# The Distributional Effects of COVID-19 and Mitigation Policies

Sewon Hur

FedBrownBag

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# Introduction

- The COVID-19 pandemic is a public health and economic crisis, with large aggregate and distributional consequences
  - old individuals face higher fatality risk
  - young individuals face worse labor market outcomes
    - + low-wage workers are less likely to be able to work from home
    - + low-wealth workers lack the resources to weather prolonged time away from work

- This paper develops a quantitative heterogeneous-agent life-cycle economic-epidemiology model to analyze the distributional effects of the pandemic and to study various mitigation policies

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- This paper develops a quantitative heterogeneous-agent life-cycle economic-epidemiology model to analyze the distributional effects of the pandemic and to study various mitigation policies

# Preview of findings

- In the absence of mitigation, young workers engage in too much economic activity, relative to the social optimum
  - especially true for young low-wage/wealth workers
  - leading to higher infection rates and deaths in the aggregate
- Two budget-neutral mitigation policies
- No trade-off: both policies save lives and are welfare improving
- Optimal policies involve

# Preview of findings

- In the absence of mitigation, young workers engage in too much economic activity, relative to the social optimum
- Two budget-neutral mitigation policies
  - subsidy-and-tax policy that subsidizes reduced work, funded by a tax on consumption
  - lockdown policy that imposes a cap on outside work hours
- No trade-off: both policies save lives and are welfare improving
- Optimal policies involve

# Preview of findings

- In the absence of mitigation, young workers engage in too much economic activity, relative to the social optimum
- Two budget-neutral mitigation policies
- No trade-off: both policies save lives and are welfare improving
  - lockdown benefits old individuals at the expense of young low-wage workers
  - subsidy-and-tax benefits old and middle-age individuals and young low-wage workers, while keeping all other individuals close to welfare-neutral
- Optimal policies involve

# Preview of findings

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- Two budget-neutral mitigation policies
- No trade-off: both policies save lives and are welfare improving
- Optimal policies involve
  - longer duration subsidies (16–18 months)
  - subsidy amount depends on welfare criterion (\$450–\$900)
  - no lockdown

# Related literature

- Heterogeneous-agent overlapping-generations model: Conesa et al. (2009), Favilukis (2017), Heathcote et al. (2010), many others
- Income fluctuations and incomplete markets
- SIR model with economics
- Empirical papers that study the heterogeneous effects of the pandemic and various mitigation policies

# Related literature

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- Income fluctuations and incomplete markets: Aiyagari (1994), Bewley (1986), Huggett (1993), Imrohorouglu (1989), many others
- SIR model with economics
- Empirical papers that study the heterogeneous effects of the pandemic and various mitigation policies

# Related literature

- Heterogeneous-agent overlapping-generations model
- Income fluctuations and incomplete markets
- SIR model with economics: Alvarez et al. (2020), Argente et al. (2020), Atkeson (2020), Aum et al. (2020), Bairoliya and Imrohoroglu (2020), Berger et al. (2020), Birinci et al. (2020), Bognanni et al. (2020), Chari et al. (2020), Chudik et al. (2020), Eichenbaum et al. (2020), Farboodi et al. (2020), Garibaldi et al. (2020), Glover et al. (2020), Jones et al. (2020), Kapicka and Rupert (2020), Kaplan et al. (2020), Krueger et al. (2020), Piguillem and Shi (2020), many others
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- Heterogeneous-agent overlapping-generations model
- Income fluctuations and incomplete markets
- SIR model with economics
- Empirical papers that study the heterogeneous effects of the pandemic and various mitigation policies: Adams-Prassl et al. (2020), Alon et al. (2020a,b), Alstadsæter et al. (2020), Bertocchi and Dimico (2020), Bick et al. (2020), Chetty et al. (2020), Osotimehin and Popov (2020), Wozniak (2020 et al. (2020), and many others

# Model

# Features of model

- Stochastic aging
- Income fluctuations + borrowing constraints + incomplete markets $\longrightarrow$ precautionary savings
- Endogenous labor supply with option to work from home
- Economic-Epidemiology model
  (Economic activities $\longleftrightarrow$ Virus transmission)
- Hospital capacity constraints

# Demographics

- Individuals of age denoted by $j \in J \equiv \{1, 2, .., \overline{J}\}$
- Stochastic aging
  - $\psi_j$: probability of transitioning from age $j$ to $j + 1$
- Retirement at $j = J^R$
- Health status $h \in \{S, I, R, D\}$
- Period utility function

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- Period utility function

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- Period utility function

$$u(c, \ell, h) = \frac{c^{1-\sigma}}{1-\sigma} - \varphi \frac{\ell^{1+\nu}}{1+\nu} + \bar{u} + \hat{u}_h$$

  - $c$: consumption
  - $\ell$: labor supply
  - $\bar{u}, \hat{u}_h$: flow value of life, health

# Epidemiological block

- Build on widely used SIR model
- Susceptible individuals get infected with probability $\pi_{It}$, which depends on individual consumption and outside labor $(c, \ell^o)$ and the measure of infected individuals $(\mu_{It})$ and their consumption and outside labor $(C_{It}, L^o_{It})$

$$\pi_{It}(c, \ell^o) = \beta_c c C_{It} + \beta_\ell \ell^o L^o_{It} + \beta_e \mu_{It}$$

- Infected individuals exit infection with probability $\pi_X$
- Recovered individuals are assumed to be immune
- Let $\Pi_{jhh't}(c, \ell^o)$ denote the transition matrix

