Health Dynamics and Heterogeneous Life Expectancies

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What we do

1. Methodology

   Estimate annual health dynamics from biennial panel data (e.g., HRS, PSID) observed at irregular frequencies
   - MLE keeps track of latent distribution over health in periods of nonresponse
   - Provides estimates of annual transition and survival probabilities

2. Demography

   Quantify the heterogeneity in life expectancy in the US along the health gradient and across race, conditional on sex and socioeconomic status
   - Racial gap at age 50: 3.8 years for women, 3.5 years for men
   - Remains after controlling for health and SES

3. Economics

   Examine the economic implications of the racial life expectancy gap
   - Amplifies differences in Social Security wealth
   - Amounts to $8,400 for black men on average
   - Related to reparations discussion in the US where life expectancy gap plays a major role

Related literature

- Large literature on estimating life expectancies in the population along various dimensions, including the gap between black and white
  - Meara, Richards, and Cutler (2008), Olshansky et al. (2012), Geruso (2012), Hummer and Hernandez (2013), Chang et al. (2015), Chetty et al. (2016), Case and Deaton (2017), Schwandt et al. (2021)
  - Does not take into account the dynamic evolution of health (or other time-variant covariates)
- Papers estimating health dynamics
  - Pijoan-Mas and Ríos-Rull (2014), Amengual, Bueren, and Crego (2021), Hosseini, Kopecky, and Zhao (2021), De Nardi, Pashchenko, and Porapakkarm (2017)
  - Improved methodology and estimation of the racial life expectancy gap
- Literature on the wealth gap between black and white
  - Smith (1995), Altonji, Doraszelski, Segal, et al. (2000), Altonji and Doraszelski (2005), Derenoncourt et al. (2022), Boerma and Karabarbounis (2021)
- Racial gap in retirement wealth
  - Francis and Weller (2021), Hou and Sanzenbacher (2021), Choukhmane et al. (2022)
- Redistributive effects of the SS system due to heterogeneity in longevity
  - Liu and Rettenmaier (2003), Sánchez-Romero and Prskawetz (2017) and Sánchez-Romero, Lee, and Prskawetz (2020), National Academies of Sciences, Engineering and Medicine (2015)
  - Either no racial gap, or no heterogeneity within race

Data & Estimation

Estimation sample

HRS waves 1–12, years 1992–2014 Survey design

	All	Nonblack		Black	
		Male	Female	Male	Female
Sample size					
N. of individuals	34,179	12,737	15,455	2,421	3,566
N. of observations	219,530	81,248	103,879	13,247	21,156
Avg. observations/indiv.	6.4	6.4	6.7	5.5	5.9
Age distribution					
[50, 60)	34.4%	36.0%	32.3%	40.7%	36.8%
[60, 70)	30.6%	31.8%	29.3%	33.0%	31.2%
[70, 80)	21.7%	21.4%	22.4%	18.4%	19.9%
[80, 90)	11.3%	9.5%	13.3%	7.0%	10.0%
90+	2.0%	1.3%	2.8%	1.0%	2.1%
Mean	66.1	65.3	67.0	64.0	65.4

Table 1: Estimation sample

Key variables

- Age, sex, race (black/nonblack)
- Date of death
- Self-reported health: 1 (excellent) to 5 (poor)
  - Respondents aggregate multidimensional information about their health (potentially unobservable to the econometrician) into a single categorical variable
  - Has repeatedly been shown to be (surprisingly) informative

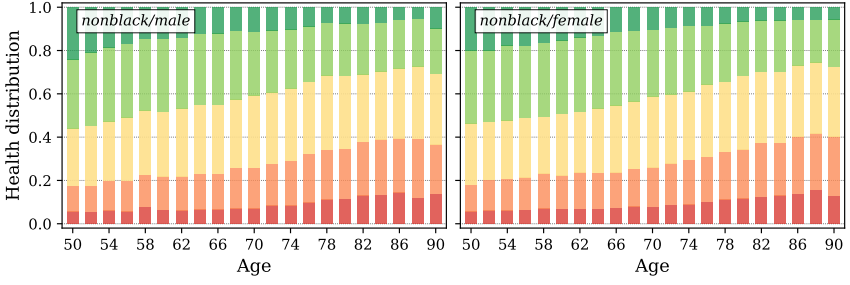

Figure 1: Cross-sectional distribution of self-reported health by age

All groups

Maximum likelihood estimator (MLE)

Main specification

- Estimates age-dependent health/survival dynamics as Markov chain at annual frequency
  - State space: 5 health states + death
  - Transition probabilities follow from a multinomial logit
- Handles irregular intervals between interviews or between last interview and death
  - Tracks latent distribution over health states in periods when individuals are not observed
- Estimated separately for men/women and black/nonblack

Estimation output

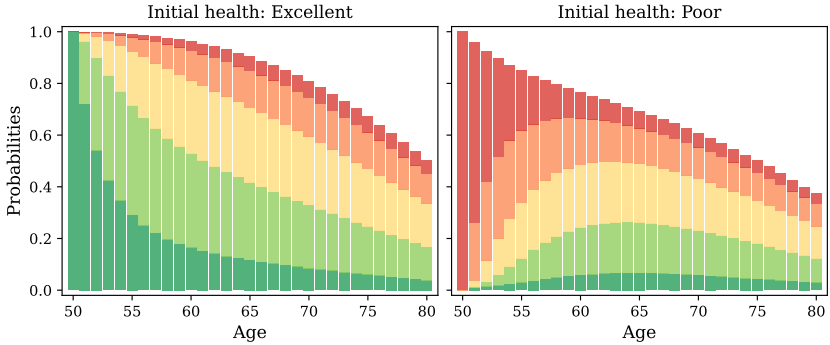

Figure 2: Predicted distribution over health, 50-year old nonblack males.

Prob. of being alive after 30 years: **50.2%** vs. **37.4%**

Health and survival follow an age-dependent yearly five-state Markov chain

All groups

Results:
Life expectancy

Inequality in life expectancy

At age 50

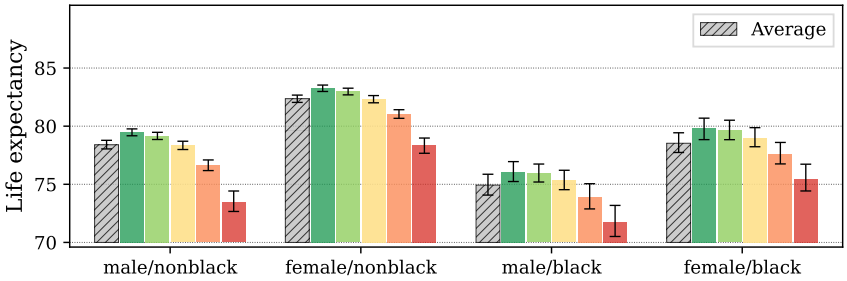

Figure 3: Life expectancy by health state at age 50. Colors indicate health states from excellent to poor. Error bars indicate bootstrapped 95% confidence intervals.

CDF At age 70 Differences across race Differences across sex

Decomposing the racial life expectancy gap

At age 50

What explains the racial life expectancy gap?

	Male	Female
Age 50		
Black life expectancy	74.9	78.5
(a) Nonblack health distribution	+0.4	+0.5
(b) Nonblack health dynamics	+1.2	+1.6
(c) Nonblack mortality	+1.4	+1.7
(d) Interaction effect	+0.4	+0.0
Total nonblack/black difference	+3.5	+3.8

- Health dynamics and mortality much more important for life expectancy differences!

