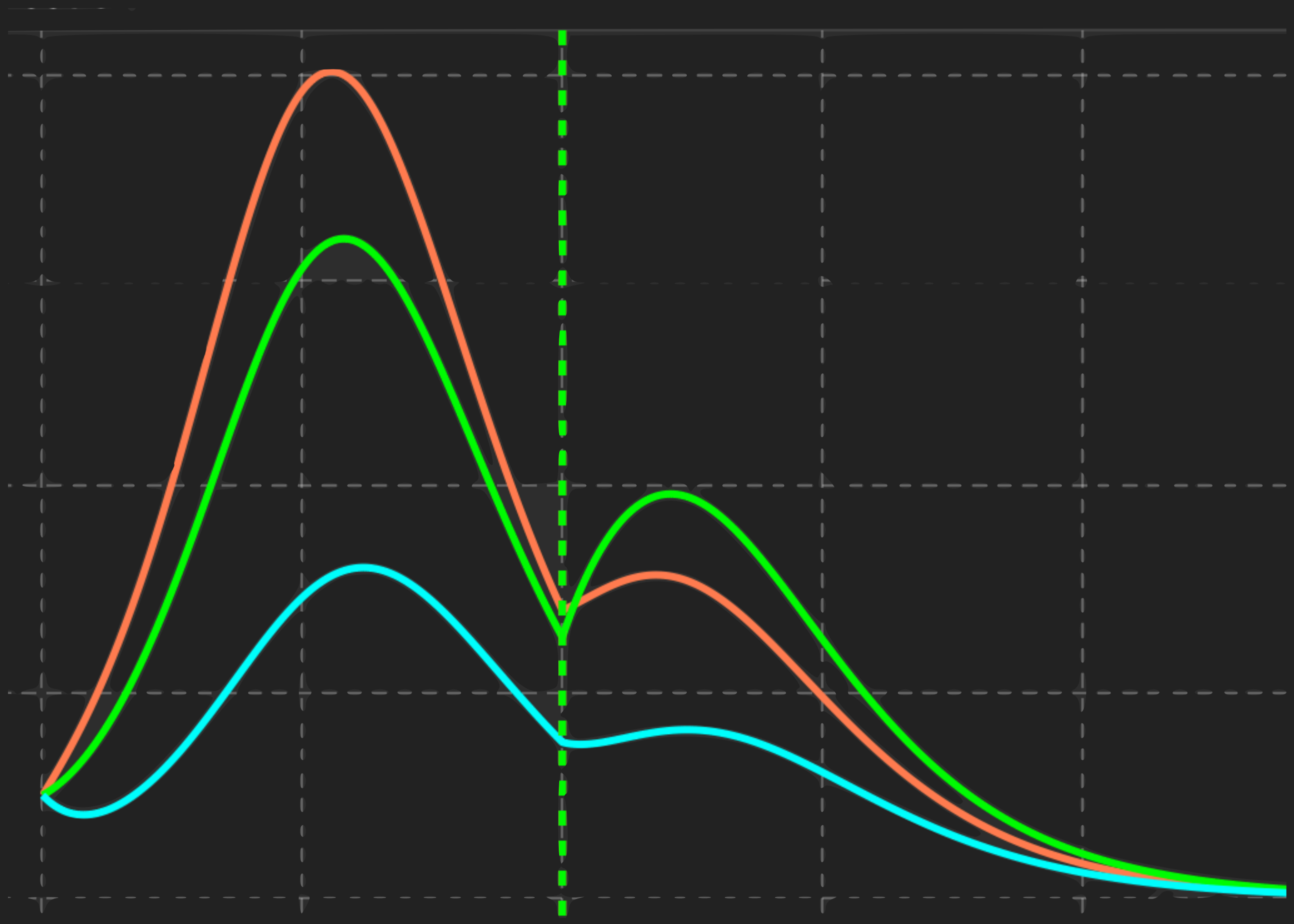

OPTIMAL TARGETED LOCKDOWNS IN A MULTI-GROUP SIR MODEL

ACEMOGLU + CHERNOZHUKOV + WERNING + WHINSTON
(MIT) (MIT) (MIT) (MIT& SLOAN)

THIS PAPER

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- **Policy analysis for COVID-19…**

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  - **Epi:** herd immunity, effect of mitigation, timing, etc.

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- **COVID-19:** <u>very</u> asymmetric effects

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

(Ferguson, 2020)

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  - **Econ:** costs of lockdowns, optimal policy, etc.
- **COVID-19:** very asymmetric effects

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

(Ferguson, 2020)

This paper: simple multi-group model

+

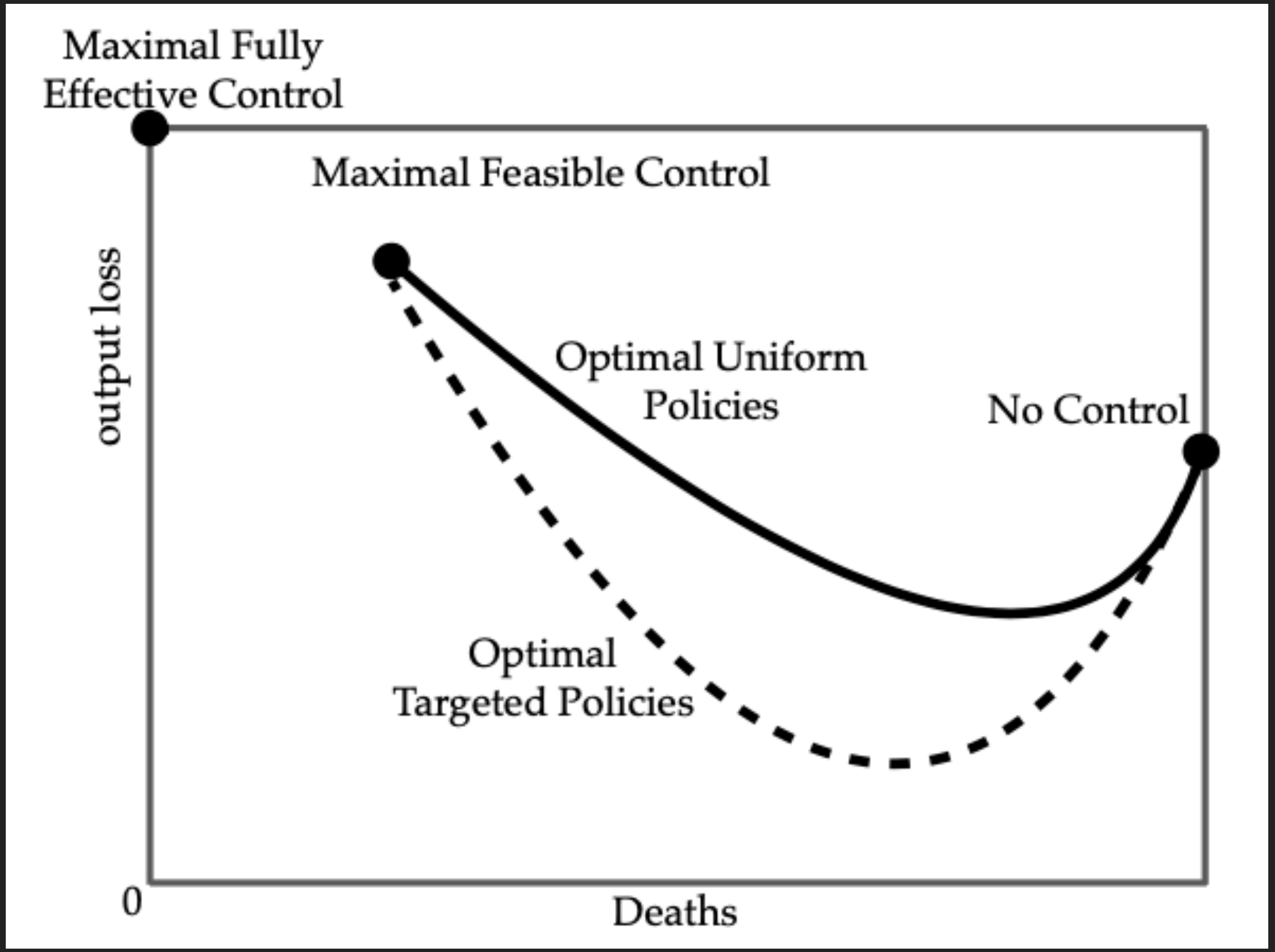
explore optimal policy implications

THIS PAPER

- Multi-group SIR/SEIR model
  - Application: young, middle-aged and old (65+)
  - Calibrate to COVID-19
  - Optimal control, contrast…
    - targeting
    - no targeting (uniform)

FINDINGS

- Large gains from targeted policy
- Most gains from simple semi-targeted policies: treat 65+ group differentially
- Do not set zero lockdown for young immediately
- Testing important



IMPORTANT CAVEATS

- We are not epidemiologists
- Model specification and parameters: very uncertain
- Our results: optimum can be sensitive to parameters
- Actual policy prescriptions: requires careful implementation tailored to situations on the ground
- We hope our analysis helps think about the bigger picture
- We welcome comments and suggestions!

OUTLINE

- Model
- Calibration
- Main Results
- Robustness

MR-SIR MODEL

MODEL

$$\text{new infections} = \beta S I$$

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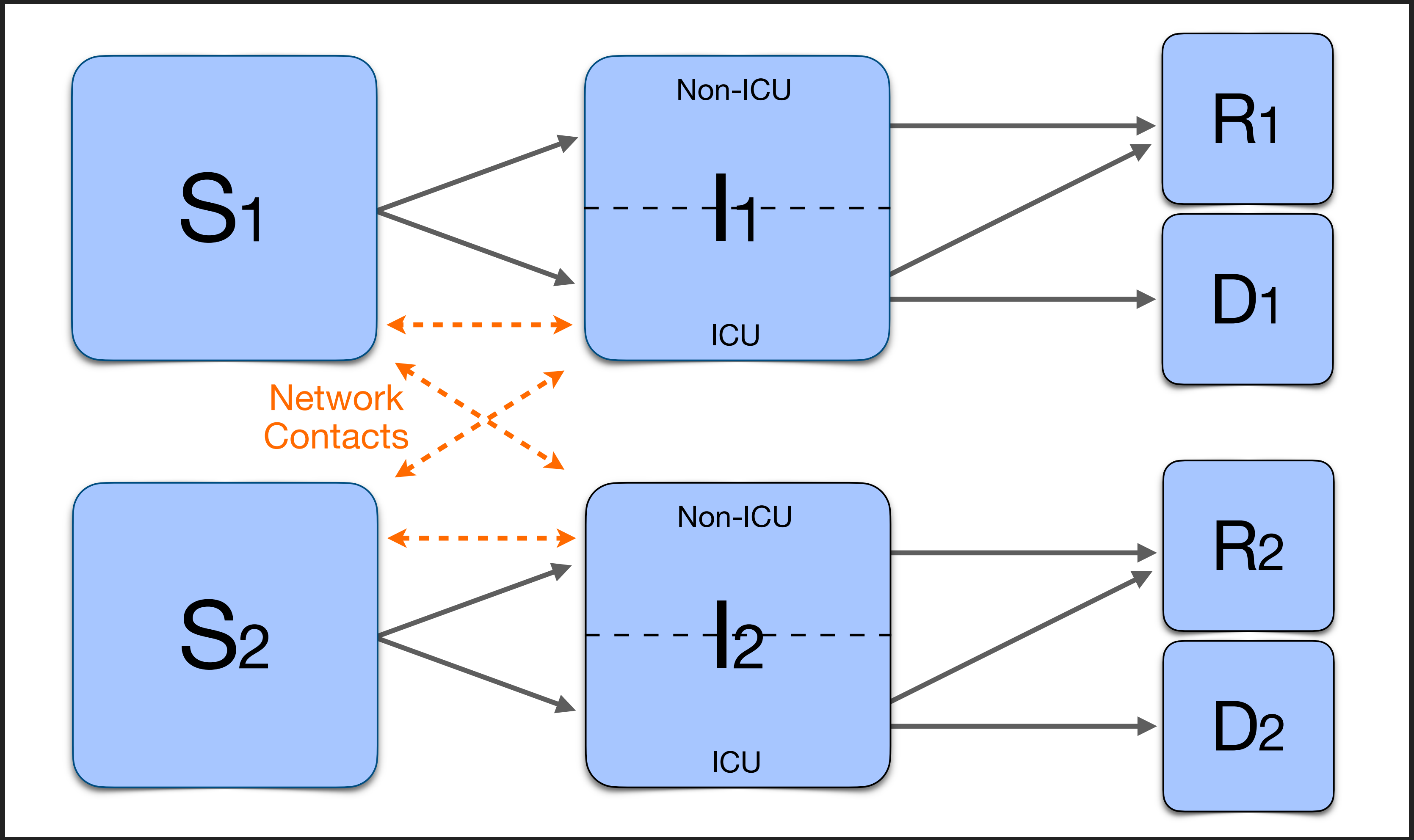
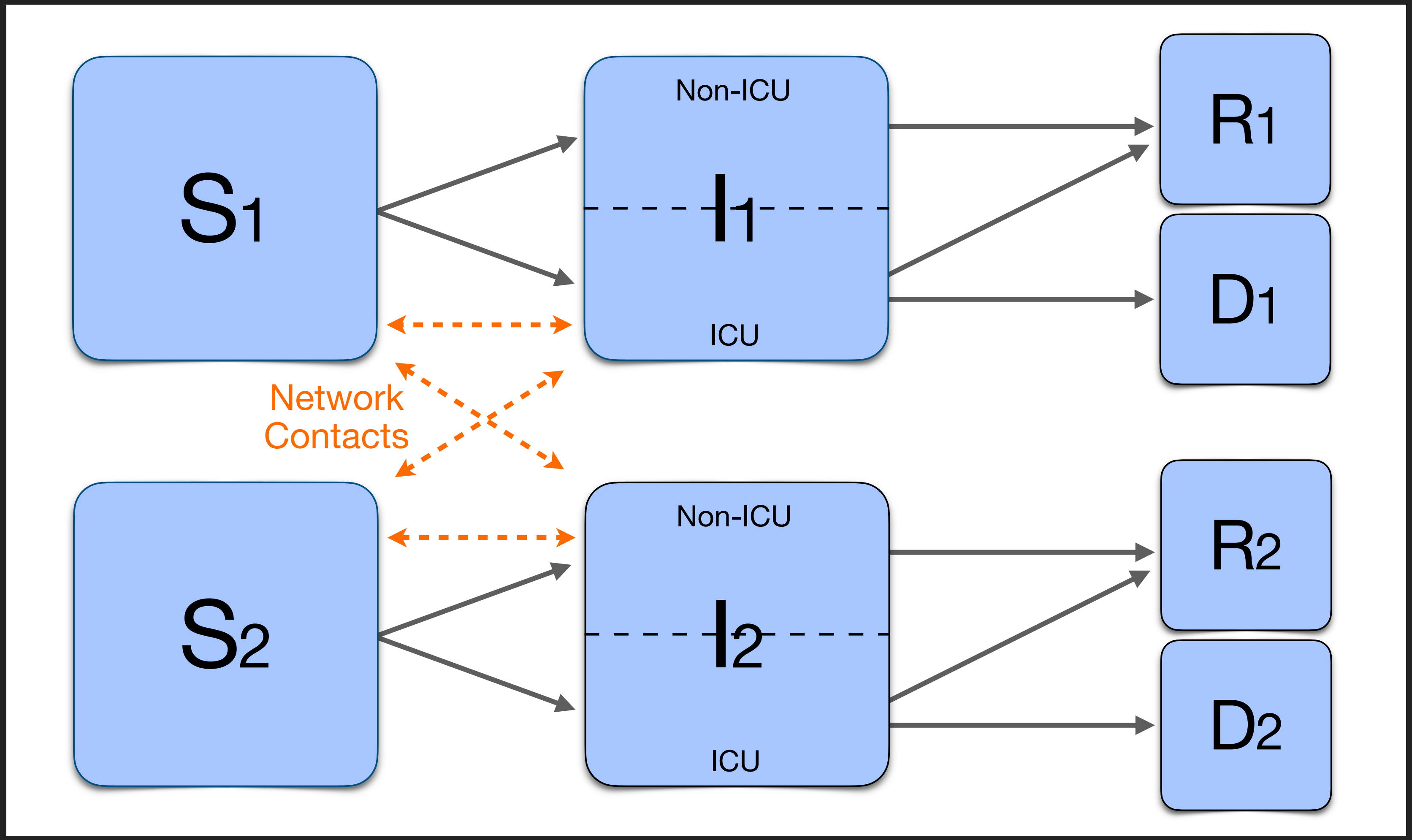


$$S_j(t) + I_j(t) + R_j(t) + D_j(t) = N_j$$

MODEL

$$\text{new infections} = \beta S I$$



$$S_j(t) + I_j(t) + R_j(t) + D_j(t) = N_j$$

$$\text{new infections in group } j = \beta S_j \sum_k \rho_{jk} I_k$$

MODEL

- j=1,2,…,J groups
- newly infected…
  - mild: $1 - \iota_j$
  - severe ("ICU"): ι_j
- all infected resolve at rate γ_j
  - mild: all recover
  - ICU: $\gamma_j = \delta_j^d(t) + \delta_j^r(t)$

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  - ICU: $\gamma_j = \delta_j^d(t) + \delta_j^r(t)$

$$\delta_j^d(t) = \psi_j(H(t))$$

$$H(t) = \sum_j \iota_j I_j(t)$$

MODEL

- Testing + Isolating
  - Non-ICU τ_j
  - ICU ϕ_j
- Not isolated: $\eta_j \equiv 1 - (\iota_j \phi_j + (1 - \iota_j)\tau_j)$
- Recovered agents…
  - assumed immune
  - detected and separated κ_j (not locked down)

PRODUCTION AND LOCKDOWN

- Lockdown $L_j \in [0, \bar{L}_j]$
  - opportunity cost w_j
  - Effectiveness is imperfect: θ_j
- Fraction interacting infections

$$1 - \theta_j L_j(t)$$

VACCINE + CURE

- Assume…
  - vaccine + cure arrives at some T
  - after this infections drop to zero and stay there
- Extension: T stochastic

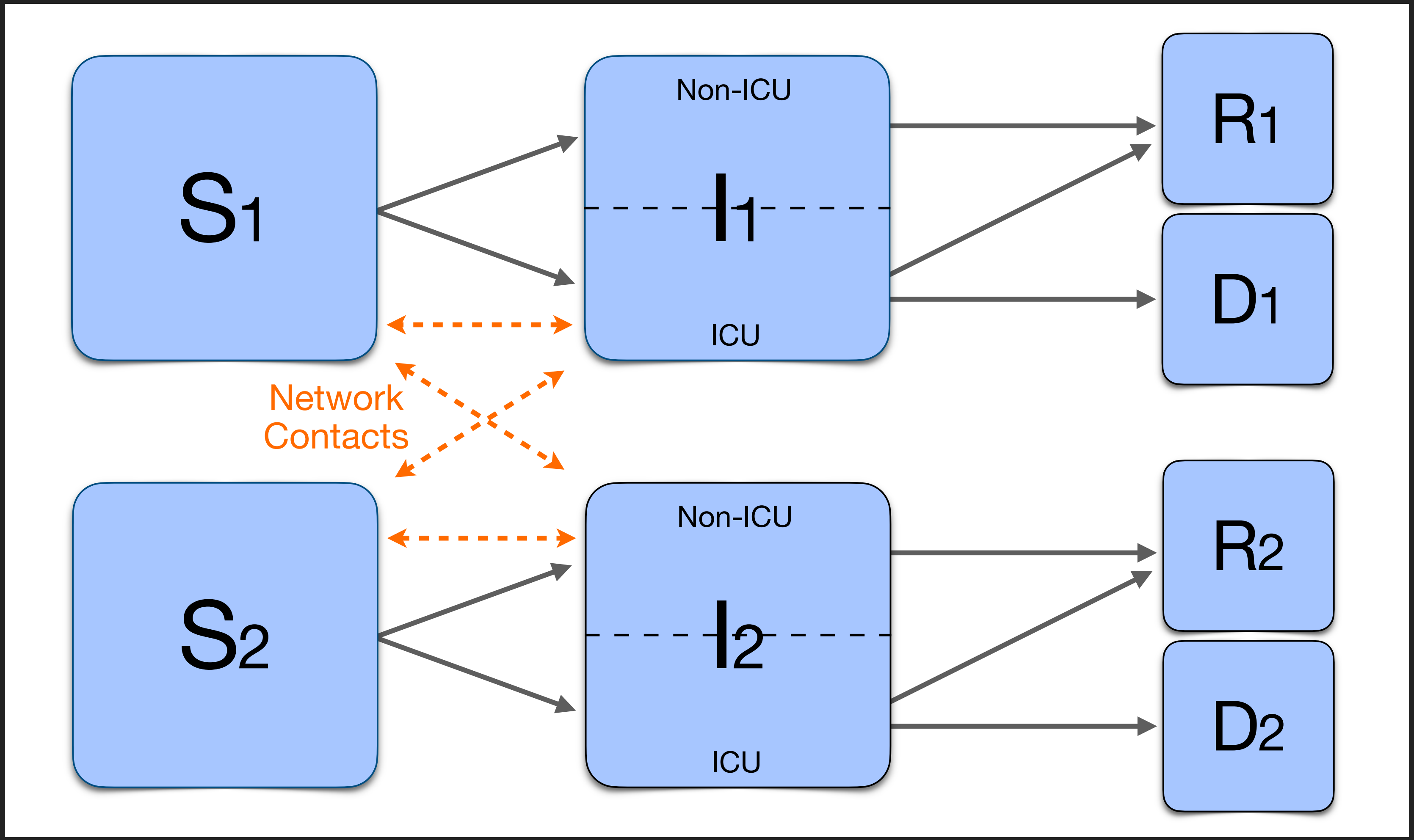
MODEL

$$\text{new infections} = \beta S I$$

$$\text{new infections in group } j = \beta(1 - \theta_j L_j) S_j \sum_k \rho_{jk} \eta_k (1 - \theta_k L_k) I_k$$