# Epidemiological block

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- Susceptible individuals get infected with probability $\pi_{It}$, which depends on individual consumption and outside labor $(c, \ell^o)$ and the measure of infected individuals $(\mu_{It})$ and their consumption and outside labor $(C_{It}, L^o_{It})$
- Infected individuals exit infection with probability $\pi_X$, then
  - recover with prob. $1 - \delta_j(\mu_{It})$
  - die with prob. $\delta_j(\mu_{It})$
- Recovered individuals are assumed to be immune
- Let $\Pi_{jhh't}(c, \ell^o)$ denote the transition matrix

# Labor income

- Each period, workers receive idiosyncratic productivity shocks $\varepsilon \in E$, which follows a Markov process, with transition matrix $\Gamma$
- Their labor income is given by $w_t \eta_{jh} \varepsilon \ell$, where
  - $w_t$: efficiency wage
  - $\eta_{jh}$: age-profile of efficiency units (depends on health)
  - $\ell$: hours worked
- A fraction $\bar{\theta}_j(\varepsilon)$ of labor can be done at home
- Retirees receive a fixed income of $s$ each period
  - can easily depend on lifetime earnings as in Hur (2018)

# Retiree's problem

- Retirees with age $j \geq J^R$, wealth $k$, and health $h$ choose consumption $c$ and savings $k'$ to solve:

$$
\begin{aligned}
V_{jt}(k,h) = \max_{c,k' \geq 0} \;& u(c,0,h) \\
& + \beta\psi_j \sum_{h' \in H} \Pi_{jhh't}(c,0) V_{j+1,t+1}(k',h') \\
& + \beta(1-\psi_j) \sum_{h' \in H} \Pi_{jhh't}(c,0) V_{j,t+1}(k',h') \\
\text{s.t.} \;\; & (1+\tau_{ct})c + k' \leq s + k(1+r_t)
\end{aligned}
$$

  - $V_{\bar{J}+1} = 0$
  - $\tau_{ct}$: consumption tax
  - $r_t$: net return to capital

# Worker's problem

- Workers with age $j < J^R$, wealth $k$, productivity $\varepsilon$, and health $h$ choose consumption $c$, labor $\ell$, outside labor $\ell^o$, and savings $k'$ to solve:

$$
\begin{aligned}
v_{jt}(k,\varepsilon,h) = \max_{c,\ell,\ell^o,k' \geq 0} \quad & u(c,\ell,h) + \beta \sum_{z' \in Z} \sum_{h' \in H} \Gamma_{\varepsilon,\varepsilon'} \Pi_{jhh't}(c,\ell^o) \\
& \times \begin{bmatrix} \psi_j v_{j+1,t+1}(k',z',h') \\ + (1-\psi_j) v_{j,t+1}(k',z',h') \end{bmatrix} \\
\text{s.t.} \quad & (1+\tau_{ct})c + k' \leq w_t \eta_{jh} (1-\tau_{\ell t}) \varepsilon \ell + k(1+r_t) \\
& \left(1 - \bar{\theta}_j(\varepsilon)\right) \ell \leq \ell^o \leq \ell
\end{aligned}
$$

  - Let $v_{jt}(k,\varepsilon,h) = V_{jt}(k,h)$ for $j \geq J^R$
  - $\tau_{\ell t}$: labor income tax

# Production

- A representative firm solves

$$\max L_f^{1-\alpha} K_f^{\alpha} - w_t L_f - (r_t + \delta) K_f$$

  where $L_f$ are effective units of labor demanded

- Optimality conditions:

$$w_t = (1-\alpha)\left(\frac{K_f}{L_f}\right)^{\alpha}$$

$$r_t = \alpha\left(\frac{K_f}{L_f}\right)^{\alpha-1} - \delta$$

# Rest of talk

1. Calibrate the model in the pre-pandemic steady state

   Definition of equilibrium

2. Introduce COVID-19 into the model as an unanticipated shock
3. Solve the transition path
4. Measure the welfare effects of pandemic, with and without mitigation policies (that resemble US policies)
5. Optimal mitigation policies

# Calibration

# Economic parameters

- Period length: 2 weeks
- Number of age cohorts: 3 (25–44, 45–64, 65–84)
- Newborn endowments: 85% begin with zero wealth and 15% receive accidental bequests ($\sim 25\times$ annual per capita cons.)
- Share of labor that can be done from home: set to match the Dingel and Neiman (2020) share of jobs that can be done from home by occupations sorted into wage quintiles: 0.03, 0.21, 0.32, 0.47, 0.66

# Economic parameters (2)

| Parameters | Values | Targets / Source |
|---|---|---|
| Discount factor, annualized, $\beta$ | 0.99 | Wealth-to-GDP: 4.8 (2014) |
| Risk aversion, $\sigma$ | 2 | Standard value |
| Disutility from labor, $\varphi$ | 440 | Average hours: 30 percent |
| Frisch elasticity, $1/\nu$ | 0.50 | Standard value |
| Aging prob., annualized, $\psi_j$ | 0.05 | Expected duration: 20 years |
| Efficiency units, $\eta_{1R} = \eta_{1S}$ | 1.00 | Wage ratio of age 45–64 to |
| $\eta_{2R} = \eta_{2S}$ | 1.35 | age 25–44 workers (PSID) |
| Factor elasticity, $\alpha$ | 0.36 | Capital share |
| Depreciation, annualized, $\delta$ | 0.05 | Standard value |
| Retirement income, $s$ | 1.00 | 30% of earnings per worker |
| Labor income tax, $\tau_\ell$ | 0.15 | Gov't budget constraint |
| Consumption tax, $\tau_c$ | 0.00 | |

# Productivity shocks

- $\varepsilon$ follows a finite-state Markov process which approximates the continuous process,

$$\log \varepsilon_t = \rho_\varepsilon \log \varepsilon_{t-1} + \nu_t,\ \nu_t \sim N\left(0, \sigma_\nu^2\right)$$

