Maximize Utility Subject to $R \leq 1$: A Simple Price-Theory Approach to Covid-19 Lockdown and Reopening Policy

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- But: because of the $R \leq 1$ constraint, (1) reasonably *approximates* the pure medical objective in (2)
- At the same time, *very* different policy implications

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2. "Expand the Frontier"
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- Overall, optimal way to get to $R \leq 1$
  - Use masks, tests, etc. (except where reduction is trivial)
  - Then targeted activity bans

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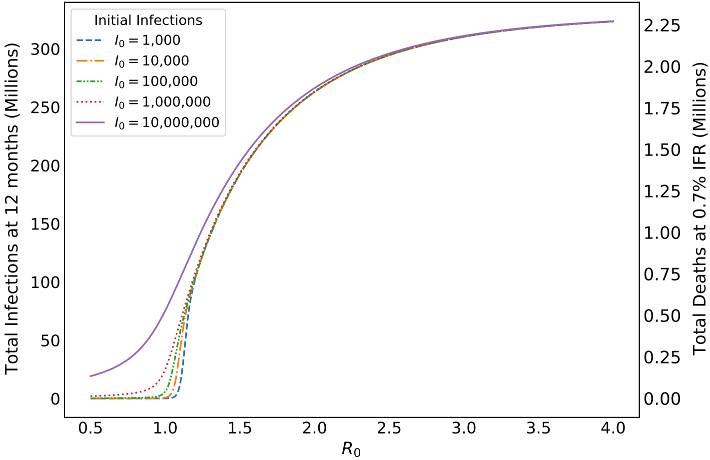
  - Much more focus on R, masks and social distance as an alternative to lockdown, etc.
- But: safe to say that society did not converge on "Max Utility s.t. $R \leq 1$"

Why $R \leq 1$: Exponential Growth



Note: Output is based on the standard SIR model. Each line depicts a different initial infection seed. The γ parameter is fixed throughout at $1/5$, which represents a duration of infectiousness of 5 days. The β parameter, which represents the rate of infectiousness, is varied such that $R_0 = \beta/\gamma$ is the value depicted along the horizontal axis.

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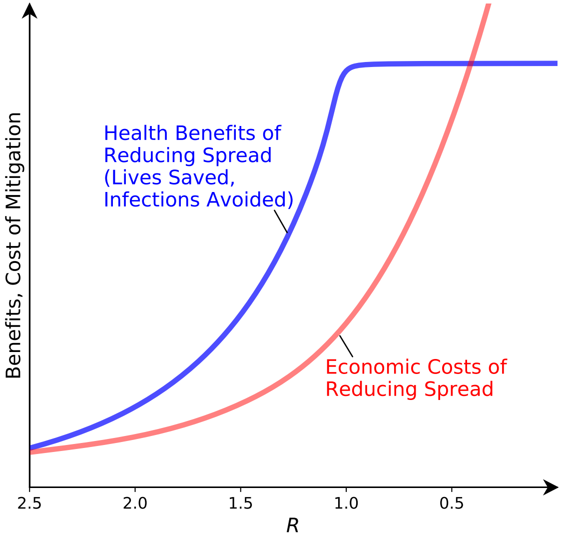
- Aside on new variant
  - Suppose R_0 is 4.0 instead
  - Then need a 3/4 reduction (i.e., $\frac{4-1}{4} = \frac{3}{4}$)
  - Again, not crazy

Is $R \leq 1$ Optimal? Simple Price Theory



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  - This formulation implicitly assumes mortality rate is high and Susceptible population is high.
  - If not then $R \leq 1$ likely too restrictive
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- I will come back to both of these issues towards the end of the talk

Basic Model Setup

- Society chooses a vector of activities $x \in X = [0,1]^n$. For each activity i:
  - Utility v_i: traditional economic benefits and costs, v_i and c_i
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- $R \leq 1$ as a constraint:

$$\max_{x_i} \quad \sum_{i=1}^{n} x_i (v_i - c_i) \tag{5}$$

$$\text{subject to} \quad \sum_{i=1}^{n} x_i r_i \leq 1$$

Max Utility s.t. $R \leq 1$: Solution

- Key object: ratio of economic value to disease-transmission risk for each activity i

