L3: Demand for health: the human capital model

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Outline

- The human capital (aka Grossman) model in one time period
- Stock versus flow variables
- Acquiring and producing health stock
- Acquiring and producing other goods and services
- Constraints (budget and time)
- Equilibrium in one period
- The dynamic model
- Trade-offs, trade-offs, and more trade-offs
- Where is education?
- Why do people cannot keep using resources to live forever?
- What is health?
- Is health a choice?

Big picture first

- The human capital model might appear to be a lot of obvious stuff dressed up in math
- That's a relatively fair criticism, although I'll point out the not-so-obvious insights that can be illuminating
- You will appreciate its value when we use it to frame some important policy problems
- In a sense, the fact that we still use the human capital framework is *because* the model makes sense, with a few questionable assumptions and odd conclusions
- This model is about the **demand** for health care, with health conceptualized in different dimensions
- It's an adaption of the "human capital" approach. Human capital refers to the accumulation of attributes that make a person more productive: knowledge, skills, punctuality, management ability... **Human capital** can be formally acquired (education) or by on-the-job training and experience

Model basics

- At any given time t, people are assumed to have a utility function that depends on **health** H and the consumption of goods and services Z:

  $U_t = U(H_t, Z_t)$
- We are not writing a specific functional form like $U_t = H_t^\alpha Z_t^{1-\alpha}$. We are just saying that people have a function that assigns utility given H and Z. We could be more precise by being specific about certain features, like marginal utility being positive for both (i.e. $\frac{\partial U}{\partial Z} > 0$ and $\frac{\partial U}{\partial H} > 0$)
- In other words, people prefer more of H and Z than less (again, health, **not health care**. Who likes going to hospitals?)
- Let's say that time is years. So U_t is utility at year t

Stock and flow variables

- In models like this, since we will make them "dynamic" shortly by seeing what happens over a lifetime, distinguishing between **flow** and **stock** variables is important
- A flow is a variable that is measured over a period of time. Here, Z is a flow variable in the sense that Z is produced and consumed during each year t. So consumption comes and goes during each year
- **Health is a stock variable** in the sense that it's measured at one point in time but represents something that has been accumulated or depreciated over time
- An important implication is health being a stock variable is that health in year t depends on health in year $t-1$

Stock and flow variables

- Another way to conceptualize this distinction is that flow variables can add or subtract the stock of another variable
- Think of stock variables as a glass of water. You can pour more water (a flow) or drink from the glass, which reduces the stock of water (another flow). Or the glass could have leaks
- At any point in time, you could measure how much water there is in the glass
- That's what the model assumes about health: it's stock that can be **drained** (we will use the term "depreciated," like your car –capital– depreciates) and it can be **replenished** (going for a run or being "repaired" during surgery)
- Actually, I should say: resting after going for a run, that's when the improvement happens...

More on the utility function in Grossman

- Ignoring the little math we introduced so far, what we have is:
  1. We assume that people care about their health status H at any given point in time, which is the result of what happened in the past. Think of H_t as a composite health status index. Your health now depends on your behavior today and your behavior in the past (exercise, vaccinations, smoking)
  2. We assume that people care about consuming good and services: buying food, going to restaurants, buying ski passes, getting a watch. That's Z. Now, Z is peculiar because it includes things like food or a new watch. Some goods and services could improve H (food), but others can't (a watch for example). We will be more specific about different types of good and services in a bit
- Again, health care is not directly in the utility function (for now). We assume that people care about health. In this sense, **health H is a consumption good**
- Where do H and Z come from? In this human capital framework, they can be **acquired/purchased** in the market or they can be "**produced**" by people

Acquiring and producing health stock H

- Here is the way we will formalize the idea of acquiring or producing H. H will be produced by (this is a "**production function**"): (1) $H_t = H(H_{t-1}, T_t^H, M_t)$
- H_{t-1} is the stock of health in the previous period, T_t^H is the *time* we spend improving our health, and M are market products or services we can purchase to improve health (**health care**)
- So at any given time, our stock of health depends on our health in the past and the time we spend doing things that improve health: hiking, doing yoga, running, brushing teeth, improving our relationships, sleeping... And we can also buy some things –running shoes, ski passes, vaccines, surgeries, treadmills– that improve our health
- Note the role of past health, H_{t-1}. At the beginning, day $t = 0$, when we are born, **we are born with a stock of health H_0 (health endowment)**
- For now, we are thinking about this model in one period of time, so in that period H_{t-1} is "given"

