Macroeconomic Dynamics and Reallocation in a Pandemic

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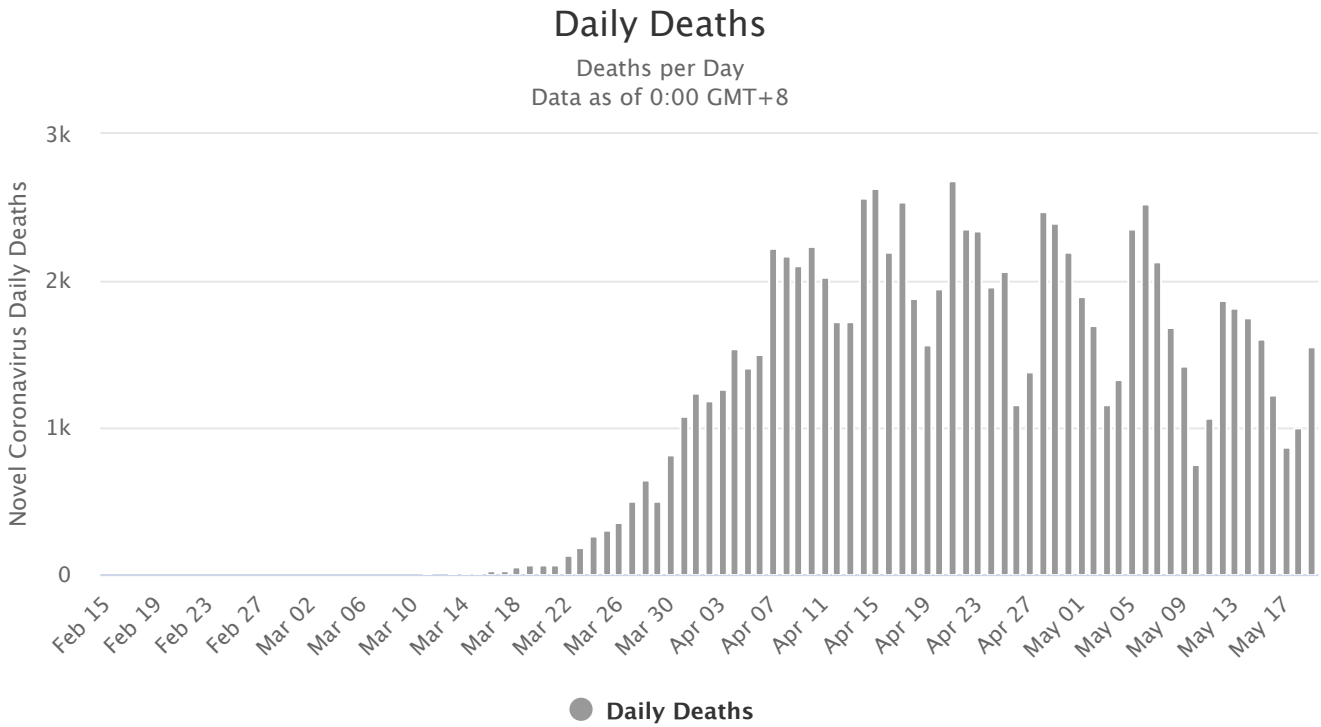
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Motivation: Health Dimension of the CoViD-19 Crisis

- Corona Virus Disease (CoViD-19) is the disease caused by the virus SARS-CoV-2, aka "novel coronavirus"
- As of May 19, 2020, more than 5.16 million cases, more than 332,000 deaths
- U.S. Daily Deaths (CSSE, Johns Hopkins University)



Motivation: Economic Dimension of CoViD-19 Crisis

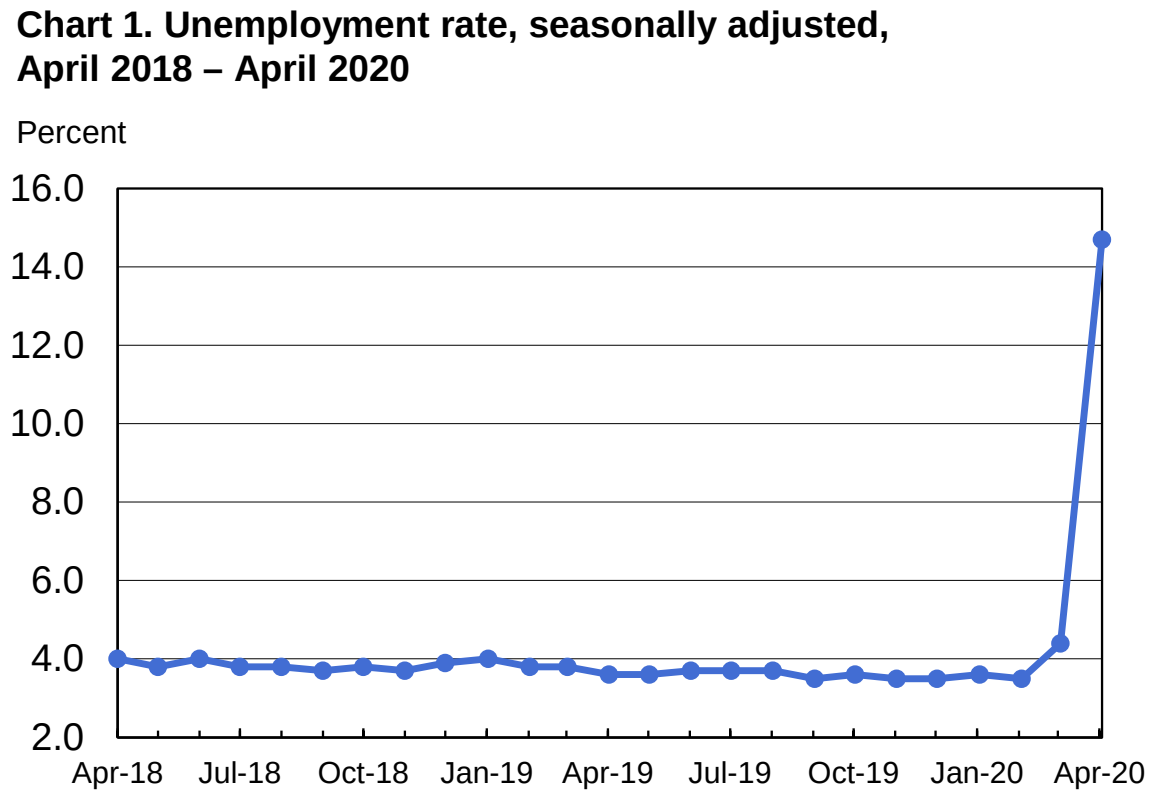


Figure: Unemployment Rate in the U.S.

- Unemployment rate 14.7% in April 2020.
- Labor force participation rate 60.2%, lowest since early 1970's.

