How to allocate vaccines across countries?

Manuel Huth
University of Bonn

ORCHESTRA

Overview

General question	How to efficiently allocate vaccines?
Current practice	Constant fraction based on population size.
Our research	Is there a *better* solution than the current practice?
Methods	Simulation of ODE compartment models.
Preliminary findings	In our model, a (pareto) improvement is possible.

Model structure

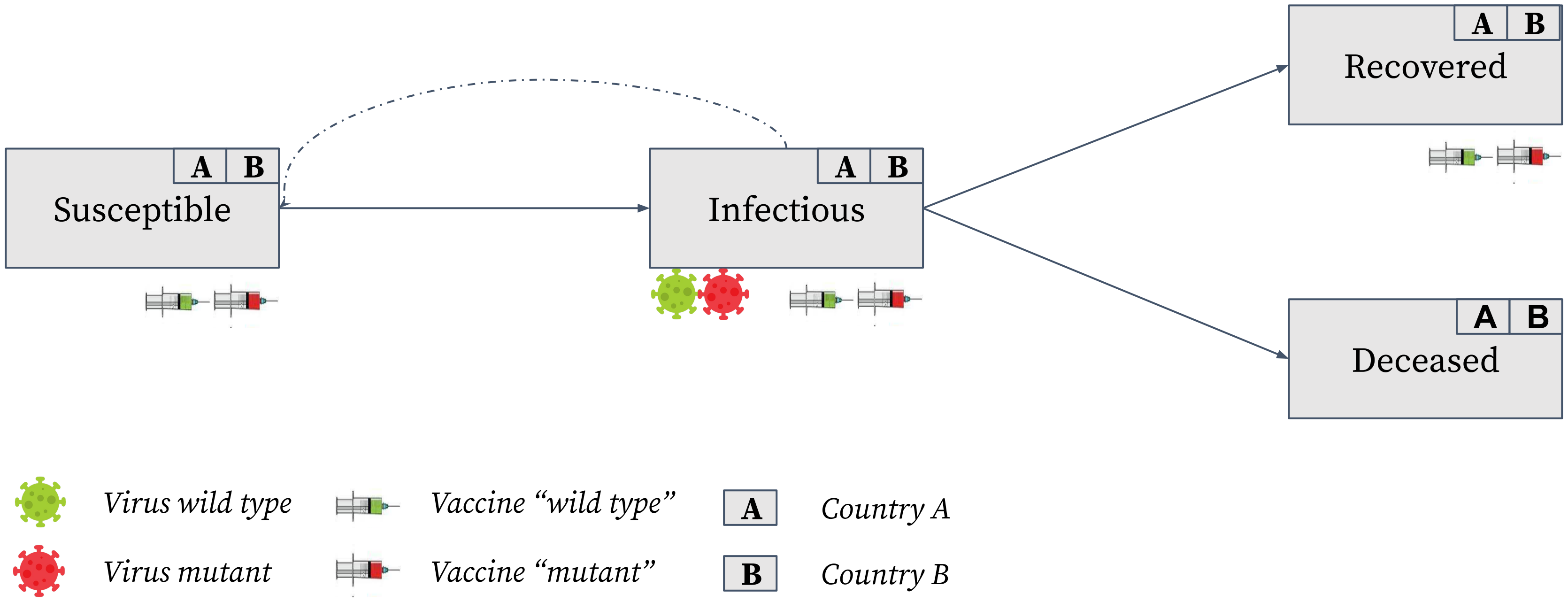


Figure 1 - Model compartments for a world with two countries A and B.

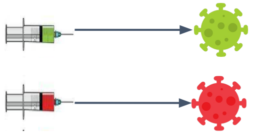
Simulation setup

1) Vaccine implementation

- Continuous inflow of vaccines
- Logistically transformed cubic hermite splines.
- Domain of Polynomials are intervals with length of 14 days.

2) Vaccine properties

- Vaccines decrease infection probability by 80% and probability of dying by 90%.
- No cross-effectiveness of vaccines.



3) Parameters

- The reproduction number is 3.0[1] for the wild type and 3.6 for the mutant.
- Start with 8 million susceptible individuals in each country.
- Country A has one wild type and Country B has one mutant case at the start.

4) Objective

- Minimize the total number of deceased individuals.
- Optimize over boundary conditions of splines.
- Consider only allocations that yield a pareto improvement.

