PRINCETON UNIVERSITY

BENDHEIM CENTER FOR FINANCE

Webinar: The benefits of targeted COVID-19 policies

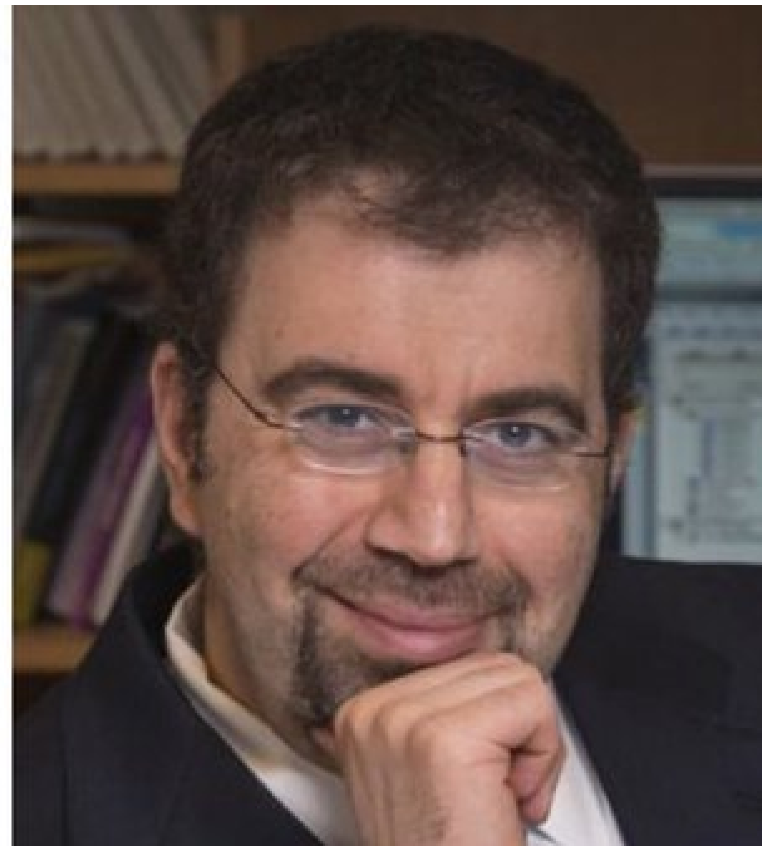
WITH DARON ACEMOGLU

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Friday, May 8, 12:30 PM ET

Pre-Registration Required

BENDHEIM CENTER FOR FINANCE · Griswold Center · Public Policy & Finance · PRINCETON ECONOMICS



