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)
  • Compare policies without taking stand on economic value of life
  • Seek policies that flatten and shift the frontier

Kaplan, Moll and Violante (2020)
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

Kaplan, Moll and Violante (2020)
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

Kaplan, Moll and Violante (2020)
Outline

1. Model

2. Parameterization

3. Results

4. Conclusions

5. Linked Slides
Epidemiological Model

- \( S_t \): susceptible
- \( I_t \): infectious
- \( R_t \): recovered
- \( E_t \): exposed = latent virus, not yet infectious
- \( C_t \): critical = in ICU, may ultimately die
- \( N_t \): population = \( S_t + E_t + I_t + C_t + R_t \)

\[
\begin{bmatrix}
\dot{S}_t \\
\dot{E}_t \\
\dot{I}_t \\
\dot{C}_t \\
\dot{R}_t
\end{bmatrix} =
\begin{bmatrix}
-\beta_t \frac{I_t}{N_t} & \beta_t \frac{I_t}{N_t} & 0 & 0 & 0 \\
0 & -\lambda_E & \lambda_E & 0 & 0 \\
0 & 0 & -\lambda_I & \lambda_I \chi & \lambda_I (1 - \chi) \\
0 & 0 & 0 & -\lambda_C & \lambda_C (1 - P(C_t, C_{max})) \\
\lambda_R & 0 & 0 & 0 & -\lambda_R
\end{bmatrix}
\begin{bmatrix}
S_t \\
E_t \\
I_t \\
C_t \\
R_t
\end{bmatrix}
\]

- Deaths (flow) \( \dot{D}_t = P(C_t, C_{max}) \lambda_C C_t \), cumulative deaths \( D_t \)

Two key features:

1. Death probability of \( C_t \)'s depends on \( C_t \geq \text{max ICU capacity } C_{max} \)
2. \( \beta_t = \beta(C_{st}, L_{wt}, t) \): transmission depends on economic activity and time
Occupations (j)

<table>
<thead>
<tr>
<th></th>
<th>Flexible</th>
<th>Rigid</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-intensive</td>
<td>Software engineer, architect</td>
<td>Car mechanic, miner</td>
</tr>
<tr>
<td>S-intensive</td>
<td>Event planner, social scientist</td>
<td>Waiter, shop assistant</td>
</tr>
<tr>
<td>Essential</td>
<td>Police, nurse, supermarket clerk</td>
<td></td>
</tr>
</tbody>
</table>

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, $(\xi_j^s, \xi_j^c)$

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

3. **Essential occupations**: not affected by workplace lockdown

Kaplan, Moll and Violante (2020)
Households

• Period utility: \( U[c, s, h] - V[\ell_w, \ell_r, h] \)
  
  • \( c \): regular consumption
  • \( \ell_w \): workplace hours
  • \( h \): home production
  
  • \( s \): social consumption
  • \( \ell_r \): remote hours

Kaplan, Moll and Violante (2020)
Households

• Period utility: \( U[c, \upsilon_s(\dot{D})s, h] - V[\upsilon_\ell(\dot{D})\ell_w, \ell_r, h] \)

  - \( c \): regular consumption
  - \( s \): social consumption
  - \( \ell_w \): workplace hours
  - \( \ell_r \): remote hours
  - \( h \): home production
  - \( \upsilon_s, \upsilon_\ell \): disutility of infection risk (“fear factor”)

• Externality: when choosing \( s, \ell_w \), do not take into account effect on \( \dot{D}_t \), disutility of others

• Budget constraint of healthy household working in occupation \( j \)

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

  - \( b \): liquid assets
  - \( a \): illiquid assets
  - \( \phi^j \in [0, 1] \): flexibility of occupation \( j \)
  - \( \chi \): transaction cost

• Sick households (= \( C \), in ICU): cannot produce, gov’t provides \( c \) and \( s \)
Lockdowns

1. Social sector lockdown: Mandated decrease in $K$ utilization in $s$ sector
   \[ Y_s = Z_s (\kappa_s K_s)^{\alpha_s} N_s^{1-\alpha_s}, \quad \kappa_s < 1 \]

