Closing Down the Shop: Optimal Health and Wealth Dynamics near the End of Life

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\textsuperscript{4}Swiss Finance Institute
\textsuperscript{5}CEPR

Jan. 18, 2017
1- Health falls, 2- death risk exposure increases, esp. poor

<table>
<thead>
<tr>
<th>Age</th>
<th>40 to 70</th>
<th>70 to 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share in poor/ bad health</td>
<td>×2</td>
<td>×2</td>
</tr>
<tr>
<td>Drop survivors</td>
<td>−19.3%</td>
<td>−29.7%</td>
</tr>
</tbody>
</table>

Notes: Health: [Banks et al., 2015, Smith, 2007, Heiss, 2011, Van Kippersluis et al., 2009], survivors [Arias, 2014].

<table>
<thead>
<tr>
<th>Income decile</th>
<th>Longevity 1940 cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>73.3</td>
</tr>
<tr>
<td>3rd</td>
<td>77.9</td>
</tr>
<tr>
<td>6th</td>
<td>81.8</td>
</tr>
<tr>
<td>10th</td>
<td>84.6</td>
</tr>
</tbody>
</table>

Notes: [Bosworth et al., 2016]
3.a- Health expenses increase

<table>
<thead>
<tr>
<th>Age</th>
<th>Average total expend.</th>
</tr>
</thead>
<tbody>
<tr>
<td>70–90 last year</td>
<td>$25’000</td>
</tr>
<tr>
<td></td>
<td>$43’000</td>
</tr>
</tbody>
</table>

Notes: [De Nardi et al., 2015b]

- Concentrated in long-term care (LTC), less curative care.
- LTC very income/wealth elastic $\approx$ normal consumption good.
3.b- Health expenses change in composition

Notes: Source: [De Nardi et al., 2015b, Fig. 3, p. 22].
3.b- Health expenses change in composition

![Graph showing health expenses change in composition by age and payor type.](image)

**Notes:** Source: [De Nardi et al., 2015b, Fig. 3, p. 22].
4- Wealth falls

- Fall by 50% last 3 years, 30% last year alone, vs 2% for survivors [De Nardi et al., 2015a, French et al., 2006].
- LTC not covered by Medicare, means-testing for Medicaid.
- Correlated with changes in health, family composition [Poterba et al., 2015, Lee and Kim, 2008].
Standard explanation

**Ineluctable** aging process:
- Biological decline in health status.
**Ineluctable** aging process:

- Biological decline in health status.
- Mechanical increase in death risk.
Standard explanation

**Ineluctable** aging process:
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- Expand comfort care, reduce curative care.
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- Expand comfort care, reduce curative care.
- Deplete financial resources to cover expenses → accidental bequests.
Ineluctable aging process:

- Biological decline in health status.
- Mechanical increase in death risk.
- Expand comfort care, reduce curative care.
- Deplete financial resources to cover expenses → accidental bequests.
- Medicaid once depleted wealth.
Main research question

Joint decline in \((H_t, W_t)\) \iff \textbf{optimal decisions}, rather than inevitable?

- Four hypotheses:
Main research question

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- Four hypotheses:
  - Health spending affect health.
Main research question

Joint decline in \((H_t, W_t) \iff \text{optimal decisions}\), rather than inevitable?

- Four hypotheses:
  1. Health spending affect health.
  2. Health affect exposure to death risk.
Main research question

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  4. Dynamically consistent decisions by agents:
     - Horizon \(\Rightarrow\) dynamic decisions, and
     - Horizon \(\Leftarrow\) dynamic decisions.
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- Conditions under which close down the shop near the end of life:
Main research question

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  1. Optimal joint depletion of health, and wealth capital.
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  2. Threshold after which health depletion accelerated.
Main research question

Joint decline in \((H_t, W_t)\) \(\iff\) optimal decisions, rather than inevitable?