Motivation: Economic Dimension of CoViD-19 Crisis

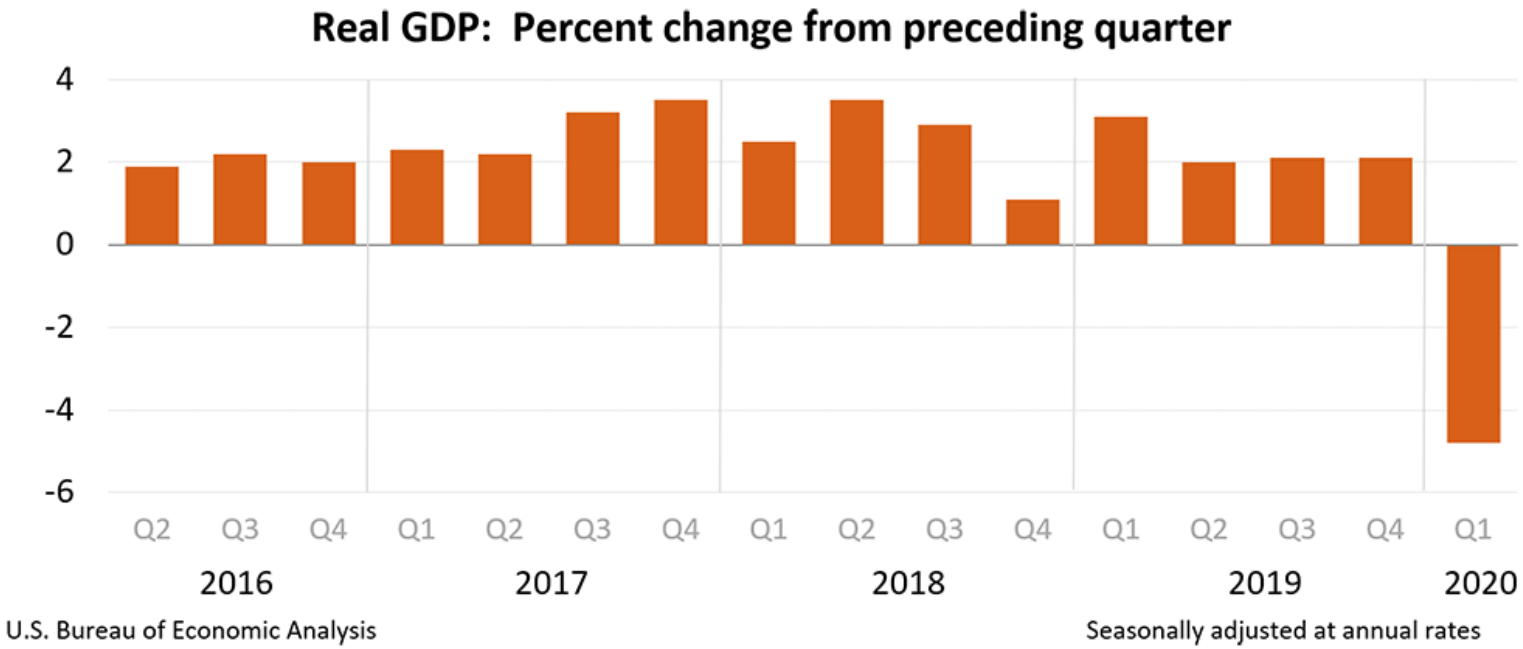


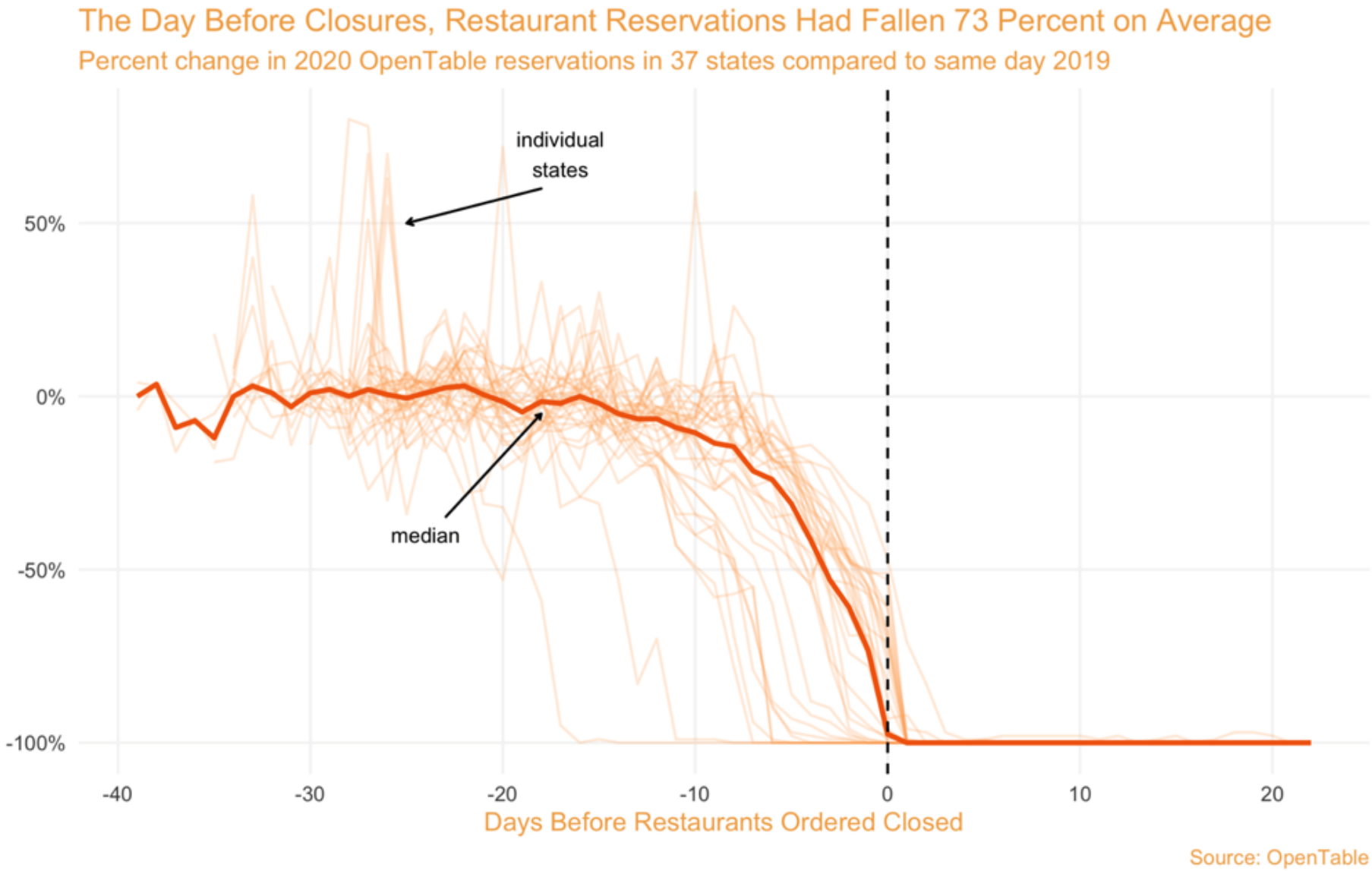
Figure: Real GDP Growth, 1st Quarter 2020

- Quarter 1, 2020 was bad.
- Quarter 2, 2020 will be ugly: -28% according to Blue Chip consensus forecast (with large standard error)

Paper in a Nutshell

- **Broad Question about COVID 19 Epidemic:**
  - Trading off **Health v/s Econ**, how drastic should lockdown be?
  - **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.
  - People get **infected when they consume**. (ERT: also when work, when interacting socially)
  - Key innovation: **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 the homogeneous-sector economy of ERT.
  - Social planner allocation drastic: **stops pandemic immediately**.
- **What does this mean?**
  - Swedish solution? Too Optimistic?

Private Response to CoViD-19



The Model: Macro Part

- Continuum of initially living agents of health types $j \in \{s, i, r\}$
- **Preferences** over differentiated (by sector k) consumption, hours:

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

where

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

and

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

- Dead agents: $U = 0$.
- **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: Epidemiological 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).
  - Sector-specific relative contagiousness $\phi(k)$,

$$\int \phi(k)dk = 1$$

  - Probability for a susceptible agent s to become infected:

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

  - (π_s, π_a) are contagion parameters.
  - $T_t = \tau_t S_t$ 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 $x \in \{i, r\}$ face no further health risks.
- Value variety of consumption if elasticity of substitution $\eta < \infty$.
- $\Rightarrow$ spread consumption evenly across sectors: $c^x_{tk} \equiv c^x_t$, $\forall t, k, x$.
- Intratemporal optimality condition and budget constraint imply **optimal labor, consumption choice** for $x \in \{i, r\}$:

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

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 $\mathbf{c^s_{tk}}$.

Theoretical Results: $\eta = 0$ equal to "Representative" Sector Case.

Proposition

Suppose that $\eta = 0$, i.e. that the consumption aggregation is Leontieff. In that case, the multisector economy is equivalent to the homogeneous-sector economy of ERT. Infection probability becomes

$$\tau_t = \pi_s I_t c_t^s c_t^i + \pi_a I_t$$

- Recall: in generall case, infection probability was

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

- If households aren't willing to substitute at all ($\eta = 0$), then

$$c_{tk}^s \equiv c_t^s.$$

Theoretical Results: $\eta \to \infty$ implies Low Infection Probability.

Proposition

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

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

and

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

Infection probability becomes

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

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

Theoretical Results: $\eta = \infty$: Continuum of equilibria.

