

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*.

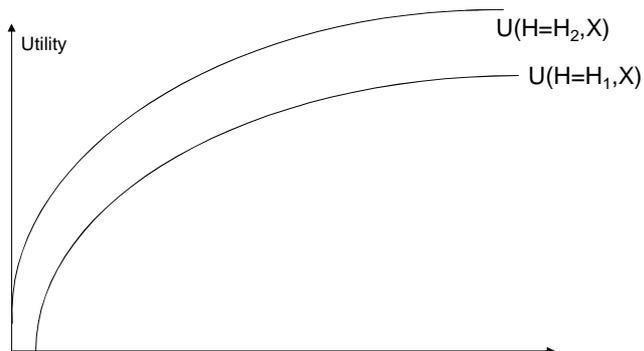
Health is also a consumption good because it enters in the utility function of the individuals. Utility increases in Health

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.

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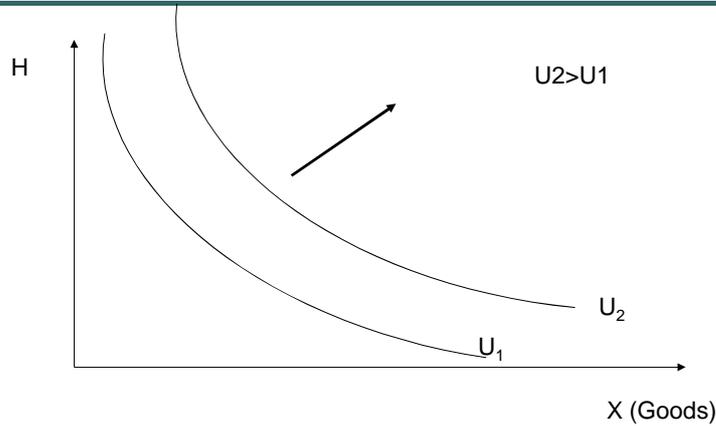
1.2. The Health Production Function



Assume $H_2 > H_1$ $\frac{\partial U}{\partial H} > 0$ $\frac{\partial U}{\partial X} > 0$ $\frac{\partial^2 U}{\partial H \partial X} > 0$ X (Other Goods/Services)

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1.2. The Health Production Function



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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 out 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?

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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

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THE ROLE OF MEDICINE

DREAM, MIRACLE OR NEMESIS?

Thomas Mckeown

BASIL BLACKWELL

1979

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McKeown, 1979

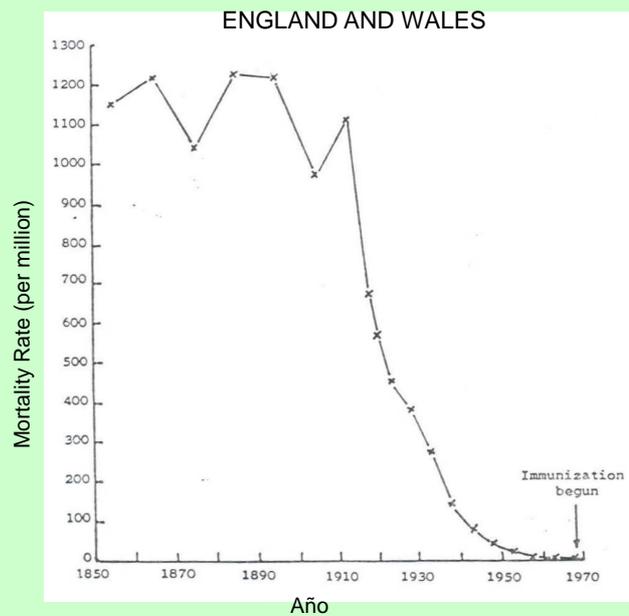
REDUCTION OF MORTALITY IN ENGLAND AND WALES 1848 -1971

	<u>% of reductions</u>
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)

