Macroeconomic Dynamics and Reallocation in a Pandemic

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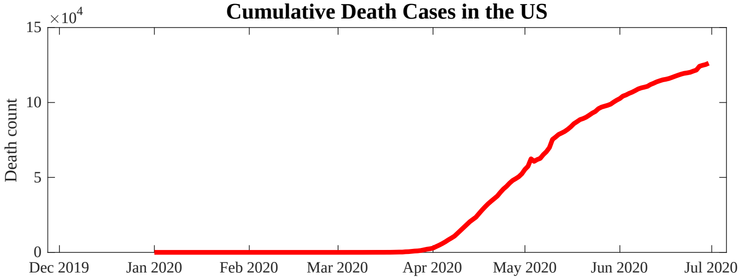
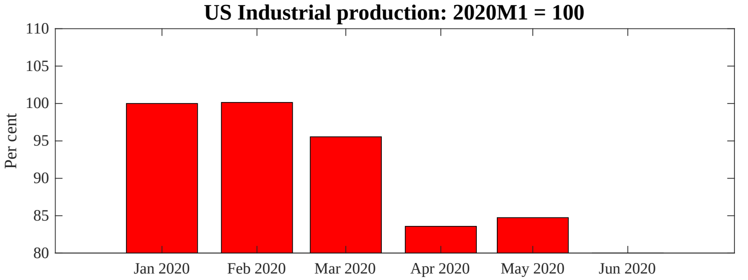
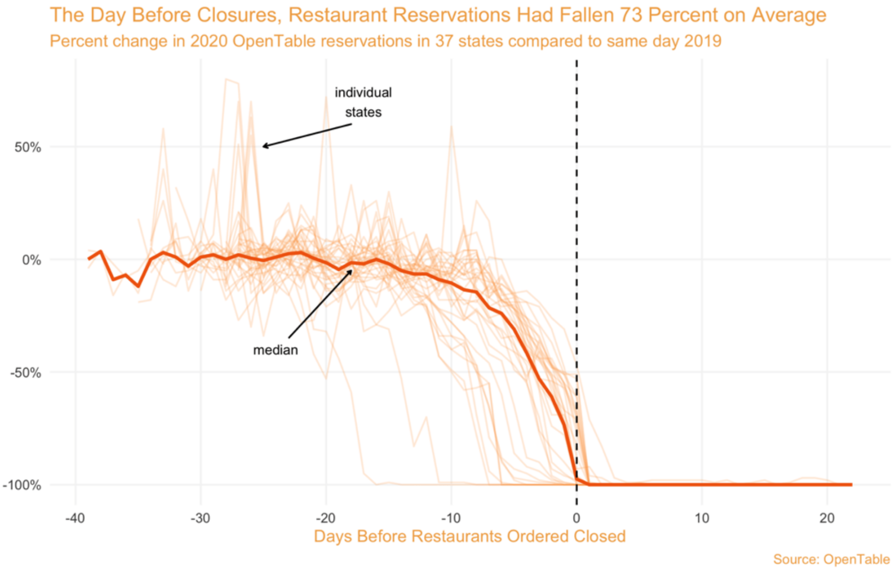
Motivation: The CoViD-19 Crisis





Private Response to CoViD-19



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:**
  - Starting point: Eichenbaum-Rebelo-Trabandt [ERT] (2020).
  - Neoclassical economic model cum SIR epidemiological model.
  - Agents can be **s**usceptible, **i**nfected, **r**ecovered, 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 η; rel. contagiousness ϕ.
- **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 $j \in \{\mathbf{s}, \mathbf{i}, \mathbf{r}, d\}$
- **Preferences** over differentiated (by sector k) consumption, hours:

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

where

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

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 $c_t^d = 0, n_t^d = 0$.

- **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**:

$$\int c_{tk}^j dk = A n_t^j$$

The Model, Epidemiology: SIR with Cons Dependency.

