Health and Inequality

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Work in Progress

Introduction

Motivation

- Inequality (economic 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 (2017)

▷ We want to *compare* and *relate* *inequality in health outcomes* to pure *economic inequality*.

What we do

- We develop novel ways of measuring

  a/ Health-related preferences

  b/ Health-improving technology with medical expenditures

- In particular

  1. We use consumption growth data to estimate how health affects the marginal utility of consumption
  2. We use standard measures of VSL and HRQL to infer how much value individuals place on their life in different health states
  3. We use observed medical health spending and people's valuation of life to infer health technology

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) with
   - Household level data on consumption growth
   - Household level data on OOP medical spending
   - Household level data on health outcomes
   - Data on VSL and HRQL standard in clinical analysis
3. Use our estimates to
   - Welfare analysis: compare fate of 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 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
- Resolution:
  - Unobserved shock to health between t and $t+1$ shapes
    - the health outlook
    - the returns to investment
  - Higher expenditure signals higher likelihood of bad health shock

▷ Add this feature explicitly into the model

Model

Model

Life-Cycle Model (mostly old-age)

1. Abusing language, Individuals state $\omega \in \Omega \equiv I \times E \times A \times H$ is
   - Age $i \in I \equiv \{50, \ldots, 89\}$
   - Education $e \in E \equiv \{\text{HSD}, \text{HSG}, \text{CG}\}$
   - 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 η
   - Implementation error ϵ in health spending
4. (Stochastic) Health technology:
   - Survival given by $\gamma^i(h)$ (note no education of wealth)
   - Health transitions given by $\Gamma^{ei}[h' \mid h, \eta, x\epsilon]$. (Back to this)

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 π_η
   - ▷ Mechanism to obtain health transitions that worsen with valuable medical spending x
   - Changes return to health investment and probability of health outcomes
4. Health spending decision $x(\omega, \eta)$ is made
5. *Medical treatment implementation shock* $\log \epsilon \sim N\left(-\frac{1}{2}\sigma_\epsilon^2, \sigma_\epsilon^2\right)$
   - ▷ Mechanism to account for individual variation in health spending
   - Once health spending is made, the shock determines actual treatment obtained $\tilde{x} = x(\omega, \eta)\epsilon$, and also savings $a'(\omega, \eta, \epsilon)$.
   - Allows for the econometric implementation of the Bayesian updating of who gets the bad health outlook shock and who does not.

The Bellman equation

The retiree version

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

$$v^{ei}(h,a) = \max_{c,x(\eta),a'(\eta,\epsilon)} \Big\{ u^i(c,h) + \beta^e \gamma^i(h) \sum_{h',\eta} \pi_\eta^{ih} \int_\epsilon \Gamma^{ei}[h' \mid h,\eta,x(\eta)\epsilon] \; v^{e,i+1}[h',a'(\eta,\epsilon)] \; f(d\epsilon) \Big\}$$

- S.T. the budget constraint and the law of motion for cash in hand

$$\begin{aligned} c + x(\eta) + y(\eta) &= a \\ a'(\eta,\epsilon) &= [y(\eta) - (\epsilon - 1)\, x(\eta)]R + w^e \end{aligned}$$

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

FOC for consumption

- Optimal choice of consumption for individuals of type ω

$$u_c^i[h, c(\omega)] = \beta^e R\, \gamma^i(h)$$
$$\sum_{h'\,\eta} \pi_\eta^{ih} \int_\epsilon \Gamma^{ei}[h' \mid h, \eta, x(\omega, \eta)\epsilon] \quad u_c^{i+1}\left[h', c\left(\omega, \eta, h', \epsilon\right)\right] f(d\epsilon)$$

- Standard Euler equation for consumption w/ sophisticated expectation

  (Over survival, health tomorrow h', outlook shock η, and implementation shock ϵ)

- Note that our timing assumptions Consumption is independent of shocks.