Intro: MARKUS BRUNNERMEIER Twitter: @MarkusEconomist

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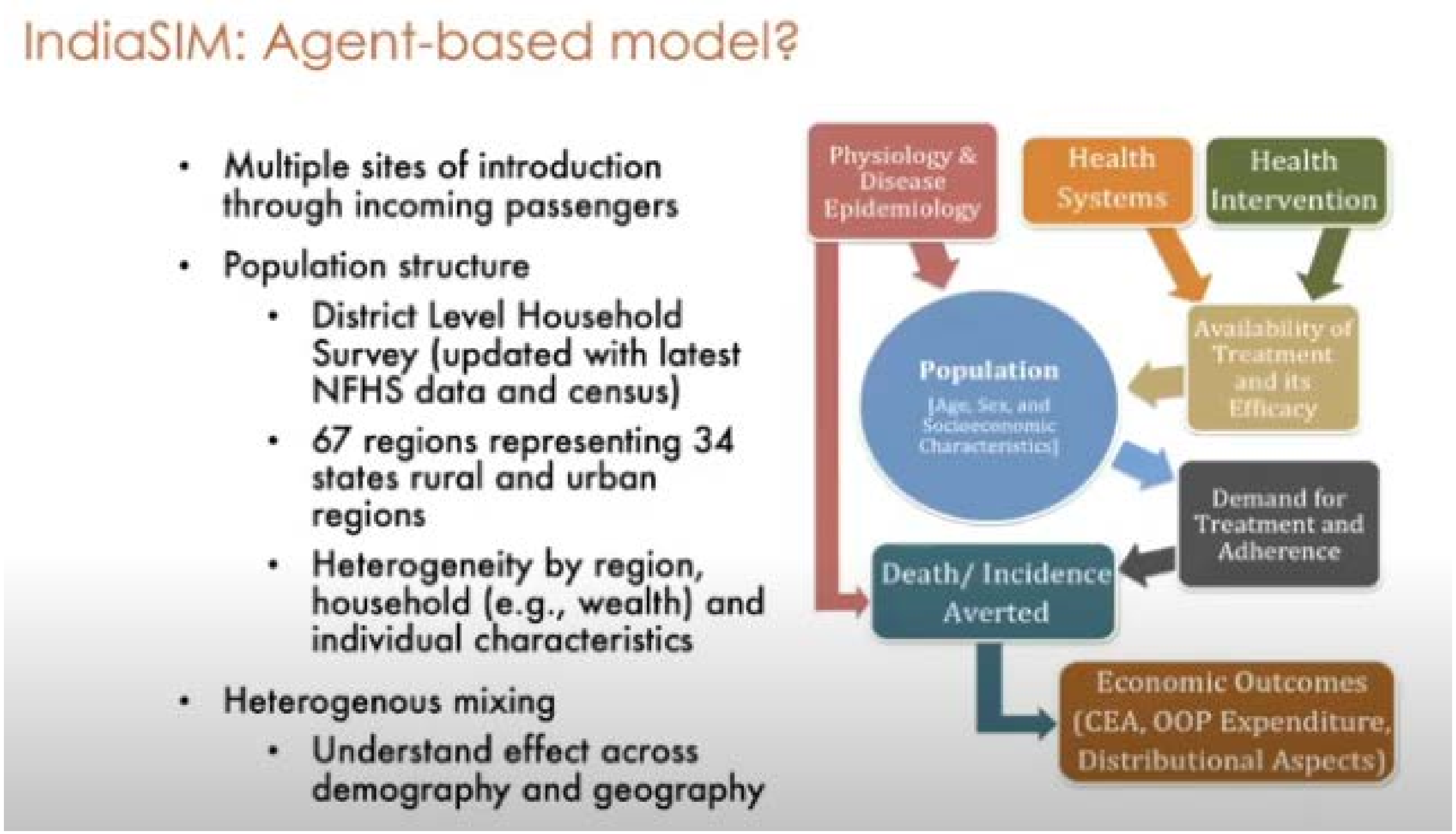
Markus' intro

- Previous/future webinars
  - Ramanan Laxminarayan: Epidemology models
  - Daron Acemoglu: On the benefits of targeted policies
  - Jeremy Stein Fed-Treasury credit programs
- Speakers

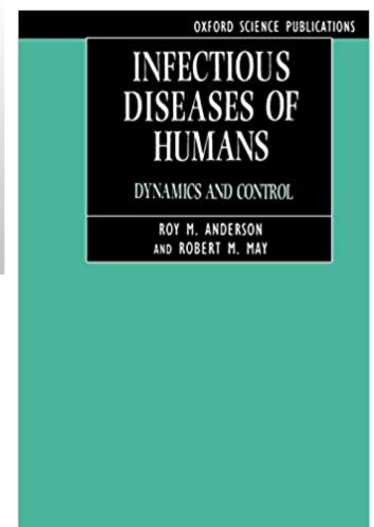
Ramanan Laxminarayan

- https://www.youtube.com/watch?v=z1yHjM7szBk



cddep.org

Leading textbook



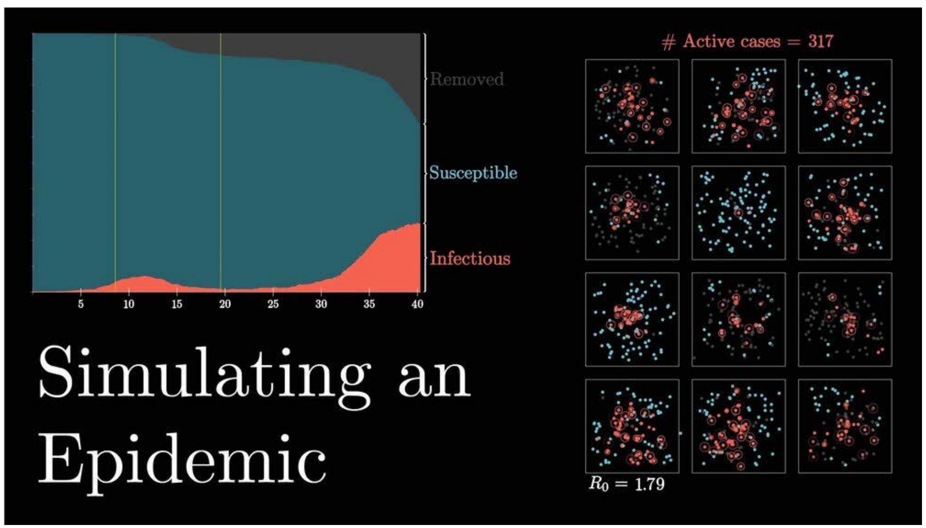
- Agent based models to capture behavioral response
- Expectations play limited role

