1.2. The Health Production Function

Def: Production Function: Is the maximum output that can be produced out of a given combination of inputs.

Health depends on a number of factors, some of which can be influenced by the individual himself. Hence, health can be produced.

Health is also a consumption good because it enters in the utility function of the individuals. Utility increases in Health.

Health lasts for more than one period.

Health (H) is a **durable** good that can be produced by the individual. One of the obvious inputs into this production is Health Care.

Assume $H_2 > H_1$

$$\frac{\partial U}{\partial H} > 0 \quad \frac{\partial U}{\partial X} > 0 \quad \frac{\partial^2 U}{\partial H \partial X} > 0$$

$X$ (Other Goods/Services)
1.2. The Health Production Function

Health care (e.g. visits to the dentist, flu shots, etc, x-rays, blood tests, etc.) is not a "good" that increases utility per se.

- **Demand for Health Care** is a derived demand, its purpose is to create health, just like an input into a production function. It is an obvious **INPUT** into the production of HEALTH.

- **What is the relationship between Health Care and Health?**
1.2. The Health Production Function

What is the relationship between Health Care and Health?

- Historically the contribution of Health care to the reduction of mortality rates is relatively small (smaller than one might think). When the big innovations of the XX century were introduced, mortality rates had already fall substantially (McKeown, 1976) due to the decrease in infectious (contagious) diseases such as typhus, pneumonia, tuberculosis, polio, whooping cough, smallpox.
- The crucial contribution was the establishment of a sewage system in the large cities and the provision of drinkable water.
McKeown, 1979

REDUCTION OF MORTALITY IN ENGLAND AND WALES
1848 -1971

% of reductions

Micro-organisms 74
   1. Airborne diseases 40
   2. Water and food borne 21
   3. Other micro-organism 13

Other conditions 26

All diseases 100

Source: Mckeown (1979)

MEASLES: MORTALITY RATE AMONGST YOUNGER THAN 15 YEARS OLD.

ENGLAND AND WALES

Mortality Rate (per million)

Source: McKeown (1988)
1.2. The Health Production Function

- The First human being treated with Penicillin was in 1941
- Sulfonamides (1930) eradicate tuberculosis (TB) in few years
- Nowadays although the health care sector contributes a lot to the good health of the population it serves, its marginal contribution is relatively small.
The History of Penicillin

“After further testing, Fleming was able to isolate the juice of the mould and it was then that he named it penicillin. This new breakthrough destroyed such nasties as gonorrhea, meningitis, diptheria and pneumonia bacteria. Best of all, it was not poisonous to humans. The medical community reacted coldly to this new discovery, however. They were adamant that once a bacterium entered the body, there was nothing that could be done. Penicillin was seen by them as a non-event.

The overwhelming casualties on the battlefield during the 2nd World War led two medical researchers, Howard Florey and Ernst Chain, to look at resurrecting Fleming’s work with penicillin. After much refinement they were able to develop a powdered form of penicillin. In 1941 the first human was successfully treated. Before long, penicillin was in full production. Fleming, Florey and Chain were awarded the Nobel Prize for Medicine in 1945.”

1.2. The Health Production Function

The basic model of the Health Production Function:

\[ H = f(\text{HC}, \text{Other Inputs}; I_0) \]
\[ \text{HC} \equiv \text{Health Care} \]
\[ I_0 \equiv \text{Initial Conditions} \]
\[ \frac{\partial f}{\partial \text{HC}} > 0; \quad \frac{\partial^2 f}{\partial \text{HC}^2} < 0 \]
1.2. The Health Production Function

Let’s assume that we can measure all the variables perfectly. Then we may write the health production function as:

\[ H = f(H_C, \text{Life style, Environmental Factors, Genetics, occupation, education, etc}) \]

It is reasonable to suppose that HC has a positive effect. Life Style includes habits such as: tobacco and alcohol consumption, physical exercise, nutrition etc. Environmental Factors includes:
- Pollution, climate, geography (sea and beach, altitude, urban/rural)

\[ \Delta H \text{ from } A \text{ to } B > \Delta H \text{ from } n \text{ to } n+1 \]

