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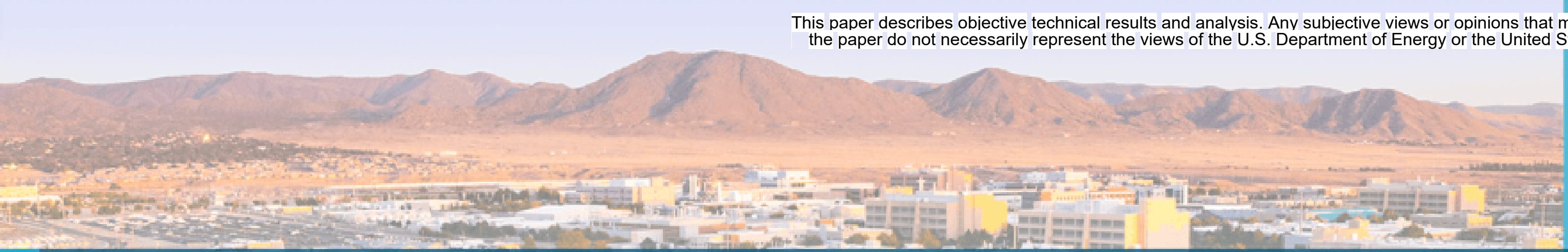

Sandia National Laboratories

Evaluation of the US COVID-19 vaccine allocation strategy

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Introduction: Background to CDC Allocation

- Advisory Committee on Immunization Practices (ACIP)
  - Ensure equity in allocation and distribution
  - Reduce the burden on vulnerable groups
  - Maintain infrastructure and social order
  - Reduce mortality
  - Ensure transparency

- 4 Phases:
  - 1a. Healthcare personnel, and long-term care facility residents
  - 1b. Frontline essential workers, and 75+ year-olds
  - 1c. Other essential workers, 16-64 year-olds with comorbidities, and 65-74 year-olds
  - 2. 16-64 year-olds without comorbidities

Introduction: Model Overview

- Compartmental Disease Model (20 compartments)
- US population stratified by characteristics in CDC allocation (17 groups)
- Four phases
- Important characteristics of COVID-19 pandemic:
  - Age-dependent susceptibility to infection
  - Age- and comorbidity-dependent CFR
  - Social contact rates
  - Case-dependent social-distancing levels
  - Speed of the vaccine roll-out
  - Vaccine hesitancy
  - Time-varying transmissibility of virus

Introduction: Model Overview

- ~17.5 million potentially optimal strategies
  - $4^{17} \approx 1.7 \times 10^{10}$ total possible, then reduced
- Four primary metrics:
  - Total deaths
  - Total infections
  - Total cases
  - Years of life lost (YLL)
- Secondary metric: equitability
- Model parameters
  - Most derived from literature
  - Four parameters estimated using an elitist genetic algorithm, fit to data

Methods: 17 Population Groups

Stratify the US population by:

1. Age (4 classes)
   1. 0-15 years
   2. 16-64 years
   3. 65-74 years
   4. 75+ years
2. Comorbidity (2 classes: with and without)
3. Job type (4 classes in 16-64 age group)
   1. Healthcare workers
   2. Frontline essential workers
   3. Other essential workers
   4. All others
4. Living situation (2 classes in 65-74 and 75+ age groups: congested living or not)

Methods: 20 Compartments

S: Susceptible

E: Exposed, recently infected but not yet spreading the virus

P: Pre-clinical, not yet showing symptoms but spreading the virus

A: Asymptomatic, not symptomatic but spreading the virus

C: Clinical, symptomatic and spreading the virus

Q: Quarantine, symptomatic but not spreading the virus due to isolation or hospitalization

