Macroeconomic Dynamics and Reallocation in a Pandemic

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Paper in a Nutshell

- **Question we ask:**
  - COVID 19 epidemic: how much government mitigation, when to open up again?
  - Key question here: **how much will people do on their own?**
- **What we do:**
  - Starting point: Eichenbaum-Rebelo-Trabandt (2020).
  - Neoclassical growth cum SIR model.
  - Infection happens when people consume. (ERT: also when work, when interacting socially)
  - Key: **Heterogeneous consumption sectors** differ in infection risk.
  - Susceptible agents make conscious decisions. **Shift consumption** towards low-infection sectors.
  - Stylized model. Appropriate parameterization?
- **What we find:**
  - Output decline, infection rates **reduced by 80 percent** compared to homogeneous-sector economy.
  - Social planner stops even more drastic: **stops epidemic immediately**.
  - Too Panglossian?

The model: the macro part

- Living agents $j \in [0,1]$ or $j \in \{s, i, r\}$ have utility

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t^j, n_t^j)$$

where

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

and

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

- Dead agents: $U = 0$.
- Production and labor market: competitive, linear, frictionless. One unit of labor $=$ A unit of any good.
- Budget constraint:

$$\int c_{tk}^j dk = A n_t^j \quad (2)$$

- Markets clear.

The model: the SIR part

- 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.
  - Overall contagion parameters π_s, π_a.
  - Variety-specific relative contagiousness $\phi(k)$,

$$\int \phi(k)dk = 1 \tag{3}$$

  - Probability for a susceptible agent s to become infected:

$$\tau_t = \pi_s I_t \int \phi(k) c_{tk}^s c_{tk}^i dk + \pi_a I_t, \tag{4}$$

- Paper: similar mechanics in case of infection-via-workplace.
- Infection dynamics. Let T_t denote newly infected.

$$\begin{aligned} T_t &= \tau_t S_t & (5) \\ S_{t+1} &= S_t - T_t & (6) \\ I_{t+1} &= I_t + T_t - (\pi_r + \pi_d) I_t & (7) \\ R_{t+1} &= R_t + \pi_r I_t & (8) \end{aligned}$$

Analysis: Choices of Infected and Recovered Agents

$$n_t^x = \frac{1}{\sqrt{\theta}},\ c_{tk}^x \equiv c_t^x = \frac{A}{\sqrt{\theta}}$$

for $x \in \{i, r\}$.

Analysis: Choices of Susceptible Agents.

- Recall **infection constraint** (6):

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

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

$$U^s_t = u(c^s_t, n^s_t) + \beta[(1-\tau_t)U^s_{t+1} + \tau_t U^i_{t+1}] \tag{9}$$

- First-order condition wrt consumption of variety k:

$$u_1(c^s_t, n^s_t) \cdot \left(\frac{c^s_t}{c^s_{tk}}\right)^{1/\eta} = \lambda^s_{bt} + \lambda_{\tau \mathbf{t}} \pi_s \frac{A}{\sqrt{\theta}} I_t \phi(\mathbf{k}) \tag{10}$$

  where
  - λ^s_{bt} is the Lagrange multiplier on the budget constraint
  - $\lambda_{\tau \mathbf{t}}$ is the Lagrange multiplier on the **infection constraint**.

Theoretical Results: $\eta = 0$ equal to "homogeneous".

Proposition

Suppose that $\eta = 0$, i.e. that the consumption aggregation is Leontieff. In that case, the multisector economy is equivalent to a homogeneous-sector economy. Equation (6) becomes

$$\tau_t = \pi_s I_t c_t^s c_t^i + \pi_a I_t \tag{11}$$

Recall: equation (6) was

$$\tau_t = \pi_s I_t \int \phi(k) c_{tk}^s c_{tk}^i dk + \pi_a I_t,$$

Theoretical Results: $\eta \to \infty$ implies low infection.

Proposition

Suppose that $\eta \to \infty$ (perfect substitutes in the limit). Let $\underline{k} = \sup_k \{k \mid \phi(k) = \phi(0)\}$. Suppose $\underline{k} > 0$. Then $c^j_{tk;\eta} \to c^j_{tk;\infty}$ for $j \in \{s, i, r\}$, where

$$c^s_{tk;\infty} = \begin{cases} c^s_t/\underline{k} & \text{for } k < \underline{k} \\ 0 & \text{for } k > \underline{k} \end{cases} \tag{12}$$

and

$$c^j_{tk} \equiv c^j_t \text{ for } j \in \{i, r\} \tag{13}$$

Equation (6) becomes

$$\tau_t = \phi(\mathbf{0})\pi_s I_t c^s_t c^i_t + \pi_a I_t \tag{14}$$

Note: size $\underline{k}$ of low-infection sector does not matter.

