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

Julien Hugonnier\textsuperscript{1,4,5} Florian Pelgrin\textsuperscript{2,6} Pascal St-Amour\textsuperscript{3,4,6}

\textsuperscript{1}École Polytechnique Fédérale de Lausanne
\textsuperscript{2}EDHEC Business School
\textsuperscript{3}University of Lausanne, Faculty of Business and Economics (HEC)
\textsuperscript{4}Swiss Finance Institute
\textsuperscript{5}CEPR
\textsuperscript{6}CIRANO
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>1\textsuperscript{st}</td>
<td>73.3</td>
</tr>
<tr>
<td>3\textsuperscript{rd}</td>
<td>77.9</td>
</tr>
<tr>
<td>6\textsuperscript{th}</td>
<td>81.8</td>
</tr>
<tr>
<td>10\textsuperscript{th}</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</td>
<td>$25’000</td>
</tr>
<tr>
<td>last year</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

![Graph showing the change in health expenses by age and category.](image)

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

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.

Mechanical increase in death risk.
Expand comfort care, reduce curative care.
Deplete financial resources to cover expenses → accidental bequests.

Medicaid once depleted wealth.
Ineluctable aging process:
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- Medicaid once depleted wealth.
Main research question

Joint decline in \((H_t, W_t) \iff \text{aging (inevitable), (and/) or optimal?}\)

- Four hypotheses:
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Joint decline in \((H_t, W_t)\) \iff\ aging (inevitable), (and/) or optimal?

- Four hypotheses:
  1. Health spending affect health.

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Joint decline in \((H_t, W_t)\) ⇐ aging (inevitable), (and/) or optimal?

- 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 \(\implies\) dynamic decisions, and
     - Horizon \(\iff\) dynamic decisions.
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     - Horizon \(\iff\text{dynamic decisions.}\)

- Conditions under which close down the shop near the end of life:
Main research question

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  1. \textit{Optimal joint} depletion of health, and wealth capital.
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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*. 

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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]:
  \[
  dH_t = \left(\frac{l_t}{H_t}\right)^\alpha - \delta \right) H_t dt - \phi H_t dQ_{st}, \quad H_0 > 0,
  \]
Model [Hugonnier et al., 2013, RESTUD]

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- Poisson health shocks (sickness, death): Endogenous exposure
  \[ \lambda_k(H_t) = \begin{cases} 
  \lambda_{s0} & k = s \quad \text{(sickness)} \\
  \lambda_{m0} + \lambda_{m1} H_t^{-\xi_m} & k = m \quad \text{(death)}
  \end{cases} \]
Model [Hugonnier et al., 2013, \textit{RESTUD}]

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  \[ Y(H_t) = y_0 + \beta H_t. \]
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- Health shock insurance: Actuarially fair
  \[ X_t - dM_{st} = X_t - dQ_{st} - X_t - \lambda_{s0} dt. \]
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- 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: $V(W_t, H_t) = \sup_{(C, n, x, \lambda)} U_t(C)$, 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,

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

  $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

\[ I^*(W, H) = \underbrace{KBH}_{\text{Order-0 demand}} + \underbrace{\mathcal{I}_1 H^{-\xi m} N_0(W, H)}_{\text{Death risk hedging demand}} \]

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

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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.
- Non-monotone in \( H \):
  - Low \( H \): Net wealth effect dominant, investment increases if better health.
  - High \( H \): Mortality risk effect dominant, investment decreases if better health.
Admissibility and preference for life

- Consumption:

\[
C^*(W, H) = a + \left[ A + C_1 H^{-\xi_m} \right] N_0(W, H)
\]
\[
N_0(W, H) = W + BH + \left( y_0 - a \right) / r
\]
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:**
  \[ C^*(W, H) \geq a \iff A = \{(W, H) : N_0(W, H) \geq 0\}, \]
  \[ = \{(W, H) : W > x(H) = -(y_0 - a)/r - BH\} \],
Admissibility and preference for life

