Health, Consumption, and Inequality

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Work in Progress (still)
Motivation

- Inequality is one of the themes of our time.
  - Large body of literature documenting inequality in labor earnings, income, and wealth across countries and over time
    Katz, Murphy (QJE 1992); Krueger et al (RED 2010); Piketty (2014)
    Kuhn, Ríos-Rull (QR 2016); Khun et al (2017)

- We also know of large socio-economic gradients in health outcomes
  - In mortality
    Kitagawa, Hauser (1973); Pijoan-Mas, Rios-Rull (Demography 2014)
    De Nardi et al (ARE 2016); Chetty et al (JAMA 2016)
  - In many other health outcomes
    Marmot et al (L 1991); Smith (JEP 1999)
    Bohacek, Bueren, Crespo, Mira, Pijoan-Mas (2018)

- We want to compare and relate inequality in health outcomes to pure economic inequality.
The project

1. Write a model of consumption, saving and health choices featuring
   (a) Health-related preferences
   (b) Health technology

2. Use the FOC (only) to estimate (a) and (b)
   - Consumption growth data to estimate how health affects the marginal utility of consumption
   - Standard measures of VSL and HRQL to infer how much value individuals place on their life in different health states
   - Medical health spending, health transitions (and people’s valuation of life) to infer health technology

3. Use our estimates to
   - Welfare analysis: compare different groups given their allocations
   - Ask what different groups would do if their resources were different and how much does welfare change
   - Evaluate public policies?
Main empirical challenge

- **Theory:**
  - Out-of-pocket expenditures improve health

- **Data:**
  - Cross-section: higher spending leads to better health transitions across groups (education, wealth)
  - Panel: higher spending leads to worse outcomes
    - unobserved health shocks spur medical spending

- **Add explicitly into the model**
  - Unobserved shock to health between $t$ and $t+1$ that shapes
    - probability of health outcomes
    - the returns to health spending
  - Higher expenditure signals higher likelihood of bad health shock
Model
Life-Cycle Model (mostly old-age)

1. Individuals state $\omega \in \Omega \equiv I \times E \times A \times H$ is
   - Age $i \in I \equiv \{50, \ldots, 89\}$
   - Education $e \in E \equiv \{\text{HSD, HSG, CG}\}$
   - Net wealth $a \in A \equiv [0, \infty)$
   - Overall health condition $h \in H \equiv \{h_g, h_b\}$

2. Choices:
   - Consumption $c \in \mathbb{R}^{++} \rightarrow$ gives utility
   - Medical spending $x \in \mathbb{R}_+ \rightarrow$ affects health transitions
   - Next period wealth $a' \in A$

3. Shocks:
   - Unobserved health outlook shock $\eta$
   - Implementation error $\epsilon$ in health spending

4. (Stochastic) Health technology:
   - Health transitions given by $\Gamma^{ei}[h' | h, \eta, x\epsilon]$
   - Survival given by $\gamma^i(h)$ (note no education or wealth)
Uncertainty and timing of decisions

1. At beginning of period $t$ individual state is $\omega = (i, e, a, h)$

2. Consumption $c$ choice is made

3. Health outlook shock $\eta \in \{\eta_1, \eta_2\}$ with probability $\pi_\eta$

4. Health spending decision $x(\omega, \eta)$ is made

5. Medical treatment implementation shock $\log \epsilon \sim N\left(-\frac{1}{2}\sigma^2_\epsilon, \sigma^2_\epsilon\right)$
   - Once health spending is made, the shock determines actual treatment obtained $\tilde{x} = x(\omega, \eta) \epsilon$
   - Allows for the implementation of the Bayesian updating of who gets the bad health outlook shock
The Bellman equation

The retiree version

- The household chooses $c, x(\eta), y(\eta)$ such that

$$ v^{ei}(h, a) = \max_{c, x(\eta), y(\eta)} \left\{ u'(c, h) + \beta^e \gamma^i(h) \sum_{h', \eta} \pi^h \int_{\epsilon} \Gamma^{ei}[h' | h, \eta, x(\eta)\epsilon] v^{e,i+1}[h', a'(\eta, \epsilon)] f(d\epsilon) \right\} $$

