Macroeconomic Dynamics and Reallocation in a Pandemic

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Motivation: The CoViD-19 Crisis

Cumulative Death Cases in the US

US Industrial production: 2020M1 = 100
As Charles Fain Lehman of the Washington Free Beacon notes, polling data show that Americans are skeptical about going back to work, shopping, and transportation. "Recent data from Axios/Ipsos show that large majorities consider common public activities, like going grocery shopping or attending a family gathering, to be a large or moderate risk right now. Data from the Harris Poll show that a majority of Americans believe that more than a month is needed before they should 'start returning to work and life as normal.' A Seton Hall poll found that 72 percent would not attend sporting events until a vaccine for SARS-CoV-2 is found."

So it's not just a matter of either the president or a governor issuing a "back to work" order. Lots of Americans are going to be concerned about returning to normalcy. And while many people are bored or stir-crazy or simply missing normal interaction, we've also learned a lot about how to work remotely. There may be unanticipated changes in lifestyle and work arrangements as a result of our forced confinement. Forced, I would suggest, at least as much by the coronavirus as by any governmental order. And by the way, Robinson knows that:

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Macro Reallocation in Pandemic
Jul 2020 3 / 24
Paper in a Nutshell

- **Broad Question about COVID 19 Epidemic:**
  - Trading off health v/s econ. Re-opening debate.
  - **Specific Question:** how much will people do on their own?

- **What we do:**
  - Neoclassical economic model cum SIR epidemiological model.
  - Agents can be susceptible, infected, recovered, or dead.
  - People get infected when they consume.
  - Key innovation: consumption sectors differ in infection risk.
  - Susceptible agents make conscious decisions. Shift consumption towards low-infection sectors.
  - Key margins: elasticity of substitution $\eta$; rel. contagiousness $\phi$.

- **What we find:**
  - Output decline, infection rates reduced substantially compared to a homogeneous-sector economy [ERT].
The Model, Macro: Neoclassical, no $k$.

- Continuum of agents $i \in [0, 1]$. Changing health status $j \in \{s, i, r, d\}$.
- **Preferences** over differentiated (by sector $k$) consumption, hours:

$$U = E \left[ \sum_{t=0}^{\infty} \beta^t u^j (c^j_t, n^j_t) \right]$$

where

$$c_t^j = \left( \int (c_{tk})^{1-1/\eta} dk \right)^{\eta/(\eta-1)}$$

and where for $j \in \{s, i, r\}$,

$$u^j (c, n) = \ln c - \theta \frac{n^2}{2}$$

while for dead agents: $u^d \equiv 0$ and $c^d_t = 0, n^d_t = 0$.

- **Technology**: one unit of labor $\Rightarrow A$ units of goods in each sector.
- Competitive frictionless labor and goods **markets**. Wage $w = A$

- **Household budget constraint**:

$$\int c^j_{tk} dk = A n^j_t$$
The Model, Epidemiology: SIR with Cons Dependency.

- Agents can be susceptible, infected, recovered, or dead.
  Population fractions: $S_t$, $I_t$, $R_t$.
- **Infection** is transmitted while **consuming** (or autonomously).
  - Probability for a susceptible agent $s$ to become infected:
    \[
    \tau_t = \pi_s I_t \int \phi(k) c_{tk}^s c_{tk}^i dk + \pi a I_t,
    \]
    - $(\pi_s, \pi_a)$ are contagion parameters.
    - Sector-specific relative contagiousness $\phi(k)$,
      \[
      \int \phi(k) dk = 1
      \]
    - $T_t = \tau_t S_t$ is the number of new infections.
- Similar mechanics if infections occur in **workplace** (see paper).
- **Dynamics of the pandemic:** $I_0 = \epsilon, S_0 = 1 - \epsilon, R_0 = 0$ and
  \[
  S_{t+1} = S_t - T_t
  
  I_{t+1} = I_t + T_t - (\pi_r + \pi_d)I_t
  
  R_{t+1} = R_t + \pi_r I_t
  \]
Infected and recovered \( j \in \{i, r\} \) face no further health risks.

Value variety of consumption if elasticity of substitution \( \eta < \infty \).

⇒ spread consumption evenly across sectors: \( c_{tk}^j \equiv c_t^j, \forall t, k, j \).

Intratemporal optimality condition and budget constraint imply optimal labor, consumption choice for \( j \in \{i, r\} \):

\[
n_t^j = \frac{1}{\sqrt{\theta}}, \quad c_t^j = \frac{A}{\sqrt{\theta}}
\]
Analysis: Choices of Susceptible Agents.

- Recall **infection probability**:
\[
\tau_t = \pi_s I_t \int \phi(k) c_{tk}^s c_t^i dk + \pi_a I_t,
\]
where \( c_{tk}^i \equiv c_t^i = \frac{A}{\sqrt{\theta}} \).

- Bellman equation:
\[
U^s_t = u(c^s_t, n^s_t) + \beta[(1 - \tau_t)U^s_{t+1} + \tau_t U^i_{t+1}]
\]

- First-order condition wrt consumption \( c^s_{tk} \) of variety \( k \):
\[
u_1(c^s_t, n^s_t) \cdot \left( \frac{c^s_t}{c^s_{tk}} \right)^{1/\eta} = \lambda^s_{bt} + \lambda_{\tau t} \pi_s \frac{A}{\sqrt{\theta}} I_t \phi(k)
\]

- \( \lambda^s_{bt} \) : Lagrange multiplier the budget constraint: common across \( k \).
- \( \lambda_{\tau t} \) : Lagrange multiplier on **infection constraint**. Higher \( \phi(k) \) rises price of good \( k \). Lowers consumption \( c^s_{tk} \).
Three Theoretical Results

1. $\eta = 0$ (Leontief): Back to homogeneous-sector ERT case.