MODEL

$$\text{new infections} = \beta S I$$



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TWO OBJECTIVES

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$$\text{Lives Lost} = \sum_j D_j(T)$$

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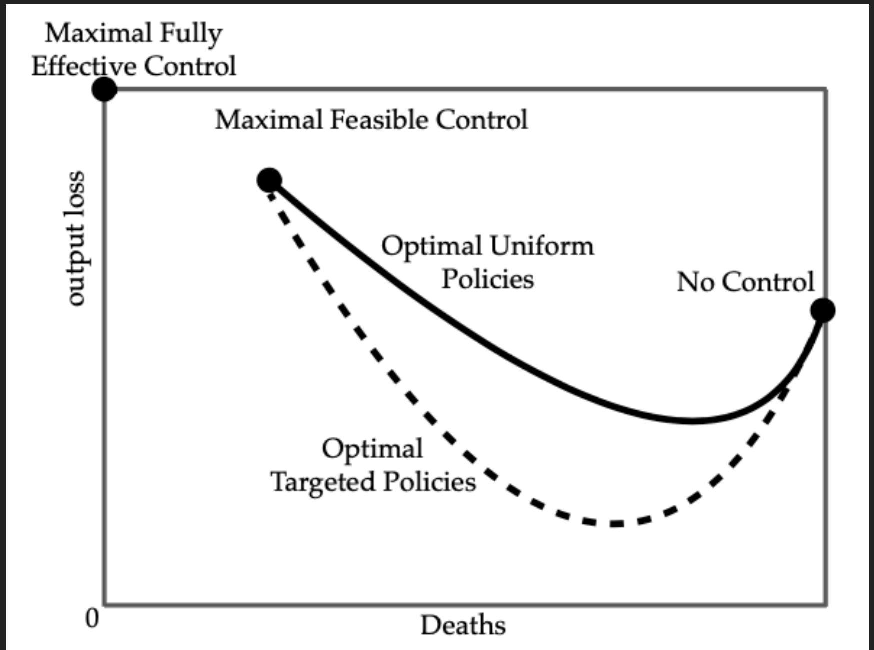

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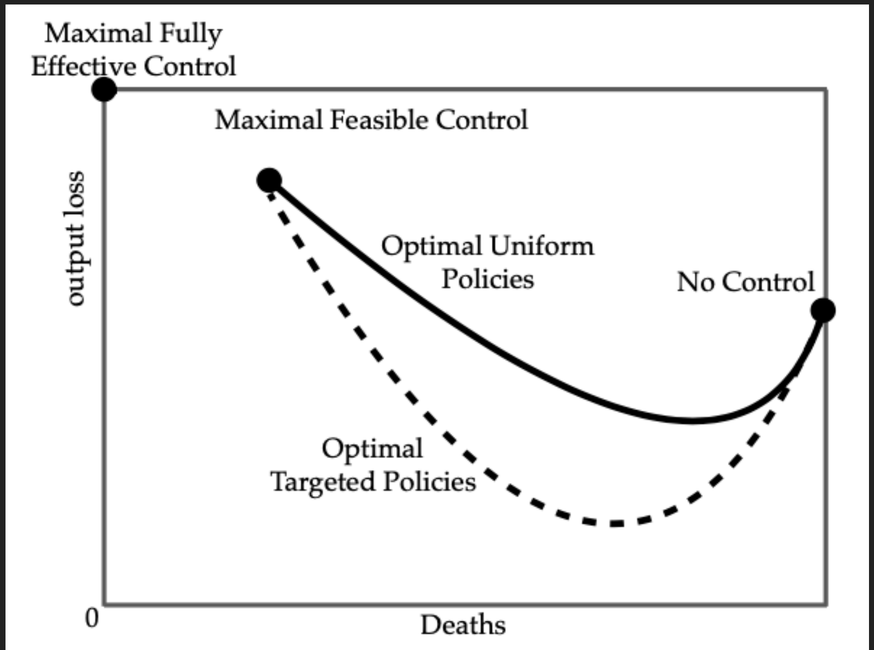

$$\text{Economic Losses} + \chi \text{Lives Lost}$$

GAINS FROM TRAGETING

- Better tailoring… (not subtle)
  raise lockdown for old
  + lower lockdown for young

- Targeted herd immunity… (more subtle)
  even just lower lockdown for young can protect old

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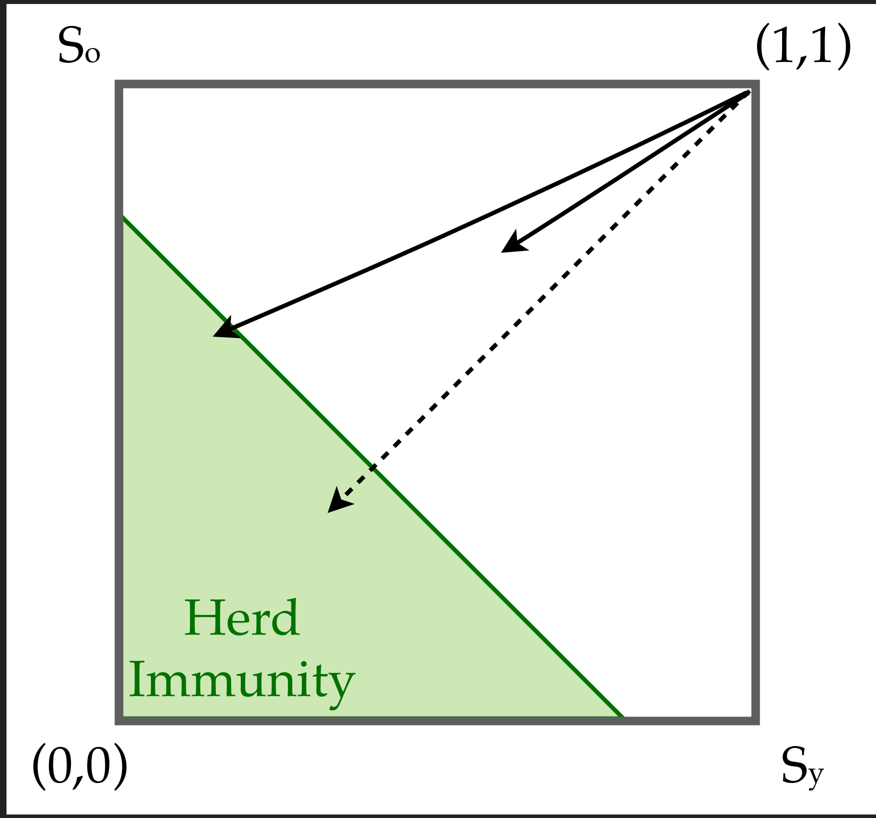


QUESTIONS?

PARAMETER CALIBRATION

PARAMETERS

- Fatality rates…
  - Ferguson & South Korea
  - for us: age dependence more than levels

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

- Contagion rate $\beta = 0.134$ (R_0=2.4)
- Duration of disease $\gamma_j = 1/18$
- Interactions uniform: $\rho = 1$ (later calibrate contact matrix)
- Groups sizes and earnings…

$$N_y = 0.53, N_m = 0.26, N_o = 0.21$$

$$w_y = 1, w_m = 1, w_o = 0.26$$

PARAMETERS

- Hospital Capacity effects

$$\delta_j^d(t) = \underline{\delta}_j^d \cdot [1 + \lambda H(t)]$$
$$= \underline{\delta}_j^d \cdot [1 + \widehat{\lambda} \sum_k \underline{\delta}_k^d I_k(t)]$$

  - calibrate $\hat{\lambda}$ so mortality is 10% higher when 10% infection rate
  - Examine hard “ICU constraint” later

PARAMETERS

- Low testing and isolation:

$$\eta_j = 0.9$$

- Lockdowns…
  - effectiveness $\theta_j = 0.75$
  - maximums $\bar{L}_y = 0.7, \bar{L}_m = 0.7, \bar{L}_o = 1$
- Immunity cards for recovered $\kappa_j = 1$
- … but explore opposite case later

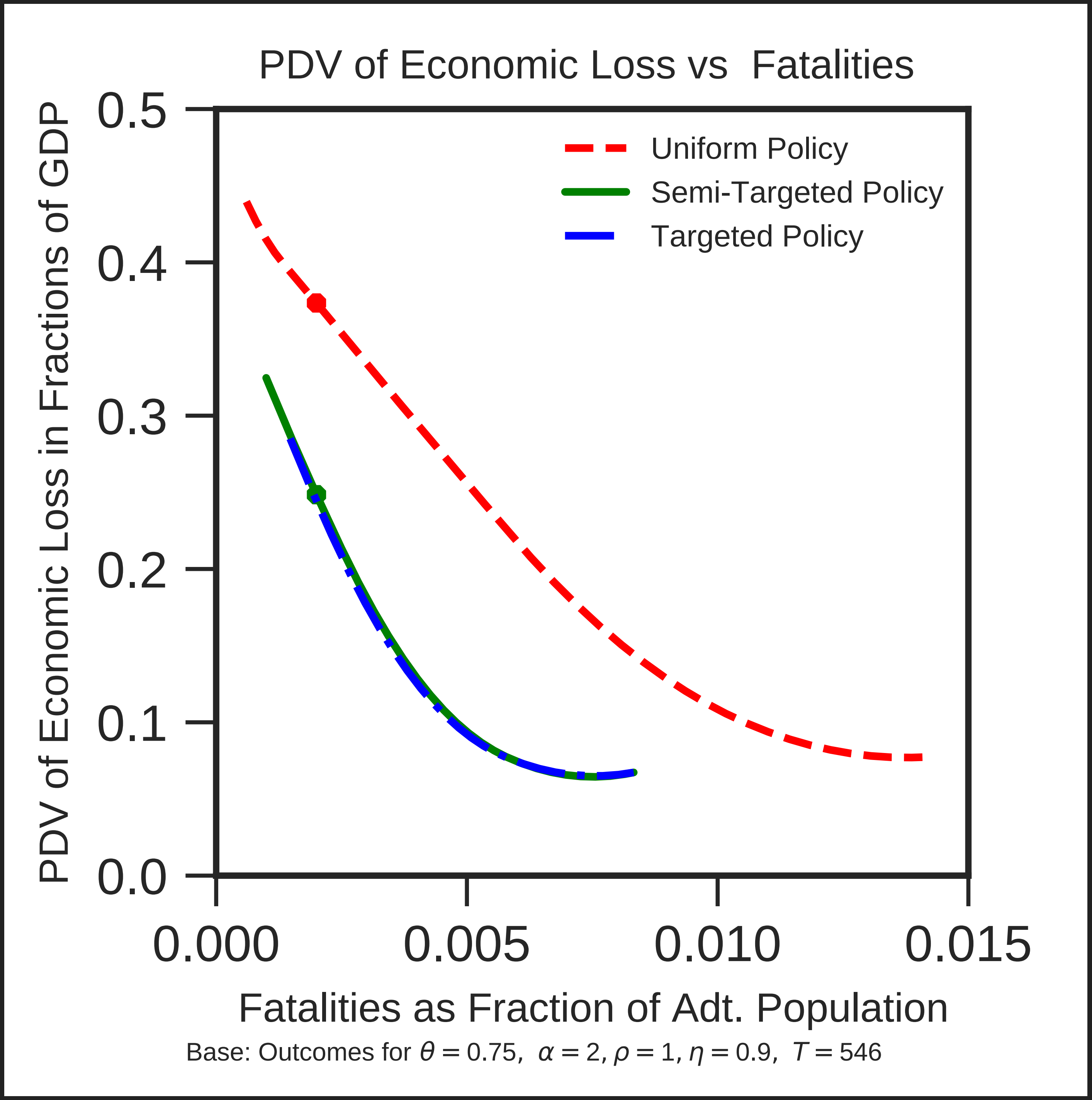
PARAMETERS

- Cost of death: adjust economic cost for finite work time
  - young: 30 years $\Delta_y = 30 \times 365$
  - middle: 7.5 years $\Delta_m = 7.5 \times 365$
- Vaccine baseline: T=1.5 years
- Also explore more optimistic cases

QUESTIONS?