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- Conditions under which close down the shop near the end of life:
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- Conditions under which close down the shop near the end of life:
  1. *Optimal joint* depletion of health, and wealth capital.
  2. Threshold after which health depletion *accelerated*.
  3. Optimal increase in death risk.
  4. Convergence towards state where *indifferent* between life and death.
Model [Hugonnier et al., 2013, *RESTUD*]

- Health dynamics [Grossman, 1972, augmented]:
  \[
  dH_t = \left( \left( \frac{l_t}{H_t} \right)^\alpha - \delta \right) H_t dt - \phi H_t dQ_{st}, \quad H_0 > 0,
  \]

- Income: Health-dependent
  \[
  Y(H_t) = y_0 + \beta H_t.
  \]

- Health shock insurance: Actuarially fair
  \[
  X_t - dM_{st} = X_t - dQ_{st} - X_t - \lambda_s d_t.
  \]

- Wealth dynamics:
  \[
  dW_t = \left( rW_t - C_t - I_t \right) dt + \Pi_t \sigma S(dZ_t + \theta dt) + X_t - dM_{st}.
  \]
Theoretical framework

Economic environment

Model [Hugonnier et al., 2013, *RESTUD*]

- Health dynamics [Grossman, 1972, augmented]:
  \[ dH_t = \left( \frac{l_t}{H_t} \right)^\alpha - \delta \right) H_t dt - \phi H_t dQ_{st}, \quad H_0 > 0, \]

- Poisson health shocks (sickness, death): Endogenous exposure
  \[ \lambda_k(H_t) = \begin{cases} 
  \lambda_{s0} & k = s \text{ (sickness)} \\
  \lambda_{m0} + \lambda_{m1} H_t^{-\xi_m} & k = m \text{ (death)} 
\end{cases} \]
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  \end{cases}
  \]

- **Income: Health-dependent**
  \[
  Y(H_t) = y_0 + \beta H_t.
  \]
Model [Hugonnier et al., 2013, *RESTUD*]

- Health dynamics [Grossman, 1972, augmented]:
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  \[ \lambda_k(H_t) = \begin{cases} \lambda_{s0} & \text{if } k = s \text{ (sickness)} \\ \lambda_{m0} + \lambda_{m1}H_t^{-\xi_m} & \text{if } k = m \text{ (death)} \end{cases} \]

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  \[ X_{t-} \, dM_{st} = X_{t-} \, dQ_{st} - X_{t-} \lambda_{s0} \, dt. \]
- Wealth dynamics:
  \[ dW_t = (rW_{t-} + Y_t - C_t - l_t) \, dt + \Pi_t \sigma_S (dZ_t + \theta \, dt) + X_{t-} \, dM_{st}. \]
Model [Hugonnier et al., 2013, RESTUD]

Objectives: \( V(W_t, H_t) = \sup_{(C, \pi, \chi, l)} U_t(C) \), where

\[
U_t(C) = 1_{\{T_m > t\}} E_t \int_t^{T_m} \left( f(C_\tau, U_\tau,) - \frac{\gamma \sigma_\tau^2}{2U_\tau} - \sum_{k=m}^{s} F_k(U_\tau, H_\tau, \Delta_k U_\tau) \right) d\tau,
\]

where,

\[
f(C, U) = \frac{\rho U}{1 - 1/\varepsilon} \left( ((C - a)/U)^{1-\frac{1}{\varepsilon}} - 1 \right)
\]

\[
F_k(U, H, \Delta_k U) = U \lambda_k(H) \left[ \frac{\Delta_k U}{U} + u(1; \gamma_k) - u \left( 1 + \frac{\Delta_k U}{U}; \gamma_k \right) \right],
\]

\[
u(c; \gamma_k) = \frac{c^{1-\gamma_k}}{1 - \gamma_k}, \quad k = m, s.
\]

subject to health, wealth dynamics.
Health investment: Two components

\[ I^*(W, H) = K_B H + I_1 H^{-\xi_m} N_0(W, H) \]

where \( N_0(W, H) \) is net total wealth. Other solutions for \( X^*, \Pi^* \).

