Health and (other) Asset Holdings

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October 14, 2009

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Strong links health and financial status/decisions

Health, wealth on portfolio, health expenditures:

Impact of Variable	Dependent Variable: Risky port. share of wealth	Health expend. share of wealth	Labor income
Wealth	$(+)$	$(-)$	
Health	$(+)$	$(-)$	
• pre-retire.			$(++)$
• post-rerire.			$(+)$

- Should treat portfolio/health expend. as *joint* decision process, $(H_t, W_t) \rightarrow (\pi_t, I_t) \rightarrow (H_{t+s}, W_{t+s}), \ldots$
- (almost) Never done.

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Theoret. explan.: Two segmented strands of research

	Health Econ.	Fin. Econ.	This paper
Health investment			
health expend.	✓		✓
mortality risk	✓		✓
health dynamics	✓		✓
health effects:			
-utility	✓		
-income	✓		✓
-mortality	✓		✓
health insur.	✓		
Portfolio/savings			
consumption	✓	✓	✓
asset allocation		✓	✓
life cycle	✓	✓	✓

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Main elements of model

Standard financial asset allocation [Merton, 1971]

- IID returns, constant investment set
- intermediate consumption utility,

Health investment model [Grossman, 1972]

- health as human capital
- locally deterministic process

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Main elements of model

Additional features:

- Preferences:
  - Generalized recursive: VNM as special case.
  - Non-homothetic: Min. subsistence cons.
- Health effects:
  - (partially) Endogenous mortality
  - Positive effects on labor income
- Technology:
  - Convex health adjustment costs
  - Decreasing returns in mortality control
- Life cycle:
  - Different pre- post-retirement health elasticities of income
  - Life cycle properties for all variables

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Solution concepts

Dual effects of health on income, mortality: Proceed in two steps

1. Abstract from endogenous mortality risk: Closed forms,
2. Allow endogenous mortality risk: No closed-form solutions.
    - Perturbation method around first-step benchmark,
    - Characterize solutions in (W_t, H_t) space.

Advantages:

1. Analytical tractability: No calibration exercise for comparative statics.
2. Econometric tractability: Conditionally linear estimated optimal rules.

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Main findings

	Data	Exo. mortality	Endo. mortality
Portfolios			
• H_t	$(+)$	$(+)^*$	$(+)^*$
• W_t	$(+)$	$(+)^*$	$(+)^*$
Health invest.			
• H_t	$(-)$	$(+)$	$(-)^*$
• W_t	$(-)$	$(-)$	$(-)^*$

**: In certain areas of* (W_t, H_t) *space.*

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Empirical analysis

Fully structural econometrics:

- *Dynamic* theoretical model with predictions in closed-forms optimal portfolio, health investment shares.
- *Cross-sectional* estimation using HRS data.

Econometric tractability:

- Conditional linear optimal rules: SRF estimation.
- Can recover structural parameters from SRF estimated parameters.

Empirical analysis

Main estimation results confirm theoretical model relevance:

- Health technology parameters:
  - Rapid depreciation of health in absence of invest.
  - Adjustments feasible, but . . .
  - . . . strongly diminishing returns
- Mortality distribution parameters:
  - Important incompressible mortality, but . . .
  - . . . mortality is partially controllable
  - Predicted longevity in accord with data

▶ Dual effects of H_t are relevant.

- Preference parameters
  - Subsistence consumption important
  - Realistic risk aversion, EIS
  - VNM preferences rejected

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Related literature

authors	similarities	differences
[Edwards, 2008]	• asset selection	• no mortality risks • health non-storable • perm. health expend. if sick • no preventive expend. • no health-dep. income
[Hall and Jones, 2007]	• endo. mortality • health investment • convex adjust.	• no asset selection • aggreg. health spend. • non structural econometrics • spec. of prefs.
[Yogo, 2008]	• health investment • asset selection	• no health-dep. income • no life cycle • health can be sold • calibration • optimal annuities mkt. • exogenous mortality only

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Outline of the talk

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Data description

- Health and Retire. Survey (HRS) resp. aged 51+, 5^{th} wave (2000),
- Financial wealth: $W_j = \text{Safe}_j + \text{Bonds}_j + \text{Risky}_j$
  - safe assets (check. and saving accounts, money mkt. funds, CD's, gov. savings bonds and T-bills)
  - bonds (corp., muni. and frgn. bonds, and bond funds)
  - risky assets (stock and equity mutual funds)
- Self-reported health level (poor, fair, good, v. good, excel.)
- Health investment
  - Medical expenditures (doctor visits, outpatient surg., home, hosp. and nurs. home care, prescr. drugs, . . .)
  - OOP (unins. cost over prev. 2 yrs.)