[1]Robert Koch Institute (2021)

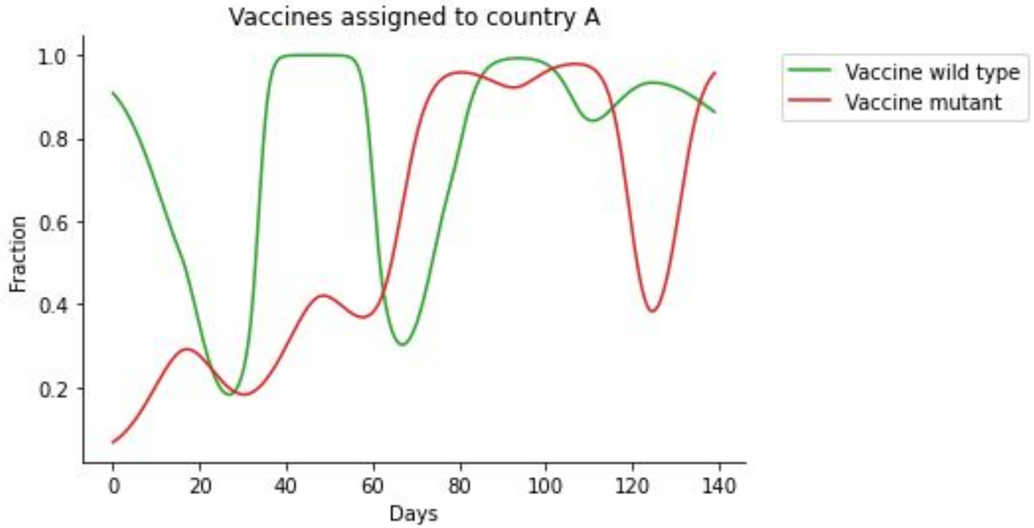
RCHESTRA

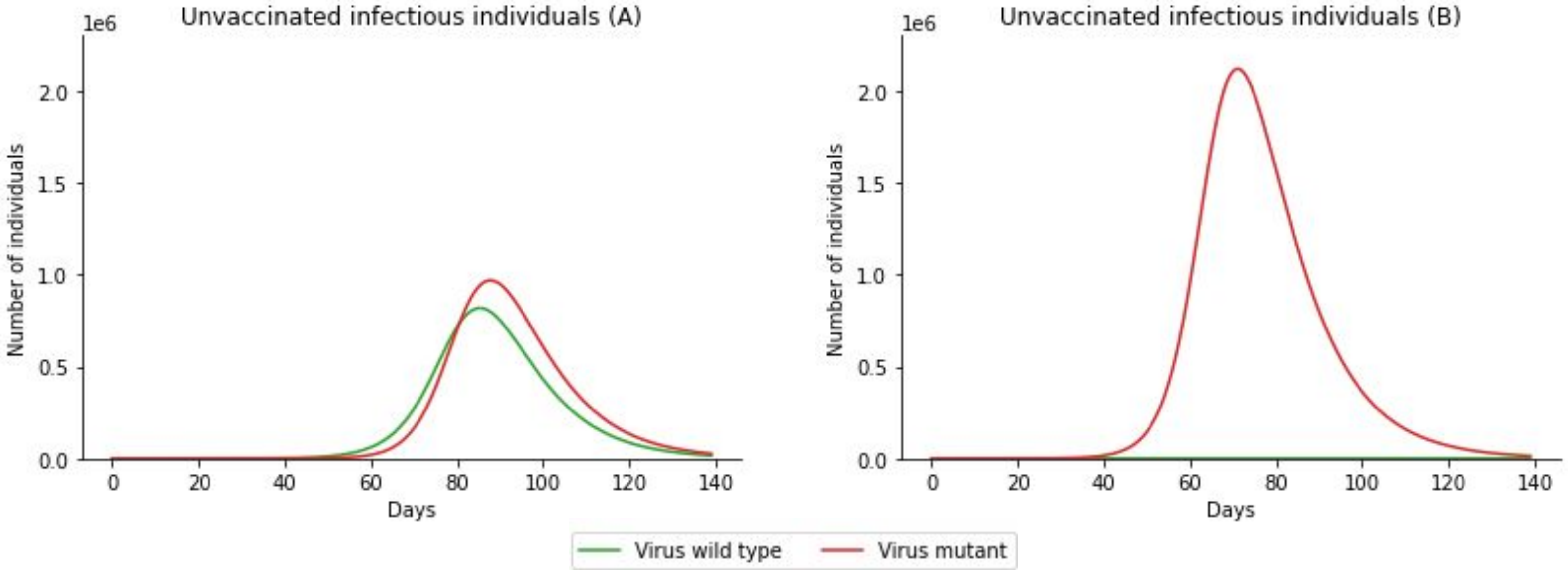
Results for different policies

	Current policy	*Optimal policy*	*One Vaccine per country*
Deceased country A	206,562	204,607	218,045
Deceased country B	208,782	201,888	186,863
Total	414,344	406,495	404,908

Table 1 - Deceased individual dependent on vaccination strategies.