- Then, it is easy to estimate w/o other parts of the model: *expected transitions are the same for all individuals of same type* ω

FOC for health spending

- Individuals of type ω make different health spending choices $x(\omega, \eta)$ depending on their realized η
- The FOC for individual of type ω is η-specific:

$$\underbrace{R \sum_{h'} \int_{\epsilon} \epsilon \, \Gamma^{ei}[h' \mid h, \eta, x(\omega, \eta)\epsilon] \; u_c^{i+1}[h', c(\omega, \eta, h', \epsilon)] \; f(d\epsilon)}_{\text{Expected utility cost of forgone consumption}} =$$

$$\sum_{h'} \int_{\epsilon} \underbrace{\epsilon \, \Gamma_x^{ei}[h' \mid h, \eta, x(\omega, \eta)\epsilon]}_{\text{improvement in health transition}} \; \underbrace{v^{e,i+1}\{h', a'(\omega, \eta, \epsilon)\}}_{\text{value of life tomorrow}} \; f(d\epsilon)$$

- In order to use this for estimation we need to
  - Allocate individuals to some realization for η
  - Compute the value function

The value functions

- The value achieved by an individual of type ω is given by

$$\begin{aligned} v^{ei}(h,a) &= u^{i}(c(\omega),h) \\ &\quad + \beta^{e}\gamma^{i}(h)\sum_{h'\eta}\pi_{\eta}^{ih}\int_{\epsilon}\Gamma^{ei}\left[h'|h,\eta,x(\omega,\eta)\epsilon\right]v^{ei+1}\left(h',a'(\omega,\eta,\epsilon)\right)f^{x}(d\epsilon) \end{aligned}$$

with

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

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

$$v^{ei}(h,p) = \frac{1}{N_{\omega}}\sum_{j}\mathbf{I}_{\omega_j=\omega}\,u^{i}(c_j,h_j) + \beta^{e}\widetilde{\gamma}_{h}^{i}\sum_{h',p'}\widetilde{\Gamma}\left[h',p'|\omega\right]v^{ei+1}(h',p')$$

where we have replaced the expectation over η and ϵ by the joint transition probability of assets and health, $\widetilde{\Gamma}\left[h',p'|\omega\right]$

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 $\widehat{\Omega} \equiv E \times I \times H \times P$
- Functional forms
  - Utility function

$$u^i(h, c) = \alpha_h + \chi_h^i \frac{c^{1-\sigma_c}}{1-\sigma_c}$$

  - Health transitions

$$\Gamma^{ie}(g|h, \eta, x) \quad = \quad \lambda_{0\eta}^{ieh} + \lambda_{1\eta}^{h} \frac{x^{1-\nu^h}}{1-\nu^h}$$

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

General strategy

- Estimate vector of parameters θ by GMM without solving the model
  - $\rightarrow$ Use the restrictions imposed by the FOC
  - $\rightarrow$ Need to compute value functions with observed choices
- Two types of parameters

1/ Preferences: $\theta_1 = \{\beta^e, \sigma_c, \chi_h^i, \alpha_h\}$

- Can be estimated independently from other parameters
- Use consumption Euler equation to obtain $\beta^e, \sigma_c, \chi_h^i$
- Use VSL and HRQL conditions to estimate α_h

2/ Health technology: $\theta_2 = \{\lambda_{0\eta}^{ieh}, \lambda_{1\eta}^{h}, \nu^h, \pi_\eta, \sigma_\epsilon^2\}$

- Requires $\theta_1 = \{\beta^e, \sigma_c, \chi_h^i, \alpha_h\}$ as input
- Use medical spending Euler equations plus health transitions
- Problem: we observe neither η_j nor ϵ_j
- Need to recover posterior probability of η_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 $\widetilde{\gamma}_h^i$, $\widetilde{\Gamma}(h_g|\omega)$, $\widetilde{\varphi}(h_g|\omega, \tilde{x})$, $\widetilde{\Gamma}(h', p'|\omega)$
2. PSID (1999+) gives
   - Households headed by white males aged 50-88
   - We observe individual type ω_j
   - 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 ω as a proxy for the expectation over η, h', and ϵ

$$\beta^e R \, \tilde{\gamma}_h^i \frac{1}{N_\omega} \sum_j \mathbf{I}_{\omega_j = \omega} \frac{\chi_{h'_j}^{i+1}}{\chi_h^i} \left(\frac{c'_j}{c_j} \right)^{-\sigma} = 1 \qquad \forall \omega \in \widetilde{\Omega}$$

