

Causes and consequences of life expectancy inequality

Vegard Mogleiv Nygaard

University of Houston

Workshop on the Economic Challenges of Demographic Inequalities

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Motivation

- Strong relationship between income and life expectancy:
 - 7 year difference in life expectancy between richest and poorest 25 percent of Americans at age 40
- **Question 1:** How can policies be designed to reduce differences in life expectancy across income groups without lowering average life expectancy?
- **Question 2:** What are the consequences of these policy reforms for welfare and the macroeconomy?

This paper

Develops structural life-cycle model with incomplete markets, heterogeneous agents, and endogenous health:

- Health affects mortality risk, medical expenditure risk, and earnings
- Agents can affect their health transition probabilities by choosing a healthier, but more expensive, consumption basket

Applies the model to study the effects of health insurance and income tax reforms:

- Implications for average life expectancy and life expectancy inequality
- Implications for welfare and the macroeconomy

Data and calibration strategy

Measure health in the data:

- Get micro-level panel data on different health indicators
- Construct frailty index: Objective measure of health
- Show how frailty affects mortality risk, medical expenditure risk, and earnings
- Show how frailty covaries with income, education, and wealth

Calibrate model to match observed heterogeneity in health by income:

- Health transition probabilities in model depend on choice of consumption basket:
 - Do not observe consumption in the data
 - Cannot estimate health transition probabilities directly from the data
- Use indirect inference approach to calibrate coefficients of health transition matrix:
 - Income predicts next-period health in the data
 - Calibrate coefficients of health transition matrix to match this relationship

Mechanism and preview of main results

Feedback loop between income and health:

- Health affects income through its effect on labor market outcomes
- Income indirectly affects health by facilitating healthier consumption

Policy reforms:

- Provide universal health insurance:
 - Higher average life expectancy and lower life expectancy inequality
 - Lower healthcare spending, higher GDP/capita, higher steady state welfare
- Expand Medicaid or increase income tax progressivity:
 - Higher average life expectancy and lower life expectancy inequality
 - Lower labor supply, lower capital accumulation, lower GDP/capita

Related literature

Relationship between socioeconomic status and longevity:

- Deaton and Paxson (2001), Lin et al. (2003), Attanasio and Emmerson (2004), Pijoan-Mas and Ríos-Rull (2014), Chetty et al. (2016), Milligan and Schirle (2018)

Life-cycle implications of health shocks:

- Hubbard et al. (1994), Palumbo (1999), De Nardi et al. (1999, 2010), Attanasio et al. (2010), Pashcenko and Porapakkarm (2013), Kopecky and Koreshkova (2014), Braun et al. (2017), De Nardi et al. (2018), Conesa et al. (2018, 2020), Nakajima and Telyukova (2018), Hosseini et al. (2021)

Modeling endogenous health:

- Hall and Jones (2007), Ozkan (2014), De Nardi et al. (2016), Jung and Tran (2016), Scholz and Seshadri (2016), Cole et al. (2018), Pijoan-Mas and Ríos-Rull (2018), Kotera (2018), Fonseca et al. (2020)

Medical literature on health implications of diets:

- Drewnowski and Specter (2004), Danaei et al. (2009), Lim et al. (2012), Murray et al. (2013), Rehm et al. (2016)

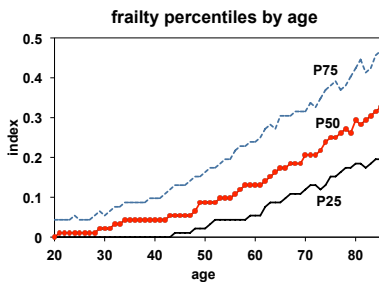
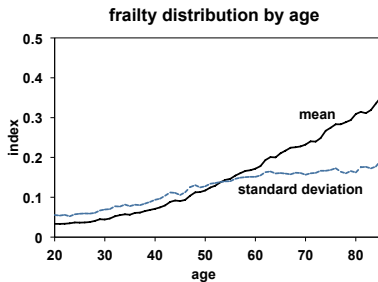
Data

