Health versus Wealth: On the Distributional Effects of Controlling a Pandemic

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Introduction

- What is the appropriate economic policy response to the pandemic?
- How extensive should the shut-down be, and when should it end?
- Key item: Large distributional implications of lock down policies.
    - Benefits are concentrated among the old
    - Costs are concentrated among the young and especially, the young who face unemployment
- Need some combination of shut-down and redistribution

What we do

- Build an epidemiological/economic model with heterogeneous agents
- Assume that transfers across agents are **costly**
- Assess two policies
  - Mitigation (less output but also less contagion)
  - Redistribution toward those whose jobs are shuttered
- Characterize optimal policy
- Interaction:
  - Mitigation creates the need for redistribution
  - If redistribution is costly, reduces the incentives for mitigation
  - Need heterogeneous agent model to analyze this trade-off.

Epidemiology: The SAFER SIR Model

- Stage of the disease
  - **S**usceptible
  - Infected **A**symptomatic
  - Infected with **F**lu-like symptoms
  - Infected and needing **E**mergency hospital car
  - **R**ecovered (and **D**ead)
- Worst case disease progression: **S** $\rightarrow$ **A** $\rightarrow$ **F** $\rightarrow$ **E** $\rightarrow$ **D**
- But recovery is possible at each stage
- Three infected types spread virus in different ways:
  - **A** at work, while consuming, at home
  - **F** at home
  - **E** to health-care workers

Economics: Heterogeneity by Age and Sector

- Age $i \in \{y, o\}$
  - Only young work
  - Old have more adverse outcomes conditional on contagion
  - But young more prone to contagion (they work)
  - Old discount future at higher rate, reflecting shorter life expectancy
- Sector of production $\{b, \ell\}$
  - Basic (health care/food production/law enforcement/government)
    - Will never want shut-downs in this sector
    - Workers in this sector care for the hospitalized
  - Luxury (restaurants, entertainment etc.)
    - Government chooses how much of this sector to shutter
    - Workers face shutdown unemployment risk
    - But they are less likely to get infected

Interactions between Health and Wealth

- Mitigation
  - Reduces contagion
  - Reduces risk of hospital overload
  - Reduces average consumption
  - Increases inequality (more unemployment)
- Redistribution
  - Helps the unemployed $\Rightarrow$ makes mitigation more palatable
  - But redistribution is costly $\Rightarrow$ makes mitigation more expensive
- What policies do different types prefer?
- How does the utilitarian optimal policy vary with the cost of redistribution?

Preferences

- Lifetime utility (for old)

$$E\left\{\int e^{-\rho_o t}\ \left[u(c_t^o) + \bar{u} + \widehat{u}_t^j\right]\ dt\right\}$$

  - ρ_o: time discount rate
  - $u(c_t^o)$ instantaneous utility from old age consumption c_t^o
  - $\bar{u}$: value of life
  - $\widehat{u}_t^j$: intrinsic (dis)utility from health status j (zero for $j \in \{s, a, r\}$)

- Differences in expected longevity through $\rho_y \neq \rho_o$ (no aging)

Technology

- Young permanently assigned to b or ℓ
- Linear production: output equals number of workers
- Only workers with $j \in \{s, a, r\}$ work
- Output in basic sector:

$$y^b = x^{ybs} + x^{yba} + x^{ybr}$$

- Output in luxury sector is

$$y^\ell = [1 - m] \left(x^{y\ell s} + x^{y\ell a} + x^{y\ell r} \right)$$

- Total output given by

$$y = y^b + y^\ell.$$

- Fixed amount of output $\eta\Theta$ spent on emergency health care
- Θ measures capacity of emergency health system, η its unit cost