- Agents can be **s**usceptible, **i**nfected, **r**ecovered, 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:

$$\tau_{\mathbf{t}} = \pi_s I_t \int \phi(k) c^s_{tk} c^i_{tk} dk + \pi_a I_t,$$

  - (π_s, π_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

$$\begin{aligned} S_{t+1} &= S_t - T_t \\ I_{t+1} &= I_t + T_t - (\pi_r + \pi_d) I_t \\ R_{t+1} &= R_t + \pi_r I_t \end{aligned}$$

Analysis: Choices of Infected and Recovered Agents

- Infected and recovered $j \in \{i, r\}$ face no further health risks.
- Value variety of consumption if elasticity of substitution $\eta < \infty$.
- $\Rightarrow$ spread consumption evenly across sectors: $c^j_{tk} \equiv c^j_t, \forall t, k, j$.
- Intratemporal optimality condition and budget constraint imply **optimal labor, consumption choice** for $j \in \{i, r\}$:

$$n^j_t = \frac{1}{\sqrt{\theta}}, \; c^j_t = \frac{A}{\sqrt{\theta}}$$

Analysis: Choices of Susceptible Agents.

- Recall **infection probability**:

$$\tau_t = \pi_s I_t \int \phi(k) c^s_{tk} c^i_{tk} dk + \pi_a I_t,$$

where $c^i_{tk} \equiv c^i_t = \frac{A}{\sqrt{\theta}}$.

- 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 $\mathbf{c^s_{tk}}$ of variety k:

$$u_1(c^s_t, n^s_t) \cdot \left(\frac{c^s_t}{\mathbf{c^s_{tk}}}\right)^{1/\eta} = \lambda^s_{bt} + \lambda_{\tau\mathbf{t}} \pi_s \frac{A}{\sqrt{\theta}} I_t \phi(\mathbf{k})$$

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

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.

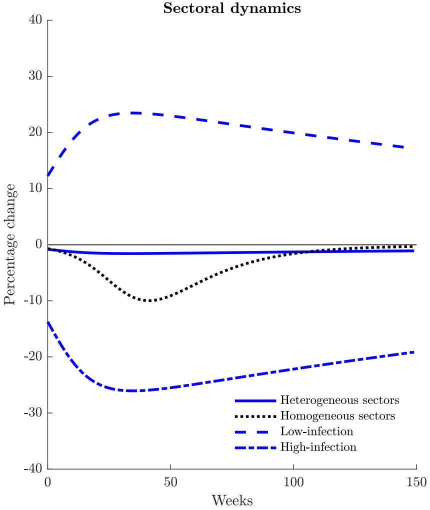
Numerical Illustration: Choice of Parameter Values

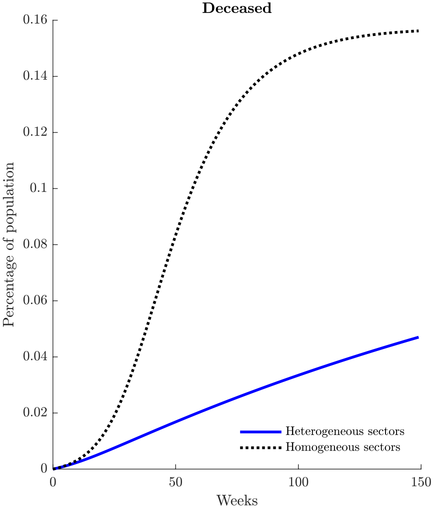
- Most parameters **borrowed from ERT**.
- For this presentation, autonomous infections $\pi_a = 0$.
- Mostly two equally-sized sectors. Clarifies the mechanisms.
- **Relative contagiousness:** $\phi_1 = 0.2$, $\phi_2 = 1.8$.
- **Substitution elasticity** $\eta = 10$. Also: $\eta = 3$.
- Compare to ERT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