RESULTS

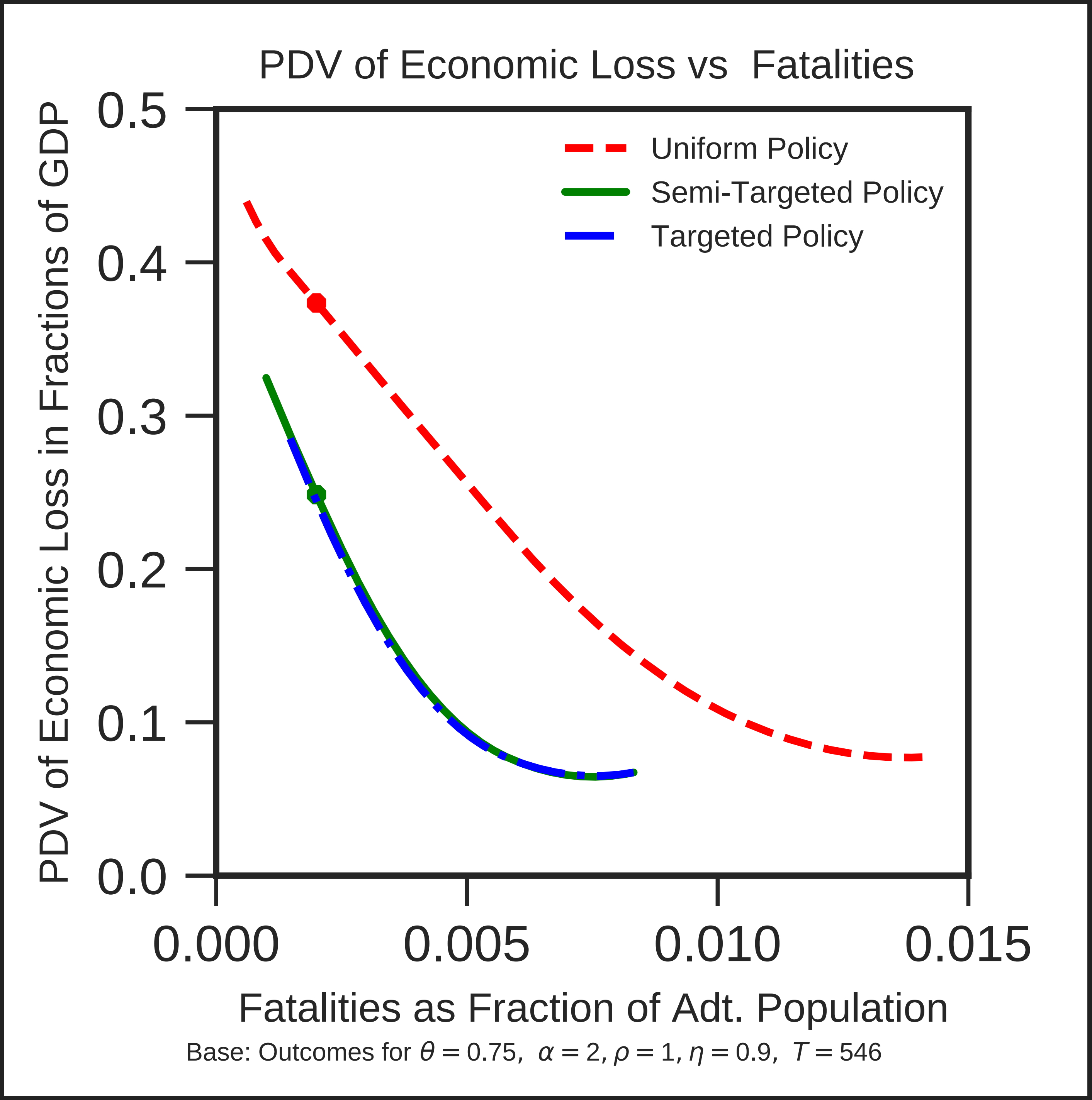
FRONTIER



Large gains for Semi-Targeting

Small gains for Full-Targeting

FRONTIER

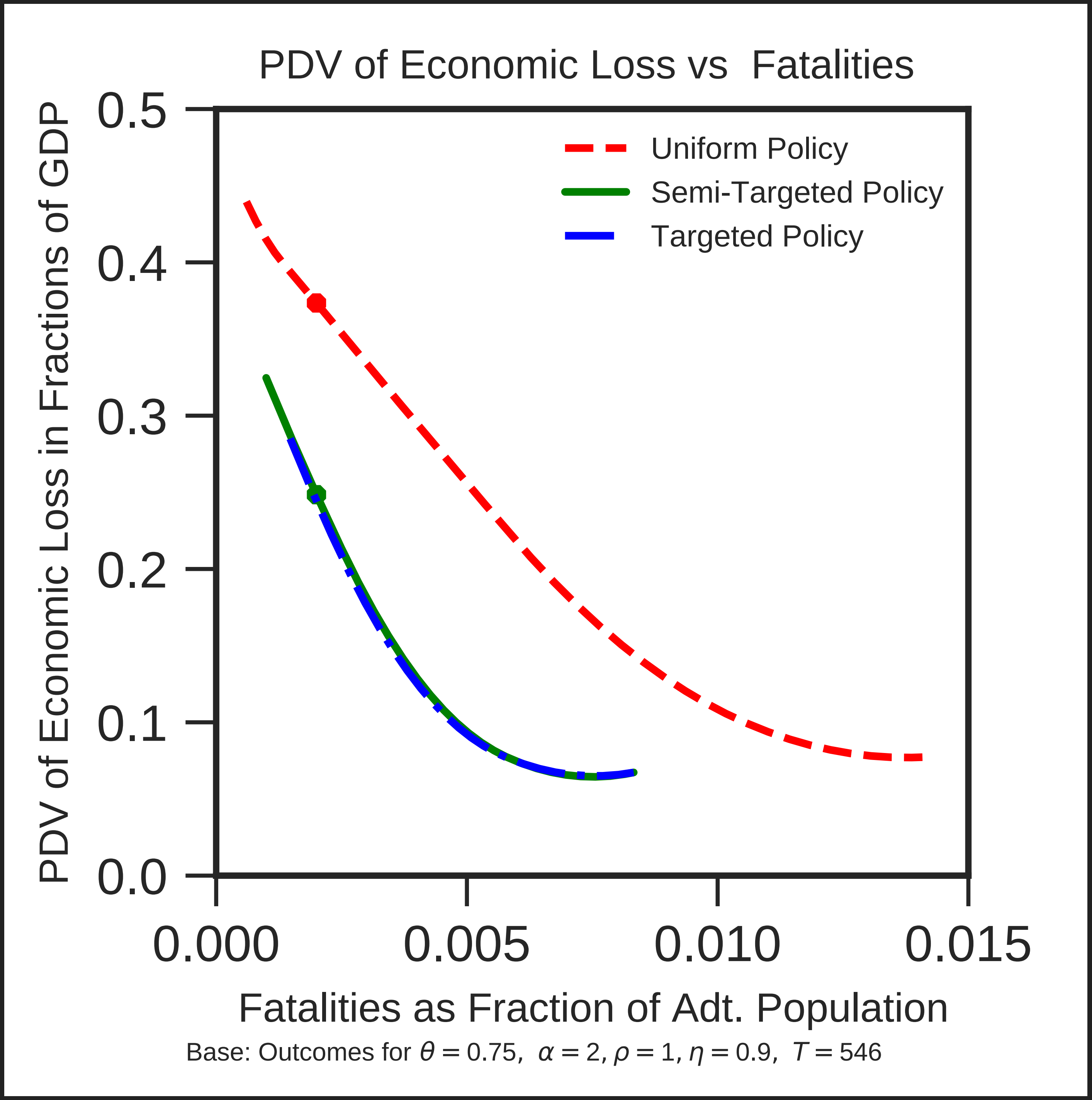


Safety-Focused = 0.2% mortality

Large gains for Semi-Targeting

Small gains for Full-Targeting

FRONTIER



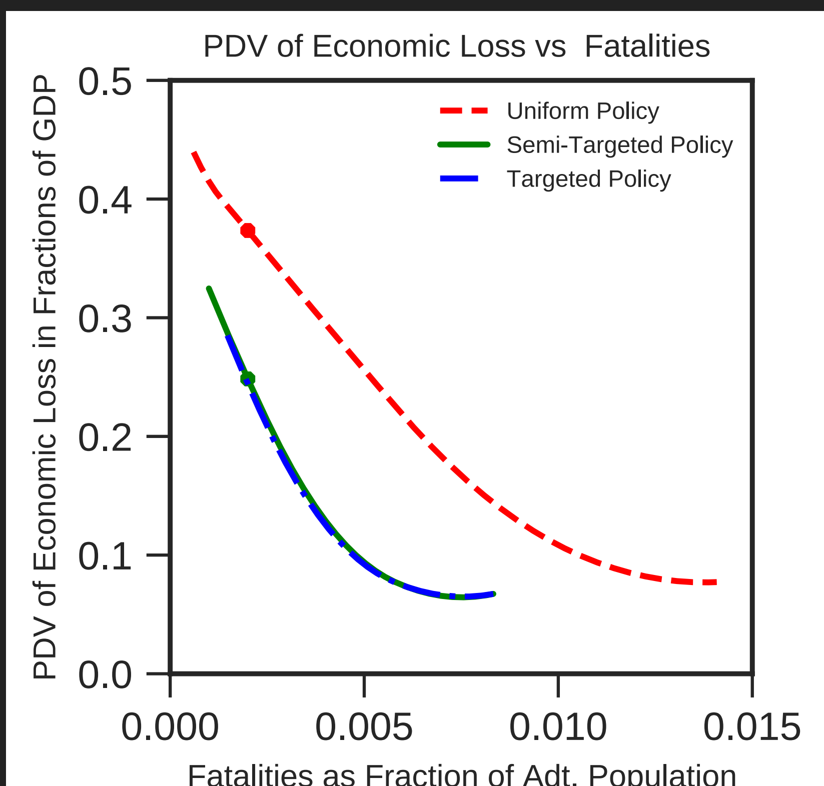
Safety-Focused = 0.2% mortality

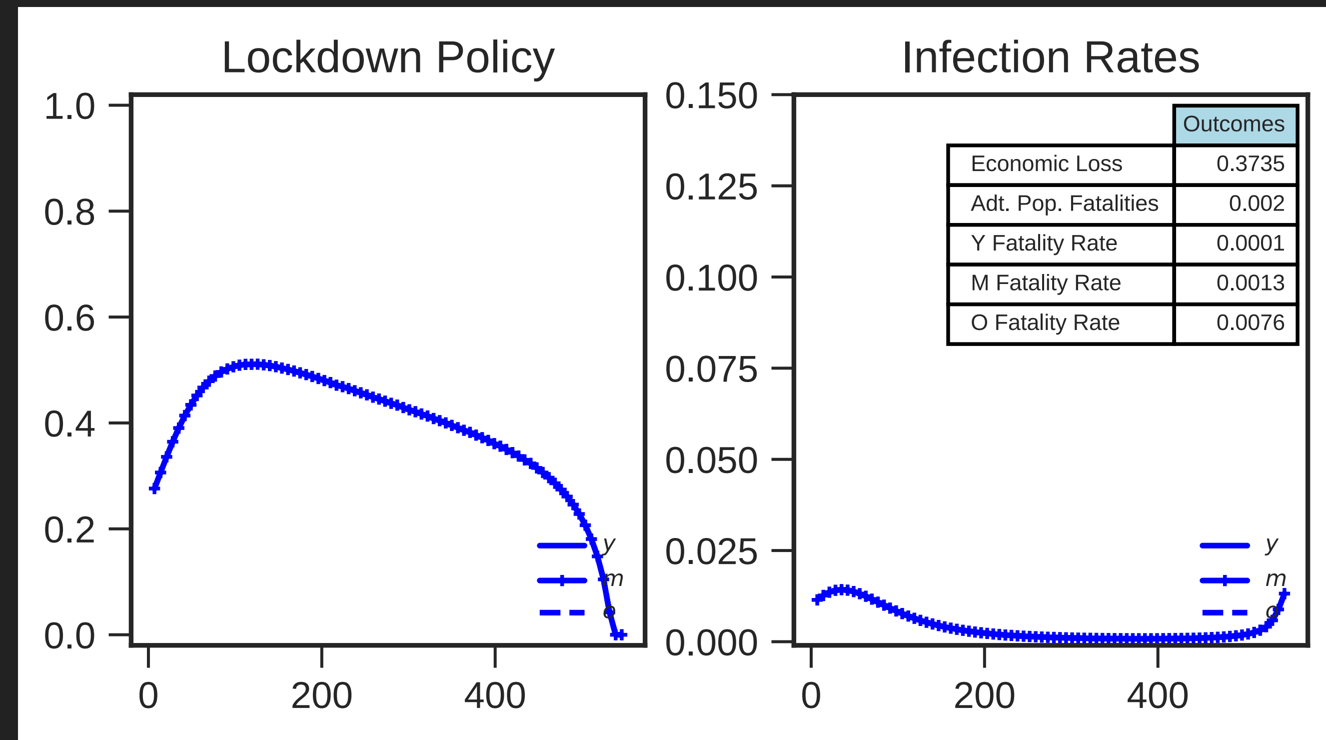
Economy-Focused = 10% output loss

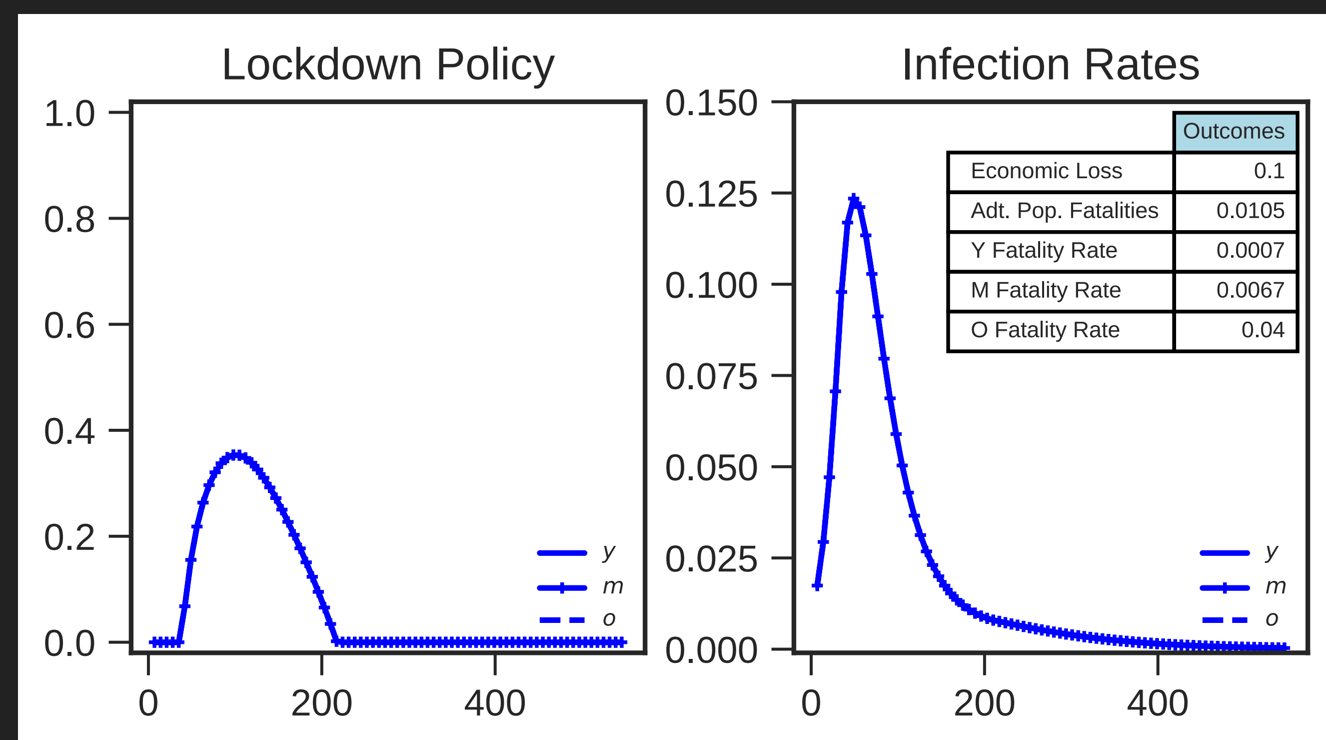
Large gains for Semi-Targeting

Small gains for Full-Targeting

OPTIMAL UNIFORM POLICIES







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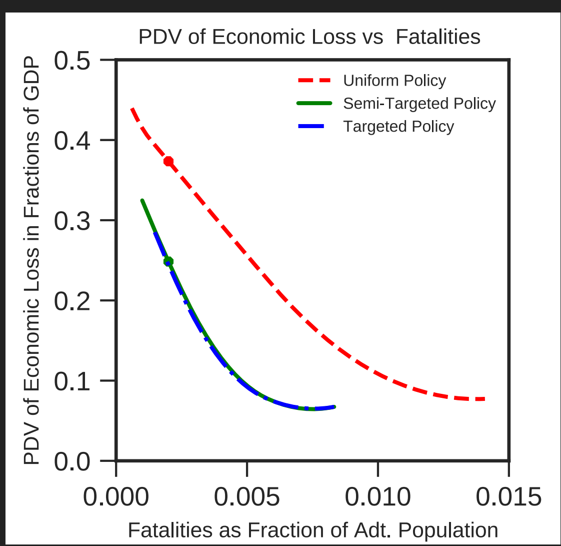

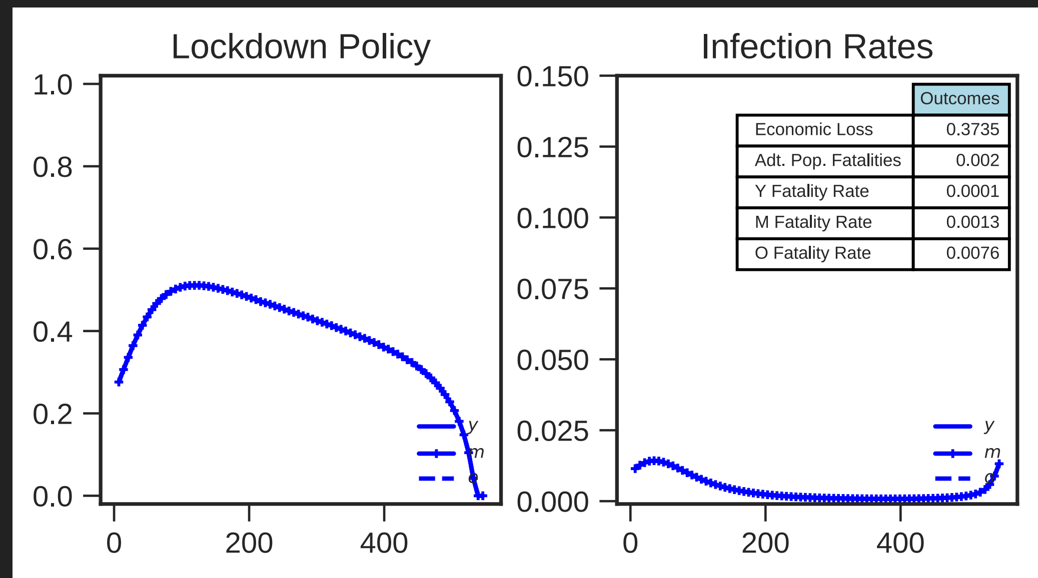

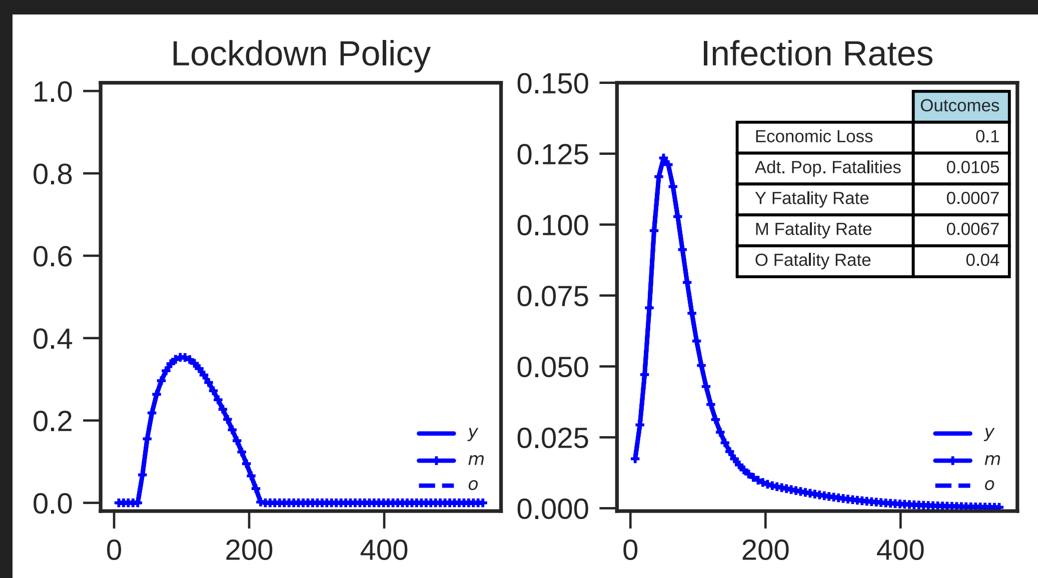

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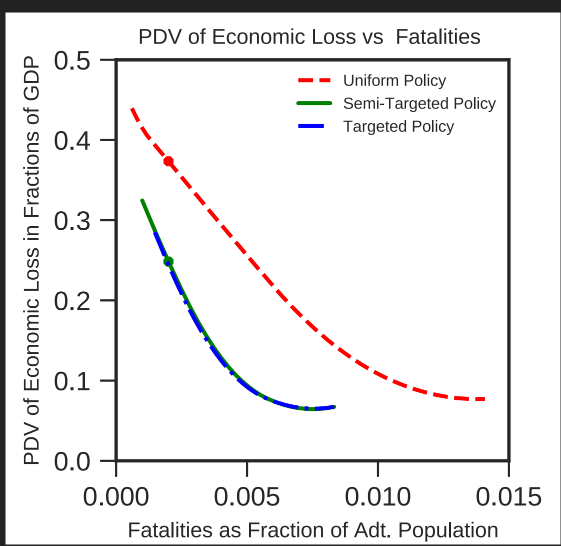