Acquiring and producing goods and services Z

- We can improve our utility (make ourselves happier) by increasing Z. The production function for Z is:
- (2) $Z_t = Z(T_t^Z, J_t)$, where T^Z is the time we spend on leisure or "playing and J represents market goods
- As before, we can buy goods and services that increase the non-health good and services Z
- But we can also "produce" them by spending time doing some activities. In your textbook, these activities are leisure type of activities
- Combining (1) and (2), we have different good and services (M and J) or "things" we can purchases that improve H or Z
- Not critical to make a clear distinction between M and J. An Apple Watch could be both – or so says Apple Inc.

Constraints I

- Why not get an infinite amount of everything and live happily ever after? Because we face **constraints**
- One constraint is that we are born with a stock of health H_0. We could be unlucky in the gene lottery and/or the circumstances lottery. We could have been born in a poor country, with lack of access to good nutrition (or a wealthy country with extreme income inequality)
- We also face **time constraints** and **income constraints**. People have a limited amount of hours during each period: $\Theta_t = T_t^W + T_t^Z + T_t^H + T_t^S$
- T^S is sick time. Sick time is unproductive. T^W is time we spend working
- Think about implications. If we spend a lot of time working, we need to reduce the amount of time we spend "playing" or improving health (jogging). If all we do is exercise or spend our time cooking super healthy meals, we may not be able to work and then we can't buy other things, *including health care*, which is part of M
- **Remember: Constraints imply trade-offs**

Constraints II

- To buy things, we need money. We get money by working (no trust-fund kids or loans here)
- How much money we get depends on wages. So we can write the other constraint as $Y_t = w * T_t^W$, where Y is income in year t
- We assume that people can't borrow
- Note that in this model wages are **exogenous**. That's jargon for saying that wages are "given" or a number, but wages are not determined in the model (**endogenous**)
- **This is an important simplification** since wages do depend on education and good health (hard to learn when you are sick)
- The skills that you learn through education can translate into good health. **Remember the strong correlation between education and health**
- In the Grossman model, **health affects income because people in good health have less sick time**

Constraints III: Budget and prices

- Prices are fundamental in economics in a more general sense than just the price of bread or watches. Prices can also be "costs" and opportunity costs
- We have two market goods in this model: M and J. Their prices are P_M and P_J, respectively
- We have seen the budget constraint before (that's why I used M and J in the intro lectures):

  $J_t * P_J + M_t * P_M = Y_t$
- In words, the amount of good and services we buy and consume during each period of time must be equal to the amount of income we earn. Since income depends on the amount of time we spend working, our consumption capacity is limited by the time we have to work
- **Repeat after me: constraints imply trade-offs, constraints imply trade-offs...**

Where are we?

- We have a **utility** function: $U_t = U(H_t, Z_t) = U(H_{t-1}, T_t^H, M_t, T_t^Z, J_t)$
- We have **production functions**:
  1. $H_t = H(H_{t-1}, T_t^H, M_t)$
  2. $Z_t = Z(T_t^Z, J_t)$
- We have **constraints** (I combined budget and income):
  1. $\Theta_t = T_t^W + T_t^Z + T_t^H + T_t^S$
  2. $J_t * P_J + M_t * P_M = w * T_t^W$
- Most are endogenous variables. The exogenous variables (at least in this one-period model) are H_{t-1}, w, Θ, P_M, and P_j
- **Remember, this model is not reality. It's a simplification that we use to gain some insight about reality –and make predictions**

Solving the model

- You already know what we mean by "solving" these models. It means finding **equilibrium conditions** and seeing what happens when things change (**comparative statics**)
- We will discuss some equilibrium conditions in the dynamic version of the Grossman model. These are things that must equal each other when there is an equilibrium
- Whenever something changes, other things must also change to go back to equilibrium, and **that's the part that is a lot easier to see with math than words**, although we will use graphs
- But can use what we have so far to discuss the **trade-offs** and limitations people face in acquiring health while living life...