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HRS data: Effects of health, wealth

Table: Summary stats. by net fin. wealth and health for retired agents

	Net financial wealth quintile				
Health	1	2	3	4	5
Fair					
Wealth	−\$6,114	\$596	\$12,683	\$59,366	\$514,602
$P(\text{risky} > 0)$	2%	1%	14%	42%	74%
risky assets	−2%	1%	7%	24%	42%
Health inv. share	−245%	710%	46%	12%	2%
Good					
Wealth	−\$10,911	\$718	\$13,094	\$64,108	\$436,456
$P(\text{risky} > 0)$	5%	2%	19%	45%	77%
risky assets	−5%	3%	12%	24%	45%
Health inv. share	−79%	476%	31%	7%	1%
Very Good					
Wealth	−\$7,108	\$960	\$13,578	\$64,905	\$467,585
$P(\text{risky} > 0)$	7%	4%	24%	52%	82%
risky assets	−61%	7%	12%	27%	50%
Health inv. share	−86%	188%	21%	5%	1%

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HRS data: Effects of health on income

Table: Income and health regression

	All	Non-retired	Retired
		A. Individual income	
Constant	0.0047**	0.0052	0.0091***
	(0.0021)	(0.0051)	(0.0012)
Health	0.0104***	0.0130***	0.0065***
	(0.0006)	(0.0014)	(0.0004)
Observations	19,571	8,836	10,735
		B. Household income	
Constant	0.0077**	0.0116***	0.0130***
	(0.0022)	(0.0053)	(0.0013)
Health	0.0141***	0.0174***	0.0082***
	(0.0007)	(0.0014)	(0.0004)
Observations	19,571	8,836	10,735

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Health dynamics and survival

$$\mathrm{d}H_t = \left(I_t^{\alpha} H_t^{1-\alpha} - \delta H_t\right)\mathrm{d}t, \qquad H_0 > 0, \tag{1}$$

$$\lim_{s \to 0} \frac{1}{s} P_t\left[t < \tau \leq t + s\right] = \lambda(H_t) = \lambda_0 + \frac{\lambda_1}{H_t^{\xi}} \tag{2}$$

$$P_0[\tau > t] = E_0\left[e^{-\int_0^t \lambda(H_s)\mathrm{d}s}\right] \tag{3}$$

- Health as human capital, locally deterministic [Grossman, 1972]
- Convex adj. costs [Ehrlich, 2000, Ehrlich and Chuma, 1990]
- Poisson mortality [Ehrlich and Yin, 2005, Hall and Jones, 2007]
  - Incompressible mortality λ_0,
  - Path dependence of health decisions

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Income dynamics

$$Y_t \equiv Y(t, H_t) = 1_{\{t \leq T\}} Y_t^{\mathrm{e}} + 1_{\{t > T\}} Y_t^{\mathrm{r}} \quad (4)$$

$$Y_t^i \equiv Y^i(H_t) = y^i + \beta^i H_t, \quad (5)$$

- Two employment phases $i = \mathrm{e}$ (employed) or $i = \mathrm{r}$ (retired)
- Health-dependent labor income,
  - Higher wages to agents in better health, less absent from work, better access to promotions.
  - Differences in pre- post- retirement fixed income (e.g. pensions) and health sensitivity.