- Normalize $\chi_g^i = 1$ and parameterize $\chi_b^i = \chi_b^0 \left(1 + \chi_b^1\right)^{(i-50)}$
- Use cons growth from PSID by educ, health, wealth quintiles
- We obtain
  1. Health and consumption are complements Finkelstein, Luttmer, Notowidigdo (JEEA 2012), Koijen, Van Nieuwerburgh, Yogo (JF 2016)
  2. More so for older people
  3. Uneducated are NOT more impatient: they have worse health outlook

RESULTS

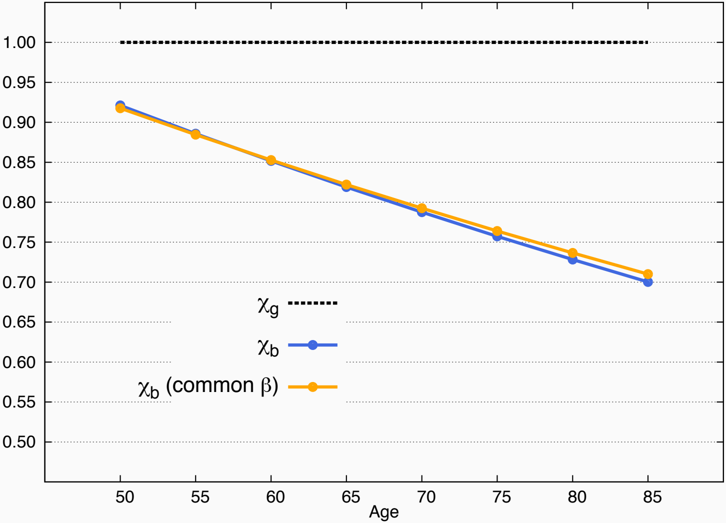
Men sample (with $r = 4.04\%$)

	β edu specific		β common	
σ	1.5		1.5	
β^d (s.e.)	0.8861	(0.0175)	0.8720	(0.0064)
β^h (s.e.)	0.8755	(0.0092)	0.8720	(0.0064)
β^c (s.e.)	0.8634	(0.0100)	0.8720	(0.0064)
χ_b^0 (s.e.)	0.9211	(0.0575)	0.9176	(0.0570)
χ_b^1 (s.e.)	-0.0078	(0.0035)	-0.0073	(0.0035)
observations	15,432		15,432	
moment conditions	240		240	
parameters	5		3	

Notes: estimation with biennial data. Annual interest rate of 2%, annual β: 0.9413, 0.9357, 0.9292 in first column and 0.9338 in the second one.

Marginal utility of consumption

Results



Value of life in good and bad health

We use standard measures in clinical analysis to obtain α_g and α_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 translatesu 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 *Health Utility Index Mark 3* (HUI3) is a HRQL scoring used in clinical analysis Horsman *et al* (2003), Feeny *et al* (2002), Furlong *et al* (1998)
  - Trade-off between years of life under different health conditions
  - From patient/individual/household surveys: no *revealed preference*

- It measures quality of Vision, Hearing, Speech, Ambulation, Dexterity, Emotion, Cognition, Pain up to 6 levels

- It aggregates them into utility values to compare years of life under different health conditions
  - Score of 1 reflects perfect health, score of 0 reflects dead
  - A score of 0.75 means that a person values 4 years under his current health equal to 3 years in perfect health

Preliminary Estimates: health technology

The moment conditions: Preview

- We have
  - 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 ω
  - But there are 30 cells that are empty (20 in age 85+, 5 in age 80-84)
- For each $\omega = (i, e, h, p)$, we have four distinct moment conditions.
  - (M1) Health spending EE for η_g
  - (M2) Health spending EE for η_b
  - (M3) Average Health transitions for $x >$ median(x_ω)
  - (M4) Average Health transitions for $x <$ median(x_ω)
- We have 210×4 = 840 moment conditions

The Problem

- Key problem: How to deal with unobserved health shock η
  - Needed to evaluate the moment conditions (M1) to (M4)
- We construct the posterior probability of η given observed health investment $\tilde{x}_j$ and the individual state ω_j

$$Pr\left[\eta_g|\omega_j,\widetilde{x}_j\right]=\frac{Pr\left[\widetilde{x}_j|\omega_j,\eta_g\right]Pr\left[\eta_g|\omega_j\right]}{Pr\left[\widetilde{x}_j|\omega_j\right]}$$