- Estimate using PSID
  - $\rho_\varepsilon = 0.94$ and $\sigma_\nu = 0.19$
  - Convert to higher frequency, following Krueger et al. (2016)

# Epidemiological parameters

- Death rates: as in Piguillem and Shi (2020) and other papers, I use the functional form

$$\delta_j(\mu_I) = \delta_j^u \min\left\{1, \frac{\kappa}{\mu_I}\right\} + \delta_j^c \max\left\{0, 1 - \frac{\kappa}{\mu_I}\right\}$$

  - $\delta_j^u$: unconstrained death rates
  - $\delta_j^c$: untreated death rates
  - $\kappa$: measure of infected individuals that can be treated

- 924 thousand hospital beds in the US (0.28% of population)

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  - $\delta_j^u$: unconstrained death rates
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  - $\kappa$: measure of infected individuals that can be treated
- 924 thousand hospital beds in the US (0.28% of population)
  - not all infected cases require hospitalization $\rightarrow \kappa = 0.01$

# Epidemiological parameters (2)

| Parameters | Values | Targets / Source |
|---|---|---|
| Infection exit rate, $\pi_X$ | 0.78 | Expected infection duration: 18 days |
| Unconstrained death rate, | | Fatality rates in South Korea |
| $\delta_1^u \times 100$ | 0.09 | |
| $\delta_2^u \times 100$ | 0.94 | |
| $\delta_3^u \times 100$ | 8.47 | |
| Untreated death rate, $\delta_j^c$ | $2\delta_j^u$ | Piguillem and Shi (2020) |
| Flow value of life, $\bar{u}$ | 9.51 | Value of statistical life: \$11.5 mil. <br> Derivation |
| Flow value of infection, $\hat{u}^I$ | –4.57 | 50 percent reduction in flow utility value of average agent |
| Efficiency units, $\eta_{jI}$ | $0.5\eta_{jS}$ | |

# Reproduction number

- Total new infections:

$$T = \beta_c C_S C_I + \beta_\ell L_S^o L_I^o + \beta_e \mu_S \mu_I$$

- The basic reproduction number, as $\mu_I \to 0$ and assuming $C_I/\mu_I \to C_S/\mu_S$ and $L_I^o/\mu_I \to L_S^o/\mu_S$, is given by

$$R_0 = \frac{\beta_c C_S^2 + \beta_\ell L_S^2 + \beta_e}{\pi_X}$$

- Most estimates range between 2.2 and 3.1. I use $R_0 = 2.2$
- I assume that, initially, virus transmission equally likely between 3 channels (evidence from other infectious diseases: Ferguson et al. 2006, Mossong et al. 2008)

# The COVID-19 crisis of 2020

# Quantitative exercises

- Use the calibrated model to investigate the aggregate and distributional effects of the pandemic and mitigation policies
  - COVID-19 introduced as an unanticipated MIT-shock
  - transition path solved in partial equilibrium
    - prices fixed
    - capital and goods markets need not clear
    - gov't budget constraints (pension) need not clear
    - bequests and endowments need not clear
  - Mitigation policies are budget-neutral in present value
- First, explore how the economic-epi model of virus transmission differs from an exogenous one ($\beta_c = \beta_\ell = 0$)
- Second, compare two budget-neutral mitigation policies
- Third, explore optimal mitigation policies

# Quantitative exercises

- Use the calibrated model to investigate the aggregate and distributional effects of the pandemic and mitigation policies
- First, explore how the economic-epi model of virus transmission differs from an exogenous one ($\beta_c = \beta_\ell = 0$)
  - The effects of private mitigation are large
- Second, compare two budget-neutral mitigation policies
- Third, explore optimal mitigation policies

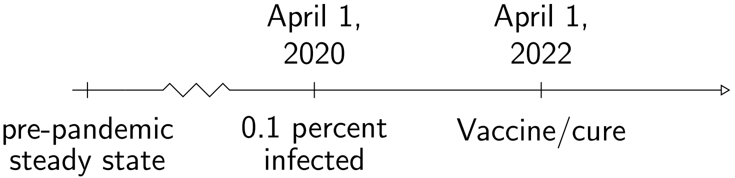
# Quantitative exercises

- Use the calibrated model to investigate the aggregate and distributional effects of the pandemic and mitigation policies
- First, explore how the economic-epi model of virus transmission differs from an exogenous one ($\beta_c = \beta_\ell = 0$)
- Second, compare two budget-neutral mitigation policies
    1. *subsidy-and-tax*: subsidy to individuals working less than 10 hours per week, funded by a tax on consumption
    2. *lockdown*: impose a cap of 10 outside work hours per week
- Third, explore optimal mitigation policies

# Quantitative exercises

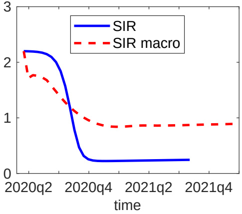
- Use the calibrated model to investigate the aggregate and distributional effects of the pandemic and mitigation policies
- First, explore how the economic-epi model of virus transmission differs from an exogenous one ($\beta_c = \beta_\ell = 0$)
- Second, compare two budget-neutral mitigation policies
- Third, explore optimal mitigation policies

