The Great Lockdown and the Big Stimulus: Tracing the Pandemic Possibility Frontier for the U.S.

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Slides at `http://benjaminmoll.com/PPF_slides/`

What We Do

- US policy response to COVID-19:
  - Lockdown: workplace and social sector
  - Stimulus: CARES Act
- Goal: quantify trade-offs
  - Aggregate: Lives versus livelihoods
  - Distributional: Who bears the economic costs?
- Approach: distributional Pandemic Possibility Frontier (PPF) → PPF
  - Compare policies without taking stand on economic value of life
  - Seek policies that flatten and shift the frontier

How We Do It

- Integrated SIR + Heterogeneous Agent model with necessary ingredients
  - Sectors: (i) regular; (ii) social; (iii) home production
  - Types of labor: (i) workplace; (ii) remote; (iii) home production
  - Occupations: (i) flexibility; (ii) sectoral intensity; (iii) essentiality
  - Two-way behavioral feedback: between virus & economic activity
- Economic exposure to pandemic correlated with financial vulnerability
- Calibrate model to U.S. economy and examine counterfactuals
  - Laissez-faire vs lockdowns vs fiscal stimulus (CARES Act)
  - Smarter policies: (i) targeted lockdowns; (ii) Pigouvian taxes

What We Find

1. Economic welfare costs of pandemic: large and heterogeneous
    - Regardless of the policy response
    - Laissez-faire vs lockdown: who bears the cost differs
    - Large welfare costs for middle of earnings distribution
2. Slope of PPF varies with length lockdown
    - Driven by hospital beds constraint and eventual arrival of vaccine
    - Reconcile conflicting views on extent of health-wealth trade-off
3. U.S. CARES Act:
    - Reduced economic cost by 20% on average, highly redistributive
    - Explains rapid recovery in consumption of poor households
4. Taxation-based alternatives to lockdown: favorable mean trade-off but more dispersion

→ dimensions not considering today

Outline

1. Model

2. Parameterization

3. Results

4. Conclusions

5. Linked Slides

Epidemiological Model

- $\mathcal{S}_t$: susceptible
- $\mathcal{I}_t$: infectious
- $\mathcal{R}_t$: recovered
- $\mathcal{E}_t$: exposed = latent virus, not yet infectious
- $\mathcal{C}_t$: critical = in ICU, may ultimately die
- $\mathcal{N}_t$: population = $\mathcal{S}_t + \mathcal{E}_t + \mathcal{I}_t + \mathcal{C}_t + \mathcal{R}_t$

$$\begin{bmatrix} \dot{\mathcal{S}}_t \\ \dot{\mathcal{E}}_t \\ \dot{\mathcal{I}}_t \\ \dot{\mathcal{C}}_t \\ \dot{\mathcal{R}}_t \end{bmatrix} = \begin{bmatrix} -\beta_t \frac{\mathcal{I}_t}{\mathcal{N}_t} & \beta_t \frac{\mathcal{I}_t}{\mathcal{N}_t} & 0 & 0 & 0 \\ 0 & -\lambda_E & \lambda_E & 0 & 0 \\ 0 & 0 & -\lambda_I & \lambda_I \chi & \lambda_I (1-\chi) \\ 0 & 0 & 0 & -\lambda_C & \lambda_C (1 - P(\mathcal{C}_t, \mathcal{C}_{\max})) \\ \lambda_R & 0 & 0 & 0 & -\lambda_R \end{bmatrix}^\top \begin{bmatrix} \mathcal{S}_t \\ \mathcal{E}_t \\ \mathcal{I}_t \\ \mathcal{C}_t \\ \mathcal{R}_t \end{bmatrix}$$

- Deaths (flow) $\dot{\mathcal{D}}_t = P(\mathcal{C}_t, \mathcal{C}_{\max}) \lambda_C \mathcal{C}_t$, cumulative deaths $\mathcal{D}_t$

Two key features:

1. Death probability of $\mathcal{C}_t$'s depends on $\mathcal{C}_t \gtrless$ max ICU capacity $\mathcal{C}_{\max}$
2. $\beta_t = \beta(C_{st}, L_{wt}, t)$: transmission depends on economic activity and time

→ lockdowns in SIR models

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Occupations (j)

	Flexibile	Rigid
C-intensive	Software engineer, architect	Car mechanic, miner
S-intensive	Event planner, social scientist	Waiter, shop assistant
Essential	Police, nurse, supermarket clerk	

1. Flexibility: substitutability between remote and workplace hours
   - Total labor supply = $L^j_w + \phi^j L^j_r$
2. Employment intensities in social versus regular sector , (ξ^j_s, ξ^j_c)

$$Y_i = Z_i N_i^{\alpha_i} K_i^{1-\alpha_i}, \quad N_i = \left[\sum_{j=1}^{J} \left(\xi^j_i\right)^{\frac{1}{\sigma}} \left(N^j_i\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad i \in \{s, c\}$$

3. Essential occupations: not affected by workplace lockdown

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Households

- Period utility: $U[c, s, h] - V[\ell_w, \ell_r, h]$

    - c: regular consumption
    - s: social consumption
    - ℓ_w: workplace hours
    - ℓ_r: remote hours
    - h: home production

Households

- Period utility: $U[c, \upsilon_s(\dot{\mathcal{D}})s, h] - V[\upsilon_\ell(\dot{\mathcal{D}})\ell_w, \ell_r, h]$
    - c: regular consumption
    - s: social consumption
    - ℓ_w: workplace hours
    - ℓ_r: remote hours
    - h: home production
    - $\upsilon_s, \upsilon_\ell$: disutility of infection risk ("fear factor")
- Externality: when choosing s, ℓ_w, do not take into account effect on $\dot{\mathcal{D}}_t$, disutility of others
- Budget constraint of healthy household working in occupation j

$$\dot{b} = (1-\tau)w^j z\left(\ell_w + \phi^j \ell_r\right) + r^b b + T - c - p_s s - d - \chi(d, a)$$
$$\dot{a} = r^a a + d$$

    - b: liquid assets
    - a: illiquid assets
    - $\phi^j \in [0, 1]$: flexibility of occupation j
    - χ: transaction cost
- Sick households ($= \mathcal{C}$, in ICU): cannot produce, gov't provides $\underline{c}$ and $\underline{s}$