Virus Transmission

- Types of transmission
  - work: young workers infected by a workers w/ prob $\beta_w(m)$
  - consumption: young & old infected by a w/ prob $\beta_c(m) \times y(m)$
  - home: young & old infected by a and f w/ prob β_h
  - emergency: basic workers infected by e w/ prob β_e
- Shutdowns (mitigation) help by:
  - Reducing number of workers $\Rightarrow$ less workplace transmission
  - Reducing output $y(m)$ $\Rightarrow$ less consumption transmission
  - Reducing infection rates $\beta_w(m)$ & $\beta_c(m)$

$$\beta_w(m) = \alpha_w \left[\frac{y^b + y^\ell(m)(1-m)}{y(m)} \right]$$

- Similar for $\beta_c(m)$
- Micro-founded via sectoral heterogeneity in social contact rates
- Smart mitigation shutters most contact-intensive sub-sectors first

Flow into asymptomatic (out of susceptible)

$$\dot{x}^{ybs} = -\Big[\beta_w(m) \quad \Big[x^{yba} + (1-m)x^{y\ell a}\Big] + \beta_c(m)x^a y(m) + \beta_h\left(x^a + x^f\right) + \beta_e x^e \ \Big] \ x^{y}$$

$$\dot{x}^{y\ell s} = -\Big[\beta_w(m)(1-m) \quad \Big[x^{yba} + (1-m)x^{y\ell a}\Big] + \beta_c(m)x^a y(m) + \beta_h\left(x^a + x^f\right) \quad \Big] \ x^{y}$$

$$\dot{x}^{os} = -\Big[\quad \beta_c(m)x^a y(m) + \beta h\left(x^a + x^f\right) \quad \Big] \ x$$

Flows into other health states

- For each type $j \in \{yb, y\ell, o\}$

$$\begin{aligned}
\dot{x}^{ja} &= -\dot{x}^{js} - \left(\sigma^{jaf} + \sigma^{jar}\right) x^{ja} \\
\dot{x}^{jf} &= \sigma^{jaf} x^{ja} - \left(\sigma^{jfe} + \sigma^{jfr}\right) x^{jf} \\
\dot{x}^{je} &= \sigma^{jfe} x^{jf} - \left(\sigma^{jed} + \sigma^{jer}\right) x^{je} \\
\dot{x}^{jr} &= \sigma^{jar} x^{ja} + \sigma^{jfr} x^{jf} + (\sigma^{jer} - \varphi) x^{je} \\
\varphi &= \lambda_o \max\{x^e - \Theta, 0\}.
\end{aligned}$$

- where all the flow rates σ vary by age
- $x^e - \Theta$ measures excess demand for emergency health care. Reduces flow of recovered (Increases flow into death)

Redistribution

- Costly transfers between workers, non-workers (old, sick, unemployed)
- Utilitarian planner: taxes/transfers don't depend on age/sector/health
  - Workers share common consumption level c^w
  - Non-workers share common consumption level c^n
- Define measures of non-working and working as

$$\mu^n = x^{y\ell f} + x^{y\ell e} + x^{ybf} + x^{ybe} + m\left(x^{y\ell s} + x^{y\ell a} + x^{y\ell r}\right) + x^o$$

$$\mu^w = x^{ybs} + x^{yba} + x^{ybr} + [1-m]\left(x^{y\ell s} + x^{y\ell a} + x^{y\ell r}\right)$$

$$\nu^w = \frac{\mu^w}{\mu^w + \mu^n}$$

- Aggregate resource constraint

$$\mu^w c^w + \mu^n c^n + \mu^n T(c^n) = y - \eta\Theta = \mu^w - \eta\Theta$$

Instantaneous Social Welfare Function

- Consumption allocation does not affect disease dynamics $\Rightarrow$ optimal redistribution is a static problem
- With log-utility and equal weights, the period social welfare is

$$W(x,m) = \max_{c^n, c^w} \left[\mu^w \log(c^w) + \mu^n \log(c^n)\right] + (\mu^w + \mu^n)\bar{u} + \sum_{i,j \in \{f,e\}} x^{ij} \widehat{u}$$

- Maximization subject to resource constraint gives $\frac{c^w}{c^n} = 1 + T'(c^n)$.