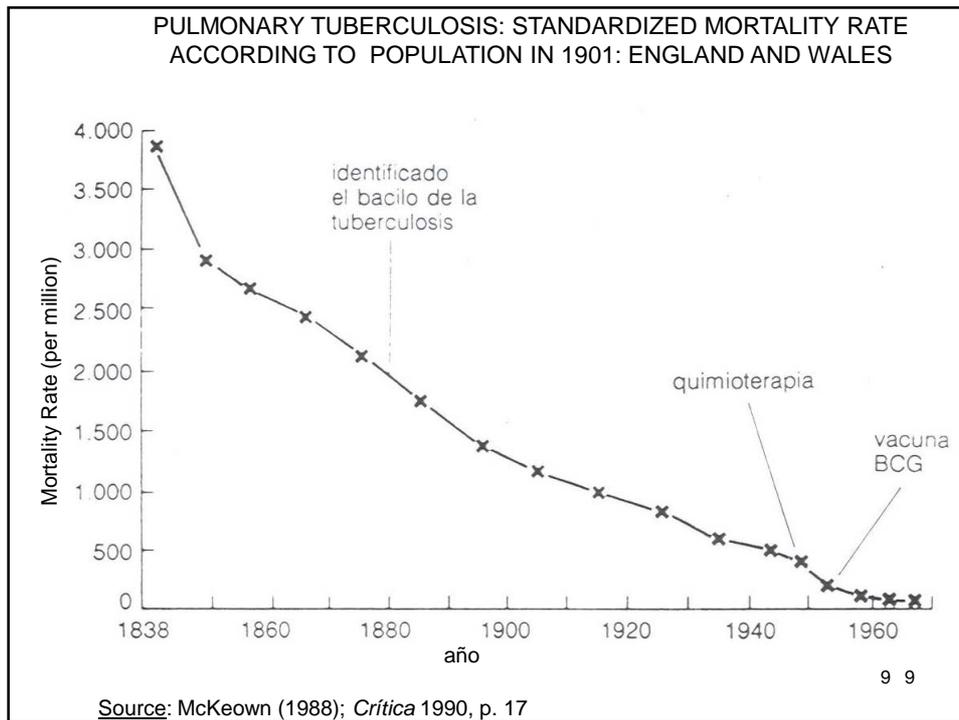
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MEASLES: MORTALITY RATE AMONGST YOUNGER THAN 15 YEARS OLD.



Source: McKeown (1988)

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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, diphtheria 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 bacteria 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”

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1.2. The Health Production Function

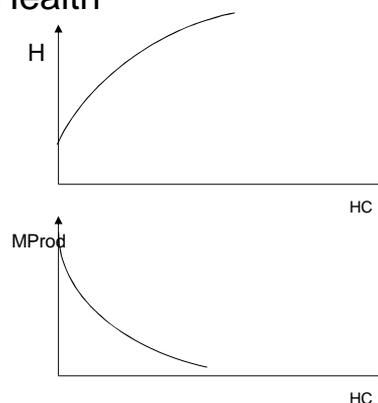
The basic model of the Health Production Function:

$$H = f(HC, \text{Other Inputs}; I_0)$$

$HC \equiv$ Health Care

$I_0 \equiv$ Initial Conditions

$$\frac{\partial f}{\partial HC} > 0; \frac{\partial^2 f}{\partial HC^2} < 0$$



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1.2. The Health Production Function

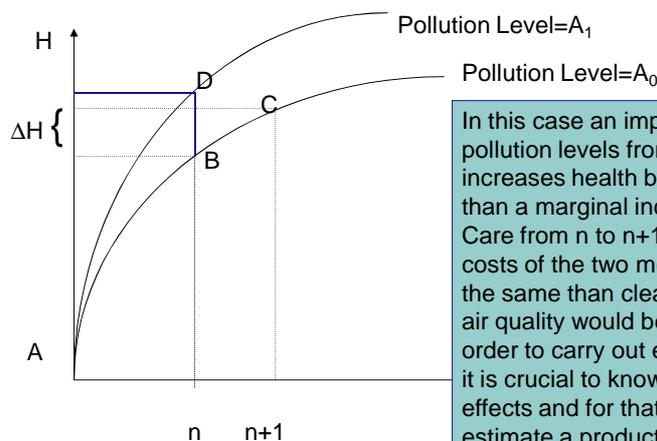
Let's assume that we can measure all the variables perfectly. Then we may write the health production function as:

$$H = f(\underbrace{HC}_+, \text{Life style, Environmental Factors, Genetics, occupation, education, etc})$$

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)

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1.2. The Health Production Function



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.