At age 70

Additional covariates

Education

Results

- Education level (fully interacted with age and health)
  1. Less than high school
  2. High school
  3. (Some) college or more

Marital status

Results

- Allowed to be time varying

Permanent income

Results

- Defined as average income in retirement
- Includes Social Security retirement benefits, private pensions and annuities, and government transfers (following De Nardi, French, and Jones (2010))
- Averaged within household
- Imputed for younger individuals

Economic implications

Implications for Social Security wealth

- How much does the current black population lose out in Social Security wealth due to lower life expectancy, holding everything else constant?
- Define Social Security wealth W_t as the present value of expected future retirement income:

$$W_t(\boldsymbol{x}, \text{retinc}) = \sum_{\tau=t}^{T_{max}} \underbrace{\frac{1}{(1+r)^{\tau-t}}}_{\text{Discounting}} \times \underbrace{\Pr\left(\text{alive at } \tau \,\middle|\, \boldsymbol{x}\right)}_{\text{Survival prob.}} \times \underbrace{\text{retinc}}_{\text{from HRS}}$$

  $\boldsymbol{x}$ includes race, sex, health, permanent income and age
- Take as given:
  - Avg. retirement income reported in HRS
  - Distribution over race, sex, health, permanent income and age ≥ 65 from HRS wave 6 (in 2002)
  - Interest rate $r = 2\%$

frame:ssw:final

Descriptive statistics Age distribution

Social Security wealth

Cross-sectional distribution of Social Security wealth in HRS wave 6

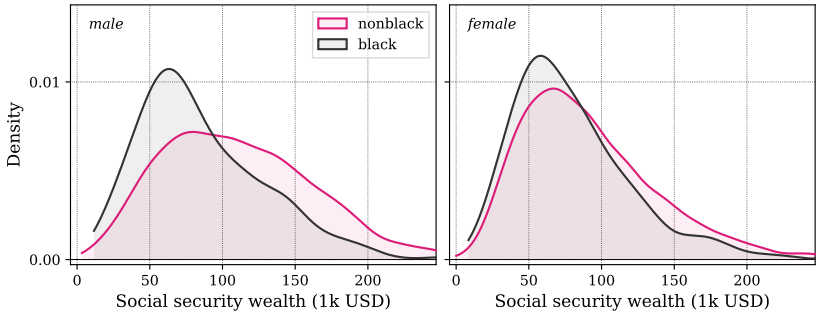

Figure 4: Estimated Social Security wealth (in thousands of year 2000 USD)

Averages: males: $112k vs. $83k; females: $93k vs. $80k

Social Security wealth: role of health and survival

Counterfactual experiments

1. Assign black individuals health dynamics & mortality of comparable nonblack group (age, sex, health, permanent income)
2. Additionally, assign black individuals health distribution of comparable nonblack group

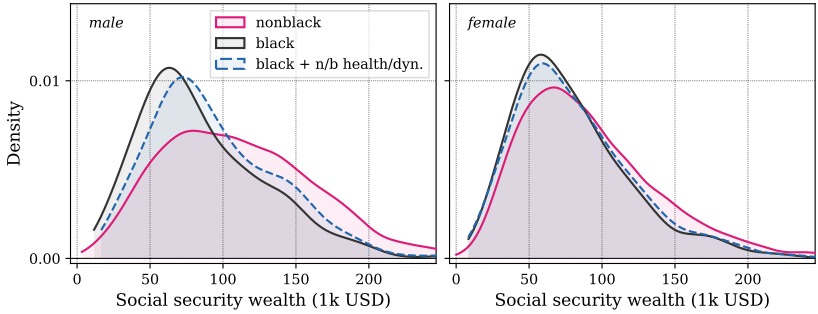

Figure 5: Estimated Social Security wealth (in thousands of year 2000 USD)

Changes in Social Security wealth

Counterfactual experiments result in sizable changes to Social Security wealth among black population.

	Male	Female
(1) Nonblack health dynamics + mortality		
Absolute change	\$6,052	\$479
Relative change	7.5%	−0.4%
% of net total wealth	8.3%	0.9%
% of net financial wealth	58.4%	8.4%
(2) Nonblack health dynamics, mortality + distribution		
Absolute change	\$8,410	\$2,322
Relative change	12.9%	3.2%
% of net total wealth	11.6%	4.5%
% of net financial wealth	81.2%	40.5%

Table 2: Average changes in Social Security wealth for black individuals

- Relative change in SSW computed as $\mathbf{E}\left[\,\Delta W_i / W_i \,|\, sex\,\right]$
- % of net total/financial wealth computed as $\mathbf{E}\left[\,\Delta W_i / net\ wealth_i \,|\, sex\,\right]$

Avg. wealth & income By PI quintile Frac. of wealth

Evaluating the welfare loss

How much is this loss worth in welfare terms? — Answer through the lens of a structural model

Model overview

- Life cycle model of retired individuals a la De Nardi, French, and Jones (2010)
- Each period corresponds to one year
- Individuals differ in terms of
  - Demographics: age, race, sex
  - Health state
  - Permanent income
  - Medical expenditures (persistent and transitory)
  - Wealth
- No attempt to explain differences present at retirement:
  - Initial distribution over states taken from HRS

Household problem Calibration

Welfare effects of lump sum transfer

Average CEV: 2.24% for males, 0.92% for females.

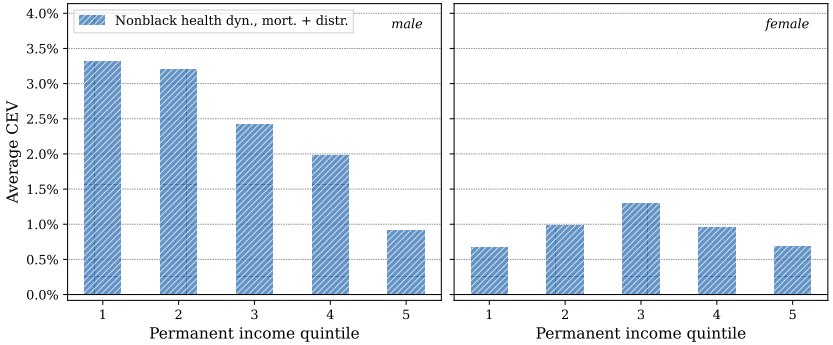

Figure 6: Consumption equivalent variation (CEV) of transferring difference in Social Security wealth to black individuals as lump sum

Details

Conclusions

- We provide improved estimates for an age-dependent annual five-state Markov chain for health and survival probabilities
- Estimates can be used to assess life expectancy inequality in the population
- We show that the racial life expectancy gap is large even controlling for health, education or permanent income
- This has substantial effects on Social Security wealth

Additional slides

Additional slides — Data & Estimation

HRS data (pooled sample)

- Survey design
- Descriptive statistics
- Data structure examples
- Health distribution by age/race/sex
- Attrition by wave
- Wealth / Income by race/sex

HRS data (wave 6, 2002)

- Descriptive statistics
- Age distribution

Predicted health distribution

- All groups

Additional checks

- Long-run survival: model vs. data

Transition & survival probabilities

- Health transitions for nonblack group
- Survival for nonblack group
- Health transitions for black group
- Survival for black group

Transition probabilities: model vs. data

- Nonblack men
- Nonblack women
- Black men
- Black women

Additional results — Life expectancy

Life expectancy (main specification)

- Age 50: CDF50
- Age 70: Life expectancy
- Differences across race
- Differences across sex
- Decomposition at age 70

Life expectancy by education

- Age 50: Life expectancy
- Age 50: Differences across race
- Age 50: Differences across sex

Life expectancy by marital status

- Age 50: Life expectancy
- Age 50: Differences across race
- Age 50: Differences across sex

Life expectancy by permanent income

- Age 50: Life expectancy
- Age 50: Differences across race
- Age 50: Differences across sex
- Age 70: Life expectancy
- Age 70: Differences across race
- Age 70: Differences across sex

Additional slides — Economic model

Social Security wealth

- Wealth differences by PI quintile
- As fraction of net total wealth

Model details

- Household problem
- Calibration
- Medex: Empirical model
- Medex: Moments

Welfare

- Definition

Data: the Health and Retirement Study (HRS)