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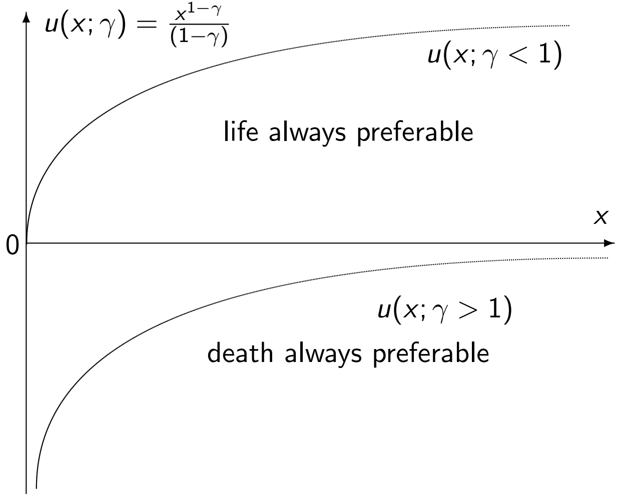
Standard approaches under endo. mortality

Standard approach: $U_t = 1_{\{\tau > t\}} \mathrm{E}_t[\int_t^\tau e^{-\rho(s-t)} u(c_s) \mathrm{d}s]$



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Preferences

Our approach: Abandon VNM

$$U_t = 1_{\{\tau > t\}} \mathrm{E}_t \left[\int_t^\tau \left(f(c_s, U_s) - \frac{\gamma}{2U_s} |\sigma_s(U)|^2 \right) \mathrm{d}s \right] \tag{6}$$

$$f(c, v) = \frac{v\rho}{1 - 1/\varepsilon} \left[\left(\frac{c - a}{v} \right)^{1-1/\varepsilon} - 1 \right]. \tag{7}$$

- Generalized recursive [Duffie and Epstein, 1992, Schroder and Skiadas, 1999].
  - $f(\cdot)$ h.d. 1 $\rightarrow U(\cdot)$ h.d. 1 $\rightarrow U_t, c_t - a$ in same metric
  - $c_t - a \geq 0 \iff U_t \geq 0 \rightarrow$ life always preferable by monotonicity.
- Non-homothetic for $a \neq 0$,
- Health-, time-indep., no bequest.

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Financial market and budget constraint

$$S_t^0 = e^{rt} \tag{8}$$

$$\mathrm{d}S_t = \mu S_t \mathrm{d}t + \sigma S_t \mathrm{d}Z_t, \qquad S_0 > 0, \tag{9}$$

$$\mathrm{d}W_t = (rW_t + Y_t - I_t - c_t)\mathrm{d}t + W_t \pi_t \sigma(\mathrm{d}Z_t + \theta \mathrm{d}t), \tag{10}$$

- Riskless and risky assets,
- Constant investment set,
- Incomplete markets.

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Iso-morphism

1- With health-dependent preferences:

$$V(t, W_t, H_t) = \sup_{(\pi, c, I)} U_t(c)$$

$$\text{s.t. } dW_t = (rW_t + y + \beta H_t - I_t - c_t)\mathrm{d}t + W_t \pi_t \sigma(\mathrm{d}Z_t + \theta \mathrm{d}t)$$

$$\iff V(t, W_t, H_t) = \sup_{(\pi, x, I)} U_t(x + \beta H),$$

$$\text{s.t. } dW_t = (rW_t + y - I_t - x_t)\mathrm{d}t + W_t \pi_t \sigma(\mathrm{d}Z_t + \theta \mathrm{d}t).$$

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Iso-morphism

2- With complete market + infinite horiz. + endo. discount.

$$
\begin{aligned}
U_t &= 1_{\{\tau > t\}} \mathsf{E}_t \left[\int_t^\tau \left(f(c_s, U_s) - \frac{\gamma}{2U_s} |\sigma_s(U)|^2 \right) \mathrm{d}s \right] \\
&= 1_{\{\tau > t\}} U_t^o,
\end{aligned}
$$

where,

$$
U_t^o = \mathsf{E}_t \left[\int_t^\infty e^{-\int_t^s \lambda(H_u) \mathrm{d}u} \left(f(c_s, U_s^o) - \frac{\gamma}{2U_s^o} |\sigma_s(U^o)|^2 \right) \mathrm{d}s \right].
$$

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Optimal rules

Two channels for health effects:

1. Income $y_t = y_0 + \beta H_t$
2. Mortality $\lambda(H_t) = \lambda_0 + \lambda_1 H_t^{-\xi}$

Abstract first from mortality ($\lambda_1 = 0$) to highlight income effects, then re-introduce mortality.