Lockdowns

1. Social sector lockdown: Mandated decrease in K utilization in s sector
$$Y_s = Z_s(\kappa_s K_s)^{\alpha_s} N_s^{1-\alpha_s}, \qquad \kappa_s < 1$$
2. Workplace lockdown: Mandated maximum (share of) workplace hours
$$\ell_w \leq \kappa_\ell(\ell_w + \ell_r), \qquad \kappa_\ell < 1$$

- Full lockdown: $\kappa_s = \kappa_\ell = 0$
- Lockdowns reduce infections because reduce $\beta_t = \beta(C_{st}, L_{wt}, t)$
- Lockdowns affect same behavioral margins as pandemic...
- ... but reduce cumulative deaths for four reasons:
  1. reduce epidemic “overshoot” (small)
  2. vaccine after 24 months (small except for very long lockdowns)
  3. ICU constraint $\mathcal{C}_{\max}$
  4. “learning” = logistic time trend in β_t

Kaplan, Moll and Violante (2020)

Remaining Model Ingredients

Firms

- Monopolistic intermediate-good producers $\rightarrow$ final s,c goods
- Baseline: flexible prices (extension: sticky prices)

Investment Fund

- Illiquid assets = shares of an investment fund
- The fund owns K and equity of intermediate producers in c, s sectors

Government

- Issues liquid debt (B^g), spends (G), taxes and transfers (T)
- Central bank absorbs the additional debt needed to finance CARES Act

→ market clearing conditions

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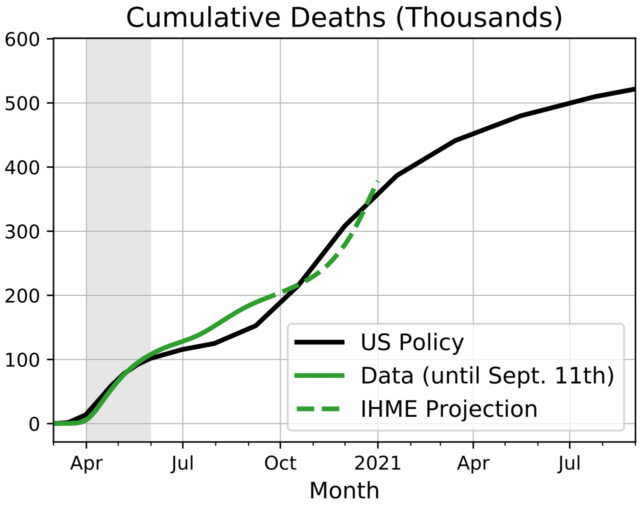
Key Aspects of Parameterization

1. Epidemiological block
   - SEIR parameters: epidemiological and clinical studies → SEIR parameters
2. Occupational parameters
   - Flexibility measures by occupation: O*NET, ATUS → occupation flexibility details
   - Sectoral employment intensities in C and S: OES, CPS → occupation sectoral details
   - Earnings and liquid wealth by occupation: SIPP, CPS, SCF → exposure vs vulnerability
3. Two-way feedback: virus $\leftrightarrow$ economic activity
   - Economic activity $\rightarrow$ virus: drop in R_t after lockdown → feedback: activity → virus
   - Virus $\rightarrow$ economic activity: VSL literature
     → feedback: virus → activity

Model fits deaths data reasonably well despite simple epi block



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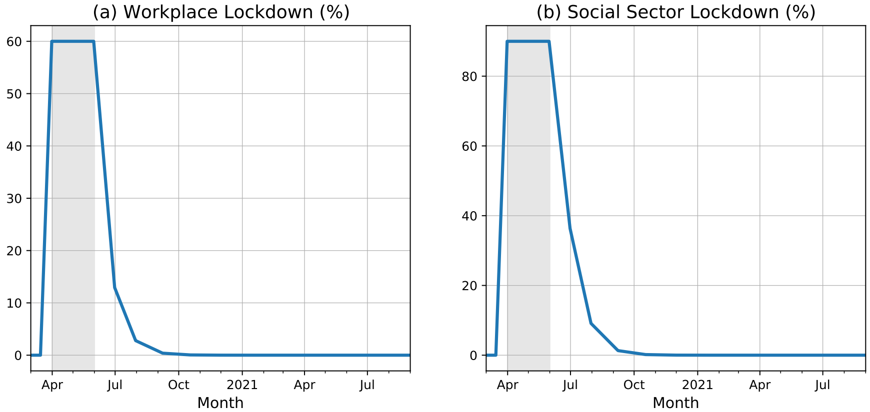
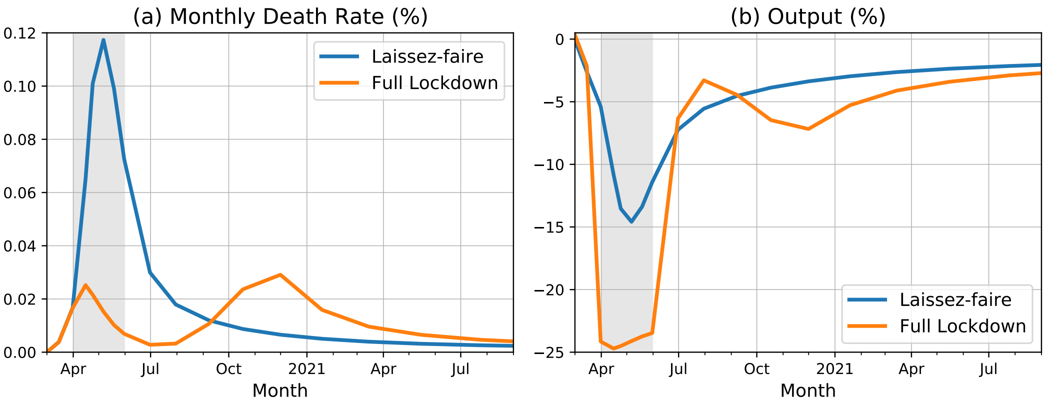
Lockdown Scenario



- Calibrated to obtain decline in workplace and retail activity (Google)
- Assumption: no future lockdown in case of 2nd wave