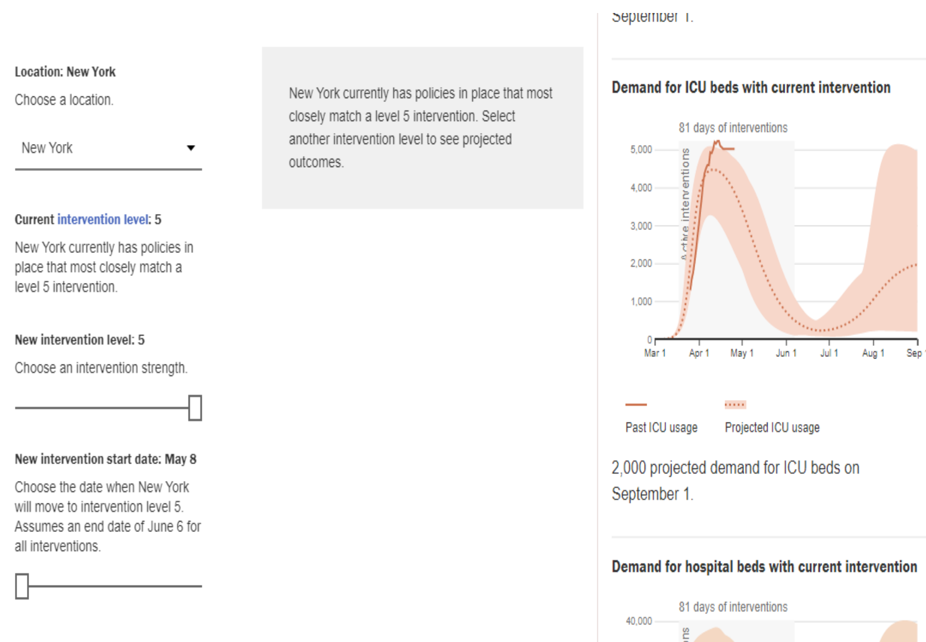
Anderson & May

Nice simulations

- 3blue1brown: Grant Sanderson
  https://www.youtube.com/watch?v=gxAaO2rsdIs

- Random Corporation
  https://www.rand.org/pubs/tools/TLA173-1/tool.html





Ex-ante vs. ex-post targeting

- Trade-off: Ex-ante vs. ex-post targeting (flexibility)

- German "emergency break"
  - "Regional targeting" in Germany
  - Lockdown region if
    - More than 50 out of 100,000 inhabitants
    - Infected within a week

- Enforceability? Incentive to monitor your neighbor?

Ethics: Statistical Value of Life

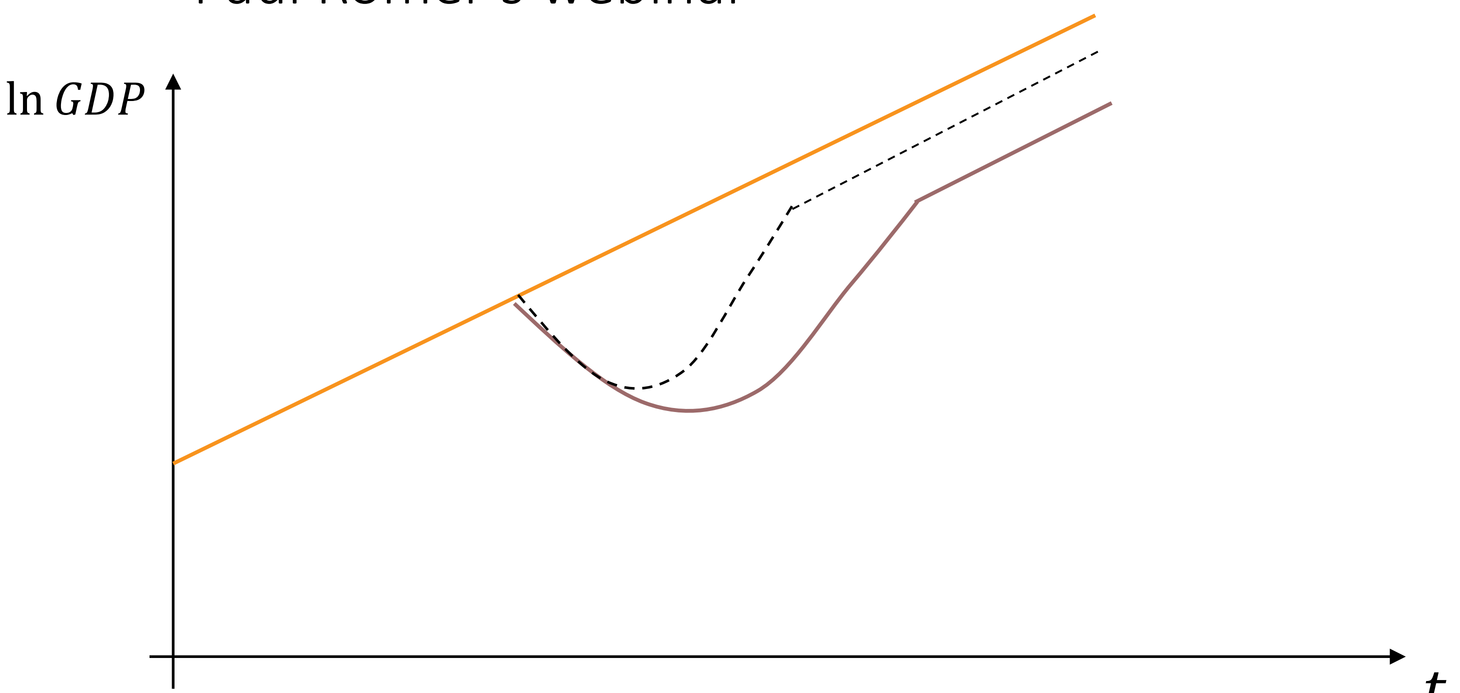
- Infer from wage difference between hazardous and non hazardous occupations
  - Impacted by risk aversion