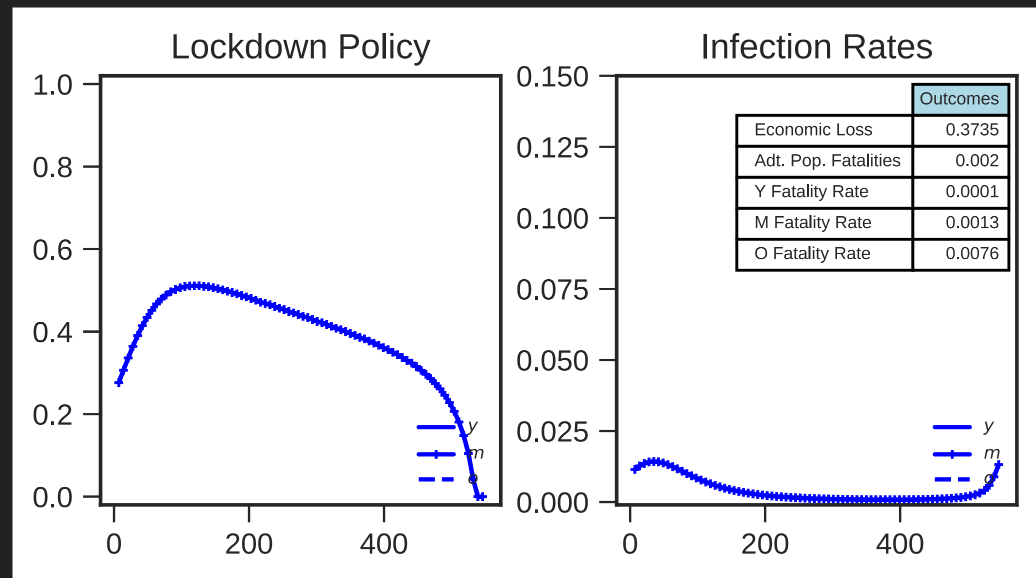

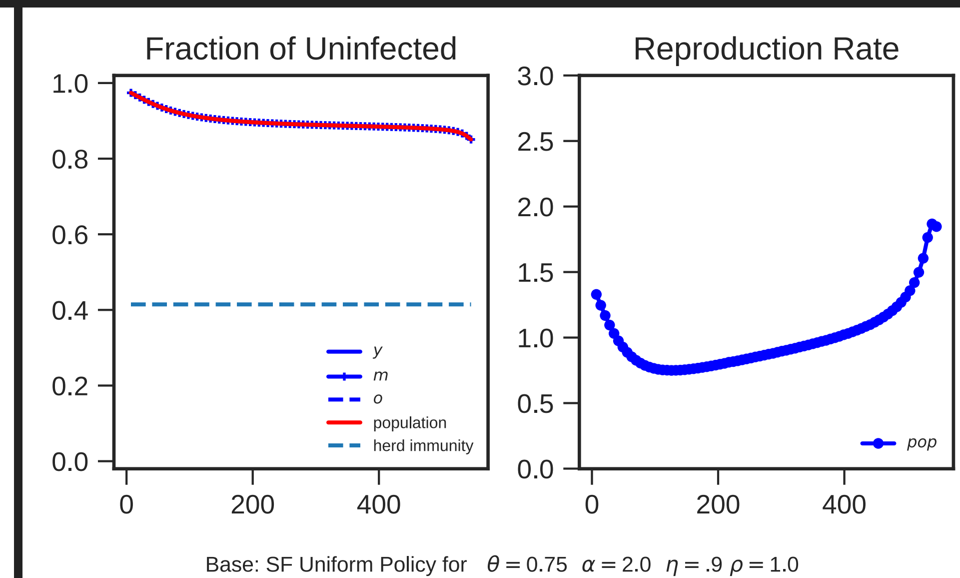

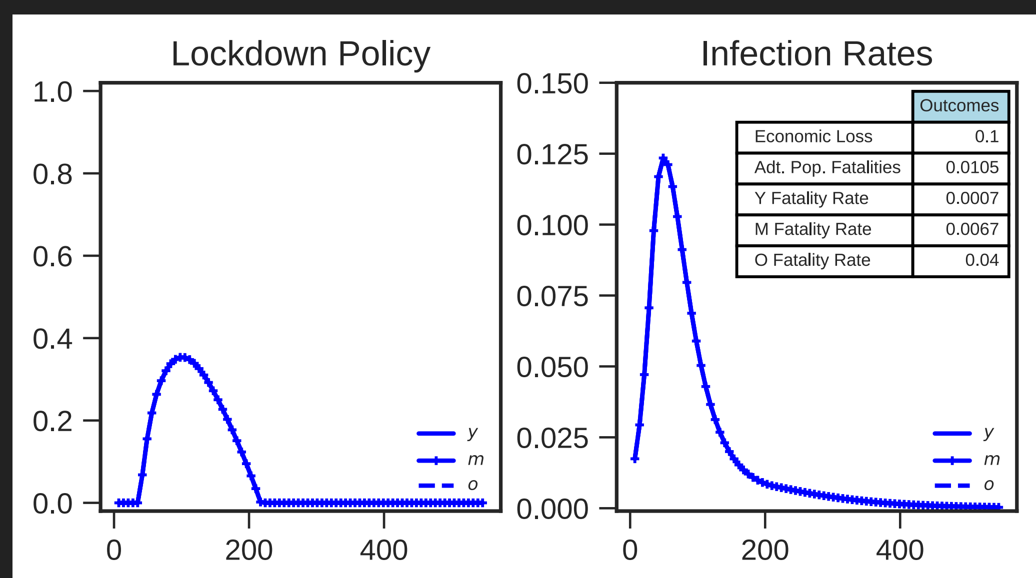

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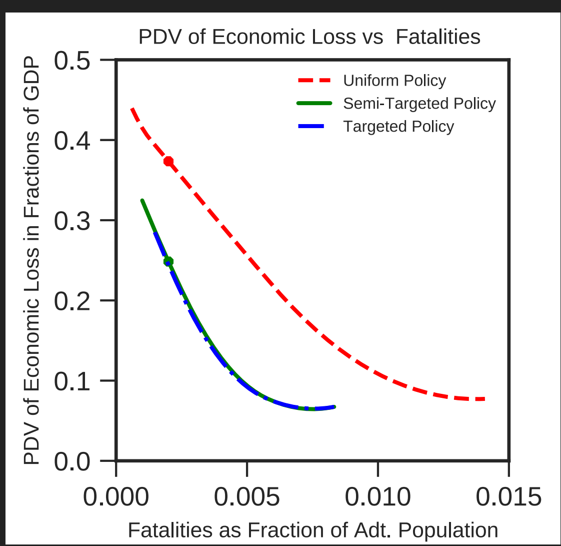
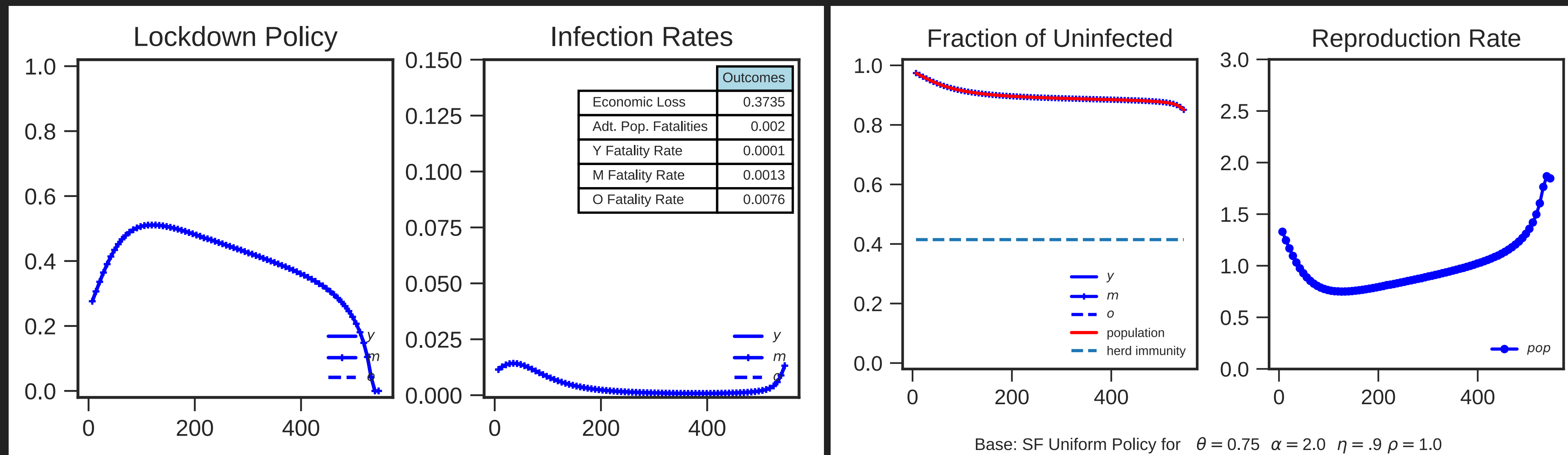
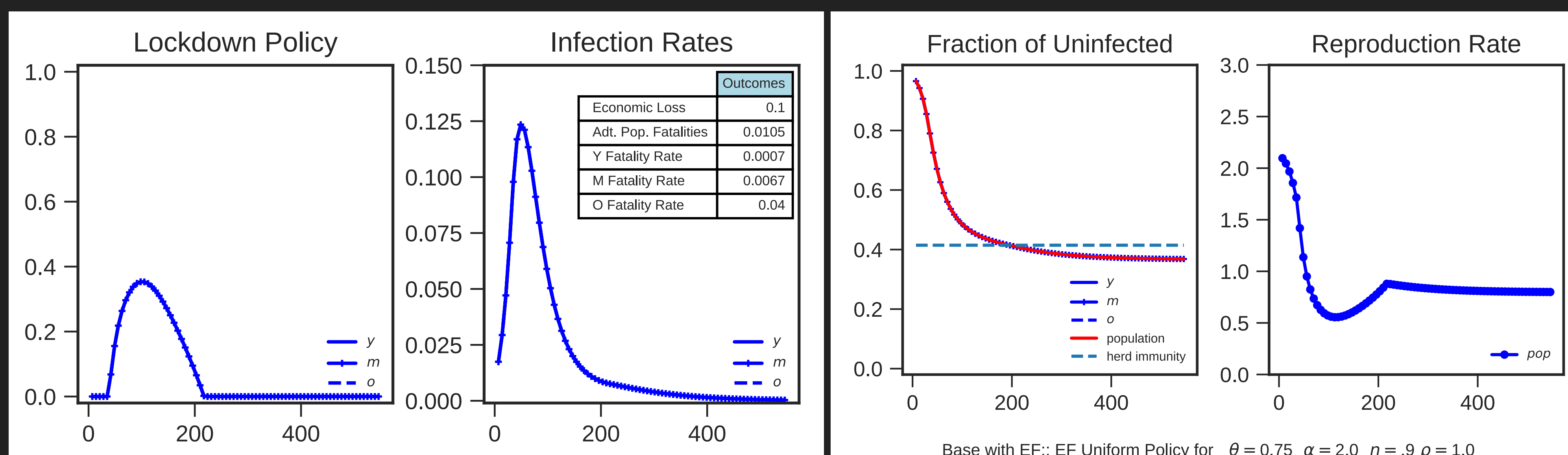
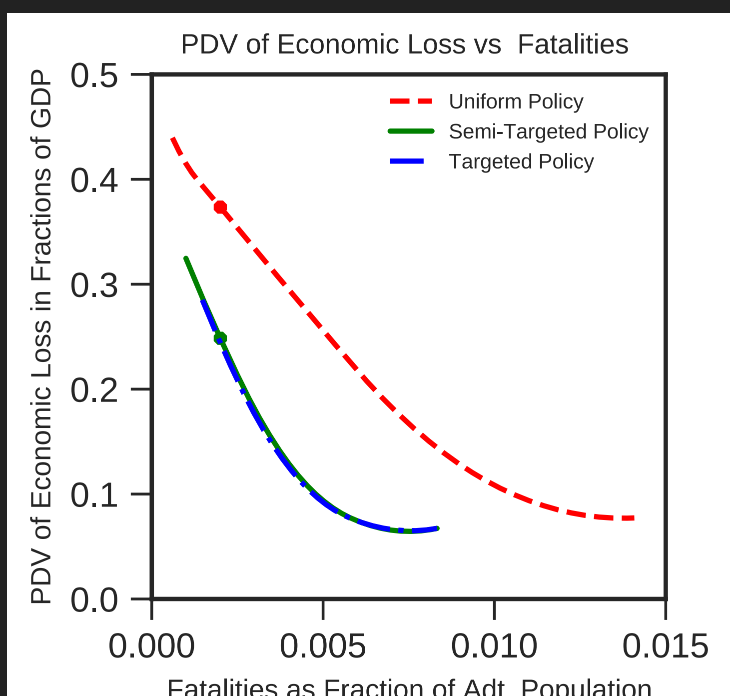
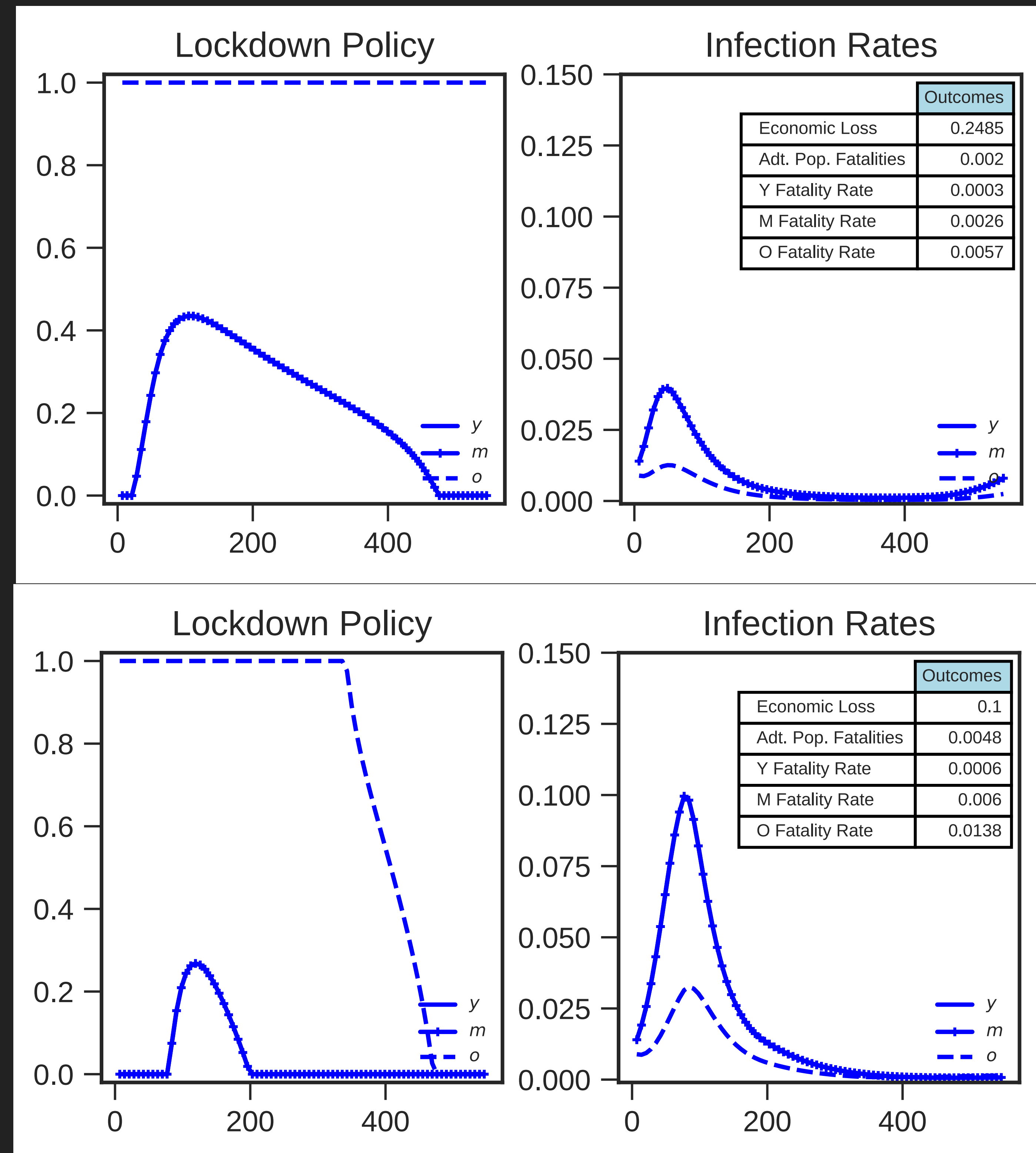