2. Workplace lockdown: Mandated maximum (share of) workplace hours
   \[ \ell_w \leq \kappa_\ell (\ell_w + \ell_r), \quad \kappa_\ell < 1 \]
   - 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 $C_{\text{max}}$
     4. “learning” = logistic time trend in $\beta_t$
Remaining Model Ingredients

Firms

• Monopolistic intermediate-good producers → 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
1. Model

2. Parameterization

3. Results

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5. Linked Slides
Key Aspects of Parameterization

1. Epidemiological block
   - SEIR parameters: epidemiological and clinical studies

2. Occupational parameters
   - Flexibility measures by occupation: O*NET, ATUS
   - Sectoral employment intensities in C and S: OES, CPS
   - Earnings and liquid wealth by occupation: SIPP, CPS, SCF

3. Two-way feedback: virus ↔ economic activity
   - Economic activity → virus: drop in $R_t$ after lockdown
   - Virus → economic activity: VSL literature
Model fits deaths data reasonably well despite simple epi block

Cumulative Deaths (Thousands)

- US Policy
- Data (until Sept. 11th)
- IHME Projection

Kaplan, Moll and Violante (2020)
Outline

1. Model

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4. Conclusions

5. Linked Slides
• Calibrated to obtain decline in workplace and retail activity (Google)
• Assumption: no future lockdown in case of 2nd wave
• Lockdown $\rightarrow$ second wave, but fewer cumulative deaths
• Lockdown $\rightarrow$ longer, deeper contraction and $W$-shaped recovery
Laissez-faire vs Lockdown Dynamics

- Large drop in income for S-intensive occupations even in laissez faire
- Lockdown → further drop in income for C-intensive occupations

Kaplan, Moll and Violante (2020)
• 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
Distribution of Economic Welfare Costs

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

Kaplan, Moll and Violante (2020)
CARES Act Shifts Down the PPF

- CARES Act: stimulus checks, pandemic UI, PPP

Kaplan, Moll and Violante (2020)
Distribution of Economic Welfare Costs

- Big impact of CARES Act on households below the median

Kaplan, Moll and Violante (2020)
Consumption Dynamics

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

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

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**Smarter Alternative Policies**

(a) Comparison
- Mean: US Lockdown
- Mean: Lockdown w/ C Sector Exempted
- Mean: Social Consumption Tax
- Mean: Workplace Hours Tax

(b) Lockdown w/ C Sector Exempted
- Mean
- p10-p90
- p25-p75

(c) Social Consumption Tax
- Mean
- p10-p90
- p25-p75

(d) Workplace Hours Tax
- Mean
- p10-p90
- p25-p75

Kaplan, Moll and Violante (2020)
Outline

1. Model

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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 ⇒ 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!
Outline

1. Model
2. Parameterization
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5. Linked Slides
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
   (Baqee-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. ...
Background on Lockdowns in SIR Models

- Some vocabulary:
  1. Basic reproduction number: \( R_0 := \frac{\beta_0}{\lambda_t} \)
  2. Effective reproduction number: \( R^e_t := R_0 \times \frac{S_t}{N_t} \)
  3. Herd immunity threshold: \( \frac{S^*/N}{R^e_t} := \frac{1}{R_0} \) or \( \frac{R^*/N}{R_0} = 1 - \frac{S^*/N}{R^e_t} = 1 - 1/R_0 \)
  4. Final size of disease: \( S_\infty = e^{-R_0(1-S_\infty)} \)

- Two key features of SIR models:
  1. Infections \( \uparrow \) if \( R^e_t > 1 \) or \( S > S^* \) and \( \downarrow \) otherwise
  2. Epidemic “overshoot”: total infections > herd immunity, \( S_\infty > S^* \)

- 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

Kaplan, Moll and Violante (2020)
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
  \[ N^c_j + N^s_j = \int z(\ell^i_w(h, a, b, z) + \phi^i \ell^i_r(h, a, b, z)) d\mu, \quad j = 1, \ldots, 5 \]

- Liquid asset market
  \[ B^h = B^g \]