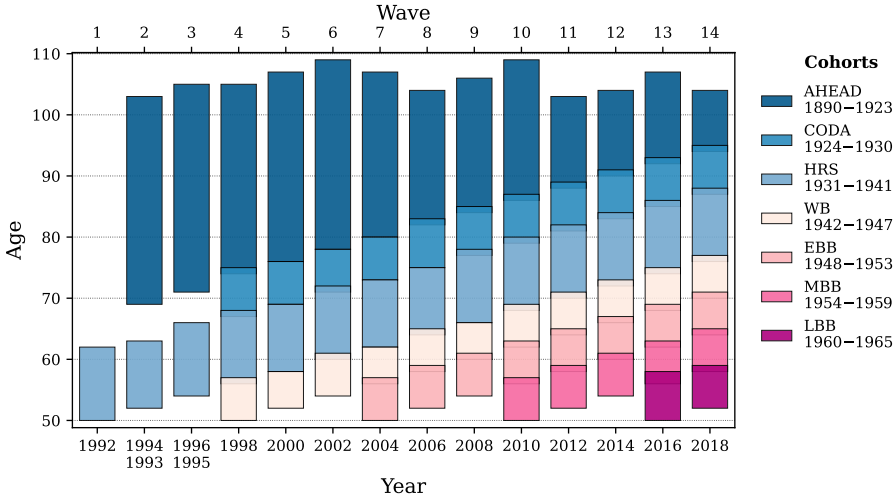

Figure 7: Longitudinal survey design of the HRS.

Estimation sample

Estimation sample

HRS waves 1–12, years 1992–2014

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Sample size					
N. of individuals	34,179	12,737	15,455	2,421	3,566
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90+	2.0%	1.3%	2.8%	1.0%	2.1%
Mean	66.1	65.3	67.0	64.0	65.4

Table 3: Estimation sample

Data structure: examples

HRS is administered every two years, but timing of individual observations may differ.

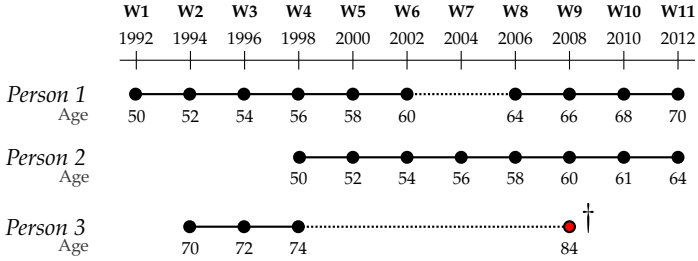


Figure 8: Three individuals in the HRS, illustrating the irregular and missing observations. Waves and calendar years indicate the biennial structure, age indicates the actual age at the time of the interview.

HRS: Health distribution by age/race/sex

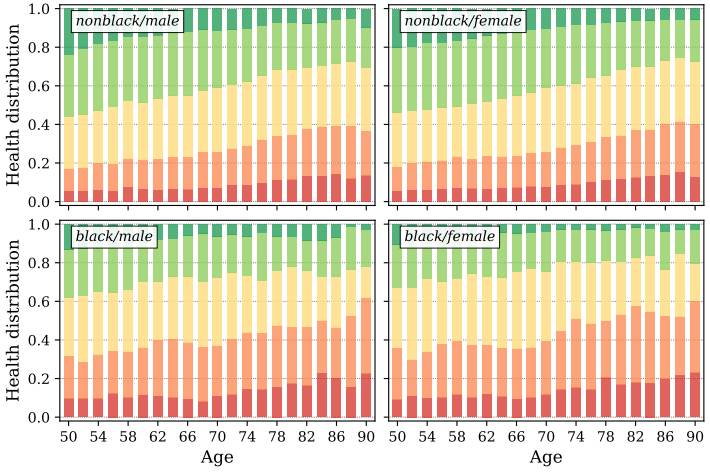


Figure 9: Distribution of health states by age, race and sex.

Back to self-reported health

HRS: Attrition by wave

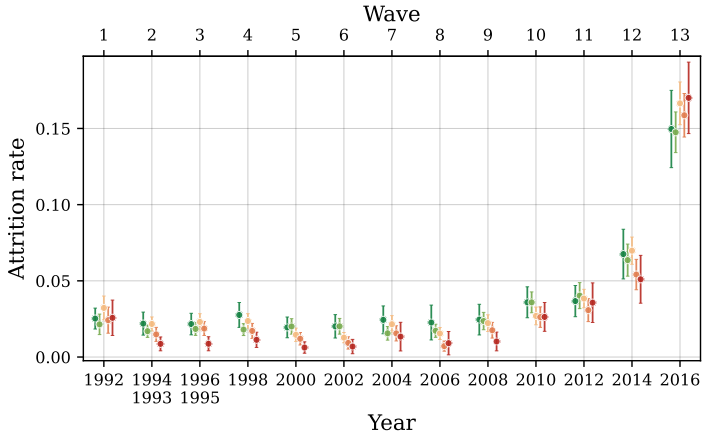


Figure 10: Fraction of participants who do not respond to any of the subsequent survey waves. Dark green indicates best (“excellent”) while red indicates worst (“poor”) health.

HRS: Wealth / Income by race and sex

	Nonblack		Black	
	Male	Female	Male	Female
Net financial wealth	100.4	87.0	10.4	5.7
Net total wealth	272.1	231.8	72.7	51.9
Permanent income	16.6	14.8	12.5	10.8
Average Social Security benefits	11.1	8.4	8.9	7.3

Table 4: Average wealth and income by race/sex (in thousands of year 2000 USD). Wealth measures and permanent income are averaged within households.

Net financial wealth: Stocks, bonds, checking & savings accounts, CDs and all other savings minus other debt (CC, medical debts, loans from relatives, etc.)

Net total wealth: Net financial wealth plus primary residence & any other real estate (excluding secondary residence), businesses, IRAs and Keoghs minus total mortgages and other home loans

Permanent income: (Imputed) average income in retirement, including Social Security benefits, private pensions and annuities, and government transfers (following De Nardi, French, and Jones 2010)

SSW changes

HRS Wave 6 (2002): Descriptive statistics

Sample restricted to individuals aged 65 and above.

	All	Nonblack		Black	
		Male	Female	Male	Female
Sample size					
N. of individuals	10,698	4,003	5,354	517	824
Self-reported health distribution					
(1) Excellent	9.3%	10.8%	9.1%	7.2%	2.8%
(2) Very good	26.2%	26.8%	27.1%	19.5%	16.6%
(3) Good	32.7%	33.0%	32.8%	29.0%	33.1%
(4) Fair	21.2%	20.2%	20.3%	30.2%	32.5%
(5) Poor	10.5%	9.3%	10.8%	14.0%	15.0%
Average age	75.0	74.3	75.7	73.4	74.6
Average remaining lifetime	11.8	11.1	12.5	10.2	12.2

Table 5: Descriptive statistics for HRS Wave 6 (for age $\geq$ 65)

HRS Wave 6 (2002): Age distribution

Sample restricted to individuals aged 65 and above.