Optimal allocation





How to allocate vaccines across countries?

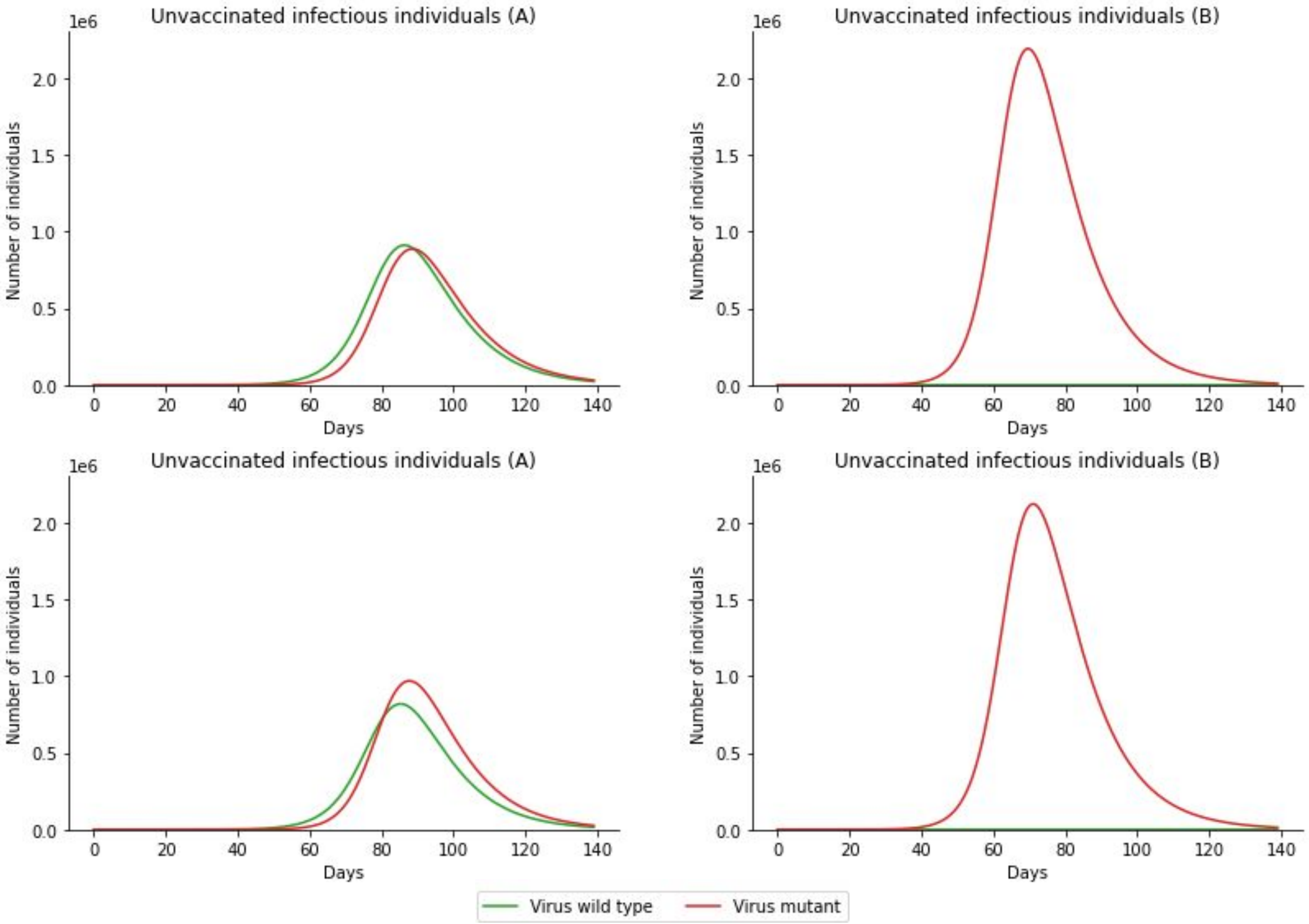
Manuel Huth
University of Bonn

Additional material

Unvaccinated infectious individuals

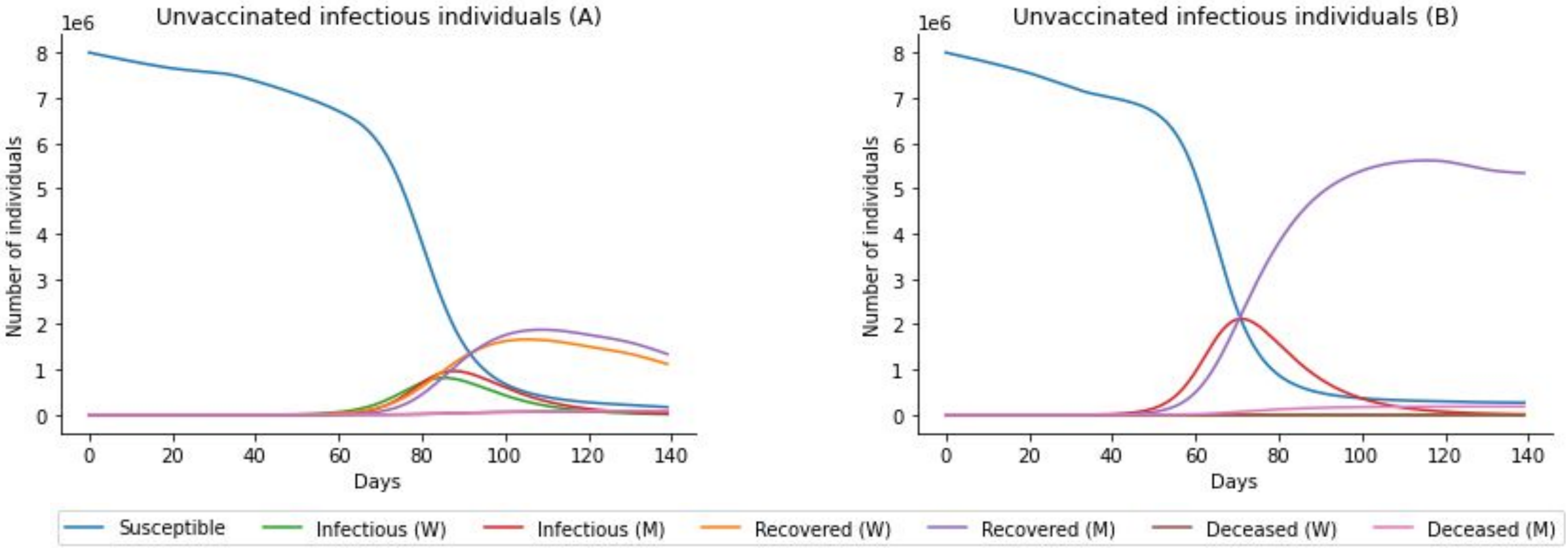
Current strategy

Optimal strategy



RCHESTRA

Compartments in the optimal setup



Splines

1) Basis polynomials

$$b_1(t) = 2t^3 - 3t^2$$
$$b_2(t) = t^3 - 2t^2 + t$$
$$b_3(t) = -2t^3 + 3t^2$$
$$b_4(t) = t^3 - t^2$$

2) Finite difference approximation

$$P_1'(t_1) \approx \frac{P_2(\theta;t_2) - P_1(t_1)}{t_2 - t_1}$$
$$P_i'(\theta;t_i) \approx \frac{1}{2}\left[\frac{P_{i+1}(t_{i+1}) - P_i(t_i)}{t_{i+1} - t_i} + \frac{P_i(t_i) - P_{i-1}(t_{i-1})}{t_i - t_{i-1}}\right]$$
$$P_z'(t_{z+1}) \approx \frac{P_{z+1}(t_{z+1}) - P_z(t_z)}{t_{z+1} - t_z}$$

3) Polynomials

$$\begin{aligned} P_i(\theta;t) = {} & b_1(t')\overbrace{P_i(t_i)}^{\theta_i} \\ & + b_2(t')(t_{i+1} - t_i)P_i'(\theta;t_i) \\ & + b_3(t')\underbrace{P_{i+1}(t_{i+1})}_{\theta_{i+1}} \\ & + b_4(t')(t_{i+1} - t_i)P_i'(\theta;t_{i+1}) \end{aligned}$$

$$t' = (t - t_i)/(t_{i+1} - t_i)$$

4) Exemplary spline