The Value of Life and the Rise in Health Spending

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Introduction

• Rising health share in U.S. Why? Future?

• Framework
  – Utility depends on quantity (years) and quality (consumption)
  – \( c + h = y \)
  – How much to spend on health?

• Standard utility function delivers:
  – MUC falls quickly, while value of life rises.
  – A health share that optimally rises with income...
    - as long as diminishing returns in production are not extremely sharp.
Recent health literature emphasizes technical change as key to a rising health share (e.g. Newhouse 1992)
- Existing explanation is incomplete.
- Why use? Why invent?

- $c$ versus $h$: Grossman (1972), Erlich and Chuma (1990)
Figure 1. The Health Share
Figure 2. Life Expectancy

Life Expectancy

Year


68 70 72 74 76 78

The Value of Life and the Rise in Health Spending
Basic Model

- Our approach: Social Welfare
  - What allocation maximizes social welfare?
  - Alternative would be to study equilibrium with institutions...
- Strong assumptions, relax in full model
  - Representative agent (no age-specific mortality)
  - Constant income and productivity: stationary model.
- \( x \equiv \text{health status.} \)
  - Mortality rate is \( 1/x \).
  - So \( x \) is also life expectancy.
Environment

- Expected lifetime utility

\[ U(c, x) = \int_0^\infty e^{-(1/x)t} u(c) \, dt = xu(c). \]

- Resource constraint

\[ c + h = y \]

- Production function for health

\[ x = f(h) \]
Optimal Allocation of Resources

\[
\max_{c,h} f(h)u(c) \quad s.t. \quad c + h = y
\]

- Solution: Allocations proportional to elasticities

\[
\frac{h}{c} = \frac{s}{1 - s} = \frac{\eta_h}{\eta_c} = \text{Elasticity of } f(h) \quad \text{Elasticity of } u(c)
\]

- Our story: Declining \( \eta_c \). Why?

\[
u(c) = b + \frac{c^{1-\gamma}}{1 - \gamma}, \quad b > 0, \quad \gamma > 1
\]

- More generally: \( u(c) \) bounded, \( u(c) = \log c \)
\[
\frac{s}{1 - s} = \frac{\eta_h}{\eta_c}
\]

- Requires \( \eta_h \equiv f'(h)x/h \) not to fall too quickly. 
  i.e. diminishing returns cannot be extremely sharp.
  - True for empirically estimated \( f(h) \) (below).
  - Examples: \( x = f(h) = (zh)^\theta \Rightarrow \eta_h = \theta \)
  - Or \( x = f(h) = \phi \log(zh) \Rightarrow \eta_h = \phi/x. \)
Alternative characterization

- **Value of life:** \( L(c, x) \equiv U(c, x) / u'(c) \)
- Then,
  \[
  s = \eta_h \cdot \frac{L(c, x)}{y} \]
- With CRRA utility, value of a life year is
  \[
  \frac{L(c, x)}{x} = bc^\gamma - \frac{c}{\gamma - 1}.
  \]
  Will grow faster than income for \( \gamma > 1 \).
Generalizing Utility: $U(c, x)$

- Solution:
  $$\frac{s}{1 - s} = \frac{\eta_x \eta_h}{\eta_c}$$

  where $\eta_x \equiv U_x x / U$.

- Health share rises when consumption elasticity falls faster than the product of the production and life expectancy elasticities.

- Example: $U(c, x) = x^\alpha u(c)$ delivers a constant $\eta_x$ even with $\alpha$ close to zero.

- Summary: health share rises with income if the joy of living an extra year does not diminish as fast as the MU of consumption.
Discussion

- Simple model inadequate for three reasons:
  1. Constant income and productivity (we cheated!).
  2. No age-specific mortality.
     ⇒ Turn to our full, dynamic model.