- s.t. the budget constraint and the law of motion for cash-in-hand

$$ c + x(\eta) + y(\eta) = a $$

$$ a'(\eta, \epsilon) = [y(\eta) - (\epsilon - 1)x(\eta)]R + w^e $$

- The FOC give:
  - One Euler equation for consumption $c$
  - One Euler equation for health investments at each state $\eta$
FOC for consumption

- Optimal choice of consumption for individuals of type $\omega$
- Standard Euler equation for consumption w/ sophisticated expectation
  (Over survival, health tomorrow $h'$, outlook shock $\eta$, and implementation shock $\epsilon$)

\[
u^i_c[h, c(\omega)] = \beta^e \gamma^i(h) R \\
\sum_{h', \eta} \pi^i_{\eta} \int_{\epsilon} \Gamma^{e i}[h' \mid h, \eta, x(\omega, \eta)\epsilon] u^{i+1}_c[h', c(\omega, \eta, h', \epsilon)] f(\epsilon) \]

- Timing assumptions $\Rightarrow$ consumption independent from shocks $\eta, \epsilon$
- Then, it is easy to estimate w/o other parts of the model:
  - *expected transitions are the same for all individuals of same type $\omega$*
FOC for health spending

- Individuals of type \( \omega \) make different health spending choices \( x(\omega, \eta) \) depending on their realized \( \eta \).

- The FOC for individual of type \( \omega \) is \( \eta \)-specific:

  \[
  \sum_{h'} \int_{\epsilon} \epsilon \Gamma_x^{e_i}[h' \mid h, \eta, x(\omega, \eta)\epsilon] \left\{ v^{e,i+1}[h', a' (\omega, \eta, \epsilon)] \right\} f(d\epsilon) = R \sum_{h'} \int_{\epsilon} \epsilon \Gamma_x^{e_i}[h' \mid h, \eta, x(\omega, \eta)\epsilon] u^{i+1}_c[h', c(\omega, \eta, h', \epsilon)] f(d\epsilon)
  \]

- Expected utility cost of forgone consumption

- In order to use this for estimation we need to
  - Allocate individuals to some realization for \( \eta \)
  - Compute the value function
Estimation
Preliminaries

- We group wealth data $a_j$ into quintiles $p_j \in P \equiv \{p_1, \ldots, p_5\}$
  - State space is the countable set $\Omega \equiv E \times I \times H \times P$

- Functional forms
  - Utility function
    \[ u^i(h, c) = \alpha_h + \chi_h^i \frac{c^{1-\sigma_c}}{1-\sigma_c} \]
  - Health transitions
    \[ \Gamma^{ie}(g|h, \eta, x) = \lambda^{ieh}_0 \eta + \lambda^{ieh}_1 \eta^* \frac{c^{1-\nu^h}}{1-\nu^h} \]

- Estimate several transitions in HRS data
  - Survival rates $\tilde{\gamma}^i_h$
  - Health transitions $\tilde{\Gamma}(h_g|\omega)$
  - Health transitions conditional on health spending $\tilde{\varphi}(h_g|\omega, x)$
  - Joint health and wealth transitions $\tilde{\Gamma}(h', p'|\omega)$
General strategy

• Estimate vector of parameters $\theta$ by GMM without solving the model
  → Use the restrictions imposed by the FOC
  → Need to compute value functions with observed choices and transitions

• Two types of parameters

1/ Preferences: $\theta_1 = \{ \beta^e, \sigma_c, \chi^i_h, \alpha_h \}$
   - Can be estimated independently from other parameters
   - Use consumption Euler equation to obtain $\beta^e, \sigma_c, \chi^i_h$
   - Use VSL and HRQL conditions to estimate $\alpha_h$