Instantaneous Social Welfare Function

- Assume $\mu^n T(c^n) = \mu^w \frac{\tau}{2} \left(\frac{\mu^n c^n}{\mu^w} \right)^2$
- Optimal allocation

$$\begin{aligned} c^n &= \frac{\sqrt{1 + 2\tau \frac{1-\nu^2}{\nu} \tilde{y}} - 1}{\tau \frac{1-\nu^2}{\nu}} \\ c^w &= c^n(1 + T'(c^n))) = c^n \left(1 + \tau \frac{1-\nu}{\nu} c^n \right) \end{aligned}$$

where $\tilde{y} = \nu - \frac{\eta \Theta}{\mu^w + \mu^n}$.

- $\left(1 + \tau \frac{1-\nu}{\nu} c^n\right)$ is the effective marginal cost of transfers.
- It increases with c^n and τ, decreases with share of workers ν
- Higher mitigation m reduces ν, thus increases marginal cost
- $\Rightarrow$ policy interaction between m, τ.

Mapping to Data

Calibration: Preferences:

- $u(c) = \log(c)$
- Young < 65 (85% of population), Old ≥ 65
- $\rho_y = 4\%$ and $\rho_o = 10\%$: pure discount rate of 3% plus adjustment for 47.5 & 14 years of residual life expectancy
- $\bar{u} = 11.4 - \log(\bar{c})$: VSL is \$11.5m $\Rightarrow$ \$515k flow value or 11.4 $\times$ US cons. pc
    - Static trade-off: pay 10.8% of cons. to avoid 1% death probability
    - Dynamic: give up 25% of cons. for 6 months for 0.16% increase in chance of living 10 more years
- $\hat{u}^f$, $\hat{u}^e$: flu reduces baseline utility by 30%, hospital by 100%

Calibration: Disease Progression (Imperial Model)

1. Avg. duration asymptomatic: 5.3 days
    - 50% recover (important unknown)
    - 50% develop flu
2. Avg. duration of flu: 10 days
    - 96% of young recover
    - 75% of old recover
    - rest move to emergency care
3. Avg. duration of emergency care: 8 days
    - 95% of young recover (absent overcapacity)
    - 80% of old recover (absent overcapacity)
    - rest die

- These moments pin down all the σ parameters
- Implied death rates (absent overuse) 2.5% for the old, 0.1% for young

Calibration: Economics

- Production
  - Size of basic Sector: 45%
    - basic = health, agriculture, utilities, finance, federal govt
    - luxury = manuf., constr., mining, educ., leisure & hospitality
    - split the rest similarly
  - $\Theta = 0.042\%$ (100,000 beds), λ_o s.t. mortality up 20% at infection peak
- Redistribution
  - Marginal excess burden 38% pre-COVID ($\tau = 3.5$, Saez, Slemrod, Giertz 2012)
  - $\Rightarrow$ planner chooses $\frac{c^n}{c^w} = \frac{1}{1.38}$
- Mitigation time path

$$m(t) = \frac{\gamma_0}{1 + \exp(-\gamma_1(t - \gamma_2))}$$

Calibration: Virus Transmission

- Set α_w/β_h, α_c/β_h to match evidence on number of potentially infectious contacts from Mossong et al. (2008)

  - 35% of transmission occurs in workplaces and schools (model work)
  - 19% occur in travel and leisure activities (model consumption)

- β_h then determines basic reproduction number R_0 (next slide)

- Set β_e so that at infection peak, 5% of infections are to health care workers

Calibration: Initial Conditions

- Will focus on alternative mitigation policies starting from April 12
- But how many people are already infected? How fast is the virus spreading?
- Data challenges:
  - Estimates of COVID-19 R_0 from early days in Wuhan are outdated: behaviors and policies have changed drastically
  - Limited testing $\Rightarrow$ positive test counts understate true infection levels
  - Hardest numbers we have are for deaths (even those under-counted)