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

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

and note that it satisfies

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

Then there is an equilibrium with infection probability given by

$$\tau_t = \mu_t \pi_s I_t c_t^s c_t^i + \pi_a I_t$$

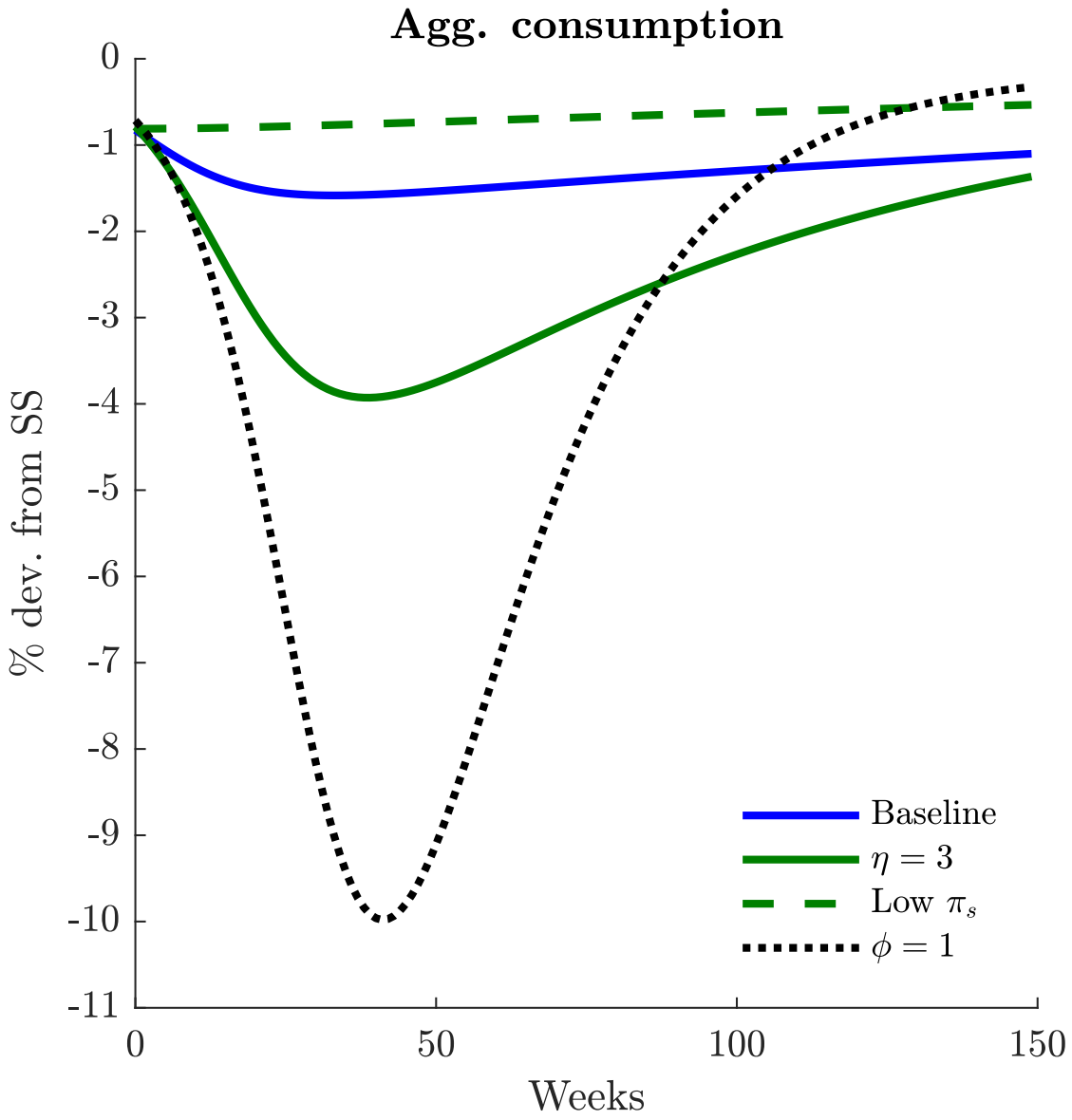
Numerical Illustration: Choice of Parameter Values

- Most parameters **borrowed from ERT**.
- Initially set autonomous infections $\pi_a = 0$.
- Mostly **two equally-sized sectors**. Clarifies the mechanisms. $\phi_1 = 0.2, \phi_2 = 1.8$.
- **Substitution elasticity** $\eta = 10$. Also: $\eta = 3$.
- Choose π_s to get 10% consumption decline in homogeneous sector case, as in ERT.
- **Robustness Analysis**:
  - $\pi_a > 0$ to obtain 50% susceptible in the limit.
  - 9 sectors.
  - Vary η.
  - Somewhat lower π_s.

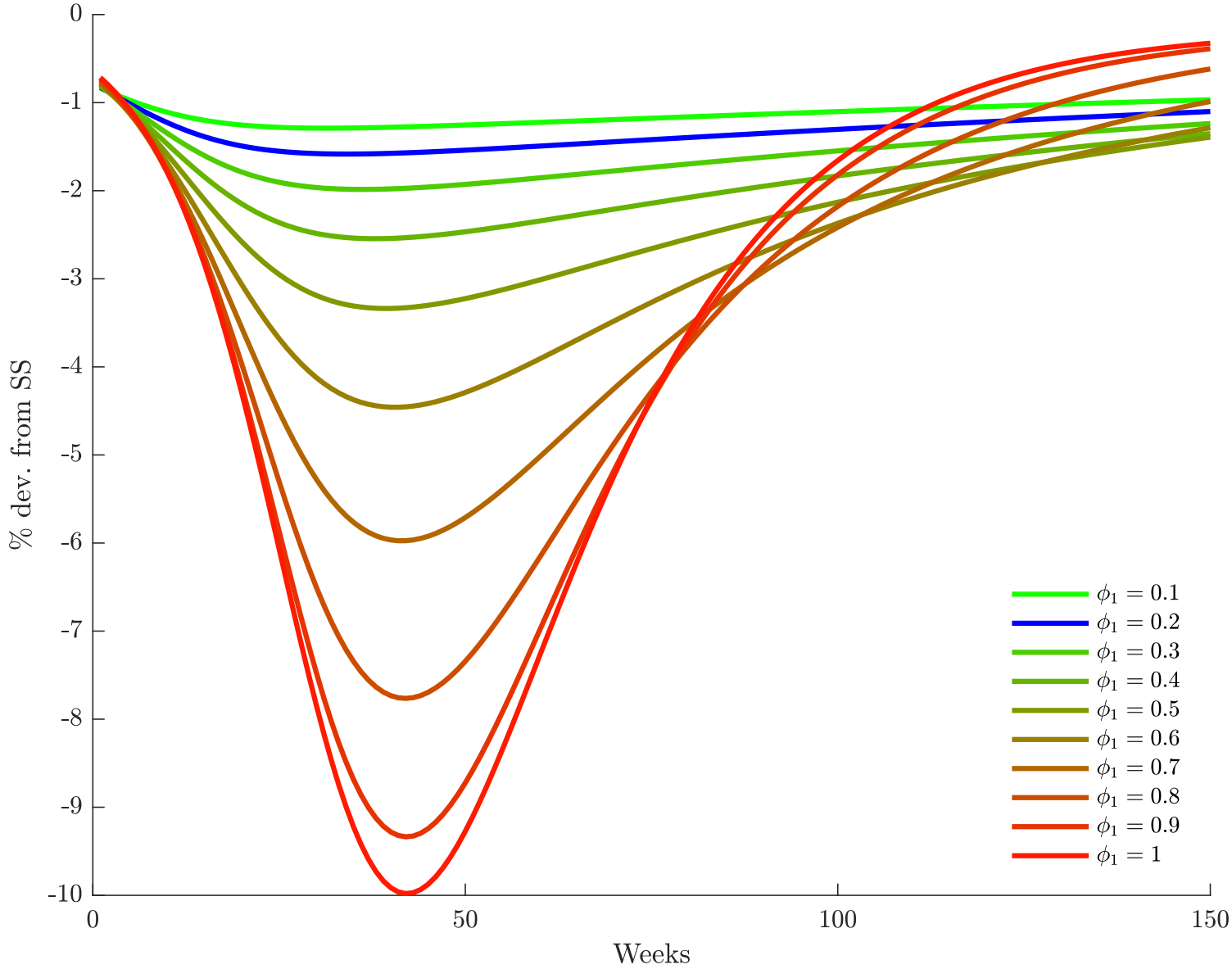
Numerical Results: Parameter Values

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	**infect. intens., sect. 1**
ϕ_2	1.8	1.8	**infect. intens., sect. 2**