Data strategy

- Study the dynamics and the implications of health in the data
- Get micro-level panel data on health indicators, income, wealth, medical spending, and demographics from two data sources:
 - Medical Expenditure Panel Survey
 - Health and Retirement Study
- Construct frailty index: Objective measure of health:
 - Show that higher frailty is associated with higher mortality risk, higher medical expenditure risk, and lower labor earnings
 - Show that frailty covaries negatively with income, college attainment, and wealth [More](#)
 - Corresponding findings derived by Hosseini et al. (2022)

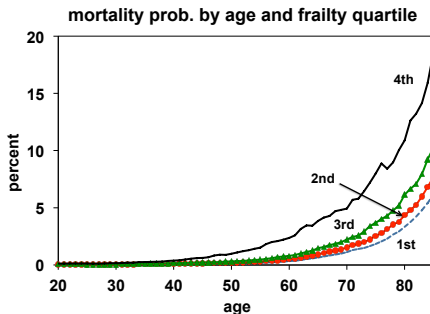
Frailty index

- Construct frailty index: Count how many diseases and disabilities a person has:
 - Follow conventions in the medical literature to construct the index
- Diseases (cancer, high blood pressure, diabetes, etc.)
- Activities of daily living (difficulty walking, dressing, etc.)
- Instrumental activities of daily living (difficulty taking medications, etc.)
- Cognitive impairments Variables



Implications of frailty for mortality risk

- Mortality probabilities by age and frailty estimated by fitting a logistic regression
- Higher frailty associated with higher mortality risk



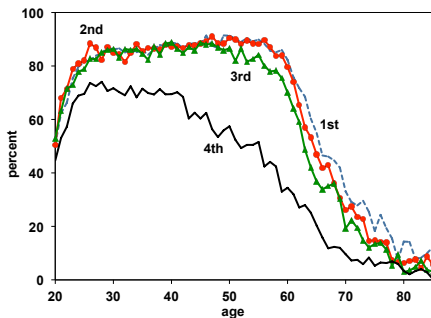
Implications of frailty for medical expenditure risk

- Average total medical spending by age group and frailty percentiles (2009 USD)
- Total medical spending includes all costs covered by private insurance, public insurance, and out-of-pocket
- Higher frailty associated with higher average medical spending

Age group	Frailty quartile				Top	
	1st	2nd	3rd	4th	90-95	95-100
20-64	1,200	1,900	3,400	9,600	11,000	18,300
65+	3,400	5,800	9,200	17,200	18,200	25,200

Implications of frailty for labor market outcomes

- Estimating effect of frailty on labor productivity (hourly wages)
 - Focusing on 25–64 year-olds that work at least 10 hours per week
 - Semi-elasticity of hourly wages with respect to frailty: -0.4
- Higher frailty associated with lower labor productivity
- Computing labor force participation rates by age and frailty quartile
- Higher frailty associated with lower labor force participation



Model

Environment

Consumers:

- Face medical expenditure, labor productivity, and frailty shocks
- Consume generic goods, consume healthy goods, supply labor, save, and choose whether to buy private health insurance

Government:

- Provides Medicare, Medicaid, Social Security
- Runs welfare program that provides minimum consumption
- Finances expenditures through progressive income tax

Health insurance:

- Private health insurance
- Employer-provided health insurance

Firms:

- Hire labor and rent capital from consumers to produce goods

Consumers

- Idiosyncratic state $s = (j, f, a, \eta, \xi, i, e)$: Age, frailty, assets, stochastic labor productivity, medical expenditure shock, health insurance status, education
- Enter economy at age 20
- Education e is permanent (college or non-college)
- Consume generic goods c , consume healthy goods c_h , and supply labor ℓ
 - Generic and healthy goods are perfect substitutes
 - Healthy goods are more expensive, but reduce expected frailty