RC: Recovered after having shown symptoms

RA: Recovered after an asymptomatic infection

D: Dead

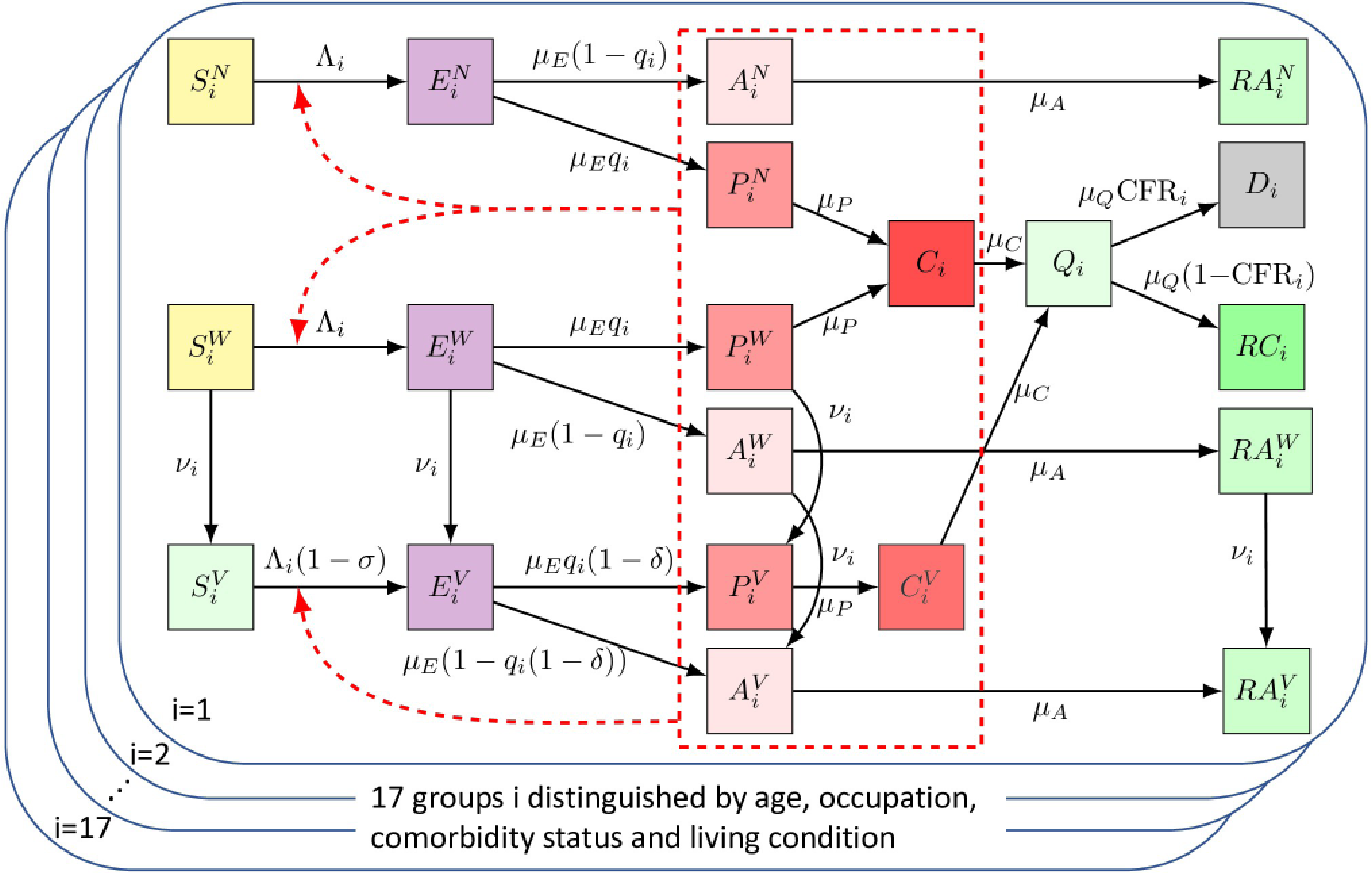
N: Not willing to be vaccinated

W: Willing to be vaccinated but not yet vaccinated

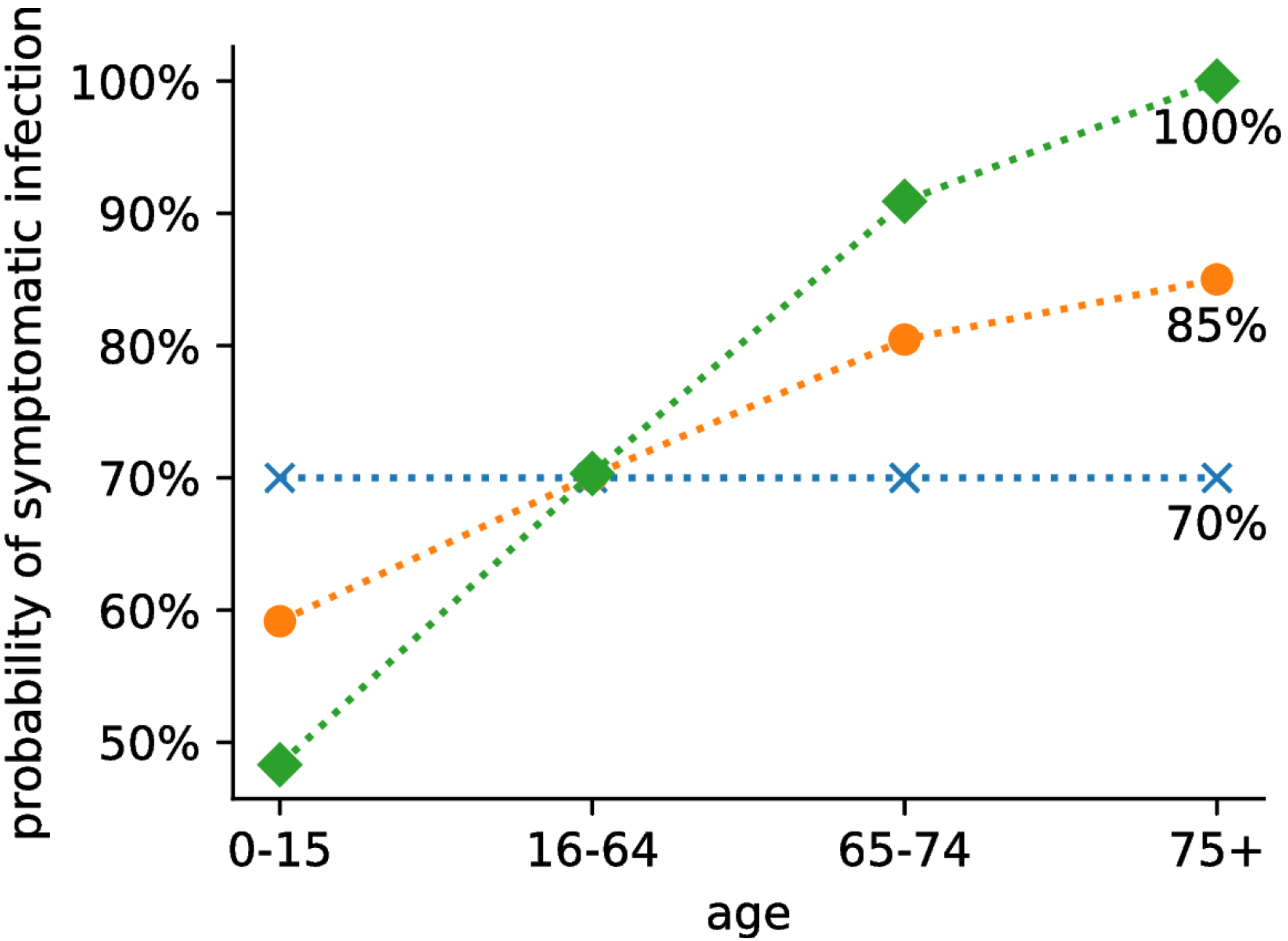
V: Vaccinated

$S^N, S^W, S^V, E^N, E^W, E^V, A^N, A^W, A^V, RA^N, RA^W, RA^V, P^N, P^W, P^V, C, C^V, Q, RC, D$

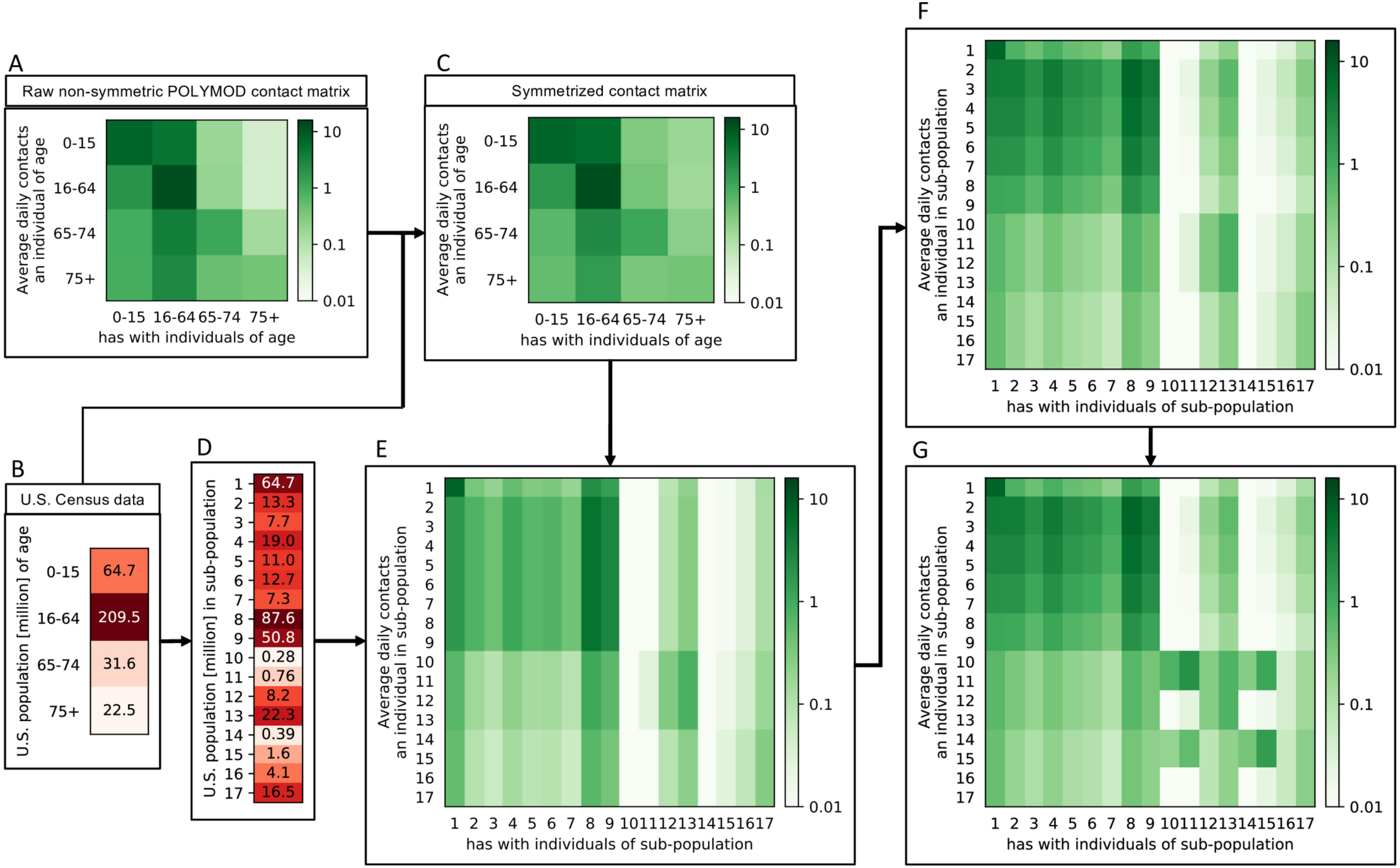
Methods: Model Schematic



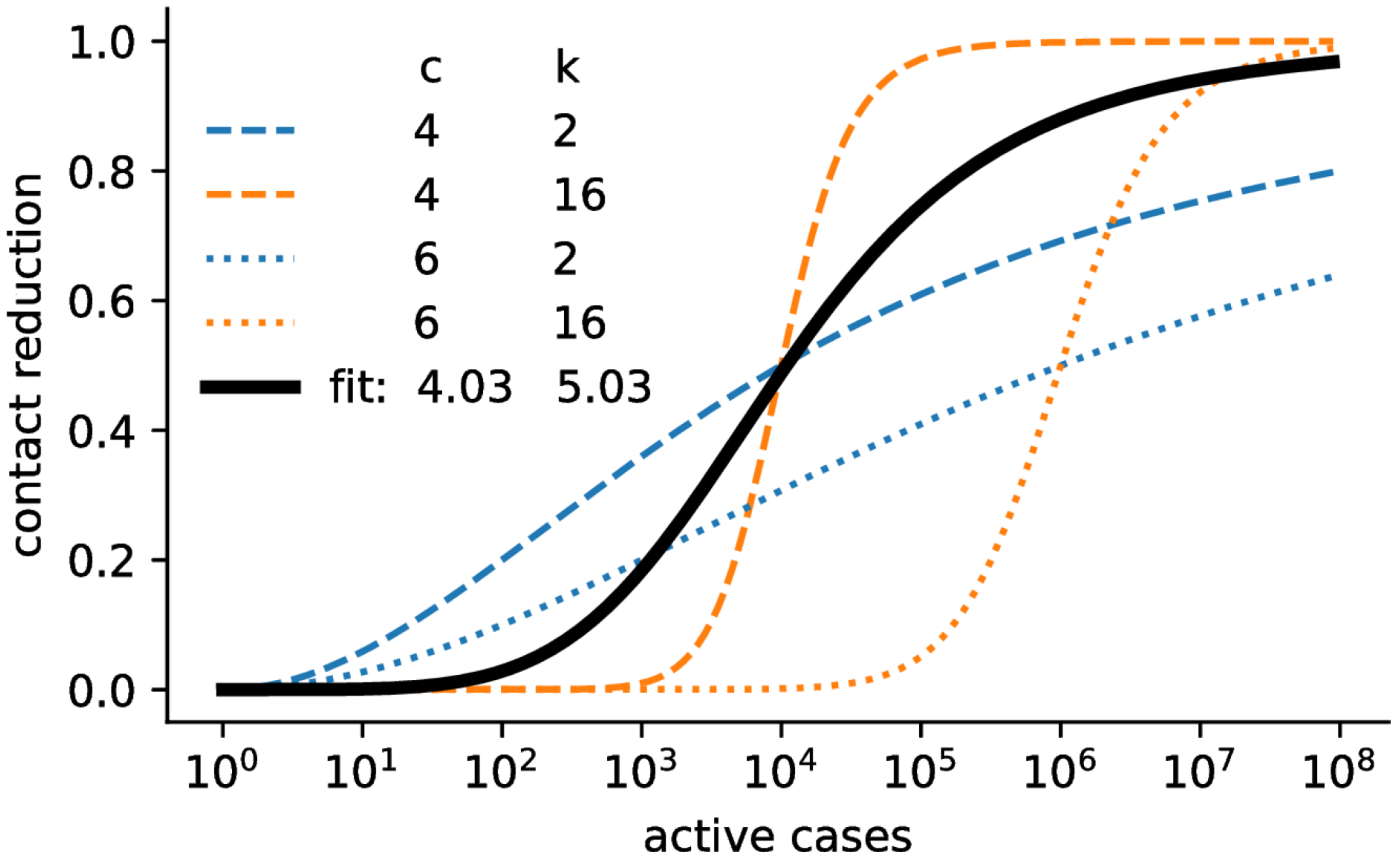
Methods: Age-Dependent Susceptibility



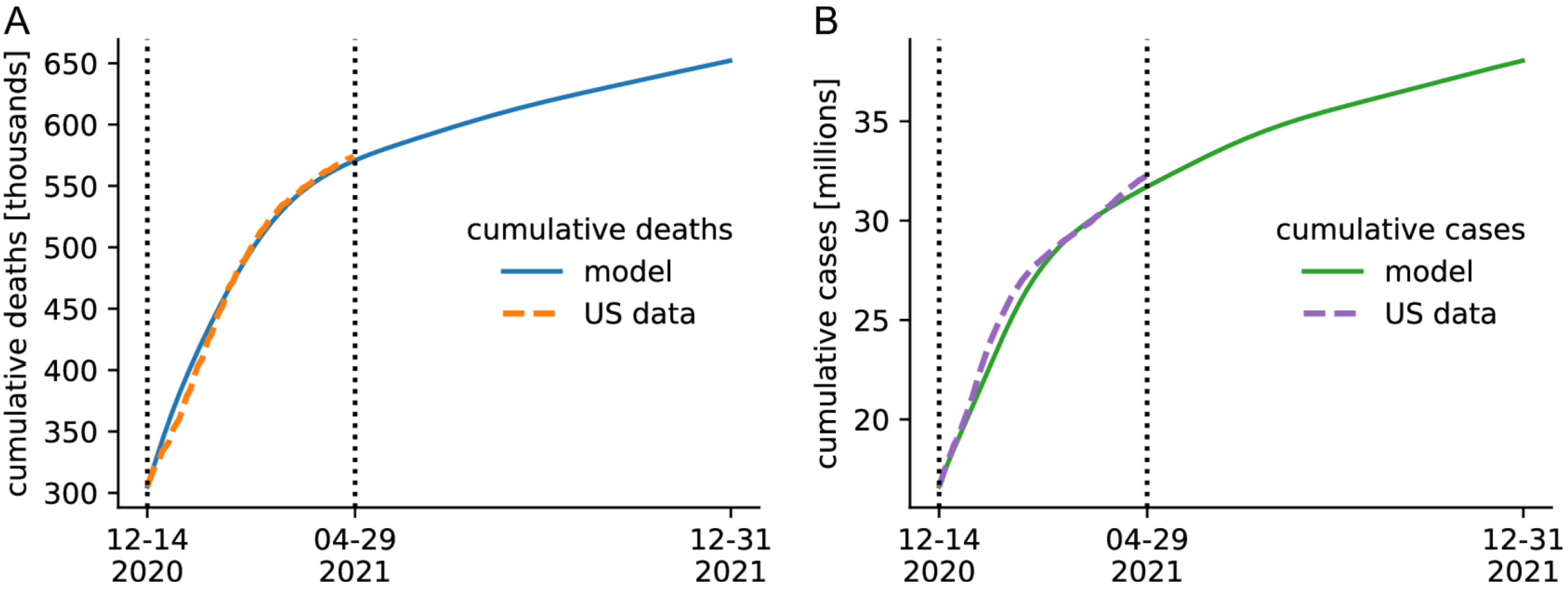
Methods: Contact Matrix



Methods: Case-Dependent Contact Reduction



Methods: Model Fit

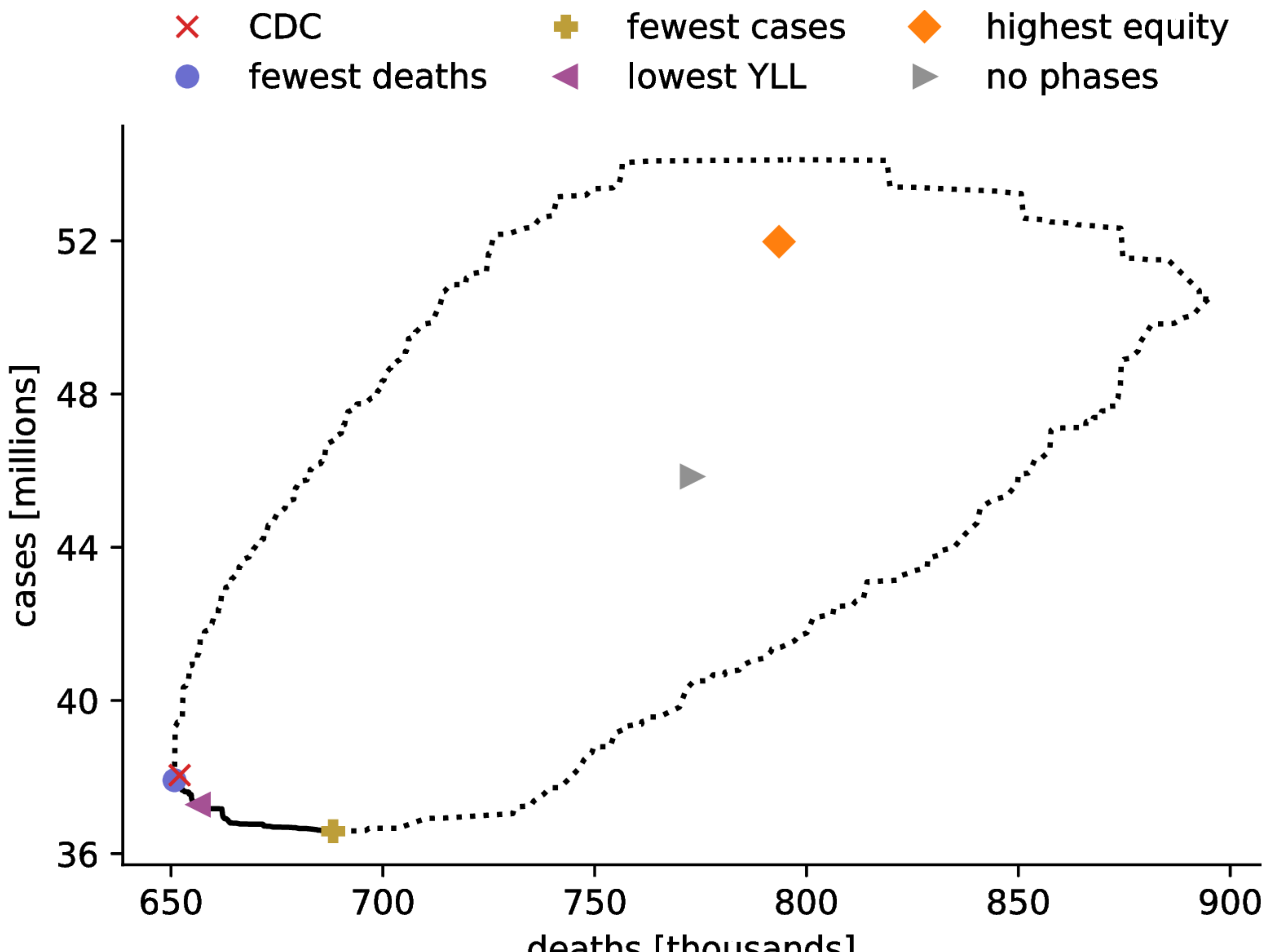


Results: Comparison of CDC and Optimal Strategies

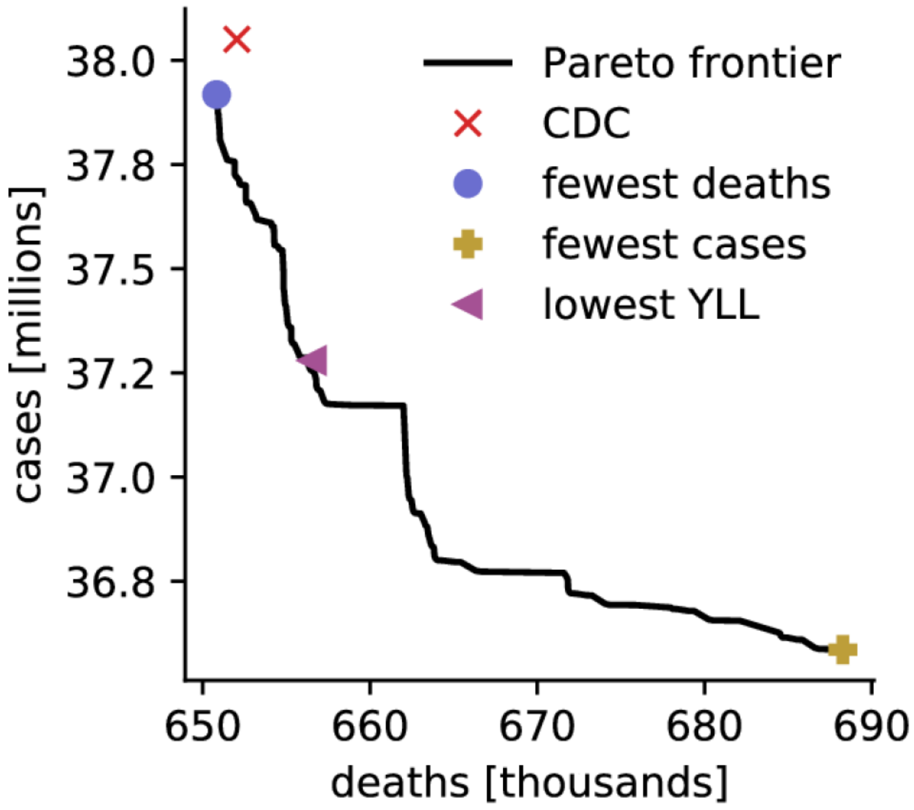
Age	Job / living situation	Comorbidity	Number of people [millions]	Sub-population ID in model	CDC allocation	fewest deaths [thousands]	lowest YLL [millions]	fewest cases [millions]	fewest infections [millions]
0-15	NA	NA	64.71	1	4	4	4	4	4