Theoretical Results: $\eta = \infty$ implies a range.

Proposition

Suppose that $\eta = \infty$, i.e. that the sector-level consumption goods are perfect substitutes. Let μ_t be any function of time satisfying

$$0 \leq \mu_t \leq \bar{\mu}$$

where $\bar{\mu}$ is defined as

$$\bar{\mu} = \frac{1}{\int \frac{1}{\phi(k)} dk} \tag{15}$$

and note that it satisfies

$$\phi(0) \leq \bar{\mu} \leq 1 \tag{16}$$

Then there is an equilibrium with equation (6) replaced by

$$\tau_t = \mu_t \pi_s l_t c_t^s c_t^i + \pi_a l_t \tag{17}$$

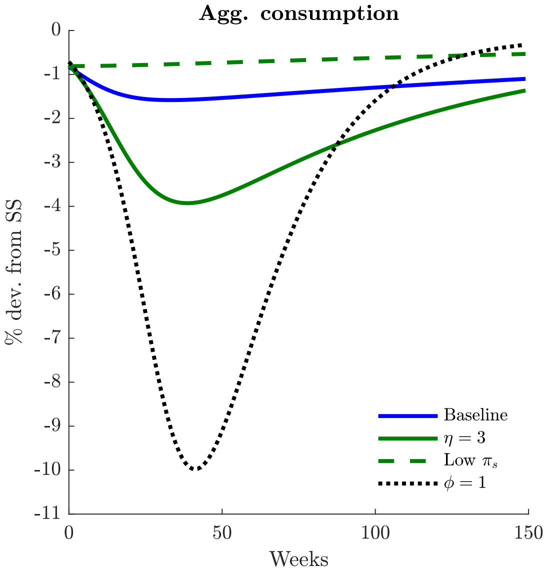
Numerical Results: Choice of Parameter Values

- Similar to Eichenbaum-Rebelo-Trabandt (2020).
- Set $\pi_a = 0$. Set π_s to get 10% cons decline in homogeneous sector case.
- Mostly two equally-sized sectors: $\phi_1 = 0.2, \phi_2 = 1.8$.
- Why? In order to investigate the mechanism.
- $\eta = 10$. Also: $\eta = 3$.
- Variations:
  - $\pi_a > 0$ to obtain 50% susceptible in the limit.
  - 9 sectors.
  - Vary η.
  - Somewhat lower π_s.

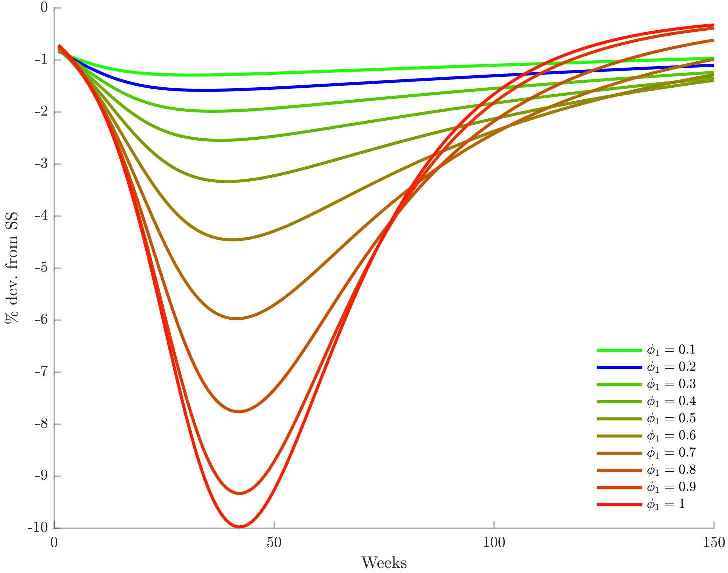
Numerical Results: Parameter Values

Parameter	$\pi_a = 0$	$\pi_a \neq 0$	**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	**infection intensity, sect. 1**
ϕ_2	1.8	1.8	**infection intensity, sect. 2**