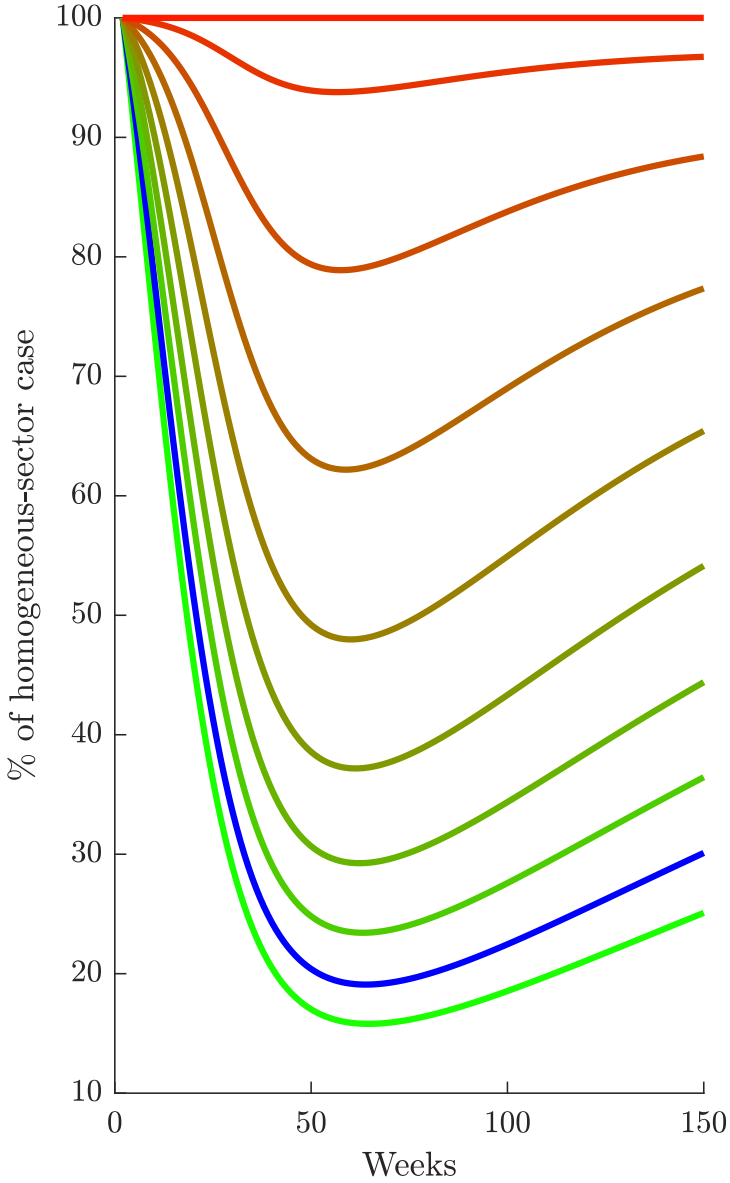
Results: Aggregate Consumption Decline

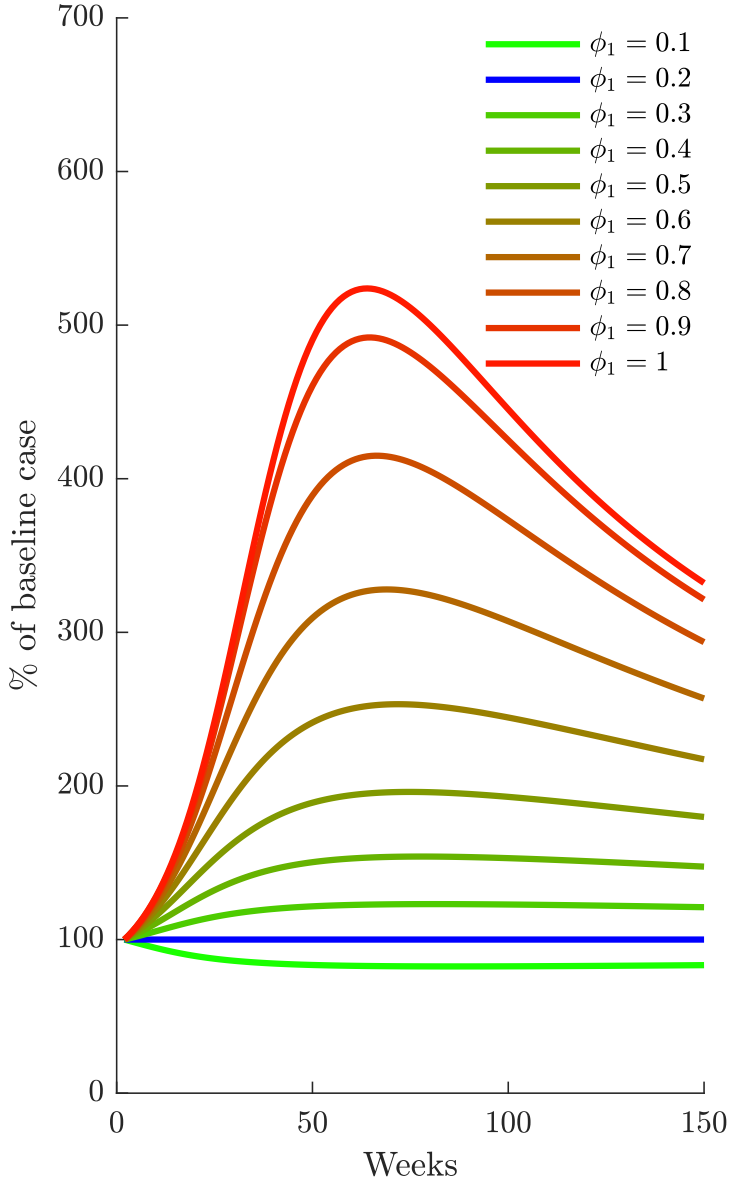


Results: Aggregate Consumption Decline, Various $\phi_1 \in [.1, 1]$

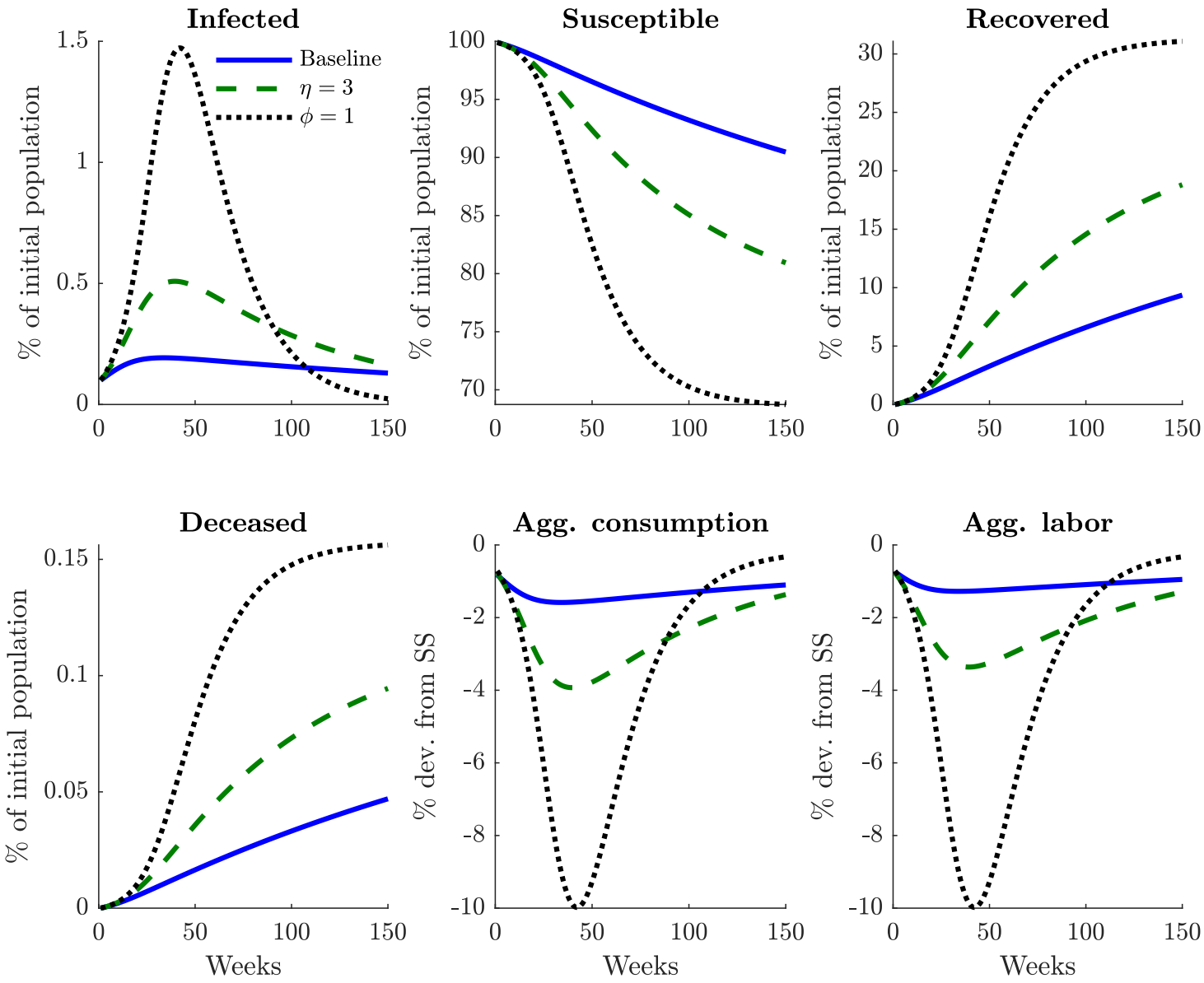


Results: Deceased, Various ϕ_1, when $\pi_a = 0$.