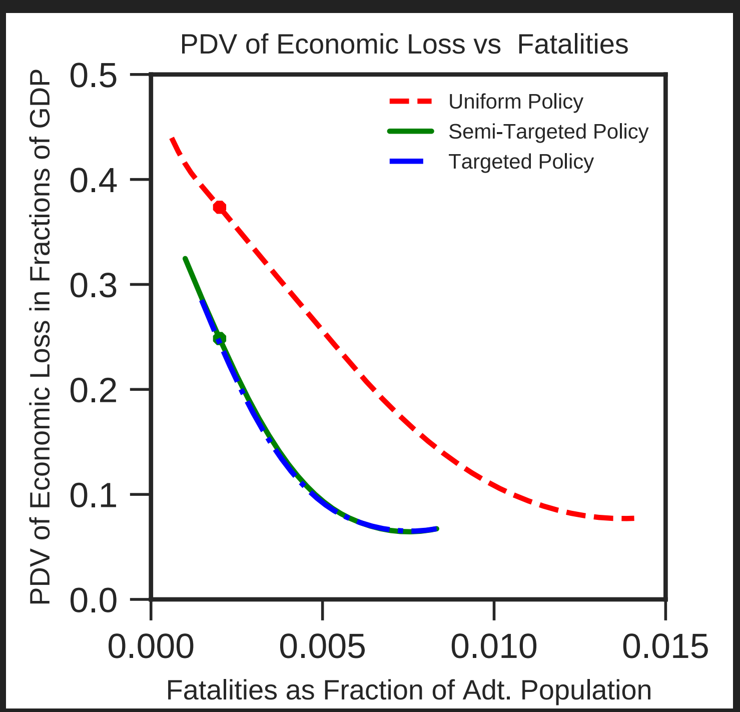
OPTIMAL SEMI TARGETED

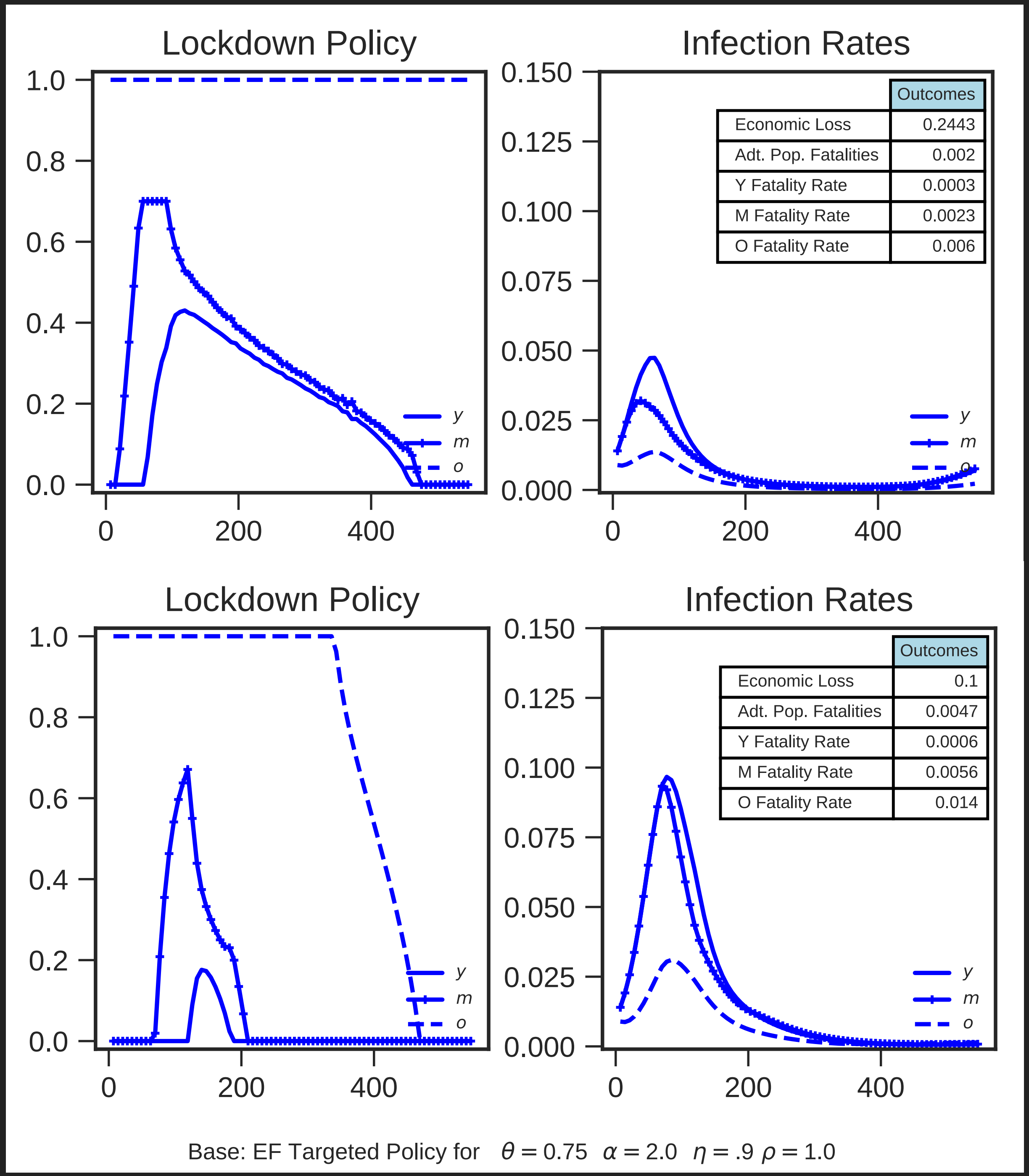




Big Improvements vs. Uniform Policy

OPTIMAL FULLY TARGETED

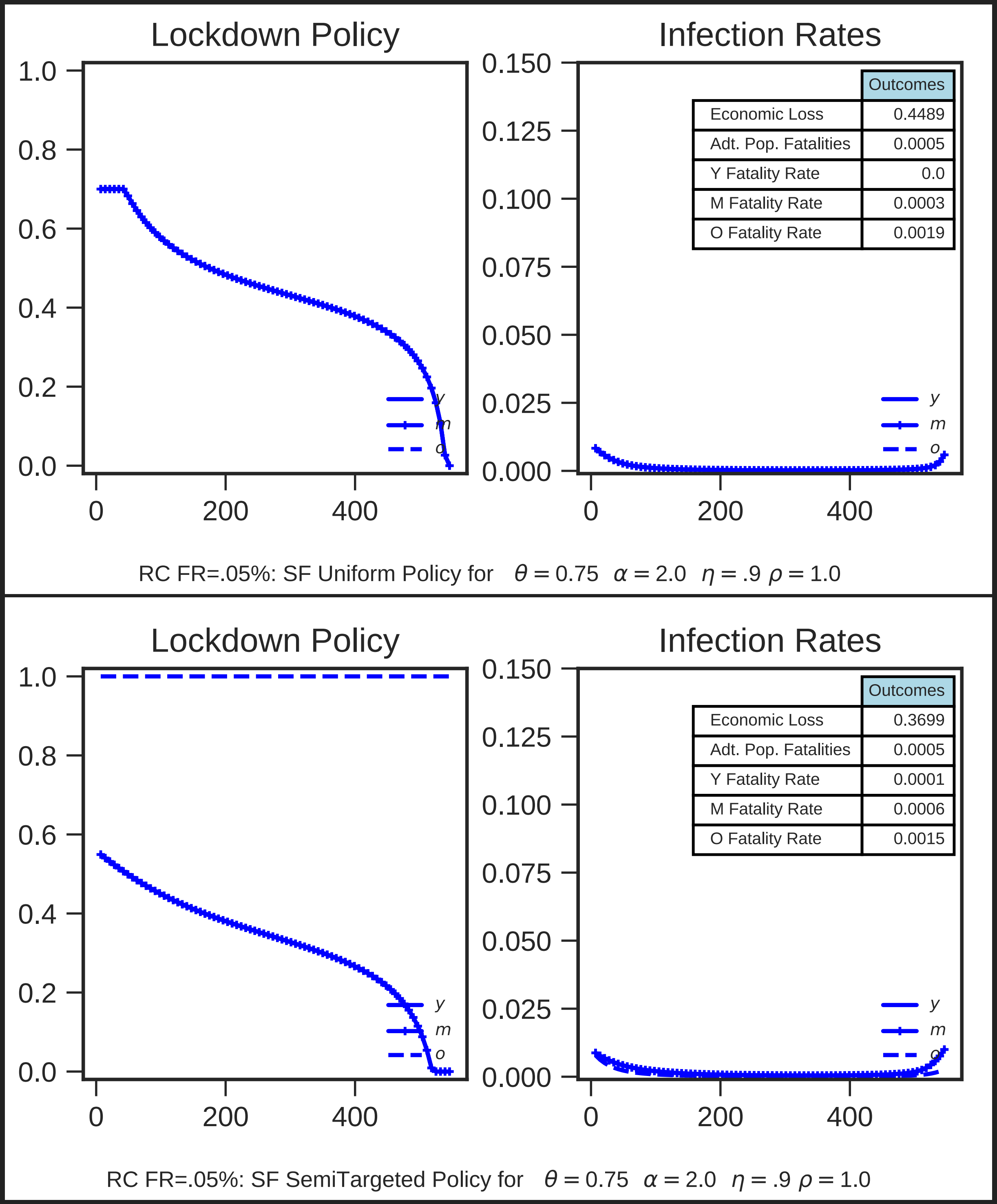




Additional gains, but small:
semi-targeting gets to most of it

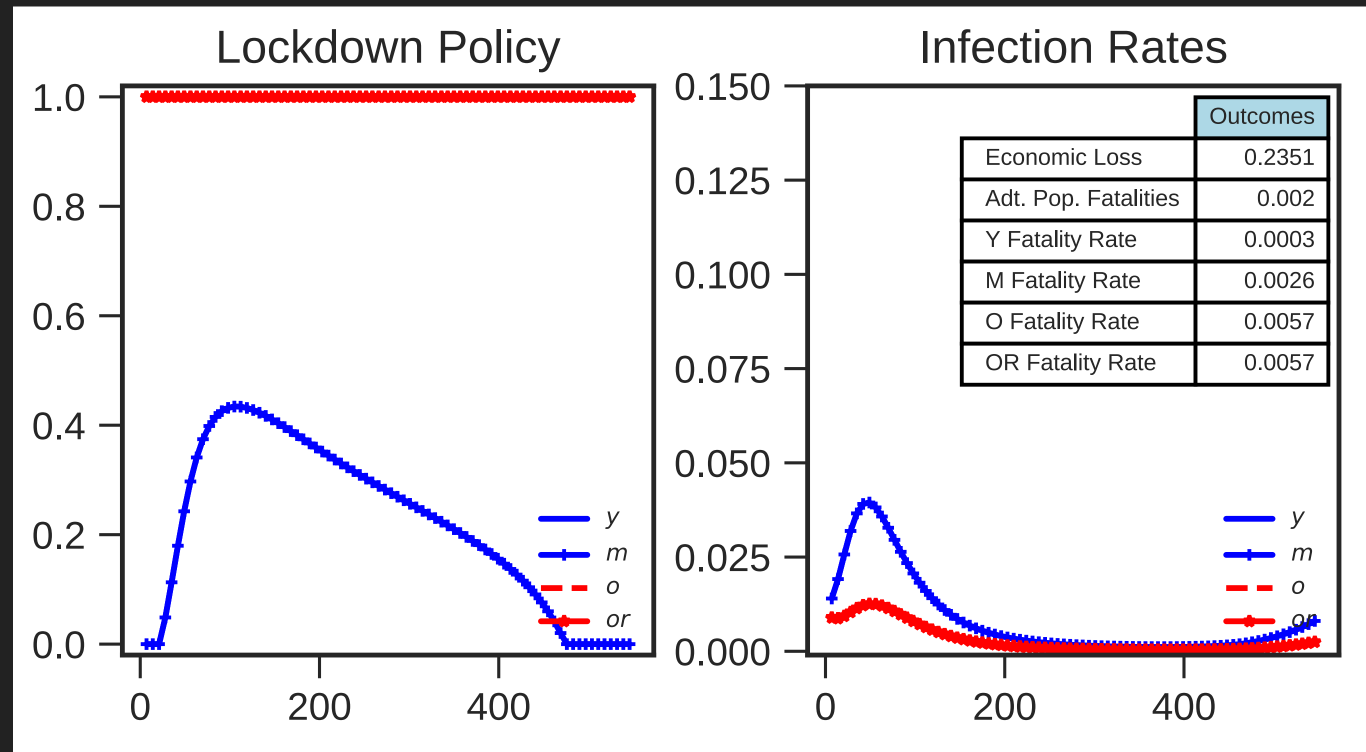
SAFETY FIRST

- Point on frontier with 0.05% adult mortality

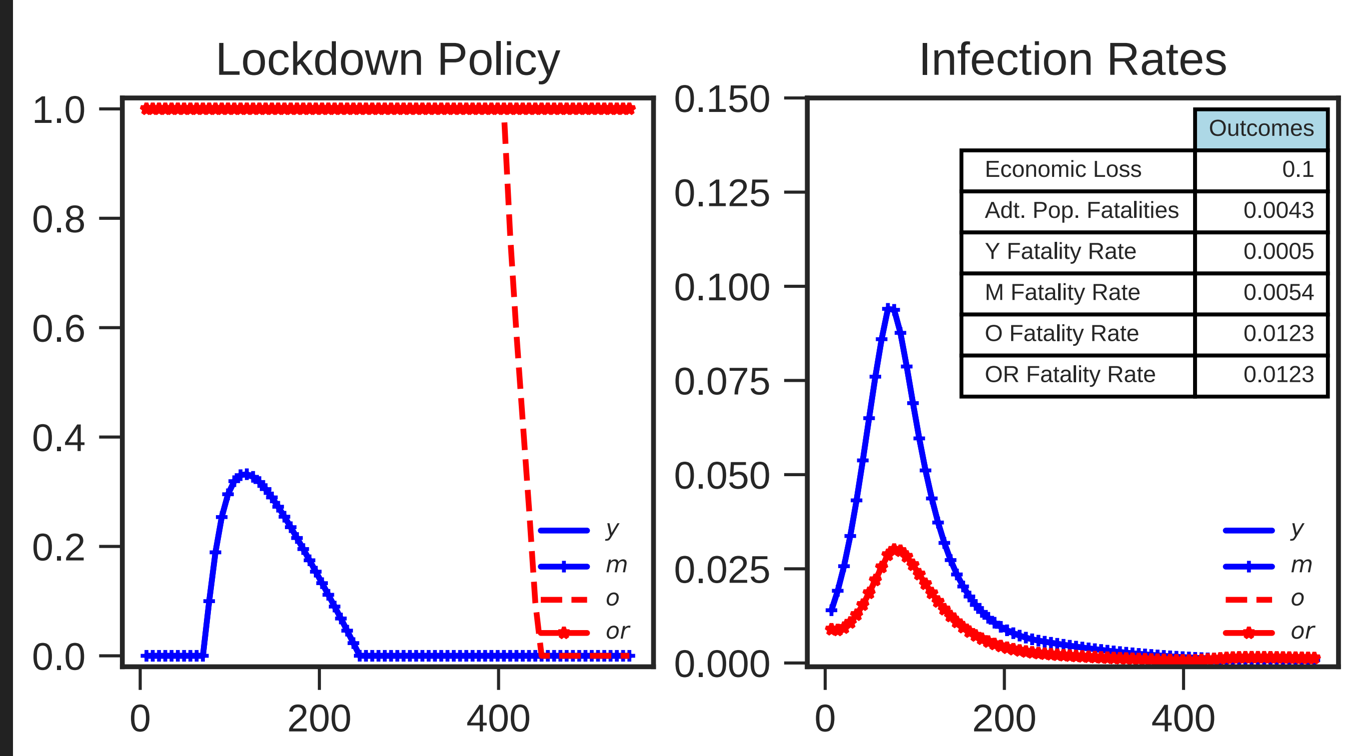


4G MODEL

- Split old into working and not working…

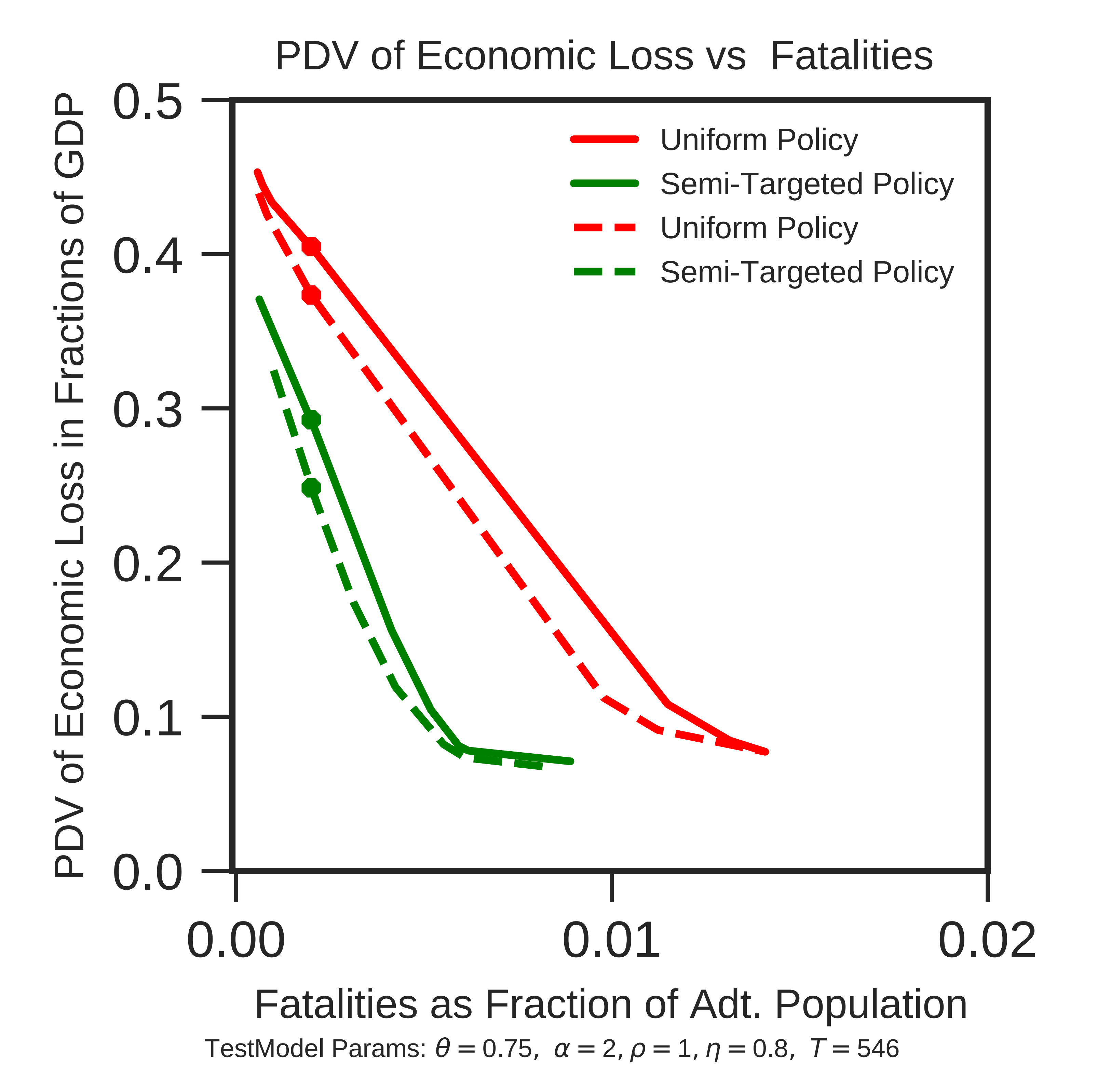


4G: SF SemiTargeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = .9$ $\rho = 1.0$

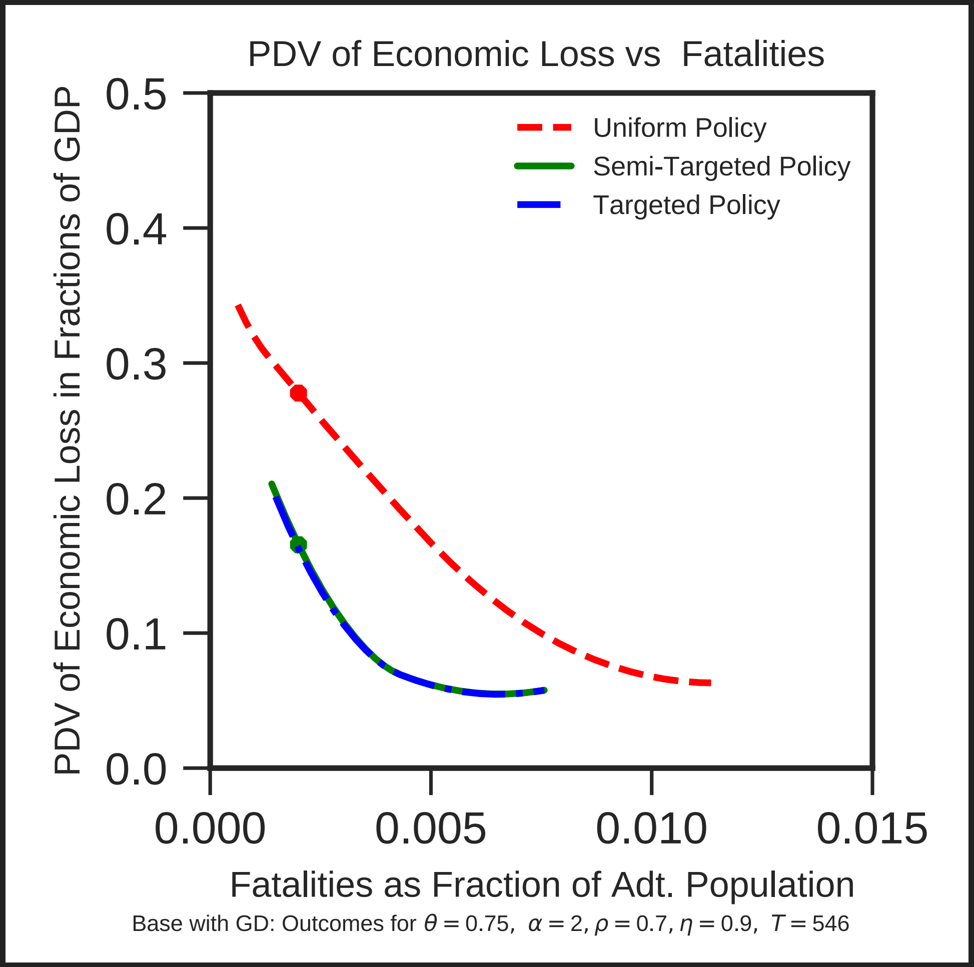


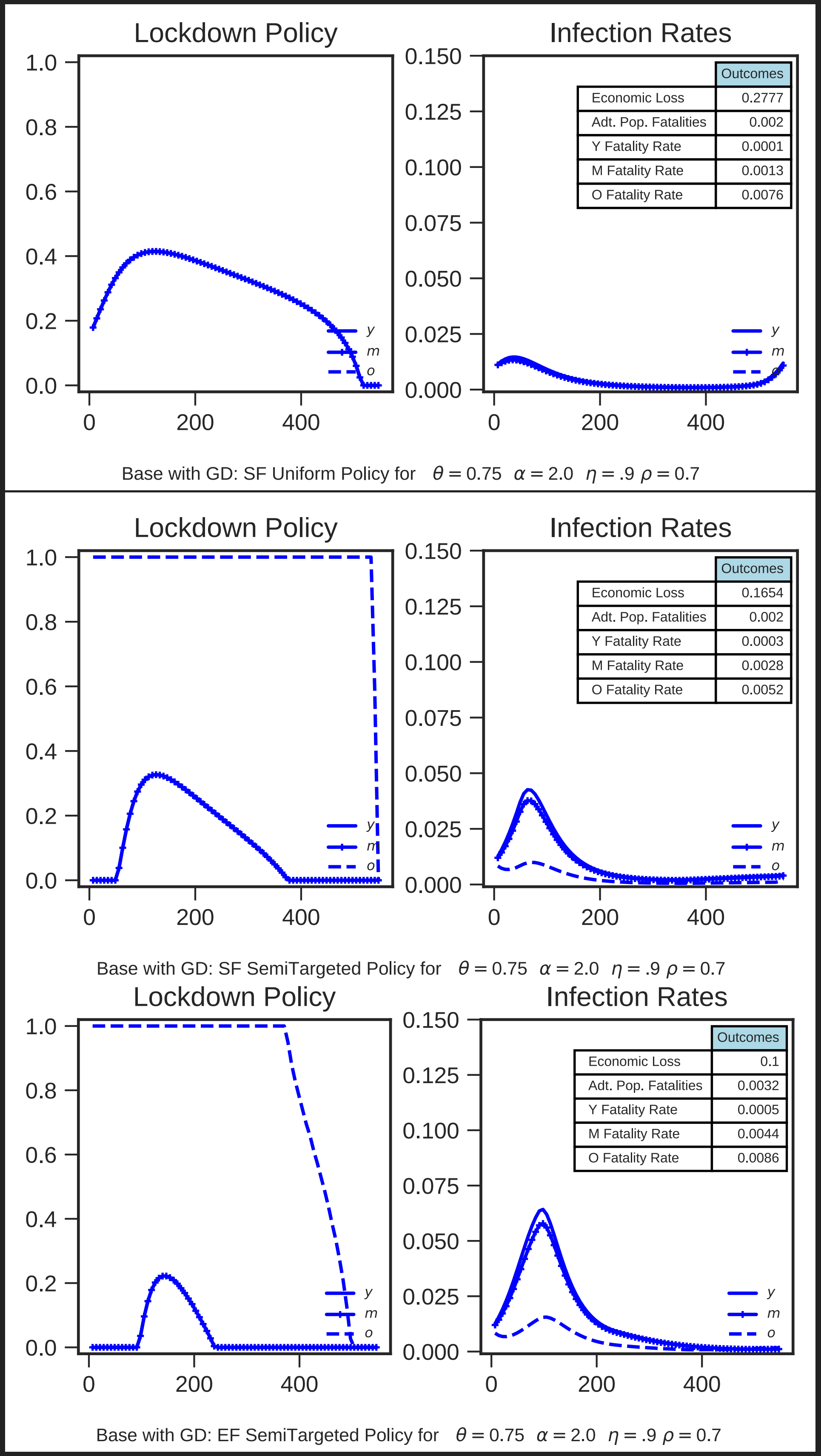
4G: EF SemiTargeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = .9$ $\rho = 1.0$

RECOVERED, NO IMMUNITY CARD



GROUP DISTANCING (RHO=0.7; BASELINE = 1)



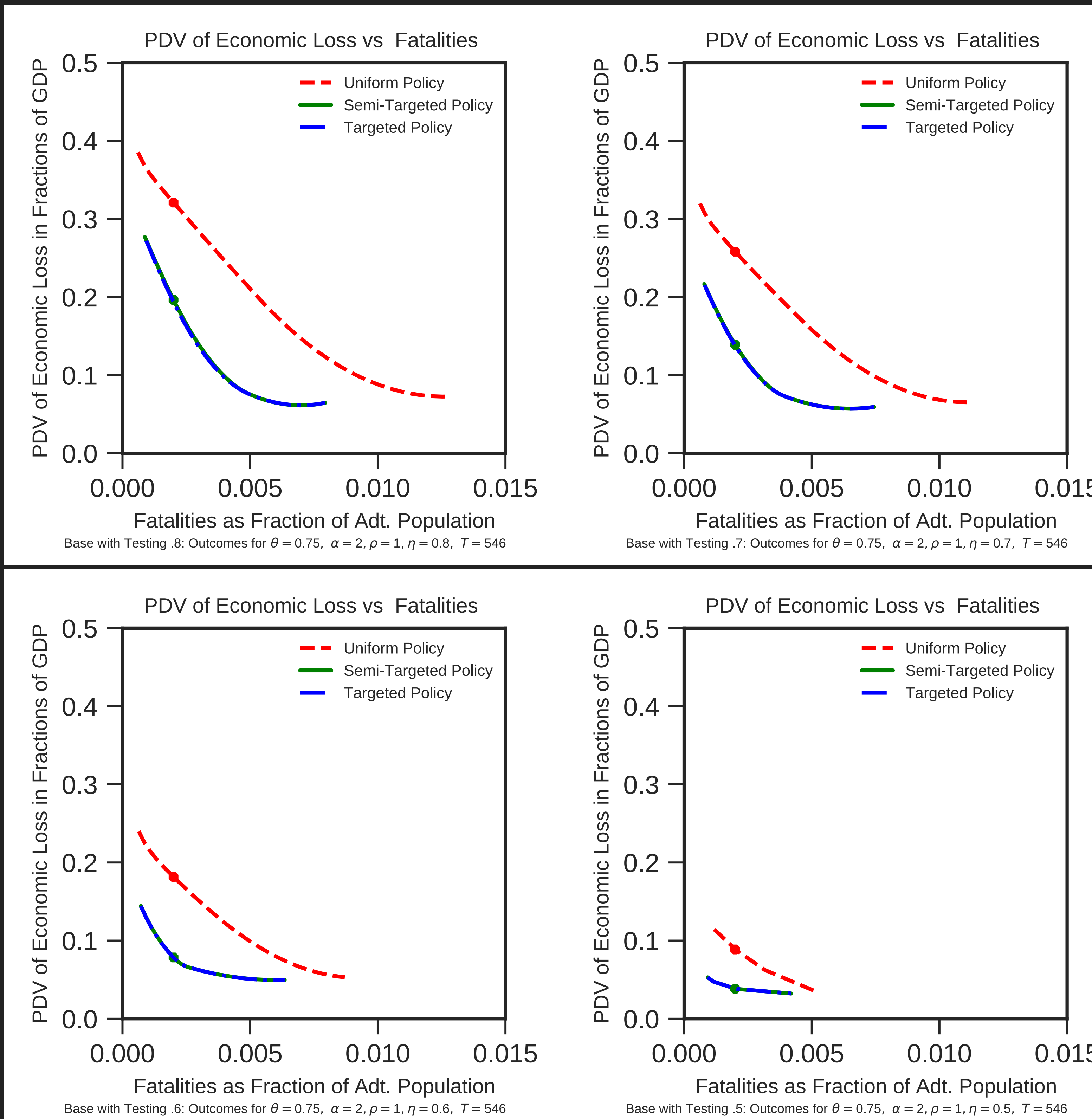


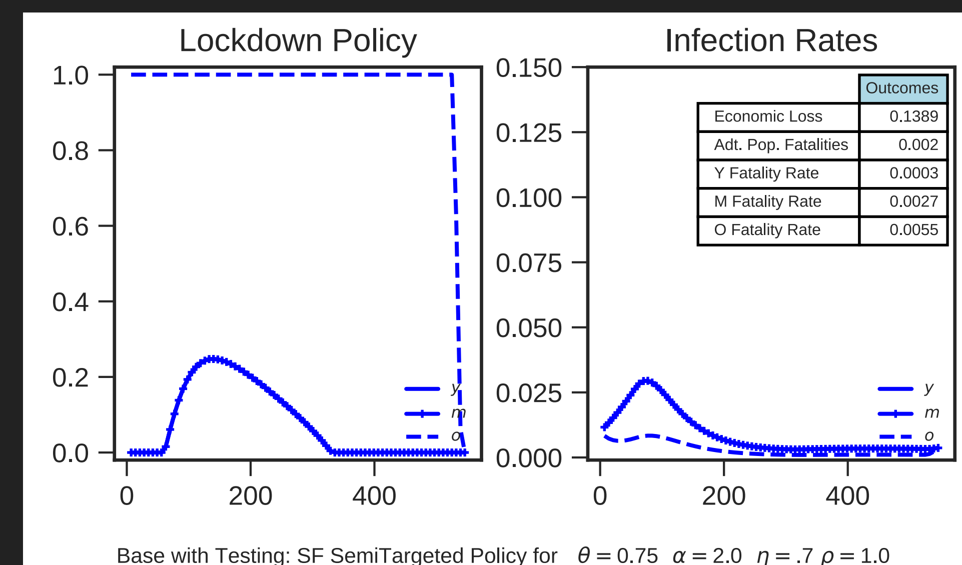
Valuable

especially with targeting!