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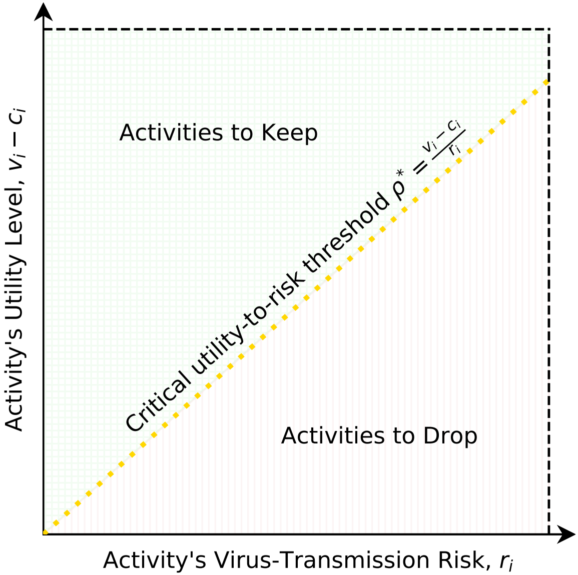
  - optimum sorts not by *absolute* risk, but by utility per unit of risk

Solving the Basic Model: Graphic Depiction



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- Thus: *allows society to engage in more activity and achieve more utility while staying within* $R \leq 1$ *budget*

“Optimal Masks”

- Let’s use the phrase “masks” to represent the suite of potential low-cost interventions
  - Changing over time as understanding improves
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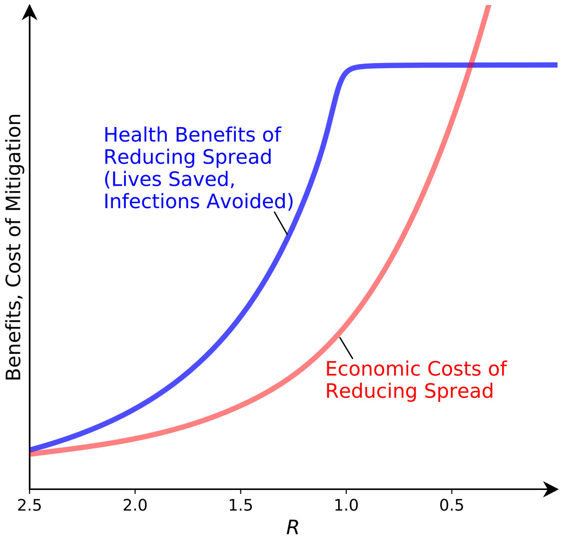
- The <u>optimal</u> mask policy for activity *i* maximizes

$$\underbrace{\Delta r_i}_{\substack{\text{risk reduction} \\ \text{from mask}}} \cdot \underbrace{\rho^*}_{\substack{\text{marginal value} \\ \text{of risk budget}}} - \underbrace{\Delta u_i}_{\substack{\text{utility harm} \\ \text{of mask}}}$$

Simple Interventions Reduce the Cost of Mitigation



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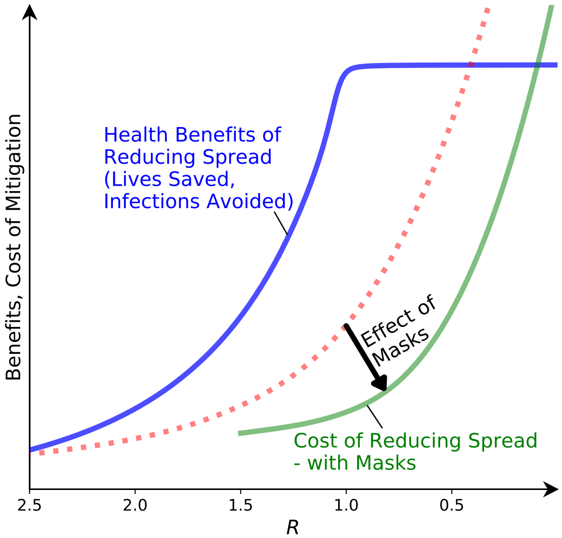

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- If society does all activities, then total risk is R_0 (that's what R_0 means: risk in a society that is unaware)
  - Consider range of 2.0-4.0
- "Masks" reduce risk by anywhere from 30-70%
  - Abaluck et al, Hatzius et al: cloth face-masks alone on order of 20-50% reduction
  - Chu et al, Howard et al, meta-analyses (labs, hospitals, ecological)
  - Romer mass tests
  - Other rapid test variations
  - Also: distance, hand-washing, etc.