- Should targeted policy includes
  - statistical value of life
    - Angus Deaton is critical of this concept (see earlier webinar)
  - Expected life expectancy

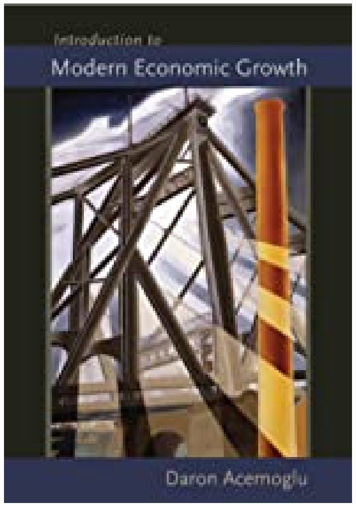
- Q: Doesn’t matter since only externality (spreading virus) should be taken into account.

Epidemics & Growth

- Interact epidemic model with (endogenous) growth model
  - Across different **exit strategies**/testing
  - Paul Romer's webinar



New chapter for



Brunnermeier, Merkel, Payne, Sannikov (2020) (Tuesday at VMACS)

End of MARKUS' INTRODUCTORY REMARKS

Now

Please ask questions in Q&A box

A Multi-Risk SIR Model with Optimally Targeted Lockdown

Daron Acemoglu Victor Chernozhukov Iván Werning Michael D. Whinston

April 2020.

Introduction

- SIR models are playing an increasingly central role in understanding and policy-making in the context of the COVID-19 pandemic.
- One of the key trade-offs is between economic and public health outcomes.
- But "optimal policy" coming from baseline models assuming homogeneous vulnerability and economic participation may be misleading.

Varieties of Heterogeneity

- Many dimensions of heterogeneity—occupation, productivity, issues related to joint labor supply.
- Risk factors are particularly important (COVID-19 characterized as two separate diseases by some medical professionals, a deadly one for older populations or those with comorbidities, and similar to seasonal flu for younger, healthier groups).

Age Group	Mortality rate
20-49	0.001
50-64	0.01
65+	0.06

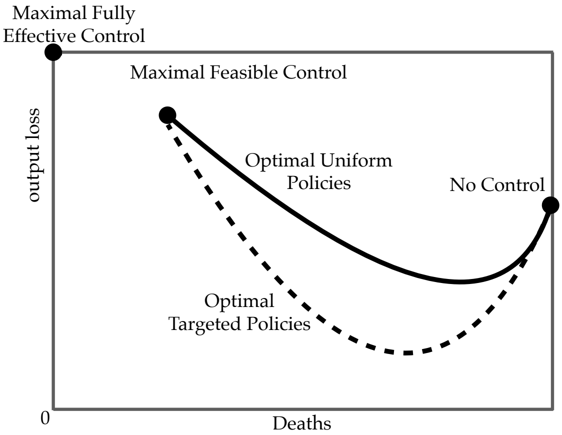
Table: Mortality rates (conditional on infection) from COVID-19.