Our Strategy

- Assume America changed on March 21
  - Assume initial arrival of infected individuals on Feb 12
  - $m = 0 \rightarrow m = 0.5$ plus one-time proportional drop in α_w, α_c, β_h
  - 27.7% fall in employment consistent with Faria-e-Castro (2020) and Bick & Blandin (2020)
- Set infection-generating rates pre-and post March 21 and Feb 12 infected population to match:
  1. Cumulative deaths on March 21: 300
  2. Cumulative deaths on April 12:22,100
  3. Daily death toll around April 12: 2,000

Target	$I_{t_1} = 12$	$D_{t_2} = 300$		$D_{t_3} = 22,105$ $D_{t_3} - D_{t_3-1} = 2,000$
Parameter	$R_{t_1} = 3.0$	$R_{t_2} = 0.72$, under $m_{t_2} = 0.5$		
t_0	Febr. 16 (t_1)	March 21 (t_2)		April 12 (t_3) Time t

Table 1: Millions of People in Each Health State

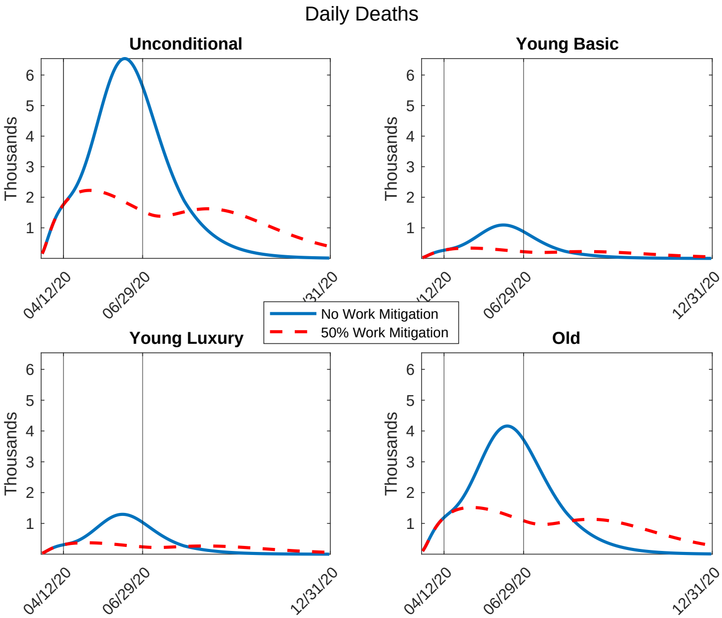
	S	A	F	E	R
March 21	321.84	5.57	1.04	0.01	1.54
April 12	305.39	4.16	3.68	0.15	16.59