- Illiquid asset market
  \[ A = V_{\text{fund}}(K, \Theta_c, \Theta_s), \quad K = K_c + K_s \]
Epidemiological Parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial basic reproduction number</td>
<td>$R_0^{\text{init}} = \beta_0^{\text{init}} / \lambda_I$</td>
<td>2.5</td>
</tr>
<tr>
<td>Final basic reproduction number</td>
<td>$R_0^{\text{end}} = \beta_0^{\text{end}} / \lambda_I$</td>
<td>2</td>
</tr>
<tr>
<td>Avg. duration of Infectious</td>
<td>$T_I \Rightarrow \lambda_I = 1/T_I$</td>
<td>4.3 days</td>
</tr>
<tr>
<td>Avg. duration of Exposure (latency)</td>
<td>$T_E \Rightarrow \lambda_E = 1/T_E$</td>
<td>5.0 days</td>
</tr>
<tr>
<td>Infection fatality rate</td>
<td>$\text{IFR} = \chi_0 \delta_C$</td>
<td>$0.02 \times 0.33 = 0.066$</td>
</tr>
</tbody>
</table>

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

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

Correlation between Flexibility and Median Liquid Wealth Across Occupations

Weighted Correlation: 0.51

Kaplan, Moll and Violante (2020)
## Occupations: Exposure vs Vulnerability

<table>
<thead>
<tr>
<th>Occupation</th>
<th>$\phi^j$</th>
<th>$\xi_c^j$</th>
<th>$\xi_s^j$</th>
<th>Empl Share</th>
<th>Earnings</th>
<th>Liq Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential</td>
<td>0.1</td>
<td>0.19</td>
<td>0.35</td>
<td>0.31</td>
<td>$45K</td>
<td>$1,300</td>
</tr>
<tr>
<td>CF: C-intensive, Flexible</td>
<td>1</td>
<td>0.57</td>
<td>0.12</td>
<td>0.21</td>
<td>$79K</td>
<td>$18,400</td>
</tr>
<tr>
<td>SF: S-intensive, Flexible</td>
<td>1</td>
<td>0.03</td>
<td>0.19</td>
<td>0.10</td>
<td>$51K</td>
<td>$8,900</td>
</tr>
<tr>
<td>CR: C-intensive, Rigid</td>
<td>0.1</td>
<td>0.19</td>
<td>0.04</td>
<td>0.13</td>
<td>$45K</td>
<td>$1,000</td>
</tr>
<tr>
<td>SR: S-intensive, Rigid</td>
<td>0.1</td>
<td>0.04</td>
<td>0.29</td>
<td>0.24</td>
<td>$32K</td>
<td>$900</td>
</tr>
</tbody>
</table>

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
Feedback: Economic Activity to Virus

• Transmission rate for infections:

\[ \beta_t = \hat{\beta}_t \left( \frac{C_{st}}{C_s} \right)^{\nu_s^B} \left( \frac{L_{wt}}{L_w} \right)^{\nu_w^B} \]

• Google COVID-19 Community Mobility Data:

• Estimates of \( R_t \) drop from 2.5 to 0.8 after lockdown

• Drop in activity of 50% ⇒ elasticities: \( \nu_s^B = \nu_w^B = 0.8 \)

Kaplan, Moll and Violante (2020)
Feedback: Virus to Economic Activity

• Parameterize utility shifters as:

\[
\nu_\ell(\dot{D}) = \exp\left(-\nu^0_\ell \dot{D}^1\right), \quad \nu_s(\dot{D}) = \exp\left(-\nu^0_s \dot{D}^1\right)
\]

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

\[
\log w_{it} = \gamma^0_\ell \left(\nu^0_\ell \dot{D}^1_t\right) + \gamma^1_\ell X_{it}
\]

• 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)
Aggregates Dynamics: Laissez-Faire

(a) Reproduction Number

(b) Infectious (% of Population)

(c) Monthly Death Rate (%)

(d) Output (%)

(e) Consumption (%)

(f) Investment and Share Price (%)

(g) Hours (%)

(h) Labor (%)

(i) Government Debt

Kaplan, Moll and Violante (2020)
Aggregates Dynamics: Lockdown

(a) Reproduction Number
(b) Infectious (% of Population)
(c) Monthly Death Rate (%)
(d) Output (%)
(e) Consumption (%)
(f) Investment and Share Price (%)
(g) Hours (%)
(h) Labor (%)
(i) Government Debt