What We Do

- Develop a multi-risk SIR model and characterize dynamics of infection in this context.
  - In practice, apply this to a setting with three groups, young, middle-aged and old (65+).
- Set up an optimal control problem for this environment—allowing targeting by group.
- Characterize and contrast optimal uniform and optimal targeted policies using parameter values from the literature for COVID-19.
- Clarify how the trade-offs change with targeted policies.

Summary of Main Findings

- Big gains and significantly improved trade-offs from targeted policy.
- Most of the gains can be realized by very simple semi-targeted policies that just treat the 65+ group differentially.



Important Caveats

- We are not epidemiologists.
- These are really sensitive topics $\cdots$
- There is huge amount of uncertainty about both the disease parameters and the relevant economic parameters.
- We welcome comments, suggestions and criticisms.

Outline

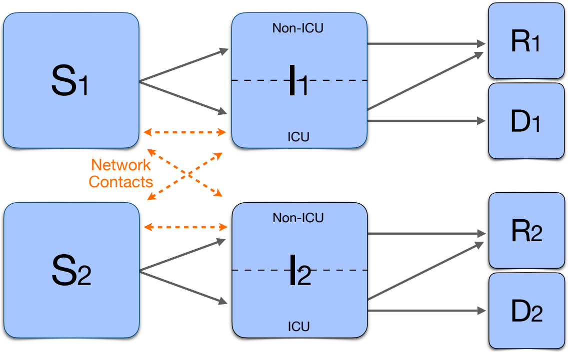


Figure: MR-SIR: Multiple-Risk Susceptible Infected Recovered Model. Solid lines show the flows from one state to another. Dashed lines emphasize interactions that take place across risk groups.

Key Equations

- In classic SIR:
$$\text{new infections} = \beta S I.$$
- In our model, absent lockdowns and isolations:
$$\text{new infections in group } j = \beta S_j \frac{\sum_k \rho_{jk} I_k}{\left(\sum_k \rho_{jk}(S_k + I_k + R_k)\right)^{2-\alpha}}$$
where $\{\rho_{jk}\}$ are social contact rates between group j and k.
- Here $\alpha \in [1, 2]$ is the returns to scale in matching.
- We normalize: $\sum_j N_j = 1$.
- As usual:
$$S_j(t) + I_j(t) + R_j(t) + D_j(t) = N_j.$$

Infection Dynamics

- Before the vaccine, $t \in [0, T)$, for group j:

$$\dot{I}_j = \beta M_j (1 - \theta_j L_j) S_j \sum_k \rho_{jk} (1 - \theta_k L_k) I_k - \gamma_j I_j,$$

$$M_j = \left(\sum_k \rho_{jk} [(S_k + I_k + R_k)(1 - \theta_j L_k)] \right)^{\alpha - 2},$$

where $\rho_{jk} \geq 0$ are contact coefficients and I have assumed no testing/tracing/isolation for the slides (these are allowed in the paper and quantitative analysis below).

- Employment is then given by

$$E_j(t) = (1 - L_j(t))(S_j(t) + I_j(t) + R_j(t)).$$

Parameters

- $\gamma_j = \delta_j^d(t) + \delta_j^r(t)$: exit rate from infection due to recovery or death.
- $\delta_j^d(t) = \psi_j(\text{total infections})$: probability of death for individual of type j depending on overcapacity in the hospital system.
- ρ_{ij}: social contact rate between individuals of group i and j.
- β: infection rate.
- $L_j(t)$: time-varying lockdown.
  - $L_j(t) \leq \bar{L}_j \leq 1$, where $\bar{L}_j < 1$ allows for "essential" workers.
- θ_j: effectiveness of lockdown.
- w_j: economic contribution of an individual from group j.
- χ_j: additional non-pecuniary cost of death.

An Aggregation Result

- Our MR-SIR model generalizes the standard SIR model.
- Suppose $\beta_{jk} = \beta$ and $\gamma_j = \gamma$.
- Consider uniform lockdowns $L_j(t) = L(t)$ for all j.
- Suppose further that infection rates are initially identical across groups, so that $S_j(0)/N_j$, $I_j(0)/N_j$ and $R_j(0)/N_j$ are independent of j.
- Then the model behaves identically to a homogeneous SIR model.
    - except deaths that naturally vary by group.