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Optimal rules: Exo. mortality ($\lambda_1 = 0$)

Solution concept exogenous mortality:

1. Choose I to max. disposable wealth:

$$P(t, H_t) = \sup_{I \geq 0} \mathrm{E}_t \left[\int_t^\infty \xi_{t,s} \big(Y(s, H_s) - a - I_s \big) ds \right] \text{ s.t. (1)} \tag{11}$$

2. Replace $N_t \equiv N(t, W_t, H_t) = W_t + P(t, H_t)$. Choose c, π to max. util. s.t. process for $\mathrm{d}N$.

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Optimal rules: Exo. mortality ($\lambda_1 = 0$)

variable		λ_0	H	W
$N(t, W, H)$	$= W + B(t)H + C(t)$		$(+)$	$(+)$
I_0^s	$= W^{-1} H \big(\alpha B(t)\big)^{\frac{1}{1-\alpha}}$		$(+)$	$(-)$
data			$(-)$	$(-)$
V_0	$= \rho (A/\rho)^{\frac{1}{1-\varepsilon}} N(t, W, H)$	$(-)$	$(+)$	$(+)$
π_0	$= \frac{\theta}{\gamma \sigma W} N(t, W, H)$		$(+)$	$(+)^*$
data			$(+)$	$(+)$
c_0	$= a + A\, N(t, W, H)$	$(-)^\dagger$	$(+)$	$(+)$
$C(t)$	$\equiv \int_t^\infty e^{-r(s-t)} \big(Y(s,0) - a\big)\, ds$			
A	$\equiv \varepsilon\rho + (1-\varepsilon)\left(r - \lambda_0 + \frac{1}{2\gamma}\theta^2\right)$	$(-)^\dagger$		

*: if $B(t)H + C(t) < 0$, †: if $\varepsilon < 1$

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Optimal rules: Endo. mortality ($\lambda_1 > 0$)

HJB equation:

$$\lambda(H)V = \max_{(\pi,c,I)} \left\{ L^{\pi,c}V + f(c,V) - \frac{\gamma(\pi\sigma W V_W)^2}{2V} \right\} \tag{12}$$

where,

$$\begin{aligned} L^{\pi,c} = {} & \partial_t + (H^{1-\alpha}I^{\alpha} - \delta H)\partial_H \\ & + ((r + \pi\sigma\theta)W + Y - c - I)\partial_W + \frac{1}{2}(\pi\sigma W)\partial_{WW} \end{aligned} \tag{13}$$

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Optimal rules: Endo. mortality ($\lambda_1 > 0$)

- Main problem: No closed-form solutions when $\lambda_1 \neq 0$
- Solution: $n^{th}-$ order expansion around exo. mortality benchmark solution $\lambda_1 = 0$

$$V \approx V_0 + \lambda_1 V_1 + \cdots + \frac{1}{m!}\lambda_1^m V_m + \cdots \frac{1}{n!}\lambda_1^n V_n,$$

$$V_m \equiv V_m(t, W, H) = \frac{\partial^m}{\partial \lambda_1^m} V(t, W, H)\Bigg|_{\lambda_1 = 0}$$

Once V solved, substitute in FOC, expand again $X = X_0 + \lambda_1 X_1, \ldots$ to get closed-form solutions.

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Optimal rules: Endo. mortality ($\lambda_1 > 0$)

variable		effect of λ_1
$\lambda(t, H)$	$= \lambda_0 + \lambda_1 H^{-\xi}$	$> \lambda_0$
$N(t, W, H)$	$= W + B(t)H + C(t)$	
V	$= V_0 - \frac{\lambda_1}{H^\xi}\Delta(t)V_0$	$< V_0$
π_1	$= \pi_0$	
c_1	$= c_0 - \frac{\lambda_1}{H^\xi}\Delta(t)(1-\varepsilon)AN(t, W, H)$	$< c_0^\dagger$
I_1	$= I_0(t, H) + \frac{\lambda_1}{H^\xi}\Delta(t)(\alpha B(t))^{\frac{\alpha}{1-\alpha}}\eta N(t, W, H)$	$> I_0$
$C(t)$	$\equiv \int_t^\infty e^{-r(s-t)}\big(Y(s,0) - a\big)ds$	
A	$\equiv \varepsilon\rho + (1-\varepsilon)\left(r - \lambda_0 + \frac{1}{2\gamma}\theta^2\right)$	

$\dagger$: if $\varepsilon < 1$

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Optimal rules: Endo. mortality ($\lambda_1 > 0$)

Two effects of $\lambda_1 > 0$:

1. Higher mortality risk $\lambda(H_t) = \lambda_0 + \lambda_1 H_t^{-\xi}$, but, ...,
2. ... can partially offset through higher I_t

Impact on optimal rules:

- $V < V_0$, (because $\lambda(H_t) \uparrow$)
- $I_1 > I_0$, (because $\lambda(H_t) \uparrow$)
- π unchanged,
- $c_1 < c_0$ if $\varepsilon > 1$.