Relationship between consumption and health in the data

Frailty

- Frailty transition probabilities depend on current frailty, age, education, and healthy consumption: $\mathbb{P}(f'|f, j, e, c_h)$
- Frailty affects:
 - Survival probability $\psi(f, j)$
 - Medical spending distribution $\mathbb{P}(\xi'|\xi, f, j)$
 - Deterministic life-cycle labor productivity $\epsilon(e, f, j)$

Private health insurance

- Consumers can purchase private health insurance for the following period
- Price is actuarially fair for each insurance pool (f, j, ξ) :

$$\pi(f, j, \xi) = \begin{cases} \frac{\psi(f, j)(1 - \chi_P) \int \xi' \mathbb{P}(\xi' | \xi, f, j)}{1 + r'} & \text{if } j < j_r - 1 \\ \frac{\psi(f, j)(1 - \chi_P) \chi_{CARE} \int \xi' \mathbb{P}(\xi' | \xi, f, j)}{1 + r'} & \text{if } j \geq j_r - 1 \end{cases}$$

- Medicare is primary insurance provider for all the elderly:
 - If agents have both pvt. insurance and Medicare, Medicare pays first

Employer-sponsored insurance (ESI)

- A fraction of consumers work for an employer that provides health insurance
- Following Conesa et al. (2018, 2020), consumers cannot opt out of ESI
- Employer pools medical expenses of all its employees and splits the cost evenly across the workers:

$$\pi_E = (1 - \chi_E) \frac{\int \xi \Phi(ds|i = i_E)}{\int \Phi(ds|i = i_E)}$$

Young consumers without ESI (20–64): Value function

- Idiosyncratic state $s = (j, f, a, \eta, \xi, i, e)$: Age, frailty, assets, stochastic labor productivity, medical expense shock, health insurance status, education

$$V(s) = \max_{c, c_h, \ell, a', i'} u(c + c_h, f, \ell) + \beta \psi(f, j) \mathbb{E}_{[f'|f, j, e, c_h]} \mathbb{E}_{[\eta'|\eta]} \mathbb{E}_{[\xi'| \xi, f, j]} V(s')$$

s.t.

$$c + \rho c_h + a' + H(\xi, i) + \mathbb{I}_{i'=i_P} \pi(f, j, \xi) = w\epsilon(e, f, j) \eta \ell - T(y) + TR(s, \ell) + (1+r)(a+B) + \mathbb{I}_{Med}(s, \ell) (1 - \chi_{CAID}) H(\xi, i)$$
$$y = w\epsilon(e, f, j) \eta \ell + r(a+B)$$
$$H(\xi, i) = \mathbb{I}_{i=i_P} \chi_P \xi + (1 - \mathbb{I}_{i=i_P}) \xi$$
$$c, c_h, \ell, a' \geq 0$$
$$i' \in \{i_S, i_P\}$$

- ρ denotes relative price of healthy consumption goods

Young consumers with ESI (20–64): Value function

- Idiosyncratic state $s = (j, f, a, \eta, \xi, i, e)$: Age, frailty, assets, stochastic labor productivity, medical expense shock, health insurance status, education

$$V(s) = \max_{c, c_h, \ell, a'} u(c + c_h, f, \ell) + \beta \psi(f, j) \mathbb{E}_{[f'|f, j, e, c_h]} \mathbb{E}_{[\eta'|\eta]} \mathbb{E}_{[\xi'| \xi, f, j]} V(s')$$

$$\begin{aligned} \text{s.t. } c + pc_h + a' + H(\xi, i) + \pi_E &= w\epsilon(e, f, j)\eta\ell - T(y) \\ &\quad + TR(s, \ell) + (1+r)(a+B) + \mathbb{I}_{Med}(s, \ell)(1 - \chi_{CAID})H(\xi, i) \end{aligned}$$

$$y = w\epsilon(e, f, j)\eta\ell + r(a+B)$$

$$H(\xi, i) = \chi_E \xi$$

$$c, c_h, \ell, a' \geq 0$$

- Consumers with ESI pay health insurance premium π_E
- Share χ_E of medical expenses covered by employer