# Timeline (without mitigation policy)

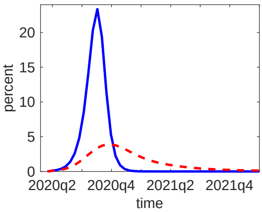


# Private mitigation is large

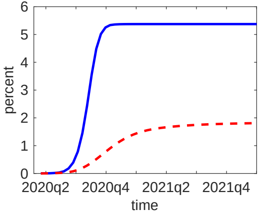
(a) $R_t$



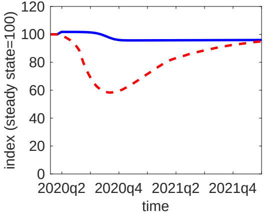

(b) Current infections



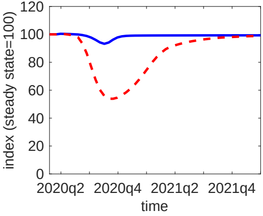

(c) Cumulative deaths




(d) Agg. consumption




(e) Aggregate hours

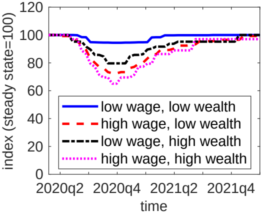


# Private mitigation is large

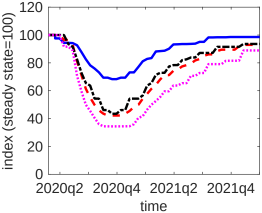
- Let's now consider the policy functions of low/high wage/wealth individuals (no mitigation policy)

# Reduction in economic activities is broad-based ...

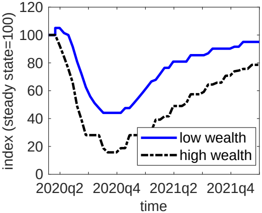
(a) Consumption (young, susceptible)



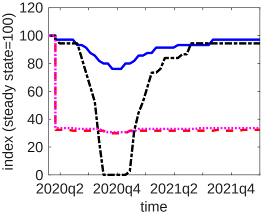

(b) Consumption (middle, susceptible)




(c) Consumption (old, susceptible)




(d) Outside hours (young, susceptible)

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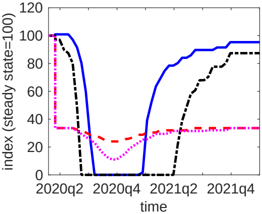
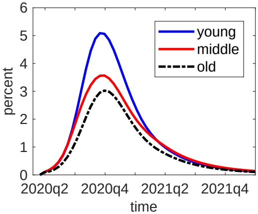



(f) Current infections by age



# ... but smallest for young low wage/wealth workers

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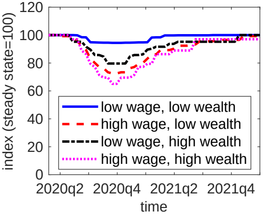


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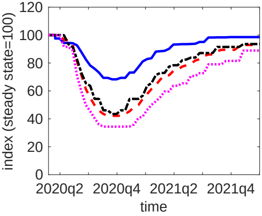


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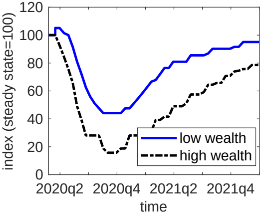


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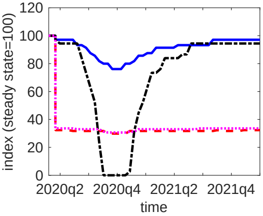


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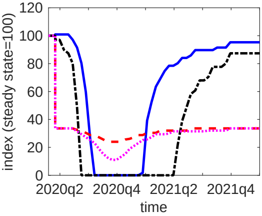


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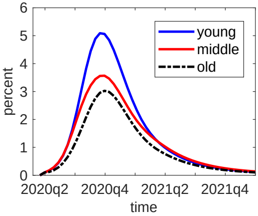
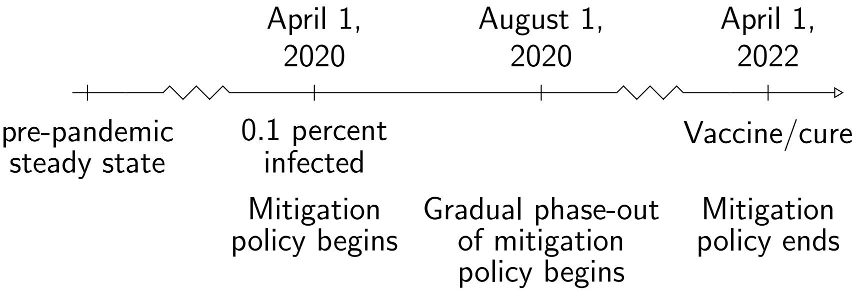
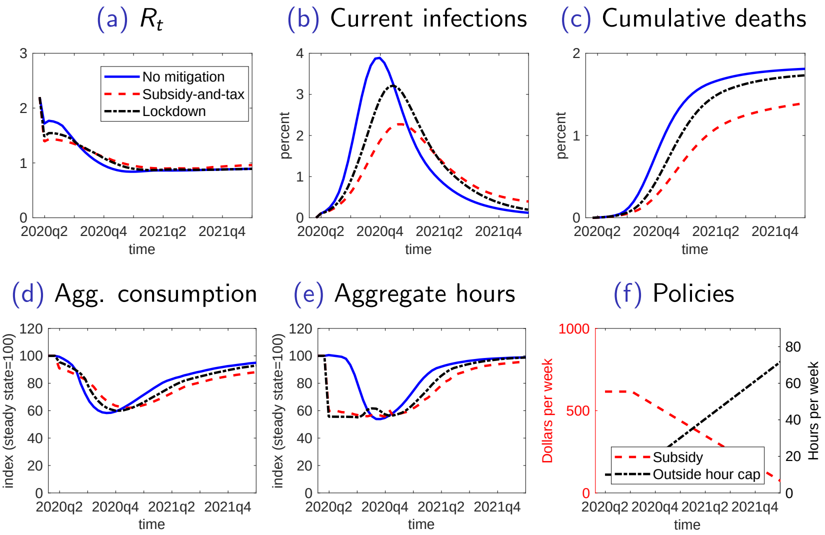