Experiments

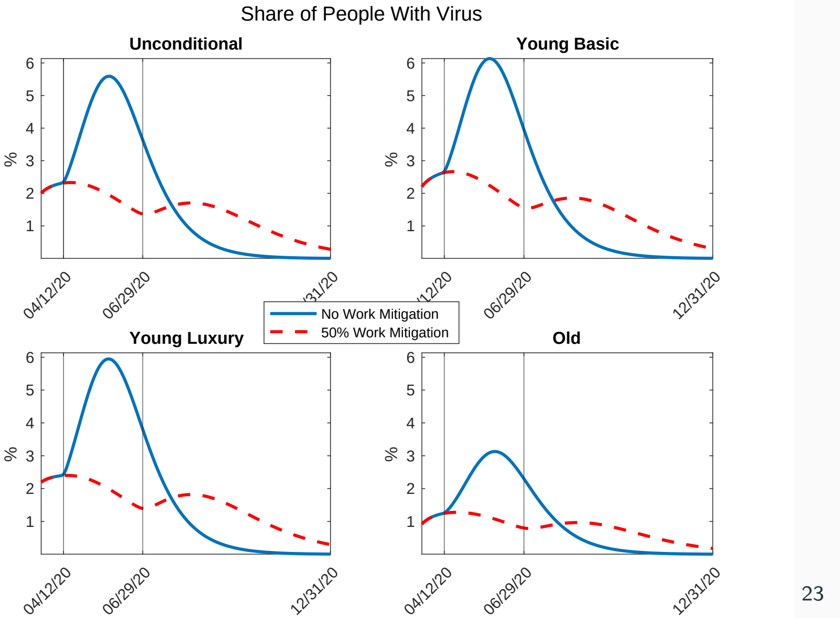
1. Baseline comparison: $\gamma_0 = 0.5$, $\gamma_1 = -0.3$, $\gamma_2 =$ March 21 $+100$ (mitigation ends around June 29), vs. no mitigation from April 12
2. Alternative severity: $\alpha_0 = 0.25, 0.10$
3. Optimize (starting April 12) over γ_0, γ_1, γ_2

- For each policy, compute welfare gains rel. to no mitigation by type
- How do gains from mitigation vary with cost of redistribution τ?
- How does optimal mitigation vary with cost of redistribution?