In this case an improvement of the pollution levels from \( A_0 \) to \( A_1 \) increases health by more (\( B \rightarrow D \)) than a marginal increase in Health Care from \( n \) to \( n+1 \) (\( B \rightarrow C \)). If the costs of the two measures were the same than clearly increasing air quality would be preferable. In order to carry out economic policy it is crucial to know the marginal effects and for that one needs to estimate a production function.
1.2. The Health Production Function - Empirics

- Essential Questions:
  - How to measure H?
    - Studies using Individual data: number of inactive days due to illness, number of days with restricted activity due to illness
    - Studies using aggregated data:
      - Mortality rate, child mortality rate (less than 5), infant mortality rate (less than 1), neonatal mortality rate (less than 4 weeks), life expectancy (in the west there is not a lot of variation between countries but the advantage of this information is that they have been used a lot in the past – which allows comparisons with previous studies - and the data is objective and well measured. One disadvantage of mortality rates is that they only give info about an extreme occurrence and not directly about the state of health. Some diseases may not cause death but may affect health considerably leading to a lot of losses of working days, example: rheumatism)
  - How to measure Health Care? HC has a lot of different dimensions (visits to the GP, visits to the specialist, home visits, blood tests, screening and diagnosis, medicine, surgeries, etc.) In order to aggregate all dimensions it is common to convert than to monetary units, say Euros.

1.2. The Health Production Function - Empirics

*How to eliminate regression biases? Biases may occur when we cannot observe or measure all inputs into the production function:

Example: Suppose we can write the following simple health prod. Function:

$$H = f(m, \xi)$$

where:

- $m =$ physicians per 1000 inhab. (observable)
- $\xi =$ physical exercise (not observable)

Estimation:

$$H = \alpha m + \beta \xi + \alpha m + u \quad u = \text{error term}$$

*If $u$ is independent of $m$ than $\alpha$ can be estimated by OLS with no BIAS

*But most likely $\text{corr}(m, \xi)<0 \Rightarrow \text{corr}(m, u)<0$, because it is likely that the supply of doctors be larger in those regions where people practice less exercise, have worse health and, therefore, demand more medical services. This implies: $\Rightarrow \hat{\alpha} < \alpha$

that is there is a NEGATIVE BIAS when $\alpha$ is estimated by OLS.
1.2. The Health Production Function - Empirics

A simple Example: $\alpha = 1; \beta = 10$

<table>
<thead>
<tr>
<th>Getafe</th>
<th>Leganés</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_G = 50$</td>
<td>$m_L = 30$</td>
</tr>
<tr>
<td>$e_G = -0.5$</td>
<td>$e_L = 0.5$</td>
</tr>
<tr>
<td>$H_G = 1(50) + 10(-0.5) = 45$</td>
<td>$H_L = 1(30) + 10(0.5) = 35$</td>
</tr>
</tbody>
</table>

The estimated $\alpha$ is negatively biased because we do not control for the physical exercise.
### 1.2. The Health Production Function - Empirics

\[ H = \alpha m + \beta(0.5) = m + 5 \]

\[ H = \alpha m = m \]

\[ H = \alpha m + \beta(-0.5) = m - 5 \]

\[ H = 0.5m + 20 \]

---

#### Some Empirical studies: Aggregated Data

- One of the first empirical studies was by **Auster et al. 1969**. The unit of analysis are the states of USA. They propose a Cobb-Douglas health production function of the following form:

\[ H_i = CZ_i^\alpha X_i^\beta M_i e^{\delta_i} e^{\epsilon_i} \]

- \( H_i = \) is the mortality rate in state \( i \) corrected for the demographic composition (i.e. what would be the mortality rate in state \( i \) if that state had the same demographic composition as the US average)
- \( Z_i = \) is a vector of economic *inputs* of state \( i \)
- \( X_i = \) *inputs* related to consumption
- \( M_i = \) medical *inputs*
- \( D_i = \) Organization of health care services – these do not come in logs because are dummy variables.
- \( u_i = \) error term
Some Empirical studies: Aggregated Data