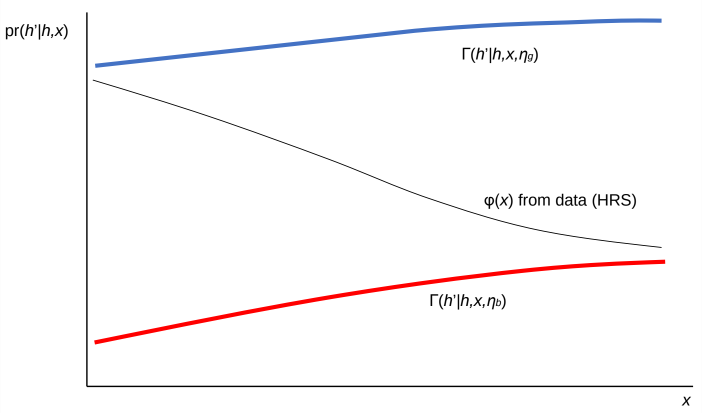
  - where $Pr\left[\widetilde{x}_j|\omega_j,\eta_g\right]$ is the density of $\epsilon_j=\widetilde{x}_j/x\left(\omega_j,\eta_g\right)$
  - where $Pr\left[\eta_g|\omega_j\right]=\pi_{\eta_g}$
  - where $Pr\left[\widetilde{x}_j|\omega_j\right]=\sum_\eta Pr\left[\widetilde{x}_j|\omega_j,\eta\right]Pr\left[\eta|\omega_j\right]$
- 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, σ_ϵ^2
  - the probability distribution of health outlooks sock, $\pi_{\eta_g}^{ih}$
- We identify all these objects through the observed health transitions $\widetilde{\varphi}(h_g|\omega, \tilde{x})$ as function of the state ω and health spending $\tilde{x}$

$$\underbrace{Pr\left[h_g|\omega, \widetilde{x}\right]}_{observed\ \ in\ \ the\ \ data} = \Gamma^{ei}[h_g \mid h, \eta_g, \widetilde{x}] \underbrace{Pr\left[\eta_g|\omega, \widetilde{x}\right]}_{posterior} + \Gamma^{ei}[h_g \mid h, \eta_b, \widetilde{x}] \underbrace{\left(1 - Pr\left[\eta_g|\omega, \widetilde{x}\right]\right)}_{posterior}$$

The Problem



Health Spending Euler Equation

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

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

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

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

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

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

Moment conditions

Average Health Transitions

- Moment conditions (M3) to (M4) identify the $\lambda^{ie}_{0\eta}$
- $\forall\omega$ and $X \in \left\{X_{L(\omega)}, X_{H(\omega)}\right\}$ we have

$$\widetilde{\Gamma}(h_g|\omega, X) = \sum_{\eta} \frac{1}{M_{\omega\eta X}} \sum_{j} \mathbf{1}_{\omega_j=\omega, \tilde{x}_j \in X} \left[\lambda^{ieh}_{0\eta} + \lambda^{ih}_{1\eta} \frac{\tilde{x}_j^{1-\nu^h} - 1}{1-\nu^h}\right] \Pr[\eta|\omega_j, \tilde{x}_j]$$

where

- $M_{\omega\eta X} = \sum_j \mathbf{1}_{\omega_j=\omega, \tilde{x}_j \in X} \Pr[\eta|\omega_j, \tilde{x}_j]$
- $X_{L(\omega)} = \{x <= \tilde{x}_{\mathbf{med}}(\omega)\}$
- $X_{H(\omega)} = \{x > \tilde{x}_{\mathbf{med}}(\omega)\}$

Estimates I

- We parameterize the age-dependence of $\lambda_{0\eta}^{ieh}$ as follows

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

where $L_{\eta}^{ieh} = \mathsf{a}_{\eta}^{eh} + \mathsf{b}_{\eta}^{eh} \times (i - 50)$