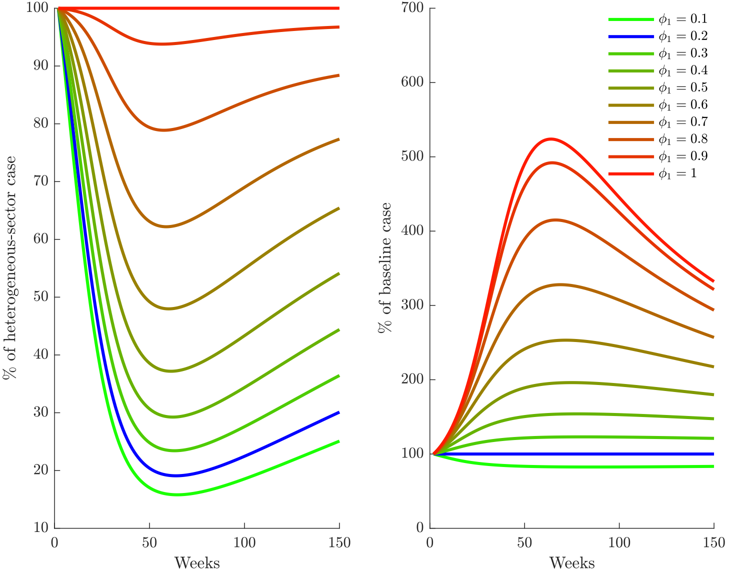
Numerical Results: Consumption Decline



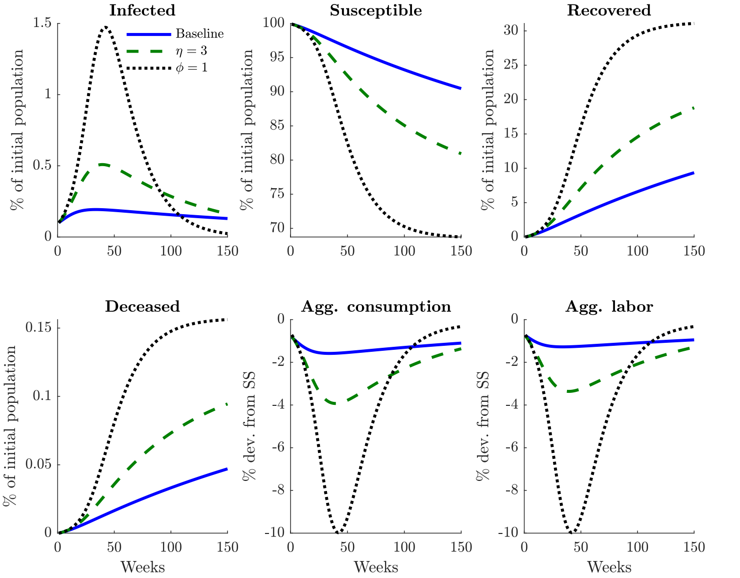
Numerical Results: Consumption Decline, various ϕ_1



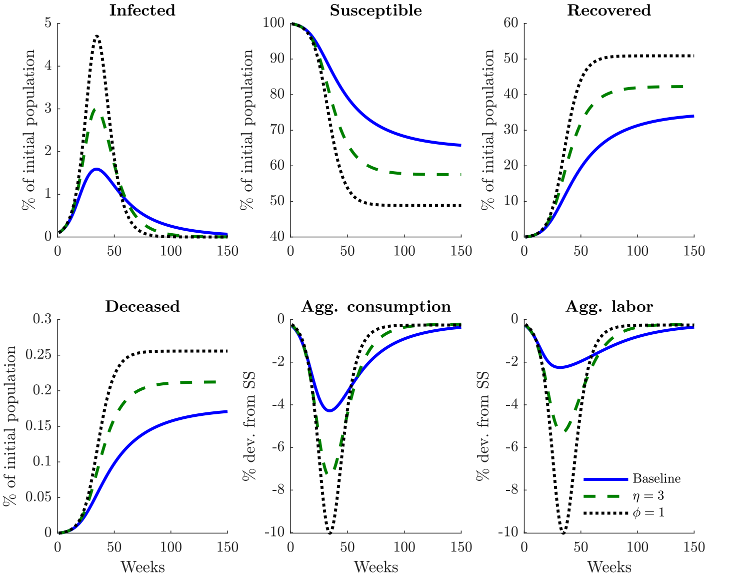
Numerical Results: Deceased, various ϕ_1, when $\pi_a = 0$.