- The authors linearize the equation by applying logarithms to both sides and in this way estimate it by OLS:
  \[ \ln H_i = \ln C + \alpha \ln Z_i + \beta \ln X_i + \gamma \ln M_i + \delta T_i + u_i \quad i = 1, \ldots, 50 \]
- The coefficients on each variable with the exception of \( \delta \) are elasticities:
  \[ \frac{\partial \ln H_i}{\partial \ln Z_i} = \frac{H_i}{Z_i} = \eta(H, Z) = \alpha \]
- If \( Z \) increases by 1% then \( H \) increases by \( \alpha \% \)

Elasticities

A review
Elasticities (a review)

What is the meaning of “the elasticity of life-expectancy with respect to income is 0.5”? 
- It means that if income increases by 1%, life-expectancy increases by 0.5%.
- Let’s have an example where life-expectancy (LE) is 80 years and average income is 25,000 USD. If average income increases to 27,000 what is the expected increase in life-expectancy?
- In this example, average income increases by 8% therefore life-expectancy should increase: 0.5 × 0.08 = 0.04. A 4% increase means a life-expectancy of 83.2 years.

Or seen in a different way: if we know that average income increases by 8% and life-expectancy by 4% then we can compute an elasticity of life-expectancy with respect to average income:

\[ \eta(LE,\text{income}) = \frac{\Delta LE}{LE} \times \frac{\Delta \text{income}}{\text{income}} = \frac{83.2-80}{80/27000-25000/25000} = 0.04 = 0.5 \]
### Some Empirical studies: Aggregated Data

| Zi                      | Income p.c.
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Years of schooling – education may influence productivity in the production of health.</td>
</tr>
<tr>
<td></td>
<td>Percentage of people who live in urban areas – environmental factor</td>
</tr>
<tr>
<td></td>
<td>Percentage of industry in terms of employment – environmental factor</td>
</tr>
</tbody>
</table>

| Xi                      | Consumption of Alcohol and Tobacco p.c. – Life styles, can also be endogenous |

| Mi – All these factors are potentially endogenous | Consumption of Pharmaceuticals p.c. – ceteris paribus should improve health but it can also indicate a sicker population (endogeneity). |
|                                                  | Density of Physicians (number of physicians per 1000 inhabitants) – it is the most popular indicator of physician services. |
|                                                  | Auxiliary Personnel |
|                                                  | Hospital Capital Stock p.c. – e.g., number of beds, etc |

| Di                      | Percentage of Group Practices – promotes the transfer of information between physicians and there is an incentive to control quality. |
|                         | Existence of Medical School in State i \{0, 1\} |