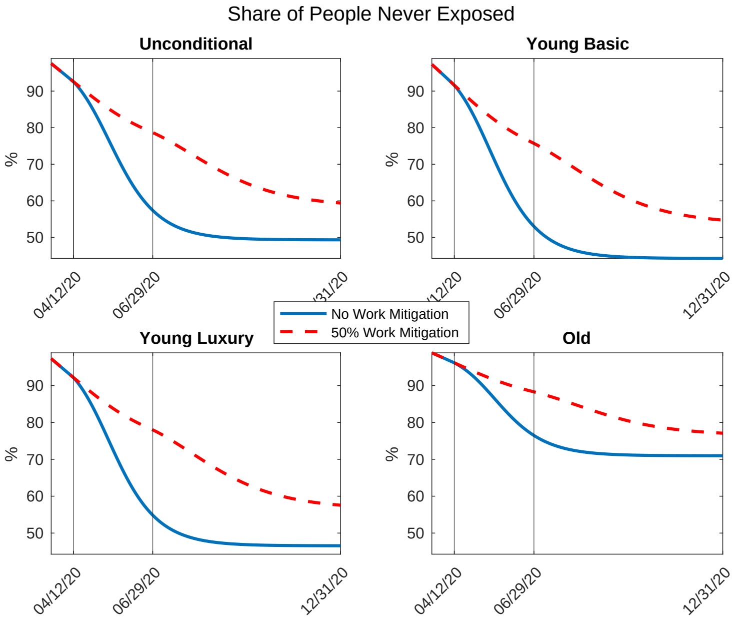
Number of Deaths



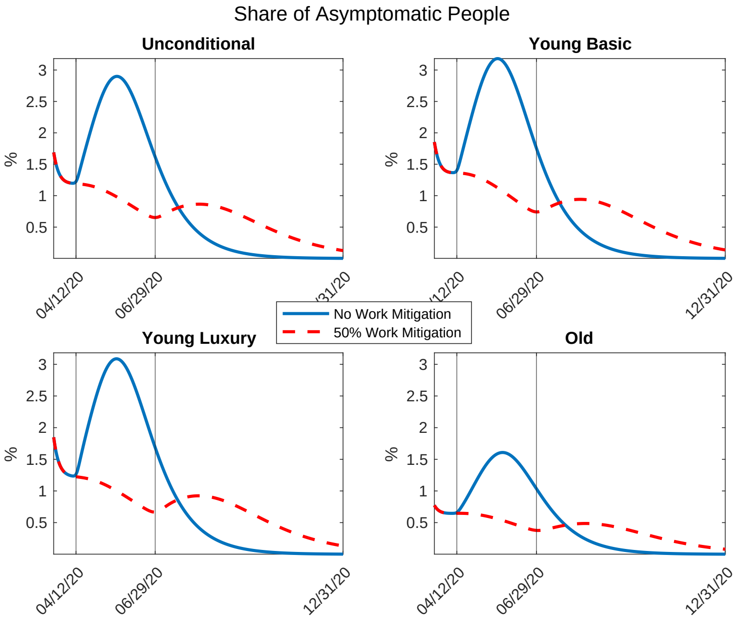
Shares Currently Infected



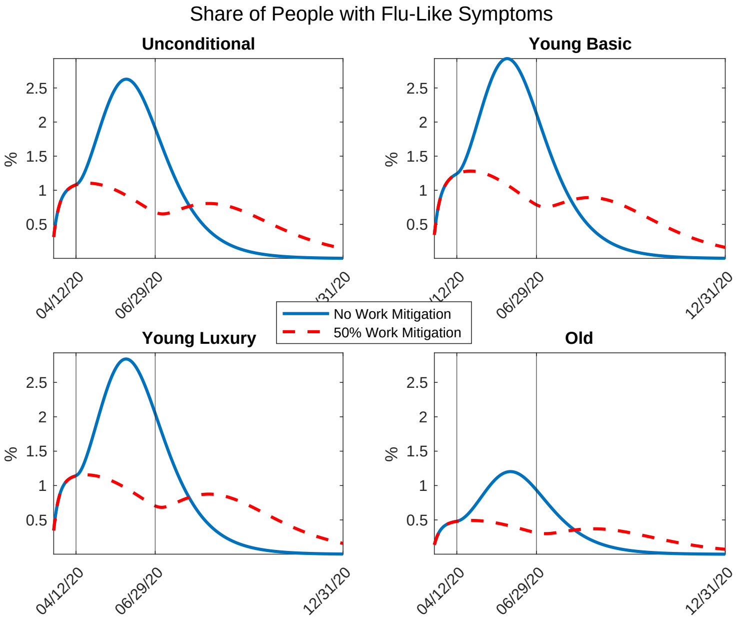
Shares Never Infected



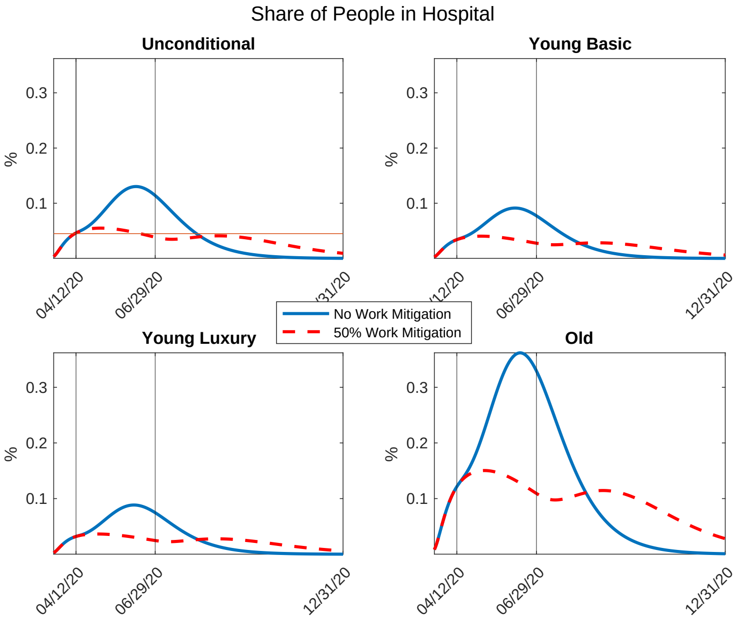