The time trade-off: work, leisure, and health

- In this model, a person needs to allocate her time into working, playing, or improving health
- Time is a scarce resource: $\Theta_t = T_t^W + T_t^Z + T_t^H + T_t^S$
- It helps to think of time as either "productive time" or "sick time." Productive time is $T_t^P = \Theta - T_t^S = T_t^W + T_t^Z + T_t^H$
- So productive time depends on health, but in a one period model, **a person cannot entirely control health**
- What a person does today affects future health, but what we do today depends on what we did in the past
- Still, after taking into account sick time, a person still needs to allocate T^W, T^Z, and T^H
- How do people make this decision? **In this framework, it depends on preferences**, which means that it depends on the utility function
- But note an important thing: **health is an investment (stock)**. In the human capital framework, health investments today means more Z and H in the future

The goods H and Z trade off

- The trade-off in the allocation of time implies a trade-off in H and Z of course
- Depending on preferences, a person could decide to to spend all his time on health activities (T^H) and health products and services M, although there would be no way to purchase M if a person does not spend some time working (T^W)
- But the other way around is not possible. A person in this model cannot have zero H because a person with $H_t = 0$ wouldn't be alive to work and produce income to acquire any Z
- This type of trade-offs are very basic in economics. It's the origin of "**production possibility frontiers**" (PPF)
- All these situations can be depicted graphically, although at this point the intuition you get from graphs is the same you can get with words

PPF and choice

- The equilibrium quantities, denoted by Z^* and H^*, depend on preferences
- The red ones are different possibilities with different **indifference curves**
- The point A would not be chosen by a rational person since more of H and Z could be achieved, which means achieving a higher utility

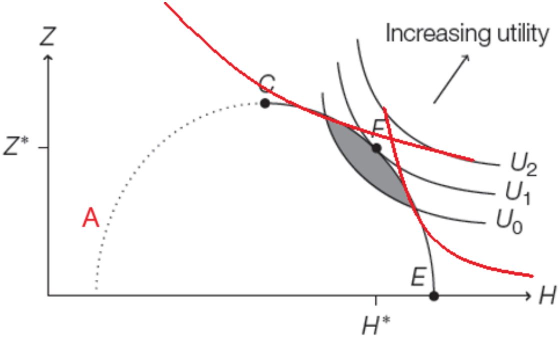


Figure: Adapted form BHT

Equilibrium, intuition

- The intersection of the FPP with the utility functions marks the model equilibrium
- Note that the amount of H and Z depends on **preferences**. Said another way, it depends on the shape of indifference curves, which means that it depends on the "taste" for each type of good
- This is the same we saw before: **in equilibrium, the marginal (additional) cost of more H equals the marginal (additional) benefit of more H** (here the cost is the quantity of one type of good you need to give up to obtain more of the the other type of good)
- But prices must be in the picture at some point. What is the cost of more health (not health care) H? Well, the price of M, which is P_M but also the opportunity cost of spending more time producing H via T^H. That "cost" is the amount of Z we can't get because we put more time into producing H, so it depends on P_J as well

Dynamics: utility

- The human capital model is more helpful when considered over time rather than during a single period
- One key difference is that now utility depends on consumption and health over a **lifetime**
- Pay attention because I'm changing the notation from your textbook to follow more closely Grossman (1972,2000)
- Your textbook has some parts that may lead to confuse model assumptions with model outcomes so I changed some small things
- **You do need to read the textbook very carefully**

Discounting and investment opportunity costs

- If somebody asked you whether you prefer \$100 now or in five years, you should say now of course – unless the person offers more than \$100 in five years
- The reason is not just inflation but **opportunity costs**. If you get the money now, you can invest it, say, in an inflation-protected bond with a rate of return of 3%. So in five years you would have: $100 \times (1 + r)^t = 100 \times (1 + 0.03)^5 = \$115.92$. That's the future value (FV)
- You can reverse the operation. The present value is: $\frac{FV}{(1+r)^t} = \frac{115.92}{(1+0.03)^5} = 100$
- Another way of writing it: $PV = FV \times \frac{1}{(1+r)^t}$
- See slides 15-17 here for more: `https://clas.ucdenver.edu/marcelo-perraillon/sites/default/files/attached-files/lecture_4_costsii.pdf`
- **More related to the Grossman model**: *investing in something always has an opportunity cost*. If you "invest" in your health now, you can't use those resources in something else