16-64	healthcare workers	no	13.29	2	1	1	1	1	1
		yes	7.71	3	1	1	1	1	1
	frontline essential workers	no	18.98	4	2	2	2	2	2
		yes	11.02	5	2	2	2	2	2
	other essential workers	no	12.66	6	3	3	3	2	2
		yes	7.34	7	3	3	2	2	2
	remaining people	no	87.61	8	4	4	4	3	3
		yes	50.85	9	3	3	3	3	3
65-74	congested living	no	0.28	10	1	2	3	3	3
		yes	0.76	11	1	1	2	3	3
	remaining people	no	8.20	12	3	3	4	4	4
		yes	22.34	13	3	3	3	4	4
75+	congested living	no	0.39	14	1	3	3	3	4
		yes	1.57	15	1	1	2	3	4
	remaining people	no	4.07	16	2	3	4	4	4
		yes	16.47	17	2	2	3	4	4
Respective outcome of specific allocation					**CDC**	652	11.6	38.1	56.4
					fewest deaths	651	11.6	37.9	56.2
					lowest YLL	657	11.5	37.3	55.3
					fewest cases	688	11.8	36.6	54.2
					fewest infections	695	11.9	36.6	54.2
% difference in outcome between specific and respective optimal allocation					**CDC**	0.19	0.97	4	4.07
					fewest deaths	0	0.67	3.64	3.74
					lowest YLL	0.88	0	1.9	2.08
					fewest cases	5.75	2.44	0	0.01
					fewest infections	6.73	2.84	0.03	0