- If death risk can be hedged \( \implies \) larger demand for health.
Health investment: Two components

\[ I^*(W, H) = \underbrace{KBH}_{\text{Order-0 demand}} + \underbrace{I_1 H^{-\xi_m} N_0(W, H)}_{\text{Death risk hedging demand}} \]

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- If death risk can be hedged \( \implies \) larger demand for health.
- Monotone increasing in \( W \).
Theoretical framework

Admissible policies

Health investment: Two components

\[ I^*(W, H) = KBH + \mathcal{I}_1 H^{-\xi_m} N_0(W, H) \]

where \( N_0(W, H) \) is net total wealth. Other solutions for \( X^*, \Pi^* \).

- If death risk can be hedged \( \Rightarrow \) larger demand for health.
- Monotone increasing in \( W \).
- Non-monotone in \( H \).
Admissibility and preference for life

- Consumption:

\[
C^*(W, H) = a + \left[ A + C_1 H^{-\xi_m} \right] N_0(W, H)
\]

\[
N_0(W, H) = W + BH + (y_0 - a)/r
\]
Admissibility and preference for life

- Consumption:

\[ C^*(W, H) = a + \left[ A + C_1 H^{-\xi_m} \right] N_0(W, H) \]
\[ N_0(W, H) = W + BH + (y_0 - a)/r \]

- Admissibility: \( C^*(W, H) \geq a \iff A = \{(W, H) : N_0(W, H) \geq 0\}, \)
  \[ = \{(W, H) : W > x(H) = -(y_0 - a)/r - BH\}, \]}
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- Homogeneity of preferences: \( C^* - a > 0 \iff V > 0 \)
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  - Versus welfare at death \( V \equiv 0 \implies \) life preferred to death.
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  \]
  \[
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  \]

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  \[
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  \]
  \[
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  \]

- **Homogeneity of preferences:**
  \[
  C^* - a > 0 \implies V > 0
  \]
  - Versus welfare at death \( V \equiv 0 \implies \text{life preferred to death.} \)
  - As approach non-admissible region, become indifferent between life and death.
Expected local dynamics and depletion: Health

Local expected changes:

\[
E_t [\text{d}H] = \left[ I^* h(W, H)^\alpha - \frac{\tilde{\delta}}{\delta + \lambda s_0 \phi} \right] H \text{d}t,
\]

Health depletion/accelerating regions:

\[
D_H = \left\{ (W, H) \in A : E_t [\text{d}H] < 0 \right\},
\]

\[
AC = \left\{ (W, H) \in D_H : I^* h(W, H) > 0 \right\}.
\]
Expected local dynamics and depletion: Health

1. Local expected changes:

\[ E_t[-dH] = \left[ I^h(W, H) - \frac{\delta}{\delta + \lambda_s \Phi} \right] H dt, \]

2. Health depletion/accelerating regions:

\[ D_H = \{(W, H) \in A : E_t[-dH] < 0\}, \]
\[ A_C = \left\{(W, H) \in D_H : I^h(W, H) > 0\right\}. \]
Expected local dynamics and depletion: Wealth

Local expected changes:

\[
E_t[-dW] = [rW + Y(H) - C^*(W, H) - I^*(W, H) + \Pi^*(W, H)\sigma_S\theta] dt,
\]
Expected local dynamics and depletion: Wealth

1. Local expected changes:

\[ E_t[-dW] = [rW + Y(H) - C^*(W, H) - I^*(W, H) + \Pi^*(W, H)\sigma_S\theta] dt, \]

2. Wealth depletion region:

\[ \mathcal{D}_W = \{(W, H) \in A : E_t[-dW] < 0\}. \]
Sufficient conditions for Closing down: Realistic for EOL

Health depletion/accelerating:
- High depreciation and/or low ability to generate income:
  \[ \beta < \tilde{\delta}^{1/\alpha} \]