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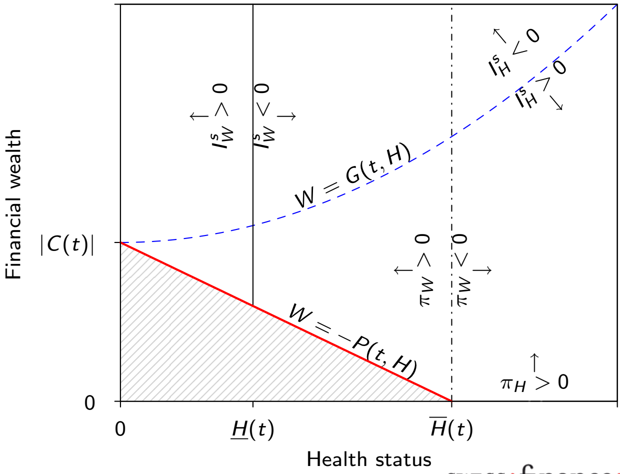
Optimal rules: Endo. mortality ($\lambda_1 > 0$)

Figure: Comparative statics of the first order rules



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Econometric model

Structural estimation of optimal rules:

$$\pi_j W_j = \theta_{\pi,0}(t_j)W_j + \theta_{\pi,1}(t_j)H_j + \theta_{\pi,2}(t_j) + \epsilon_{\pi,j}, \tag{14}$$

$$I_j = \theta_{I,1}(t_j)H_j + \theta_{I,2}(t_j)H_j^{-\xi}W_j + \theta_{I,3}(t_j)H_j^{1-\xi} + \theta_{I,4}(t_j)H_j^{-\xi} + \epsilon_{I,j}, \tag{15}$$

$$[\epsilon_{\pi,j}, \epsilon_{I,j}] \sim \mathcal{N}(\mathbf{0}, \mathbf{\Sigma})$$

Problems:

- Pre-retire. is heavy computation. $\longrightarrow$ use post-retire. only.
- Censored dependent variable $\longrightarrow$ use Tobit.
- Very non-linear in parameters + s.t. non-linear constraints $\longrightarrow$ 2-step proc.

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Econometric model

Back-out structural parameters:

$$
\begin{aligned}
\theta_{\pi,0} &= \frac{\theta}{\gamma\sigma}, & \theta_{I,1} &= (\delta + J)^{\frac{1}{\alpha}}, \\
\theta_{\pi,1} &= \theta_{\pi,0} B, & \theta_{I,2} &= \frac{\alpha \lambda_1 \xi (J+\delta)}{(1-\alpha)(\xi J + A)}, \\
\theta_{\pi,2} &= \theta_{\pi,0} C, & \theta_{I,3} &= \theta_{I,2} B, \\
& & \theta_{I,4} &= \theta_{I,2} C,
\end{aligned} \tag{16}
$$

where $C \equiv C(T) = (y^{\mathrm{r}} - a)/r$, and (J, B) solves

$$
J = (\alpha B)^{\frac{\alpha}{1-\alpha}} - \delta, \tag{17}
$$

$$
B = \frac{\beta^{\mathrm{r}}}{r + \alpha\delta - (1-\alpha)J}. \tag{18}
$$

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Econometric model

Table: Summary of calibrated and estimated parameters

Item	Symbol	Calibrated	Estimated
Income dynamics (Eq.(5))			
Constant	y^{r}		✓
Health sensitivity	β^{r}		✓
Financial markets (Eqs.(8),(9))			
Interest rate	r	0.048	
Std. error risky return	σ	0.200	
Mean risky return	μ	0.108	
Health dynamics (Eq.(1))			
Convexity	α		✓
Depreciation	δ		✓
Death intensity (Eq.(2))			
Convexity	ξ	$\in [3.8, 4.7]$	
Exogenous	λ_0		✓
Health sensitivity	λ_1		✓
Preferences (Eqs.(6),(7))			
Discount rate	ρ	0.025	
Risk aversion	γ		✓
Subsistence cons.	a		✓
EIS	ε		✓