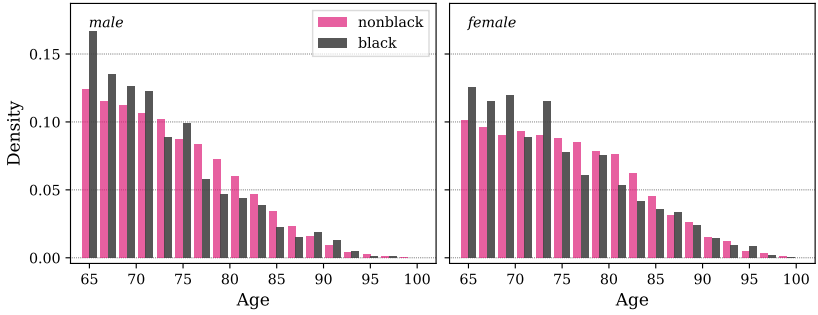


Figure 11: Age distribution in HRS wave 6 (for age $\geq$ 65)

One-year health transition probabilities

Nonblack men/women

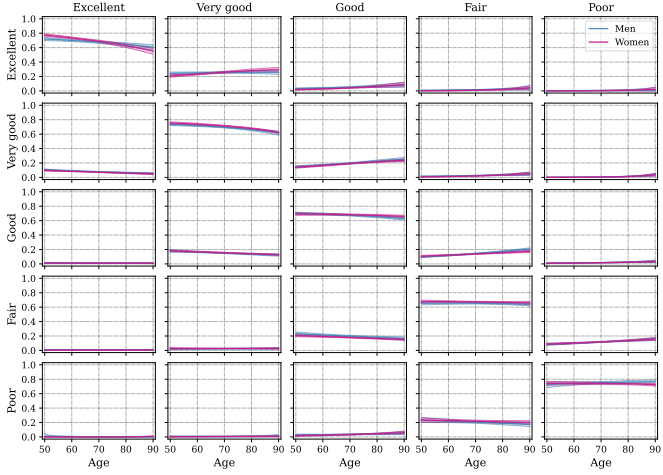


Figure 12: One-year health-to-health trans. probabilities for nonblack men/women. Shaded areas indicate 95% CI.

One-year survival probabilities

Nonblack men/women

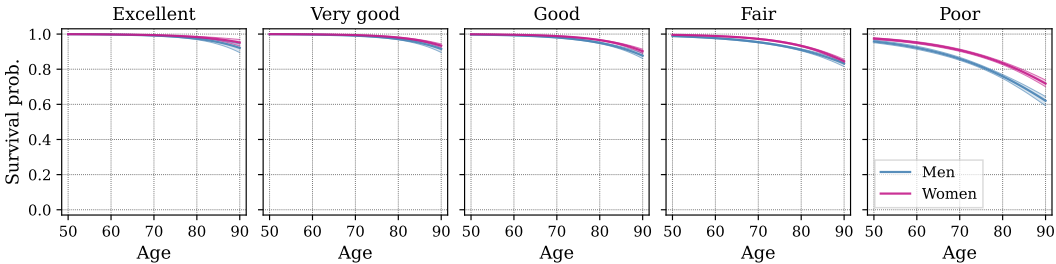


Figure 13: One-year survival probabilities by health for nonblack men/women

One-year health transition probabilities

Black men/women

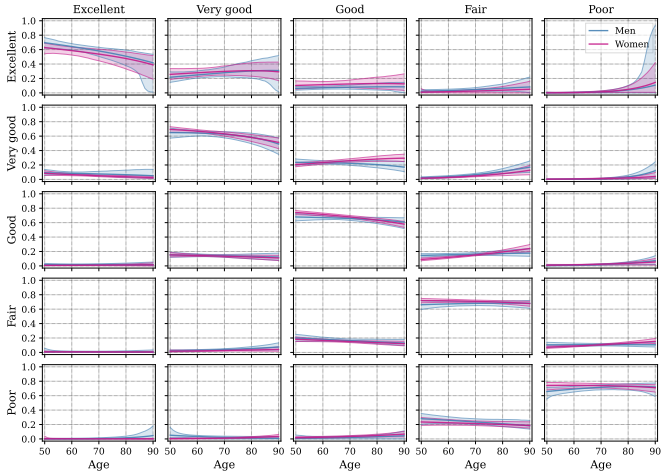


Figure 14: One-year health-to-health trans. probabilities for black men/women. Shaded areas indicate 95% CI.

One-year survival probabilities

Black men/women

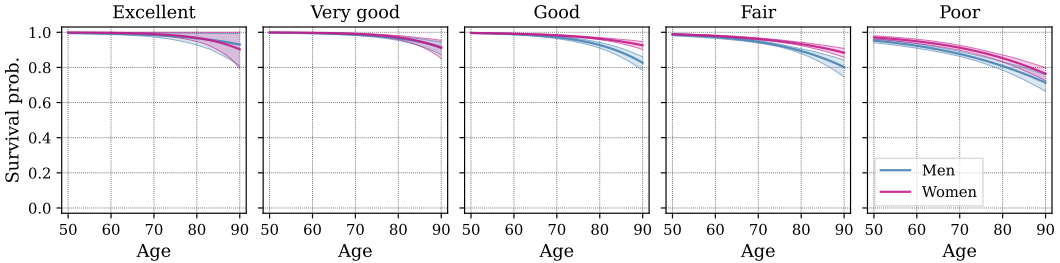
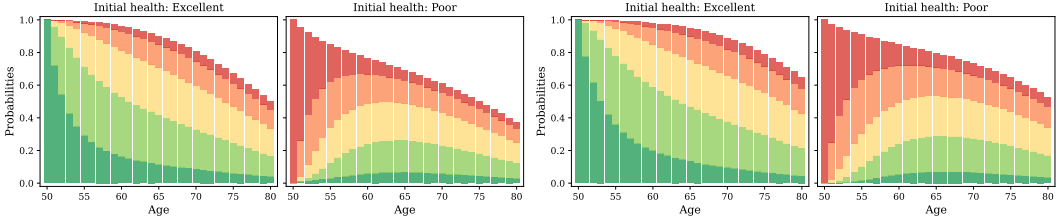


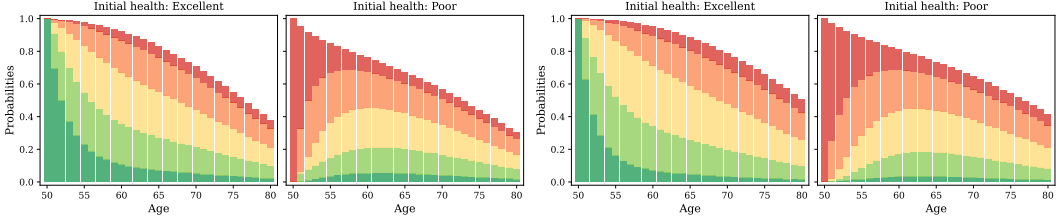
Figure 15: One-year survival probabilities by health for black men/women

Back to nonblack

Predicted health distribution and survival probabilities



(a) 50-year-old nonblack men (left) and women (right)

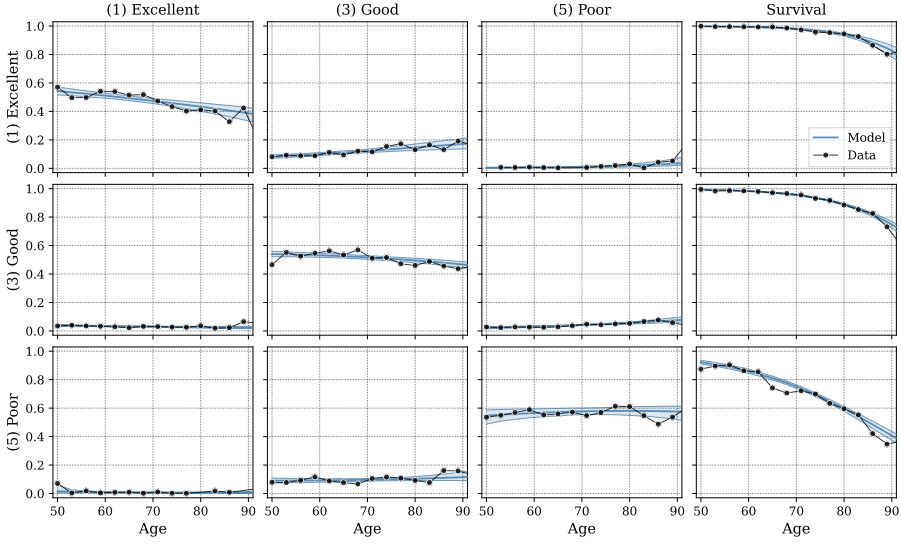


(b) 50-year-old black men (left) and women (right)

