Health Economics

Demand for health capital

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An individual’s production of health

The Grossman model: how do age, education, health status and income influence the production of health through the demand for health capital?

Special features: deviations from traditional demand approaches

- People want health – they demand medical care inputs to **produce** it
- Health is not passively purchased from markets – it is produced in combining time with purchased medical inputs
- Health is a capital good – it does not depreciate instantly
- Health can be treated both as a consumption and an investment good
  - consumption: health makes people feel better
  - investment: it increases the number of healthy days to work and to earn income
Health capital

- The stock of health capital provides the output of “healthy days”
- Consumers apply a set of inputs to make investments in health capital
  - market inputs of health care
  - diet, exercise, time, …
- The health stock may grow, decline, or remain constant over time (depending on age, illness or injury)

Optimal resource allocation

We will see how much time and money people will invest in their health capital. The prices of health care, people’s wages and their productivity in the production of health will determine how resources are to be allocated between health capital and other goods and services that people buy.
Investing in health capital

Health inputs

Health care
Diet
Exercise
Environment
Income
Time

Health capital stock over time

Heath outputs each year

Healthy days:
Physical health
Mental health
Activity limitation

Demand for health capital
Grossman model: health investment & the home good

\[ I = I(M, T_H) \]  \hspace{1cm} (1)

\[ B = B(X, T_B) \]  \hspace{1cm} (2)

- \( I \): health investment
- \( M \): market health inputs (medical services, drugs, \ldots)
- \( T_H \): time spent improving health
- \( B \): home good production (reading, playing, preparing meals, watching television, \ldots)
- \( X \): market goods necessary for the production of the home good
- \( T_B \): time spent in producing the home good
Time constraint

\[ T = 365 \text{ days} = T_H + T_B + T_L + T_W \]  \hspace{1cm} (3)

- **T**: total time available (365 days per period)
- **T_W**: working time (income is necessary to buy medical care goods \( M \) and other goods \( X \))
- **T_L**: time lost to illness (some of the time is taken over by ill health)

**Time available for work or leisure** = \( 365 - T_{H0} - T_{L0} = T_W + T_B \)  \hspace{1cm} (4)

- **T_B**: is now called leisure time
- **T_{H0}**: fixed health enhancing time
- **T_{L0}**: fixed time lost to illness
The slope of the VS line (the labor-leisure trade-off) reflects individual preferences according to income and leisure: optimal choice ($0 = Y_2$).

Equilibrium

Slope = Wage rate

Income

Leisure time

$0 \quad A \quad (365 - T_{H0} - T_{L0}) \quad T_W + T_B$
$T_H$ increases: $T_{H0} \rightarrow T_{H1}$; as a consequence

$T_L$ decreases: $T_{L0} \rightarrow T_{L1}$

two effects: (1) less time available for other activities; (2) the increased health stock reduces time lost to illness

If the net effect is positive: **the pure investment effect of health demand**

Health investments add to potential leisure and increase potential income
Investment in health-improving activities II

Demand for health capital
Investment in health-improving activities III

- The income-leisure line is shifted outward: VS → RQ
- Utility is increased \((E \rightarrow E')\)
  - more (future) income
  - more leisure (see figure)
  - and the individual is feeling better
- The improved health status might also increase a person’s productivity at work (higher wages and a steeper income-leisure curve)

The investment aspect of health demand

An individual wishes to invest in her health even if the only value of health is its effect on earning future income.
Production of healthy days

![Graph showing the relationship between healthy days and health stock, with a formula $H_{min}$ and a value of 365 days on the vertical axis.]

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Investment & consumption aspects of health

$U_1$: Ed derives utility from bread only

$U_2$: Ed derives utility from both health and bread

Diagram:
- Health on the vertical axis
- Bread on the horizontal axis
- Points A, B, C, D, E
- Curves representing utility levels $U_1$ and $U_2$
The production possibility trade-off between $H$ and $B$ given the total amount of time available:
- $A \rightarrow C$: health improvements increase the amount of $B$
- $H > H_{\text{min}}$: a minimum health capital stock is necessary to obtain income and leisure time necessary to produce $B$
- $E \rightarrow C$: more time is made available for health $\rightarrow$ more leisure time and income for the production of the home good

Suppose the utility from health is solely the ability to produce income and leisure time to produce the home good:
- vertical indifference curves
- utility-maximizing choice in $C$

If instead utility is not only derived from producing $B$ but also directly from health itself (the consumption feature):
- the more familiar indifference curve $U_2$
- utility-maximizing choice in $D$
- a higher health stock is chosen ($B_1 < B_0$)
Investment over time

