Empirical studies of the production of health. Lecture 4

Eleonora Fichera[1]

[1]Manchester Centre for Health Economics, University of Manchester

October 22, 2013

Outline

1. Overview
   - Introduction
   - Summary
2. Studies based on aggregate data
   - Mortality Rates and Life Expectancy as measures of output?
   - Marginal productivity of a health care system
   - More recent evidence
   - Marginal productivity of selected medical interventions
   - Economic Instability and Health
3. Studies based on individual data
   - Measurement of health status
   - Marginal productivity of medical infrastructure
   - The productivity of medical interventions
   - Environmental Quality and the state of health
4. Conclusions
   - Summary
   - References

Introduction

- Life expectancy at birth has increased between 1900 and 1930;
- But the rate of increase slowed down between 1980 and 1998;
- Why?
- The transformation curve for consumption services and health can explain these phenomena and can be used to infer policy implications.

Determining factors

1. *Choice of output indicator*: Is it life expectancy or mortality rates? Maybe Quality Adjusted Life Years (QALYs)?
2. *Consumption and health as outputs*: Consumption of services have an opportunity cost in terms of health. For instance, state of health $\downarrow$ might indicate consumption $\uparrow$ which might not be balanced by increased medical care productivity;
3. *Relative productivity of inputs*: Life Expectancy (LE) $\downarrow$ with Health Care Expenditure (HCE) $\uparrow \not\Rightarrow$ MP of Medical Care $\downarrow$
   For example, other inputs such as health behaviours may be important $\Rightarrow$ relative marginal productivity
4. *Composition of the population*: Population ageing and concentration of medical care expenditure

Summary

- *Studies based on aggregate data*: a) Mortality vs. LE; b) MP of health care system; c) MP of specific medical interventions; d) Economic instability
- *Studies based on individual-level data*: a) Measurement of output; b) MP of medical infrastructure; c) MP of medical interventions; d) Air quality and tobacco consumption

Mortality Rates and Life Expectancy as measures of output?

- "Outputs" of aggregate production function $\Rightarrow$ mortality rates and life expectancy;
- Mortality rates: should be at least by age but yet limited information only on π_h. Limited compared to QALY but easy to compare across countries;
- Life expectancy: implies that current $1 - \pi_t$ depends on sequence of survival probabilities since birth.

Marginal productivity of a health care system

- Health status and mortality depend on the economic status of the population [see Malthus, 1798];
- 1930s: first drugs permitted eradication of TB;
- Auster et al. (1969): were the first to examine the effectiveness of medicine, adopting the concept of a production function

Auster et al. (1969) study:

- Compared std. mortality rates (by age and gender) across state of USA;
- Four groups of factors in a Cobb-Douglas production function:

$$S_i = cZ_i^{\alpha} X_i^{\beta} M_i^{\gamma} e^{D_i \delta} e^{u_i}$$

they include 12 variables in 4 groups: Z_i =economic input factors; X_i =consumption; M_i =medical care inputs; D_i =organisation of health care; u_i =stochastic variable.

Auster et al. (1969) study (cntd.):

- *Economic factors* Z_i: Income per capita stands for: i) preferences (i.e. MRS_{CH}) or MRT_{CH}; ii) education; iii) proxies environmental influences (i.e. urbanization and industrialization);
- *Consumption factors* X_i: most important health-damaging factors: alcohol and cigarette consumption;
- *Medical factors* M_i: i) pharmaceuticals expenditure; ii) density of supply; iii) auxiliary staff and iv) per capita capital available at hospital-level;
- *Organisational factors* D_i: i) information flow between different specialties; and ii) availability of a medical school within the State.