Optimal Control

- Social objective:

$$\min \int_0^\infty e^{-rt} \sum_j (w_j(N_j - E_j(t)) + \chi_j \delta_j^d(t) I_j(t))\, dt$$

  - $\chi_j \delta_j^d(t) I_j(t)$: non-pecuniary costs of deaths
- With vaccine (and cure) arriving at T, integration-by-parts yields

$$\int_0^T e^{-rt} \sum_j \Psi_j(t)\, dt, \tag{1}$$

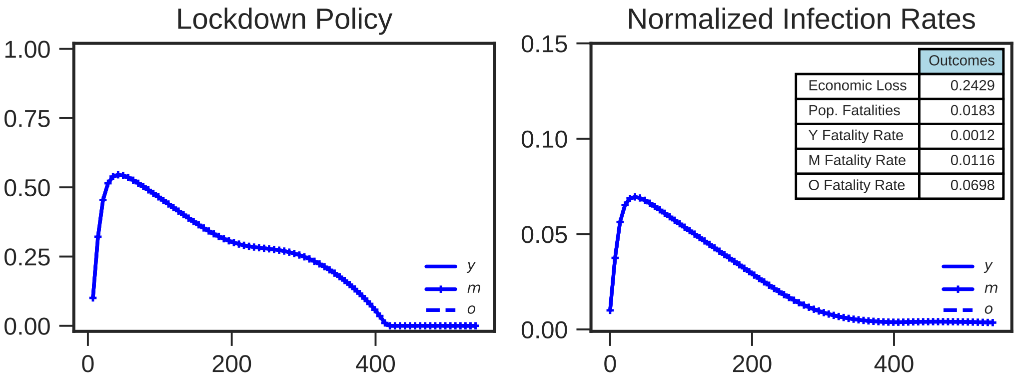
where, allowing for partial isolation of the infected and identification of the recovered, the flow cost for group j is given by

$$\begin{aligned} \Psi_j(t) &= w_j S_j(t) L_j(t) + w_j I_j(t)(1 - \eta_k(1 - L_j(t))) \\ &\quad + w_j(1 - \kappa_j) R_j(t) L_j(t) + \left[\frac{(1 - e^{-r\Delta_j}) w_j}{r} + \chi_j \right] \delta_j^d(t) I_j(t). \end{aligned}$$

Parameter Choices

- Fatality rates (conditional on infection) from the table above.
- $N_y = 0.53$, $N_m = 0.26$, and $N_o = 0.21$.
- $w_o = 0$ and $w_y = w_m = 1$.
- $\bar{L}_o = 1$ and $\bar{L}_j = 0.7$.
- $\theta_j = 0.75$
- probabilities of detection and isolation in the baseline: $\phi_j = \tau_j = 0$
- probability of identifying recovered individuals: $\kappa_j = 1$
- $\gamma_j = 1/18$.
- $\beta\rho_{ij} = \bar{\beta} = 0.2$ (later allow $\rho_{ij} = \rho$ for $i \neq j$ where $\rho = 0.5$).
- $\delta_j^d(t) = \underline{\delta}_j^d \cdot [1 + \widehat{\lambda} \cdot \text{total infections}]$. We set $\widehat{\lambda}$ such that if there is a 30% infection rate in the overall population, then mortality rates are 5 times the base mortality rates.

Optimal Uniform Policy

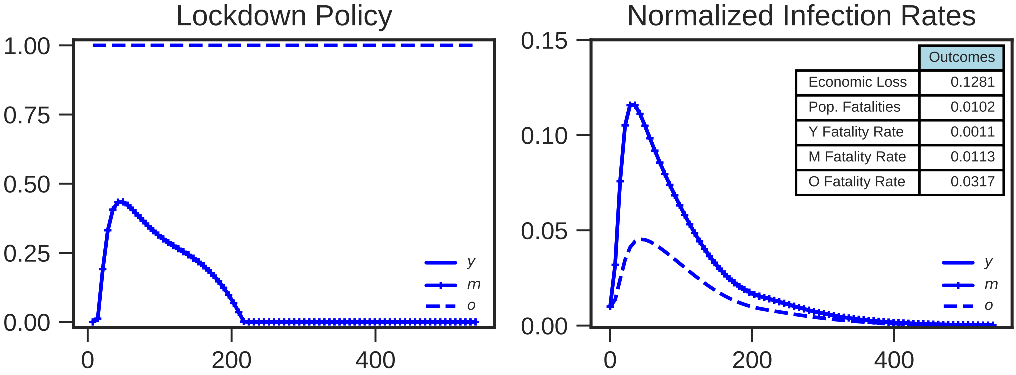


Base: Uniform Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 1.0$ $\chi = 20$

- Both high numbers of lives lost (1.8% of adult population) and big economic damage (24.3% of one year's GDP).