Optimum without Simple Interventions

	Value of R_0				
	2.0	2.5	3.0	3.5	4.0
To Achieve $R \leq 1$:					
% Activities Dropped	37.5	45.0	50.0	53.7	56.7
% Pre-Virus Utility Dropped	18.8	27.0	33.3	38.3	42.3
Relative to Pre-Virus Economy:					
% Activities Kept	62.5	55.0	50.0	46.3	43.3
% Utility Kept	81.2	73.0	66.7	61.7	57.7

Optimum with Simple Interventions

Main R_0 Scenario

		Mask Efficacy				
	No Masks	30%	40%	50%	60%	70%
R if all activities are kept	2.50	1.75	1.50	1.25	1.00	0.75
To achieve $R \leq 1$:						
% Activities Dropped	45.0	32.1	25.0	15.0	0.0	0.0
% Pre-Virus Utility Dropped	27.0	13.8	8.3	3.0	0.0	0.0
Society % of Pre-Virus Utility:						
if Masks Reduce Utility by 0%	73.0	86.2	91.7	97.0	100.0	100.0
if Masks Reduce Utility by 10%	N/A	77.6	82.5	87.3	90.0	90.0

Note: The term "Masks" is used to denote the set of Simple Interventions including face-masks, tests, social distance, etc.

Optimum with Simple Interventions

High R_0 Scenario

		Mask Efficacy				
	No Masks	30%	40%	50%	60%	70%
R if all activities are kept	4.00	2.80	2.40	2.00	1.60	1.20
To achieve $R \leq 1$:						
% Activities Dropped	56.7	48.2	43.7	37.5	28.1	12.5
% Pre-Virus Utility Dropped	42.3	31.0	25.5	18.8	10.5	2.1
Society % of Pre-Virus Utility:						
if Masks Reduce Utility by 0%	57.7	69.0	74.5	81.2	89.5	97.9
if Masks Reduce Utility by 10%	N/A	62.1	67.0	73.1	80.5	88.1

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Optimum with Simple Interventions

Low R_0 Scenario

	No Masks	Mask Efficacy 30%	40%	50%	60%	70%
R if all activities are kept	2.00	1.40	1.20	1.00	0.80	0.60
To achieve $R \leq 1$:						
% Activities Dropped	37.5	21.4	12.5	0.0	0.0	0.0
% Pre-Virus Utility Dropped	18.8	6.1	2.1	0.0	0.0	0.0
Society % of Pre-Virus Utility:						
if Masks Reduce Utility by 0%	81.2	93.9	97.9	100.0	100.0	100.0
if Masks Reduce Utility by 10%	N/A	84.5	88.1	90.0	90.0	90.0