Determinants of mortality in 48 States of USA (1960)

Explanatory variable[b]	OLS[c]		2SLS[c]	
Constant	–0.065	(0.157)	0.037	(0.251)
Income per capita	0.105	(0.079)	0.183	(0.116)
Average no. of years of schooling	–0.161	(0.121)	–0.288	(0.216)
Share of population in urban areas	–0.001	(0.005)	–0.001	(0.005)
Share of industry in total employment	0.051**	(0.023)	0.042	(0.040)
Alcohol consumption per capita	–0.002	(0.037)	0.013	(0.044)
Cigarette consumption per capita	0.094*	(0.053)	0.097	(0.058)
Pharmaceutical outlay per capita[d]	–0.070*	(0.040)	–0.076	(0.066)
No. of physicians per capita[d]	0.143**	(0.064)	0.044	(0.111)
Medical auxiliary staff per capita[d]	–0.190**	(0.076)	–0.031	(0.195)
Capital stock of hospitals per capita[d]	–0.004	(0.048)	–0.109	(0.141)
Share of group practices	0.007	(0.012)	0.007	(0.021)
Existence of a medical school (1=yes, 0=no)	–0.034***	(0.012)	–0.024	(0.019)
R^2	0.639		0.586	
Elasticity with respect to medical services (pharmaceutical outlay, no. of physicians, medical auxiliary staff and capital stock of hospitals, each per capita)	–0.121		–0.172	

Source: Auster et al. (1969)

Drawbacks & Solution:

- *Simultaneity*: Mortality rates depend on factors dating back years ago;
- *Reverse causality*: Areas with increased risk of death may be those where doctors set up practices;
- *Two Stages Least Squares (2SLS)*: All medical care variables are regressed on a set of exogenous factors (mainly demographic variables at State-level);
- See results in previous table.

Evidence from USA

- Thornton (2002): presents a re-estimation using 1990 data and adding other health-related factors with both medical care and income are endogenous;
- Aggregate health production function:

$$lnS_i = \beta_0 + \beta_M lnM_i + \beta_S lnX_i + \beta_L lnL_i + \beta_E lnE_i + \beta_C R_i + u_i$$

where S_i =age-adjusted mortality rate in State i; X_i =vector of socioeconomic variables; M_i =medical care expenditure; L_i =vector of lifestyle variables; E_i =vector of environmental variables; R_i =race and gender; u_i =stochastic variable.

Thornton (2002) study (cntd.):

- *Medical care* M_i: Expenditure is more appropriate than stocks (quality & quantity);
- *Socioeconomic status* S_i: Education (% pop. 25+ who has more than a high school degree) & income (per capita);
- *Environmental factors* E_i: Urbanisation=% pop. residing in a std. metropolitan area. Industrialisation=% workers employed in manufacturing+ no. of violent crimes per 100,000 people;
- *Race and gender* R_i: % non-whites in the state population and of women.

Determinants of mortality in 48 States of USA (1990)

Explanatory variable	2SLS		Comparison with Table 4.2 (2SLS)
Constant	6.590***	(1.430)	now significant
Medical care expendit.	–0.065	(0.151)	new variable
Income[a)]	–0.179*	(0.096)	change from insignificant to –
Education[b)]	–0.200**	(0.083)	new definition of variable[b)]
Cigarette consumption	0.077***	(0.024)	change from insignificant to +
Alcohol consumption	0.038	(0.040)	again insignificant
Married households	–0.572***	(0.195)	new variable
Urbanization	–0.025	(0.025)	again insignificant
Manufacturing	0.013	(0.019)	again insignificant
Crime	0.038***	(0.013)	new variable
R^2 unadjusted	0.800		
R^2 adjusted	0.740		larger value

Source: Thornton (2002)

Evidence from OECD countries

- Miller and Frech (2000) investigate the production of health in 21 industrialised countries using 1996 OECD data;
- They relate LE at birth, at age 40, and 60 to economic and medical inputs;
- They also use HCE deflated by PPP performed by OECD;
- They distinguish between pharmaceutical and non-pharmaceutical outlays.