Kaplan, Moll and Violante (2020)
Cumulative infections and deaths

(a) Cumulative Infections (Millions)

- Laissez-faire
- US Lockdown
- US Policy

(b) Cumulative Deaths (Thousands)

- Laissez-faire
- US Lockdown
- US Policy

Data (until Sept. 11th)
IHME Projection

Kaplan, Moll and Violante (2020)
Economic Welfare Cost Distribution

(a) Economic Welfare Cost
- Laissez-faire
- US Policy
- US lockdown

(b) Lockdown - Laissez-faire

(c) Fiscal - Lockdown

(d) Fiscal - Laissez-faire

Kaplan, Moll and Violante (2020)
Production Possibility Frontier by Occupation

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

Kaplan, Moll and Violante (2020)
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

Kaplan, Moll and Violante (2020)
Aggregates Dynamics: Lockdown + CARES Act

(a) Reproduction Number
(b) Infectious (% of Population)
(c) Monthly Death Rate (%)
(d) Output (%)
(e) Consumption (%)
(f) Investment and Share Price (%)
(g) Hours (%)
(h) Labor (%)
(i) Government Debt

Kaplan, Moll and Violante (2020)
Decomposition of CARES Act Elements

(a) Effective R
(b) Labor Income (%)
(c) Workplace Hours (%)
(d) Monthly Death Rate (%)
(e) Consumption (%)
(f) Share Price (%)

Kaplan, Moll and Violante (2020)
CARES Act by Income Quartile

(a) Labor Income (%)
(b) Total Income (%)
(c) Consumption (%)

(d) Labor Income (%)
(e) Total Income (%)
(f) Consumption (%)

Kaplan, Moll and Violante (2020)
CARES Act Components by Income Quartile

(a) Labor Income (%)
(b) Total Income (%)
(c) Consumption (%)
(d) Labor Income (%)
(e) Total Income (%)
(f) Consumption (%)

Kaplan, Moll and Violante (2020)
Introduction

The Covid-19 pandemic led to a large and immediate decline in U.S. aggregate spending and an increase in aggregate private savings. In this paper, we use anonymized bank account information on millions of JPMorgan Chase customers to measure the microeconomic dynamics underlying these aggregate patterns. Specifically, we use our household level account data to explore how spending and savings over the initial months of the pandemic vary with household-specific demographic characteristics, such as pre-pandemic income and industry of employment.

Figure 1: Aggregate Consumption and Savings

Figure shows the year-over-year growth of Personal Consumption Expenditures and the Personal Savings rate, calculated from monthly Bureau of Economic Analysis data.

Measuring and understanding the link between income, spending, and savings is useful for understanding the causes and dynamics of this recession. For instance, the relationship between individual income, spending and savings can shed light on the role of supply factors (such as shut-downs and reducing activities with high infection risk) versus demand factors (such as Keynesian spill-overs across sectors as unemployed workers reduce spending). Understanding these factors can be informative about the effectiveness of different stimulus policies for targeting different households and businesses.

Many data sets have already been used to study the dynamics of geographic level spending during the pandemic, but aggregated relationships may or may not be identical to those at the individual household level at which economic behavior is ultimately determined.

Our paper provides an initial step in analyzing these household-level dynamics.

To differentiate the role of income from the role of physical location, we look at the relationship between income and spending over the pandemic within narrow geographic areas. In particular, we compute the following regression:

\[
c_{2020, z, q} - c_{2019, z, q} = \text{Quartile}_q + \text{ZIP}_z + \#_z, q
\]

where \(c_{t, z, q}\) is average spending per customer with \(t\) as the year (for the time period April 15-May 28), \(z\) is zip code and \(q\) is the income quartile. We take two steps to minimize the influence of outliers. First, note that the denominator is \(\bar{c}_{2019, q}\) which uses everyone in the income quartile. This prevents

Source: Cox-Ganong-Noel-Vavra-Wong-Farrell-Greig

Consumption of poor recovers faster than consumption of rich

Kaplan, Moll and Violante (2020)