Old consumers (65–100): Value function

- Idiosyncratic state $s = (j, f, a, \eta, \xi, i, e)$: Age, frailty, assets, stochastic labor productivity, medical expense shock, health insurance status, education

$$V(s) = \max_{c, c_h, \ell, a', i'} u(c + c_h, f, \ell) + \beta \psi(f, j) \mathbb{E}_{[f' | f, j, e, c_h]} \mathbb{E}_{[\eta' | \eta]} \mathbb{E}_{[\xi' | \xi, f, j]} V(s')$$

$$\text{s.t. } c + pc_h + a' + H(\xi, i) + \mathbb{I}_{i'=i_P} \pi(f, j, \xi) = SS(e) + w\epsilon(e, f, j)\eta\ell - T(y) \\ + TR(s, \ell) + (1+r)(a+B) + \mathbb{I}_{Med}(s, \ell)(1 - \chi_{CAID})H(\xi, i)$$

$$y = SS(e) + w\epsilon(e, f, j)\eta\ell + r(a+B)$$

$$H(\xi, i) = \mathbb{I}_{i=i_P} \chi_P \chi_{CARE} \xi + (1 - \mathbb{I}_{i=i_P}) \chi_{CARE} \xi$$

$$c, c_h, \ell, a' \geq 0$$

$$i' \in \{i_S, i_P\}$$

- Old consumers receive Social Security $SS(e)$ and Medicare from the government

Calibration

Utility and Social Security function

- Building on Hall and Jones (2007), utility given by:

$$u(c, e) = b + \frac{((c + c_h)^\gamma (1 - \ell - \mu(f, j))^{1-\gamma})^{1-\sigma}}{1 - \sigma}$$

- $\mu(f, j) = \mu_1 \exp(\mu_2 f) + \mathbb{I}_{j \geq j_r} \mu_3$
 - μ_1 and μ_2 calibrated to match LFPR by frailty quartile
 - μ_3 calibrated to match drop in LFPR at age 65
- Building on Conesa and Krueger (1999), Social Security given by:

$$SS(e) = \frac{d(e) wN}{\int \Phi(ds|j < j_r)}$$

- $d(e)$ denotes education-specific Social Security replacement rates
- N denotes aggregate labor supply

Taxes, labor earnings process, and technology

- Income tax schedule from Gouveia and Strauss (1994):

$$T(y) = a_0 \left(y - (y^{-a_1} + a_2)^{-\frac{1}{a_1}} \right)$$

- $a_0 = 0.258$ and $a_1 = 0.768$ as in Gouveia and Strauss (1994)
 - Adjust a_2 to balance the government budget period-by-period
- Calibrate labor productivity process to match labor earnings distribution as in Castañeda et al. (2003)
- Technology:

$$C + pC_h + G + H + K' - (1 - \delta)K = \theta K^\alpha N^{1-\alpha}$$

Parameters determined outside the model

Parameter	Description	Source	Value
Preference and technology parameters			
J	Maximum life span		81
j_r	Agents receive SS and Medicare		46
α	Capital share of income	Castañeda et al. (2003)	0.36
δ	Depreciation rate	Castañeda et al. (2003)	0.06
γ	Consumption share in utility	French (2005)	0.57
σ	Risk aversion		3.00
	Population growth rate		0.01
	Percent of agents with college degree		0.32
Health insurance coinsurance rates			
χ_P	Private insurance coinsurance rate	MEPS	0.23
χ_E	Employer insurance coinsurance rate	MEPS	0.23
χ_{CARE}	Medicare coinsurance rate	MEPS	0.29
χ_{CAID}	Medicaid coinsurance rate	MEPS	0.14
Medicaid income limits			
y^{CAT}	Medicaid categorical income limit	Kaiser Family Foundation	0.20
y^{MN}	Medicaid medically needy income limit	Kaiser Family Foundation	0.09