Production of health, OECD countries (1985)

Explanatory variable	Remaining life expectancy at birth	at age of 40	at age of 60
Constant	–0.534*	–0.026	–0.895
Women (=1, Men=0)	0.039***	0.100***	0.137***
Pharmaceutical outlays[a)]	0.005	0.017*	0.040**
Non-pharmaceutical outlays[c)]	0.005	–0.011	–0.015
Income per capita	0.012	0.057**	0.088**
Share of Smokers	–0.007	–0.010	0.002
Alcohol per capita, in liters	–0.009**	–0.014	–0.019
(Alcohol)×(Women)	0.017***	0.015**	0.031***
Animal fat consumption per capita	1.404***	0.955***	0.910**
Animal fat consumption per capita, squared	–0.105***	–0.073***	–0.071**
Adjusted R^2	0.952	0.911	0.909
Sample size	42	42	42

Source: Miller and Frech (2000)

Evidence from two neighbouring areas

- Fuchs (1974): Utah and Nevada have similar desert climate; are sparsely populated and have similar density of physicians and other health workers; and have similar education levels.
- Deaths of cirrhosis and lung cancer are almost 7 times higher in Nevada (male age group 30-39) than in Utah;
- One explanation is lifestyle factors driven by societal factors;
- Nevada is composed by migrants, it's mobile and unstable;
- Utah is composed by Mormons with emphasis on abstinence;
- In this application lifestyle and habit seem to matter more than medical care.

Marginal productivity of selected medical interventions

- Limited research from Health Economists: a) lack of clinical data; b) HCE exceeds optimum at any rate;
- Epidemiologists study global mortality by cause of death;
- McKinlay et al. (1989) study USA and a broad range of disease categories.

McKinlay et al. (1989):

- *Infectious diseases*: Better control 1900-1973 reduced mortality by 40 percent;
- *Chronic illnesses*: CVD and cancer: reduction mainly due to prevention (frequency reduced rather than severity)
- McKinlay et al. (1989) again seem to confirm prevention rather than medical care seem to be important.

Economic instability and health

- Brenner (1979): using annual data 1936-1979 found a statistical association between mortality rate and unemployment rate in England and Wales;
- In theory economic instability changes productivity of several factors;
- In the healthy state, loss of income due to unemployment $\Rightarrow \frac{\partial \pi}{\partial t^l} \uparrow \Rightarrow$ long-run production possibilities in (C_h, T_h)-space;
- In the sick state, worse economic conditions $\Rightarrow \frac{\partial \pi}{\partial M} \uparrow \Rightarrow T_s \uparrow$;
- Increased mortality rates.

Mortality rates in England, Wales and Scotland

	[Lag][a)]	England and Wales 1954–76	Scotland 1954–76	Combined sample 1955–79
Constant		–3.53	32.76†††	15.42†††
Real income per capita, trend		–0.013†††	–0.025†††	–0.013†††
Real income, Δ previous year		–0.003†	ϕ	–
Unemployment rate[b)]	[1-6]	0.355††	31.62††	0.035†
Unemployment ratio, 20–40-year-old men	[1-2]	5.10†††	0.704†	0.986††
Unemployment ratio, 40+-year-old-men	[0-2]	7.25†††	0.840†	0.981†
Weekly working time, industrial		ϕ	–0.344††	–
Cigarette consumption per capita	[2-5]	0.0027†††	0.0030†††	0.001†
Spirits consumption per capita		ϕ	10.10†††	–
Health expenditure & public exp.	[0-1]	–20.56†††	–14.02	–4.53†
Average temperature in February		–	–	–0.016†
Regional income ratio		–	–	–3.33††
R^2		0.97	0.95	0.96
DW after Cochran-Orcutt transformation[c)]		1.90	2.68	2.08
N		23	23	50

Source: Brenner (1979)

Criticisms [Gravelle, 1984]

- *Inaccurate theoretical foundation*: Consumption affects health through alcohol and tobacco, but these are financed out of disposable income. Thus income does not belong to the equation unless indicates lifestyle as well;
- *Simultaneity problem*: Changes in health affect income (and vice versa), therefore income is not predetermined;
- *Functional form*: Mortality rates combine unemployed and employed but not theory. Thus consider squared term and interaction with income changes.