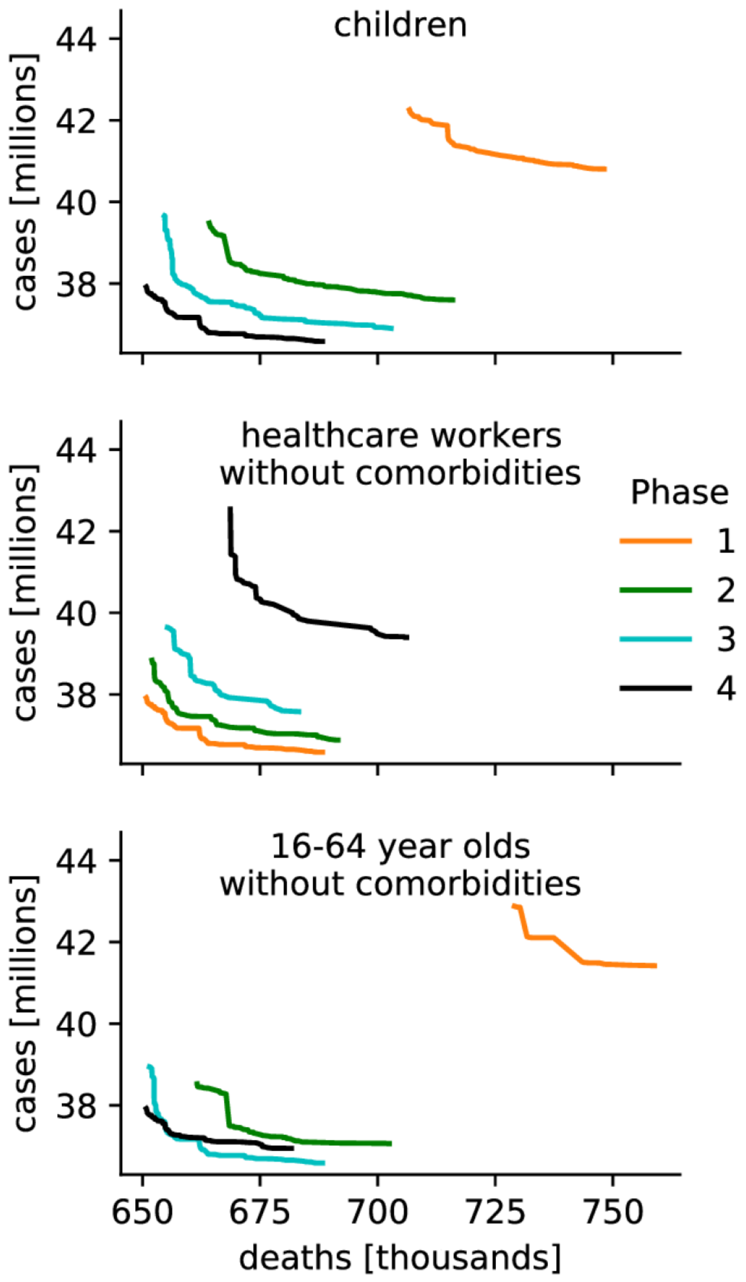
https://doi.org/10.1371/journal.pone.0259700.t002

Results: All Strategies

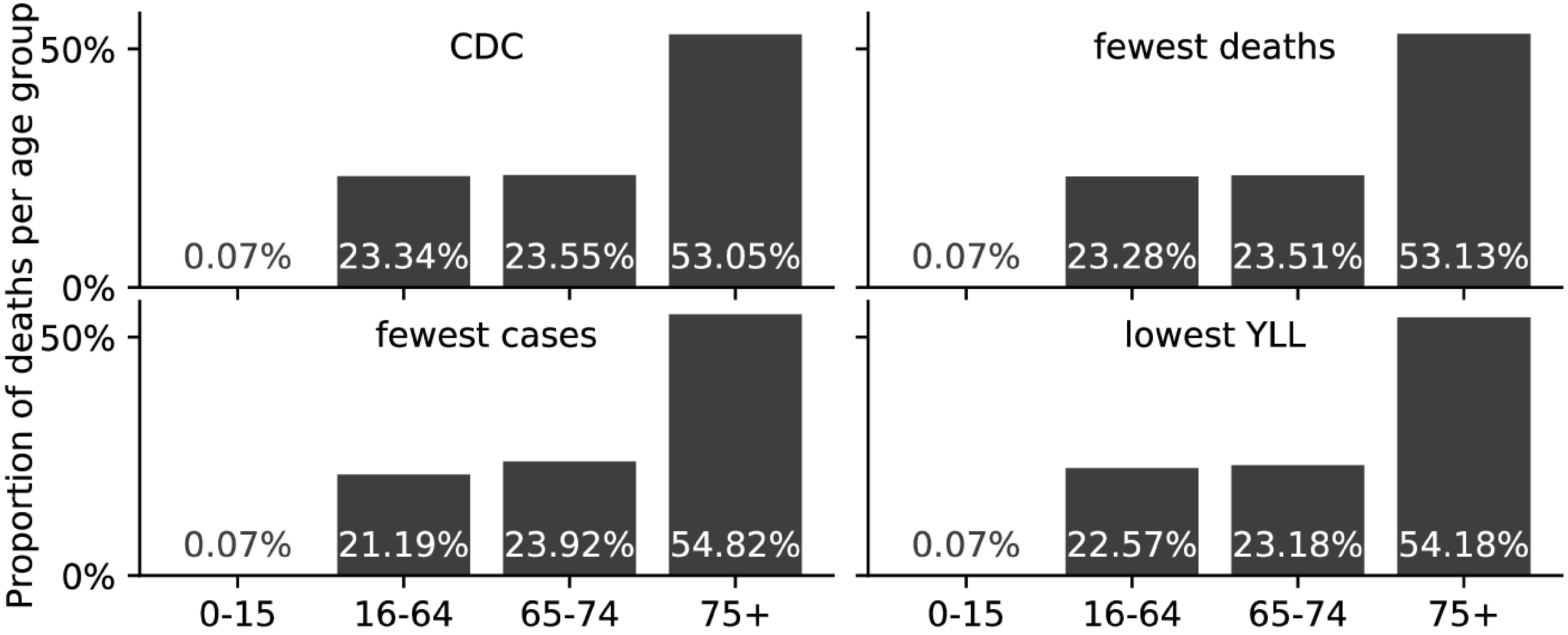


Results: Pareto Frontier





Results: Equity



Limitations

1. All sub-populations exhibit the same level of vaccine hesitancy
2. Vaccine hesitance does not change over time
3. Uncertainty in key model parameters:
    1. Contact matrix
    2. Contagiousness of asymptomatic individuals and vaccinated individuals
4. No reinfections
5. Vaccine is fully effective immediately after 1 dose

Sensitivity analysis

Extensions: Homophily & Contact Matrices

In the US, People of Color (POC) have been disproportionately affected by COVID-19

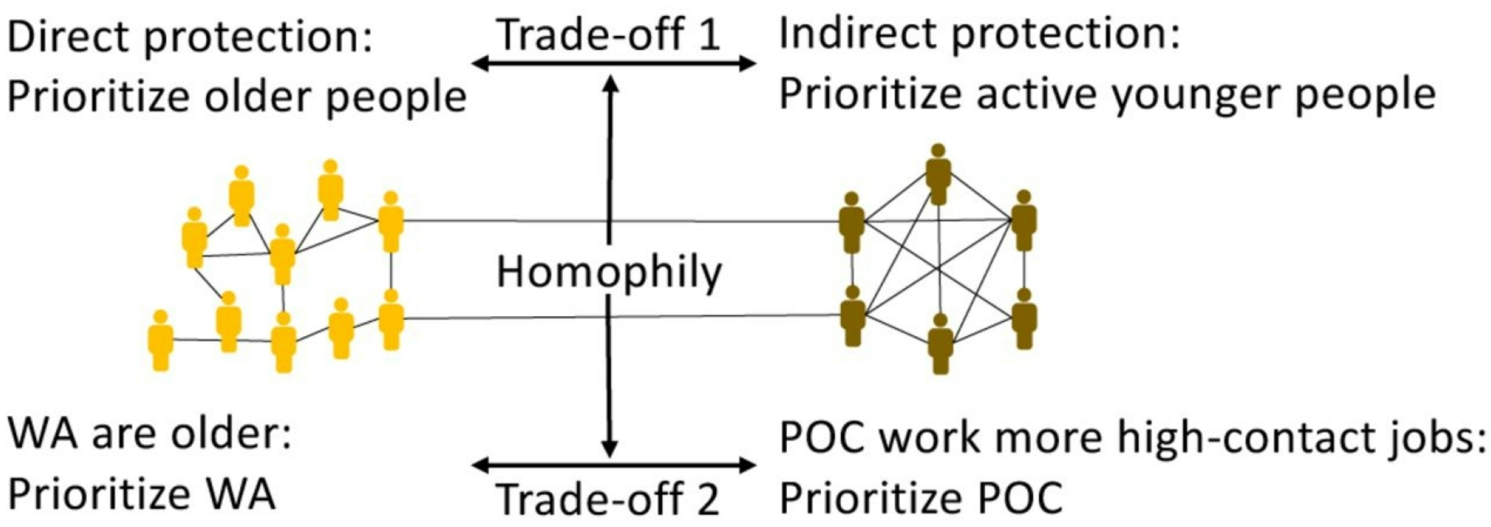
- As of 2022, POC comprise 34.1% of the US population, but suffered 42.2% of cases
- Studies from 2020:
  - Infection rate in predominately Black counties was 3x that of predominately white counties
  - Navajo Nation had more cases per capita than any US state
  - Black pop in Chicago is 30% but suffered over 50% of deaths
  - NYC 2x as many deaths per capita in Black and Latino pops than white pops
  - Across the US, the 20% of disproportionately Black counties account for 52% of cases and 58% of deaths

Why?