Shares Asymptomatic



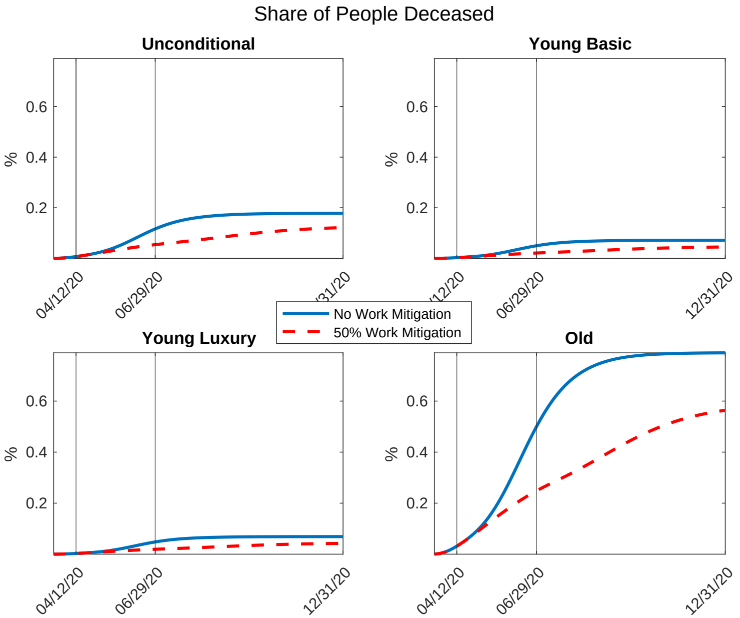
Shares with Flu Symptoms



Shares Hospitalized



Cumulative Deaths



Consumption

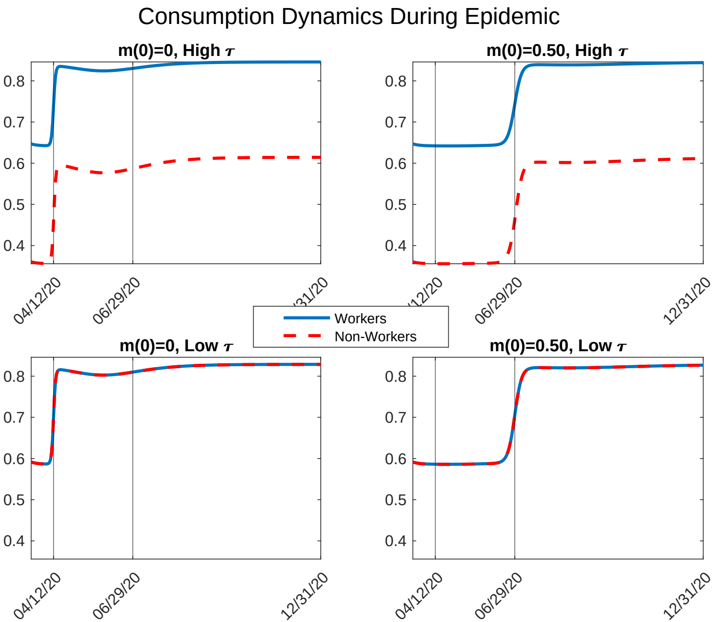
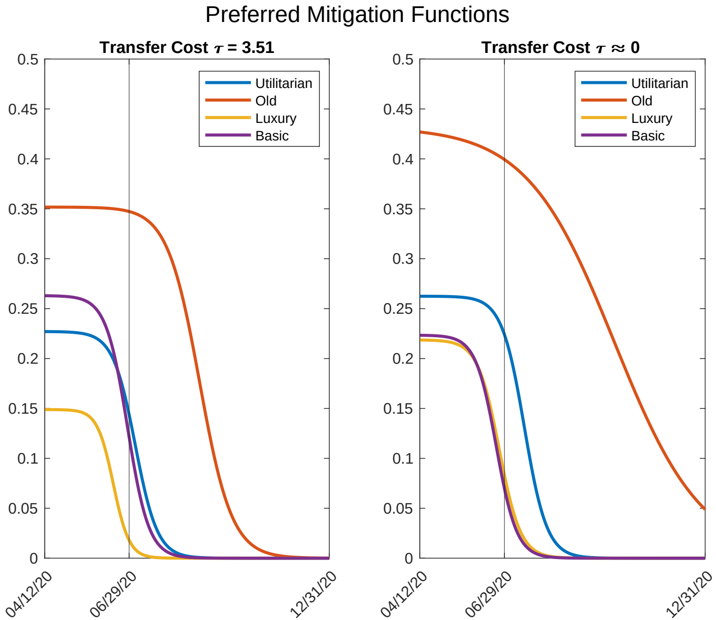


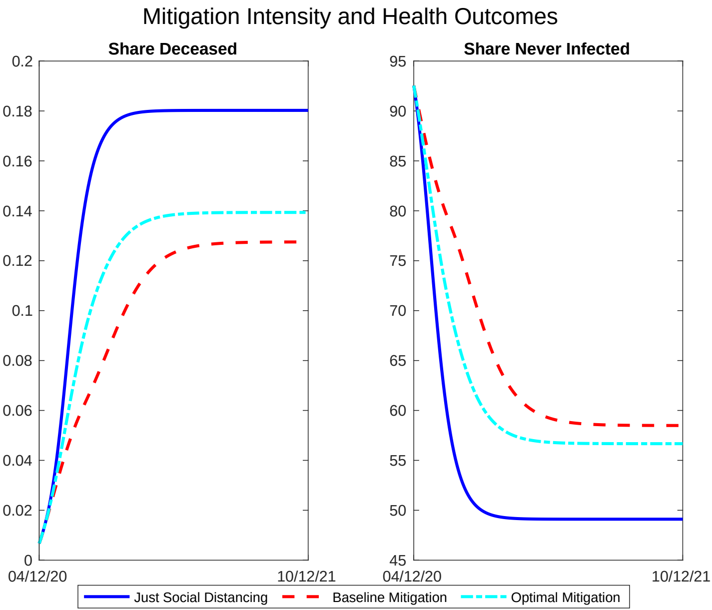
Table 2: Welfare Gains (+) or Losses (-) From Mitigation

Mitigated Share	50%		25%		10%	
Transfer Cost (τ)	3.51	0.001	3.51	0.001	3.51	0.001
Young Basic	0.03%	-0.04%	0.12%	0.08%	0.08%	0.06%
Young Luxury	-0.27%	-0.04%	0.00%	0.09%	0.04%	0.07%
Old	1.43%	1.97%	1.49%	1.83%	0.80%	0.95%

Optimal Policies



Outcome Comparisons



Welfare Gains under Optimal Policies

Welfare Gains (+) or Losses (-) From Preferred Mitigation, $\tau = 3.51$

	Utilitarian	Old	Young Luxury	Young Basic
Young Basic	0.16%	0.12%	0.12%	0.16%
Young Luxury	0.07%	-0.14%	0.08%	0.07%
Old	1.45%	2.02%	0.93%	1.45%

Welfare Gains (+) or Losses (-) From Preferred Mitigation, $\tau \approx 0$

	Utilitarian	Old	Young Luxury	Young Basic
Young Basic	0.19%	-0.07%	0.17%	0.17%
Young Luxury	0.08%	-0.33%	0.10%	0.10%
Old	1.85%	2.22%	1.44%	1.42%

Conclusions

- Current baseline simulation suggests current shutdowns should be partially relaxed but extended
- Welfare gains are uneven: large for the old, small for the young
- Cost of redistribution matters: harder shutdown optimal when redistribution is costless
- Results sensitive to parameters:
  - Value of life
  - Importance of economic activity in disease transmission
  - Disease lethality
  - Reading of current state: how many infections? how fast spreading?