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

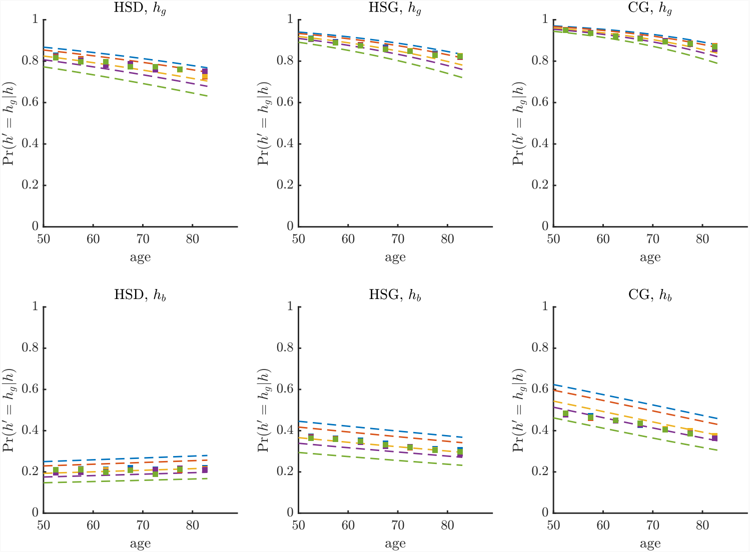
$$\theta_2 = \{\underbrace{\mathsf{a}_{\eta}^{eh}, \mathsf{b}_{\eta}^{eh}}_{\lambda_{\mathbf{0}\eta}^{ieh}}, \lambda_{1\eta}^{h}, \nu^{h}, \sigma_{\epsilon}^{2}\}$$

(This is 12+12+4+2+1 = 31 parameters)

- They 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

Health transitions: Wealth Matters in Data not in Model

Data dashed and model dot each wealth quintile



Estimates II

- Let's allow the λ_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 $L_\eta^{iehp} = \mathtt{a}_\eta^{eh} + \mathtt{ap}_\eta^{eh} \times (p-3) + \mathtt{b}_\eta^{eh} \times (i-50)$

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

$$\theta_2 = \{\underbrace{\mathtt{a}_\eta^{eh}, \mathtt{ap}_\eta^{eh}, \mathtt{b}_\eta^{eh}}_{\lambda_{\mathbf{0}\eta}^{iehp}}, \lambda_{1\eta}^{h}, \nu^h, \sigma_\epsilon^2\}$$

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

- Now: Wealthier experience better health transitions

Parameters ν, λ_1

- If less curvature in health production than in consumption
  - Health expenditure shares would increase with income
  - As in Hall, Jones (QJE 2007) (but completely different ifentification)
- Bad health outlook shock η_b increases return to money (especially so in good health state)

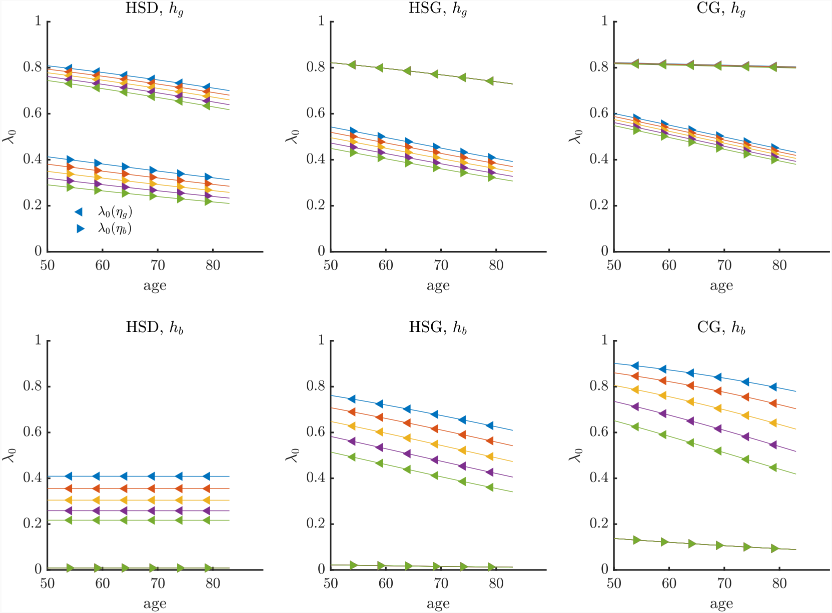
parameter	with $\pi = 0.5$
$\nu(h_g)$	1.2325 (0.022)
$\nu(h_b)$	0.8204 (0.034)
$\lambda_1(h_g, \eta_g)$	0.0466 (0.0087)
$\lambda_1(h_b, \eta_g)$	0.0019 (0.0006)
$\lambda_1(h_g, \eta_b)$	0.0912 (0.0169)
$\lambda_1(h_b, \eta_b)$	0.0022 (0.0007)