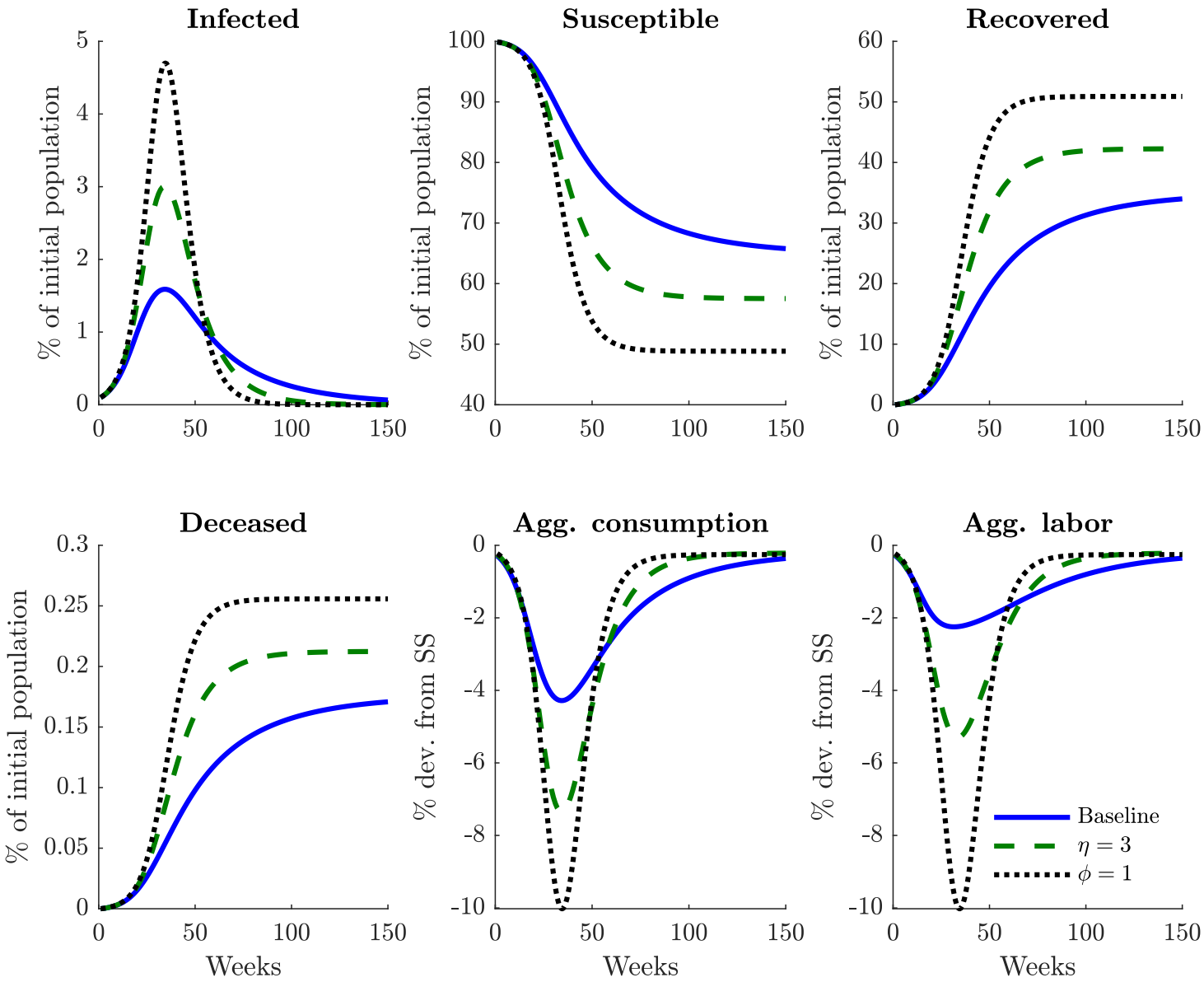




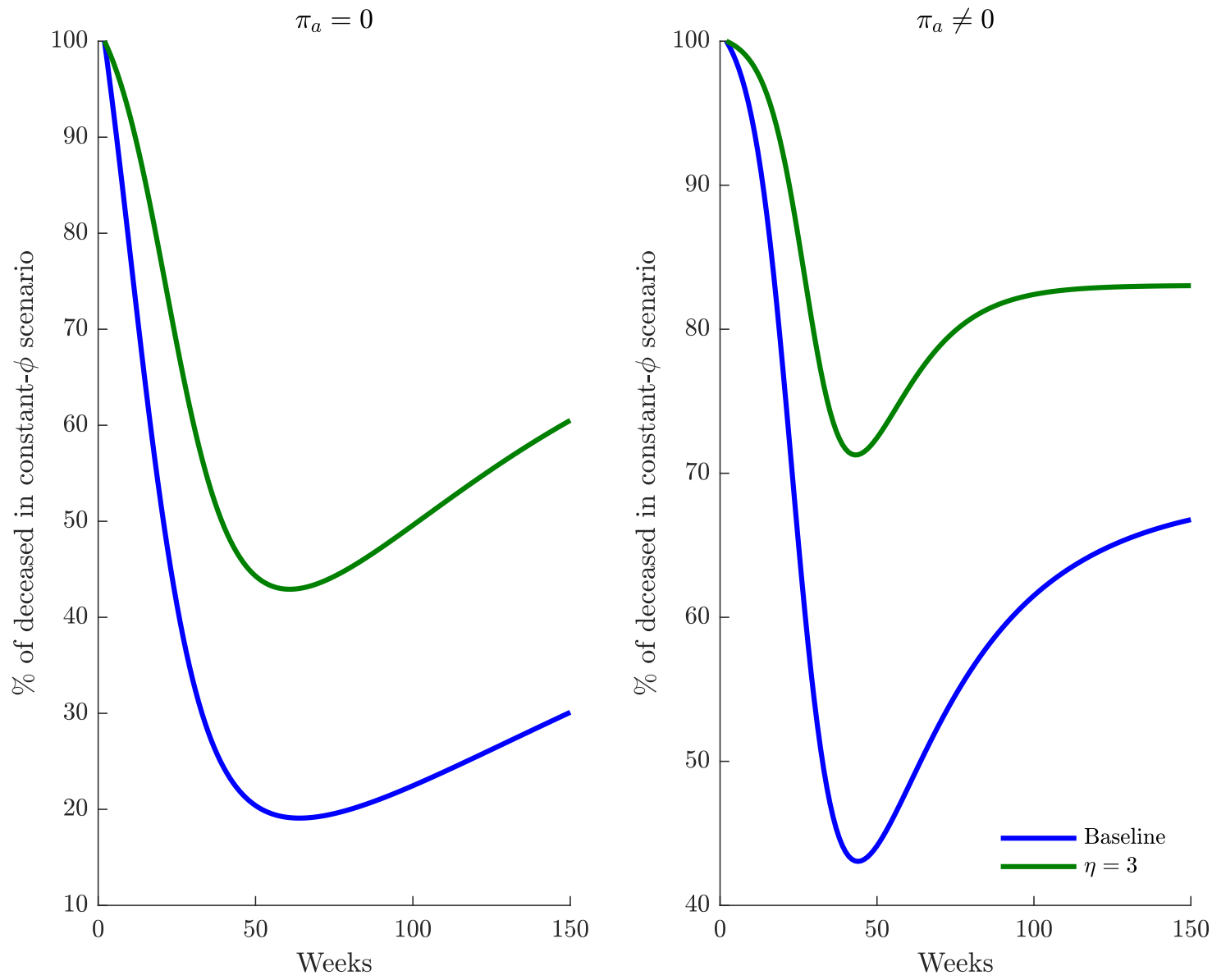
Numerical Results: Baseline Comparison



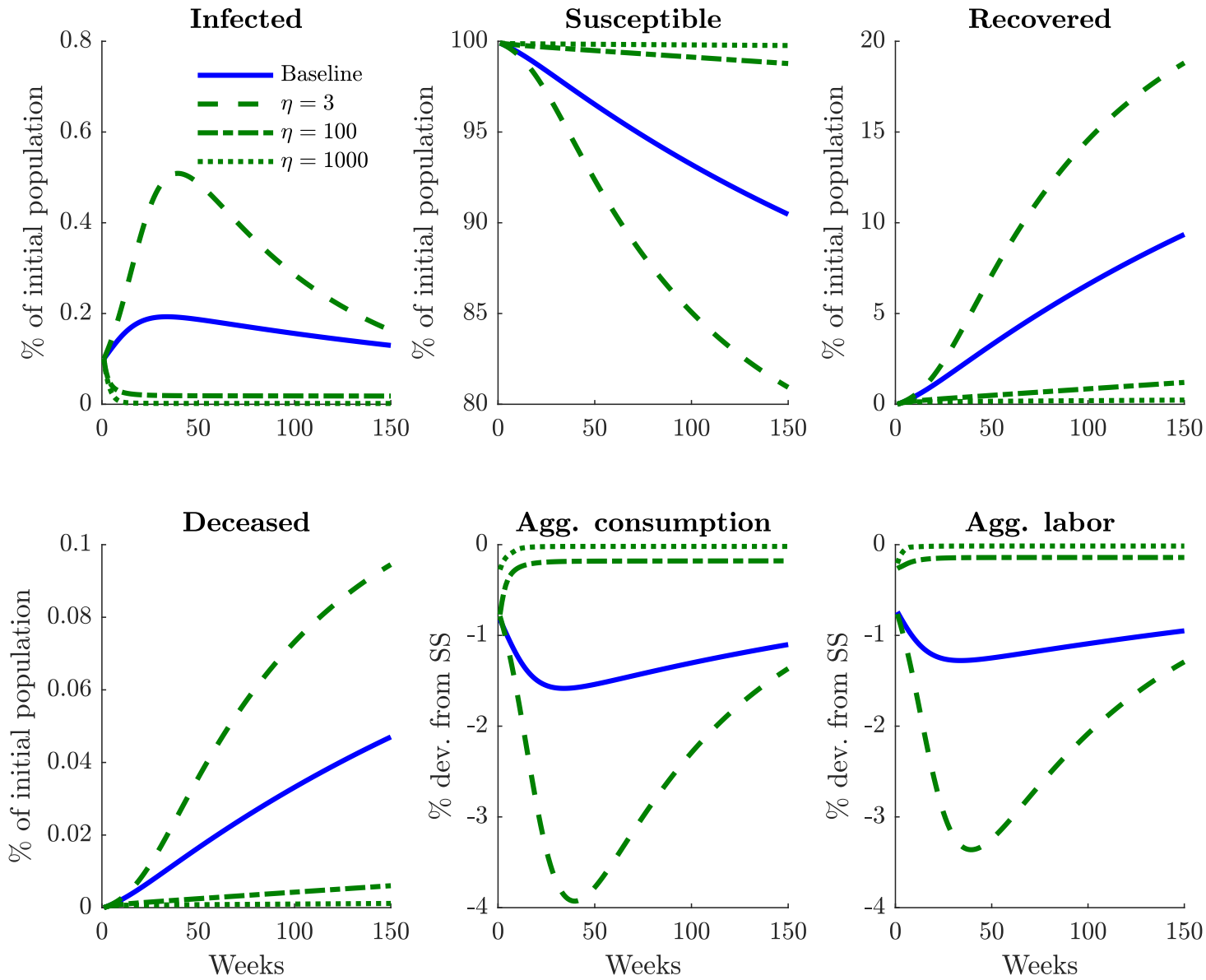
Numerical Results with Autonomous Infections, $\pi_a > 0$