Wealth depletion:
Sufficient conditions for Closing down: Realistic for EOL

Health depletion/accelerating:
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Wealth depletion:
- Sufficient elasticity inter-temporal substitution \( \varepsilon \geq 1 \).
Sufficient conditions for Closing down: Realistic for EOL

Health depletion/accelerating:
- High depreciation and/or low ability to generate income:
  \[ \beta < \frac{\tilde{\delta}^{1/\alpha}}{1}, \]

Wealth depletion:
- Sufficient elasticity inter-temporal substitution \( \varepsilon \geq 1 \).
- High consumption \( \iff (\gamma, \rho, \lambda_{m0}, \gamma_m) \) high
  \[ (1 + \varepsilon) \frac{\theta^2}{2\gamma} < \varepsilon (\rho - r) + (\varepsilon - 1) \frac{\lambda_{m0}}{1 - \gamma_m}. \]
Phase diagram

Figure: Health and wealth dynamics
Phase diagram

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Figure: Health and wealth dynamics
Terminal illness: $\lambda_m(H) = \lambda_{m0}, \forall H$, and $\lambda_{m0}, \delta \uparrow$

Main result: $\mathcal{D}_H = \mathcal{A}; \mathcal{AC} = \emptyset$
Terminal illness: $\lambda_m(H) = \lambda_{m0}$, $\forall H$, and $\lambda_{m0}, \tilde{\delta} \uparrow$

Main result: $\mathcal{D}_H = \mathcal{A}; \mathcal{AC} = \emptyset$
Reducing incidence of Closing Down strategies

Figure: Increase in $y_0$ (e.g. Social Security)
Policy

Increasing base income ($y_0$)

Reducing incidence of Closing Down strategies

Figure: Increase in $y_0$ (e.g. Social Security)
Model and data

- Structural trivariate econometric model:
  \[
  I_j = K_0 BH_j + K_m H_j^{-\xi m} N_0(W_j, H_j) + u_{Ij},
  \]
  \[
  \Pi_j = (\theta/\gamma S) N_0(W_j, H_j) + u_{\Pi j},
  \]
  \[
  Y_j = y_0 + \beta H_j + u_{Yj},
  \]

- Closed-form solutions for parameters.
- Additional transversality conditions.
- By iterative 2-step ML.
Model and data

- Structural trivariate econometric model:
  \[
  l_j = K_0 BH_j + K_m H_j^{-\xi_m} N_0(W_j, H_j) + u_{lj},
  \]
  \[
  \Pi_j = (\theta/(\gamma \sigma_s)) N_0(W_j, H_j) + u_{\pi j},
  \]
  \[
  Y_j = y_0 + \beta H_j + u_{Yj},
  \]

- Closed-form solutions for parameters.
- Additional transversality conditions.
- By iterative 2-step ML.

- Data: HRS, 2002
  - Detailed info on total health spending.
  - Focus on elders 65+, with positive wealth (9,817 obs., mean age 75.3).
  - No consumption data.
  - Medicare \(\implies\) drop optimal insurance.
## Estimated and calibrated parameters

Realistic for relatively old population (75.3 years):

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.6940*</td>
<td>$\delta$</td>
<td>0.0723*</td>
<td>$\phi$</td>
<td>0.011c</td>
</tr>
<tr>
<td>$\lambda_{s0}$</td>
<td>0.2876*</td>
<td>$\lambda_{m0}$</td>
<td>0.2356*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda_{m1}$</td>
<td>0.0280*</td>
<td>$\xi_m$</td>
<td>2.8338*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma_0$</td>
<td>0.0082*$\dollar$</td>
<td>$\beta$</td>
<td>0.0141*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.108c</td>
<td>$r$</td>
<td>0.048c</td>
<td>$\sigma_s$</td>
<td>0.20c</td>
</tr>
<tr>
<td>$a$</td>
<td>0.0127*$\dollar$</td>
<td>$\epsilon$</td>
<td>1.6738*</td>
<td>$\gamma$</td>
<td>2.7832*</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.025c</td>
<td>$\gamma_m$</td>
<td>0.75c</td>
<td>$\gamma_s$</td>
<td>N.I.</td>
</tr>
</tbody>
</table>