Numerical Results: Parameter Values

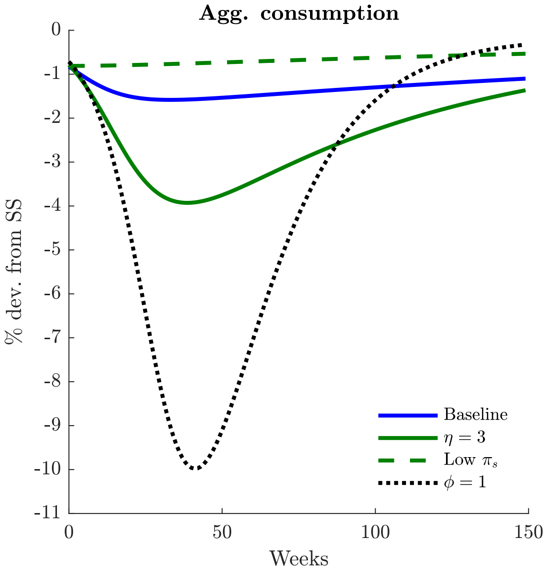
Param.	$\pi_a = 0$	$\pi_a \neq 0$	**Description**
π_s	4.05×10^{-7}	1.77×10^{-7}	Infection from cons.
π_r	0.387	0.387	Recovery
π_d	1.944×10^{-3}	1.944×10^{-3}	Death
π_a	**0**	**0.34**	Autonomous infection
η	**10**	**10**	**Elasticity of substitution**
θ	1.275×10^{-3}	1.275×10^{-3}	Labor supply parameter
A	39.835	39.835	Productivity
β	$0.96^{1/52}$	$0.96^{1/52}$	Discount factor
ϕ_1	0.2	0.2	**Rel. contagiousn., sect. 1**
ϕ_2	1.8	1.8	**Rel. contagiousn., sect. 2**