Back to nonblack men

Comparing model predictions and data: nonblack men

Aggregated to biennial frequency



Comparing model predictions and data: nonblack women

Aggregated to biennial frequency

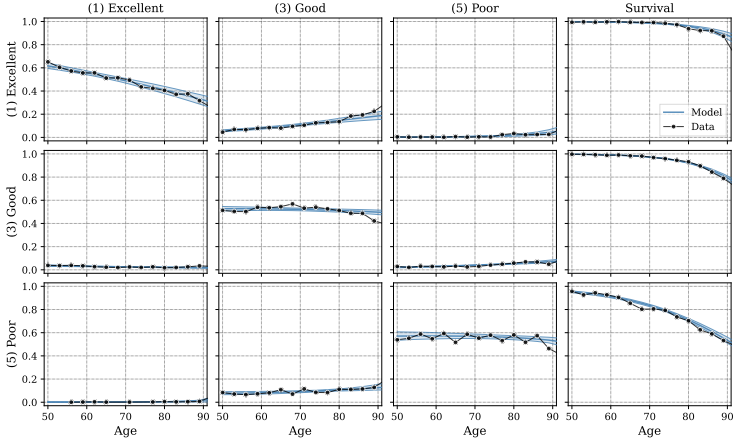
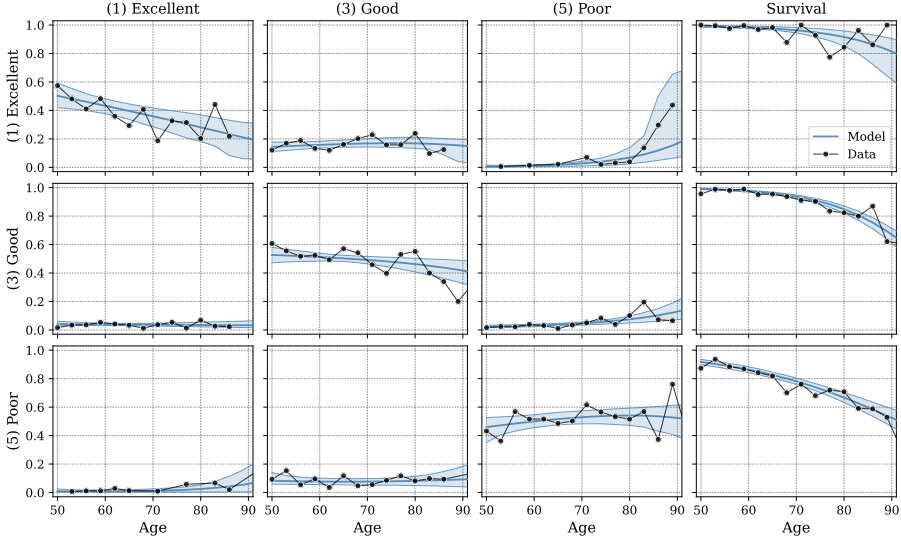


Figure 18: Two-year health-to-health transitions for nonblack women: data vs. model.

Back to nonblack women

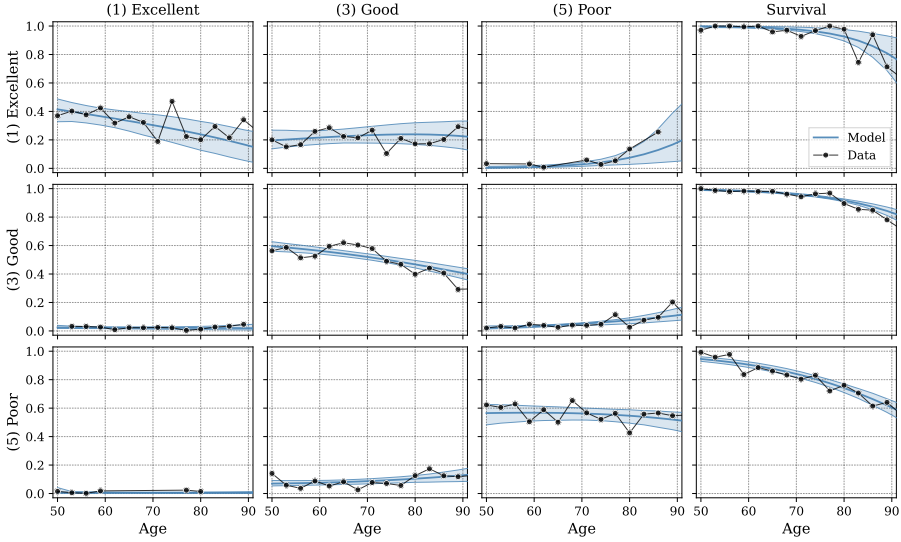
Comparing model predictions and data: black men

Aggregated to biennial frequency



Comparing model predictions and data: black women

Aggregated to biennial frequency



Comparing actual vs. predicted survival over long periods

Model captures long-run survival probabilities over period from 1994–2014 well.

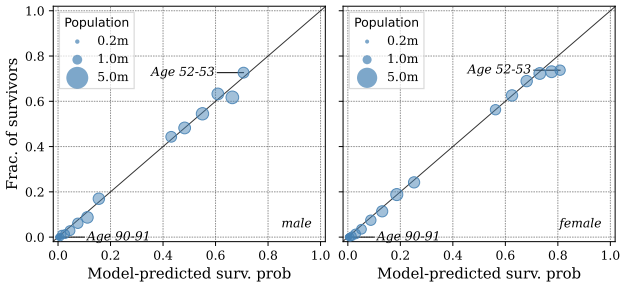


Figure 21: Model-predicted survival probabilities (on the x-axis) against the fraction of survivors (on the y-axis) for nonblack individuals observed in 1994. Each dot represents the fraction of survivors in 2014. Dots are grouped into two-year age bins based on age in 1994.

Inequality in life expectancy: Cumulative distribution

At age 50

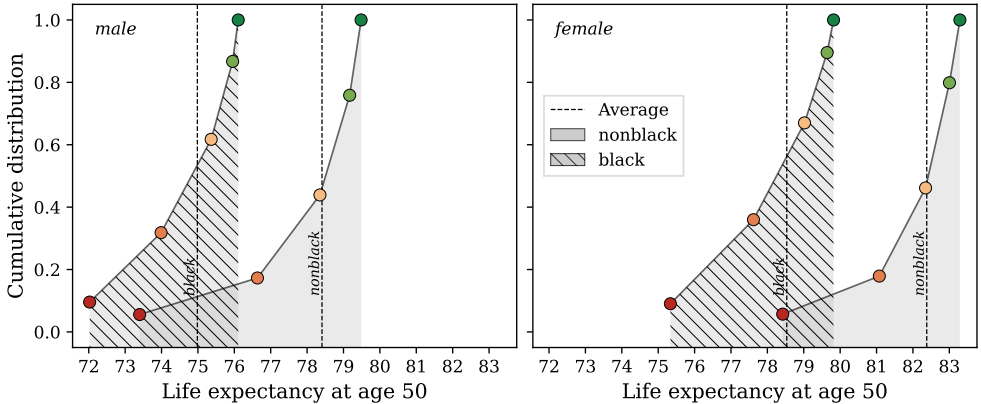


Figure 22: Life expectancy by health state at age 50. Colors indicate health states from excellent to poor.

Inequality in life expectancy

At age 70

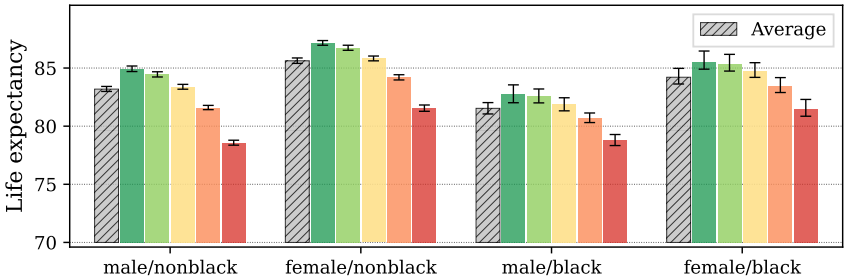


Figure 23: Life expectancy by health state at age 70. Colors indicate health states from excellent to poor. Error bars indicate bootstrapped 95% confidence intervals.