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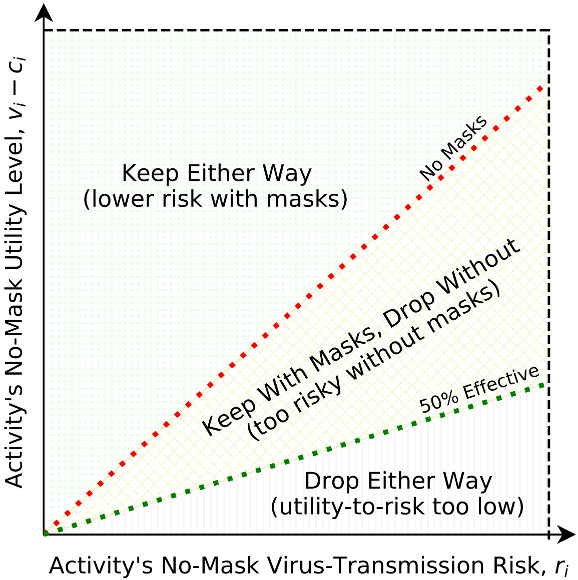
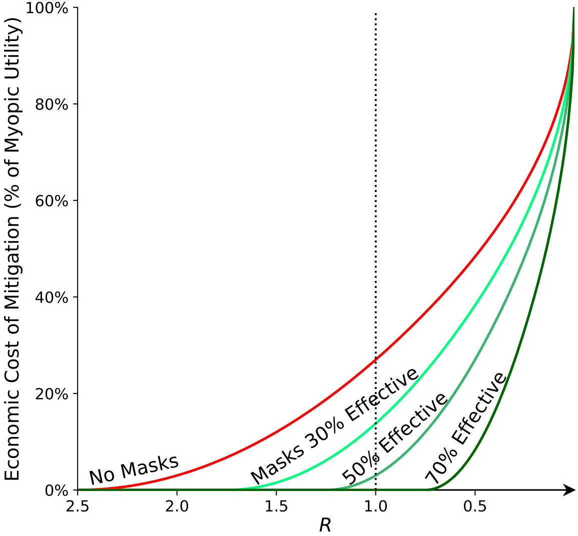
Effect of Simple Interventions on Keep/Drop



Effect on the Economic Cost of Mitigation



Discussion: is $R \leq 1$ Enough? Too Much?

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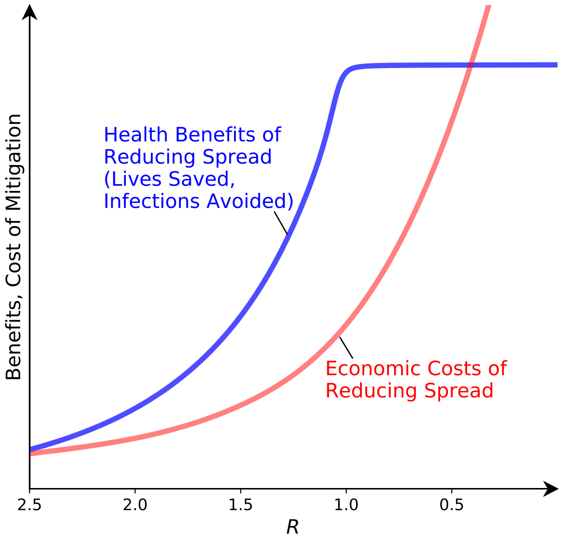
- Is $R \leq 1$ Too Much?
  - "Herd immunity": if $R > 1$, then eventually 200+ million infections
  - Initially there was a lot of uncertainty about infection fatality rate and rates of severe cases
  - With what we know now: the more credible case to consider is a "Young-Old" strategy, along the lines of Acemoglu, Chernozhukov, Werning and Whinston (also Great Barrington Declaration)

Effect of High Stock of Infections ("Fear of the Virus")



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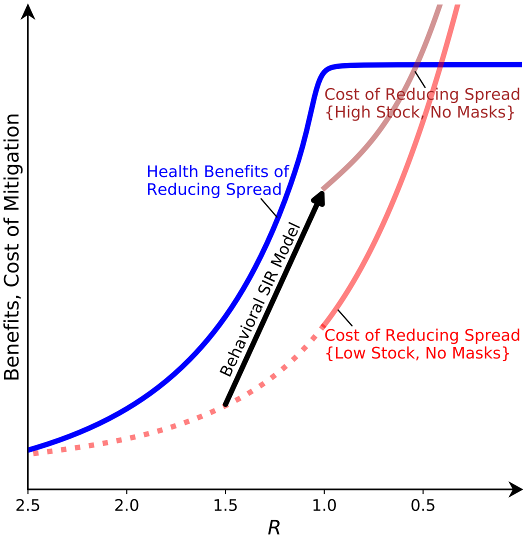