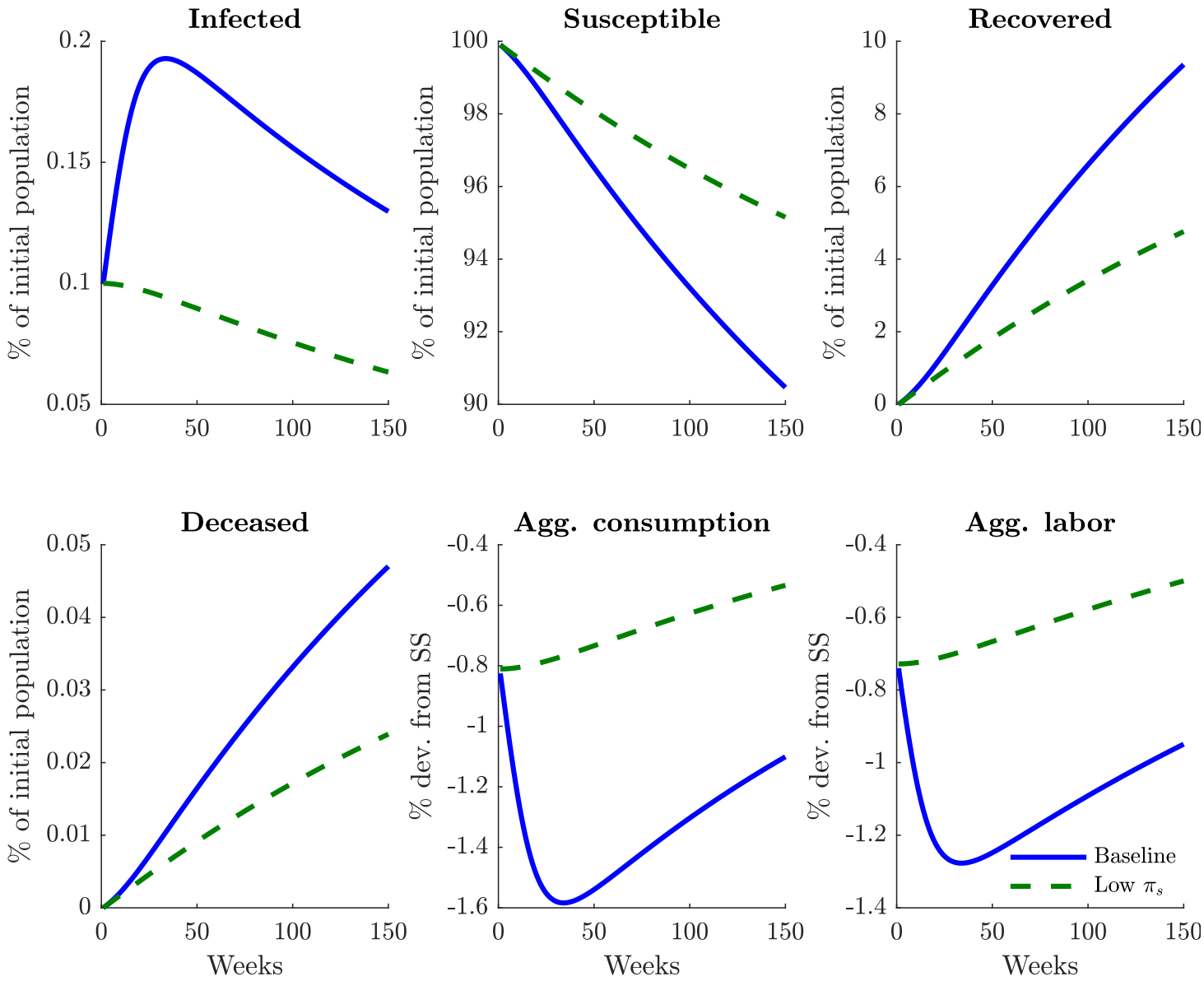
Results: Deceased: $\pi_a = 0$ vs $\pi_a > 0$



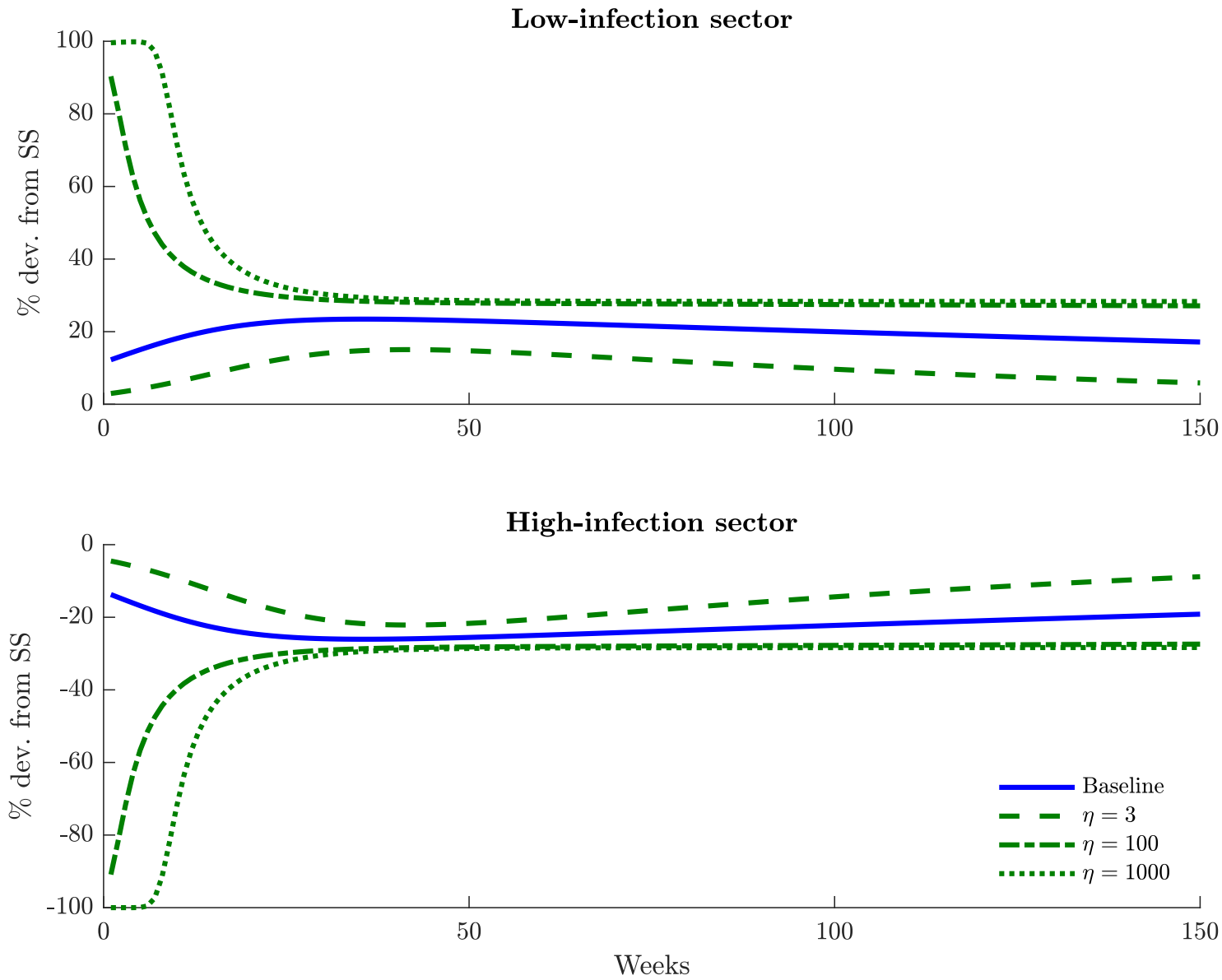
Results: Various Substitution Elasticities η ($\pi_a = 0$)