Parameters determined jointly in equilibrium

Parameter	Description	Target	Value
Preference and technology parameters			
θ	Choice of units for output	GDP per capita = 1	0.65
β	Discount factor	Capital to output = 3.3	0.96
$d(c)$	SS college replacement rate	Avg. SS college \approx 14,200	0.37
$d(nc)$	SS non-college replacement rate	Avg. SS non-college \approx 11,900	0.31
b	Constant term in utility function	Average frailty at 60	6.50
p	Relative price healthy goods	LE diff. by inc. quart. at 40	1.08
\underline{c}	Guaranteed consumption	Minimum consumption \approx 3,500	0.07
	Eligible for ESI	Perc. with pvt. or emp. ins. = 0.51	0.48
	Scale for healthcare costs	Healthcare spending to GDP = 0.17	1.80
Labor productivity process parameters			
σ_η	Variance	Earnings GINI = 0.67	3.94
η_{top}	Productivity at the top	Earnings top 1% = 0.15	25.02
π_{top}	Probability at the top	Earnings top 10% = 0.44	0.004
ρ_η	Persistence	2-year pers.: Bot. 80% = 0.94	0.91
ρ_{top}	Persistence at the top	2-year pers.: Top 1% = 0.58	0.79

Frailty transition probabilities

- 1 Let frailty transitions follow ordered logistic process that depends on current frailty, age, education, and income
- 2 Estimate process in the data using data from the MEPS
- 3 Estimate same process using simulated data from the model
- 4 Iterate on the parameters of the model and on the coefficients of the frailty transition matrix until the regression estimates coincide [More](#)

Results

Model validation

Targeted calibration moments:

- Distribution of frailty by age and income [More](#)
- Labor force participation rates by age and frailty [More](#)
- Labor earnings distribution [More](#)

Non-targeted calibration moments:

- Wealth distribution [More](#)
- Relationship between wealth and frailty [More](#)

Health insurance reforms

- Universal health insurance reform:
 - Government covers 86.2 percent of all healthcare expenses
- Medicaid categorical reform:
 - Expand Medicaid to all agents with income no greater than 138 percent of the Federal Poverty Level (FPL)
- Medicaid medically needy reform:
 - Expand Medicaid to all agents with income net of out-of-pocket medical expenses no greater than 138 percent of FPL
- Finance reforms by increasing average income taxes (change a_2 in tax function)

Macroeconomic effects of universal health insurance reform

Variable	Benchmark	Universal HI
Life expectancy (years)		
Life expectancy at 20	78.90	79.00
Life expectancy difference at 40 by income quartile	7.01	6.60
Macroeconomic aggregates (% change from bench.)		
GDP per capita	-	0.50
Capital per capita	-	0.68
Effective labor supply per capita	-	0.40
Healthcare spending per capita	-	-0.18
Total consumption per capita	-	0.14
Government spending (percent)		
Government spending to GDP	20.00	24.56
Public healthcare spending to GDP	9.37	13.78
Social Security spending to GDP	4.77	4.82

- Universal HI: Government covers 86.2 percent of healthcare expenses (tax financed):
 - Higher avg. LE, lower LE inequality, higher GDP/capita
 - Higher welfare in steady state (1.82 percent increase in CEV)

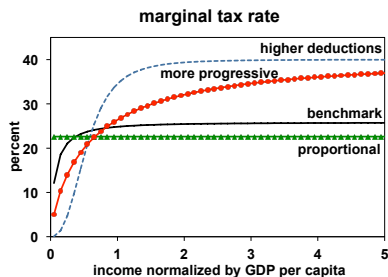
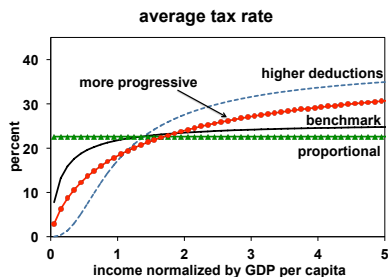
Macroeconomic effects of Medicaid reforms