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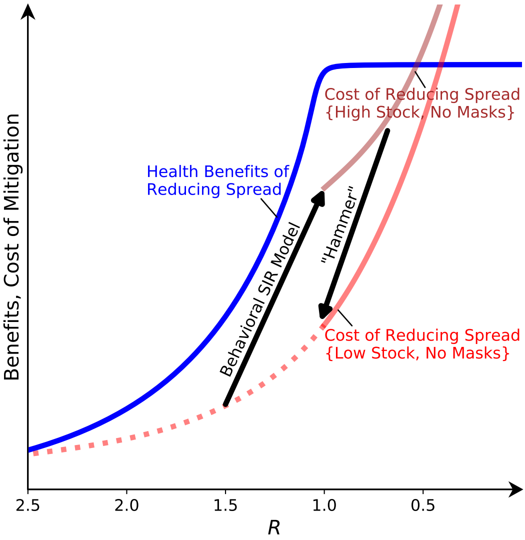

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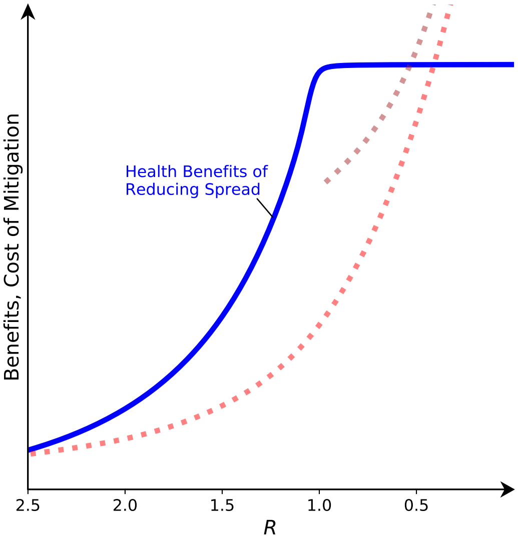

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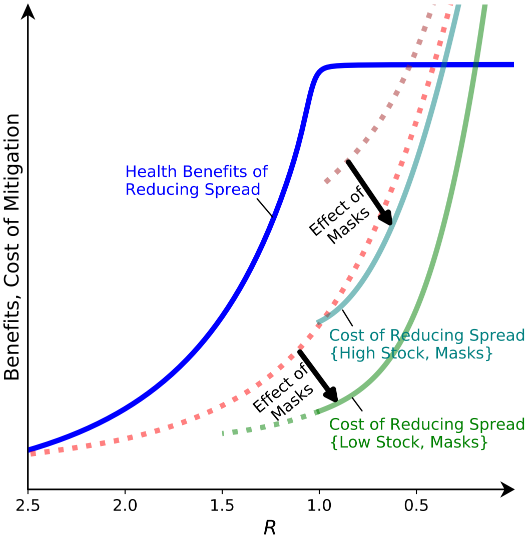
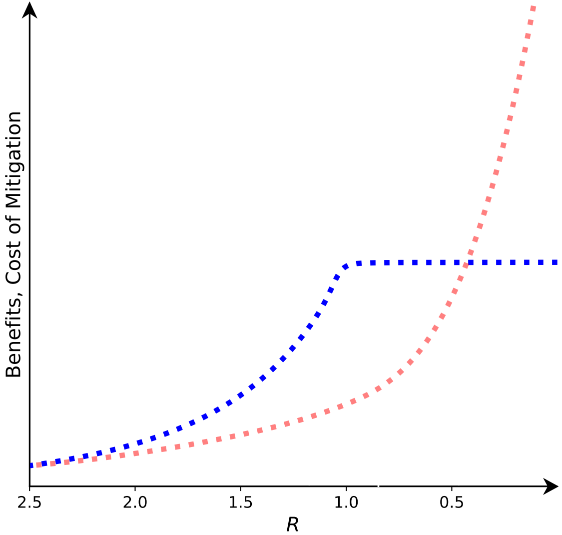