Dynamics: utility

- The utility function over a lifetime is now:
  $U = U(H_0, Z_0) + \frac{1}{(1+\rho)^1} U(H_1, Z_1) + \cdots + \frac{1}{(1+\rho)^T} U(H_T, Z_T) =$
  $\sum_{t=0}^{T} \frac{1}{(1+\rho)^t} U(H_t, Z_t)$
- Lower-case rho (ρ) is the discount rate; T is the maximum amount of time lived
- Although it looks esoteric, all we are saying is that **people care about their flow of utility over a lifetime**, which we bring to the present using a discount factor ρ
- The discount factor is actually important. Look at the equation, If $\rho = 0$, all years have the same "weight" ($\frac{1}{(1+\rho)^t} = 1$)
- We assume $\rho > 0$, which means that current utility is preferred to future utility. This just reflects human nature: **in general, we tend to value more the present than the future**. **It reflects economics as well**: a dollar now is better than a dollar in the future because of opportunity costs (not inflation but also inflation matters)

Dynamics: health

- We can be more explicit about how health is changing over time:
  $H_{t+1} = \theta H(M_t, T_t^H) + (1 - \gamma_t)H_t$
- Lower-case theta (θ) is a parameter (a number given) that represents the efficiency (technology) by which a person transforms M and time T^H into health. Another way of writing the above equation: $H_{t+1} = I_t + (1 - \gamma_t)H_t$, where I is the (gross) investment in health
- Lower-case gamma (γ) is a "depreciation" factor that **depends on time (years)**. In other words, that's aging and other things that lower our stock of health. Note that the depreciation factor depends positively on time (aging)
- If H_t is too low, then a person dies. We can say that there is a threshold H_{min} that determines death. Death happens if $H_t < H_{min}$
- So health in the next period (year) (H_{t+1}) depends on health goods purchased today and the time we put into health activities
- It also depends on "depreciation" of past-year health. This reflects life: health decays year to year (unless we do something and/or receive treatment)

Health as capital

- Health is a form of capital in several senses
- Health accumulates or gains value from investments in previous periods, but it also depreciates over time (the parameter γ is the rate of depreciation)
- As others form of capital, **health also has a rate of return**: investments in health now have consequences for the future
- In this model, better health means more productive time, which means more time to work or more investments in health for the future
- It also means more happiness because health enters the utility function (health as consumption)
- Health has another feature in this model: We **assume diminishing marginal returns to health**
- This is a common feature of many models: If a person is in bad health, small improvements will make a big different. But if a person is in good health, then returns on health are smaller

For PhD students

- Go over Grossman (2000). The set up is slightly different. Only two goods, health versus other goods: $U = U(h_t, Z_t)$, where $h_t = \phi H_t$. ϕ are the health related services (or products) people get in each period (flow). *Net investment* in health equal gross investment minus depreciation: $H_{t+1} - H_t = I_t - \delta_t H_t$, which means $H_{t+1} = I_t + (1 - \delta_t) H_t$
- Production functions: $I_t = I_t(M_t, TH; E)$ and $Z_t = Z_t(X_t, T_t; E)$. Note the parameter (not variable) E, which is the stock of knowledge or human capital other than health. Of course, [E]ducation
- Budget constraints are lifetime budget constraints:

$$\sum_{t=0}^{n} \frac{P_t M_t + Q_t X_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{W_t TW_t}{(1+r)^t} + A_0.$$

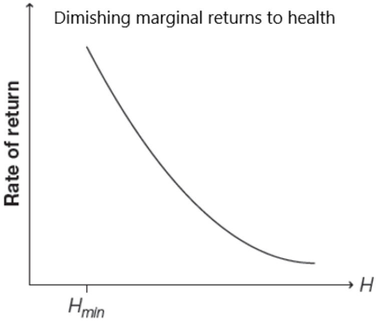
- In equilibrium:

$$\pi_{t-1} = \frac{P_{t-1}}{\partial I_{t-1}/\partial M_{t-1}} = \frac{W_{t-1}}{\partial I_{t-1}/\partial TH_{t-1}}.$$