2/ Health technology: $\theta_2 = \{ \lambda_{0\eta}^{ieh}, \lambda_{1\eta}^h, \nu^h, \pi_\eta, \sigma^2_\epsilon \}$
   - Requires $\theta_1$ as input
   - Use medical spending Euler equations plus health transitions
   - Problem: we observe neither $\eta_j$ nor $\epsilon_j$
   - Need to recover posterior probability of $\eta_j$ from observed health spending $\tilde{x}_j$
### Data: various sources

1. **HRS**
   - White males aged 50-88
   - Health stock measured by self-rated health (2 states)
   - Obtain the objects $\tilde{\gamma}_h, \tilde{\Gamma}(h_g | \omega), \tilde{\varphi}(h_g | \omega, \tilde{x}), \tilde{\Gamma}(h', p' | \omega)$

2. **PSID (1999+) gives**
   - Households headed by white males aged 50-88
   - Non-durable consumption
   - Out of Pocket medical expenditures

3. **Standard data in clinical analysis**
   - Outside estimates of the value of a statistical life (VSL)
   - Health Related Quality of Life (HRQL) scoring data from HRS
Preliminary Estimates: Preferences
Marginal utility of consumption

**Consumption Euler equation**

- We use the sample average for all individuals $j$ of the same type $\omega$ as a proxy for the expectation over $\eta$, $h'$, and $\epsilon$

$$
\beta^e R \frac{\gamma^i_h}{N_\omega} \sum_j I_{\omega j = \omega} \frac{\chi^i_{h j}}{\chi^i_h} \left( \frac{c'_j}{c_j} \right)^{\bar{\sigma}} = 1 \quad \forall \omega \in \tilde{\Omega}
$$

- Normalize $\chi^i_g = 1$ and parameterize $\chi^i_b = \chi^0_b (1 + \chi^1_b)^{(i-50)}$

- Use cons growth from PSID by educ, health, wealth quintiles

- We obtain
  
  1. Health and consumption are complements
     
     Finkelstein et al (JEEA 2012), Koijen et al (JF 2016)
  2. More so for older people
  3. Uneducated are NOT more impatient: they have worse health outlook
## Marginal utility of consumption

### Results

<table>
<thead>
<tr>
<th></th>
<th>$\beta$ edu specific</th>
<th>$\beta$ common</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>1.5</td>
<td>1.5</td>
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<tr>
<td>$\beta^d$ (s.e.)</td>
<td>0.8861 (0.0175)</td>
<td>0.8720 (0.0064)</td>
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<tr>
<td>$\beta^h$ (s.e.)</td>
<td>0.8755 (0.0092)</td>
<td>0.8720 (0.0064)</td>
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<td>$\beta^c$ (s.e.)</td>
<td>0.8634 (0.0100)</td>
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<td>$\chi_b^0$ (s.e.)</td>
<td>0.9211 (0.0575)</td>
<td>0.9176 (0.0570)</td>
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<tr>
<td>$\chi_b^1$ (s.e.)</td>
<td>-0.0078 (0.0035)</td>
<td>-0.0073 (0.0035)</td>
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<tr>
<td>observations</td>
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<td>15,432</td>
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<td>moment conditions</td>
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<td>240</td>
</tr>
<tr>
<td>parameters</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Notes: estimation with biennial data. Annual interest rate of 2%, annual $\beta$: 0.9413, 0.9357, 0.9292 in first column and 0.9338 in the second one.
Marginal utility of consumption

Results

\[
\frac{c_g}{c_b} = \left(\frac{\chi_g}{\chi_b}\right)^{1/\sigma} = \begin{cases} 
1.057 & \text{at age 50} \\
1.268 & \text{at age 85}
\end{cases}
\]
Value of life in good and bad health

We use standard measures in clinical analysis to obtain $\alpha_g$ and $\alpha_b$