- Complex social and economic reasons, but:
  - POC tend to live in more crowded conditions
  - POC tend to work in more high-contact (high-risk) jobs

Extensions: Trade-offs in Vaccination Priorities

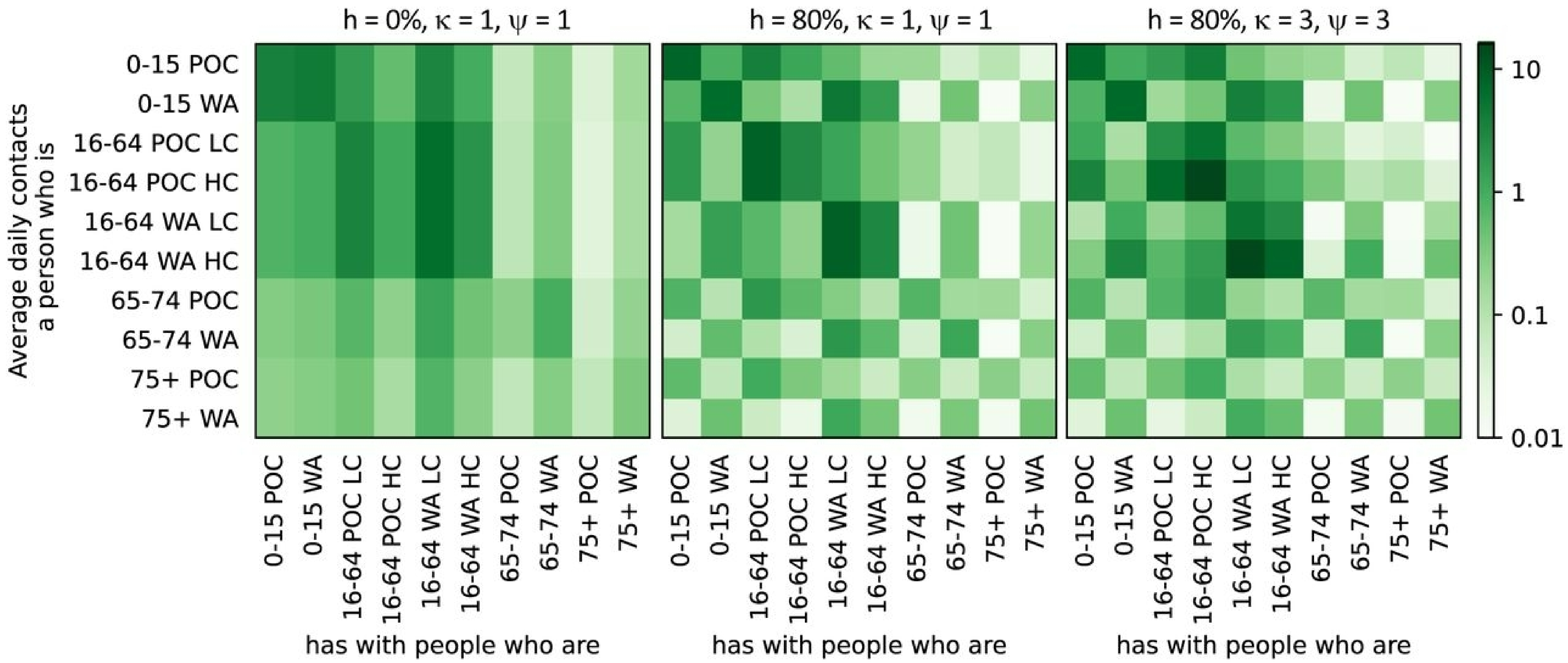
age	WA	POC	average daily contacts	CFR
0-15	55%	45%	14.0	0.01%
16-64	65%	35%	14.4	0.5%
... in high-contact jobs	≥38%	≤62%	14.4-28.7	0.5%
65-74	80%	20%	4.6	5.0%
75+	82%	18%	2.8	16.7%



Homophily:
The tendence of people from a particular demographic group to interact more frequently with people from the same group.

- Age
- Ethnicity
- Location
- Religion
- Political party
- Vaccination status
- Etc.

Extensions: Contact Matrix and Parameters



Extension: Results

Excess predicted deaths:
Predicted deaths from best strategy compared to those under the best strategy that assigns WA and POC to the same allocation phase.

Scenario			Exact number of phases in vaccine allocation			
h	κ	ψ	2	3	4	5
80%	3	3	825	8774	11610	11226
	3	1	0	312	0	0
	1	1	0	0	0	570
0%	3	3	0	0	0	0
	3	1	0	0	0	0
	1	1	0	0	0	0

Conclusions

1. Optimal strategy depends on the goal of the vaccination campaign
2. The CDC allocation strategy was close to optimal
3. Allocation could be improved by prioritizing people with comorbidities in older populations
4. Accounting for ethnic homophily:
   1. Changes which strategy is optimal
   2. Better matches actual case counts and mortality
5. Essential model features:
   1. Levels of demographic homophily
   2. Case-dependent social distancing levels
   3. Age-dependent susceptibility
   4. Age-dependent clinical fraction
   5. Time-dependent transmission rate

Thank you

Backup Slides

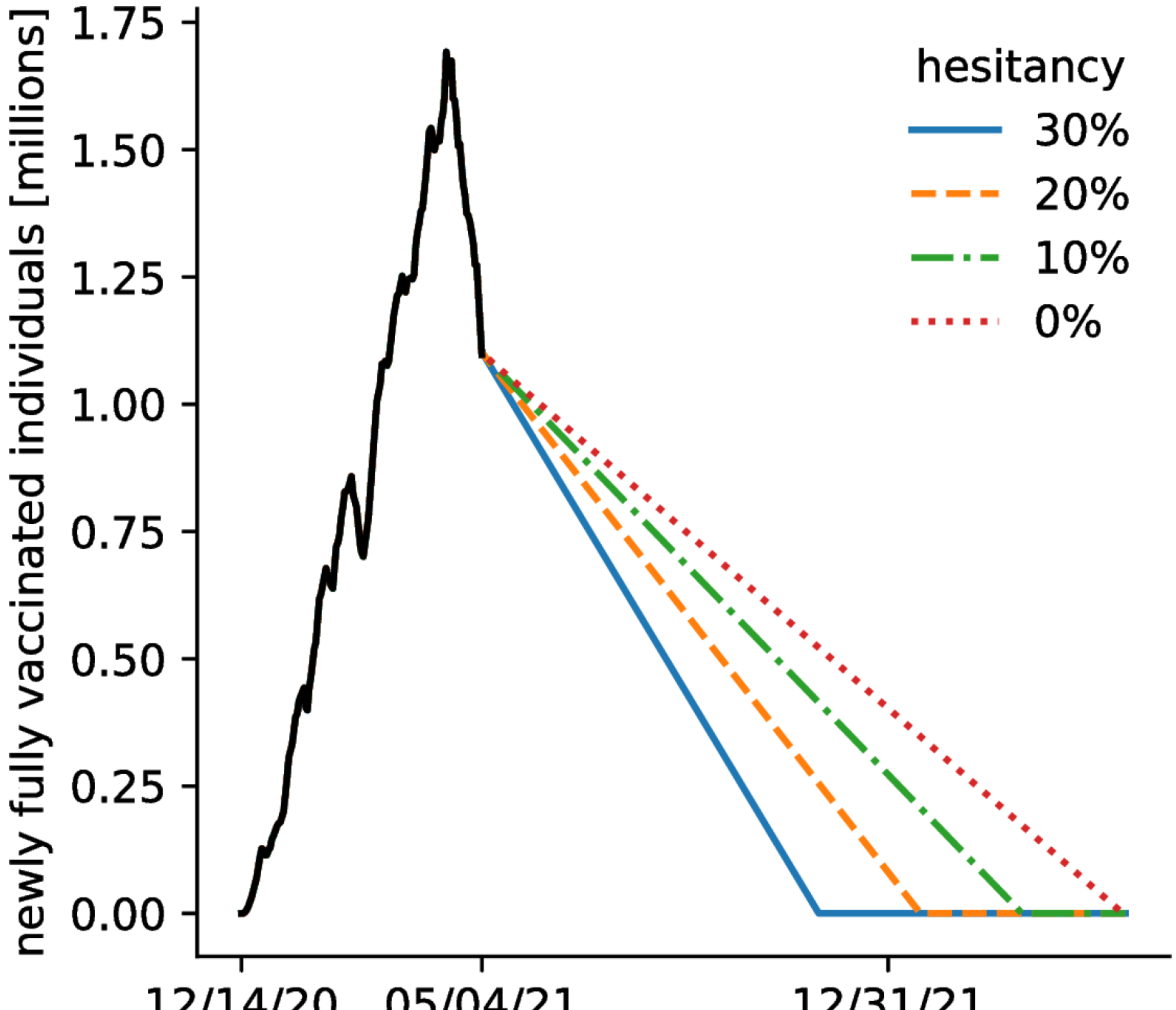
Backup Slide: Strategies that Outperform CDC