Cost of capital
People make choices for the many periods over their life cycles (we start with the pure investment model; point C in the figure)

- **Example**: investment in an X-ray equipment
  
  Cost of the X-ray machine: €100,000
  Annual income attributable to the machine: €20,000
  Alternat. savings account: \( i = 0.05 \rightarrow Y_t = 100,000 \times (1 + i)^t \)
  Depreciation: €50,000 in five years

  **Capital cost** for any one year:
  interest foregone (\( r \)) + depreciation rate (\( \delta_0: 10\% \))
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Marginal efficiency of investment (MEI)

- MEI for investments in health is downward sloping
- The production function for healthy days exhibits diminishing marginal returns
- The cost of capital reflect the interest rate plus the rate of depreciation in health
- Optimal demand for health: intersection of the MEI curve and the cost of capital curve \((r + \delta_0)\)
Optimal health stock

Demand for health capital

$r$ = foregone interest (cost of capital)

$\delta$ = rate of depreciation

$H_{min}$, $H_{1}$, $H_{0}$, $H_{2}$

Cost of capital

MEI, MEI'
Equilibrium: the role of age, wage, and education

Thus far

- an equilibrium level of health stock has been chosen
  - how much to work
  - how much time spent on health
  - what kind of diet
  - how much exercising, . . .

- resources are allocated such that a person maintains a constant health stock every year

How do the investments in health change with age, wage, and education?
Age and the optimal health stock

Cost

- Depreciation rate is expected to increase with age (health of older people deteriorates faster than health of younger ones)
- $\delta_0 \rightarrow \delta_1 \rightarrow \delta_D$ (see the figure on slide 16): The optimal health stock decreases with age ($H_1 < H_0$)
- Consistent with the observation that elderly people purchase a greater amount of medical care though

Returns from investment

- As the expected length of life decreases the MEI curve shifts to the left: the returns from an investment will last for a shorter period of time (e.g. an older person may choose not to undergo a complicated knee surgery)
- This reinforces the decrease in investment due to increased depreciation
Health stock over the life cycle

Predictions

- The pure investment model predicts that health will decline with age.
- If health is also valued for consumption reasons (people feel better): if people increase their valuation of healthy days as they age → partial offset of the predicted health stock decline.
Wage and the optimal health stock

- Increased wage rates increase the returns from healthy days
- MEI shifts to MEI’ (see the figure on slide 16)
- Higher-wage workers will tend to increase their optimal health capital stock ($H_2 > H_0$)
- The result may be ambiguous, however: increased opportunity cost of time in producing health investment → a downward shift of the MEI curve is possible
- Retirement drops the wage to zero
  - no further investment in health under the pure investment version → health capital would depreciate until death
  - under consumption effects: health stock would not necessarily drop to $H_{min}$ directly upon retirement
  - even if we include consumption effects: retirees would reduce their health stock since the investment motive has vanished
Education is assumed to improve the efficiency to produce health investments (better knowledge of harmful effects of smoking; better ability to follow medical instructions, ...)

Education raises the marginal product of direct inputs → given investments in health capital can be generated at less cost for educated people → higher rates of return to a given health stock

$MEI \rightarrow MEI' \ (H_2 > H_0)$

Apart from this supply side effect a demand effect may exist as well – difficult to disentangle

- likely to recognize the benefits of improved health
- 😊 may enjoy feeling and looking good 😊
- greater taste for health
Grossman model: a dynamic optimization problem

Utility

\[ W = \int_0^T e^{-\rho \tau} U(t^k(H(\tau)); X(\tau)) d\tau \]  \hspace{1cm} (I)

\[ \frac{\partial U}{\partial t^k} < 0, \quad \frac{\partial^2 U}{\partial (t^k)^2} > 0, \quad \frac{\partial U}{\partial X} > 0, \quad \frac{\partial^2 U}{\partial X^2} < 0, \quad \frac{\partial t^k}{\partial H} < 0 \]

Health capital

\[ \dot{H}(\tau) = I(M(\tau), t^l(\tau)) - \delta(\tau)H(\tau) \quad \{\mu(\tau)\} \]  \hspace{1cm} (II)

\[ \frac{\partial I}{\partial M} > 0, \quad \frac{\partial I}{\partial t^l} > 0, \quad \frac{\partial \delta}{\partial \tau} > 0 \]

\[ \frac{\partial^2 I}{\partial M^2} < 0, \quad \frac{\partial^2 I}{\partial (t^l)^2} < 0, \quad \dot{H}(\tau) = \frac{dH}{d\tau} \]
Wealth

\[ \dot{A}(\tau) = rA(\tau) + Y[t^k(H(\tau)) + t^l(\tau)] - P(\tau)M(\tau) - D(\tau)X(\tau) \quad \{\lambda(\tau)\} \]

\[ \frac{\partial Y}{\partial t^k} = \frac{\partial Y}{\partial t^l} < 0, \quad \dot{A}(\tau) = \frac{dA}{d\tau} \]