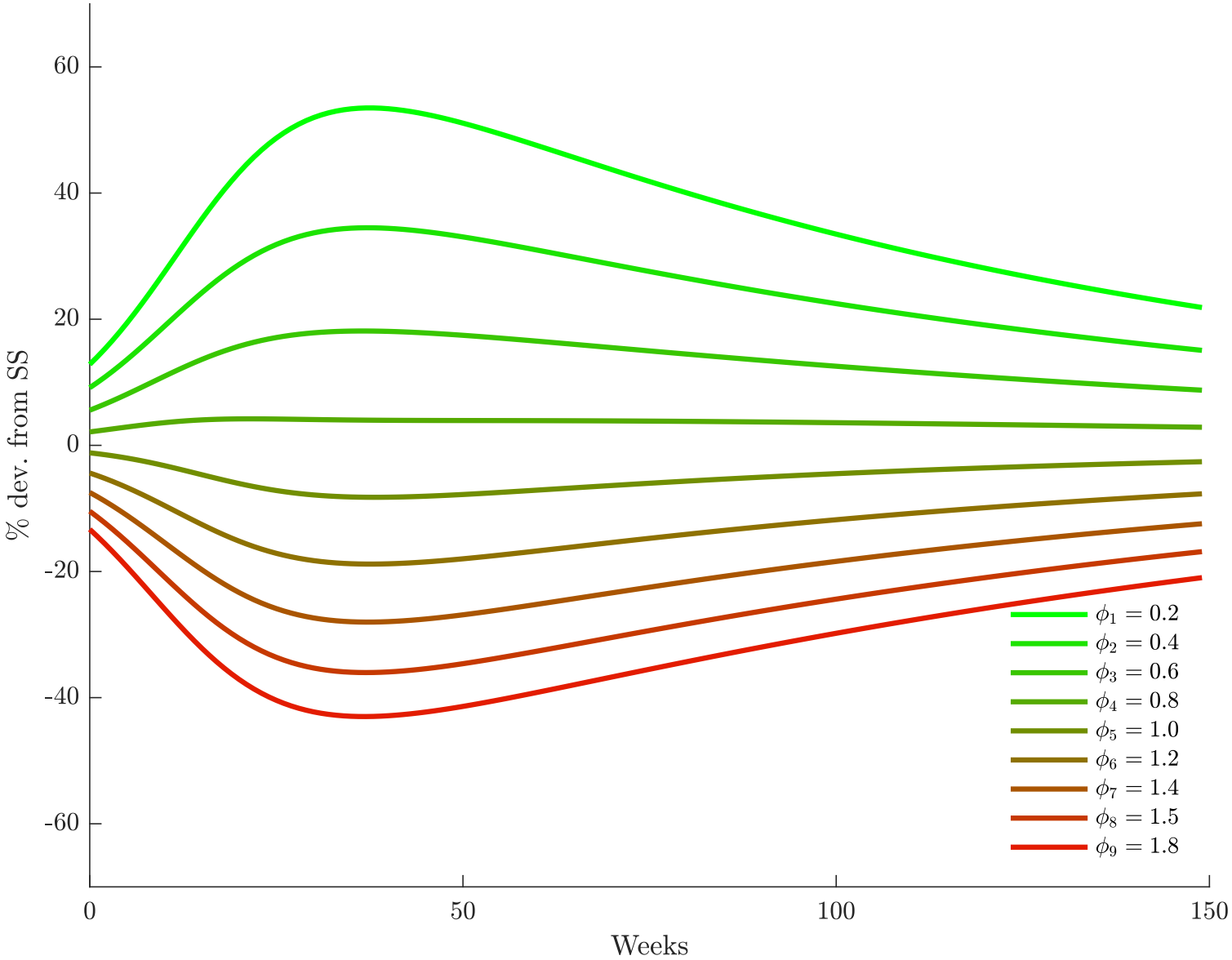
Results: Reduction of π_s to 87% (Social Distancing)