Variable	Benchmark	y^{CAT}	y^{MN}
Life expectancy (years)			
Life expectancy at 20	78.90	78.92	78.94
Life expectancy difference at 40 by income quartile	7.01	6.80	6.49
Macroeconomic aggregates (% change from bench.)			
GDP per capita	-	-1.07	-2.38
Capital per capita	-	-1.83	-4.48
Effective labor supply per capita	-	-0.63	-1.18
Healthcare spending per capita	-	-0.06	-0.12
Total consumption per capita	-	-1.04	-2.89
Government spending (percent)			
Government spending to GDP	20.00	20.75	22.69
Public healthcare spending to GDP	9.37	9.98	11.79
Social Security spending to GDP	4.77	4.80	4.81

- y^{CAT} : Increase categorical income limit to 138 percent of FPL
- y^{MN} : Increase medically needy income limit to 138 percent of FPL
- Medicaid expansion: Higher average LE, lower LE inequality, lower GDP/capita

Income tax reforms

- Three income tax reforms:
 - Proportional income tax function
 - More progressive income tax function
 - Higher maximum income tax rate but also higher deductions



Macroeconomic effects of income tax reforms

Variable	Bench.	Propor.	Prog.	Deduct.
Life expectancy (years)				
Life expectancy at 20	78.90	78.78	79.08	79.21
Life expectancy difference at 40 by income quartile	7.01	7.34	6.61	6.21
Macroeconomic aggregates (% change from bench.)				
GDP per capita	-	1.77	-1.52	-3.12
Capital per capita	-	4.86	-4.24	-8.08
Effective labor supply per capita	-	0.08	0.04	-0.20
Healthcare spending per capita	-	0.43	-0.59	-1.03
Total consumption per capita	-	0.13	-0.86	-2.56
Government spending (percent)				
Government spending to GDP	20.00	19.88	20.08	20.26
Public healthcare spending to GDP	9.37	9.30	9.34	9.38
Social Security spending to GDP	4.77	4.70	4.85	4.92

- Higher tax progressivity:

- Higher average life expectancy and lower life expectancy inequality
- Lower labor supply, lower saving, lower GDP/capita

Conclusion

Developed structural life-cycle model with incomplete markets, heterogeneous agents, and endogenous health:

- Health affects longevity, medical expenditure risk, and earnings
- Health evolves endogenously depending on healthiness of consumption

Calibrated model to match observed heterogeneity in health by income:

- Constructed frailty index: Objective measure of health
- Used indirect inference approach to calibrate coeffs. of health transition matrix

Used model to study effects of health insurance and income tax reforms:

- Universal health insurance reform:
 - Higher avg. LE, lower LE inequality, higher GDP/capita
- Expand Medicaid or increase income tax progressivity:
 - Higher avg. LE, lower LE inequality, lower GDP/capita

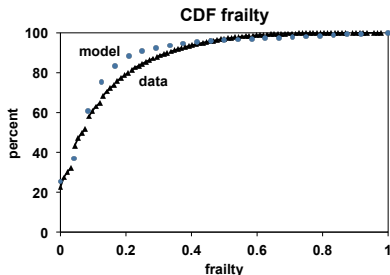
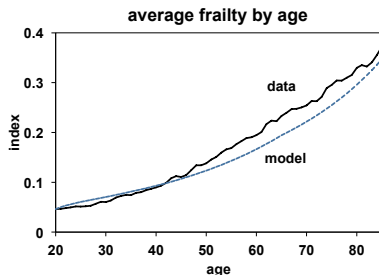
Variables included in the frailty index

- Data source: Medical Expenditure Panel Survey [Back](#)

Variable
Angina diagnosis
Arthritis diagnosis
Asthma diagnosis
Cancer diagnosis
Coronary heart disease diagnosis
High cholesterol diagnosis
Diabetes diagnosis
Emphysema diagnosis
High blood pressure diagnosis
Heart attack (MI) diagnosis
Other heart disease diagnosis
Stroke diagnosis
Need help with activities of daily living (ADLs)
Use assistive devices
Cognitive limitations
Need help with instrument activities of daily living (IADLs)
Limitation in physical functioning
Any limitations with work/housework/school
Health limitations climbing stairs
Health limitations moderate activities
Pain limit normal work
Accomplish less because of physical problems
Work limitations because of physical problems