1. Value of Statistical Life (VSL)
   - From wage compensation of risky jobs Viscusi, Aldy (2003)
   - Range of numbers: $4.0M–$7.5M to save one statistical life
   - This translates into $100,000 per year of life saved
   ▶ Calibrate the model to deliver same MRS between survival probability & cons flow Becker, Philipson, Soares (AER 2005); Jones, Klenow (AER 2016)

2. Quality Adjusted Life Years (QALY)
   - Trade-off between years of life under different health conditions
   - From patient/individual/household surveys: no revealed preference
   - Use HUI3 data from a subsample of 1,156 respondents in 2000 HRS
   - Average score for $h = h_g$ is 0.85 and for $h = h_b$ is 0.60
   ▶ Calibrate the model to deliver same relative valuation of period utilities in good and bad health
The value functions

- The value achieved by an individual of type $\omega$ is given by

$$v^{e_i}(h, a) = u^i(c(\omega), h) + \beta^e \gamma^i(h) \sum_{h', \eta} \pi^i_{h\eta} \int_\epsilon \Gamma^{e_i}[h'|h, \eta, x(\omega, \eta) \epsilon] v^{e_i+1}(h', a'(\omega, \eta, \epsilon)) f^x(d\epsilon)$$

with

$$a'(\omega, \eta, \epsilon) = (a - c(\omega) - \epsilon x(\omega, \eta))(1 + r) + w^e$$

- We can compute the value function from observed choices and transitions without solving for the whole model by rewriting the value function in terms of wealth percentiles $p \in P$:

$$v^{e_i}(h, p) = \frac{1}{N_\omega} \sum_j I_{\omega_j = \omega} u^i(c_j, h_j) + \beta^e \gamma^i_h \sum_{h', p'} \Gamma [h', p'|\omega] v^{e_i+1}(h', p')$$

where we have replaced the expectation over $\eta$ and $\epsilon$ by the joint transition probability of assets and health, $\Gamma [h', p'|\omega]$
Preliminary Estimates: health technology
The moment conditions: Preview

• For each $\omega = (i, e, h, p)$, we have four distinct moment conditions.
  
  - (M1) Health spending EE for $\eta_g$
  - (M2) Health spending EE for $\eta_b$
  - (M3) Average Health transitions for $x > \text{median}(x_{\omega})$
  - (M4) Average Health transitions for $x < \text{median}(x_{\omega})$

• We have $210 \times 4 = 840$ moment conditions
  
  - $e$: 3 edu groups $=$ \{HSD, HSG, CG\}
  - $i$: 8 age groups $=$ \{50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85-89\}
  - $h$: 2 health groups $=$ \{$h_g$, $h_b$\}
  - $p$: 5 wealth groups

▷ This gives 240 cells in $\omega$
  
  - But there are 30 cells that are empty (20 in age 85+, 5 in age 80-84)
The Problem

- Key problem: how to deal with unobserved health shock $\eta$
  - Needed to evaluate the moment conditions (M1) to (M4)

- We construct the posterior probability of $\eta$ given observed health investment $\tilde{x}_j$ and the individual state $\omega_j$

$$Pr[\eta_g | \omega_j, \tilde{x}_j] = \frac{Pr[\tilde{x}_j | \omega_j, \eta_g] Pr[\eta_g | \omega_j]}{Pr[\tilde{x}_j | \omega_j]}$$

- where $Pr[\tilde{x}_j | \omega_j, \eta_g]$ is the density of $\epsilon_j = \tilde{x}_j / x(\omega_j, \eta_g)$
- where $Pr[\eta_g | \omega_j] = \pi_{\eta_g}$
- where $Pr[\tilde{x}_j | \omega_j] = \sum_\eta Pr[\tilde{x}_j | \omega_j, \eta] Pr[\eta | \omega_j]$

- We weight every individual observation by this probability
The Problem

- To obtain the posterior distributions we need to estimate
  - the contingent health spending rule, $x(\omega, \eta)$
  - the variance of the medical implementation error, $\sigma^2_c$
  - the probability distribution of health outlooks sock, $\pi_{\eta g}$