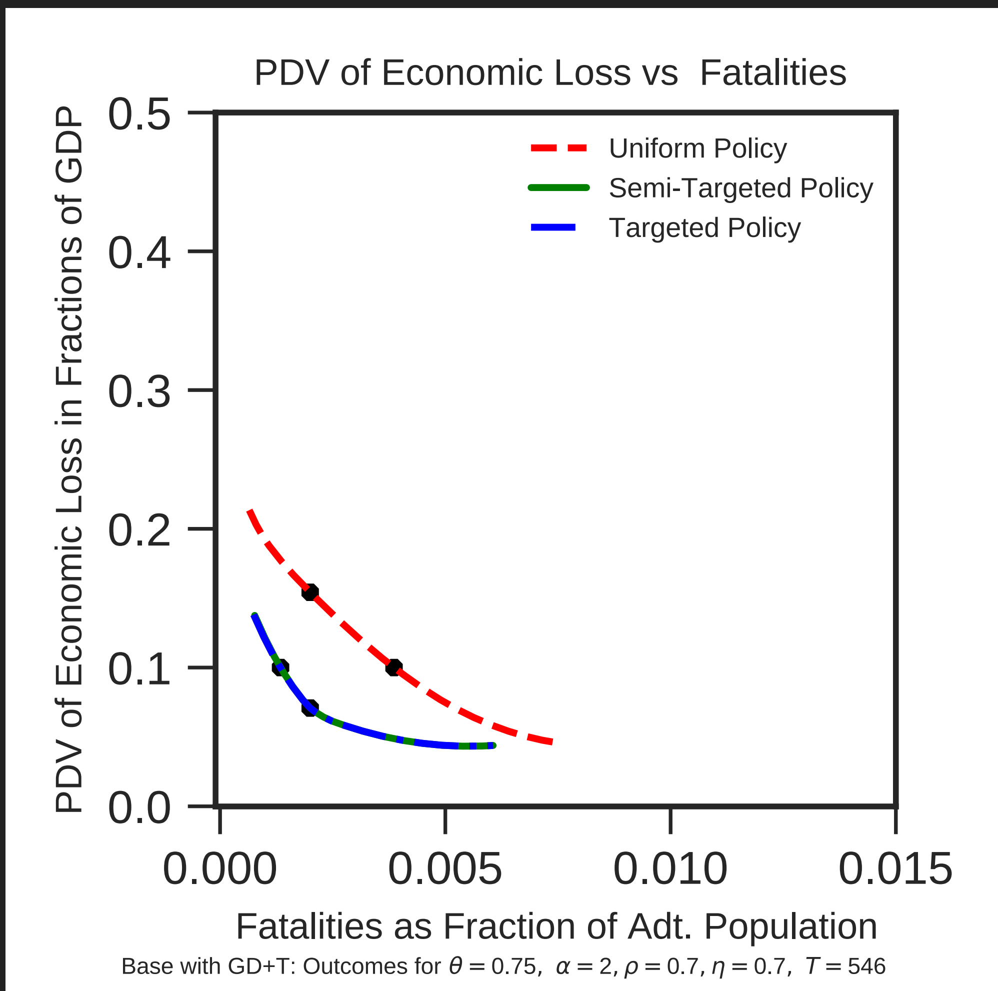
(matching technology matters here)

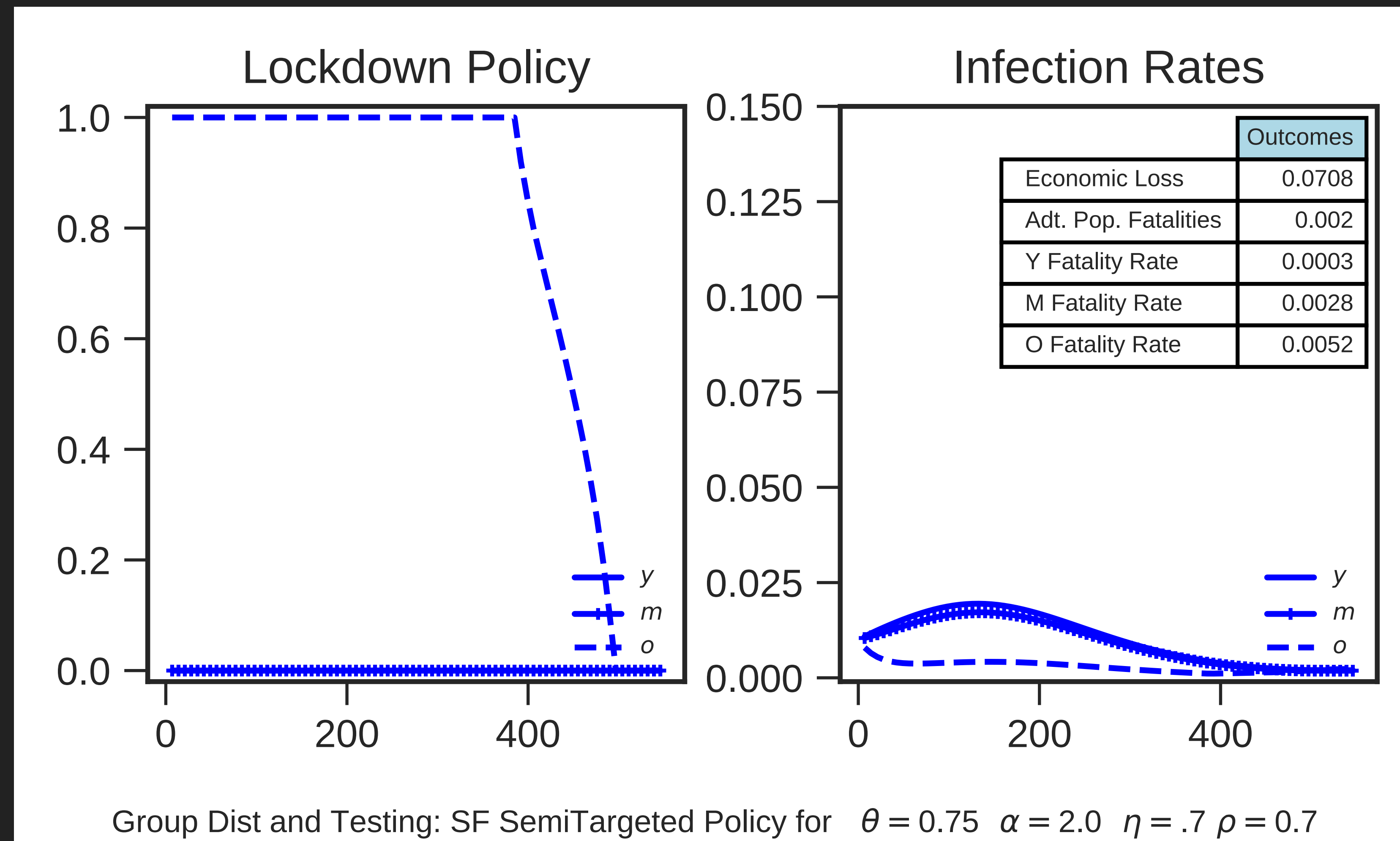
TESTING


PDV of Economic Loss vs Fatalities
PDV of Economic Loss in Fractions of GDP
Fatalities as Fraction of Adt. Population
Uniform Policy
Semi-Targeted Policy
Targeted Policy
Base with Testing .8: Outcomes for $\theta = 0.75$, $\alpha = 2$, $\rho = 1$, $\eta = 0.8$, $T = 546$
Base with Testing .7: Outcomes for $\theta = 0.75$, $\alpha = 2$, $\rho = 1$, $\eta = 0.7$, $T = 546$
Base with Testing .6: Outcomes for $\theta = 0.75$, $\alpha = 2$, $\rho = 1$, $\eta = 0.6$, $T = 546$
Base with Testing .5: Outcomes for $\theta = 0.75$, $\alpha = 2$, $\rho = 1$, $\eta = 0.5$, $T = 546$


Lockdown Policy
Infection Rates
Outcomes
Economic Loss 0.1389
Adt. Pop. Fatalities 0.002
Y Fatality Rate 0.0003
M Fatality Rate 0.0027
O Fatality Rate 0.0055
Base with Testing: SF SemiTargeted Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = .7$ $\rho = 1.0$

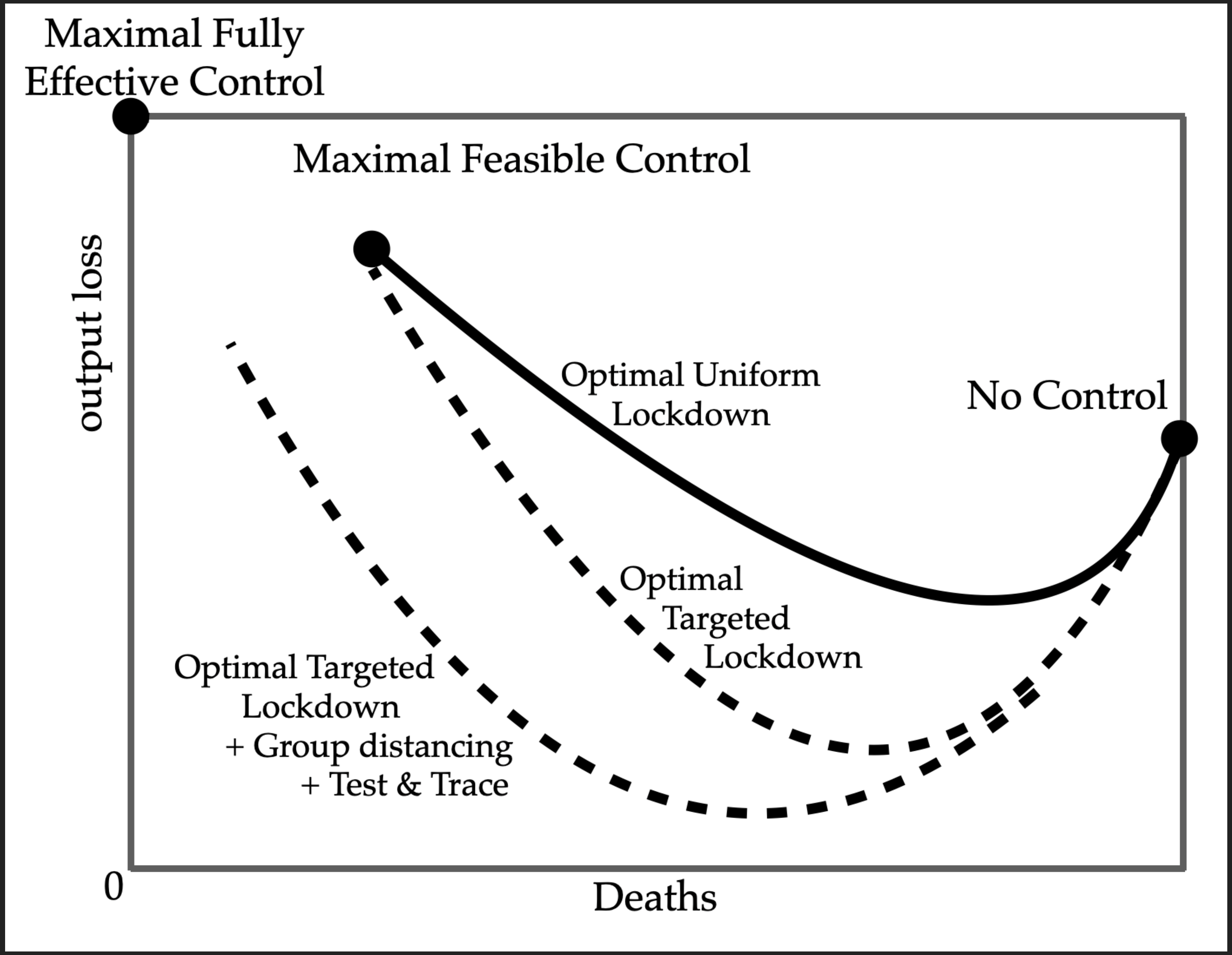
TESTING + TRACING + GROUP DISTANCING



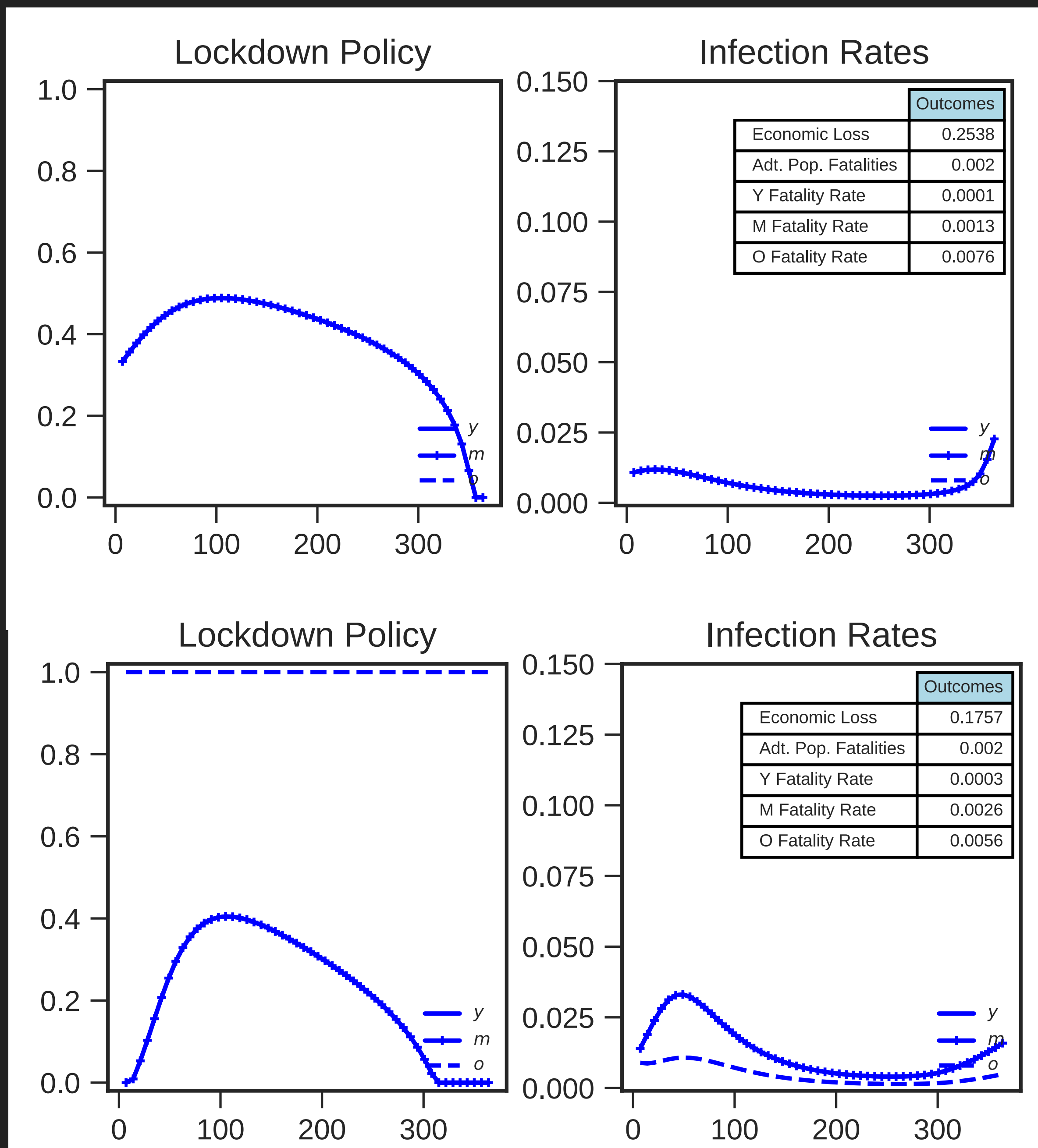


Silver Bullet?

FRONTIER


Maximal Fully
Effective Control
Maximal Feasible Control
output loss
Optimal Uniform
Lockdown
No Control
Optimal
Targeted
Lockdown
Optimal Targeted
Lockdown
+ Group distancing
+ Test & Trace
0
Deaths

EARLIER VACCINE/CURE



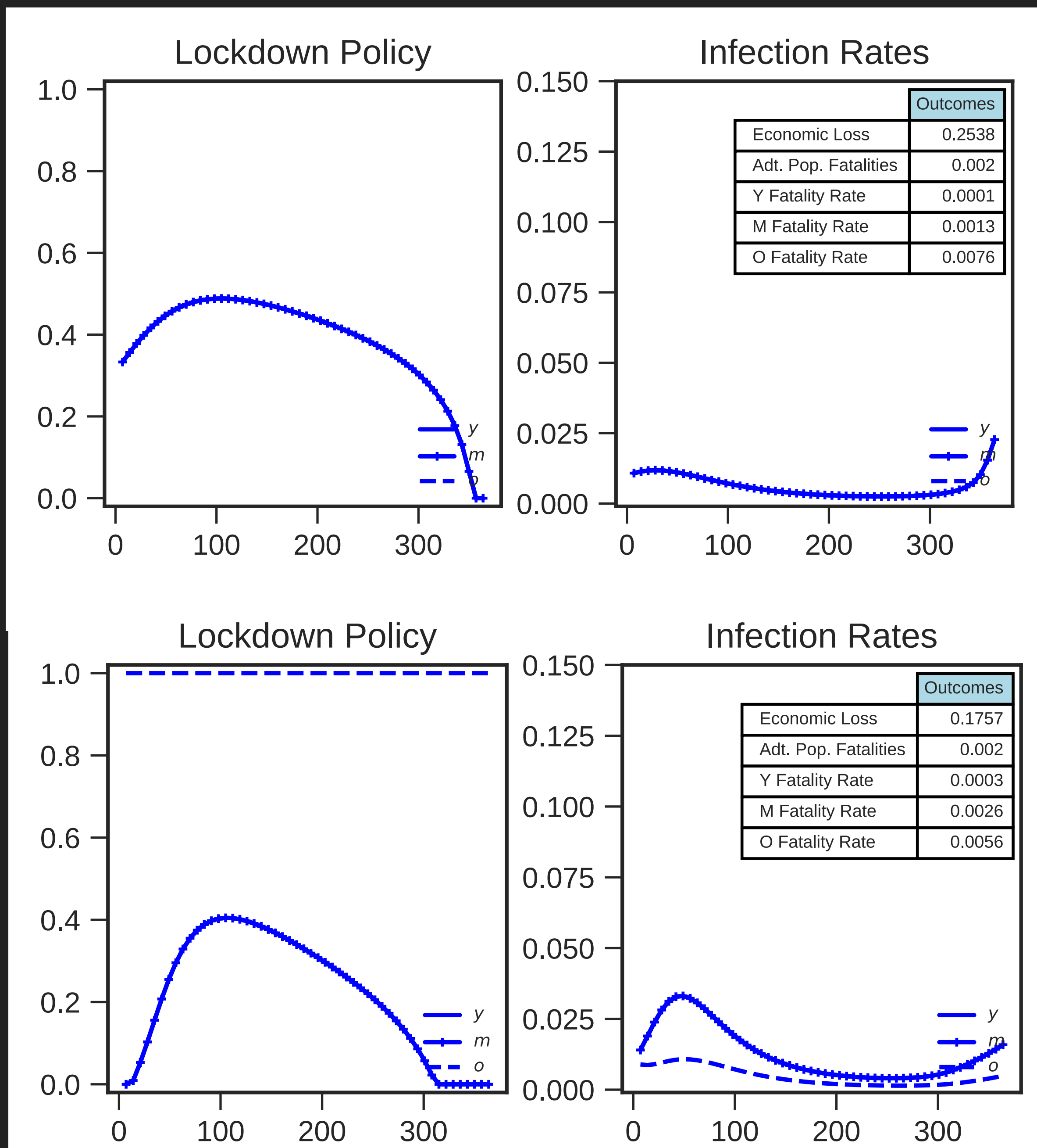
	Outcomes
Economic Loss	0.2538
Adt. Pop. Fatalities	0.002
Y Fatality Rate	0.0001
M Fatality Rate	0.0013
O Fatality Rate	0.0076