Are recessions good for your health?

- Ruhm (2000): using longitudinal data for the 1972-1991 period uses FE models of age-specific mortality aggregated and disaggregated in 10 specific causes of death;
- Microdata between 1987-1995 from BRFSS used to examine how risky behaviours and time-intensive health investments in PA, diet and preventive medical care vary with the status of the economy;
- Contrary to Brenner (1979), Ruhm (2000) shows that health is pro-cyclical;
- State unemployment and total mortality are negatively and statistically significantly related;
- Same for unemployment and 8/10 causes of deaths (suicides are an exception)

Measurement of health status

- In aggregated studies measurement of outputs is difficult for availability of data;
- In disaggregated studies availability of surveys gives more flexibility, but...
- Issues:
  a) Timing of measurement: double function of health $\Rightarrow$ Potential medical care inputs (density of supply, number of beds) vs. effective inputs (prescription etc.)
  b) Source of measurement: a) Information by individuals (subjective?) and b) Information by third party (objective?);

Marginal productivity of a health care system

- National Health Examination Survey (NHES) in US: 1960 with 6,000 individuals from 39 randomly selected areas examined for physiological aspects of their health;
- Newhouse and Friedlander (1980): relate these measurements to availability of regional medical infrastructure and individuals and environmental characteristics;

Newhouse and Friedlander (1980) study (cntd.):

- *Medical infrastructure*: PHYS=GPs, internist; OTH=other physicians; BEDS=hospital beds per 100,000 inhabitants;
- *Individual productivity*: EDU=no. of years of schooling; INC=family incomes;
- *Environmental factors*: URB=Proportion of the examined living communities having more than 2,500 inhabitants; RACE=1 for non-whites =0 for whites;

Estimated influences on clinical health indicators, USA (1960)

Clinical indicators	Medical infrastructure[b]			Individual productivity[c]		Environmental factors[d]	
	PHYS	OTH	BEDS	EDU	INC	URB	RACE
Diastol. blood pressure, conditional[f]	–0.02	–0.003	0.009	0.01	–0.003	–0.007	2.48**
Excess lipid concentration in the blood[e]	0.39	–0.03	–0.13	–0.08	0.05	–0.000	–0.02**
Lipid concentration in the blood, conditional[g]	0.02	–0.02	0.03	0.02	–0.003	0.031	–1.01
Abnormal ECG[e]	0.03	–0.06	0.06	–0.02	–0.04	0.000	0.15***
Hypertension[e]	–0.06	0.20**	0.32*	–0.25*	–0.006	–0.001***	0.12***
Abnormal X-ray[e]	–0.04	–0.07***	0.07**	–0.09***	–0.03**	0.002***	–0.082*
Varicose veins[e]	0.13	0.002	–0.44***	–0.19	–0.04	0.003	–0.05***
Periodontal index				–0.77***	–0.21***	–0.002	0.19***
Aging index[h]	–0.004	0.001	0.01	–0.05***	–0.01***	0.002	0.72**

Source: Newhouse and Friedlander (1980)

The productivity of medical interventions

- CVDs in 1960 were the most important cause of death in the USA suspected to be due to high BP, high lipid concentration in the blood and tobacco consumption;
- Framingham study: initiated in Massachusetts for 18 years give technical insights on the production of health;
- Output is reduction of cholesterol which in turn reduced BP. Medical input consists of drug treatment while the patient's own contribution consists in maintaining an appropriate diet;
- Is diet alone sufficient for reducing cholesterol or is it effective in the combination with a drug?

Complementarity/substitutability

- If hypertensive patients are considered as healthy, we saw there is substitution, but...
- They do live through periods of illness;
- Houston (1989) found that drug therapy has no definite effect on mortality for hypertensive individuals;
- Therapy in this case may undermine the success of a diet;
- Substitution of medical services with individual efforts might be possible in the long run.