# Timeline (with mitigation policies)



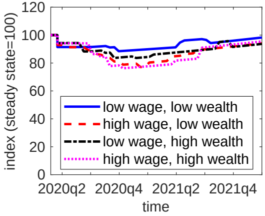
# With and without mitigation policies



# Response to pandemic (subsidy-and-tax)

lockdown

(a) Consumption (young, susceptible)

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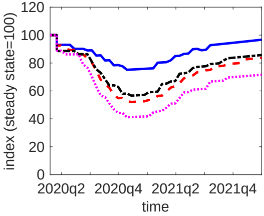
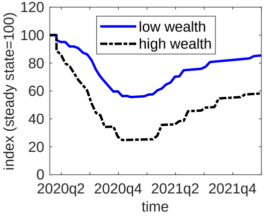
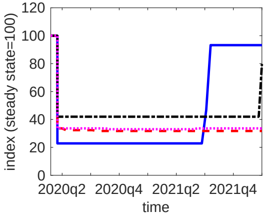



(c) Consumption (old, susceptible)




(d) Outside hours (young, susceptible)

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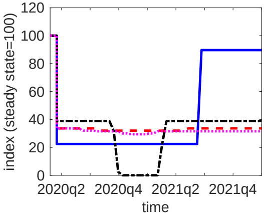


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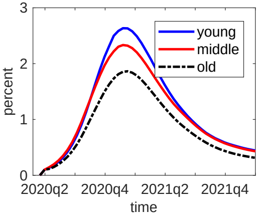


# Welfare effects of pandemic and mitigation policies

| | consumption equivalents (percent) | | | | | policy |
|---|---|---|---|---|---|---|
| wealth | low | | high | | | support |
| wage | low | high | low | high | average | (percent) |
| *no mitigation* | | | | | –19.3 | |
| young | –2.7 | –3.6 | –3.8 | –4.7 | | |
| middle | –11.4 | –14.7 | –15.2 | –20.4 | | |
| old | –29.6 | | –45.3 | | | |

# Welfare effects of pandemic and mitigation policies

| wealth | consumption equivalents (percent): low | | consumption equivalents (percent): high | | average | policy support (percent) |
|---|---|---|---|---|---|---|
| wage | low | high | low | high | | |
| *no mitigation* | | | | | −19.3 | |
| young | −2.7 | −3.6 | −3.8 | −4.7 | | |
| middle | −11.4 | −14.7 | −15.2 | −20.4 | | |
| old | −29.6 | | −45.3 | | | |
| *Subsidy-and-tax* | | | | | −16.5 | 100.0 |
| young | −2.1 | −3.5 | −3.1 | −4.4 | | |
| middle | −8.7 | −12.1 | −12.4 | −17.5 | | |
| old | −24.9 | | -39.7 | | | |
| *Lockdown* | | | | | −19.3 | 67.2 |
| young | −4.8 | −3.8 | −3.9 | −4.7 | | |
| middle | −12.1 | −14.7 | −15.0 | −20.1 | | |
| old | −28.5 | | -44.1 | | | |

- Robust to alternative [vsl] [infection utility loss] [infection efficiency loss]

# Optimal Policies

# Optimal Policies

- Investigate the properties of optimal mitigation policies, within a limited set of instruments
  - subsidy amount
  - duration
  - hours threshold
  - Lockdown intensity
- Among policies that have full support (i.e. Pareto improvements), optimal policy involves
- Output maximizing policy involves

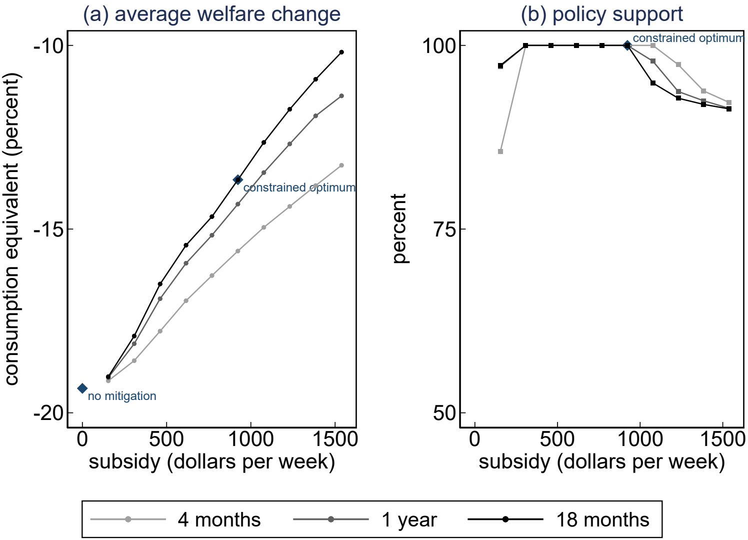
# Optimal Policies

- Investigate the properties of optimal mitigation policies, within a limited set of instruments
- Among policies that have full support (i.e. Pareto improvements), optimal policy involves
  - larger subsidy amount ($\sim$ \$900)
  - longer duration ($\sim$ 18 months)
  - lower hours threshold (0)
  - No lockdown
- Output maximizing policy involves