	deaths [thousands]	cases [millions]	YLL [millions]	Phase assignment of sub-poulation																
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CDC allocation	652.04	38.050	11.643	4	1	1	2	2	3	3	4	3	1	1	3	3	1	1	2	2
Allocations that Pareto-dominate the CDC allocation in all three metrics	650.83	37.918	11.608	4	1	1	2	2	3	3	4	3	2	1	3	3	3	1	3	2
	650.85	37.914	11.607	4	1	1	2	2	3	3	4	3	3	1	3	3	3	1	3	2
	650.90	37.881	11.606	4	1	1	2	2	3	3	4	3	2	2	3	3	2	1	3	2
	650.90	37.874	11.605	4	1	1	2	2	3	3	4	3	2	2	3	3	3	1	3	2
	650.94	37.870	11.604	4	1	1	2	2	3	3	4	3	3	2	3	3	3	1	3	2
	650.96	37.852	11.601	4	1	1	2	2	3	3	4	3	2	1	4	3	3	1	3	2
	650.98	37.848	11.600	4	1	1	2	2	3	3	4	3	3	1	4	3	3	1	3	2
	651.03	37.808	11.598	4	1	1	2	2	3	3	4	3	2	2	4	3	3	1	3	2
	651.07	37.805	11.597	4	1	1	2	2	3	3	4	3	3	2	4	3	3	1	3	2
	651.21	37.869	11.596	4	1	1	2	2	3	2	4	3	2	1	3	3	3	1	3	2
	651.24	37.865	11.596	4	1	1	2	2	3	2	4	3	3	1	3	3	3	1	3	2
	651.31	37.831	11.595	4	1	1	2	2	3	2	4	3	2	2	3	3	2	1	3	2
	651.31	37.824	11.593	4	1	1	2	2	3	2	4	3	2	2	3	3	3	1	3	2
	651.36	37.820	11.593	4	1	1	2	2	3	2	4	3	3	2	3	3	3	1	3	2
	651.40	37.811	11.591	4	1	1	2	2	3	2	4	3	2	1	4	3	3	1	3	2
	651.42	37.807	11.591	4	1	1	2	2	3	2	4	3	3	1	4	3	3	1	3	2
	651.43	37.765	11.592	4	1	1	2	2	3	3	4	3	2	2	4	3	3	1	4	2
	651.46	37.761	11.592	4	1	1	2	2	3	3	4	3	3	2	4	3	3	1	4	2
	651.50	37.773	11.590	4	1	1	2	2	3	2	4	3	2	2	4	3	2	1	3	2
	651.50	37.766	11.588	4	1	1	2	2	3	2	4	3	2	2	4	3	3	1	3	2
	651.54	37.763	11.588	4	1	1	2	2	3	2	4	3	3	2	4	3	3	1	3	2
	651.70	37.759	11.593	4	1	1	2	2	3	3	4	3	3	2	4	3	4	1	4	2
	651.81	37.772	11.587	4	1	1	2	2	3	2	4	3	2	1	4	3	3	1	4	2
	651.82	37.768	11.586	4	1	1	2	2	3	2	4	3	3	1	4	3	3	1	4	2
	651.90	37.757	11.590	4	1	1	2	2	3	3	4	3	2	1	4	3	2	2	3	2
	651.90	37.750	11.589	4	1	1	2	2	3	3	4	3	2	1	4	3	3	2	3	2
	651.91	37.734	11.585	4	1	1	2	2	3	2	4	3	2	2	4	3	2	1	4	2
	651.91	37.727	11.584	4	1	1	2	2	3	2	4	3	2	2	4	3	3	1	4	2
	651.95	37.723	11.584	4	1	1	2	2	3	2	4	3	3	2	4	3	3	1	4	2

Backup Slide: Age- and Comorbidity-Dependent CFR

- CDC age-structured (death count / case count)
  - 0.0129%, 0.4533%, 4.9781%, 16.7279%
- US population-level estimates of comorbidity prevalence
  - 18.60%, 36.72%, 73.15%, 80.18%
- 51.71% cases with comorbidities (health insurance claims)
- 83.29% deaths with comorbidities (health insurance claims)
- Persons with comorbidities have 4.65x higher CFR
- **CFR without comorbidities:**
  - **0.0129%, 0.1935%, 1.1355%, 4.2560%**
- **CFR with comorbidities:**
  - **0.0129%, 0.8997%, 6.3012%, 19.7907%**