Air quality and smoking as exogenous factors

- Ostro (1983): combined individual responses to the health survey of 1976 in USA with measurements of air quality in 84 metropolitan areas;
- TSP=concentration of total suspended particles in the air, annual average; SULF=concentration of sulphuric compounds in the air, annual average; CHRONIC=no. chronic diseases; AGE=age in years; INCOME=family income; TEMPERATURE=annual average temperature; EMPLOYED=1 if employed; BLUE COLLAR=1 if blue collar worker; POP.DENSITY=population of the metropolitan area (in 1,000 per square mile); PRECIPITATION=annual average precipitation; CIGARETTES=no. cigarettes smoked per day.

Influence of air quality on health, USA (1976)

Variable[a)]	Restricted activity days (A)[b)]	Workdays lost (B)[c)]	Probability of $B > 0$ (C)[d)]	Workdays lost if $B > 0$ (D)[d)]
Constant	–0.83***	–0.47***	–3.66***	–0.39
TSP	0.00282***	0.00145**	0.0071**	0.002
SULF	–0.00008	–0.001	–0.051*	–0.009
CHRONIC	1.25***	0.25***	0.48***	0.93**
AGE	0.0063***	0.0033***	–0.0048	0.075***
INCOME	–0.009***	–0.002	–0.004	0.012
MARRIED	–0.011	–0.011	0.227*	–1.24***
RACE	0.17***	0.045	–0.04	–0.46
TEMPERATURE	0.013***	0.0065***	0.003	0.097**
BLUE-COLLAR WORKER		–0.046*	0.29	–1.26***
EMPLOYED	–0.114***			
POP.DENSITY	0.0057	0.0056*	0.030**	–0.050
PRECIPITATION	–0.0004	–0.0004	0.0097	–0.040*
SEXF	0.093**	0.067***		
CIGARETTES	0.0032	–0.0006		
R^2	0.09	0.01		0.17
χ^2			25.8***	
N	13,230	8,294	4,473	263

Source: Ostro (1983)

Smoking as an endogenous factor

- Issue with previous studies: health is both a production AND a consumption good;
- Cigarette consumption was in previous model, but there is endogeneity;
- Mullahy and Portney (1990): use GMM to Ostro's data in 1979 instead of 1976;
- Dependent variable: no. restricted activity days 2 weeks prior to investigation for sample of people with respiratory problems;
- Other regressors: OZONE=Ozone concentration based on daily maximum values during 14 days prior to investigation; DCHRONIC=1 if individual is restricted in her activity due to chronic diseases.

Influence of air quality on health, USA (1979)

Variable[a]	Probability of nonzero restricted activity days[b] (A)		Number of restricted activity days, conditional on $A>0$ (B)	
	OLS	GMM[c]	OLS	GMM[c]
Constant	0.035	0.185***	0.0078	0.789***
CIGARETTES	–0.060	–1.91***	–0.034	–8.44***
$CIGARETTES^2$	0.25	5.81***	1.09	27.95***
OZONE	0.064	0.51	4.25**	6.64**
$OZONE^2$	–1.60	–3.97	–23.7**	–35.8**
SULF	–0.20	–0.20	–1.52	–1.77
$SULF^2$	0.65	0.56	4.87	5.07
TEMPERATURE	–0.055*	–0.090**	–0.44***	–0.61***
PRECIPITATION	–0.017	–0.034	0.033	–0.028
AGE	0.35	–0.16	2.14**	–0.90
AGE^2	–0.48*	0.077	–2.82**	0.60
DCHRONIC	0.011	–0.0066	0.19	0.094
SEXM	–0.00089	–0.032***	–0.045	–0.17***
N	2,331	2,331	89	89

Source: Mullahy and Portney (1990)

Conclusions

- Empirical studies with aggregate and disaggregate data: measurement of output and MP of health care
- They seem to suggest importance of prevention
- ... and the measurement challenges

References

- Zweifel et al. (2009) chapter 4
- Ruhm C. (2000) Are recessions good for your health? The Quarterly Journal of Economics: 617-650.