“Young-Old” Argument



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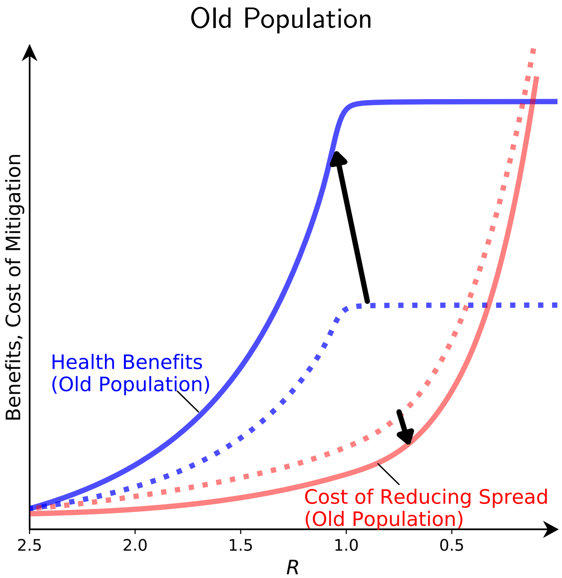

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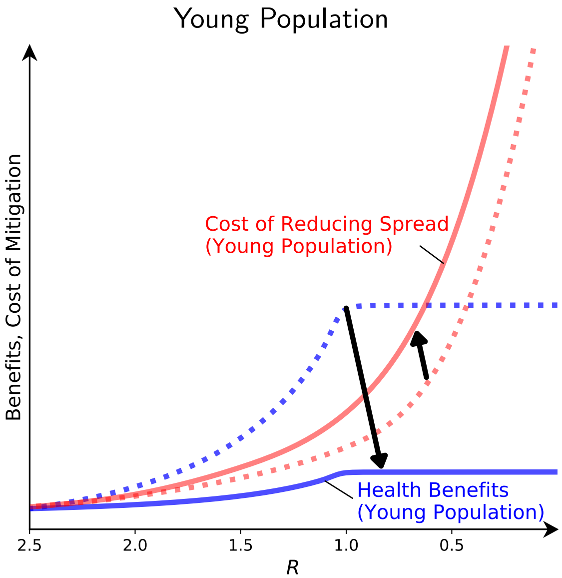

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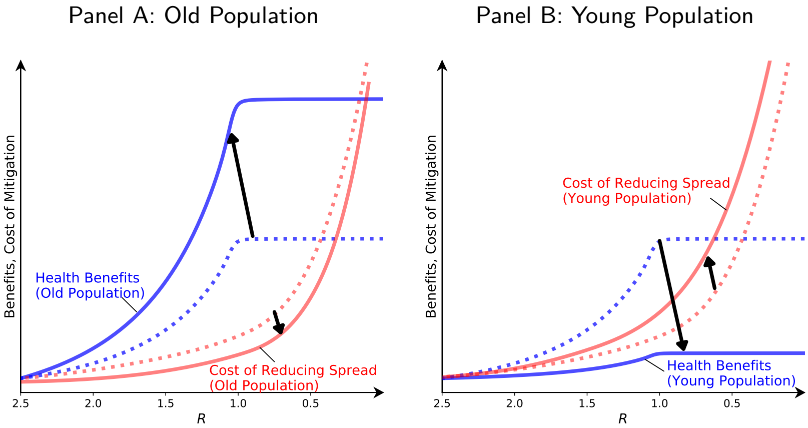

Conclusion: A New Play in the Pandemic Playbook?

Four features of Covid-19, relative to past pandemics, that justifies a new approach:

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1. Mortality / morbidity cost high
   - $R \leq 1$ a desirable policy goal even at meaningful expense
   - Recall: even $R = 1.5 \rightarrow 200$ million infections in 12 months

2. Eradication likely not feasible
   - By the time of policy intervention, eradication unrealistic for many countries
   - (If eradication were feasible: like a one-time fixed cost, versus ongoing costs of containment)

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Four features of Covid-19, relative to past pandemics, that justifies a new approach:

3. $R \leq 1$ feasible with modestly expensive measures

- Medical experts quickly converged on a suite of public-health responses
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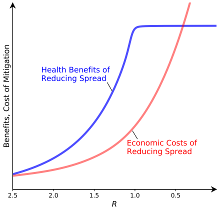
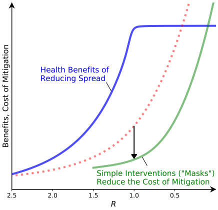
4. Minimize unboundedly expensive
   - When eradication is infeasible, second-best is "minimize" (Osterholm)
   - However, hard to think about tradeoffs *if the interventions themselves are very expensive*
   - Useful contrast: HIV