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SRF Results

Table: SRF parameter estimates

	expected sign	$\xi = 3.8$	$\xi = 4.2$	$\xi = 4.7$
		A. Labor income (Eq.(5))		
y^r	(+)	0.0091***	0.0091***	0.0091***
		(0.0013)	(0.0013)	(0.0013)
β^r	(+)	0.0065***	0.0065***	0.0065
		(0.0004)	(0.0004)	(0.0004)
		B. Risky asset levels (Eq.(14))		
$\theta_{\pi,0}$	(+)	0.8514***	0.8514***	0.8514***
		(0.0060)	(0.0060)	(0.0060)
$\theta_{\pi,1}$	(+)	0.0222***	0.0222***	0.0222***
		(0.0022)	(0.0022)	(0.0022)
$\theta_{\pi,2}$	(–)	−0.2751***	−0.2751***	−0.2751***
		(0.0081)	(0.0081)	(0.0081)
		C. Health expenditure levels (Eq.(15))		
$\theta_{I,1}$	(+)	0.0012***	0.0014***	0.0017***
		(0.0002)	(0.0002)	(0.0002)
$\theta_{I,2}$	(+)	0.0003	0.0002	0.0002
		(0.0011)	(0.0010)	(0.0009)
$\theta_{I,3}$	(+)	0.0642***	0.0779***	0.0995***
		(0.0039)	(0.0046)	(0.0057)
$\theta_{I,4}$	(–)	−0.0545***	−0.0692***	−0.0918***
		(0.0039)	(0.0046)	(0.0057)

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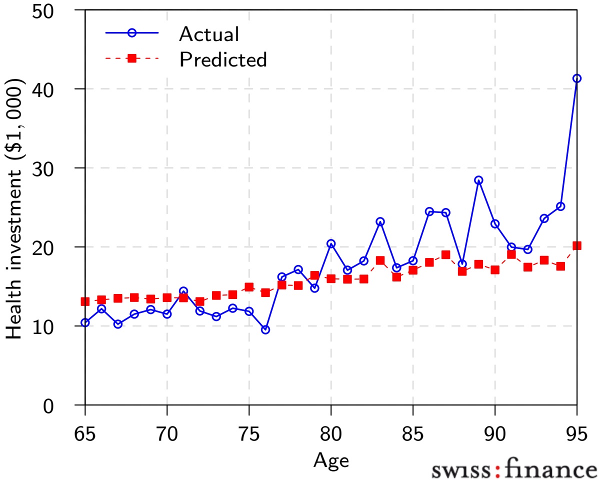
SRF Results: Health investments

Figure: Actual vs predicted health investment levels



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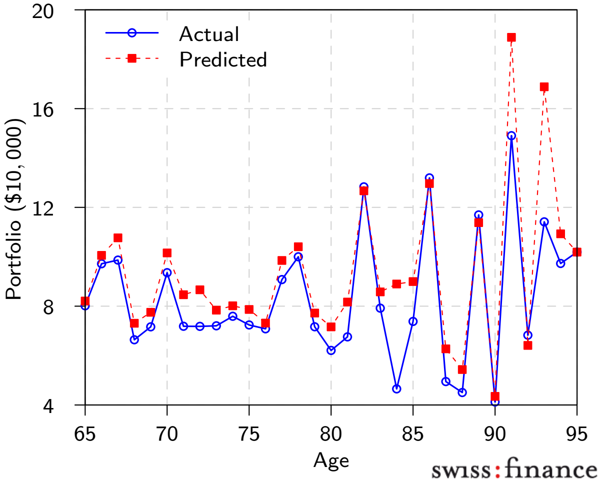
SRF Results: Portfolios