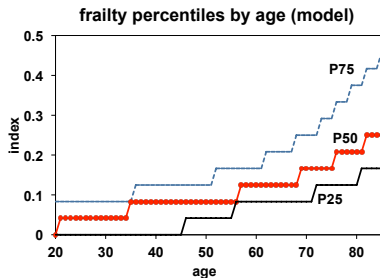
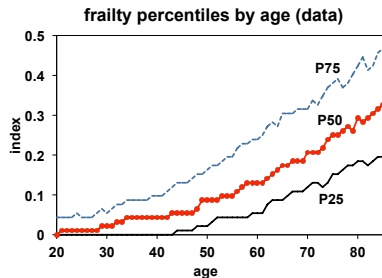
Targeted moments: Distribution of frailty

- Average frailty by age and cumulative distribution function of frailty [Back](#)
- Model closely matches distribution of frailty



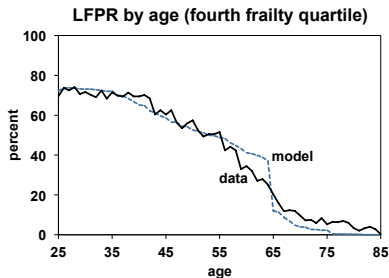
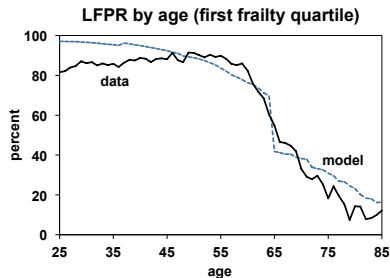
Frailty percentiles by age

- Comparing frailty percentiles by age in the model and the data [Back](#)



Labor force participation rates by age and frailty

- Comparing LFPR by age and frailty quartiles in the model and the data [Back](#)



Targeted moments: Labor earnings distribution

- Labor earnings distribution in the model and the data: [Back](#)
 - Cells denote share of total
 - Data from Kuhn and Ríos-Rull (2013)
- Right skewness of labor productivity process helps match top distribution
- Model closely matches labor earnings distribution

	Quintiles					Top			
	1st	2nd	3rd	4th	5th	90-95	95-99	99-100	Gini
Data	-0.40	3.19	12.49	23.33	61.39	12.38	16.37	14.76	0.63
Model	0.22	4.89	9.66	21.01	64.22	11.77	16.85	14.76	0.63

Non-targeted moments: Wealth distribution

- Wealth distribution in the model and the data: [Back](#)
 - Cells denote share of total
 - Data from Kuhn and Ríos-Rull (2013)
- Model closely matches wealth distribution:
 - Underestimates the concentration at the top

	Quintiles					Top			Gini
	1st	2nd	3rd	4th	5th	90-95	95-99	99-100	
Data	-0.39	1.74	5.72	13.43	79.49	12.62	23.95	29.55	0.78
Model	0.19	0.55	4.85	17.86	76.55	15.93	26.01	14.98	0.75

Non-targeted moments: Frailty-wealth relationship

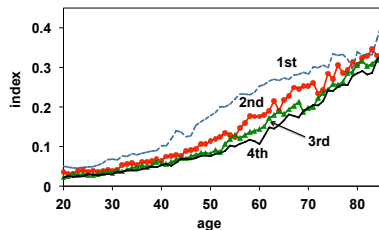
- Average net wealth ratio between first and fourth frailty quartile by age group:
 - Data from the Health and Retirement Study
- Model matches negative relationship between frailty and wealth:
 - Underestimates the relationship for younger agents [Back](#)

	Age group					
	50-54	55-59	60-64	65-69	70-74	75+
Data	3.08	3.14	3.14	2.79	2.36	1.99
Model	1.99	2.42	2.61	2.75	2.64	2.31