- If you rearrange the above, it says that marginal rate of substitution equal ratio of prices. There is a balance between investing in good and services that increase health and the time effort spent on health. (The other equilibrium part is that the marginal returns to investment in health must equal marginal benefits)

Returns to health investments: diminishing returns

- If you already eat unprocessed foods, mostly vegetables, not too much (Michael Pollan style) and exercise regularly plus meditate every day and go to the doctor for preventive checks, you won't find much additional returns investing in a treadmill
- If you are a smoker, your returns to quitting are large. For example, there is a large and immediate reduction in the risk of stroke and other cardiovascular events



Returns to health investments: diminishing returns

- The curve in the previous graph is the **marginal efficiency of capital** or MEC. It's very important to understand trade offs
- This model makes health an investment, and investing more to improve the stock of health (H) has a cost
- We assumed away other investments. But let's bring investments back. Suppose to that there are other investment opportunities in the market that have a rate of return r (bonds? houses?)
- Our rational person will consider alternatives. Invest in health or in other assets?
- The other cost of investing in health H is the depreciation rate γ
- So the cost of investment is $r + \gamma$

Why is depreciation a cost of investing in health?

- The rate of depreciation is the cost of investment because it affects investments in health decisions
- If there is one insight I got from the Grossman model is this one: the cost of investing in health is higher when the rate of depreciation is high
- For example, the rate of depreciation of health is higher when we are older. To compensate for that high rate of depreciation, we need to sacrifice more to maintain the same level of health
- When you were 9 and your body was growing and was in good health, you didn't have to do much to maintain health – could eat lots chicken nuggets, ice cream, and fries
- By middle age, you better start stretching and lifting some weights if you don't want your muscles to turn into blobs. The Bradys and Madonnas of the world use a lot of resources to maintain their health
- **The depreciation rate depends on age**

Why can't people keep using resources to live longer?

- Same as previous slide. The reason is that it gets **more and more expensive in terms of opportunity costs**
- In this model, at some point it's just too expensive to keep trying to maintain health – death ensues
- With a constant rate of depreciation, you live forever
- Research suggests that the maximum age we can attain is about $T = 120$ (Sinclair and LaPlante, 2019)

What about education?

- In the first class, I emphasized the connection between education and health. Where is education in this model?
- In the Grossman model, education is **implicit** in the production functions for H and Z (and wages w, which means more income and thus more of everything; in Grossman, 2000, it's a parameter E)
- **Education improves production efficiency**: better educated people can generate more H and Z with given resources. So they have larger θ. Higher returns for each level of H in the previous graph
- They are "better" at using time and goods to produce H and Z
- In this sense, education is like technology. This is not an outcome of the model; it's an assumption
- (More educated people are more "productive" and wages are also related to productivity, but in the Grossman model this is not taken into account)

What about education?

- Different authors have conceptualized the impact of education in different ways
- Education also makes people better at managing time preferences (ρ) in the sense of delaying gratification (Becker and Mulligan, 1997; they make time preferences "endogenous")
- Education could also influence health because education makes people choose better inputs in the production function (allocative efficiency; Kenkel, 1991): "...schooling helps people choose healthier life-styles by improving their knowledge of the relationship between health behaviors and health outcomes"
- Education could also help reduce "health depreciation" (lowers γ; Muurinen, 1982)
- In any case, **it's a simplification to treat education as given (exogenous) since education in part depends on past health (back to birth) and education is a key determinant of wages w, which means Y and more of everything**. It's a bit of a letdown that education in the Grossman model is "exogenous," but sometimes we do not know how to best model this

So what is health then?

- Health has many different functions

  1) **Health is a consumption good**. People care about good health for its own sake. Good health is valuable

  2) **Health is production input**. Better health allows people to have more productive time, which means more time to work and have fun. When we are in good health, we can do things, including working, which means more money and therefore more of everything

  3) **Health is a form of capital**. Health accumulates and depreciates. Health is a stock variable.

- Of course, 2) and 3) are connected since capital is used to generate things

Is health a choice?