---

### Table 4.2 of Zweifel’s book

**Table 4.2: Determinants of Mortality in 48 States of the United States, 1969**

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Ordinary least square ( \beta )</th>
<th>Two-stage least square ( \hat{\beta} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.065 (0.157)</td>
<td>0.057 (0.251)</td>
</tr>
<tr>
<td>X1.1 Income per capita</td>
<td>0.105 (0.079)</td>
<td>0.183 (0.316)</td>
</tr>
<tr>
<td>X1.2 Average of years of schooling</td>
<td>-0.161 (0.123)</td>
<td>-0.288 (0.216)</td>
</tr>
<tr>
<td>X2.1 Share of population in urban areas</td>
<td>-0.001 (0.005)</td>
<td>-0.001 (0.005)</td>
</tr>
<tr>
<td>X2.2 Share of industry in total employment</td>
<td>0.031** (0.023)</td>
<td>0.042 (0.040)</td>
</tr>
<tr>
<td>X3.1 Alcoholic consumption per capita</td>
<td>-0.002 (0.007)</td>
<td>0.013 (0.014)</td>
</tr>
<tr>
<td>X3.2 Cigarette consumption per capita</td>
<td>0.094 (0.053)</td>
<td>0.097 (0.058)</td>
</tr>
<tr>
<td>X4.1 Pharmaceutical output per capita ( \hat{\beta} )</td>
<td>-0.070 (0.000)</td>
<td>-0.056 (0.006)</td>
</tr>
<tr>
<td>X4.2 No. of physicians per capita ( \hat{\beta} )</td>
<td>0.143* (0.004)</td>
<td>0.047 (0.011)</td>
</tr>
<tr>
<td>X4.3 Medical auxiliary staff per capita ( \hat{\beta} )</td>
<td>-0.190** (0.006)</td>
<td>-0.003 (0.015)</td>
</tr>
<tr>
<td>X4.4 Capital stock of hospitals per capita ( \hat{\beta} )</td>
<td>-0.004 (0.018)</td>
<td>-0.109 (0.141)</td>
</tr>
<tr>
<td>X4.5 Share of group practices</td>
<td>0.007 (0.061)</td>
<td>0.007 (0.061)</td>
</tr>
<tr>
<td>X4.6 Existence of a medical school</td>
<td>0.639 (0.586)</td>
<td>0.121 (0.172)</td>
</tr>
</tbody>
</table>

---

---

---
Some Empirical studies: Aggregated Data

- Results from OLS:
  - ? ↑ income p.c. ⇒ ↑ mortality rate (not sig.) ► Possible Endogeneity
  - ? ↑ physicians p.c ⇒ ↑ mortality rate (sig.) ► Endogeneity
  - ✓ ↑ auxiliary personnel p.c ⇒ ↓ mortality rate (sig.)
  - ✓ Existence of medical school ⇒ ↓ mortality rate (sig.)
  - ✓ ↑ Education ⇒ ↓ mortality rate (sig.)

Note: They also present the results of 2SLS but there nothing is significant (bad instruments). In any case, results seem to suggest that an increase in education increases health by more than an increase in medical inputs (elasticity with respect to all medical inputs is -0.12).

Some Empirical studies: Aggregated Data

- Note: The presence of a single endogenous variable results in bias in all estimated coefficients.

- Criticisms to this study:
  - Mortality rates and life-expectancy in a given period depend also on factors from (many) previous periods.
  - Endogeneity on all variables. Causality here goes in both ways: (in equilibrium) the number of physicians is higher where demand for its services is higher.
Some Empirical studies: Aggregated Data

- Cochrane et al. (1978) uses data from OCDE countries
- The econometric model is now:

\[ H_i = C + \alpha_1 X_{1,i} + \alpha_2 X_{2,i} + \ldots + \alpha_7 X_{7,i} + u_i \]

- Where \( i \) represents a country, \( H \) represents (age or gender) specific mortality rates and \( X \)'s are explanatory variables

Some Empirical studies: Aggregated Data

- Here the coefficients have a different interpretation, they are not elasticities any longer. \( \alpha_i \)is not an elasticity but a marginal effect:

\[ \alpha_i = \frac{\partial H}{\partial X_1} \]

- To compute an elasticity from these coefficients:

\[ \eta(H, X_1) = \frac{\partial H}{\partial X_1} \times \frac{X_1}{H} = \alpha_i \frac{X_1}{H} \]

- Usually evaluated at an average value \( (\bar{H}, \bar{X}_1) \)

To obtain an average elasticity. The elasticities in this case are not constant across countries.
Conclusions:

In this study the endogeneity problem is less likely since we are talking about different regions and it is less likely that physicians and medical resources move across countries to where demand is higher. There could be still endogeneity if those countries with a sicker population increase the supply of doctors and other medical services to improve the health of their people.

Results for the variable “number of physicians p.c.” are still counter-intuitive since a larger number of physicians p.c. is associated with a higher infant and neonatal mortality. One plausible explanation is that in countries with higher medical services p.c. more pregnancies come to term whereas in other countries there are more natural abortions.