2. $\eta \to \infty$: Substitution mechanism becomes maximally potent. Susceptible agents only consume least contagious goods.

3. $\eta = \infty$: Multiple equilibria.
Numerical Illustration: Choice of Parameter Values

- Most parameters **borrowed from ERT**.
- For this presentation, autonomous infections $\pi_a = 0$.
- Mostly two equally-sized sectors. Clarifies the mechanisms.
- **Relative contagiousness:** $\phi_1 = 0.2$, $\phi_2 = 1.8$.
- **Substitution elasticity** $\eta = 10$. Also: $\eta = 3$.
- Compare to ERT scenario: $\phi_1 = \phi_2 = 1$ (homogeneous sectors).
- Choose $\pi_s$ to get 10% consumption decline in ERT scenario.
- **Robustness Analysis:**
  - $\pi_a > 0$ to obtain 50% susceptible in the limit.
  - 9 sectors.
  - Vary $\eta$.
  - Somewhat lower $\pi_s$. 
### Numerical Results: Parameter Values

<table>
<thead>
<tr>
<th>Param.</th>
<th>$\pi_a = 0$</th>
<th>$\pi_a \neq 0$</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_s$</td>
<td>$4.05 \times 10^{-7}$</td>
<td>$1.77 \times 10^{-7}$</td>
<td>Infection from cons.</td>
</tr>
<tr>
<td>$\pi_r$</td>
<td>0.387</td>
<td>0.387</td>
<td>Recovery</td>
</tr>
<tr>
<td>$\pi_d$</td>
<td>$1.944 \times 10^{-3}$</td>
<td>$1.944 \times 10^{-3}$</td>
<td>Death</td>
</tr>
<tr>
<td>$\pi_a$</td>
<td>0</td>
<td>0.34</td>
<td>Autonomous infection</td>
</tr>
<tr>
<td>$\eta$</td>
<td>10</td>
<td>10</td>
<td><strong>Elasticity of substitution</strong></td>
</tr>
<tr>
<td>$\theta$</td>
<td>$1.275 \times 10^{-3}$</td>
<td>$1.275 \times 10^{-3}$</td>
<td>Labor supply parameter</td>
</tr>
<tr>
<td>$A$</td>
<td>39.835</td>
<td>39.835</td>
<td>Productivity</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$0.96^{1/52}$</td>
<td>$0.96^{1/52}$</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>0.2</td>
<td>0.2</td>
<td><strong>Rel. contagiousn., sect. 1</strong></td>
</tr>
<tr>
<td>$\phi_2$</td>
<td>1.8</td>
<td>1.8</td>
<td><strong>Rel. contagiousn., sect. 2</strong></td>
</tr>
</tbody>
</table>
Results: Key Results

Sectoral dynamics

Deceased

Percentage change

0 10 20 30 40

Percentage of population

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16

Weeks

0 50 100 150

Heterogeneous sectors
Homogeneous sectors
Low-infection
High-infection

Heterogeneous sectors
Homogeneous sectors

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Results: Aggregate Consumption Decline

Agg. consumption

% dev. from SS

Weeks

Baseline
\eta = 3
Low \pi_s
\phi = 1
Numerical Results: Baseline Comparison

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Basic Reproduction Number, $R_0$

$$R_0 = \sum_{t=0}^{\infty} (1 - \pi_r - \pi_d)^t \times \frac{T_0}{I_0} = \frac{T_0/I_0}{\pi_r + \pi_d}$$
Results: Aggregate Consumption Decline, Various $\phi_1$
Results: Sectoral Shifts, 9 sectors
Anecdotal Data for Sectoral Shifts: NYT 2020-04-14

Change in credit and debit card spending

The chart shows the percentage change in spending from the beginning of the year. Each line is an average of the previous two weeks, which smooths out weekly anomalies. | Source: Earnest Research
Anecdotal Data for Sectoral Shifts: NYT 2020-04-14

Change in spending from 2019 for the week ending April 1. Bubbles are sized by industry sales.
Social Planner Solution

- Model has an **externality**. Equilibrium inefficient.

- What constraints does **social planner** face?
  - Agents in the model know whether they are susceptible, infected or recovered (or dead).
  - Give the social planner the same knowledge (needs widespread testing). Can discriminate between \( s \) and \( i,r \) when allocating \( c \).
  - But: planner cannot change the consumption/infection technology

- Intuition for **efficient allocation**:
  - The social planner will seek to minimize the infection via infected agents ...
  - ... while still having to feed them.
Numerical Results: Social Planner

[Graphs showing the dynamics of infected, susceptible, and recovered populations, as well as deceased, aggregated consumption, and aggregated labor.]

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Jul 2020  
21 / 24
Numerical Results: Social Planner

Per capita cons.

Low-infection

High-infection

% of SS at competitive equilibrium

Weeks

Baseline

$\eta = 3$

Constant $\phi$

% of SS at competitive equilibrium

Weeks

% of SS at competitive equilibrium

Weeks
Conclusions

- **COVID 19 epidemic**: lockdown and re-opening debate.

- **Key question**: how much will private reallocation do?

- Neoclassical economic-SIR model. Infections while consuming.
  - Sectoral variety choices: sectors differ in infectiousness.
  - Susceptible agents reduce consumption and **shift towards low-infection sectors**.

- Result: output decline and infection rates reduced substantially compared to homogeneous-sector [ERT] version.

- Even **reversal** rather than just flattening of curve is possible.

- Plus: an extreme social planner result.

- Next step: **serious quantification of reallocation mechanism**!
Thank you!