Health Investment over the Life-Cycle

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July 17th 2009, CEF Meeting
Motivation

Why do we need to invest in health?

- Individuals derive utility from being healthy: good health helps us to enjoy consumption and leisure better (*consumption motive*)
Why do we need to invest in health?

- Individuals derive utility from being healthy: good health helps us to enjoy consumption and leisure better (**consumption motive**)
- Good health enables individuals to supply more labor either to the labor market or at home via reducing sick time (**investment motive**)
How does the motive for health investment change over the life cycle?
How does the motive for health investment change over the life cycle?

How does health investment affect individuals’ labor supply and consumption decision over the life cycle?
Intuition

- Young age: Marginal utility of good health is low while length of working age is long $\implies$ C motive is low, I motive is high
- Old age: opposite
Evolution of motives interacts with two other forces along life cycle

- natural depreciation rate of health stock increases
- survival probability decreases
Preliminary results show

- I Motive keeps decreasing and disappears after the retirement
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- C Motive exhibits an interesting hump shape
Results

Preliminary results show

- I Motive keeps decreasing and disappears after the retirement
- C Motive exhibits an interesting hump shape
  - MU of health keeps increasing
Preliminary results show

- I Motive keeps decreasing and disappears after the retirement
- C Motive exhibits an interesting hump shape
  - MU of health keeps increasing
  - Effective discount factor (subjective discount rate $\times$ survival prob. $\times (1 - \text{dep}_h)$) steadily decreases
Health investment in **goods** crowds out the **consumption** at older age
Health investment in **goods** crowds out the **consumption** at older age

Health investment in **time** crowds out the **working hours** at older age
Literature

- Demand for health

- Life cycle model with exogenous health

- Life cycle model with endogenous health
Features

- OLG dynamic general equilibrium model
- Endogenous health accumulation through investment in both goods and time
- PAYG social security system
Demographics

- Populated by overlapping generations of finite-lived individuals with measure one
- Born at age $j = 1$, retire at $j_R$, die at age $J$
- Conditional survival probability from age $j - 1$ to $j$ is $\varphi_j \in (0, 1)$
- Population growth rate $n$
- Age share $\mu_j$

$$
\mu_j = \frac{\mu_{j-1} \varphi_j}{1 + n}, \quad \text{with} \quad \sum_{j=1}^{J} \mu_j = 1
$$
Utility function

\[ E_0 \sum_{j=1}^{J} \beta^{j-1} \left[ \prod_{k=1}^{j} \varphi_k \right] U(c_j, l_j, h_j) \]

\[ U(c_j, l_j, h_j) = \frac{[\lambda (c_j^{\rho} l_j^{1-\rho}) \psi + (1 - \lambda) h_j^\psi]^{1-\sigma}}{1 - \sigma} \]

\[ \text{IES} = \frac{1}{\sigma}, \text{ Elasticity b/w } h \text{ and } c - l = \frac{1}{1 - \psi} \]
Constraints

- **Time constraint**

  \[ n_j + l_j + s_j + v_j = 1, \quad \forall j \]

  sick time \( s_j = Qh_j^{-\gamma} \)

- **BC**

  \[ c_j + m_j + a_j \leq (1 - \tau_{ss}) w \varepsilon_j n_j + (1 + r) a_{j-1} + T, \quad \forall j < j_R \]

  \[ c_j + m_j + a_j \leq b + (1 + r) a_{j-1} + T, \quad \forall j \geq j_R \]

  SS benefits \( b = \kappa \sum_{i=1}^{j_R-1} w \varepsilon_j n_j \frac{1}{j_R - 1} \), \( a_j \geq 0 \)
Health Investment

- Health accumulation

\[ h_{j+1} = (1 - \delta_h) h_j + B(m^\theta v_j^{1-\theta}) \xi \]

- Age-dependent depreciation rate

\[ \delta_{h_j} = \frac{\exp(a_0 + a_1 j + a_2 j^2)}{1 + \exp(a_0 + a_1 j + a_2 j^2)} \]
Technology

- Production function
  \[ Y_t = K_t^{\alpha} N_t^{1-\alpha} \]

- Capital accumulation
  \[ K_{t+1} = (1 - \delta)K_t + I_t \]