Results: Key Results

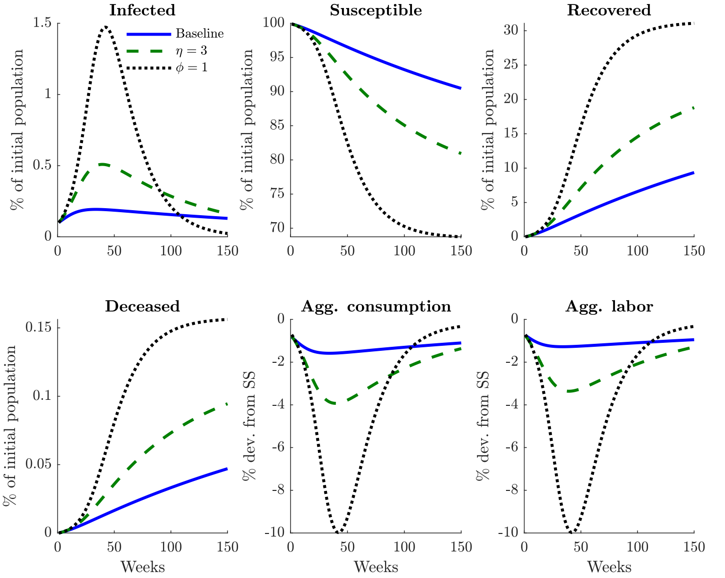




Results: Aggregate Consumption Decline

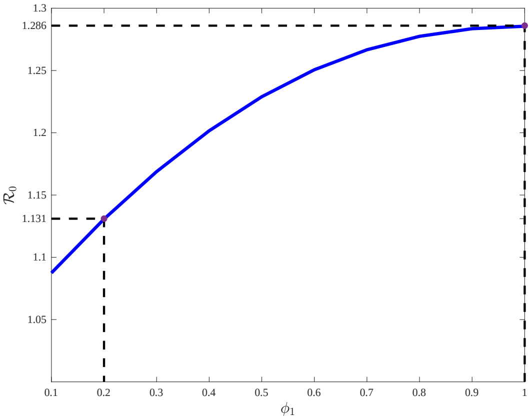


Numerical Results: Baseline Comparison

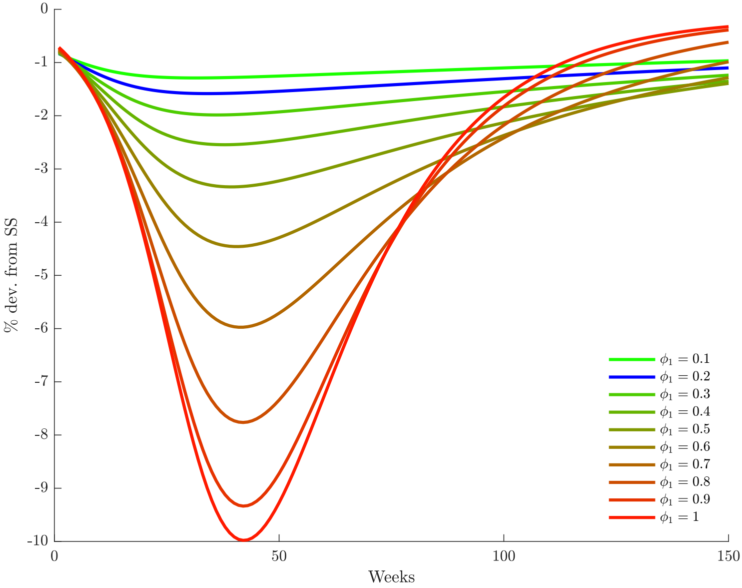


Basic Reproduction Number, $\mathcal{R}_0$

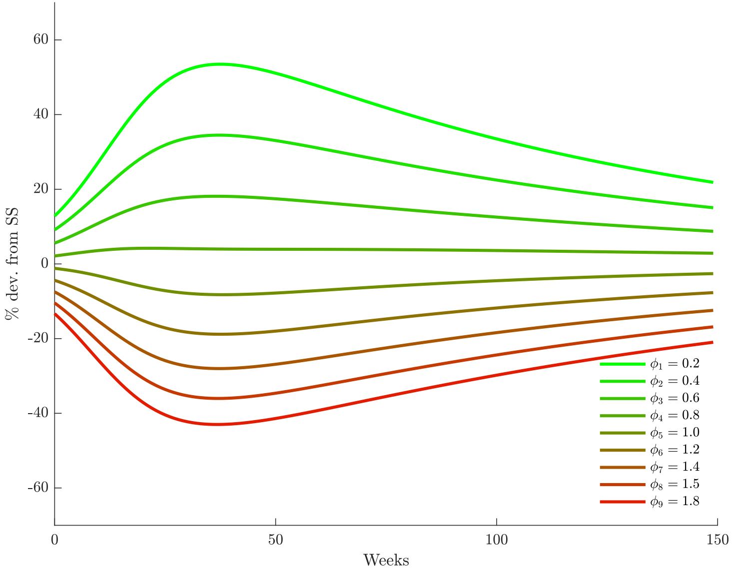
$$\mathcal{R}_0 = \sum_{t=0}^{\infty} (1 - \pi_r - \pi_d)^t \times \frac{T_0}{I_0} = \frac{T_0/I_0}{\pi_r + \pi_d}$$



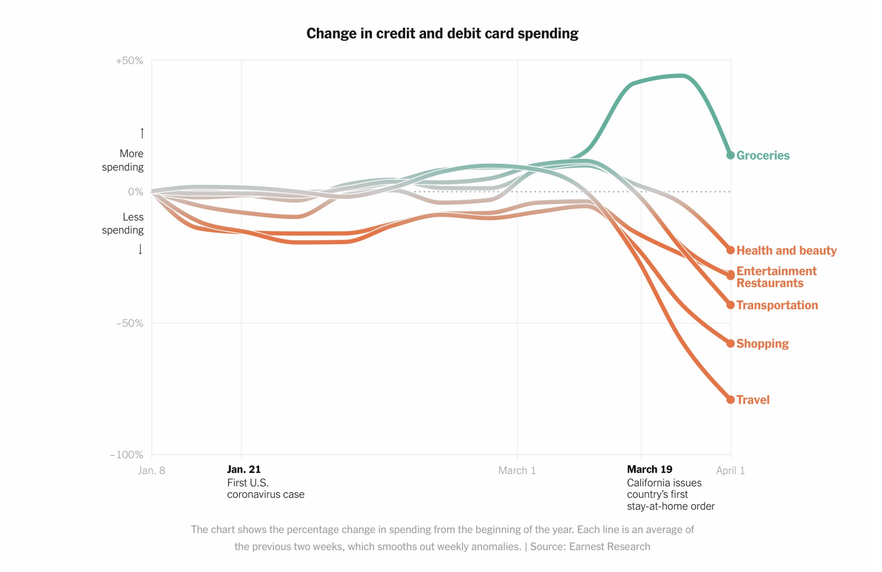
Results: Aggregate Consumption Decline, Various ϕ_1