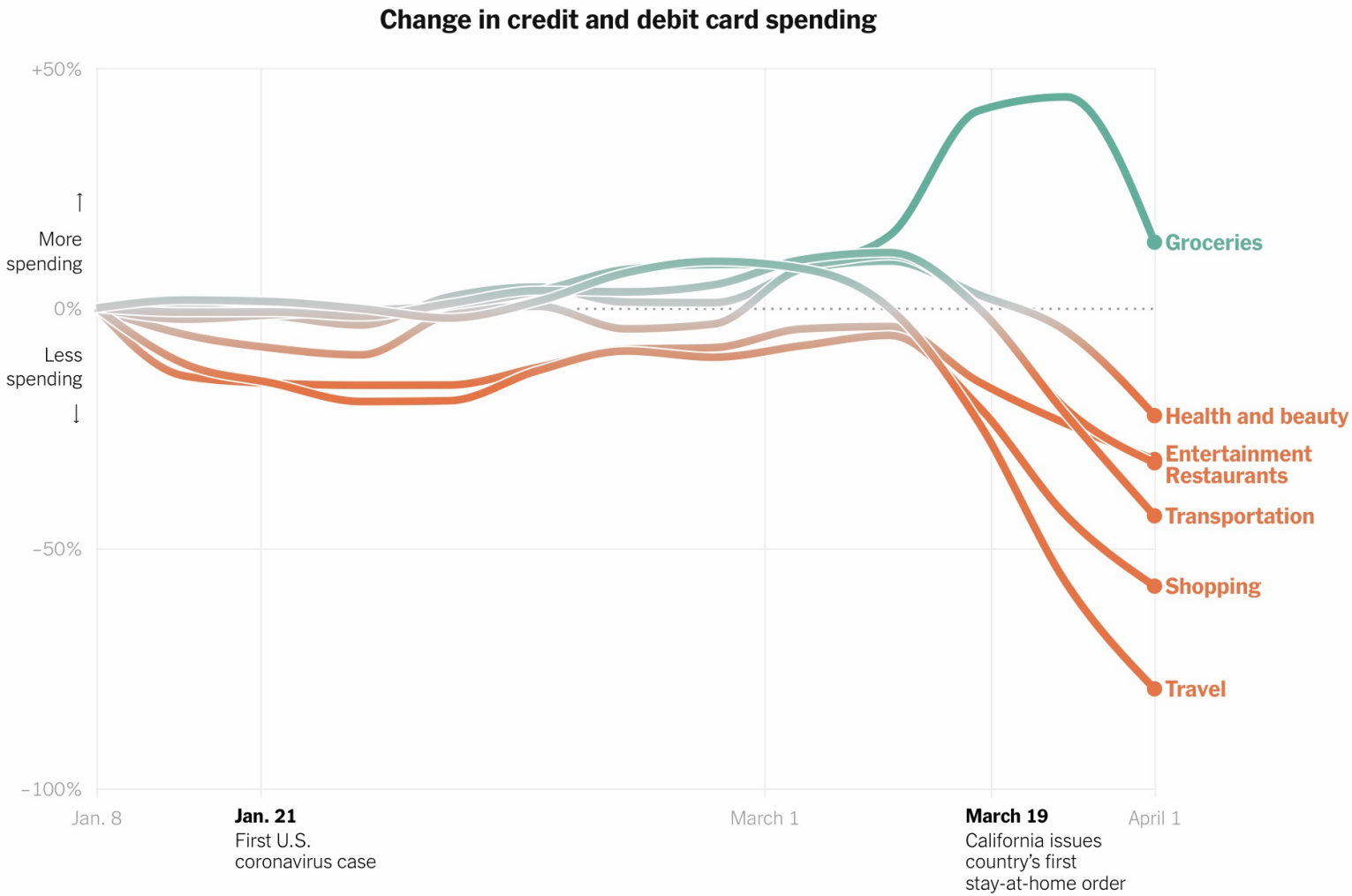
Results: Sectoral Shifts



Results: Sectoral Shifts, 9 sectors

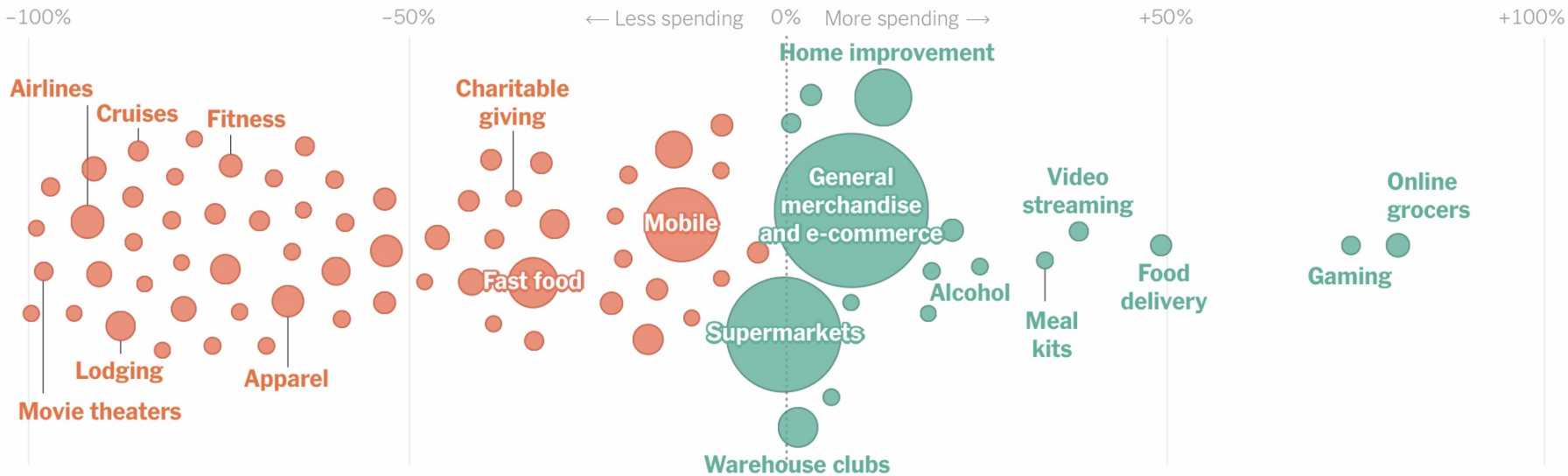


Anecdotal Data for Sectoral Shifts: NYT 2020-04-14



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

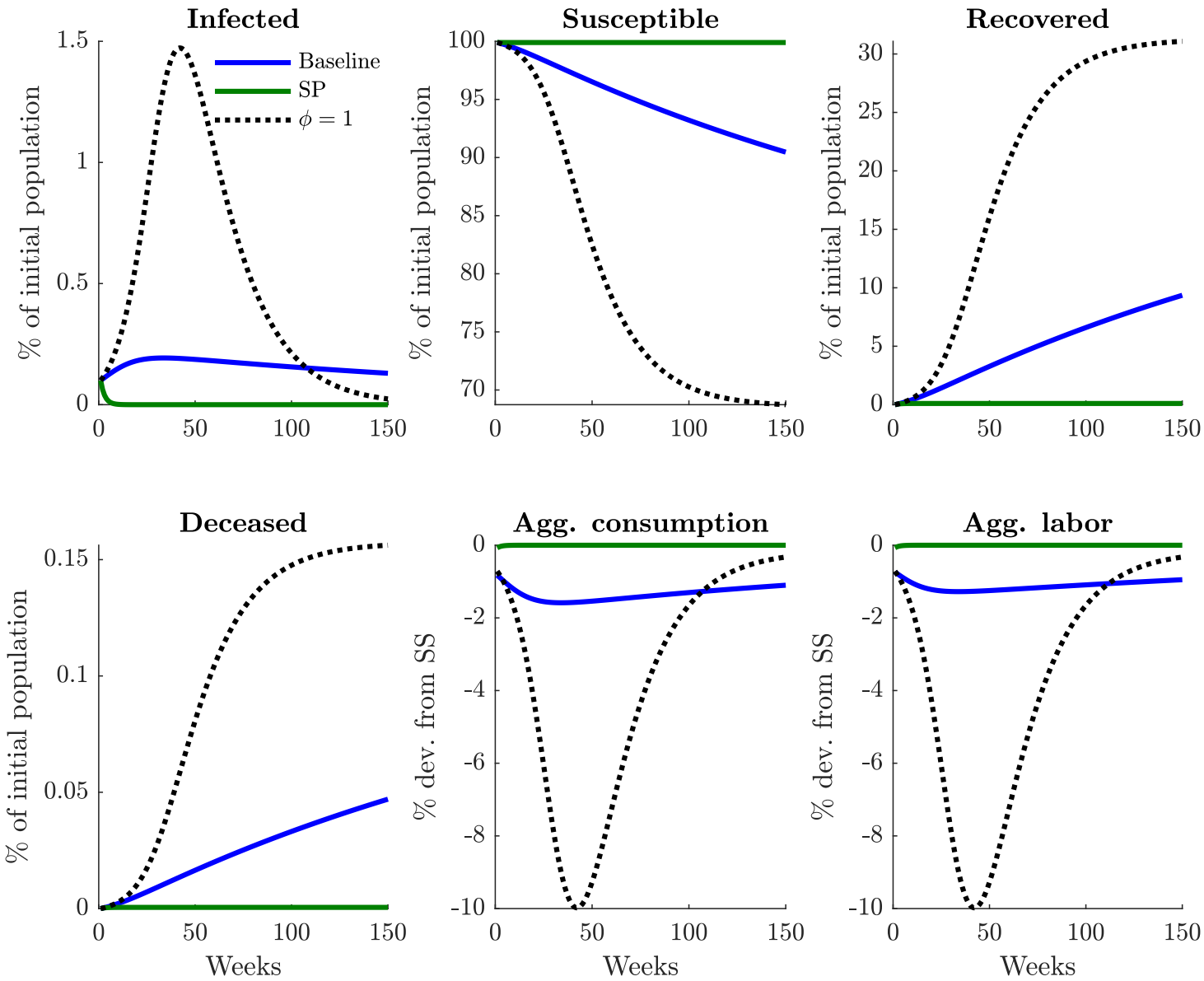


Change in spending from 2019 for the week ending April 1. Bubbles are sized by industry sales.

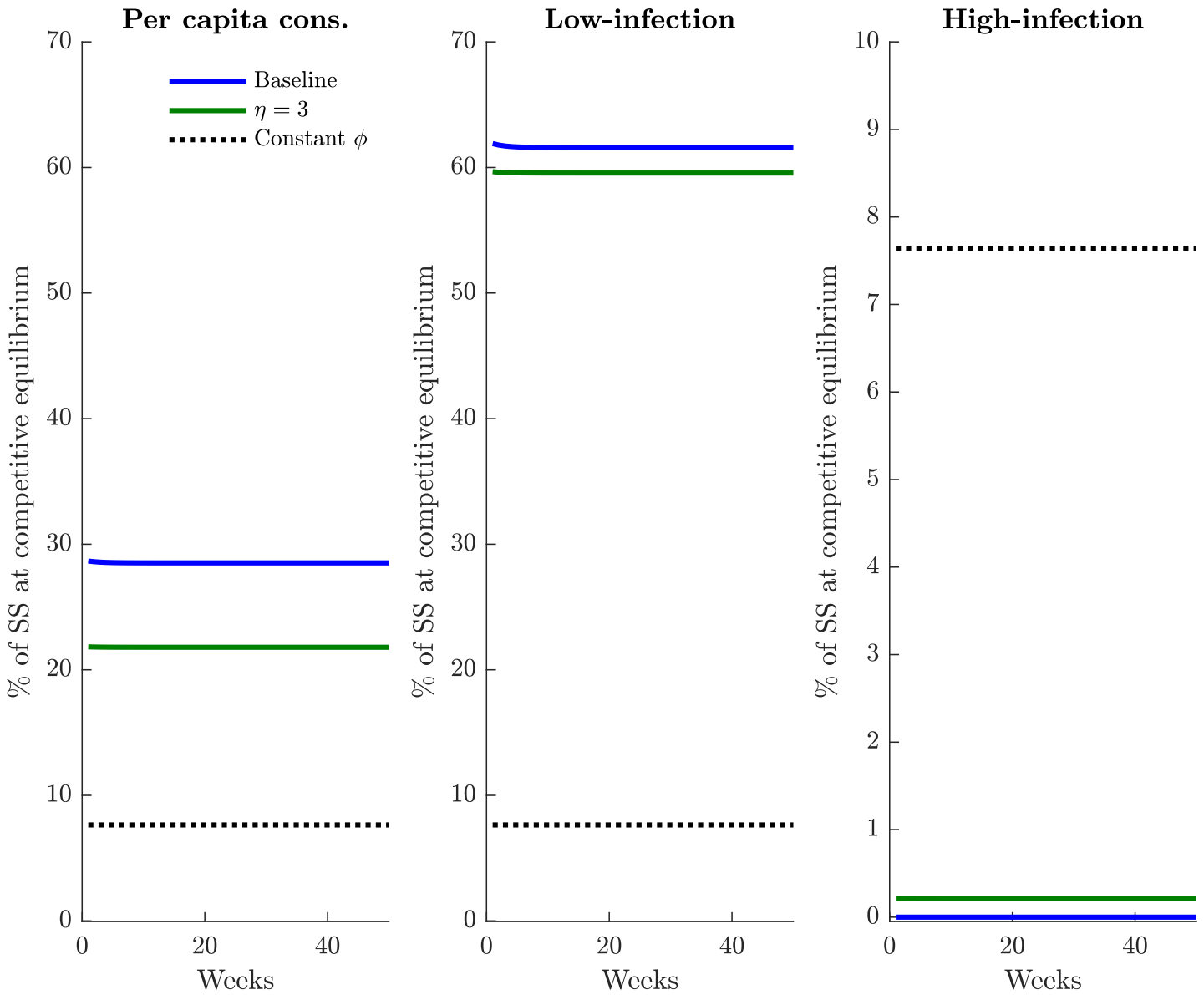
Social Planner Solution

- 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.
- Also intriguing: **Ramsey problem**: Pigouv. consumption taxes?

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 by 80 percent compared to homogeneous-sector [ERT] version.
- Even **reversal** rather than just flattening of curve is possible.
- Plus: an extreme social planner result.
- **Too Panglossian**? At least this analysis offers some hope!
- Next step: **serious quantification of reallocation mechanism**!