- Resource constraint
  \[ C_t + M_t + I_t = Y_t \]
Firm’s FOCs

\[ w = (1 - a) \left( \frac{K}{N} \right)^\alpha \]

\[ r = a \left( \frac{K}{N} \right)^{\alpha - 1} - \delta \]
Consumer's Problem

- A multi-state multi-control DP problem

\[
V_j(a_{j-1}, h_j) = \max_{c_j, a_j, m_j, l_j, n_j, v_j} \left\{ U(c_j, l_j, h_j) + \beta \varphi_j V_{j+1}(a_j, h_{j+1}) \right\}
\]

subject to

\[
\begin{align*}
    c_j + m_j + a_j & \leq (1 - \tau_{ss}) w \varepsilon_j n_j + (1 + r) a_{j-1} + T, \forall j < j_R \\
    c_j + m_j + a_j & \leq b + (1 + r) a_{j-1} + T, \forall j_R \leq j \leq J \\
    h_{j+1} & = (1 - \delta_{h_j}) h_j + B (m_j^{\theta} v_j^{1-\theta})^{\xi}, \forall j \\
    n_j + l_j + s_j + v_j & = 1, \forall j \\
    a_j & \geq 0, \forall j
\end{align*}
\]
Methodology

- Pick most of parameters that commonly used in the literature
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- Some model-specific parameters are calibrated to match several macro ratios in the data
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- Pick most of parameters that commonly used in the literature
- Some model-specific parameters are calibrated to match several macro ratios in the data
- Evaluate the model performance by comparing the model-generated life cycle profiles of interested variables with those in the data
### Parameters from the data and literature

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>population growth rate</td>
<td>1.2%</td>
</tr>
<tr>
<td>$J$</td>
<td>maximum life span</td>
<td>65 (real age 85)</td>
</tr>
<tr>
<td>$j_R$</td>
<td>mandatory retirement age</td>
<td>45 (real age 65)</td>
</tr>
<tr>
<td>${\varphi_j}_{j=1}^J$</td>
<td>conditional survival prob.</td>
<td>Faber (1982)</td>
</tr>
<tr>
<td>${\varepsilon_j}_{j=1}^{J_R-1}$</td>
<td>age-efficiency profile</td>
<td>Imrohoroglu et al. (1995)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>subjective discount factor</td>
<td>0.97</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>CRRA coefficient</td>
<td>2</td>
</tr>
<tr>
<td>$\psi$</td>
<td>elas. of sub. b/w $c$ and $h$</td>
<td>$-8$, Yogo (2008)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>share of $c$ in $c - l$ combo</td>
<td>0.36, Cooley&amp;Prescott (1995)</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>capital share</td>
<td>0.36</td>
</tr>
<tr>
<td>$\delta$</td>
<td>depreciation rate of $K$</td>
<td>0.069</td>
</tr>
<tr>
<td>$g$</td>
<td>rate of tech. change</td>
<td>1.6%</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>SS replacement ratio</td>
<td>40%</td>
</tr>
</tbody>
</table>
Parameters to be calibrated

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<thead>
<tr>
<th>Parameter</th>
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</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>share of $c - l$ composition in utility</td>
<td>0.85</td>
</tr>
<tr>
<td>$a_0$</td>
<td>depreciation rate of $h$</td>
<td>−5.8</td>
</tr>
<tr>
<td>$a_1$</td>
<td>depreciation rate of $h$</td>
<td>0.05</td>
</tr>
<tr>
<td>$a_2$</td>
<td>depreciation rate of $h$</td>
<td>0</td>
</tr>
<tr>
<td>$B$</td>
<td>productivity of $h$ accumulation technology</td>
<td>0.1</td>
</tr>
<tr>
<td>$\theta$</td>
<td>share of goods expenditure in $h$ investment</td>
<td>0.4</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>return to scale for $h$ investment</td>
<td>0.8</td>
</tr>
<tr>
<td>$Q$</td>
<td>scale factor of sick time</td>
<td>0.04</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>elasticity of sick time to $h$</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Computation Method

1. Guess aggregate quantities $K_0, N_0, T_0$ and social security tax rate $\tau_{ss0}$. From the firm’s FOCs, we derive prices $w$ and $r$.

2. Given the prices and policy instruments, solve the individual’s DP problem by backward induction.

3. Obtain the age-dependent distributions by forward recursion.

4. Compute the new aggregate quantities by using the age share, the distribution, and the decision rules and compute the new SS tax rate by using self-financing condition of SS. Check the convergence criterion. If it is satisfied, stop. If not, go to step 1 to update the initial guess.