**Notes:** *: Estimated structural and induced parameters (standard errors in parentheses), significant at 5% level; c: calibrated parameters; $\dollar$: In $\text{M}$; N.I.: non-identifiable/irrelevant under the exogenous morbidity restriction.
Conditions for depletion: All verified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta - \tilde{\delta}^{1/\alpha} )</td>
<td>(-0.0086^*)</td>
<td>( \theta^2/\gamma + r - A )</td>
<td>(-0.5533^*)</td>
</tr>
</tbody>
</table>

Notes: *: Estimated structural and induced parameters (standard errors in parentheses), significant at 5% level; \(c\): calibrated parameters; $: In $M.
Estimated and calibrated parameters

Out-of-sample checks: Expected longevity

\[ \ell(W_t, H_t) = \left( \frac{1}{\lambda_m} \right) (1 - \lambda_m \kappa_0 H_t^{-\xi_m}) \]

<table>
<thead>
<tr>
<th>Level</th>
<th>( H )</th>
<th>% Pop.</th>
<th>Exp. longev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0.50</td>
<td>10.7</td>
<td>51.94</td>
</tr>
<tr>
<td>Fair</td>
<td>1.25</td>
<td>21.1</td>
<td>77.49</td>
</tr>
<tr>
<td>Good</td>
<td>2.00</td>
<td>31.5</td>
<td>79.00</td>
</tr>
<tr>
<td>Very good</td>
<td>2.75</td>
<td>26.9</td>
<td>79.32</td>
</tr>
<tr>
<td>Excellent</td>
<td>3.50</td>
<td>9.9</td>
<td>79.43</td>
</tr>
</tbody>
</table>

Data (2002): 74.5 (M); 79.9 (F); 77.3 (A)
Estimated partitions: All in \((\mathcal{D}_H, \mathcal{D}_W)\) for \(H \geq \text{Fair}\)
Simulated life paths: Closing Down the Shop

a. Wealth (M$)
b. Health
c. Expected surviv. (remain. yrs)
d. Welfare

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Concluding remarks

Closing down the shop strategy:

- Optimal depletion of health/wealth capitals.
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- Accelerating depletion subsets.
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- Paths converging to states where indifference life/death.
Concluding remarks

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- Optimal depletion of health/wealth capitals.
- Accelerating depletion subsets.
- Paths converging to states where indifference life/death.
- Realistic sufficient theoretical conditions, verified empirically:
  - High consumption.
  - High depreciation and/or low ability to generate income.

Consistent with stylized facts:

1. Falling health.
2. Death risk increasing.
4. Falling wealth.

Applicable to incurable terminal diseases.
Concluding remarks

Closing down the shop strategy:

- Optimal depletion of health/wealth capitals.
- Accelerating depletion subsets.
- Paths converging to states where indifference life/death.
- Realistic sufficient theoretical conditions, verified empirically:
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Normative issues

Reducing incidence of closing down:

Feasible? Yes.

- Base income $y_0 \uparrow$ (e.g. Soc. Sec., min. revenues, Medicaid).
- Subsidized medical research $\delta, \lambda_{s0}, \phi \downarrow$.
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2. Optimal? No clear normative arguments.
   - Myopia? No, fully endogenize effects of choices $\iff$ horizon.
   - Market failure? No, optimal strategy by agents in complete markets setting.
   - Redistribution? No, poverty endogenously determined.
   - Against excessive/aggressive EOL therapy.
   - In favor of rights to refuse treatment.
Conclusion


Right before the end: Asset decumulation at the end of life.

On the concept of health capital and the demand for health.

Dynamics of self-rated health and selective mortality.

Health and (other) asset holdings.

A longitudinal analysis of the impact of health shocks on the wealth of elders.