Infectious-Threat Playbook

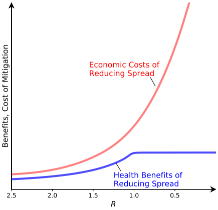
Panel A: $R \leq 1$ is Optimal



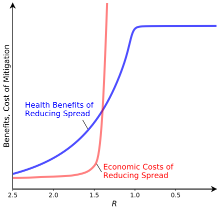
Panel B: $R \leq 1$ with Simple Interventions



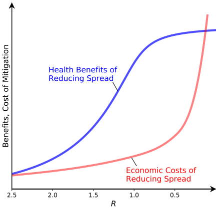
Panel C: Optimal to Ignore



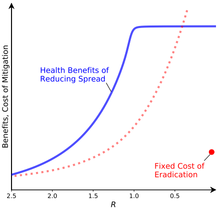
Panel D: Optimal to Partially Mitigate



Panel E: Optimal to Suppress to $R \ll 1$



Panel F: Optimal to Eradicate



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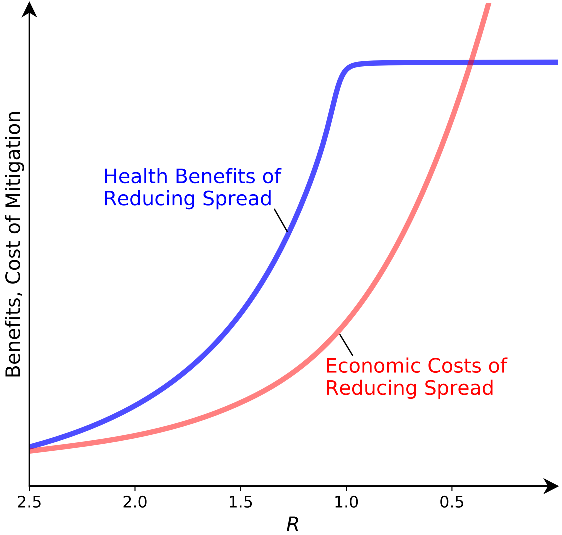
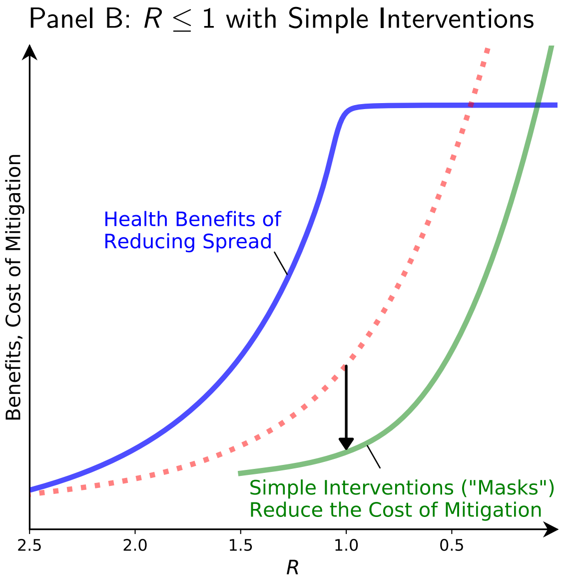


Infectious-Threat Playbook



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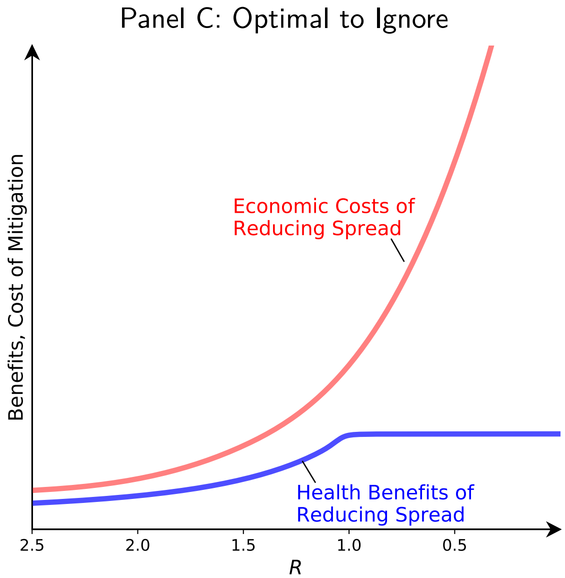