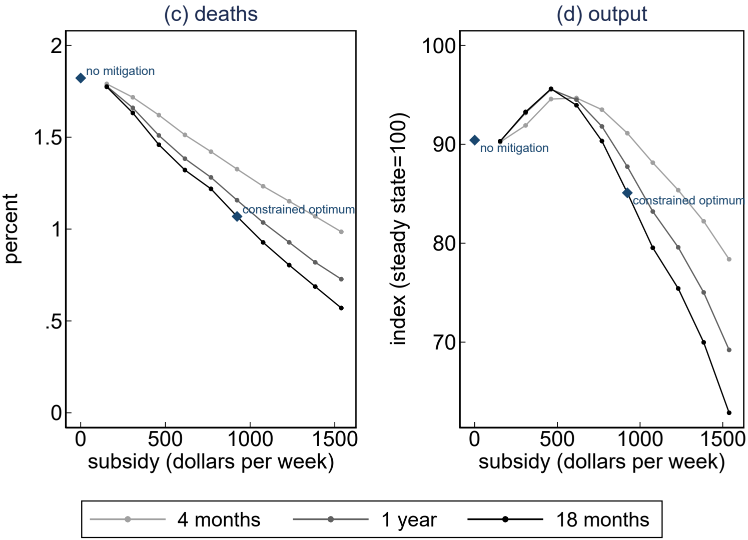
# Optimal Policies

- Investigate the properties of optimal mitigation policies, within a limited set of instruments
- Among policies that have full support (i.e. Pareto improvements), optimal policy involves
- Output maximizing policy involves
  - smaller subsidy amount ($\sim$ \$450)
  - longer duration ($\sim$ 16 months)
  - lower hours threshold (0)
  - No lockdown