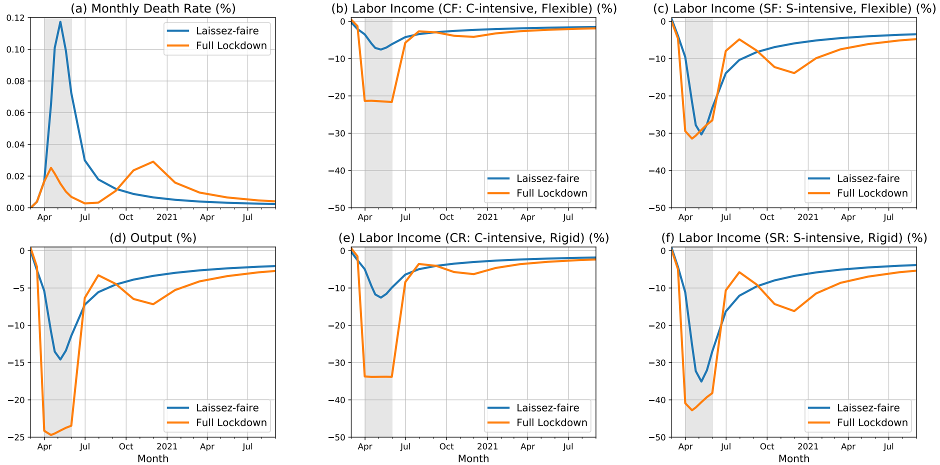
Laissez-faire vs Lockdown Dynamics



- Lockdown $\rightarrow$ second wave, but fewer cumulative deaths
- Lockdown $\rightarrow$ longer, deeper contraction and W-shaped recovery

$\rightarrow$ laissez-faire dynamics | $\rightarrow$ lockdown dynamics | $\rightarrow$ lockdown decomposition | $\rightarrow$ cumulative deaths

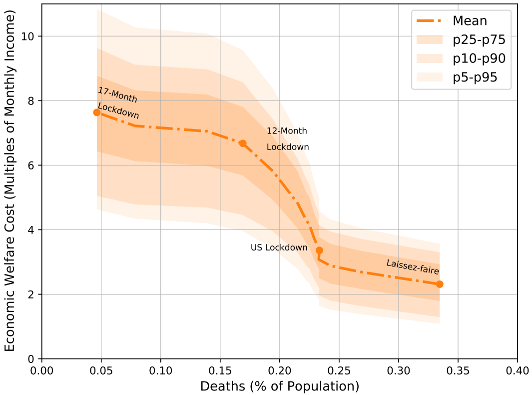
Laissez-faire vs Lockdown Dynamics



- Large drop in income for S-intensive occupations even in laissez faire
- Lockdown $\rightarrow$ further drop in income for C-intensive occupations

→ laissez-faire dynamics → lockdown dynamics → lockdown decomposition

Pandemic Possibility Frontier (PPF)



- Large average economic costs and big dispersion
- Heterogeneity in economic costs exacerbated with longer lockdowns
- Very non-linear trade-off: role of ICU constraint and vaccine

→ ppf by occupation

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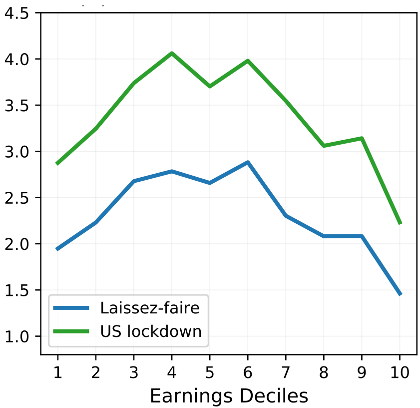
Distribution of Economic Welfare Costs



Earnings Decile

- Largest economic costs in middle of distribution
- Transfers (bottom) vs Rigid labor (middle) vs Flexible labor (top)

→ welfare cost distribution

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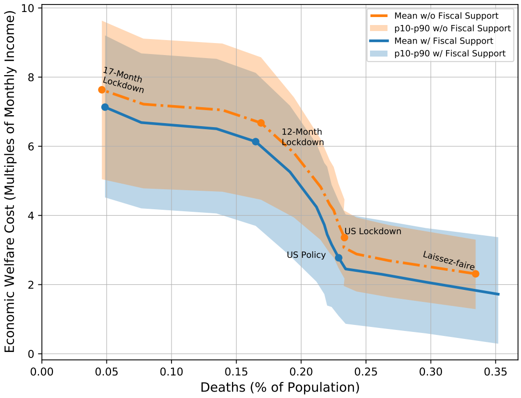
CARES Act Shifts Down the PPF

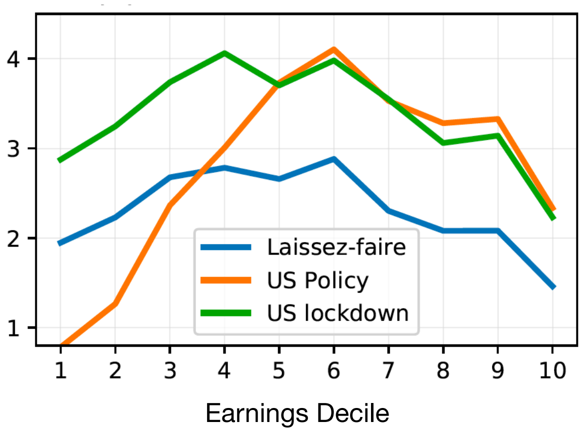


- CARES Act: stimulus checks, pandemic UI, PPP

→ CARES Act details

→ CARES Act dynamics → components of CARES Act → CARES Act by income quartile → components by income quartile → evolution of deaths

Distribution of Economic Welfare Costs



- Big impact of CARES Act on households below the median

→ welfare cost distribution

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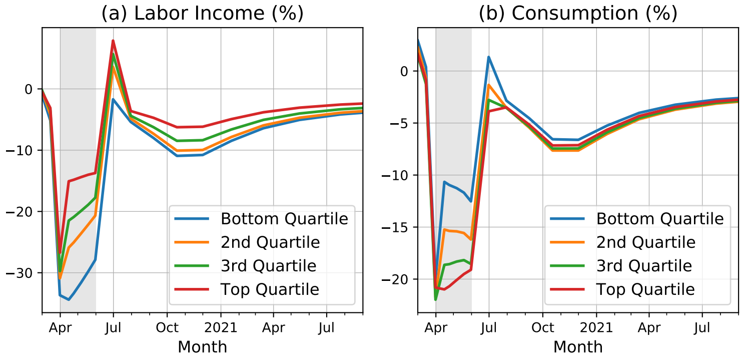
Consumption Dynamics

- US Data: biggest y drops, but fastest c recovery at the bottom of the income distribution