Boundary values

\[ H[0] > 0, \quad A[0] > 0, \quad H[T] \geq H^{min}, \quad A[T] \geq 0 \]
Maximization problem (I)-(IV)
Lagrange: maximize (I) under constraints (II)-(IV)
Control theory – dynamic optimization

Solution

$$\left[ \frac{\partial U}{\partial t_k(\tau)} e^{-\rho \tau} + \frac{\partial Y(\tau)}{\partial t_k(\tau)} \right] \frac{\partial t_k(\tau)}{\partial H(\tau)} = \left[ r + \delta(\tau) - \frac{\dot{q}(\tau)}{q(\tau)} \right] q(\tau)$$
Marginal revenue of an investment into health must be equal the marginal cost

The left-hand side expression is positive \((-\) \times \(-\))

- Health – a consumption good: marginal utility in point of time \(\tau\) due to better health
- Health – an investment good: the reduction of days spent increases labor income by \(\frac{\partial Y(\tau)}{\partial t^k(\tau)}\)

Marginal cost of holding an additional unit of health capital

- foregone interest per monetary unit
- depreciation per monetary unit
Grossman model: list of variables

- \( W \): individual welfare
- \( U \): utility per period
- \( H \): health capital
- \( \delta \): depreciation rate of health capital
- \( A \): financial wealth
- \( r \): interest rate
- \( Y \): labor income
- \( X \): consumption goods
- \( D \): price per unit of consumption goods
- \( M \): medical service
- \( P \): price per unit of medical service
- \( I \): health investment (quantities)
- \( q \): price per unit of investment in health
- \( \tau \): time
- \( t^k \): time spent ill
- \( t^l \): time for preventive actions
- \( \rho \): time preference rate
- \( \mu, \lambda \): Lagrange multipliers
Demand for health

Assuming specific functional forms for the Grossman model, logarithmic demand functions for health ($H(\tau)$) and health services ($M(\tau)$) can be derived from the pure investment model.

**Health demand ($lnH(\tau)$)**

- Wages $\rightarrow$ increasing returns of health capital $\rightarrow +$
- Price of medical services $\rightarrow$ more expensive investment $\rightarrow -$  
- Age $\rightarrow$ increasing depreciation rate $\rightarrow -$  
- Education $\rightarrow$ higher productivity of health investment $\rightarrow +$
Demand for health services

Demand for health services ($\ln M(\tau)$)

- An increase of the optimal health capital stock increases the demand for health services → +
- Wage → increases the opportunity cost of preventive actions → substitution by medical services +
- Price of medical services → substitution by preventive actions $t^l(\tau)$ → −
- Age → demand for health services increases to compensate for higher depreciation rates → +
- Education → increases the productivity of medical services → less medical services are necessary for a given stock of health capital → −
Empirical evidence in support of the Grossman model

- Many predictions of the Grossman model can be supported by empirical evidence
- Leu & Doppmann (1986) and Leu & Gerfin (1992) confirm a decrease of health capital with age
- Strauss et al. (1993) find that health based on activity limitation decreases with age and that higher education leads to improved health
- Sickles & Yazbeck (1998) find that health care and leisure consumption tend to improve health
- Gerdtham and Johannesson (1999) find that demand for health increases with income and education, and decreases with age, urbanization, being overweight, and being single.
Empirical evidence ... unexpected regression results

- **Health**
  - Wagstaff (1986) and Leu & Gerfin (1992) find a negative correlation between demand for medical services and health

- **Age**
  - The prediction of an increase in the demand for medical services with age is rejected comprehensively by the empirical literature (Duan et al. 1984, Newhouse & Phelps 1974, Zweifel 1985)

- **Education**
  - Estimating a structural demand function for medical services Wagstaff (1986) finds a positive correlation between education and the demand for medical services
Conclusion

The Grossman model

- The GM has yielded considerable insight into the determinants of health and into the allocation of time and money into health production.
- Empirical studies reveal, however, a negative correlation between health status and the demand for medical services.
- This challenges the perception that expenditure for medical services can be unequivocally derived from (health) demand.