At age 50

Life expectancy: differences across race

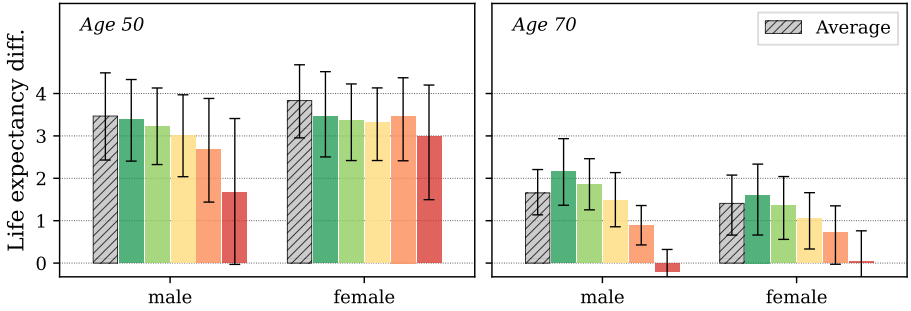


Figure 24: Life expectancy by age and health state, difference nonblack vs. black. Colors indicate health states from excellent to poor. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy at age 50

Life expectancy: differences across sex

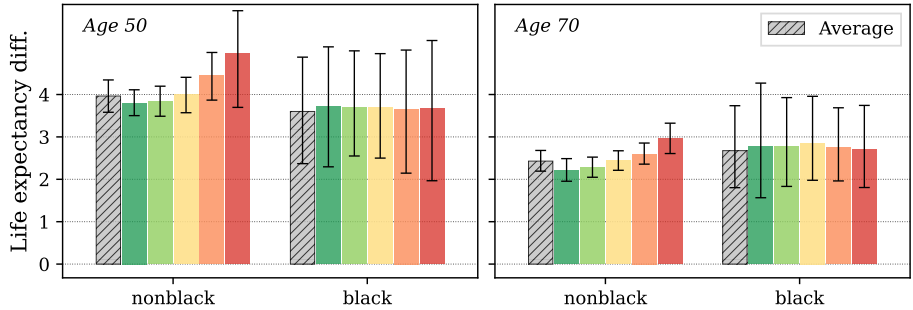


Figure 25: Life expectancy by age and health state, difference women vs. men. Colors indicate health states from excellent to poor. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy at age 50

Life expectancy: differences across sex

At age 70

	Male	Female
Age 70		
Black life expectancy	81.5	84.2
(a) Nonblack health distribution	+0.3	+0.4
(b) Nonblack health dynamics	+0.4	+0.8
(c) Nonblack mortality	+0.7	−0.0
(d) Interaction effect	+0.3	+0.3
Total nonblack/black difference	+1.7	+1.4

At age 50

Inequality in life expectancy by education

At age 50

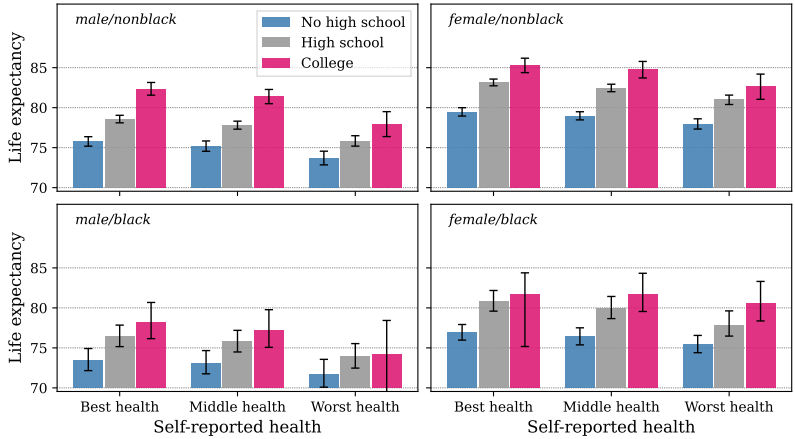


Figure 26: Life expectancy by education level and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by education: differences across race

At age 50

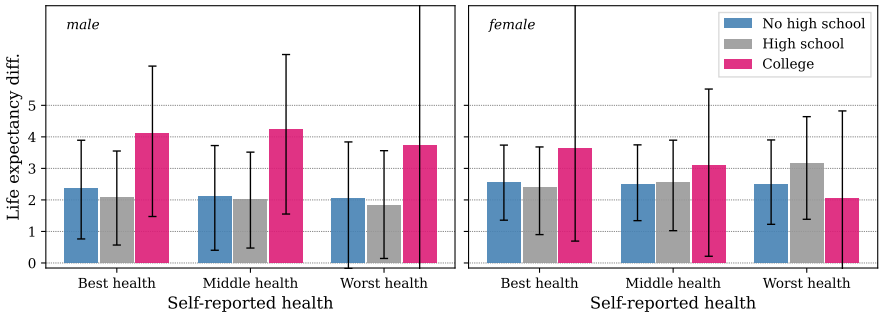


Figure 27: Life expectancy differences by education level and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by education: differences across sex

At age 50

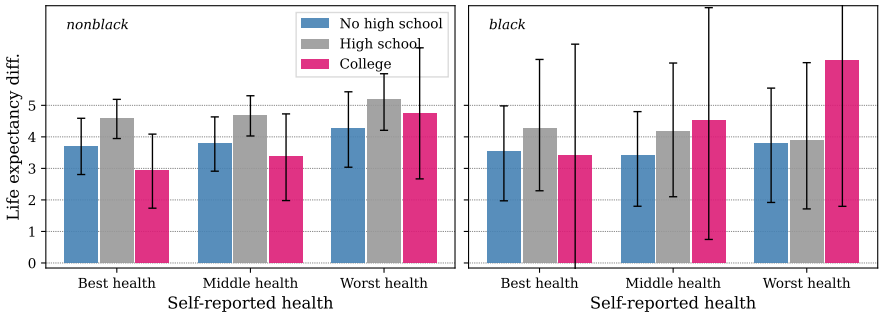


Figure 28: Life expectancy differences by education level and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Inequality in life expectancy by marital status

At age 50

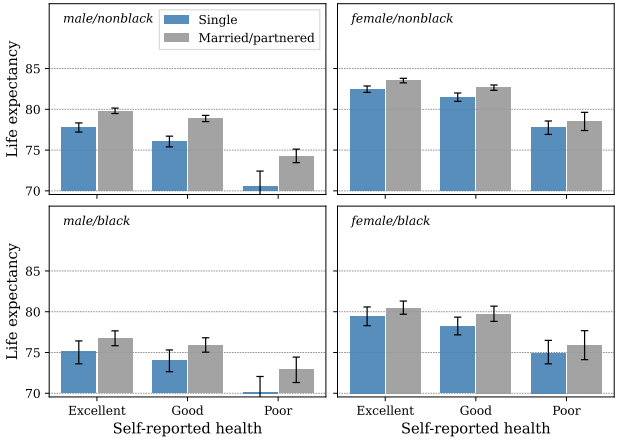


Figure 29: Life expectancy by married/single status and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Covariates

Life expectancy by marital status: differences across race

At age 50

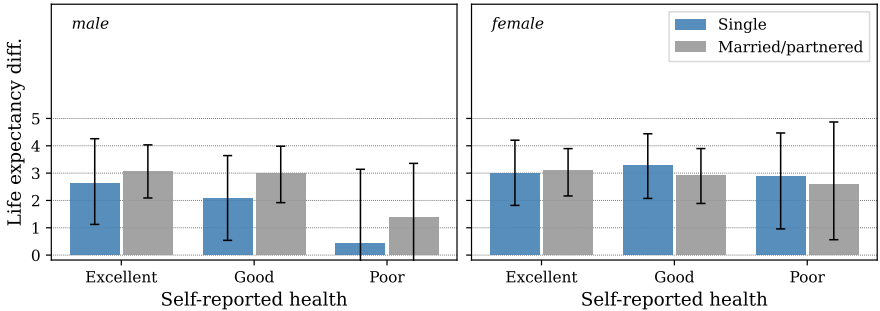


Figure 30: Life expectancy differences by marital status and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by marital status: differences across sex