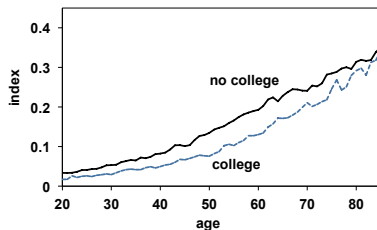
Frailty by age, income, and education

- Compute average frailty by age, income, and education
- Negative relationship between frailty and income
- Negative relationship between frailty and education

average frailty by age and income quartile

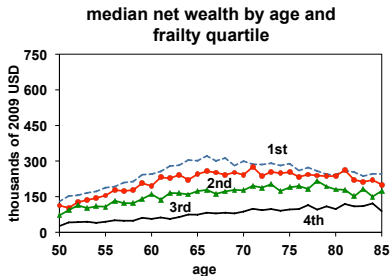
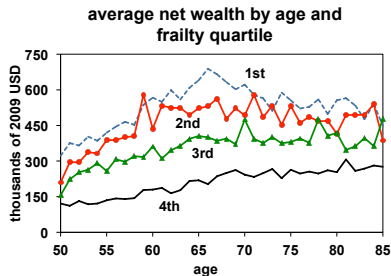


average frailty by age and educational attainment



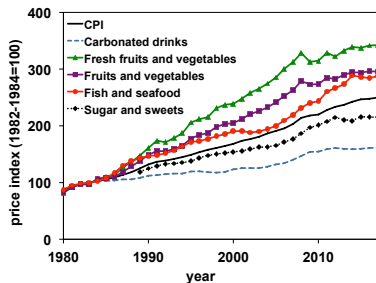
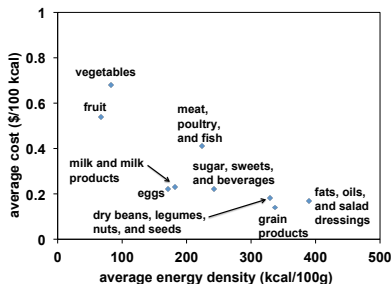
Net wealth by age and frailty

- Compute average and median net wealth by age and frailty
- Net wealth given by total value of housing, autos, savings accounts, IRAs, bonds, stocks, and other assets, net of mortgages and other debts
- Negative relationship between frailty and wealth [Back](#)



Relationship between consumption and health

- Health implications of diets: [Back](#)
 - Danaei et al. (2009) and Lim et al. (2012): Poor diets are among the leading causes of obesity, diabetes, cardiovascular diseases, and cancer
 - Murray et al. (2013): Poor diets account for 25 percent of deaths in the U.S. and 14 percent of disability-adjusted life-years lost
- Drewnowski (2010): Healthier goods tend to have higher price per calorie
- Price differences between healthy and less healthy goods have increased over time



Relationship between income and diets

Rehm et al. (2016) study how diets vary with income:

- They use data from the National Health and Nutrition Examination Survey
 - Detailed cross-sectional data on diets and demographics for a representative sample of Americans
- They compute diet scores based on adherence to the American Heart Association diet recommendations:
 - Poor diet: Less than 40 percent adherence
 - Poor diets associated with increased likelihood of obesity and chronic diseases
- They document large variations in diet quality by income:
 - More than 60 percent of low-income individuals have poor diets
 - Less than 30 percent of middle-income individuals have poor diets
 - These differences in diet scores have widened since 1999 [Back](#)

Frailty transition probabilities cont.

- Numbers in brackets denote 95 percent confidence intervals for data estimates

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Regressor	Data estimate	95% CI	Model estimate
Frailty	1.361	[1.329,1.394]	1.381
Age	0.024	[0.017,0.031]	0.028
Age squared	0.0003	[0.0002,0.0004]	0.0002
Logarithm of income	-0.051	[-0.071,-0.030]	-0.062
Education	-0.090	[-0.128,-0.053]	-0.082