# Larger and longer duration subsidies ...

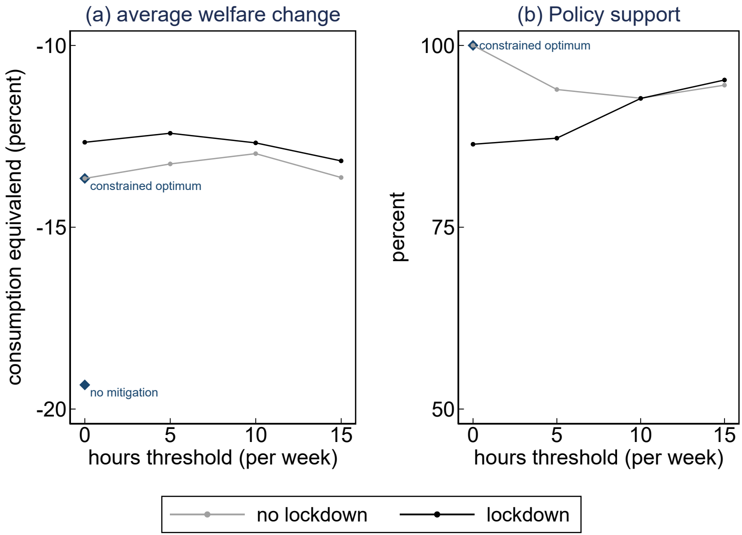


# ... lead to less deaths and possibly lower output

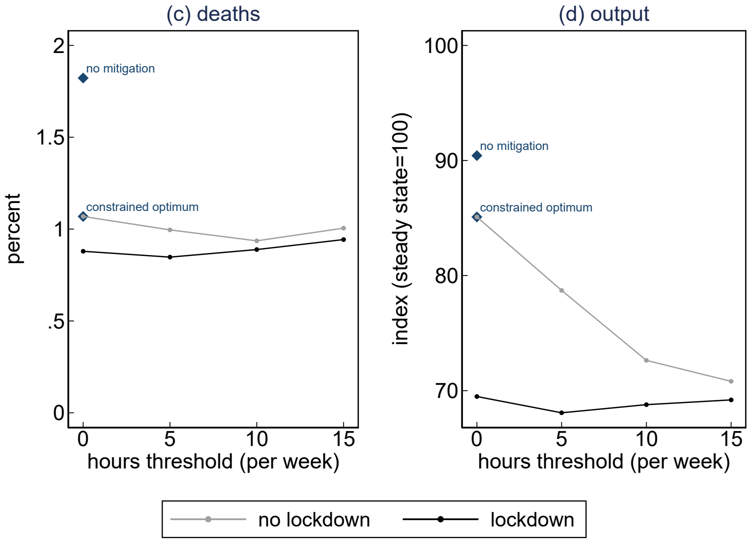


# Higher thresholds and lockdowns improve welfare

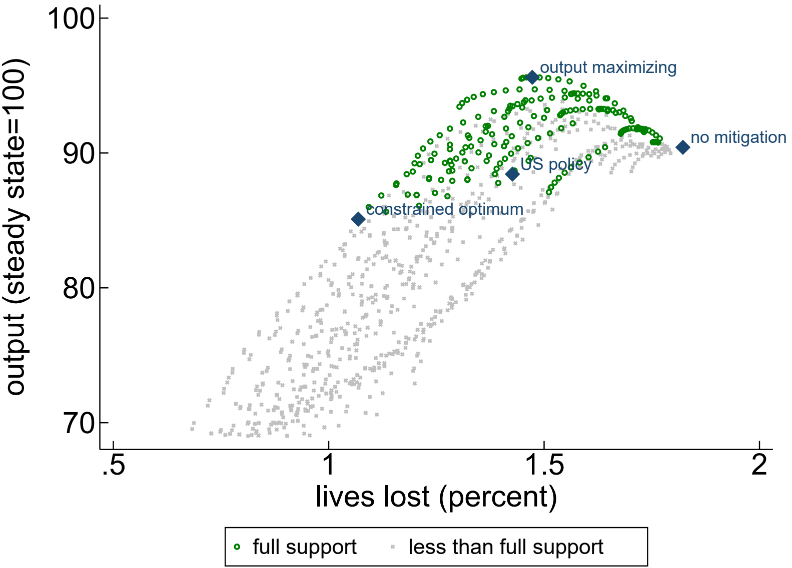
- no longer fully supported



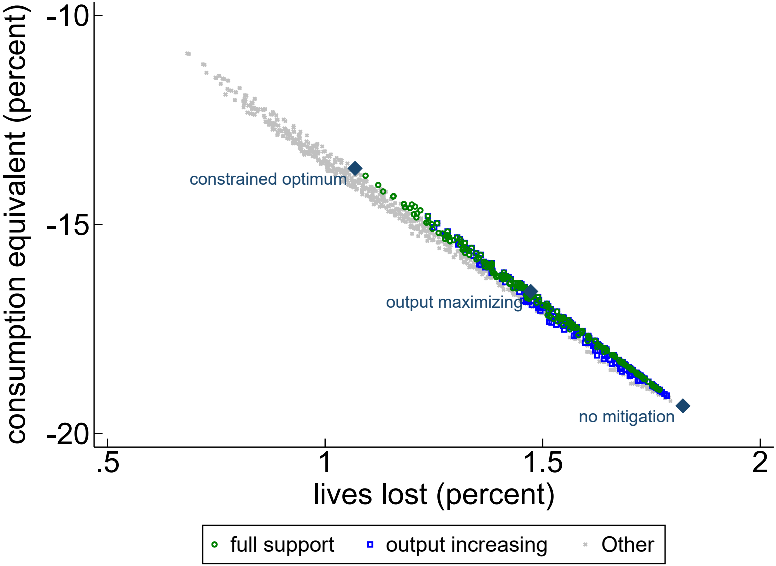
# ... but steeply reduces output



# Not necessarily a trade-off between lives and output



# No trade-off between lives and welfare



# Conclusion

- Quantitative life-cycle economic-epidemiology model
  - measure the heterogeneous welfare effects of COVID-19
  - with and without mitigation efforts
  - characterize optimal mitigation policies
- There need not be a tradeoff between saving lives and output/welfare

# Appendix

# Equilibrium back

- Let $X = K \times E \times H$ denote the state space over wealth, productivity, and health
- Let a $\sigma$-algebra over X defined by the Borel sets, $\mathcal{B}$, on $X$.
- A *steady-state recursive equilibrium*, given fiscal policies $\{\tau_c, \tau_\ell, s\}$, is
  - value functions $\{v_j, V_j\}_{j \in J}$,
  - policy functions $\{c_j, \ell_j, \ell_j^o, k_j'\}_j$,
  - prices $\{w, r\}$,
  - distribution of newborns $\omega$
  - invariant measures $\{\mu_j\}_j$

  such that:

# Equilibrium (2) back

1. Given prices, workers and retirees optimize
2. Given prices, firms optimize
3. Goods and factor markets clear
4. Government budget holds:

$$s \int_X \sum_{j \geq J^R} d\mu_j(k,\varepsilon,h) = \tau_\ell \int_X \sum_{j < J^R} w\eta_{jh} z \ell_j(k,\varepsilon,h) d\mu_j(k,\varepsilon,h) + \tau_c \int_X \sum_{j \in J} c_j(k,\varepsilon,h) d\mu_j(k,\varepsilon,h)$$

# Equilibrium (3) ▸ back

5. for any $(\mathcal{K}, \mathcal{E}, \mathcal{H}) \in \mathcal{B}$, the invariant measure $\mu_j$ satisfies

$$\mu_j(\mathcal{K}, \mathcal{E}, \mathcal{H}) = \int_X \psi_{j-1} \mathbb{1}_{\{k'_{j-1}(k,\varepsilon,h) \in \mathcal{K}\}} \sum_{\varepsilon' \in \mathcal{E}} \sum_{h' \in \mathcal{H}} \Gamma_{\varepsilon,\varepsilon'} \Pi_{jhh'} \, d\mu^*_{j-1}(k, \varepsilon, h)$$
$$+ \int_X (1 - \psi_j) \mathbb{1}_{\{k'_{j+1}(k,\varepsilon,h) \in \mathcal{K}\}} \sum_{\varepsilon' \in \mathcal{E}} \sum_{h' \in \mathcal{H}} \Gamma_{\varepsilon,\varepsilon'} \Pi_{jhh'} \, d\mu_j(k, \varepsilon, h)$$

and

$$\mu_1(\mathcal{K}, \mathcal{E}, \mathcal{H}) = \int_X (1 - \psi_1) \mathbb{1}_{\{k'_1(k,\varepsilon,h) \in \mathcal{K}\}} \sum_{\varepsilon' \in \mathcal{E}} \sum_{h' \in \mathcal{H}} \Gamma_{\varepsilon\varepsilon'} \Pi_{hh'} \, d\mu_1(k, \varepsilon, h)$$
$$+ \omega(\mathcal{K}, \mathcal{E}, \mathcal{H})$$

# Equilibrium (4) back

6. The newborn distribution satisfies:

$$\int_X k d\omega(k,\varepsilon,h) = \int_X \psi_{\bar{J}} k'_{\bar{J}}(k,\varepsilon,h) d\mu_{\bar{J}}(k,\varepsilon,h)$$

# Derivation of $\bar{u}$ ▸ back

- Assume that the VSL is computed based on the consumption of an infinitely-lived representative agent that discounts time at the rate of $\beta(1-\psi)$ in the pre-pandemic steady state, whose present discounted utility is given by

$$v = \frac{(\bar{c}+\Delta_c)^{1-\sigma}}{1-\sigma} + \bar{u} + \frac{\beta(1-\psi+\Delta_\psi)}{1-\beta(1-\psi)}\left(\frac{\bar{c}^{1-\sigma}}{1-\sigma} + \bar{u}\right)$$