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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)
 - Morbidity rate – Measures the prevalence of a disease in a given population in a given period. (An interesting data in http://www.cdc.gov/mmwr/mmwr_wk/wk_cvol.html)
 - 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 them to monetary units, say Euros.

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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:

$$H = f\left(\underset{+}{m}, \underset{+}{e}\right) \quad \begin{array}{l} m = \text{physicians per 1000 inhab. (observable)} \\ e = \text{physical exercise (not observable)} \end{array}$$

Estimation:

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

- If u is independent of m then α can be estimated by OLS with no BIAS
- But most likely $\text{corr}(m, e) < 0 \Rightarrow \text{corr}(m, u) < 0$, 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 α is estimated by OLS.

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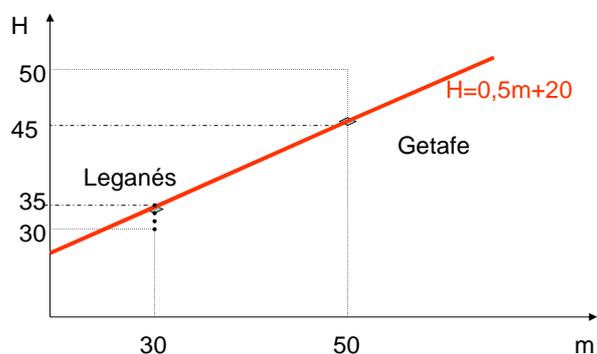
1.2. The Health Production Function - Empirics

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

Getafe	Leganés
$m_G = 50$	$m_L = 30$
$e_G = -0,5$	$e_L = 0,5$
$H_G = 1(50) + 10(-0,5) = 45$	$H_L = 1(30) + 10(0,5) = 35$

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1.2. The Health Production Function - Empirics

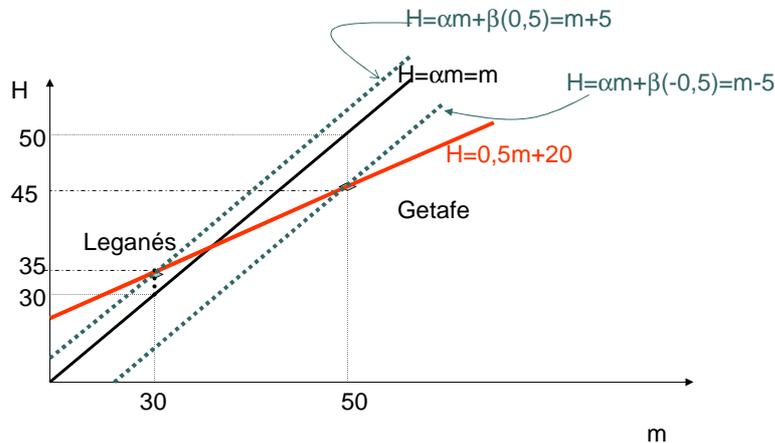


$$\hat{\alpha} = \frac{45 - 35}{50 - 30} = 0,5 < \alpha = 1$$

The estimated α is negatively biased because we do not control for the physical exercise.

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1.2. The Health Production Function - Empirics



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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:

$$H_i = CZ_i^\alpha X_i^\beta M_i^\gamma e^{\delta D_i} e^{u_i} \quad i = 1, \dots, 50$$

- 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

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Some Empirical studies: Aggregated Data

- The authors linearize the equation by applying logarithms to both sides and in this way estimate it by OLS:

$$\ln H_i = \ln C + \alpha \ln Z_i + \beta \ln X_i + \gamma \ln M_i + \delta D_i + u_i \quad i = 1, \dots, 50$$

- The coefficients on each variable with the exception of δ are elasticities:

$$\frac{\partial \ln H_i}{\partial \ln Z_i} = \frac{\frac{\partial H_i}{H_i}}{\frac{\partial Z_i}{Z_i}} = \eta(H, Z) = \alpha$$

- If Z increases by 1% then H increases by $\alpha\%$

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Elasticities

A review

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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: $0,5 \times 0,08 = 0,04$. A 4% increase means a life-expectancy of 83,2 years.