- We identify all these objects through the observed health transitions $	ilde{\varphi}(h_g | \omega, \tilde{x})$ as function of the state $\omega$ and health spending $\tilde{x}$

$$
Pr[h_g | \omega, \tilde{x}] = \Gamma[h_g | \omega, \eta_g, \tilde{x}] Pr[\eta_g | \omega, \tilde{x}] + \Gamma[h_g | \omega, \eta_b, \tilde{x}] (1 - Pr[\eta_g | \omega, \tilde{x}])
$$
The Problem

\[ \Gamma(h' | h, x, \eta_g) \] and \[ \Gamma(h' | h, x, \eta_b) \]

from data (HRS)

\[ \phi(x) \] from data (HRS)
Moment conditions

Health Spending Euler Equation

- Moment conditions (M1) to (M2) identify the curvature $\nu^h$ and slope $\lambda^h_{1\eta}$ of the health technology

- $\forall \omega \in \tilde{\Omega}$ and $\forall \eta \in \{\eta_g, \eta_b\}$ we have

$$\frac{1}{M_{\omega \eta}} \sum_j 1_{\omega_j = \omega} \tilde{x}_j \Gamma^{e_j i_j}_{x} [h_g | h_j, \eta, \tilde{x}_j] \left[ \nu^{e_j,i_j+1}(h_g, p'_j) - \nu^{e_j,i_j+1}(h_b, p'_j) \right] \Pr[\eta | \omega_j, \tilde{x}_j] =$$

$$R \frac{1}{M_{\omega \eta}} \sum_j 1_{\omega_j = \omega} \tilde{x}_j \left( \sum_{h'} \Gamma^{e_j i_j'}_{x} [h' | h_j, \eta, \tilde{x}_j] \chi^{i_j+1}(h') \left[ c^{e_j,i_j+1}(h', p'_j) \right]^{-\sigma_c} \right) \Pr[\eta | \omega_j, \tilde{x}_j]$$

where $M_{\omega \eta} = \sum_j 1_{\omega_j = \omega} \Pr[\eta | \omega_j, \tilde{x}_j]$

- Note we use $c^{e,i}(h, p)$ (a group average consumption) and $\nu^{e,i}(h, p)$
Moment conditions

Average Health Transitions

- Moment conditions (M3) to (M4) identify the $\lambda_{ie}^{0\eta}$

- $\forall \omega$ and $X \in \{X_L(\omega), X_H(\omega)\}$ we have

\[
\tilde{\Gamma}(h_g|\omega, X) = \sum_{\eta} \frac{1}{M_{\omega \eta X}} \sum_j 1_{\omega_j=\omega, \tilde{x}_j \in X} \left[ \lambda_{ieh}^{\eta} + \lambda_{ih}^{\eta} \frac{\tilde{x}_j^{1-\nu^h}}{1-\nu^h} - 1 \right] \Pr[\eta|\omega_j, \tilde{x}_j]
\]

where

- $M_{\omega \eta X} = \sum_j 1_{\omega_j=\omega, \tilde{x}_j \in X} \Pr[\eta|\omega_j, \tilde{x}_j]$
- $X_L(\omega) = \{x \leq \tilde{x}_{\text{med}}(\omega)\}$
- $X_H(\omega) = \{x > \tilde{x}_{\text{med}}(\omega)\}$
Estimates of $\nu$ and $\lambda_1$

- Less curvature in health production than in consumption

  $\Rightarrow$ *ceteris paribus*, health expenditure shares increase with income
  
  (As in Hall, Jones (QJE 2007), but completely different identification)

  - But: in the cross-sectional data health expenditure shares unrelated to income
    
    - Poorer individuals have larger gains to leave bad health state

- Bad health outlook shock $\eta_b$ increases return to money
  
  (especially so in good health state)