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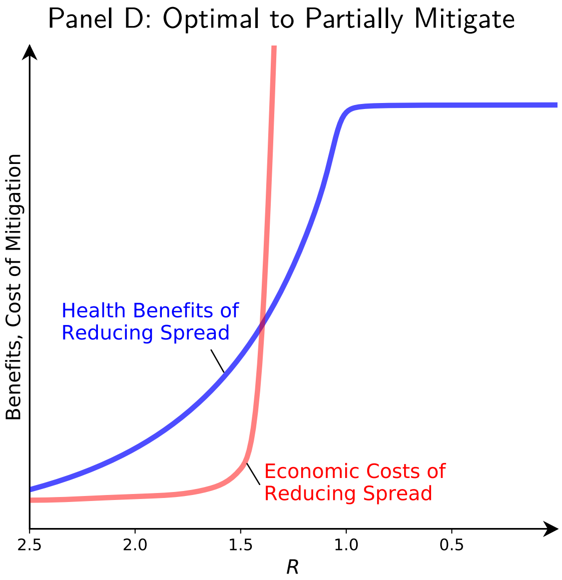

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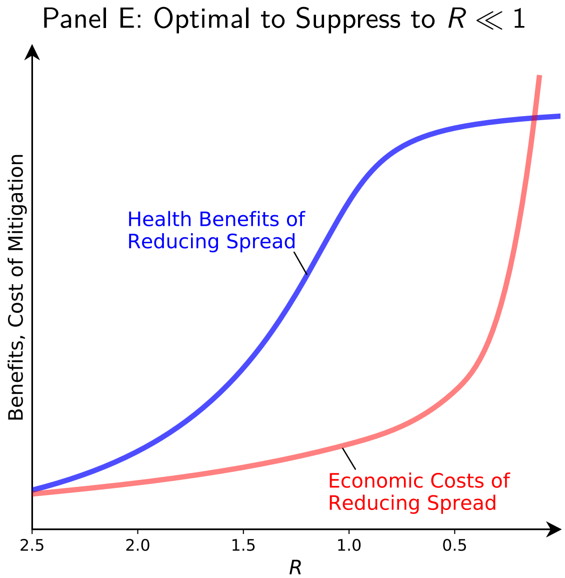

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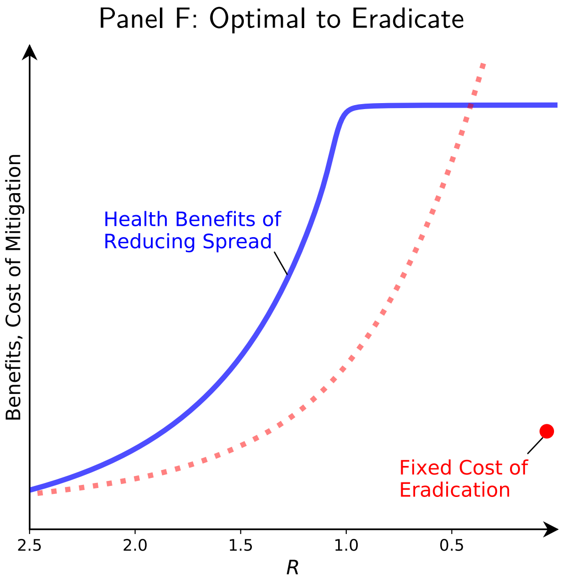

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- That is, contain the exponential growth as efficiently as possible
- Final point: this paper, at most, puts economics language on a formulation many others converged on as well
- Hopefully we will do a better job in the next pandemic.