Optimal Semi-Targeted Policy

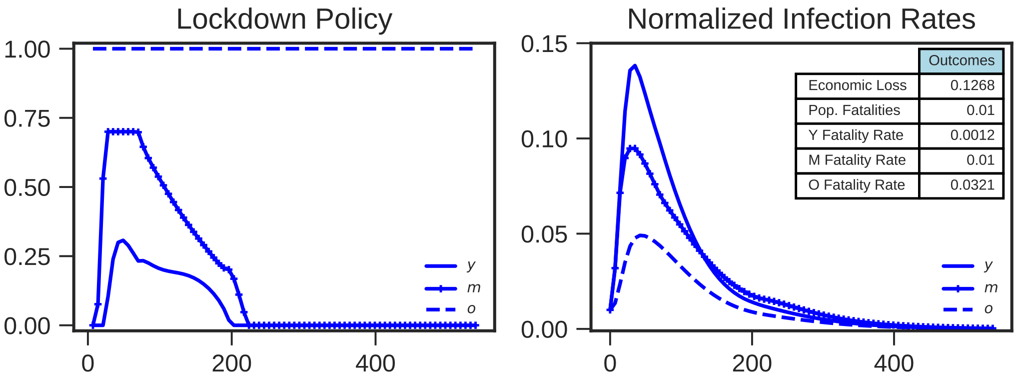
- Just applying a more strict lockdown on the oldest age group improves things significantly.
- Overall mortality rate declines from 1.8% to 1%, and economic losses decline from 24% of one year's GDP to under 13%.



Base: Semi-Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 1.0$ $\chi = 20$

Optimal Fully-Targeted Policy

- The young and the middle-age treated differently, but small gains relative to optimal semi-targeted policy.

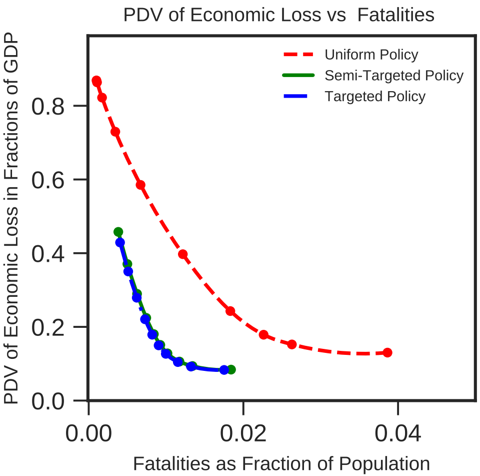


	Outcomes
Economic Loss	0.1268
Pop. Fatalities	0.01
Y Fatality Rate	0.0012
M Fatality Rate	0.01
O Fatality Rate	0.0321

Base: Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 1.0$ $\chi = 20$

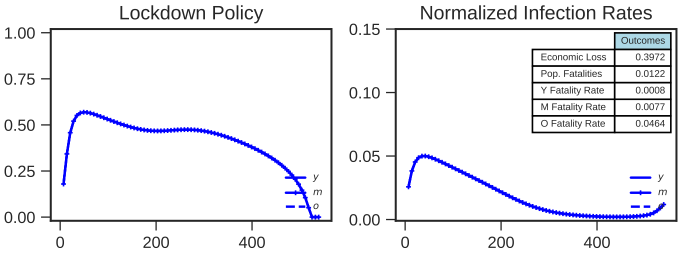
The “Pareto” Frontier

- The advantage of semi-targeted policies true for different values of χ.



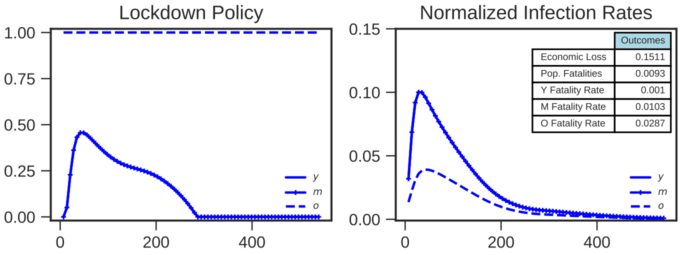
Base: Outcomes for $\theta = 1$, $\alpha = 2, \rho = 1$, $T = 546$; $\chi \in \{0, 5, 10, 20, \ldots, 80\}$

With Greater Value of Life, Another Interesting Contrast



	Outcomes
Economic Loss	0.3972
Pop. Fatalities	0.0122
Y Fatality Rate	0.0008
M Fatality Rate	0.0077
O Fatality Rate	0.0464