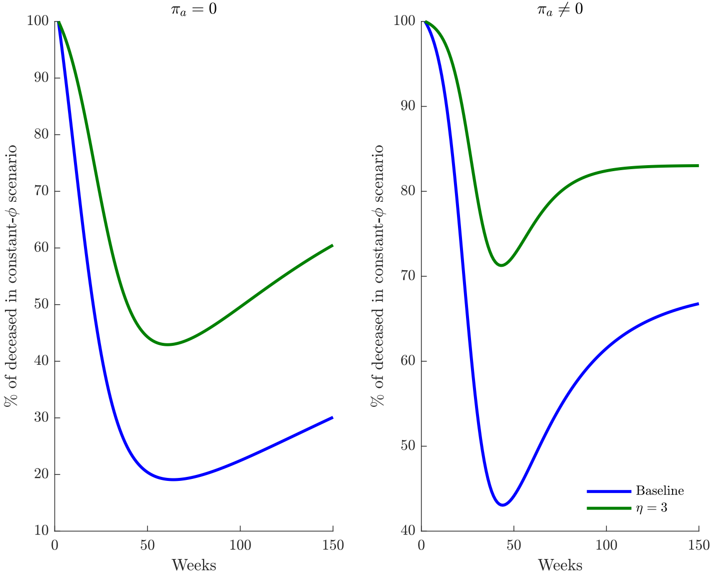
Numerical Results: Baseline Comparison



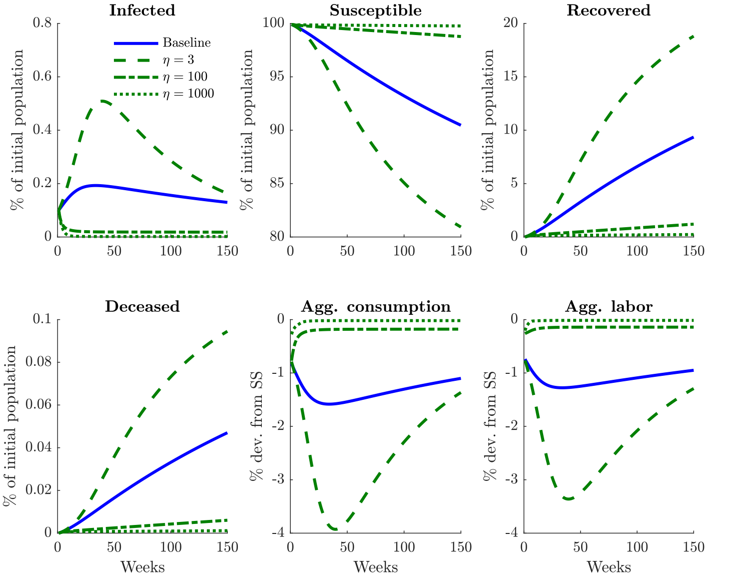
Numerical Results: with $\pi_a > 0$



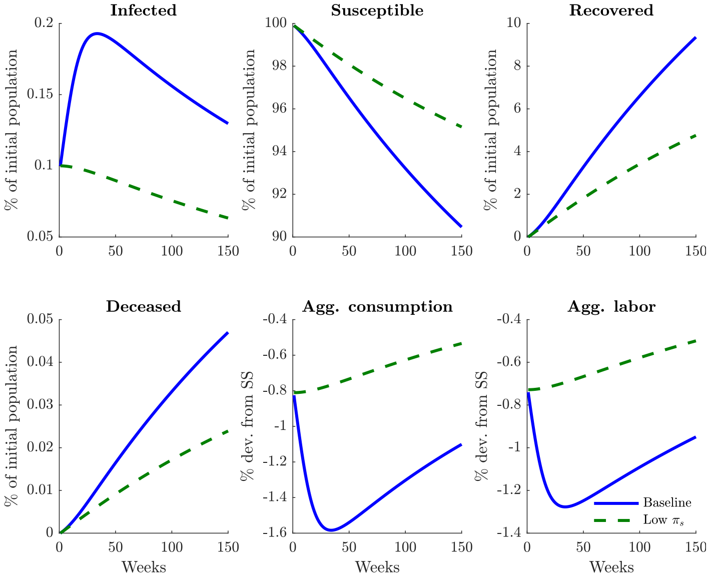
Numerical Results: Deceased: $\pi_a = 0$ vs $\pi_a > 0$