<table>
<thead>
<tr>
<th>parameter</th>
<th>with $\pi = 0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\nu(h_g)$</td>
<td>1.2325 (0.022)</td>
</tr>
<tr>
<td>$\nu(h_b)$</td>
<td>0.8204 (0.034)</td>
</tr>
<tr>
<td>$\lambda_1(h_g, \eta_g)$</td>
<td>0.0466 (0.0087)</td>
</tr>
<tr>
<td>$\lambda_1(h_g, \eta_b)$</td>
<td>0.0912 (0.0169)</td>
</tr>
<tr>
<td>$\lambda_1(h_b, \eta_g)$</td>
<td>0.0019 (0.0006)</td>
</tr>
<tr>
<td>$\lambda_1(h_b, \eta_b)$</td>
<td>0.0022 (0.0007)</td>
</tr>
</tbody>
</table>
Estimates of $\lambda_0$: Take 1

- Our estimates generate health transitions that are consistent with
  - More educated have better transitions
  - Older have worse transitions
  - Useful medical spending predicts worse transitions in the panel

▷ BUT: *not enough separation of health transitions by wealth*

- Given our estimates of $\lambda_1$ and $\nu$, observed differences of OOP medical spending across wealth types are too small
Health transitions: Wealth Matters in Data not in Model

Data dashed and model dot each wealth quintile

- HSD, \( h_g \)
- HSG, \( h_g \)
- CG, \( h_g \)

- HSD, \( h_b \)
- HSG, \( h_b \)
- CG, \( h_b \)
Estimates of $\lambda_0$: Take 2

- Let’s allow the $\lambda_0$ to depend on wealth
- We parameterize the age and wealth dependence of $\lambda_{0\eta}^{iehp}$ as follows

$$
\lambda_{0\eta}^{iehp} = \frac{\exp(L_{\eta}^{iehp})}{1 + \exp(L_{\eta}^{iehp})}
$$

where $L_{\eta}^{iehp} = a_{\eta}^{eh} + a_{\eta}^{eh} \times (p - 3) + b_{\eta}^{eh} \times (i - 50)$

- We normalize $\pi_{\eta} = 1/2$ and estimate

$$
\theta_2 = \{a_{\eta}^{eh}, a_{\eta}^{eh}, b_{\eta}^{eh}, \lambda_{1\eta}^h, \nu^h, \sigma_{\epsilon}^2\}
$$

(This is $12 + 12 + 12 + 4 + 2 + 1 = 43$ parameters)

- Now: Wealthier experience better health transitions
Health transition with wealth dependent $\lambda_0^p$
$\lambda_0(\eta, i, e, h, p)$ \textbf{graphically}

\begin{align*}
\text{HSD, } h_g & \quad \text{HSG, } h_g & \quad \text{CG, } h_g \\
\text{HSD, } h_b & \quad \text{HSG, } h_b & \quad \text{CG, } h_b
\end{align*}
So what to do about wealth-dependent transitions?

Two strategies

1. Pose unobserved types: something that increases wealth AND health
   - Bad types dissave (cannot be done without fully solving the model).
     WHICH KILLS THE BEAUTY OF THE APPROACH!!!

2. Non-linear (concave) pricing: difference in total health spending by wealth types is larger than in OOP
   - In preliminary estimates w/ MEPS data, the price of medical spending:
     - Declines with medical spending ⇒ concave pricing
       (copyaments lower for more severe treatments)
     - Is lower for the less educated individuals
       (copyaments lower in the public system)
     - Is higher in good health
       (copyaments higher for preventive care)
   - But: MEPS lacks data on wealth
Conclusions
Conclusions

- We have identified preferences for health
  - Consumption is complement with health
  - Differential value of good health seems to be increasing with age.
  - Health is very valuable:
    - Back of the envelope calculation says that the better health of college educated than high school dropouts is worth 5 times the consumption of the latter group.

- Health technology
  - Health expenditures matter little
  - Wealth matters beyond health expenditures
    - Perhaps additional type differences
    - Perhaps concave pricing
    - Perhaps differential use of expenditures