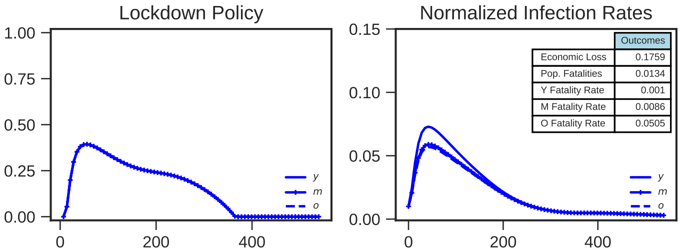
Base: Uniform Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = 1$ $\rho = 1.0$ $\chi = 30$



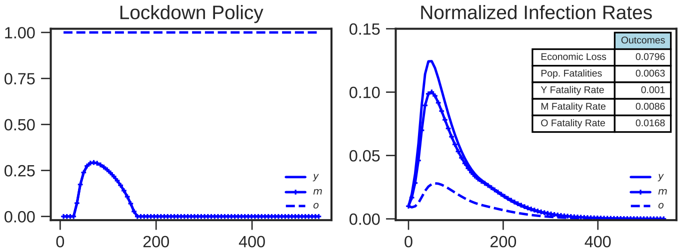
	Outcomes
Economic Loss	0.1511
Pop. Fatalities	0.0093
Y Fatality Rate	0.001
M Fatality Rate	0.0103
O Fatality Rate	0.0287

Base: Semi-Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = 1$ $\rho = 1.0$ $\chi = 30$

Bigger Gains with Between-Group Distancing

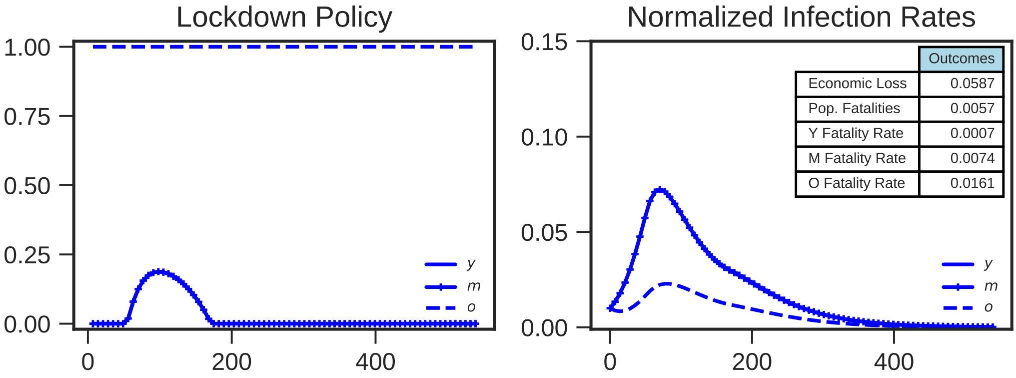


CS1: Uniform Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 0.5$ $\chi = 20$



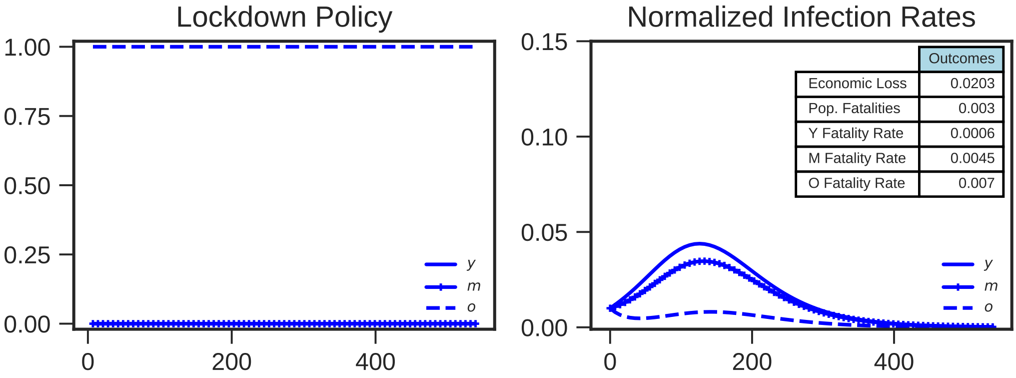
CS1: Semi-Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 0.5$ $\chi = 20$

Even Bigger Gains with Testing-Tracing



Base with Testing: Semi-Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 1.0$ $\chi = 20$

Combining Between-Group Distancing and Testing-Tracing



Group Dist and Testing: Semi-Targeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\rho = 0.5$ $\chi = 20$

Conclusion

- Still much to be done. But our research suggests targeted (semi-targeted) policies can do much better, especially with some between-group social distancing and testing-tracing: