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

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Introduction
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
• 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 care
  - **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**t 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 ⇒ makes mitigation more palatable
  - But redistribution is costly ⇒ makes mitigation more expensive

- What policies do different types prefer?

- How does the utilitarian optimal policy vary with the cost of redistribution?
Lifetime utility (for old)

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

- \( \rho_o \): time discount rate
- \( u(c_t^o) \): instantaneous utility from old age consumption \( c_t^o \)
- \( \bar{u} \): value of life
- \( \hat{u}_t^j \): 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 $\ell$.
- 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.
- $\Theta$ measures capacity of emergency health system, $\eta$ 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 $\beta_h$
  - **emergency**: basic workers infected by e w/ prob $\beta_e$

- 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)

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

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

\[ \dot{x}_{os} = - \left[ \beta_c(m)x^a y(m) + \beta_h \left( x^a + x^f \right) \right] x^s \]
Flows into other health states

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

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

- where all the flow rates $\sigma$ 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
  \[
  \mu^n = x^y \ell f + x^y \ell e + x^y b f + x^y b e + m (x^y \ell s + x^y \ell a + x^y \ell r) + x^o
  \]
  \[
  \mu^w = x^y b s + x^y b a + x^y b r + [1 - m] (x^y \ell s + x^y \ell a + x^y \ell r)
  \]
  \[
  \nu^w = \frac{\mu^w}{\mu^w + \mu^n}
  \]
- 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

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

- Maximization subject to resource constraint gives

\[
\frac{c^w}{c^n} = 1 + T'(c^n).
\]
Assume $\mu^n T(c^n) = \mu^w \frac{\tau}{2} \left( \frac{\mu^nc^n}{\mu^w} \right)^2$

Optimal allocation

$$c^n = \frac{\sqrt{1 + 2\tau \frac{1-\nu^2}{\nu} \tilde{y}} - 1}{\tau \frac{1-\nu^2}{\nu}}$$

$$c^w = c^n(1 + T'(c^n))) = c^n \left( 1 + \tau \frac{1-\nu}{\nu} c^n \right)$$

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

$(1 + \tau \frac{1-\nu}{\nu} c^n)$ is the effective marginal cost of transfers.

It increases with $c^n$ and $\tau$, decreases with share of workers $\nu$.

Higher mitigation $m$ reduces $\nu$, thus increases marginal cost.

$\Rightarrow$ policy interaction between $m, \tau$. 
Mapping to Data
**Calibration: Preferences:**

- $u(c) = \log(c)$

- Young < 65 (85% of population), Old $\geq$ 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%
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 $\sigma$ 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
  - $\Theta = 0.042\% \text{ (100,000 beds), } \lambda_o \text{ s.t. mortality up 20\% at infection peak}$

- **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 $\alpha_w/\beta_h$, $\alpha_c/\beta_h$ 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)

- $\beta_h$ then determines basic reproduction number $R_0$ (next slide)

- Set $\beta_e$ so that at infection peak, 5% of infections are to health care workers
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 $\alpha_w, \alpha_c, \beta_h$
  - 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
Calibration: Initial Conditions and $R_0$

Target
\[ I_{t_1} = 12 \quad D_{t_2} = 300 \quad D_{t_3} = 22,105 \quad D_{t_3} - D_{t_3-1} = 2,000 \]

Parameter
\[ R_{t_1} = 3.0 \quad R_{t_2} = 0.72, \text{ under } m_{t_2} = 0.5 \]

\[ t_0 \quad \text{Febr. 16 (} t_1 \text{)} \quad \text{March 21 (} t_2 \text{)} \quad \text{April 12 (} t_3 \text{)} \quad \text{Time } t \]

Table 1: Millions of People in Each Health State

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>A</th>
<th>F</th>
<th>E</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 21</td>
<td>321.84</td>
<td>5.57</td>
<td>1.04</td>
<td>0.01</td>
<td>1.54</td>
</tr>
<tr>
<td>April 12</td>
<td>305.39</td>
<td>4.16</td>
<td>3.68</td>
<td>0.15</td>
<td>16.59</td>
</tr>
</tbody>
</table>
1. Baseline comparison: $\gamma_0 = 0.5$, $\gamma_1 = -0.3$, $\gamma_2 = \text{March 21} + 100$ (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 $\gamma_0$, $\gamma_1$, $\gamma_2$
   - For each policy, compute welfare gains rel. to no mitigation by type.
   - How do gains from mitigation vary with cost of redistribution $\tau$?
   - How does optimal mitigation vary with cost of redistribution?
NUMBER OF DEATHS

Daily Deaths

- **Unconditional**
- **Young Basic**
- **Young Luxury**
- **Old**

Graphs show the number of deaths in thousands for different age groups and work mitigation levels from 04/12/20 to 12/31/20.
Share of People With Virus

Unconditional

Young Basic

Young Luxury

Old

No Work Mitigation 50% Work Mitigation
**SHARES NEVER INFECTED**

**Share of People Never Exposed**

**Unconditional**

**Young Basic**

**Young Luxury**

**Old**

**No Work Mitigation**

**50% Work Mitigation**
Share of Asymptomatic People

Unconditional

Young Basic

Young Luxury

Old

- No Work Mitigation
- 50% Work Mitigation
Share of People with Flu-Like Symptoms

Unconditional

04/12/20 06/29/20 12/31/20
0.5
1
1.5
2
2.5%

Young Basic

04/12/20 06/29/20 12/31/20
0.5
1
1.5
2
2.5%

Young Luxury

04/12/20 06/29/20 12/31/20
0.5
1
1.5
2
2.5%

Old

04/12/20 06/29/20 12/31/20
0.5
1
1.5
2
2.5%

No Work Mitigation
50% Work Mitigation
Share of People Deceased

Unconditional

Young Basic

Young Luxury

Old

No Work Mitigation

50% Work Mitigation
Consumption Dynamics During Epidemic

- $m(0)=0$, High $\tau$
- $m(0)=0.50$, High $\tau$
- $m(0)=0$, Low $\tau$
- $m(0)=0.50$, Low $\tau$

Graphs showing consumption dynamics for workers and non-workers from 04/12/20 to 12/31/20, with two sets of parameters: $m(0)=0$ and $m(0)=0.50$, and low and high $\tau$. The graphs depict consumption trends over time for different scenarios.
## Welfare Gains

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

<table>
<thead>
<tr>
<th>Mitigated Share</th>
<th>50%</th>
<th>25%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transfer Cost ($\tau$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.51</td>
<td>0.001</td>
<td>3.51</td>
</tr>
<tr>
<td>Young Basic</td>
<td>0.03%</td>
<td>-0.04%</td>
<td>0.12%</td>
</tr>
<tr>
<td>Young Luxury</td>
<td>-0.27%</td>
<td>-0.04%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Old</td>
<td>1.43%</td>
<td>1.97%</td>
<td>1.49%</td>
</tr>
</tbody>
</table>
Preferred Mitigation Functions

Transfer Cost $\tau = 3.51$

Transfer Cost $\tau \approx 0$
Mitigation Intensity and Health Outcomes

Share Deceased

Share Never Infected

04/12/20 10/12/21

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2

04/12/20 10/12/21

Just Social Distancing Baseline Mitigation Optimal Mitigation

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## Welfare Gains under Optimal Policies

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

<table>
<thead>
<tr>
<th></th>
<th>Utilitarian</th>
<th>Old</th>
<th>Young Luxury</th>
<th>Young Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young Basic</td>
<td>0.16%</td>
<td>0.12%</td>
<td>0.12%</td>
<td>0.16%</td>
</tr>
<tr>
<td>Young Luxury</td>
<td>0.07%</td>
<td>-0.14%</td>
<td>0.08%</td>
<td>0.07%</td>
</tr>
<tr>
<td>Old</td>
<td>1.45%</td>
<td>2.02%</td>
<td>0.93%</td>
<td>1.45%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Utilitarian</th>
<th>Old</th>
<th>Young Luxury</th>
<th>Young Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young Basic</td>
<td>0.19%</td>
<td>-0.07%</td>
<td>0.17%</td>
<td>0.17%</td>
</tr>
<tr>
<td>Young Luxury</td>
<td>0.08%</td>
<td>-0.33%</td>
<td>0.10%</td>
<td>0.10%</td>
</tr>
<tr>
<td>Old</td>
<td>1.85%</td>
<td>2.22%</td>
<td>1.44%</td>
<td>1.42%</td>
</tr>
</tbody>
</table>
• 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?