- Indeed slightly less curvature than utility but not by much

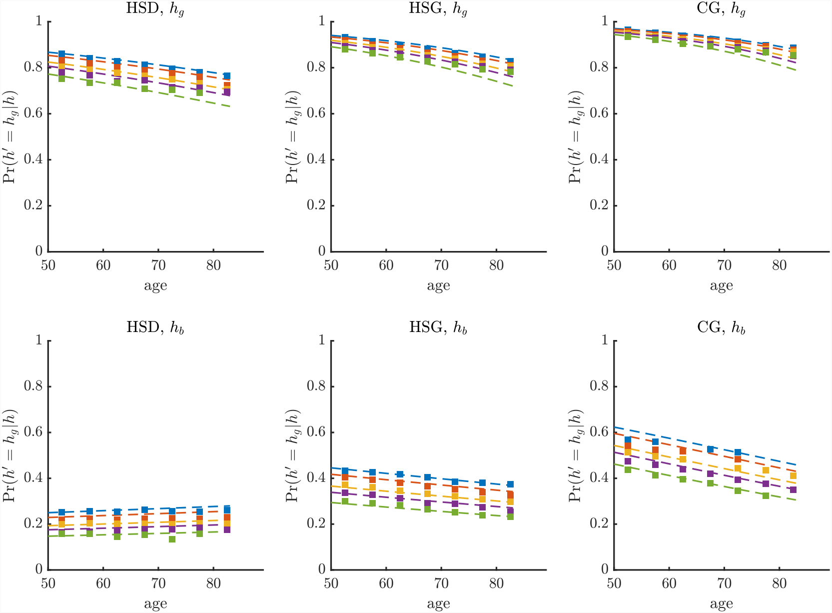
Parameters λ_0

- The parameters λ_0 are identified by the observed average health transitions by type ω given
  - parameters $\lambda_{1\eta}^h$ and ν^h
  - observed health spending by types ω
- To fit average transitions $\lambda_{0\eta}^{ieh}$ are allowed to vary by age i, education e, health h, and shock η
- However, we also need them to vary by wealth quintile p

$\lambda_0(\eta, i, e, h, p)$ GRAPHICALLY



Health transition with wealth dependent λ_0^p



So what to do about wealth dependent transitions?

- Two Strategies

1. Pose unobserved types (like education, there is something else that increases wealth AND health)
   - Unfortunately Type composition changes due to health and death pruning (can be controlled for)
   - Bad types dissave (cannot be done without fully solving the model). WHICH KILLS THE BEAUTY OF THE APPROACH!!!

2. Assume expenditures are missmeasured and yield different quantitites of health investment but in a SYSTEMATIC manner:

$$\widehat{x}^{iehp} = \frac{\sum_p x^{iehp}}{5} + \mu \left(x^{iehp} - \frac{\sum_p x^{iehp}}{5} \right)$$

Another issue: Euler Eq Errors Increase with Age

- Mechanically it comes from the fact that investments are worth less because of shorter residual horizons
- This is evidence perhaps of either
  - Cons Role of out-of-pocket medical expenditures increases with age.
  - Within the context of our model we can make sense of it as increased gradient of the value of good health.
- We have reestimated it with age dependent values of life α_h^i and λ_1^i and this seems to solve the issue:
  - λ_1^i increase some with age
  - $\alpha_g^i - \alpha_b^i$ increase some with age

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 worthe 5 times the consumption of the latter group.
- Expenditures matter some but not so much
  - It matters much more if you start in good health
  - Beyond expenditures and Education Wealth Still Matters:
    - Perhaps additional type differences (beyond those that show up in education)
    - Perhaps differential use of Ependitures