→ US data



- CARES Act redistributed heavily toward low-income households with high MPC

→ components of CARES Act by income quartile

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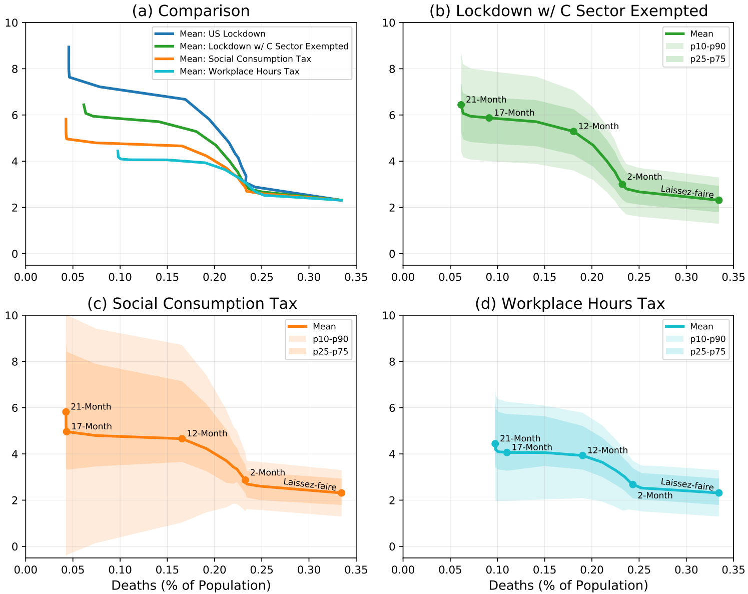
Smarter Alternative Polices



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Outline

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Messages

1. Economic costs of pandemic: large and heterogeneous, regardless of lockdowns
2. Distributional PPF is useful for quantifying trade-offs:
   - Aggregate tradeoff between lives vs livelihoods
   - Distributional tradeoff over who bears economic burden
3. Non-linear PPF: reconciles conflicting views on aggregate tradeoff
4. Exposure correlated with vulnerability $\Rightarrow$ scope for fiscal policy
5. US CARES Act:
   - Shifts PPF inward: reduces economic costs w/o increasing deaths
   - Faster recovery of spending for low income households
6. Pigouvian schemes alternative to lockdowns improve aggregate trade-off

Thanks and Stay Safe!

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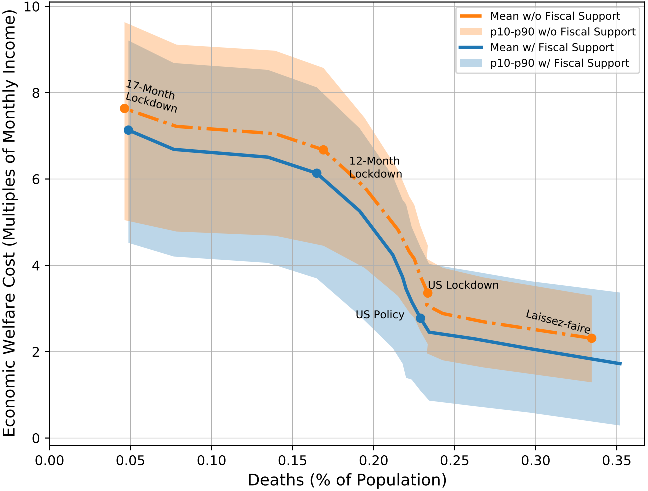
Distributional Pandemic Possibility Frontier



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back to intro

Some Dimensions we Abstract From

1. Differential impact of the epidemic across age groups
   (Glover-Heathcote-Krueger-RiosRull, Bairoliya-Imrohoroglu, Acemoglu et al., Brotherhood-Kircher-Santos-Tertilt, ...)

2. Differential impacts of the epidemic across gender
   (Alon-Doepke-Olmstead Rumsey-Tertilt, ...)

3. Impact of the epidemic on deaths from other causes

4. Input-output linkages in production
   (Baqaee-Farhi, ...)

5. Firm balance sheets, liquidity provision to firms
   (Buera-Fattal Jaef-Neumeyer-Shin, Elenev-Landvoigt-VanNieuwerburgh, ...)

6. Costly destruction of viable employment relationships

7. ...

→ model ingredients

Background on Lockdowns in SIR Models

- Some vocabulary:
  1. Basic reproduction number: $R_0 := \beta_0/\lambda_I$
  2. Effective reproduction number: $R_t^e := R_0 \times \mathcal{S}_t/\mathcal{N}_t$
  3. Herd immunity threshold: $\mathcal{S}^*/\mathcal{N} := 1/R_0$ or $\mathcal{R}^*/\mathcal{N} = 1 - \mathcal{S}^*/\mathcal{N} = 1 - 1/R_0$
  4. Final size of disease: $\mathcal{S}_\infty = e^{-R_0(1-\mathcal{S}_\infty)}$
- Two key features of SIR models:
  1. Infections $\uparrow$ if $R_t^e > 1$ or $\mathcal{S} > \mathcal{S}^*$ and $\downarrow$ otherwise
  2. Epidemic "overshoot": total infections > herd immunity, $\mathcal{S}_\infty > \mathcal{S}^*$
- Results on lockdowns := $R_0 \downarrow$
  - Even temporary lockdowns reduce total number of infections
  - But total number of infections $\geq$ herd immunity threshold
  - Best lockdowns-only can do is eliminate epidemic "overshoot"
  - If lockdown too short or too tight, get 2nd wave

→ back

Market Clearing Conditions

- Regular goods market

$$Y_c = C_c + I + G + \chi$$

- Social goods market

$$Y_s = C_s$$

- Labor market for each occupation

$$N_c^j + N_s^j = \int z(\ell_w^j(\mathfrak{h}, a, b, z) + \phi^j \ell_r^j(\mathfrak{h}, a, b, z))d\mu, \quad j = 1, ..., 5$$

- Liquid asset market

$$B^h = B^g$$

- Illiquid asset market

$$A = V_{\text{fund}}(K, \Theta_c, \Theta_s), \quad K = K_c + K_s$$

→ model ingredients

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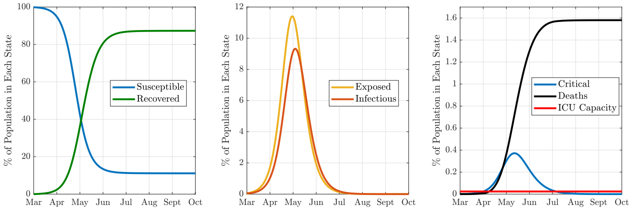
Epidemiological Parameters