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- 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:

$$\eta(LE, \text{income}) = \frac{\frac{\Delta LE}{LE}}{\frac{\Delta \text{income}}{\text{income}}} = \frac{\frac{83,2-80}{80}}{\frac{27000-25000}{25000}} = \frac{0,04}{0,08} = 0,5$$

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Some Empirical studies: Aggregated Data

Z _i	Income p.c. Years of schooling – education may influence productivity in the production of health. Percentage of people who live in urban areas – environmental factor Percentage of industry in terms of employment – environmental factor
X _i	Consumption of Alcohol and Tobacco p.c. – Life styles, can also be endogenous
M _i – 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
D _i	Percentage of Group Practices – promotes the transfer of information between physicians y there is an incentive to control quality. Existence of Medical School in State i (0,1)

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Table 4.2 of Zweifel's book

Table 4.2: Determinants of Mortality in 48 States of the United States, 1960^a

Explanatory Variable ^b	Ordinary least squares ^c	Two-stage least squares ^c
Constant	-0.065 (0.157)	0.037 (0.251)
Z _i 1. Income per capita	0.105 (0.079)	0.183 (0.116)
2. Average no. of years of schooling	-0.161 (0.121)	-0.288 (0.216)
3. Share of population in urban areas	-0.001 (0.005)	-0.001 (0.005)
4. Share of industry in total employment	0.051* (0.023)	0.042 (0.040)
X _i 5. Alcohol consumption per capita	-0.002 (0.037)	0.013 (0.044)
6. Cigarette consumption per capita	0.094 (0.053)	-0.097 (0.058)
M _i 7. Pharmaceutical outlay per capita ^d	-0.070 (0.040)	-0.076 (0.066)
8. No. of physicians per capita ^d	0.143* (0.064)	0.044 (0.111)
9. Medical auxiliary staff per capita ^d	-0.190** (0.076)	-0.031 (0.195)
10. Capital stock of hospitals per capita ^d	-0.004 (0.048)	-0.109 (0.141)
D _i 11. Share of group practices	0.007 (0.012)	0.007 (0.021)
12. Existence of a medical school	-0.034** (0.012)	-0.024 (0.019)
R ²	0.639	0.586
Elasticity with respect to medical services (variable Nos. 7–10)	-0.121	-0.172

**): Coefficient different from zero with error probability of 5% (1%).

^a Dependent variable: natural logarithm of mortality rates, standardized according to age and sex.

^b Natural logarithm, except variable No. 12; the coefficients presented are therefore elasticities (see Eq. (4.2)).

^c Standard errors of the estimated coefficients in parentheses.

^d These regressors are endogenous and are replaced in the two-stage process by their estimated values (see Table 4.3b).

Source: Auster et al. (1969).

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Some Empirical studies: Aggregated Data

- Results from OLS:

- ? \uparrow income p.c. \Rightarrow \uparrow mortality rate (not sig.) \blacktriangleright Possible Endogeneity
- ? \uparrow physicians p.c. \Rightarrow \uparrow mortality rate (sig.) \blacktriangleright Endogeneity
- ✓ \uparrow auxiliary personnel p.c. \Rightarrow \downarrow mortality rate (sig.)
- ✓ Existence of medical school \Rightarrow \downarrow mortality rate (sig.)
- ✓ \uparrow Education \Rightarrow \downarrow 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).

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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 M_i . Causality here goes in both ways: (in equilibrium) the number of physicians is higher where demand for its services is higher.