Results: Sectoral Shifts, 9 sectors



Anecdotal Data for Sectoral Shifts: NYT 2020-04-14



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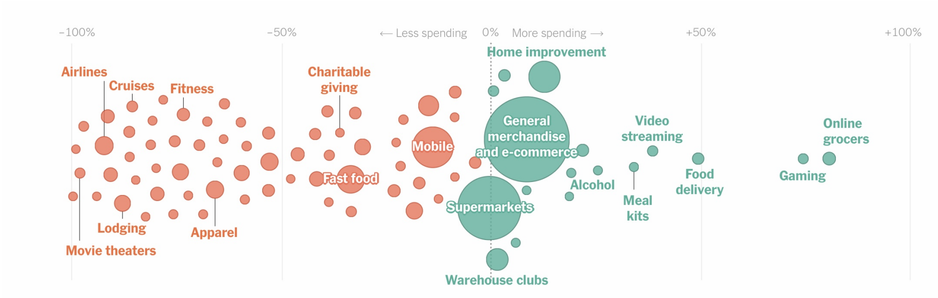
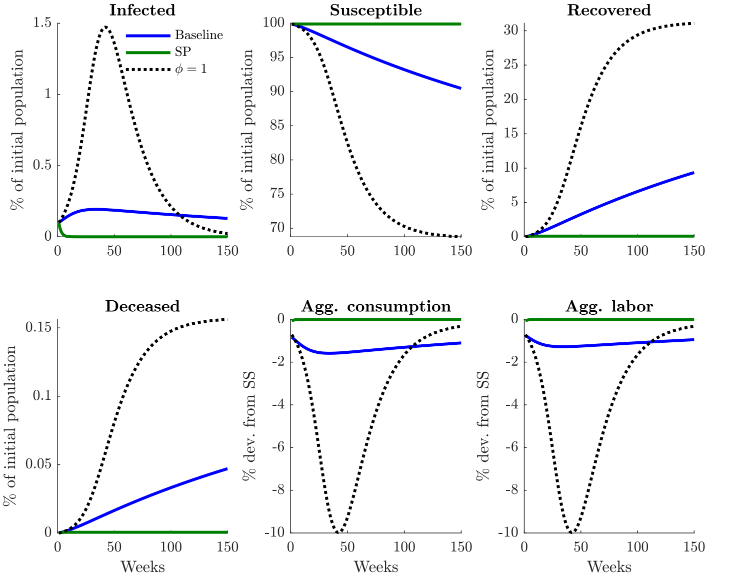


Change in spending from 2019 for the week ending April 1. Bubbles are sized by industry sales.

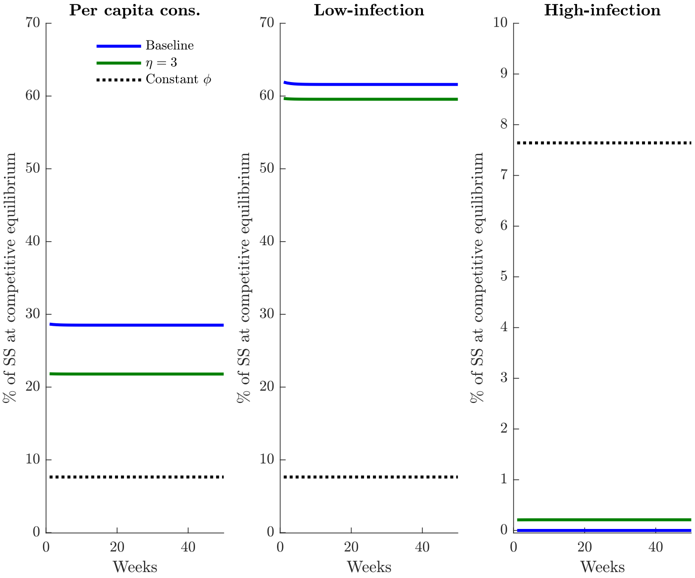
Social Planner Solution

- 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



Numerical Results: Social Planner



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 infectuousness.
  - 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!