Description	Parameter	Value
Initial basic reproduction number	$R_0^{\text{init}} = \beta_0^{\text{init}}/\lambda_I$	2.5
Final basic reproduction number	$R_0^{\text{end}} = \beta_0^{\text{end}}/\lambda_I$	2
Avg. duration of $\mathcal{I}$nfectious	$T_I \Rightarrow \lambda_I = 1/T_I$	4.3 days
Avg. duration of $\mathcal{E}$xposure (latency)	$T_E \Rightarrow \lambda_E = 1/T_E$	5.0 days
Infection fatality rate	IFR = $\chi\delta_C$	$0.02 \times 0.33 = 0.066$



- Time trend in transmissions (masks,...): $\tilde{R}_0(t) = (1-\omega(t))R_0^{\text{init}} + \omega(t)R_0^{\text{end}}$, $\omega(t)$ = logistic
- Herd immunity threshold: $1 - 1/R_0^{\text{init}} = 60\% \Rightarrow 1 - 1/R_0^{\text{end}} = 50\%$
- Vaccine arrival after 18 months

→ back to parameterization

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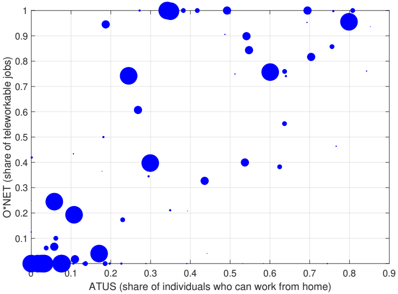
Occupations: Flexibility

- O*NET: Share of tasks that can be performed at home (Dingel-Neiman)
- ATUS Q: As part of your (main) job, **can** you work at home?
- Systematic variation across 3-digit SOC occupations



- Two flexibility levels: high flexibility occupation if O*NET share > 0.5.

→ back to parameterization

Occupations: Social vs Regular Intensity

NAICS code	Sector C (value added share: 0.74)	NAICS code	Sector S (value added share: 0.26)
11	Agriculture, forestry, fishing, and hunting	44-45	Retail trade
21	Mining	481-482-483	Air, rail, and water transportation
22	Utilities	485-487-488	Transit and scenic transportation
23	Construction	61	Educational services
31-32-33	Manufacturing	62	Health care and social assistance services
42	Wholesale trade	531-532-533	Real estate, rental and leasing services
484-486	Truck and pipeline transportation	71	Arts, entertainment, and recreation services
491-492	Postal transportation	72	Accommodation and food services
493	Warehousing and storage	81	Other services (excluding P.A.)
51	Information		
52	Finance and insurance		
–	Housing services		
54-55	Professional, technical, and scientific services		
56	Management and administrative services		

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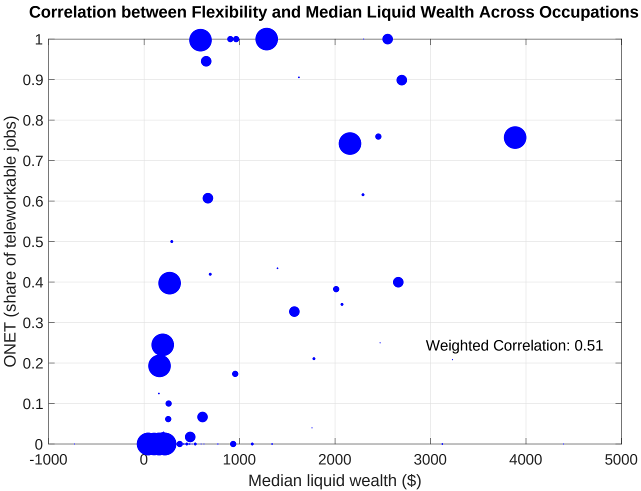
Occupations: Exposure vs Vulnerability



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Occupations: Exposure vs Vulnerability

Occupation	ϕ^j	ξ_c^j	ξ_s^j	Empl Share	Earnings	Liq Wealth
Essential	0.1	0.19	0.35	0.31	$\$45K$	$\$1,300$
CF: C-intensive, Flexible	1	0.57	0.12	0.21	$\$79K$	$\$18,400$
SF: S-intensive, Flexible	1	0.03	0.19	0.10	$\$51K$	$\$8,900$
CR: C-intensive, Rigid	0.1	0.19	0.04	0.13	$\$45K$	$\$1,000$
SR: S-intensive, Rigid	0.1	0.04	0.29	0.24	$\$32K$	$\$900$

Source: O*NET, OES, SIPP

- Estimate stochastic processes for household wage dynamics by occupation from PSID
- To match liquid wealth we add occupational-specific wedge on liquid rate

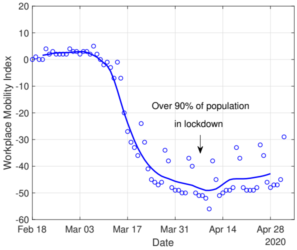
→ back to parameterization

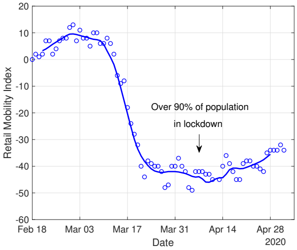
Feedback: Economic Activity to Virus

- Transmission rate for infections:

$$\beta_t = \tilde{\beta}_t \left(\frac{C_{st}}{\bar{C}_s}\right)^{\nu_\beta^s} \left(\frac{L_{wt}}{\bar{L}_w}\right)^{\nu_\beta^w}$$

- Google COVID-19 Community Mobility Data:





- Estimates of R_t drop from 2.5 to 0.8 after lockdown
- Drop in acrivity of 50% $\Rightarrow$ elasticities: $\nu_\beta^s = \nu_\beta^w = 0.8$

→ back to parameterization

Feedback: Virus to Economic Activity

- Parameterize utility shifters as:

$$\upsilon_\ell(\dot{\mathcal{D}}) = \exp\left(-\nu_\ell^0 \dot{\mathcal{D}}^{\nu_\ell^1}\right), \qquad \upsilon_s(\dot{\mathcal{D}}) = \exp\left(-\nu_s^0 \dot{\mathcal{D}}^{\nu_s^1}\right)$$

- Maps into VSL calculations: optimality condition for hours worked is

$$\log w_{it} = \gamma_\ell^0 \left(\nu_\ell^0 \dot{\mathcal{D}}_t^{\nu_\ell^1}\right) + \gamma_\ell^1 \mathbf{X}_{it}$$