Backup Slide: Speed of Vaccine Roll-Out

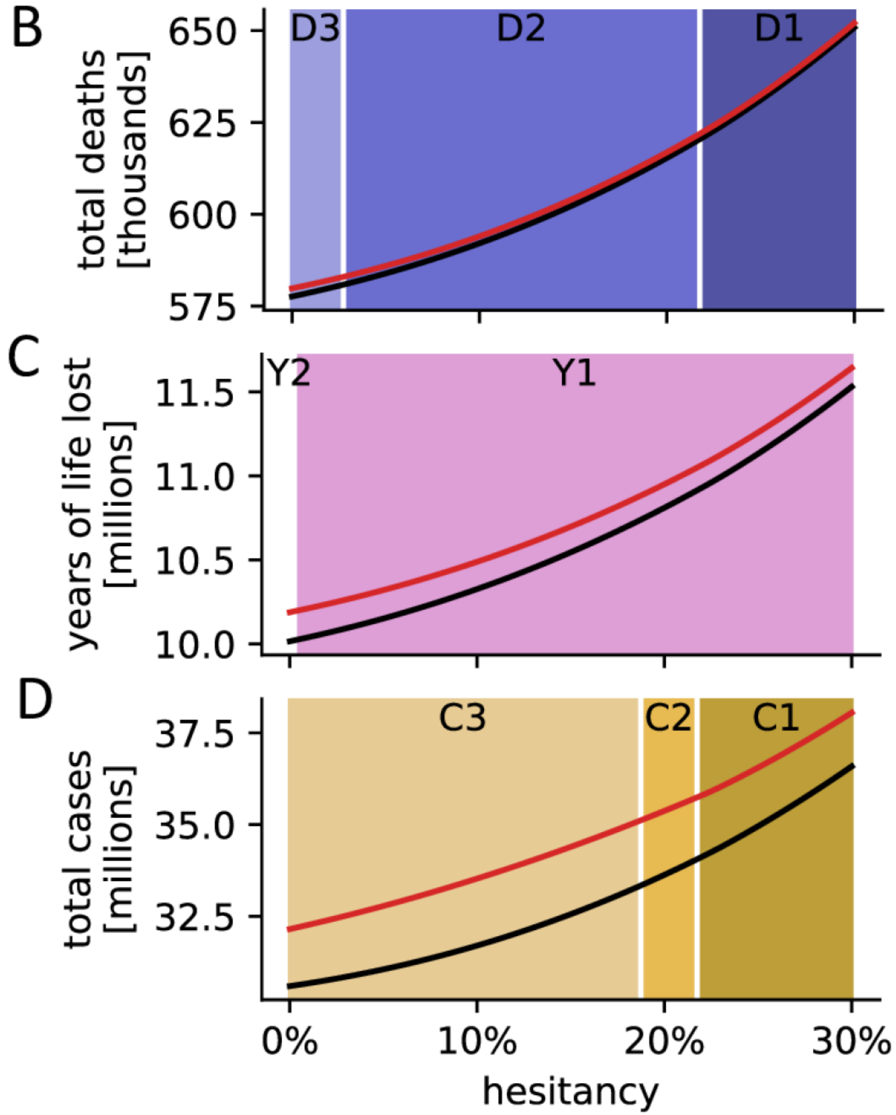


Backup Slide: Vaccine Hesitancy

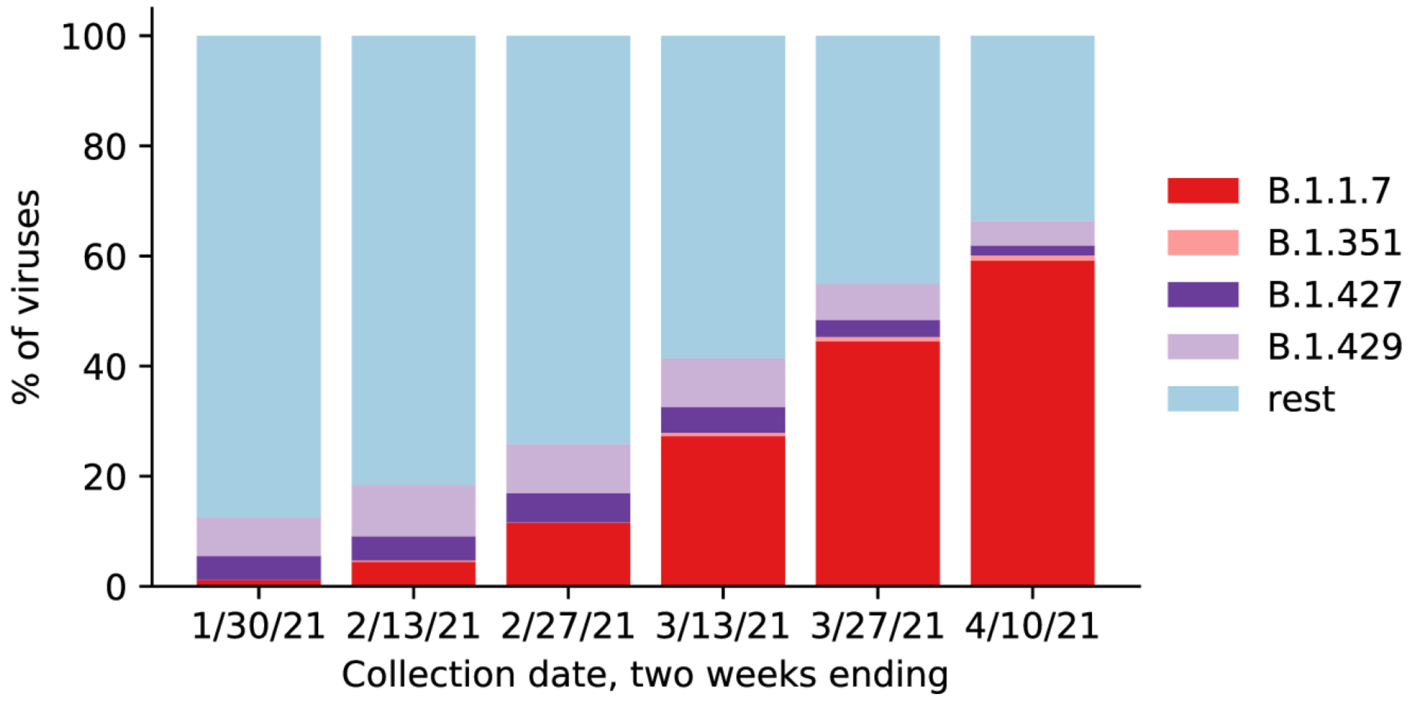
A

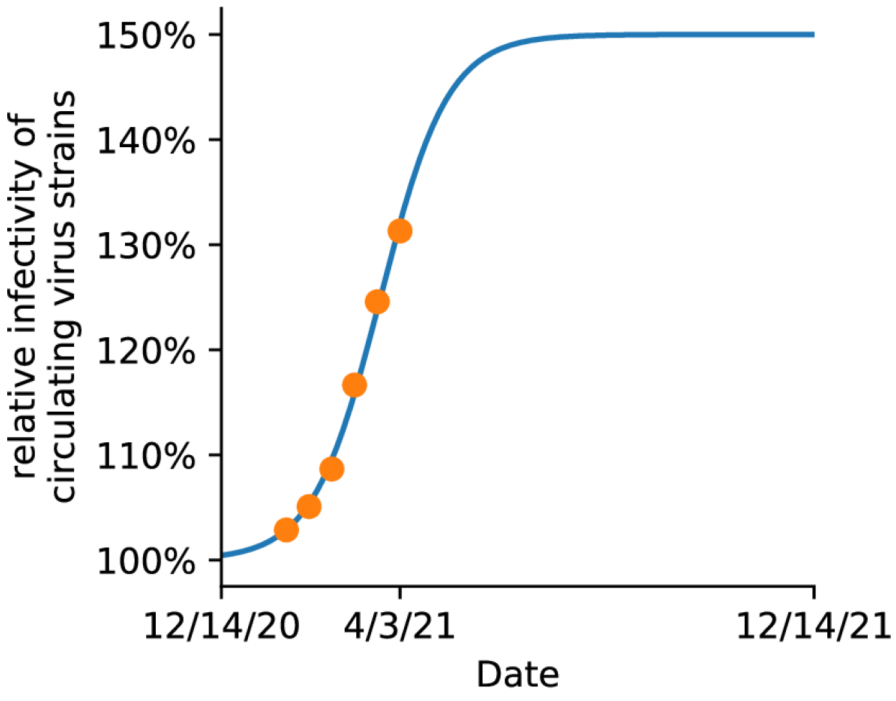
objective	minimize deaths				minimize YLL				minimize cases				CDC
hesitancy	0.3	0.2	0.1	0	0.3	0.2	0.1	0	0.3	0.2	0.1	0	
Sub-population 1	4	4	4	4	4	4	4	4	4	4	4	4	4
2	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1
4	2	2	2	2	2	2	2	2	2	2	2	2	2
5	2	2	2	2	2	2	2	2	2	2	2	2	2
6	3	3	3	3	3	3	3	3	2	2	2	2	3
7	3	3	3	3	2	2	2	3	2	2	2	2	3
8	4	4	4	4	4	4	4	4	3	3	3	3	4
9	3	3	3	3	3	3	3	3	3	3	3	3	3
10	2	2	2	3	3	3	3	3	3	3	3	3	1
11	1	2	2	2	2	2	2	2	3	2	2	2	1
12	3	3	3	4	4	4	4	4	4	4	4	4	3
13	3	3	3	3	3	3	3	3	4	4	4	4	3
14	3	3	3	3	3	3	3	3	3	4	3	3	1
15	1	1	1	1	2	2	2	2	3	3	3	3	1
16	3	3	3	3	4	4	4	4	4	4	4	4	2
17	2	2	2	2	3	3	3	3	4	4	4	4	2

D1 D2 D3 Y1 Y2 C1 C2 C3 CDC



Backup Slide: Emergence of Variants





Backup Slide: Model Parameters

Parameter	Description	Value	Source
N_i	number of people in sub-population i	see Table 2	[25]
X_{ij}	average daily number of contacts a person in sub-population i has with sub-population j	see S2G Fig	[21, 22]
c	log10 value of active cases at which overall contacts are reduced by 50%	$c = 4.0346$ (see S1 Table for fitted values used in the sensitivity analysis)	fitted (see Model calibration)
k	sensitivity of contact reduction to changes in active cases (shape of the Hill function)	$k = 5.0266$ (see S1 Table for fitted values used in the sensitivity analysis)	fitted (see Model calibration)
β_i	age-dependent susceptibility to infection	see S1 Table	fitted (see Model calibration)
$1/\mu_E$	incubation period	3.7 days	[26]
q_i	age-dependent clinical fraction	varied, see S1 Fig	[27]
$1/\mu_A$	average time of virus spread by truly asymptomatic individuals	5 days	[17]
$1/\mu_P$	average time of virus spread before symptom onset	2.1 days	[17]
$1/\mu_C$	average time of virus spread after symptom onset	2.723 days	estimated from CDC raw data
$1/\mu_Q + 1/\mu_C$	average time between symptom onset and possible death	22 days	estimated from U.S. deaths and case counts [28]
CFR_i	sub-population-dependent case fatality ratio	see Case fatality rates	calculated from [29, 30]
f_A	relative contagiousness of truly asymptomatic individuals	75% (25% and 100% in sensitivity analysis)	[27]
f_V	relative contagiousness of vaccinated individuals	50% (0% and 100% in sensitivity analysis)	no data
none	vaccine hesitancy	30%	[31, 32]
$\xi(t)$	daily number of available vaccines	see S4 Fig	[33]
none	vaccine effectiveness: reduction of symptomatic infections among vaccinated (compared to non-vaccinated)	90%	[34]
σ and δ	reduction in infections and symptomatic infections (when infected) among vaccinated (compared to non-vaccinated) individuals	70% and 66.7% (varied such that $1 - (1 - \sigma)(1 - \delta) = 90\%$ in sensitivity analysis)	[35]

Backup Slide: Genetic Algorithm

Minimize fitness function:

- 50 iterations of 1000 parameter sets
- 300 parents, 700 children
- 50% crossover probability
- 10% random mutation probability
- 1% elite ratio (top 10 par sets)
- 100 separate runs
- Weighting ensures good fit at end

$$f(\text{deaths, cases}) = \text{wSSE(deaths)} + \text{wSSE(cases)}$$

where

$$\text{wSSE(deaths)} = \sum_{d=\text{December 14, 2020}}^{\text{April 29, 2021}} w_d \cdot (\text{observed minus predicted deaths up to day } d)^2$$

$$\text{wSSE(cases)} = \sum_{d=\text{December 14, 2020}}^{\text{April 29, 2021}} w_d \cdot (\text{observed minus predicted cases up to day } d)^2$$

Quadratically-increasing weights:

$$w_{\text{December 14 2020}} = 1,\ w_{\text{December 15 2020}} = 4,\ w_{\text{December 16 2020}} = 9, \ldots$$

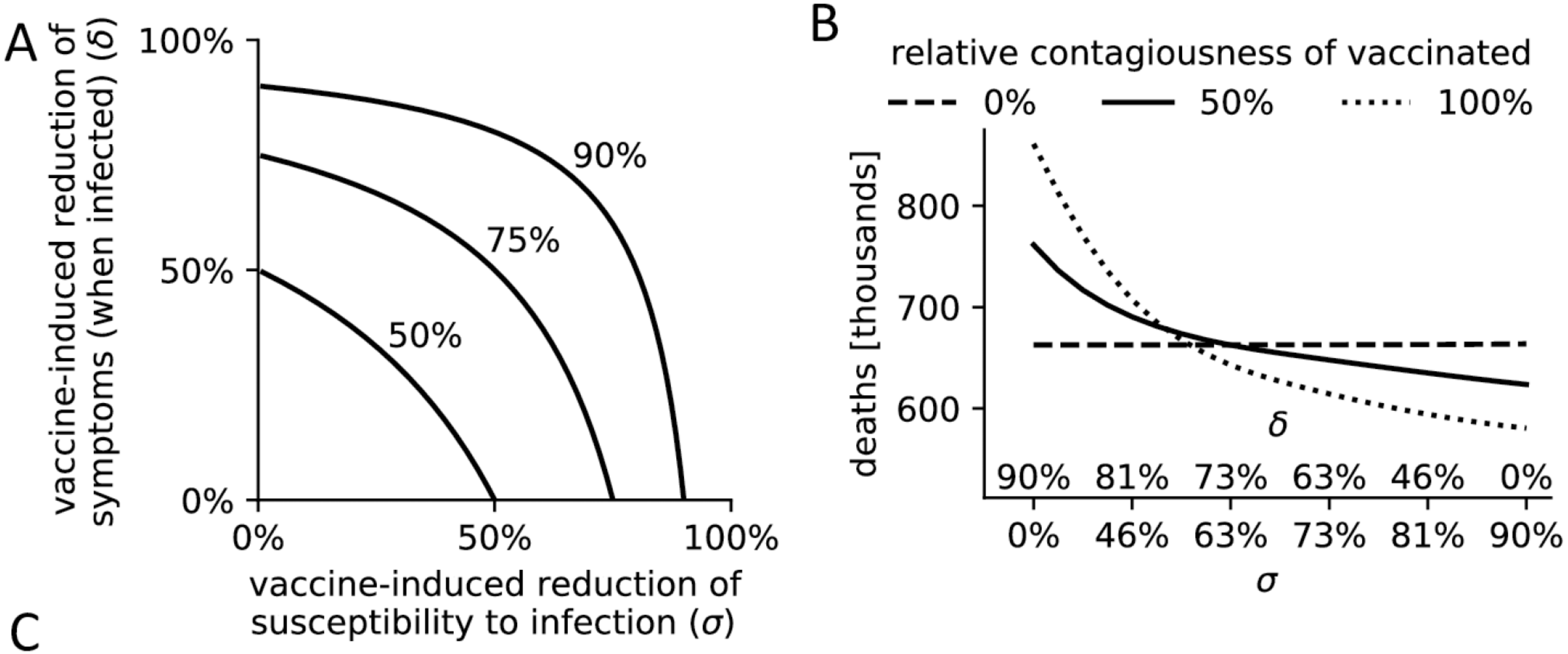
Backup Slide: Model Parameters

Varied parameters			Fitted parameters				
f_A	f_V	q_{75+}	b_0	b_1	c	k	wSSE
0.75	0.5	0.85	0.0397	0.0044	4.0346	5.0266	4.66E+13
0.75	0.5	0.7	0.0001	0.0045	4.2812	5.2282	5.56E+13
0.75	0.5	1	0.0810	0.0031	4.0382	4.9903	4.54E+13
0.25	0.5	0.85	0.0727	0.0072	4.1001	5.9356	4.33E+13
1	0.5	0.85	0.0249	0.0030	4.2441	4.8065	4.80E+13
0.75	0	0.85	0.0764	0.0081	4.3286	7.3542	3.58E+13
0.75	1	0.85	0.0157	0.0017	4.0277	2.8875	5.83E+13