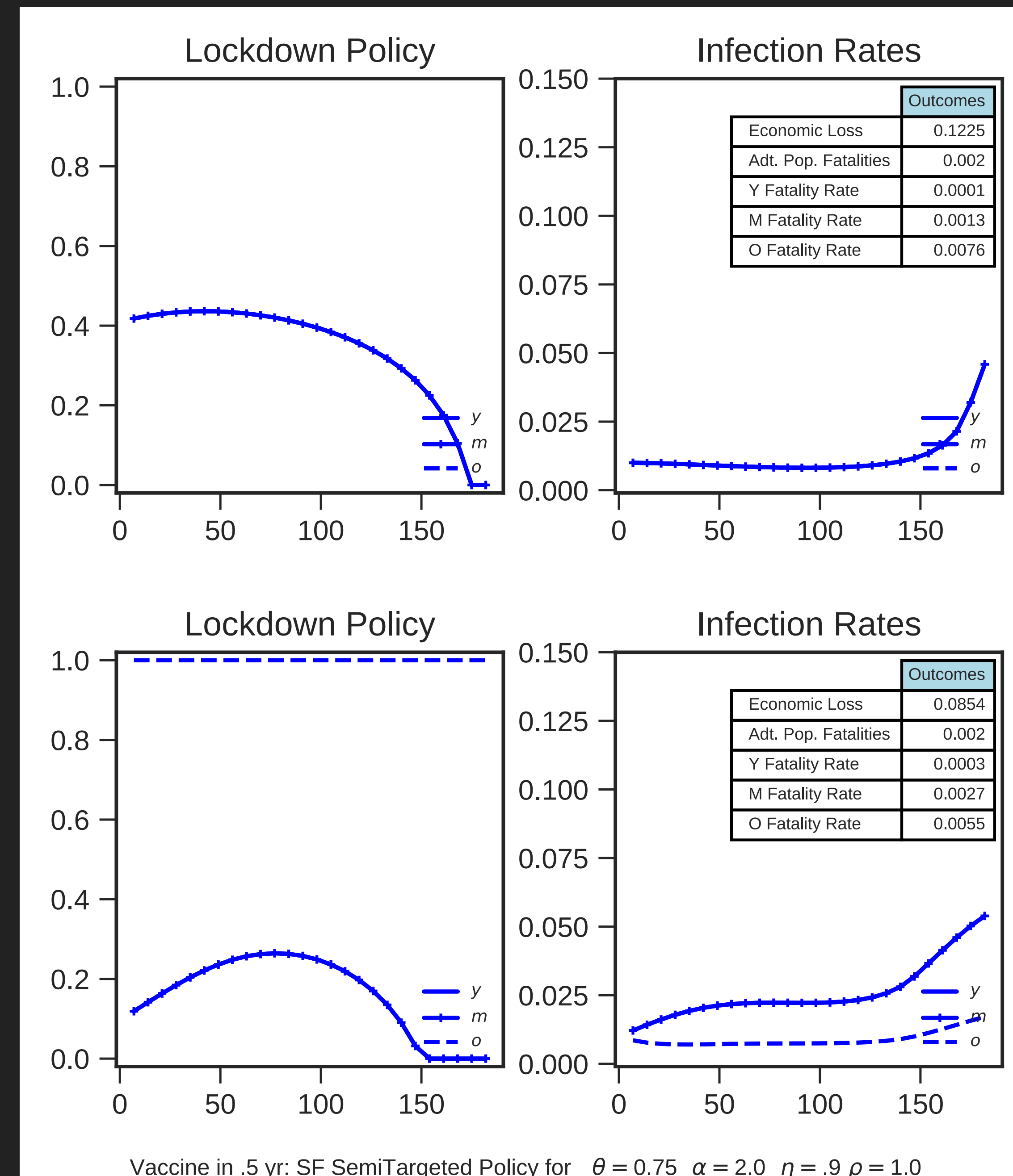
	Outcomes
Economic Loss	0.1757
Adt. Pop. Fatalities	0.002
Y Fatality Rate	0.0003
M Fatality Rate	0.0026
O Fatality Rate	0.0056

12 months

6 months

EARLIER VACCINE/CURE





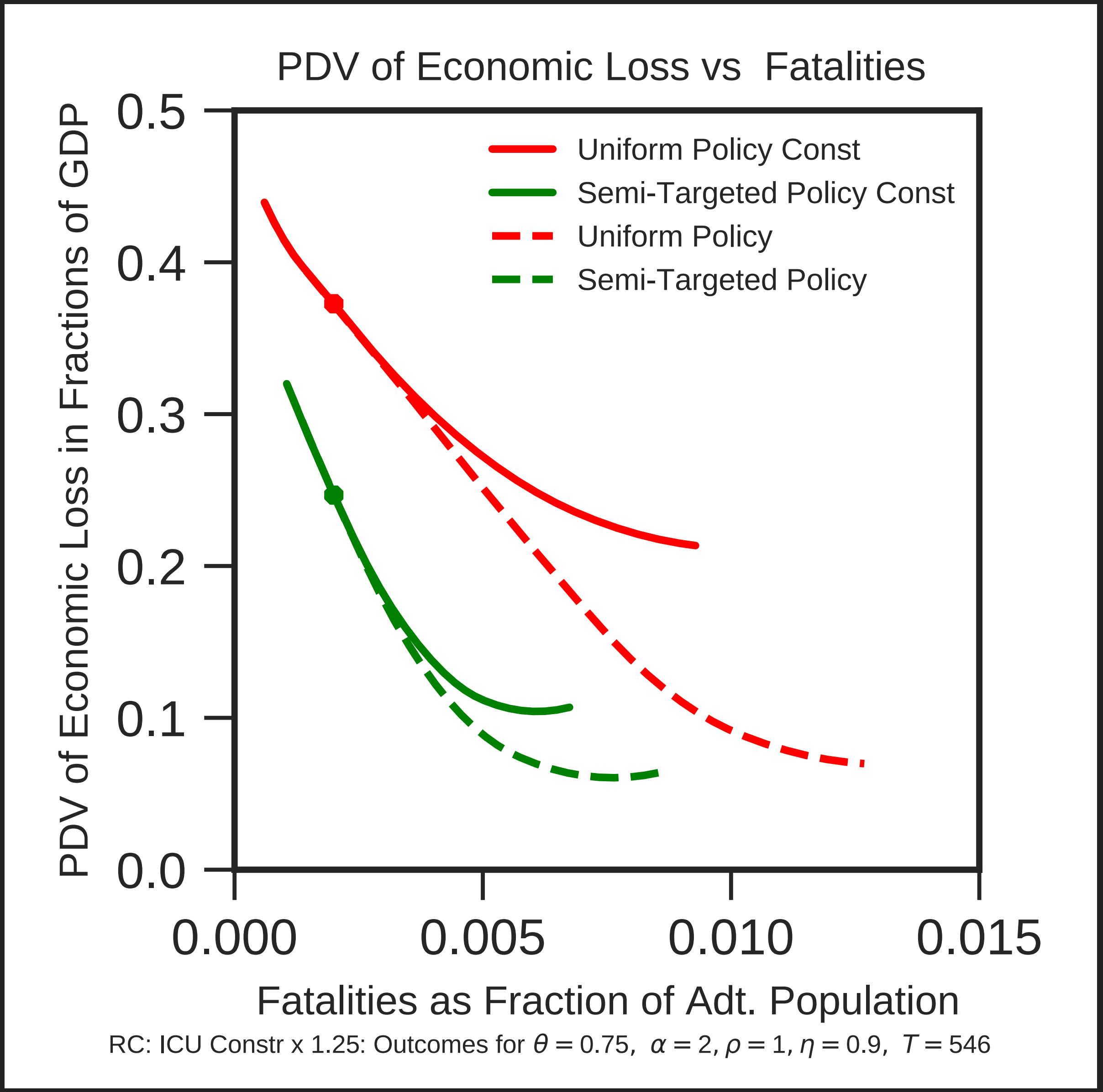
12 months

6 months

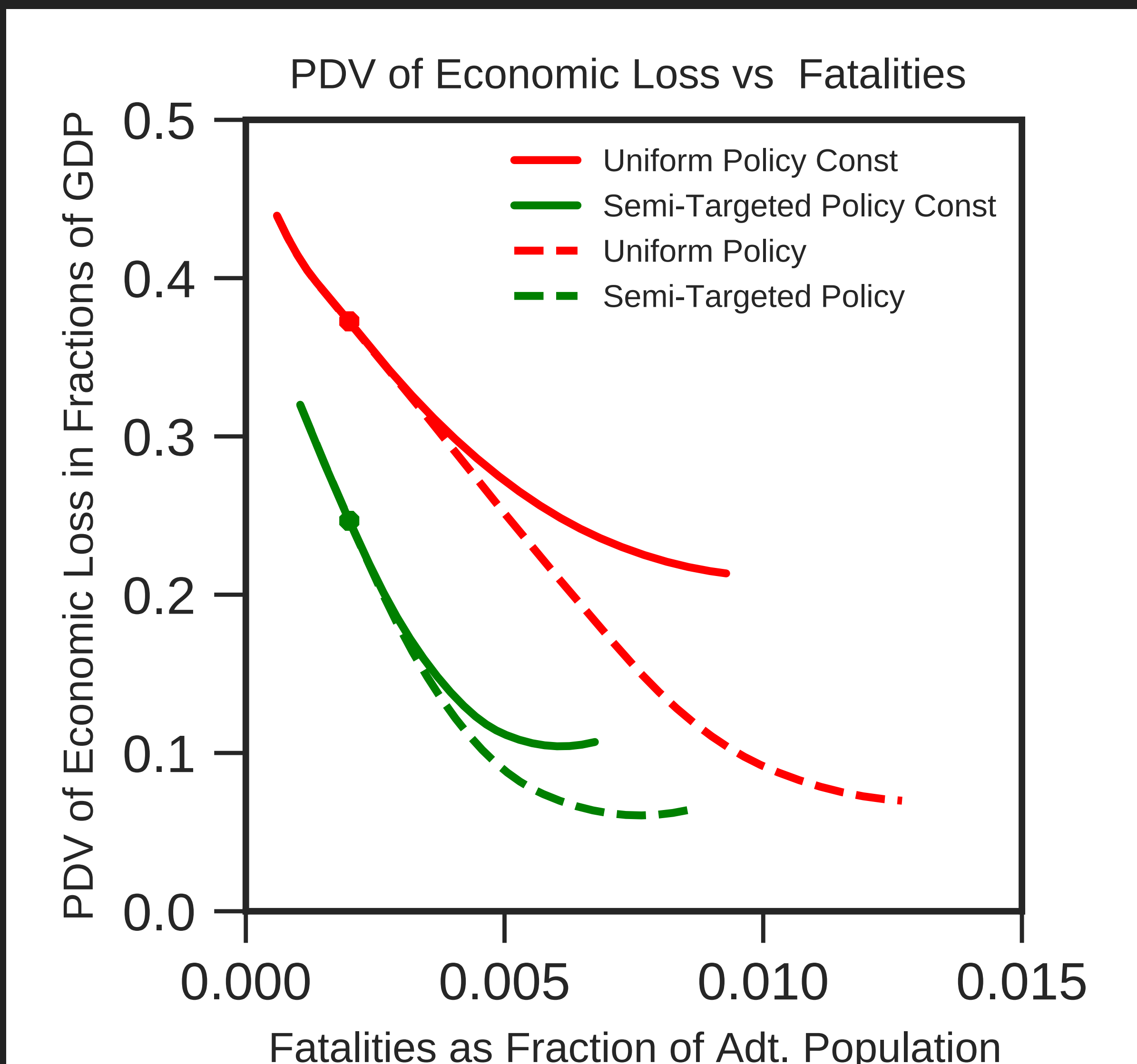
ROBUSTNESS

- ICU hard constraint
- higher mortality: South Korea
- lower transmission (e.g. masks)
- higher initial recovered
- lower effective lockdowns
- alternative group distancing
- alternative value for old in lockdown
- alternative work from home

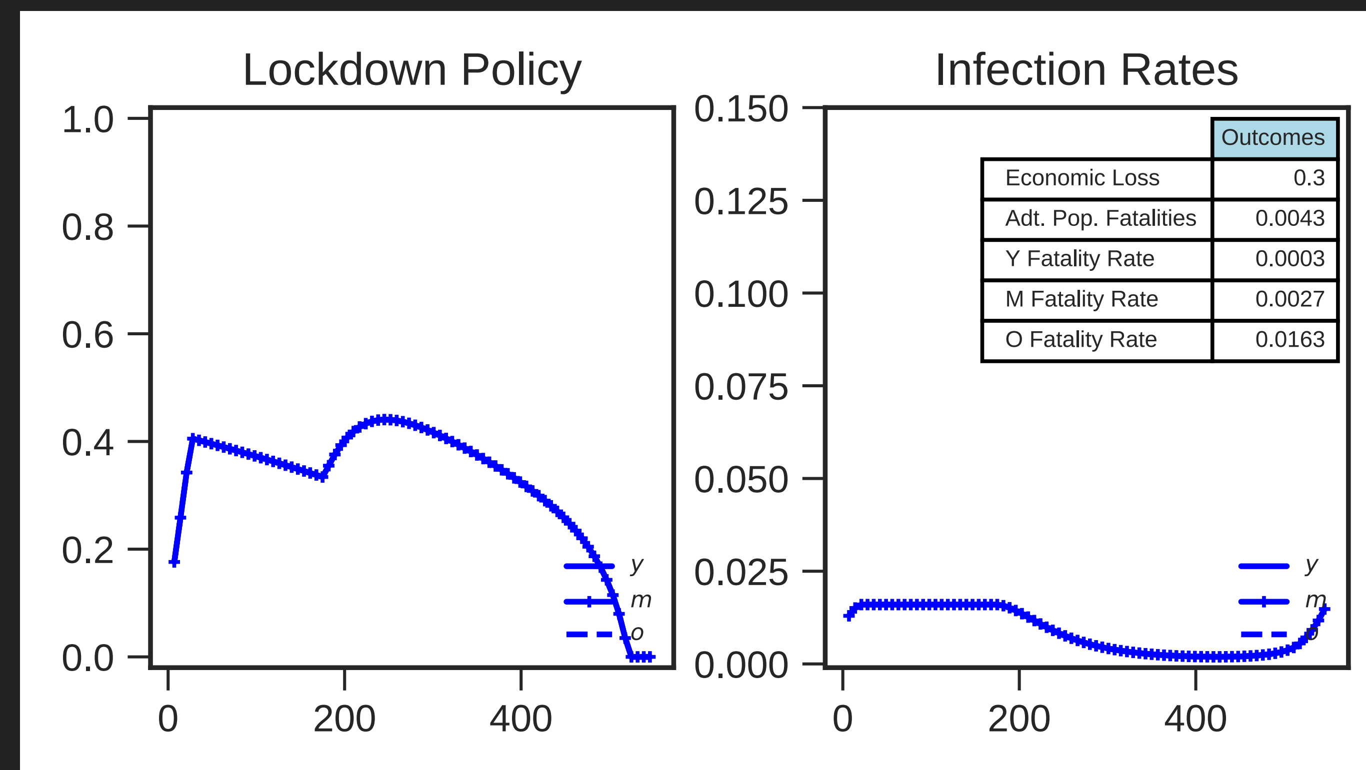
ICU HARD CONSTRAINT (INFECTIONS BELOW 2%)



ICU HARD CONSTRAINT (INFECTIONS BELOW 2%)

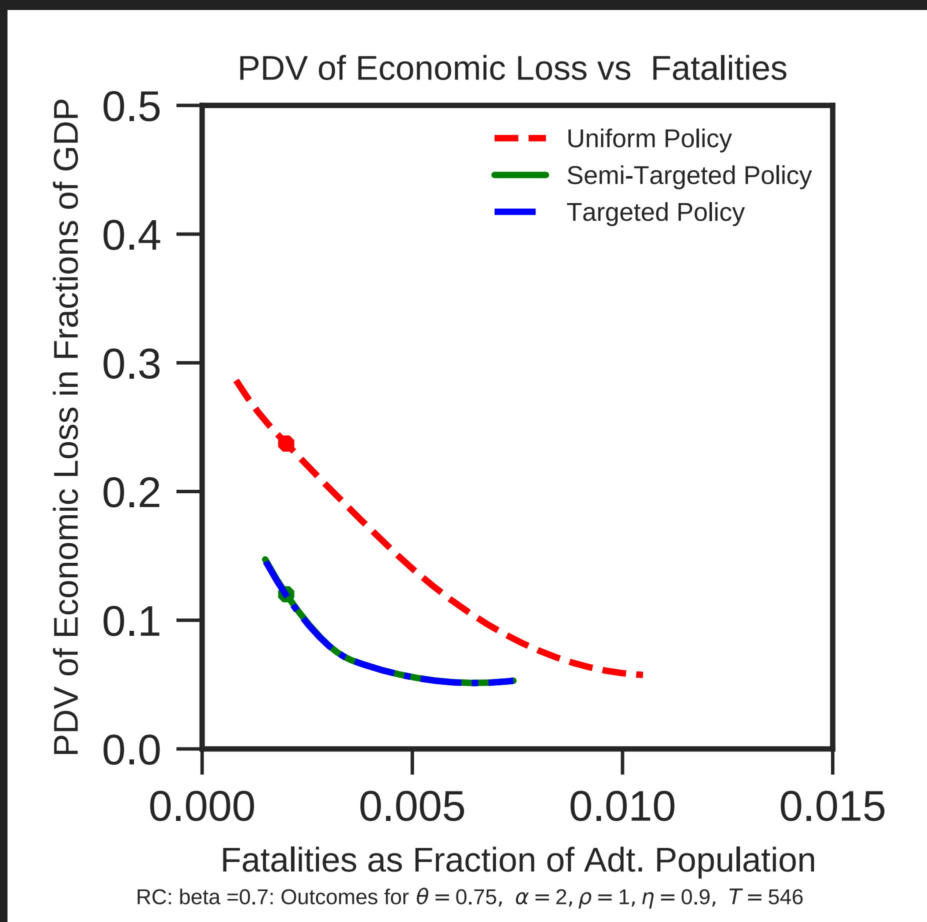


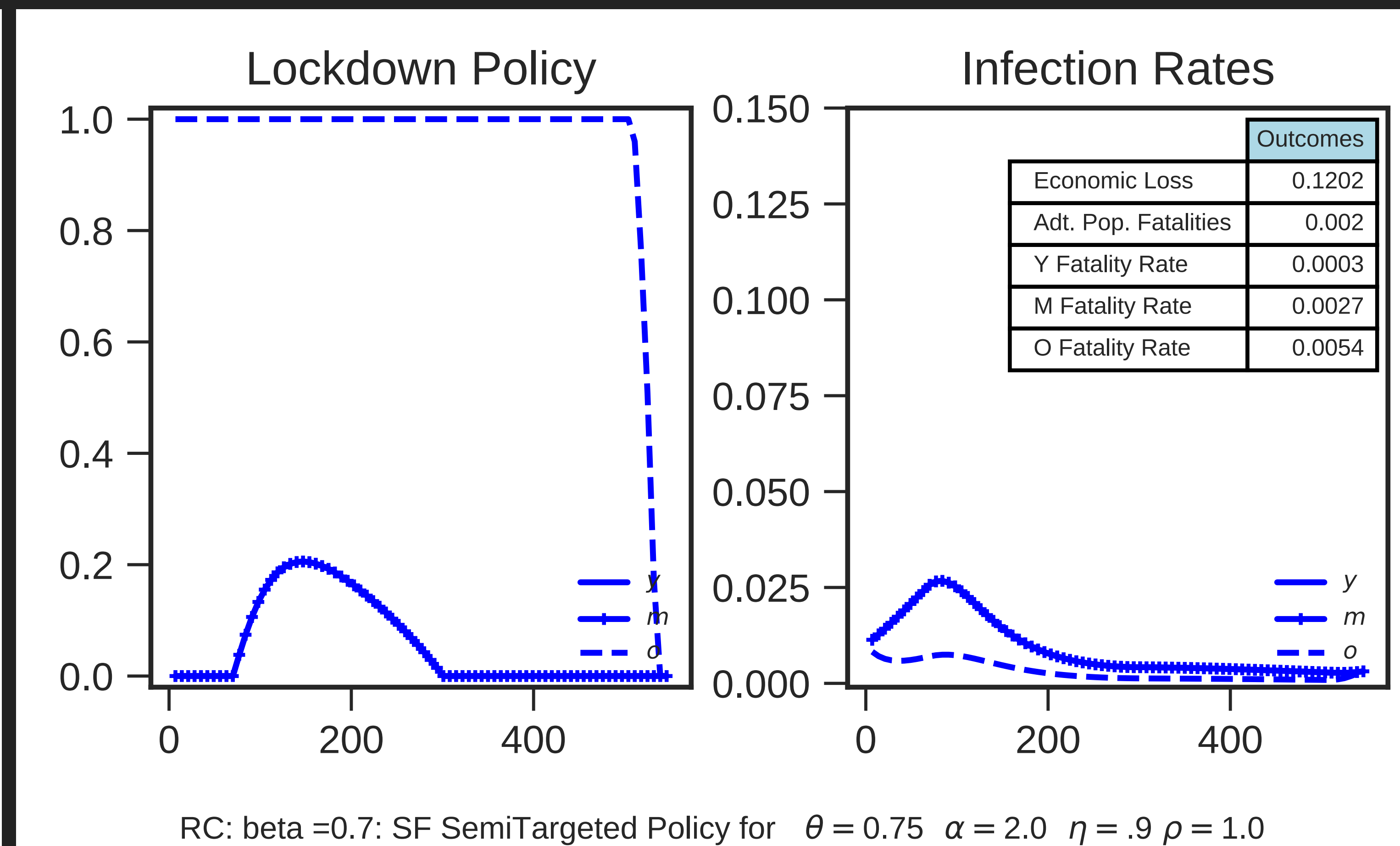
RC: ICU Constr x 1.25: Outcomes for $\theta = 0.75$, $\alpha = 2$, $\rho = 1$, $\eta = 0.9$, $T = 546$