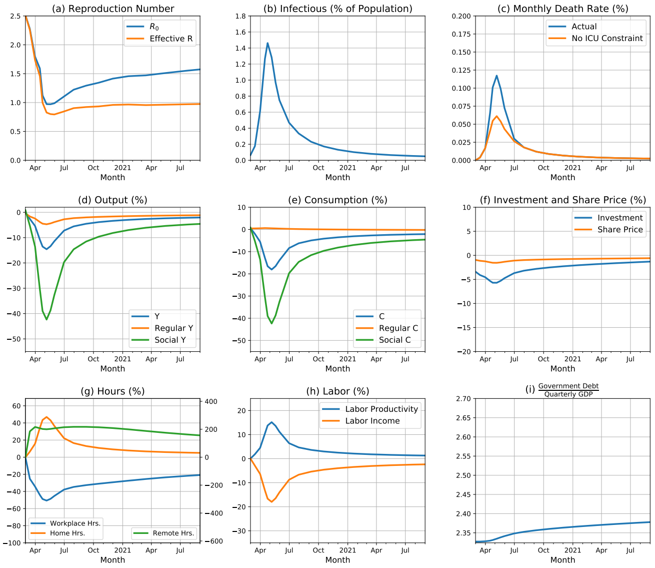
- Used to estimate monetary compensation for fatality risk
    - increasing and concave in risk

      Greenstone et al. (2014), Lavetti (2020)

- Target VSL between \$4-10M for fatality rates between 1/1,000 and 1/10,000 per quarter (relevant magnitude for COVID-19)

→ back to parameterization

Aggregates Dynamics: Laissez-Faire



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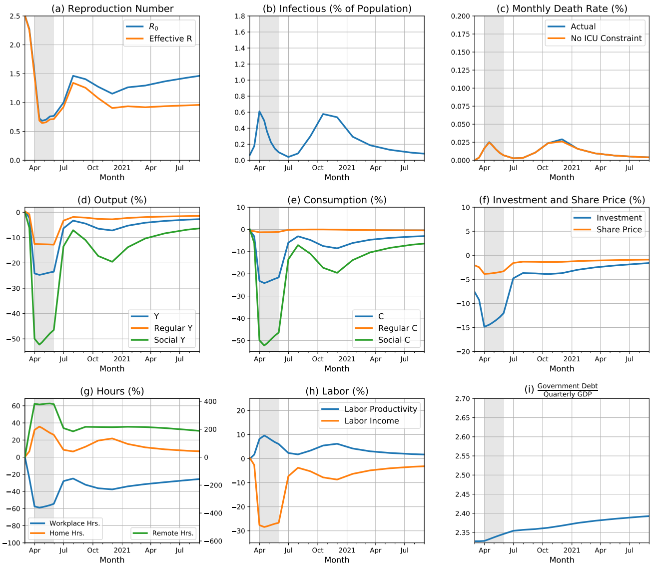
Aggregates Dynamics: Lockdown



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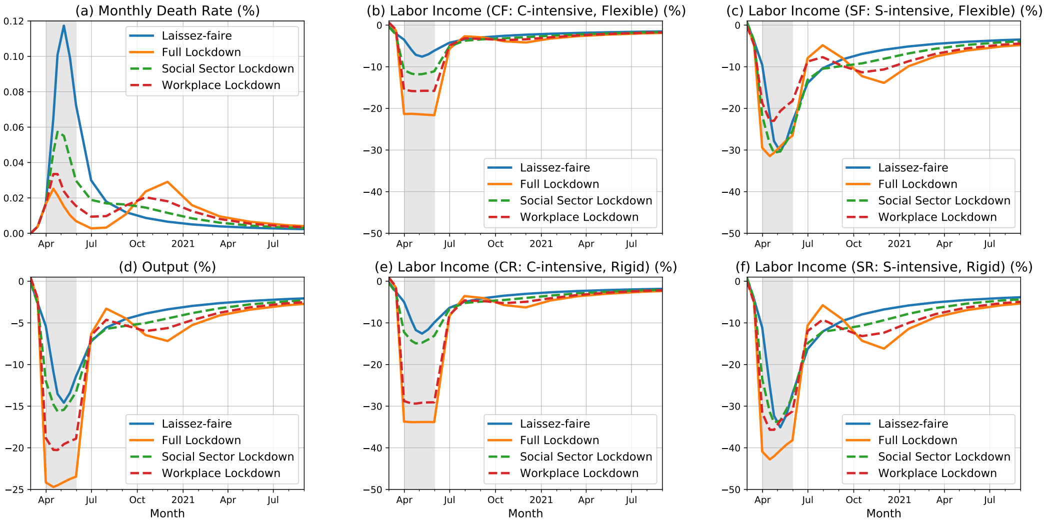
Lockdown Decomposition



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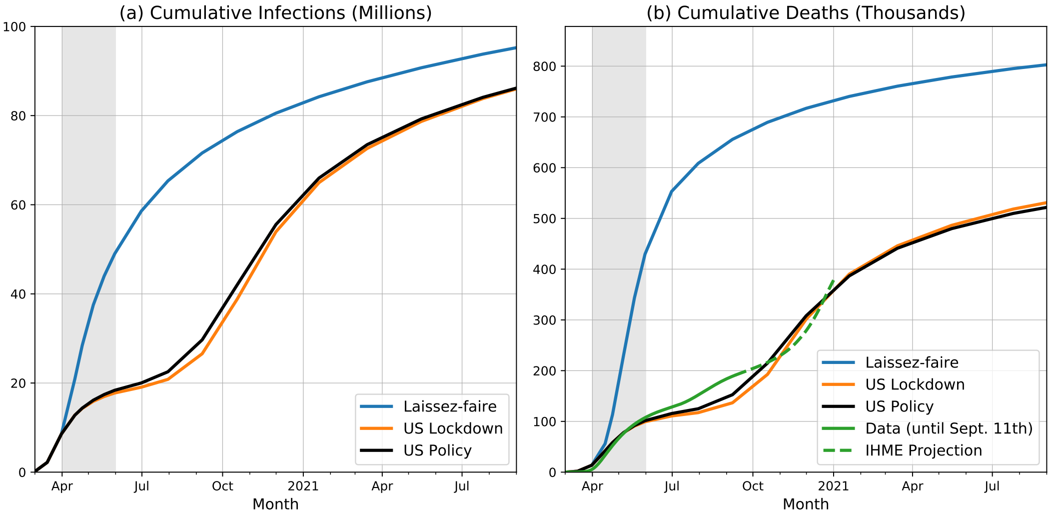
Cumulative infections and deaths