Backup Slide: Sensitivity Analysis

Age	Job or living situation	Comorbidity	Number of people [millions]	Group ID in model	CDC allocation	deaths [thousands]							YLL [millions]							cases [millions]							
						0.85	0.7	1	0.85	0.85	0.85	0.85	0.85	0.7	1	0.85	0.85	0.85	0.85	0.85	0.7	1	0.85	0.85	0.85	0.85	q_{75+}
						0.75	0.75	0.75	0.25	1	0.75	0.75	0.75	0.75	0.75	0.25	1	0.75	0.75	0.75	0.75	0.75	0.25	1	0.75	0.75	f_A
						0.5	0.5	0.5	0.5	0.5	0	1	0.5	0.5	0.5	0.5	0.5	0	1	0.5	0.5	0.5	0.5	0.5	0	1	f_V
0-15	NA	NA	64.71	**1**	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
16-64	healthcare workers	no	13.29	**2**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
		yes	7.71	**3**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	frontline essential workers	no	18.98	**4**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
		yes	11.02	**5**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	other essential workers	no	12.66	**6**	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	
		yes	7.34	**7**	3	3	3	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	remaining people	no	87.61	**8**	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	
		yes	50.85	**9**	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
65-74	congested living	no	0.28	**10**	1	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
		yes	0.76	**11**	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	2	3	2	3	2	3	
	remaining people	no	8.20	**12**	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
		yes	22.34	**13**	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	
75+	congested living	no	0.39	**14**	1	3	3	2	2	3	2	3	3	3	3	3	3	3	3	3	3	4	3	3	3	4	
		yes	1.57	**15**	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	
	remaining people	no	4.07	**16**	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
		yes	16.47	**17**	2	2	2	1	1	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	
Value for optimal allocation						650.8	645.5	651.6	658.5	647.3	661.7	620.4	11.53	11.55	11.5	11.69	11.46	11.75	10.92	36.59	36.58	36.78	37.28	36.21	37.57	33.96	
Value for CDC allocation						652	646.6	653.2	659.7	648.6	662.9	622	11.64	11.67	11.61	11.79	11.57	11.86	11.05	38.05	38.08	38.2	38.74	37.69	39.08	35.4	
% difference						0.187	0.182	0.235	0.181	0.192	0.185	0.249	0.974	1	0.984	0.892	1.012	0.971	1.167	4.003	4.104	3.869	3.909	4.066	4.029	4.244	

Backup Slide: Vaccine Function



C

Change in phase assignment ($\sigma = 90\%$, $\delta = 0\%$ compared to $\sigma = 0\%$, $\delta = 90\%$)

↑ later vaccination when δ = 90% ↓ earlier vaccination when δ = 90% - no change

	Sub-population	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Age	0-15	16-64								65-74				75+			
minimize	deaths	-	↑	-	↑	-	-	-	-	-	-	↓	↓	↓	↓	-	-	↓
	YLL	-	-	-	-	↑	-	-	-	-	↓	↓	↓	↓	-	↓	↓	↓
	cases	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Backup Slide: Ethnic Homophily Model

- 10 subpopulations:
  - 4 age groups
  - 2 ethnicity groups (WA and POC)
  - 2 occupation levels for age group 16-64 (HC and LC)
- 3 parameters (built into contact matrix):
  - *h:* ethnic homophily (0% & 80%)
  - *Ψ:* relative proportion of POC (vs. WA) in high-contact jobs (1 & 3)
  - *κ:* relative contact levels for employees in high-contact jobs vs. low-contact jobs (1 & 3)
- Varying number of allocation phases:
  - 1-5, and 10
- Global optimization approach over 2.9 million possibly optimal strategies

Backup Slide: Calculating Relative Homophily

$p \in (0,1)$ Proportion of population in WA group

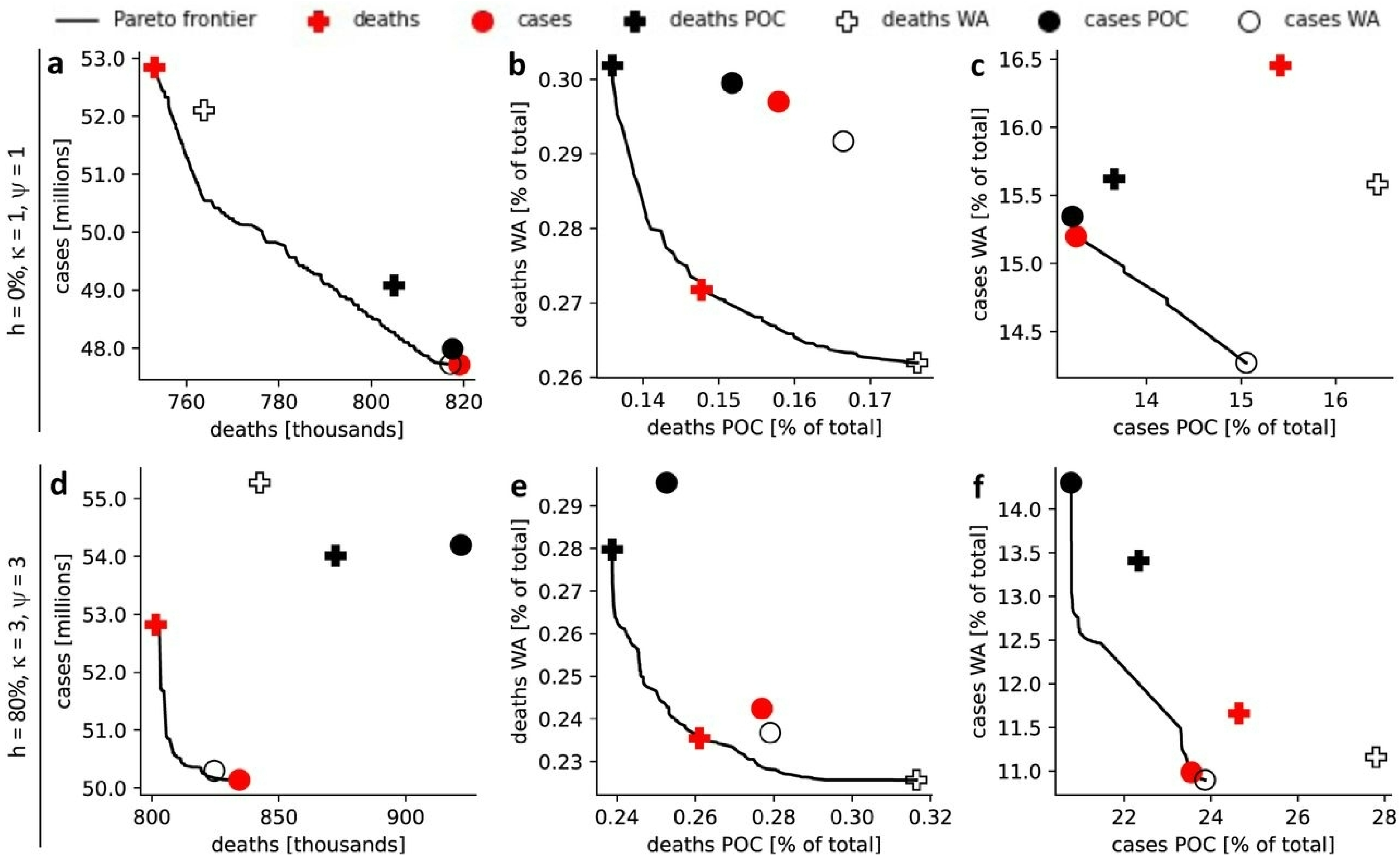
$\phi \in [0,1]$ Proportion of all contacts between people of the same ethnicity group

$$\mathbb{E}(\phi) = p^2 + (1-p)^2$$

$$\text{homophily } h = \begin{cases} \frac{\phi - \mathbb{E}(\phi)}{1-\mathbb{E}(\phi)} \in [0,1] & \text{if } \phi \geq \mathbb{E}(\phi), \\ \frac{\phi - \mathbb{E}(\phi)}{\mathbb{E}(\phi)} \in [-1,0) & \text{if } \phi < \mathbb{E}(\phi). \end{cases}$$

If $p = \frac{2}{3}$, then $E(\varphi) = \frac{5}{9}$. $\varphi = \frac{7}{9}$ therefore corresponds to 50% homophily.
$\varphi = 1$ corresponds to 100% homophily: complete segregation of WA and POC.
$\varphi = 0$ corresponds to 100% heterophily, where the contact graph is bipartite.

Backup slide: Results from Ethnic Homophily Study



Backup Slide: Results from Ethnic Homophily Study

		exact number of phases	4						5						10					
		h	80%			0%			80%			0%			80%			0%		
		κ	3		1	3		1	3		1	3		1	3		1	3		1
age	ethnicity	occupation ψ	3	1	1	3	1	1	3	1	1	3	1	1	3	1	1	3	1	1
0-15	POC	n.a.	4	4	4	4	4	4	5	5	5	5	5	4	10	10	10	9	9	9
	WA	n.a.	4	4	4	4	4	4	5	5	5	5	5	5	8	9	9	10	10	10
16-64	POC	low-contact	4	4	3	4	4	3	5	4	4	4	4	3	9	8	8	7	7	6
		high-contact	2	2	3	2	2	3	2	2	4	2	2	3	4	4	6	3	3	5
	WA	low-contact	3	4	3	4	4	3	4	4	4	4	4	3	7	7	7	8	8	8
		high-contact	1	2	3	2	2	3	1	2	3	2	2	3	2	3	5	4	4	7
65-74	POC	n.a.	3	3	2	3	3	2	3	3	2	3	3	2	5	5	4	5	5	3
	WA	n.a.	3	3	2	3	3	2	3	3	2	3	3	2	6	6	3	6	6	4
75+	POC	n.a.	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
	WA	n.a.	2	1	1	1	1	1	2	1	1	1	1	1	3	1	1	2	2	2

Backup Slide: Citations

- Islam, M.R., Oraby, T., McCombs, A., Chowdhury, M.M., Al-Mamun, M., Tyshenko, M.G. and Kadelka, C., 2021. Evaluation of the United States COVID-19 vaccine allocation strategy. *PloS one*, *16*(11), p.e0259700.
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- Kadelka, C., 2022. Projecting social contact matrices to populations stratified by binary attributes with known homophily. *arXiv preprint arXiv:2207.12328*.
- Kadelka, C. and McCombs, A., 2021. Effect of homophily and correlation of beliefs on COVID-19 and general infectious disease outbreaks. *PloS one*, *16*(12), p.e0260973.