Results for the other variables look reasonable:

- Increase in GDP p.c. reduces mortality
- Consumption of alcohol and tobacco increases mortality
- An increase in the consumption of sugar decreases mortality.
- An increase in the Public Spending in Health Care reduced mortality for some age groups
Some Empirical studies: Aggregated Data

- Study where two neighboring states are compared (Nevada and Utah) – the interesting aspect of this study is that there are large differences in mortality across the two states while there are small differences in other aspects (which can be discarded as an explanation for the different mortality):
  - Climate
  - Population density (% that lives in urban and rural areas)
  - Physician density
  - Auxiliary Medical Personnel
  - Years of Schooling
  - Income is higher in Nevada but according to previous studies the difference in income is too small to be able to explain the difference in mortality rates
- The authors conclude that the explanation for the different mortality rates must be found in the difference in life-styles. Life in Nevada is more unstable.
## Mortality in Nevada and Utah: possible determinants (1970)

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-19</th>
<th>20-29</th>
<th>30-29</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mortality in Nevada (Utah=100)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>142</td>
<td>116</td>
<td>144</td>
<td>137</td>
<td>154</td>
<td>138</td>
<td>126</td>
</tr>
<tr>
<td>F</td>
<td>135</td>
<td>126</td>
<td>142</td>
<td>148</td>
<td>169</td>
<td>128</td>
<td>117</td>
</tr>
<tr>
<td><strong>Mortality from cirrhosis and lung cancer (Utah=100)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>690</td>
<td>211</td>
<td>306</td>
<td>217</td>
</tr>
<tr>
<td>F</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>543</td>
<td>396</td>
<td>305</td>
<td>327</td>
</tr>
</tbody>
</table>

### Additional Data:

<table>
<thead>
<tr>
<th></th>
<th>Nevada</th>
<th>Utah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicians per 10,000 inhabitants</td>
<td>11.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Auxiliary Medical Personnel per 10,000 inhabitants</td>
<td>161</td>
<td>180</td>
</tr>
<tr>
<td>Income p.c. (Median) USD</td>
<td>10,942</td>
<td>9,356</td>
</tr>
<tr>
<td>Years of Schooling (median)</td>
<td>12.4</td>
<td>12.5</td>
</tr>
<tr>
<td>% rural population</td>
<td>19.1</td>
<td>19.4</td>
</tr>
<tr>
<td>% &gt;20 years old born in the state</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>% &gt;5 years old with the same residency from 1965-1970</td>
<td>36</td>
<td>54</td>
</tr>
<tr>
<td>% 35-64 years old who are single, separated, widows, married for the second time</td>
<td>47.4</td>
<td>25.5</td>
</tr>
</tbody>
</table>
Some Empirical studies: Aggregated Data

- Other studies used mortality data due to a specific disease and tried to measure the marginal effect of some procedure or specific medical intervention. For example McKinlay et al. (1989) used US data for 1900-1973 to study mortality due to several diseases:
  - Infectious diseases – only three infectious diseases (influenza, whooping cough, polio) saw their mortality rate reduced by more than 25% due to an intervention (vaccination).
  - Chronic diseases – cardiovascular and cancer. The main reduction in mortality due to heart attack is due to a smaller frequency of vascular disease which are preventable in some cases. Until 1973 the advances against cancer were very limited to particular types.
  - Finally they suggest using other measures beyond mortality and life-expectancy such as life expectancy free of handicap

Some Empirical studies: Aggregated Data

- Conclusion of the analysis of several studies:
  - Studies based on aggregated data (countries or regions) seem to confirm that differences in mortality rates depend only partially on differences of medical infrastructure (and physician density in particular). The productivity of an individual in increasing and keeping its own health seems to be of great importance.
  - In practice it is not so easy to estimate a health production function.
Some Empirical studies: Individual Data

The individual level data can be:
1. Obtained from the individual itself (e.g. health surveys, mostly self-reported)
2. Obtained from medical records or from physicians and nurses
1) are usually less objective data however for some studies they may be preferable. Example the subjective health status may be important to determine demand for health services as well as the willingness to pay for these services.