV-2 transmission across different country settings to evaluate the public health impact of potential vaccines using WHO-developed target product profiles. We identify optimal vaccine allocation strategies within- and between-countries to maximise averted deaths under constraints on dose supply. We find that the health impact of SARS-CoV-2 vaccination depends on the cumulative population-level infection incidence when vaccination begins, the duration of natural immunity, the trajectory of the epidemic prior to vaccination, and the level of healthcare available to effectively treat those with disease. Within a country we find that for a limited supply (doses for < 20% of the population) the optimal strategy is to target the elderly. However, with a larger supply, if vaccination can occur while other interventions are maintained, the optimal strategy switches to targeting key transmitters to indirectly protect the vulnerable. As supply increases, vaccines that reduce or block infection have a greater impact than those that prevent disease alone due to the indirect protection

Policy impact

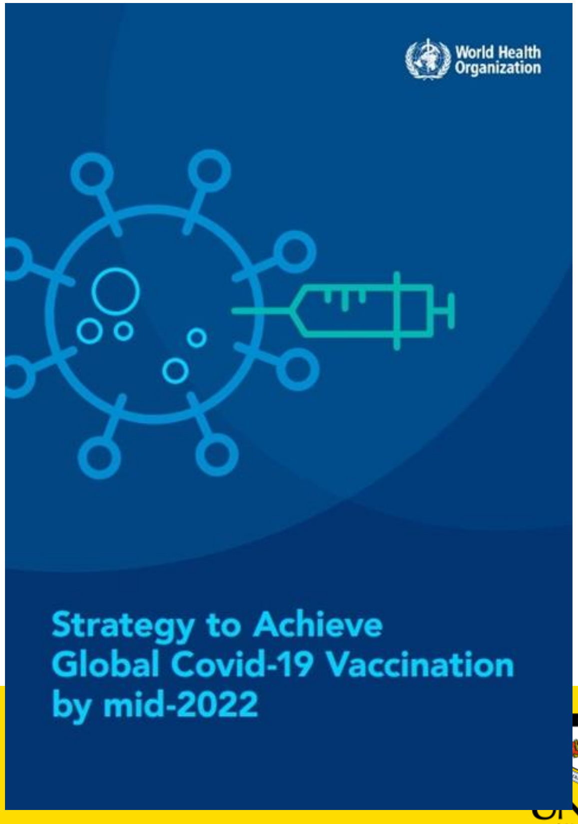

WHO SAGE ROADMAP FOR PRIORITIZING USES OF COVID-19 VACCINES IN THE CONTEXT OF LIMITED SUPPLY

An approach to inform planning and subsequent recommendations based upon epidemiologic setting and vaccine supply scenarios

Version 1.1
13 November 2020

World Health Organization

- Collaborative work (alongside outputs from other groups globally, incl. Australia)
- Formed part of the evidence base for global health policy guidance on COVID-19 vaccination
- “WHO SAGE Roadmap for Prioritizing Uses of COVID-19 Vaccines in the Context of Limited Supply” (published Nov 20, subsequently updated)*
- “WHO Strategy to Achieve Global Govid-19 Vaccination by mid-2022” (published Oct 21)^



*https://apps.who.int/iris/handle/10665/341448
^https://www.who.int/publications/m/item/strategy-to-achieve-global-covid-19-vaccination-by-mid-2022

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Jameel Institute

Combating disease threats worldwide

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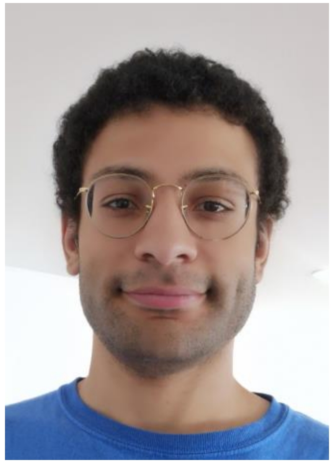

Giovanni Charles

Dr Oliver Watson

Resources

- Code for today's session:

https://github.com/abhogan/covid_model_workshop

- Paper on which today's modelling is based:

https://www.sciencedirect.com/science/article/pii/S0264410X21004278?via%3Dihub

- Code base for the paper above:

https://github.com/mrc-ide/covid_vaccine_allocation

- Documentation for the package *nimue:*

https://mrc-ide.github.io/nimue/

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