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Some Empirical studies: Aggregated Data

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

$$H_i = C + \alpha_1 X_{1,i} + \alpha_2 X_{2,i} + \dots + \alpha_7 X_{7,i} + u_i$$

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

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Some Empirical studies: Aggregated Data

- Here the coefficients have a different interpretation, they are not elasticities any longer. α_1 is not an elasticity but a marginal effect:

$$\alpha_1 = \frac{\partial H}{\partial X_1}$$

- To compute an elasticity from these coefficients:

$$\eta(H, X_1) = \frac{\partial H}{\partial X_1} \times \frac{X_1}{H} = \alpha_1 \frac{X_1}{H}$$

- 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.

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Table 4.4: Determinants of Specific Mortality Rates in 18 Industrialized Countries (around 1970)

Influencing factor (increase by one standard deviation)	Change in mortality rate in percent									
	Age groups									
	Mothers	Birth	Infants	1-4	5-14	15-24	25-34	35-44	45-54	55-64
1. Physicians ^a	1	8*	17*	3	1	0	-4	-3	-3	-1
2. GNP ^a	-15	-11*	-16*	-8*	1*	0	1	-5	-7	-9*
3. Cigarettes ^a	25	8*	10*	1	5	2	5	4	7	7
4. Alcohol ^d	18	0	5*	1	-1	0	0	-1	-3	-3
5. Pop. density	-3	0	-2	1	-2	-7*	-7	-9*	-4	-1
6. Pub. share ^b	2	-2	0	-6	-2	-16*	-10*	-9	-4	-3
7. Sugar ^d	-29	-8*	-4	-5	-6	-8	-11	-8	-3	-3
R ²	0.72	0.90	0.97	0.55	0.42	0.79	0.65	0.57	0.55	0.62

* Estimate is based on a regression coefficient that is statistically significant at the 5 percent level of confidence or better.

^a Per capita.

^b Share of public in total health care expenditure, "intervention index."

Source: Cochrane et al. (1978).

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Some Empirical studies: Aggregated Data

Conclusions:

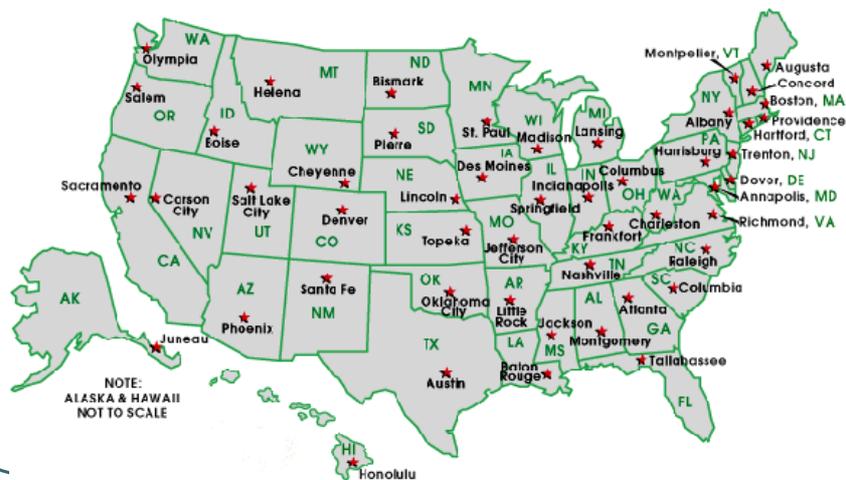
- In this study the endogeneity problem is less likely since we are talking about different regions and it is less likely that physicians and medical resources move across countries to where demand is higher. There could be still endogeneity if those countries with a sicker population increase the supply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

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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.

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Mortality in Nevada and Utah: possible determinants (1970)

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

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Mortality in Nevada and Utah: possible determinants (1970)

	Nevada	Utah
Physicians per 10.000 inhabitants	11,3	13,8
Auxiliary Medical Personnel per 10.000 inhabitants	161	180
Income p.c. (Median) USD	10.942	9.356
Years of Schooling (median)	12,4	12,5
% rural population	19,1	19,4
% >20 years old born in the state	10	63
% > 5 years old with the same residency from 1965-1970	36	54
% 35-64 years old who are single, separated, widows, married for the second time	47,4	25,5

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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*

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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.

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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.