- One takeaway of the Grossman model is that **health is a choice** in the sense that people can choose H. I think the use of the word "choice" is not accurate. It would be more accurate to say that **people have the ability to control** their level of health. Different than saying that they can actually do it, and therefore, are choosing their level of health
- Aging research does show that genes explain only a small fraction of aging
- Children don't have any control over H_0, and little over M_t or Z_t or their technology and even time preferences. It's parents, schools, peers, and and their life conditions that can impact **health over a lifetime**, from H_0 to the end of life, H_T
- As I mentioned before, this also includes their educational opportunities. **Education is a stock, much like health**. It accumulates and depreciates. Education affects health. In many circumstance, people don't have control over the quality of their education
- **This implies that early health and educational opportunities may have large consequences over a lifetime** (although we need make some changes to the model – we will see this later)

Mathematical modeling and agency

- You have to be careful with mathematical modeling and "agency." Agency refers to the capacity of individuals to act independently and to make their own free choices
- In our models, are we using them as an analogy or literally? If literally, then they make no sense
- Think about how we talk about a virus: it seems that when a coronavirus infects a human with immune problems it can linger longer. The virus then tries different mutations until it finds one that works better, becoming more dangerous. But... viruses do not have a brain. They can't have intentions, the ability to plan or make decisions. They don't have agency. Those are random mutations
- In physics, there is a law of motion that says falling objects take the shortest route. It's as if objects were calculating the shortest path – physicists were a bit disturbed by the idea. The equations that explain the path are those that show that an "object is minimizing the distance" (that's where the Lagrangian comes from, for econ students)
- Is a bunny really thinking about passing its genes for the survival of the species? **Analogies can appear real at times** because humans do have agency – at times, ask a Buddhist or try to meditate

Big picture

- **Do not take this model too seriously**. By that I mean that the human capital model is a model. A mathematical conceptual framework to understand trade-offs. It's not a description of reality and it has limitations

- **Do not dismiss this model**. By that I mean that it is an important framework to understand constraints and trade-offs. *Note that none of the assumption we made are crazy*. Most are just **basic facts** that we put into equations. The model provides many useful predictions and ways to understand difficult problems. We will use it during the semester to frame many different topics

Insights

- As I said at the beginning of these lectures, the Grossman model feels like a lot of "duh" with math
- But there are some insights that are surprising or at the very least are more prominent when we frame health as human capital. For me, these are:
  - Maintaining good health requires more resources as we get older because of the opportunity costs of maintaining health increases with age. Said another way, fighting against aging (depreciation) gets more and more "expensive" as we age
  - Individuals who make more money (higher wage) will improve health (i.e. invest in health) by buying more health care rather than using their time since their time is more valuable (hire a chef to cook healthful meals. Why bother cooking?)
  - The rate of depreciation is important. Things that affect health can accumulate. Think about hard manual jobs. A person would need to invest more to compensate, but resources are scarce, which would lead to lower optimal health

Insights

- Investing in health can have a large payoff, but up to a point since there are are diminishing marginal returns
- The investments that are made for us when we are children can compound over time. Our early life can have a sustained impact over time. Health as a child can influence education and future income (not exactly derived from Grossman, though, since education is exogenous in this model)
- Education is one “technology” that allows to make more of the resources we have

Criticisms

- There are plenty of criticisms about the Grossman model and modifications to this framework. It's almost 50 years old
- For example, Zweifel (2012) has some strong words about some features (the Grossman model, incidentally, does not predict that health expenditures will decline with age or bad health)
- Other criticisms have led to modifications and refinements
- The model ignores social context, although we could still model this by seeing what happens when "external shocks" induce changes
- Odd stuff: health doesn't impact wages. Health affects income because of less time to work, but not the wage level itself
- People optimally choose when to die

References

Becker, G.S. and Mulligan, C.B., 1997. The endogenous determination of time preference. The Quarterly Journal of Economics, 112(3), pp.729-758.

Kenkel, D.S., 1991. Health behavior, health knowledge, and schooling. Journal of Political Economy, 99(2), pp.287-305.

Muurinen, J.M., 1982. Demand for health: a generalised Grossman model. Journal of Health economics, 1(1), pp.5-28.

Sinclair, D.A. and LaPlante, M.D., 2019. Lifespan: Why We Age—and Why We Don't Have To. Atria Books.

Zweifel, P., 2012. The Grossman model after 40 years. The European Journal of Health Economics: HEPAC, 13(6), p.677