At age 50

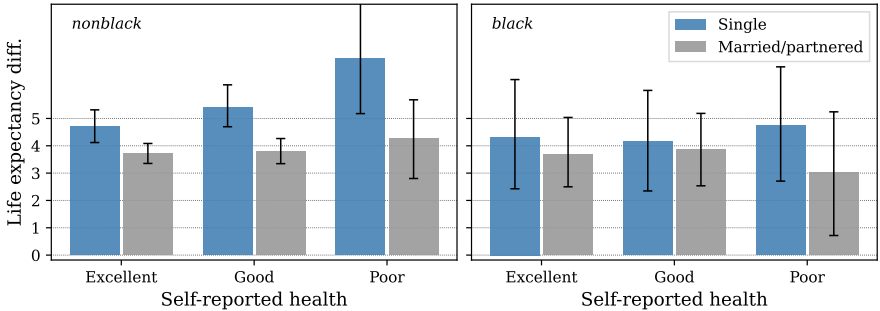


Figure 31: Life expectancy differences by marital status and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Inequality in life expectancy by permanent income

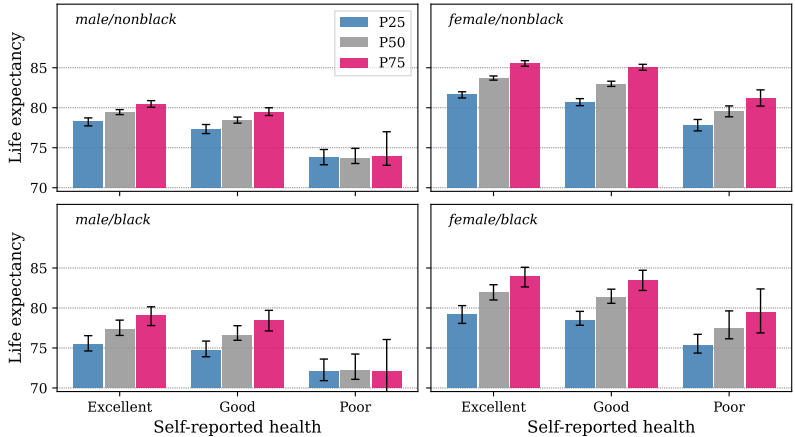


Figure 32: Life expectancy by permanent income and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by permanent income: differences across race

At age 50

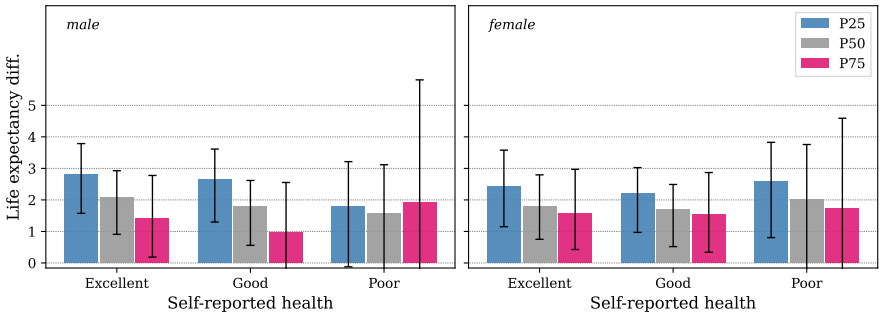


Figure 33: Life expectancy differences by permanent income and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by permanent income: differences across sex

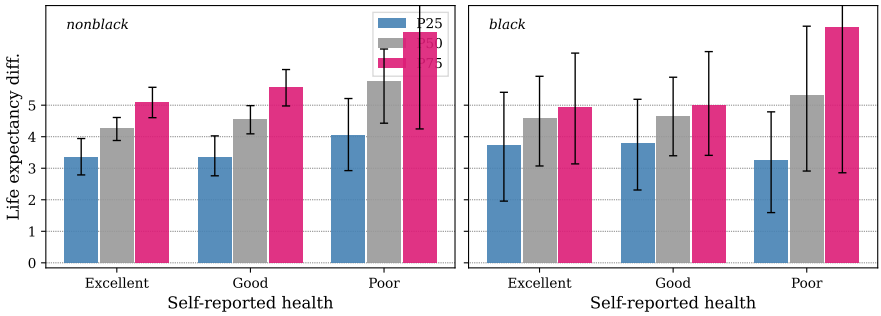


Figure 34: Life expectancy differences by permanent income and health state evaluated at the age of 50. Error bars indicate bootstrapped 95% confidence intervals.

Inequality in life expectancy by permanent income

At age 70

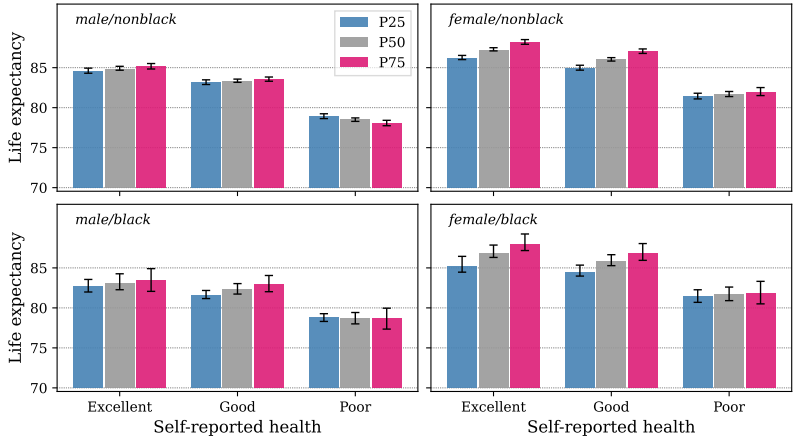


Figure 35: Life expectancy by permanent income and health state evaluated at the age of 70. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by permanent income: differences across race

At age 70

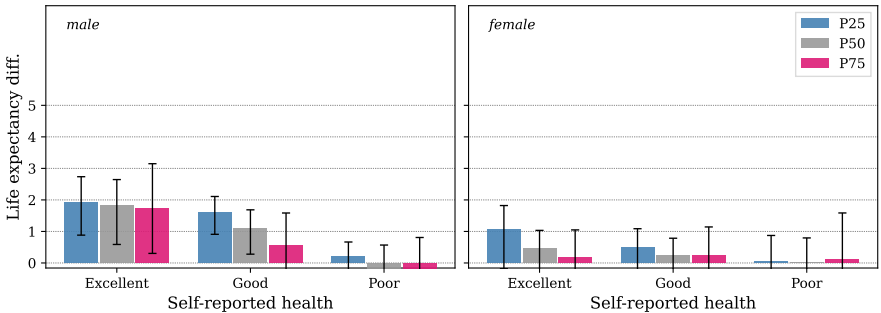


Figure 36: Life expectancy differences by permanent income and health state evaluated at the age of 70. Error bars indicate bootstrapped 95% confidence intervals.

Life expectancy by permanent income: differences across sex

At age 70

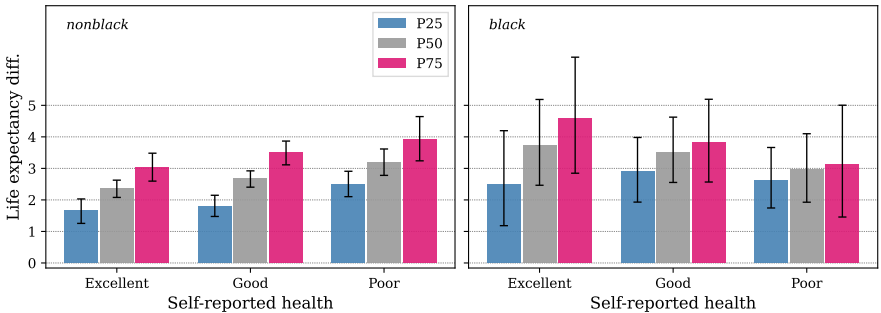


Figure 37: Life expectancy differences by permanent income and health state evaluated at the age of 70. Error bars indicate bootstrapped 95% confidence intervals.