RC0 ICU Constr x 1: EF Uniform Policy for $\theta = 0.75$ $\alpha = 2.0$ $\eta = .9$ $\rho = 1.0$

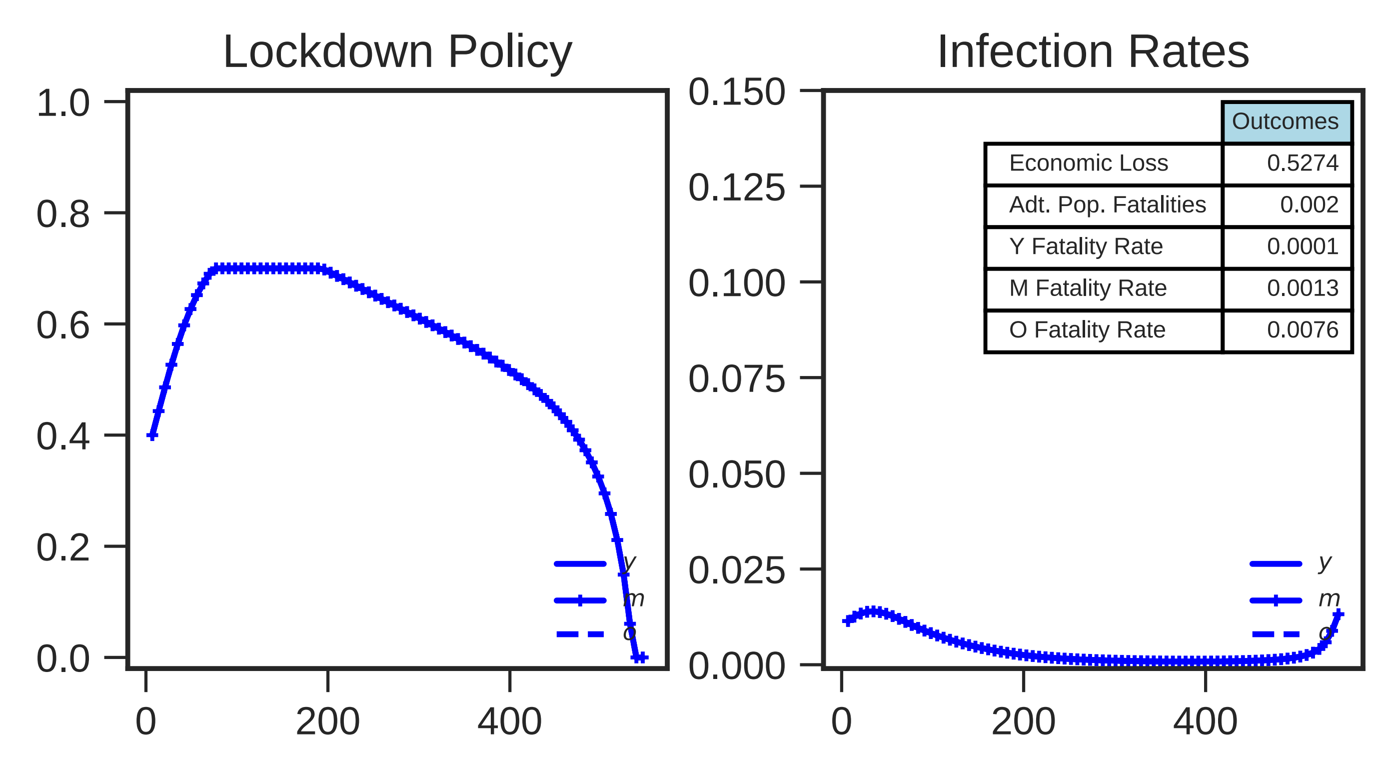
LOWER TRANSMISSION: R0=1.8 (BASELINE 2.4)



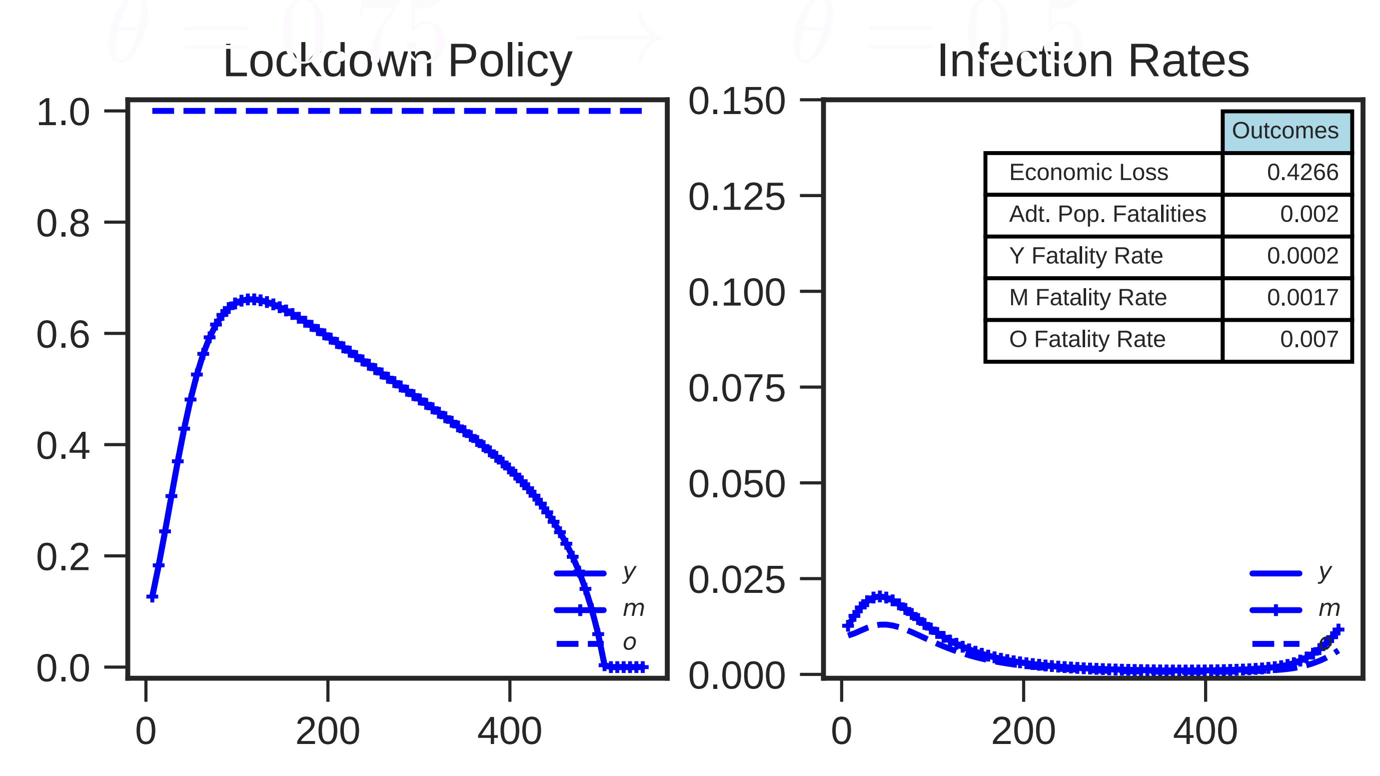


LESS EFFECTIVE LOCKDOWNS

$$\theta = 0.75 \quad \rightarrow \quad \theta = 0.5$$



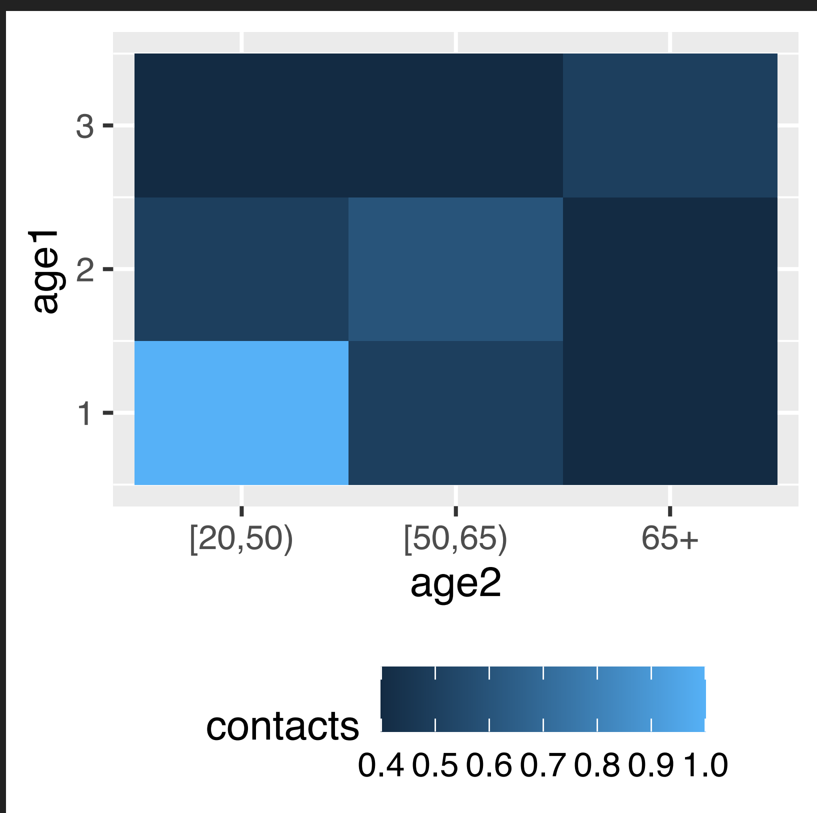
RC2: theta=0.5: SF Uniform Policy for $\theta = 0.5$ $\alpha = 2.0$ $\eta = .9$ $\rho = 1.0$

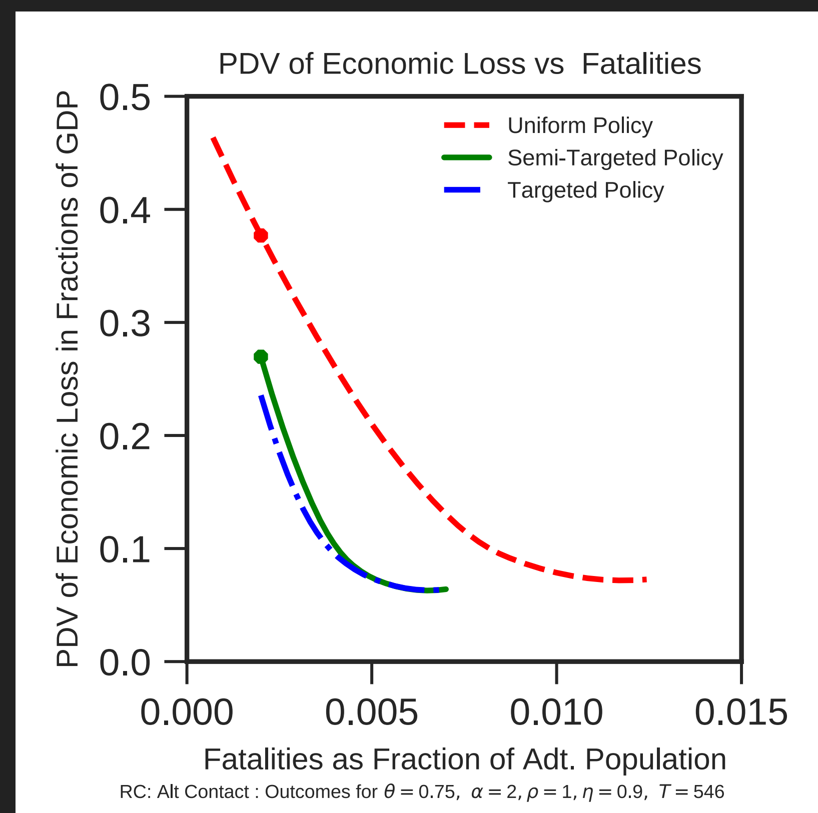


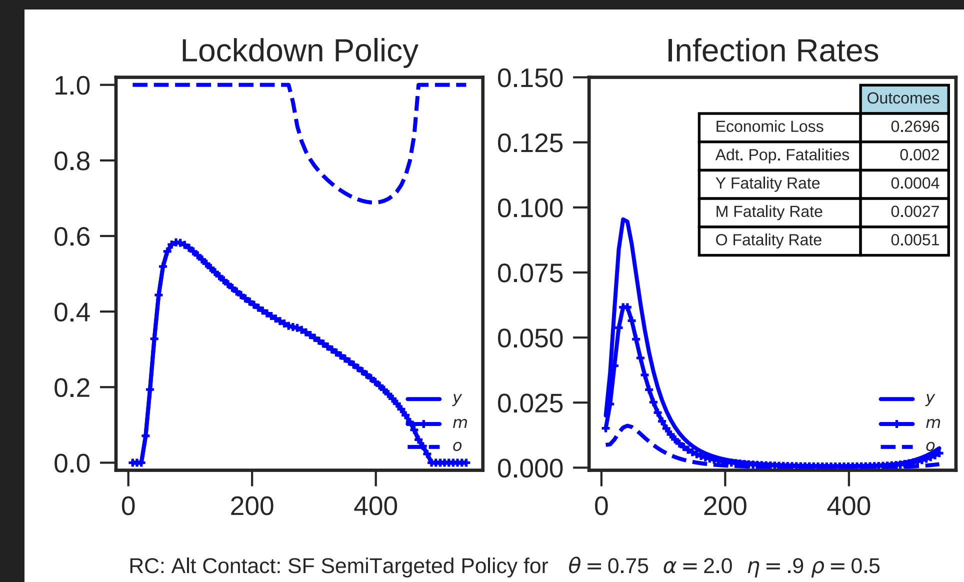
Test: SF SemiTargeted Policy for $\theta = 0.5$ $\alpha = 2.0$ $\eta = .9$ $\rho = 1.0$

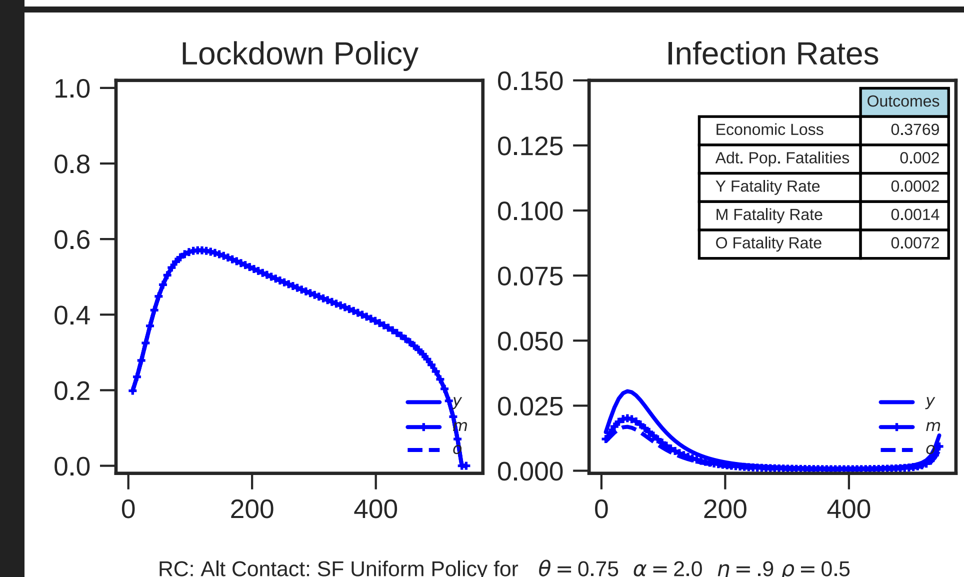
CONTACT MATRIX CALIBRATION

- BBC Pandemic Project (more recent than POLYMOD)









INTERACTIVE MR-SIR DASHBOARD

https://mr-sir.herokuapp.com/main

(link provided in our paper)

Optimal Policies | Simple Policies | Summary

This tab implements simple lockdown policies of the following form: a fraction of each group can be locked down for a set number of days, and the lockdown effectiveness varies across groups. We assume fraction .01 of the population is initially infected.

Lockdown Parameters

Fraction Lockdown: Young: **0.15**

Lockdown Time: Young: **140**

Lockdown Effectiveness (θ): Young: **1**

Fraction Lockdown: Middle: **0.45**

Lockdown Time: Middle: **140**

Lockdown Effectiveness (θ): Middle: **1**

Fraction Lockdown: Old: **0.70**

Lockdown Time: Old: **548**

Lockdown Effectiveness (θ): Old: **1**

Epidemiological Parameters

Initial Fraction Recovered: **0.01**

Fatality Rate: Young: **0.0010**

Cross-Group Contact Rate (ρ): **1**

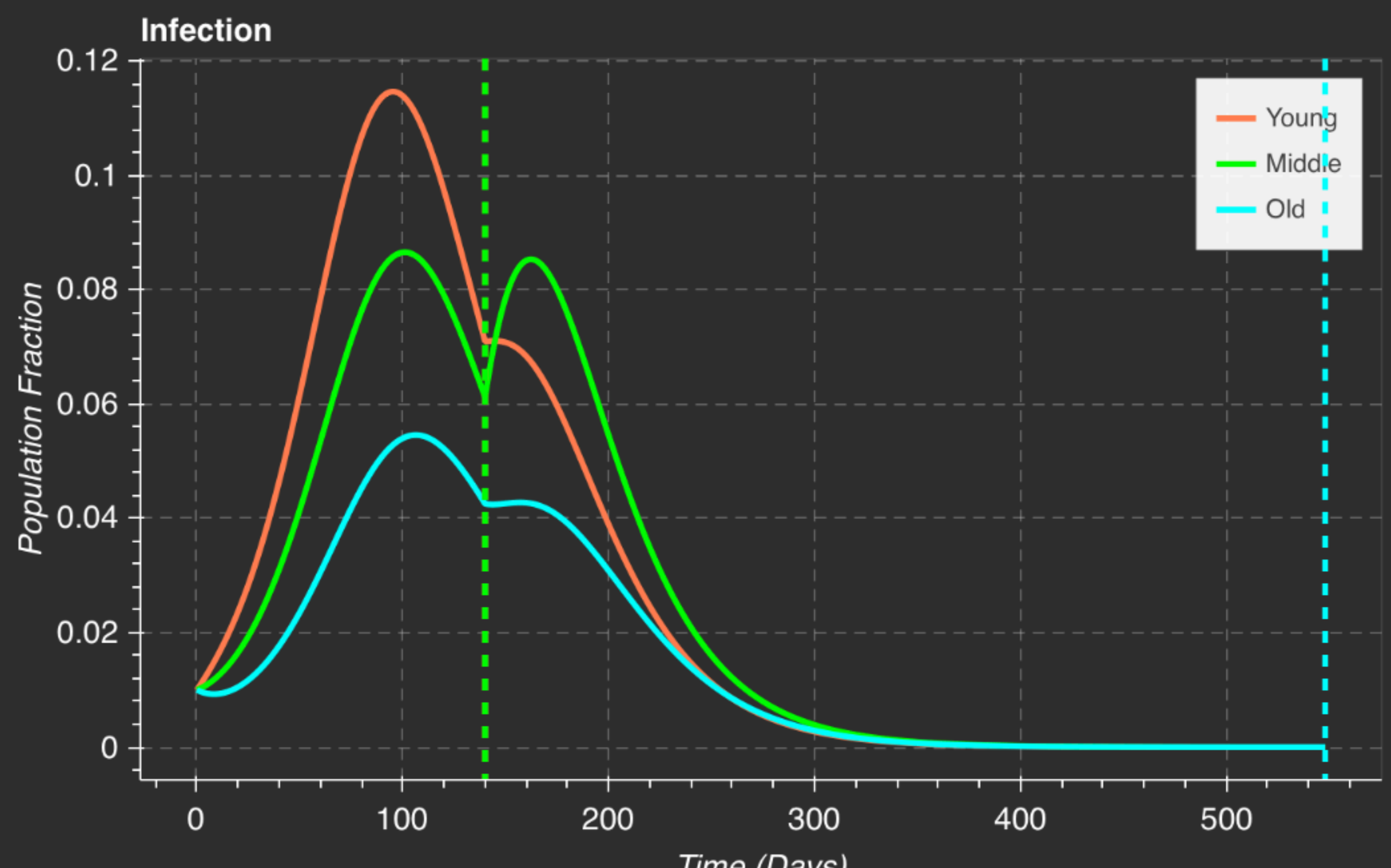
Fatality Rate: Middle: **0.012**

Days to Infection Case Resolution: **18**

Fatality Rate: Old: **0.060**

Infection Rate (β): **0.20**

	Total	Young	Middle	Old
Deaths	0.0141	0.0014	0.0151	0.045
Never Infected	0.2317	0.1368	0.1962	0.5153
Econ Loss	0.1367	-	-	-
R0	2.3161	-	-	-



NEXT STEPS…

- Parameters: update as better information
- Testing: capacity issues and build up over time
- Operationalize…
  - How to better isolate elderly?
  - Corp of workers: immune or isolated
- Our results today: targeted lockdown policies very beneficial

BEHAVIORAL RESPONSES

- Behavioral responses…
  - crucial to understand no intervention
  - but generally do not affect planning solutions
  - affect implementation
- Targeting may be easier with behavioral responses