- Does production elasticity fall faster than consumption elasticity?
  ⇒ Empirical work that follows model.
The Full Dynamic Model

- Individual health status: $x_{a,t}$
  - Mortality rate: $1/x_{a,t}$
  - Survival probability: $1 - 1/x_{a,t}$

- Production function for health:
  $$x_{a,t} = f_a(h_{a,t}; a, t)$$

- Flow utility: Incorporate quality of life considerations
  $$u_{a,t}(c_{a,t}, x_{a,t}) = b + u(c_{a,t}, x_{a,t})$$

where

$$u(c_{a,t}, x_{a,t}) = \frac{c_{a,t}^{1-\gamma}}{1 - \gamma} + \alpha x_{a,t}^{1-\sigma}/(1 - \sigma),$$
Social Welfare

- Social welfare function

\[
\sum_{t=0}^{\infty} \sum_{a=0}^{\infty} N_{a,t} \beta^t \left( b_{a,t} + u(c_{a,t}, x_{a,t}) \right).
\]

- Let \( N_t \equiv (N_{1,t}, N_{2,t}, \ldots, N_{a,t}, \ldots) \) denote the vector of populations by age.

- Let \( V(N_t; y_t, z_t) \) denote maximized social welfare.

- Bellman’s principle of optimality.
Bellman Equation

\[ V_t(N_t) = \max_{\{h_{a,t}, c_{a,t}\}} \sum_{a=0}^{\infty} N_{a,t} u_{a,t}(c_{a,t}, x_{a,t}) + \beta V_{t+1}(N_{t+1}) \]

subject to

\[ \sum_{a=0}^{\infty} N_{a,t}(y_t - c_{a,t} - h_{a,t}) = 0, \]

\[ x_{a,t} = f_{a}(h_{a,t}; a, t) \]

\[ N_{a+1,t+1} = (1 - 1/x_{a,t}) N_{a,t} \]

and \( N_{0,t} = N_0, y_{t+1} = e^{\gamma_y} y_t. \)
Optimality Conditions

- $\lambda_t \equiv$ Lagrange multiplier on the resource constraint
- FONC:
  \[
  u_c(c_{a,t}, x_{a,t}) = \lambda_t,
  \]
  \[
  \frac{\partial V_{t+1}}{\partial N_{a+1,t+1}} \cdot \frac{f'(h_{a,t})}{x_{a,t}^2} + u_x(c_{a,t}, x_{a,t}) f'(h_{a,t}) = \lambda_t.
  \]
- Social value of life: $v_{a,t} \equiv \frac{\partial V_t}{\partial N_{a,t}}$
- Then combining the FONC yields (LINK)

\[
\frac{\beta v_{a+1,t+1}}{u_c} + \frac{u_x x_{a,t}^2}{u_c} = \frac{x_{a,t}^2}{f'(h_{a,t})}
\]

Quantity effect  Quality effect  Marginal cost
Recall $v_{a,t} \equiv \frac{\partial V_t}{\partial N_{a,t}}$

Taking the derivative of the value function

$$v_{a,t} = u_{a,t}(c_t, x_{a,t}) + \beta \left( 1 - \frac{1}{x_{a,t}} \right) v_{a+1,t+1} + \lambda_t(y_t - c_t - h_{a,t})$$

- flow utility
- expected future VofL
- net resource effect
Relation to the Basic Model

- Assume $y$ constant, $\beta = 1$, $f(h)$ invariant to $a$ and $t$, and no health status in flow utility.
- Then the Bellman equation is

$$V(y) = \max_{c,h} u(c) + (1 - 1/f(h))\beta V(y) \quad \text{s.t.} \quad c + h = y$$

- Rewriting

$$V(y) = \max_{c,h} x(h)u(c) \quad \text{s.t.} \quad c + h = y$$
Data

- **Period = 5 years.**
  Ages: 0-4, 5-9, ..., 95-99.

- Age-specific mortality rates: *United States Life Tables, 2000.*


Estimating the Health PF

- Separate out accidents/homicides as exogenous.

- Non-accident mortality rate — \( \tilde{x}_{a,t} \equiv 1/m_{a,t}^{\text{non}} \):

  \[
  \tilde{x}_{a,t} = A_a (z_t h_{a,t} w_{a,t})^{\theta_a}
  \]

- Exponential technical change

  \[
  z_t = z_0 e^{g_z t}
  \]

- \( w_{a,t} \) is other unobserved determinants (education, pollution, etc.)

- Production function for overall health:

  \[
  x_{a,t} = f_{a,t}(h_{a,t}) = \frac{1}{m_{a,t}^{\text{acc}}} + \frac{1}{\tilde{x}_{a,t}}
  \]
Identification of $A_a$ and $\theta_a$

- Rewrite production function using $s_{a,t} \equiv h_{a,t}/y_t$:

$$\tilde{x}_{a,t} = A_a(z_t y_t \cdot s_{a,t} \cdot w_{a,t})^{\theta_a}.$$  

  - Technical change: $z_t y_t$
  - Resource reallocation: $s_{a,t}$
  - Other unobserved: $w_{a,t}$

- Key Identifying assumption: observed trends in $z_t y_t$ and $s_{a,t}$ account for a known fraction $\mu$ of general trend in age-specific mortality.
  - Benchmark: $\mu = 2/3 \rightarrow$ Decomposition: (35,32,33)
  - Robustness: $\mu = 1/2 \rightarrow$ Decomposition: (26,24,50)

- Generally consistent with health literature.
Figure 3. Estimates of $\theta_\alpha$
Figure 4. The Fit of the Health PF
The Marginal Cost of Saving a Life

\[ \frac{x^2}{f'(h)} = h\bar{x}/\theta. \text{ Thousands of 2000 dollars.} \]

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<td>(1,090)</td>
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Preference Parameters

- See Table 2
- $\gamma = 2$, VSL=$3$ million (to get $b$)
- Robustness checks.
The Quality of Life Parameters

  - QALY weights by age: 20=.94, 65=.73, 85=.62

- Solve these two equations for $\alpha$ and $\sigma$:

$$\frac{u(c_t, x_{20,t})}{.94} = \frac{u(c_t, x_{65,t})}{.73} = \frac{u(c_t, x_{85,t})}{.62},$$

- Results: $\alpha = 1.92$, $\sigma = 1.05$, $b = 54.2$, and $\gamma = 1.59$

- To have the health status of a 20 year old, what fraction of consumption would you give up?
  - 65 year-old: 88 percent. 85 year-old: 93 percent

Why? Because of sharp diminishing returns to consumption.
Figure 5. Simulation: Health Share
Figure 6. Robustness

Health Share, $s$

- Includes Quality of Life (7)
- VSL=$5m$
- VSL=$4m$ (5)
- Faster technical change (8) or 50% exogenous (9)

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Figure 7. Health Spending by Age

Constant 2000 dollars

Age

2050
2000
1950
Conclusions

- IF MUC falls sufficiently quickly AND health production function does not run into very sharp diminishing returns (both of which hold up empirically)...

THEN the optimal health share rises as income grows.

- Supported by
  - Estimates of low IEOS
  - Rising value of life (Costa and Kahn; Hammit, Liu, and Liu)
  - International macro evidence.

- Counter evidence? Micro income elasticities...
Evidence on VSL

- Our estimation of Health PF allows us to infer VSL. First, we discuss the existing literature.

1. Level of VSL
   - Viscusi & Aldy (2003): 4 million to 9 million
   - Ashenfelter & Greenstone (2004): 1.5 million or less

2. Change in VSL over time
   - Costa & Kahn (2003): U.S. Income elasticity = 1.6
   - Hammitt, Liu & Liu (2000): Taiwan elasticity = 2.5
   - Viscusi & Aldy (2003): Meta-analysis elasticity = 0.5
   - Basic model: Elasticity is roughly $\gamma$