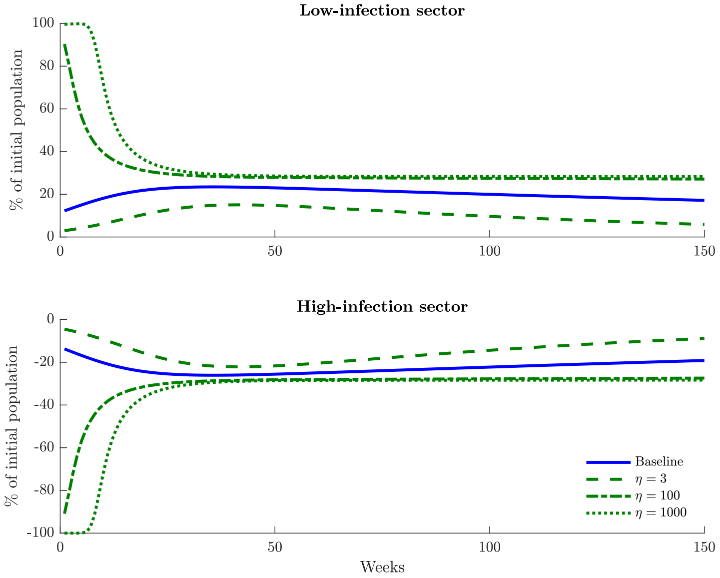
Numerical Results: Variations in η, when $\pi_a = 0$.



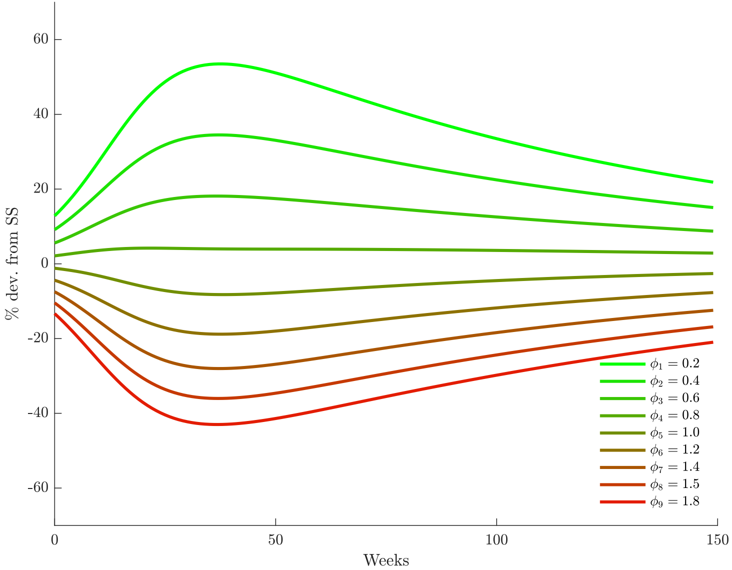
Numerical Results: Reversal for π_s to 87%