Counterfactual Social Security wealth

Heterogeneous effects by permanent income quintile

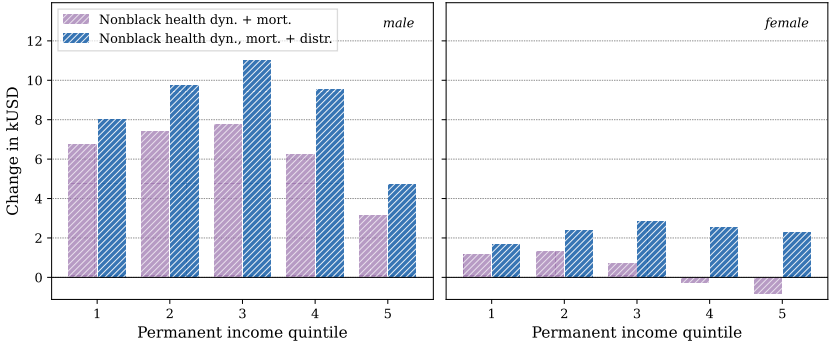


Figure 38: Change in Social Security wealth for black individuals by permanent income quintile (of black sample)

SSW differences

Counterfactual Social Security wealth

As fraction of net total wealth

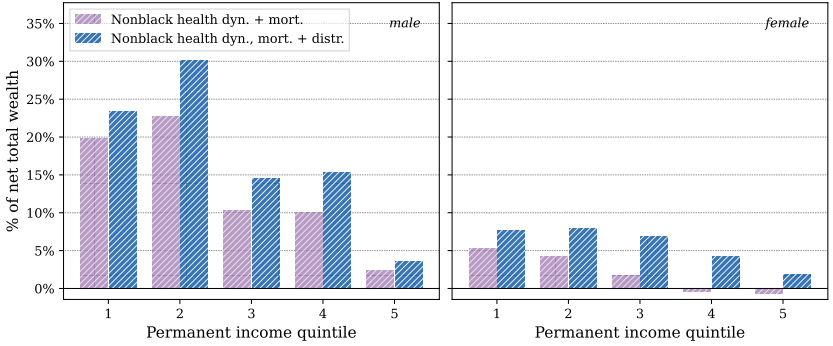


Figure 39: Change in Social Security wealth as fraction of net total wealth for black individuals by permanent income quintile (of black sample)

SSW differences

Medical expenditure estimation

- HRS collects out-of-pocket medical expenditures, including nursing home visits
  - Sample: individuals aged 65+ with at least 5 observations (7,281 indiv.; 49,784 obs.)
- Biennial log medical expenditures given by

$$\begin{aligned}
\log m_{it} &= \alpha_i + \boldsymbol{x}_{it}'\boldsymbol{\beta} + \mathbf{z}_{it}'\boldsymbol{\gamma} + \sigma(\boldsymbol{x}_{it})\,(\eta_{it} + \epsilon_{it}) \\
\eta_{it} &= \rho\eta_{it-1} + \nu_{it} \\
\nu_{it} &\overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma_\nu^2) \\
\epsilon_{it} &\overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma_\epsilon^2)
\end{aligned}$$

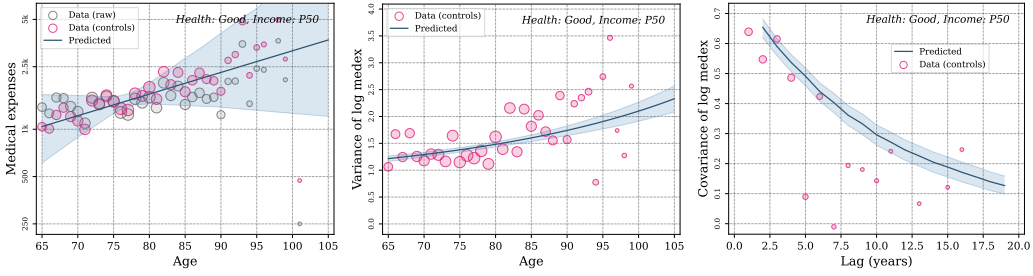
  $\mathbf{z}$ includes controls not in the life cycle model (education, cohort, time FE)
- Variance of error term $u_{it} \equiv \sigma(\boldsymbol{x}_{it})\,(\eta_{it} + \epsilon_{it})$:

$$\begin{aligned}
\text{Var}\,(\,u_{it}\,) &= [\sigma(\boldsymbol{x}_{it}, \boldsymbol{\delta})]^2 = \left[\exp\{\boldsymbol{x}_{it}'\boldsymbol{\delta}\}\right]^2 \\
\text{Var}\,(\,\eta_{it} + \epsilon_{it}\,) &= 1
\end{aligned}$$

- Annual parameters are obtained by simulated method of moments from biennial estimates

Medical expenditure moments: Illustration

- Mean and variance of log medical expenditures allowed to depend on age, race, sex, health and permanent income
- Variances/covariances estimated by GMM



(a) Mean **(b)** Variance **(c)** Covariances at age 70

Figure 40: Sample moments vs. GMM estimates for nonblack women in good health and median permanent income. Shaded areas indicate bootstrapped 95% CI.

Household problem

$$V(a,w,p,h,\eta,g) = \max_{c\geq 0,\, s\geq 0} \left\{ \frac{c^{1-\gamma}}{1-\gamma} + \pi^{s}_{aphg}\beta\, \mathbf{E}\left[V\Big(a+1, w', p, h', \eta', g\Big) \right] \right.$$
$$\left. + \big(1-\pi^{s}_{aphg}\big)\mathbf{E}\left[B\Big((1+r)s - m'\Big) \right] \right\}$$

$$\text{s.t.} \qquad c + s = w$$
$$w' = (1+r)s + p - m'(a,p,h,\eta) + b'$$
$$b' = \max\left\{0,\ \underline{c} + m' - (1+r)s - p\right\}$$

- a Age
- w Cash-at-hand
- p Permanent (retirement) income
- h Health state
- η Persistent medical expenditures
- g Demographic group: male/female, black/nonblack
- m Medical expenditures
- $\underline{c}$ Consumption floor
- b Government transfers
- B Warm-glow bequest motive

Calibration

De Nardi, French, and Jones (2010) calibration without bequest motive:

Parameter	Description	Value
β	Discount factor	0.97
γ	Relative risk aversion	3.81
$\underline{c}$	Consumption floor	\$2,663
r	Risk-free interest rate	2%

Table 6: Externally calibrated parameters

- Health & survival process estimated on race, sex, age, health and permanent income
- Medical expenditures estimated from HRS using GMM Details

Economic model

Welfare implications

- Assume each black individual receives the difference in Social Security wealth Δ_w due to health/survival as lump-sum transfer
- Use lifecycle model to estimate welfare effects for each black individual aged 65+ in the 2002 HRS
- Quantify welfare effects using consumption equivalent variation (CEV)
  - Relative increase in consumption Δ_c for remaining lifetime
- Straightforward to obtain with CRRA preferences:

$$V(w + \Delta_w, \boldsymbol{x}_a) = \mathbf{E}\left[\sum_{j=a}^{a_{\max}} \beta^{j-a} \frac{\Big(C(w_j, \boldsymbol{x}_j) \cdot (1 + \Delta_c)\Big)^{1-\gamma}}{1-\gamma} \,\middle|\, w, \boldsymbol{x}_a\right]$$
$$= (1 + \Delta_c)^{1-\gamma} V(w, \boldsymbol{x}_a)$$

where $C(w_j, \boldsymbol{x}_j)$ is the consumption policy function

CEV by PI quintile

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