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

- Admissibility: \( C^*(W, H) \geq a \iff A = \{(W, H) : N_0(W, H) \geq 0 \}, \]
  \[ = \{(W, H) : W > x(H) = -(y_0 - a)/r - BH \}, \]

- Homogeneity of preferences: \( C^* - a > 0 \implies V > 0 \)
Admissibility and preference for life

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- Homogeneity of preferences: \( C^* - a > 0 \implies V > 0 \)
  - Versus welfare at death \( V \equiv 0 \implies \) life preferred to death.
Admissibility and preference for life

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

1 Local expected changes:

\[ E_t - [dH] = \left[ I^h(W, H)^\alpha - \frac{\hat{\delta}}{\delta + \lambda_s \phi} \right] Hd\tau, \]

where

- \( E_t \) is the expected change in health at time \( t \).
- \( [dH] \) is the change in health over a small time interval \( dt \).
- \( I^h(W, H)^\alpha \) represents the health production function.
- \( \hat{\delta} \) is the expected rate of health depletion.
- \( \delta + \lambda_s \phi \) is the health depreciation rate.
- \( H \) is the health level.
- \( \tau \) is the time interval.

This equation captures the net change in health, considering both production and depletion factors.
Local expected changes:

\[ E_t[-dH] = \left[ I^h(W, H)^\alpha - \frac{I^*}{H} \right] H dt, \]

Health depletion/accelerating regions:

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

Local expected changes:

\[ E_t[\text{d}W] = \left[ rW + Y(H) - C^*(W, H) - l^*(W, H) \\
+ \Pi^*(W, H)\sigma_\delta \theta \right] \text{d}t, \]
Optimal health and wealth dynamics

Endogenous mortality

Expected local dynamics and depletion: Wealth

1. Local expected changes:

\[ E_t[\mathrm{d}W] = [rW + Y(H) - C^*(W, H) - I^*(W, H)
+ \Pi^*(W, H)\sigma S\theta] \mathrm{d}t, \]

2. Wealth depletion region:

\[ D_W = \{(W, H) \in A : E_t[\mathrm{d}W] < 0\}. \]
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

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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:
  \[ \beta < \tilde{\delta}^{1/\alpha}, \]

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

Figure: Health and wealth dynamics
Phase diagram

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Phase diagram

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

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

Main result: $D_H = A; \mathcal{A}C = \emptyset$
Reducing incidence of Closing Down strategies

Figure: Increase in $y_0$ (e.g. Social Security)
Reducing incidence of Closing Down strategies

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

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

- 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.
Model and data

- Structural trivariate econometric model:

\[ l_j = K_0 BH_j + K_m H_j^{-\xi_m} N_0(W_j, H_j) + u_{lj}, \]
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- 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 \( \Rightarrow \) drop optimal insurance.
Estimated and calibrated parameters

Realistic for relatively old population (75.3 years):

<table>
<thead>
<tr>
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<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>$y_0$</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 $\dollar$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

\[ \ell(W_t, H_t) = \left(\frac{1}{\lambda_{m0}}\right)(1 - \lambda_{m1}\kappa_0 H_t^{-\xi_m}) \]

<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

-5
-4
-3
-2
-1
0
1
2
3
4

0.5
1
1.5
2
2.5
0

0.02
0.04
0

# 10

-3
0
0.5
1

d. Welfare

-5
0
2
4

P. St-Amour (UNIL, SFI)
Concluding remarks

Closing down the shop strategy:

- Optimal depletion of health/wealth capitals.
Concluding remarks

Closing down the shop strategy:

- Optimal depletion of health/wealth capitals.
- Accelerating depletion subsets.
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:

- 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.

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Reducing incidence of closing down:

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2. Optimal? No clear normative arguments.
   - Myopia? No, fully endogenize effects of choices $\leftrightarrow$ 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


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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.


- What determines end-of-life assets? a retrospective view.

- The impact of socioeconomic status on health over the life-course.

- Health and income across the life cycle and generations in Europe.