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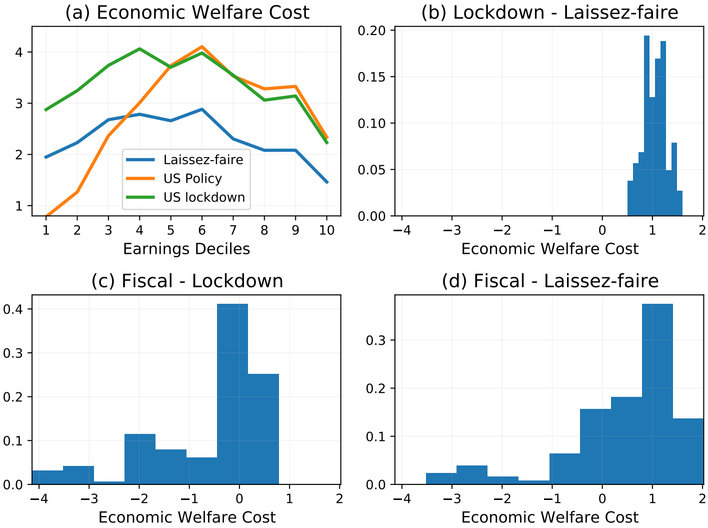
Economic Welfare Cost Distribution



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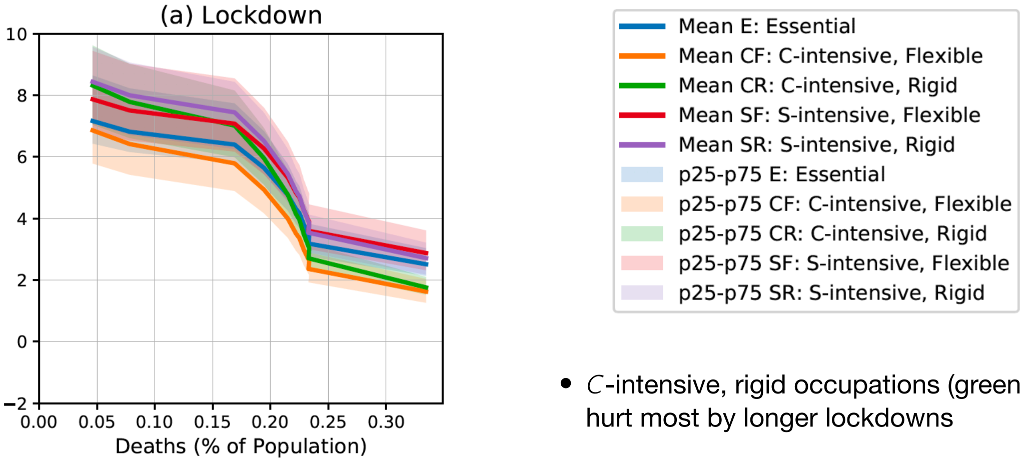
Production Possibility Frontier by Occupation



- C-intensive, rigid occupations (green line) hurt most by longer lockdowns

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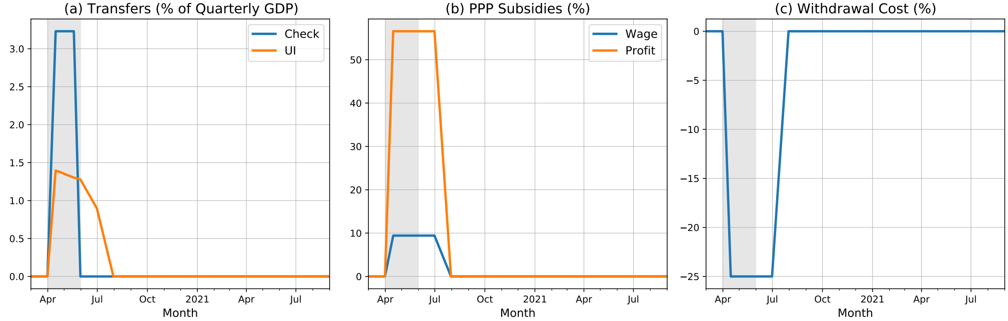
Modeling CARES Act



- Stimulus checks: unconditional transfer of $1,900 to everyone
- Pandemic UI: replacement earnings loss by decile (Ganong-Vavra)
- Paycheck Protection Program: part wage & profit subsidies (half each)
- 401(k) withdrawals up to $100,000: reduction in withdrawal cost

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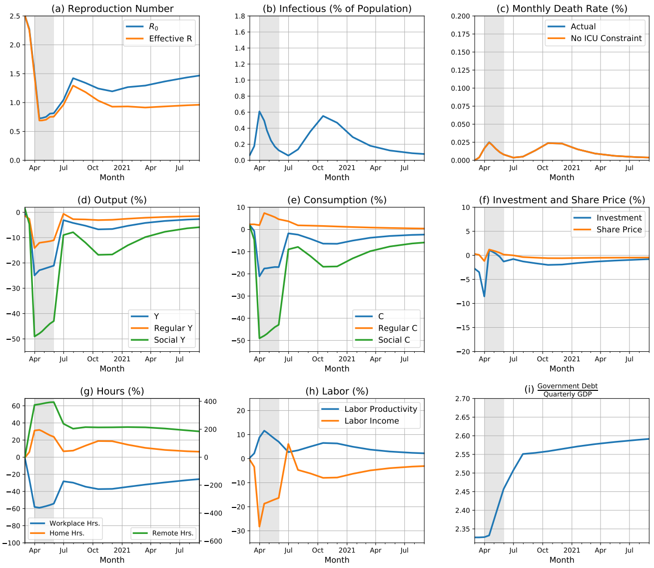
Aggregates Dynamics: Lockdown + CARES Act