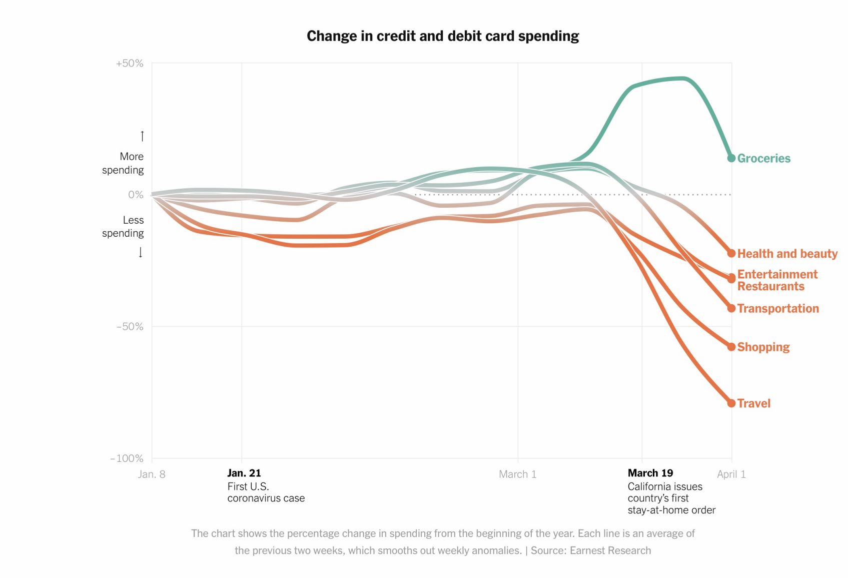
Numerical Results: Sectoral Shifts



Numerical Results: Sectoral Shifts, 9 sectors



Data: per NYT 2020-04-14, Leatherby-Gelles



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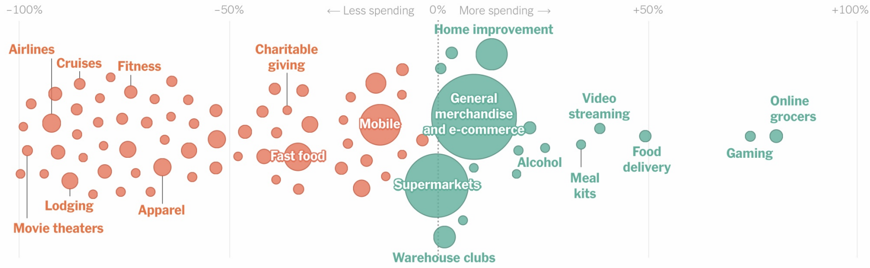
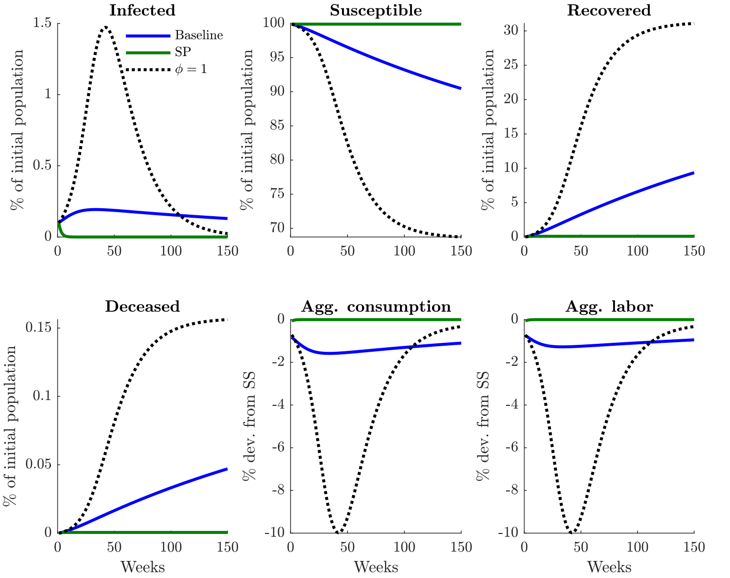


Change in spending from 2019 for the week ending April 1. Bubbles are sized by industry sales.

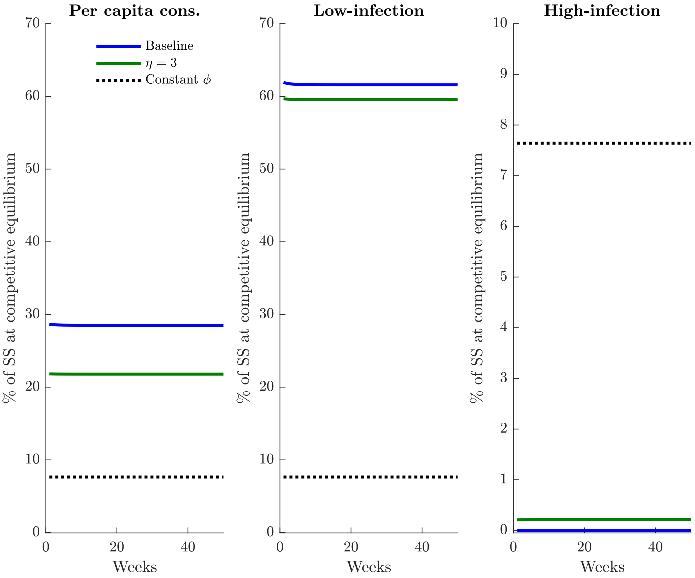
A social planner solution

- Note: agents in the model know whether they are susceptible, infected or recovered (or dead).
- So let's give the social planner the same knowledge:
  - Widespread testing.
  - Moral appeal.
- Intuition:
  - The social planner will seek to minimize the infection via infected agents ...
  - ... while still having to feed them.
- Note: no full separation is possible. Model too restrictive?

Numerical Results: Social Planner



Numerical Results: Social Planner



Conclusions

- COVID 19 epidemic: re-opening debate.
- Key issue: how much will people do on their own?
- Model: Neoclassical growth cum SIR model. Infection happens, while consuming. **Sectoral/variety choices:** different good varieties differ in their infectuousness. Susceptible agents take this into account: reduce consumption and **shift towards low-infection varieties**.
- Result: output decline and infection rates reduced by 80 percent compared to homogeneous-sector version.
- Reversal rather than flattening of curve may be possible.
- Plus: an extreme social planner result.
- Too Panglossian? At least, this analysis offers some hope!