Figure: Actual vs predicted portfolio levels



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Structural parameters

Table: Structural parameter estimates

	$\xi = 3.8$	$\xi = 4.2$	$\xi = 4.7$
	A. Preferences (Eqs.(6),(7))		
γ	1.7663***	1.7689***	1.7665***
	(0.0125)	(0.0125)	(0.0125)
a	0.0247***	0.0248***	0.0248***
	(0.0005)	(0.0005)	(0.0005)
ε	0.2807***	0.1748***	0.2968***
	(0.0000)	(0.0000)	(0.0000)
	B. Health dynamics (Eq.(1))		
α	0.2255***	0.2147***	0.2275***
	(0.0580)	(0.0620)	(0.0565)
δ	0.2817***	0.2994***	0.2789***
	(0.0128)	(0.0191)	(0.0149)
	C. Death intensity (Eq.(2))		
λ_0	0.0832***	0.0787***	0.0840***
	(0.0000)	(0.0002)	(0.0001)
λ_1	0.0037***	0.0059***	0.0057***
	(0.0009)	(0.0023)	(0.0010)

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Structural parameters

Interpretation structural parameters:

Robustness: All parameters reasonably robust to calibrated ξ.

$\gamma \approx 1.76$: Realistic $\in [0, 10]$.

$a > 0$: significant (quasi-homothetic prefs.), large (\$24,800/yr.) $\rightarrow C < 0 \rightarrow \pi_w > 0$

$\varepsilon \approx 0.28 < 1$: Agents substitute poorly across time; $\lambda_0 > 0 \rightarrow c_0 \searrow$; $\lambda_1 > 0 \rightarrow c_1 < c_0$.

$\varepsilon \neq 1/\gamma$: Reject separable VNM preferences in absence of mortality risk.

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Structural parameters

Interpretation structural parameters (cont'd):

$\alpha \approx 0.23$: Significant convexities health adjustment costs.

$\delta \approx 0.28$: Very rapid depreciation health stock absent I

$\lambda_0 \approx 0.08$: Significant (exo. mortality), large.

$\lambda_1 \approx 0.004$: Small (perturbation correct), significant (endo. mortality).

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Implied variables

Can compute expected lifetime at optimum:

$$\ell(H) = \frac{1}{\lambda_0}\left(1 - \frac{\lambda_1}{H^{\xi}}\Phi\right), \tag{19}$$

where,

$$\Phi^{-1} = \lambda_0 + \xi\left((\alpha B(T))^{\frac{\alpha}{1-\alpha}} - \delta\right) > 0 \tag{20}$$

- Independent of wealth, age
- can compare with estimates from US life tables [Lubitz et al., 2003]

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Implied variables

Table: Implied variables

	Data	$\xi = 3.8$	$\xi = 4.2$	$\xi = 4.7$
		A. Life expectancy		
$\ell(1)$	9.17	11.57	11.94	11.21
$\ell(2)$	11.26	11.98	12.66	11.88
$\ell(3)$	12.64	12.01	12.69	11.90
$\ell(4)$	13.38	12.01	12.70	11.90
$\ell(5)$	13.79	12.01	12.70	11.90
		B. Thresholds in Figure 1		
$\underline{H}$		1.36	1.42	1.48
$\overline{H}$		5.40	5.44	5.48
$P(\underline{H})$		−0.24	−0.24	−0.24
$G(\underline{H})$		0.33	0.32	0.31
$G(\overline{H})$		47.44	60.86	90.79

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Conclusion

Close feedbacks $H_t, W_t \rightarrow \pi_t, I_t \rightarrow H_{t+s}, W_{t+s}$:

- Need to be studied jointly.
- No joint model.

This model: at interface between Health and Fin. Econ.

- Consumption/portfolio/health investment in presence of mortality + financial risks.
- Health has 2 effects:
  - Endogenous mortality;
  - Human capital (labor income).
- Convex health and mortality adjust. costs
- Preferences:
  - Non-expected utility → life always valuable
  - Quasi-homothetic

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Conclusion

Main theoretical findings:

- Exogenous mortality: Incomplete success
  - Can reproduce co-movements of portfolios if subsistence consumption sufficiently high
  - Cannot reproduce co-movements of health investments.
- Endogenous mortality: Potential success
  - Exists regions of state space where can reproduce all co-movements.
  - Potential for poverty traps.

Conclusion

Empirical evaluation:

- Structural estimation of dynamic model in cross-section.
- Realistic parameters.
- Main empirical findings in line with theoretical results.

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