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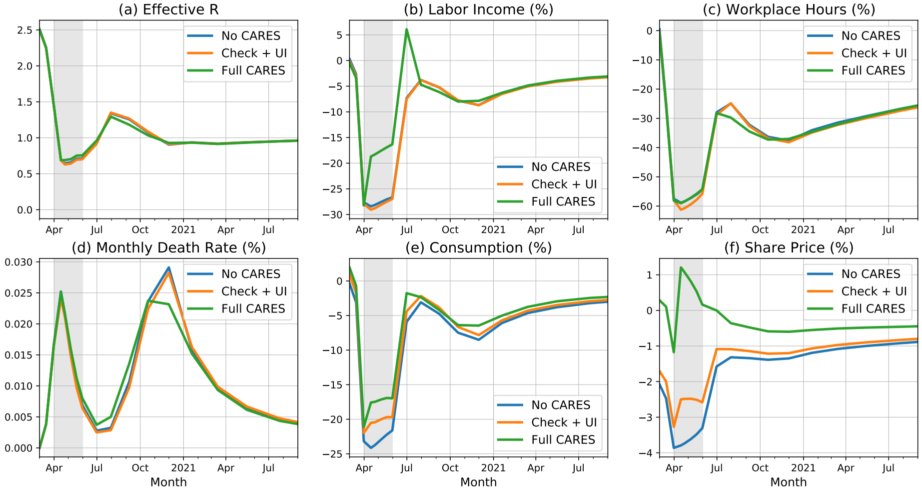
Decomposition of CARES Act Elements



Kaplan, Moll and Violante (2020)

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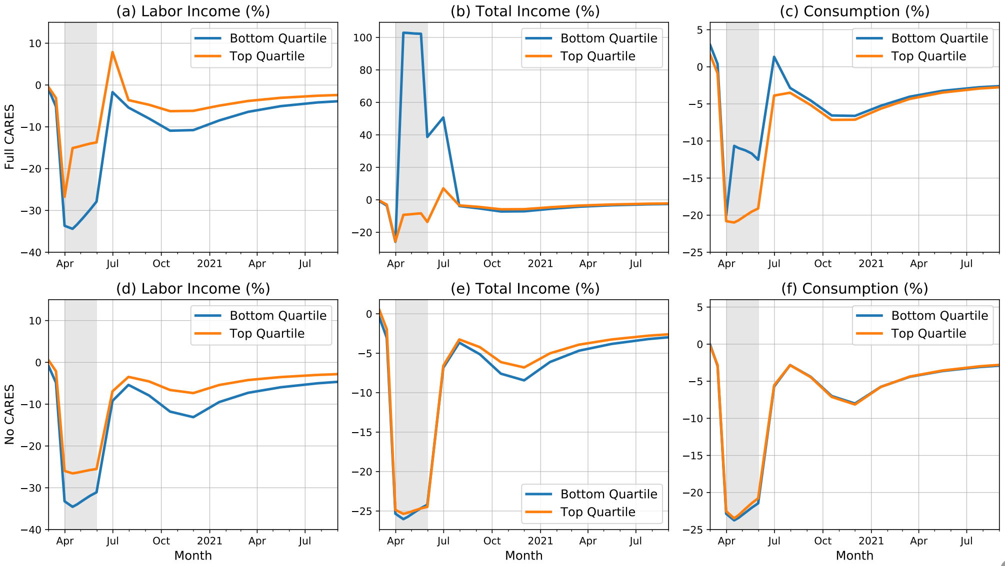
CARES Act by Income Quartile



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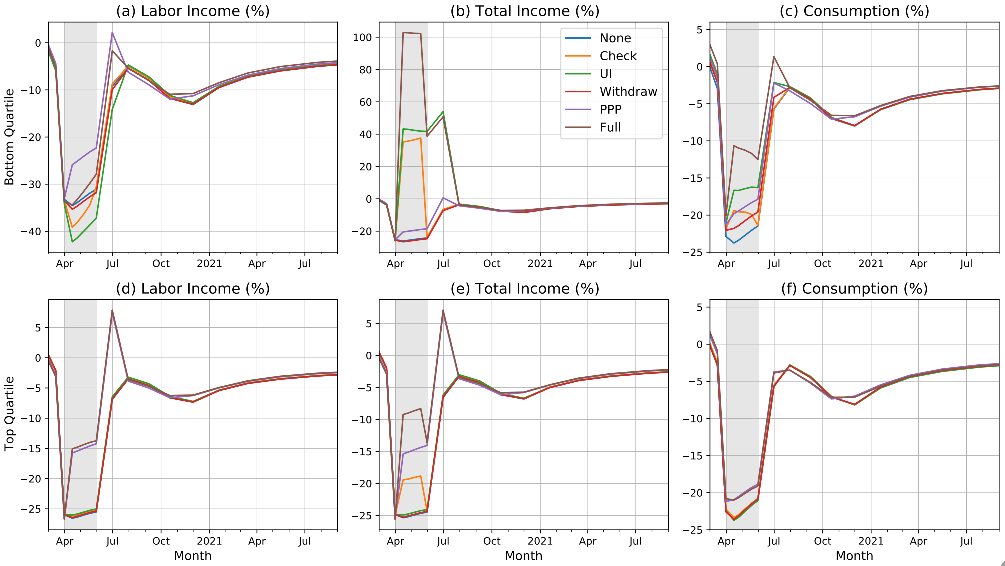
CARES Act Components by Income Quartile



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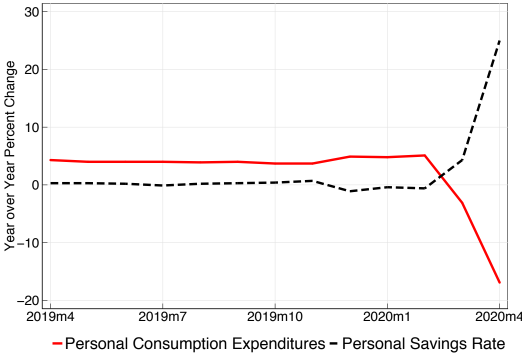
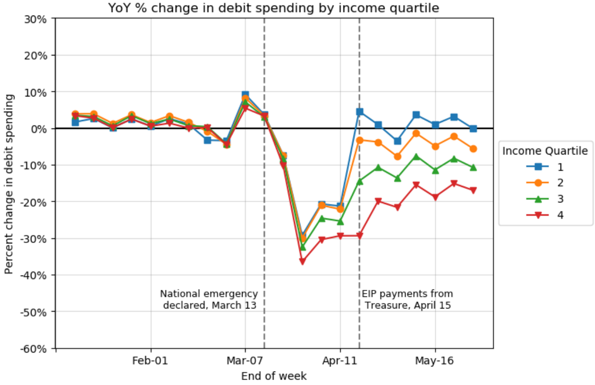
Consumption Dynamics by Income Quartile: US Data





- Source: Cox-Ganong-Noel-Vavra-Wong-Farrell-Greig
- Consumption of poor recovers faster than consumption of rich

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