  - $\bar{c}$: steady state consumption per capita
  - $\Delta_c, \Delta_\psi$: small one-time deviations to consumption and survival probability

# Derivation of $\bar{u}$ (2) back

- The VSL—defined as the marginal rate of substitution between survival and consumption—can be expressed as

$$VSL = \left. \frac{\frac{\partial v}{\partial \Delta_\psi}}{\frac{\partial v}{\partial \Delta_c}} \right|_{\Delta_c = 0} = \frac{\beta}{1 - \beta(1-\psi)} \frac{\frac{\bar{c}^{1-\sigma}}{1-\sigma} + \bar{u}}{\bar{c}^{-\sigma}}$$

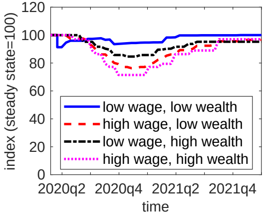
- By substituting $VSL = 7475 \times \bar{c}$, we obtain

$$\bar{u} = 7475 \times \bar{c}^{1-\sigma} \frac{1 - \beta(1-\psi)}{\beta} - \frac{\bar{c}^{1-\sigma}}{1-\sigma}$$

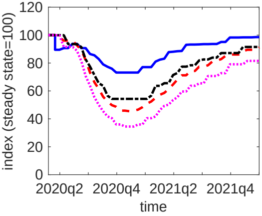
# Response to pandemic (lockdown)

▸ back

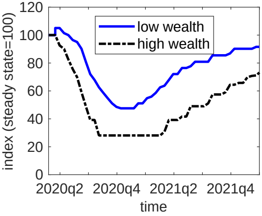
(a) Consumption (young, susceptible)



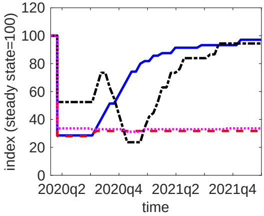

(b) Consumption (middle, susceptible)



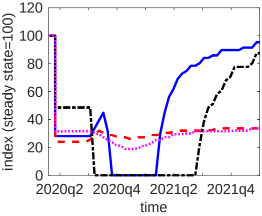

(c) Consumption (old, susceptible)



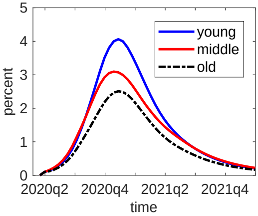

(d) Outside hours (young, susceptible)




(e) Outside hours (middle, susceptible)




(f) Current infections by age



# Sensitivity analysis ($vsl = 6208\bar{c}$) ▸ back

| | consumption equivalents (percent) | | | | |
|---|---|---|---|---|---|
| | low wealth | | high wealth | | average |
| | low wage | high wage | low wage | high wage | |
| *No mitigation* | | | | | –19.2 |
| young | –2.3 | –3.1 | –3.3 | –4.1 | |
| middle | –11.2 | –14.5 | –15.0 | –20.1 | |
| old | –29.8 | | –45.5 | | |
| *Subsidy-and-tax* | | | | | –17.4 |
| young | –2.0 | –3.3 | –2.8 | –3.9 | |
| middle | –9.5 | –12.9 | –13.2 | –18.2 | |
| old | –26.8 | | –41.8 | | |
| *Lockdown* | | | | | –19.0 |
| young | –2.7 | –3.1 | –3.3 | –4.0 | |
| middle | –11.4 | –14.3 | –14.9 | –20.0 | |
| old | –29.4 | | –45.0 | | |

# Sensitivity analysis ($\hat{u}_l = -2.74$) ▸ back

| | consumption equivalents (percent) | | | | |
|---|---|---|---|---|---|
| | low wealth | | high wealth | | average |
| | low wage | high wage | low wage | high wage | |
| *No mitigation* | | | | | –17.3 |
| young | –2.0 | –2.7 | –2.9 | –3.5 | |
| middle | –9.9 | –12.8 | –13.3 | –18.0 | |
| old | –26.7 | | –42.1 | | |
| *Subsidy-and-tax* | | | | | –15.7 |
| young | –1.7 | –2.9 | –2.4 | –3.5 | |
| middle | –8.4 | –11.5 | –11.7 | –16.3 | |
| old | –24.1 | | –38.6 | | |
| *Lockdown* | | | | | –17.2 |
| young | –2.4 | –2.7 | –2.8 | –3.5 | |
| middle | –10.0 | –12.7 | –13.2 | –17.9 | |
| old | –26.3 | | –41.6 | | |

# Sensitivity analysis ($\eta_{jI} = 0.7\eta_{jS}$) back

| | consumption equivalents (percent) | | | | |
|---|---|---|---|---|---|
| | low wealth | | high wealth | | average |
| | low wage | high wage | low wage | high wage | |
| *No mitigation* | | | | | –19.7 |
| young | –2.8 | –3.7 | –3.9 | –4.8 | |
| middle | –11.7 | –15.0 | –15.5 | –20.7 | |
| old | –30.2 | | –45.9 | | |
| *Subsidy-and-tax* | | | | | –17.7 |
| young | –2.4 | –3.8 | –3.4 | –4.6 | |
| middle | –9.9 | –13.4 | –13.7 | –18.8 | |
| old | –26.9 | | –42.0 | | |
| *Lockdown* | | | | | –19.5 |
| young | –3.2 | –3.7 | –3.9 | –4.8 | |
| middle | –11.8 | –14.9 | –15.4 | –20.6 | |
| old | –29.7 | | –45.4 | | |