- Encounter “curse of dimensionality,” use parallel computation.
## Macro Ratios

<table>
<thead>
<tr>
<th>Selected Statistics</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital-Output Ratio</td>
<td>2.6</td>
<td>2.42</td>
</tr>
<tr>
<td>Consumption-Output Ratio</td>
<td>0.78</td>
<td>0.73</td>
</tr>
<tr>
<td>Health Expenditure-GDP Ratio</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Working Hours Ratio</td>
<td>0.33</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Life Cycle Profile of Health Status

Life-Cycle profile of health status

- Model
- Data

Age vs. Health Status

0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1

20 30 40 50 60 70 80
Life Cycle Profile of med. expenditure - income ratio
Life Cycle Profile of Medical Expenditure
Life Cycle Profile of \( v \)
Life Cycle Profile of Working Time

Life-Cycle profile of working hours

- **Model**
- **Data**

![Graph showing the life cycle profile of working hours](image-url)
Life Cycle Profile of sick time

Life-Cycle profile of sick time

- Age: 20 to 90
- Sick time: 0.04 to 0.075
Life Cycle Profile of Consumption
Life Cycle Profile of Asset Holding
Euler Equation of Health Investment

\[
\frac{\partial U}{\partial c_j} = \beta \varphi_{j+1} MPM_j \left[ \frac{\partial U}{\partial h_{j+1}} \frac{\partial U}{\partial c_{j+1}} w \varepsilon_{j+1} \frac{\partial s_{j+1}}{\partial h_{j+1}} + (1 - \delta_{h_{j+1}}) \frac{\partial U / \partial c_{j+1}}{MPM_{j+1}} \right]
\]
Decomposition of Health Investment Motive

![Graphs showing consumption motive, investment motive, and continuation value of health investment over age.](Image)
Euler Equation Again

\[
\frac{\partial U}{\partial c_j} = MPM_j \sum_{t=1}^{J-j} \beta^t \left( \prod_{k=j+1}^{j+t} \varphi_k \right) \left( \prod_{k=j+1}^{j+t-1} (1 - \delta_{h_k}) \right)
\]

effective discount factor

\[
\begin{bmatrix}
\frac{\partial U}{\partial h_{j+t}} \\
\frac{\partial U}{\partial c_{j+t}} \left( w \varepsilon_{j+t} \frac{\partial s_{j+t}}{\partial h_{j+t}} \right)
\end{bmatrix}
\]

consumption motive investment motive
Decomposition of Health Investment Motive Again

Accumulative consumption motive for health investment

Accumulative investment motive for health investment
Thought

- Health might contribute to the hump shape of consumption over the life cycle (especially the declining part) because health is complementary to consumption.
- Provide another angle to explain the hump of the consumption.
- Margins in the model
  - $k \text{ vs. } h$
Thought

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  - $c$ vs. $m$
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Provide another angle to explain the hump of the consumption.

Margins in the model:
- $k$ vs. $h$
- $c$ vs. $m$
- $m$ vs. $v$
Future Research

- health investment affects the survival probability $\varphi_j(h_j)$
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- add in uncertainty

\[
h_{j+1} = (1 - \delta_j)h_j + B(m_j^{\theta}v_j^{1-\theta})\xi + \epsilon_j
\]

$\epsilon_j \sim \text{Markov process}$
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  h_{j+1} = (1 - \delta_h)h_j + B(m_j^{\theta} \nu_j^{1-\theta})\xi + \varepsilon_j
  \]
  $\varepsilon_j \sim$ Markov process

- study welfare cost of Medicare system
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  - Gain: risk sharing, consumption smoothing
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- add in uncertainty

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    h_{j+1} &= (1 - \delta_h) h_j + B(m_j^\theta v_j^{1-\theta}) \xi + \varepsilon_j \\
    \varepsilon_j &\sim \text{Markov process}
\end{align*}
\]

- study welfare cost of Medicare system
  - Gain: risk sharing, consumption smoothing
  - Cost: tax distortion; moral hazard: health investment
Conclusion

- Study the evolution of motives for health investment over the life cycle within the context of an OLG general equilibrium model
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- Investment motive keeps decreasing and disappears after the retirement
- Consumption motive exhibits a hump shape driven by the interaction b/w effective discount factor and increasing MU of health
- Health investment “crowds out” consumption and working time at older age