THE PRODUCTION OF HEALTH BY A RURAL POPULATION

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I. Introduction

The purpose of this study is to propose a model of the production of health and apply it to data obtained in a rural health survey. For our purpose the "production of health" will be defined as the process whereby individuals combine medical care, other commodities (diet, recreation, etc.) and their own time to maintain their health status. This framework permits empirical measurement of the contribution of medical care relative to that of other factors in the maintenance of health. In Section II the production model will be developed and the estimation procedure set forth. In Section III the data used in fitting the model will be described. In Section IV the results will be discussed. This will be followed by a conclusion (Section V).

II. A Model of the Production of Health

It is assumed that the typical consumer engages in three activities -- work, consumption, and health maintenance or production.[1] He supplies labor on the labor market to earn wages which he combines with his non-wage income, if any, to purchase consumption commodities and commodities used in the production of health. The production of health involves the combination of medical care, other non-consumption commodities, and the consumer's own time. The consumer has to distribute his time, as well as his income, among the three activities. He is assumed to maximize the expected value of a utility (preference) function subject to a budget constraint, a time constraint, and a production constraint.[2]

In this study we will concentrate on the production side of the model. It is assumed that an individual inherits a stock of health capital.[3] This stock is assumed to depreciate with age after some stage of the life cycle and is subject to further deterioration, largely random. To the extent that the actual stock of health falls short of the desired stock, the individual will consider health production to restore or maintain his health stock.

The production function is a mathematical statement of the technological relationship between the output of a process and the inputs. The major purpose of the production function is to present the possibilities of substitution between the inputs (factors of production) to achieve a given output. For any set of inputs, the production function is interpreted to define the maximal output realizable therefrom.[4] In the application here the output of the production process is defined as improvements in health status (gross additions to health stock) and the inputs are defined as medical care, other non-consumption commodities, and the consumer's own time.

The relative amounts of time and medical care input into the production process depend on their relative productivities and their relative prices. It is expected that persons with high earnings rates would use relatively less of their own time and relatively more medical care in the production of health than persons with low earnings rates. The earnings rate is assumed to be closely related to the individual's perception of the "price of his own time." Moreover, efficiency in production varies from person to person. The more efficient can produce a given amount of health with less input -- time and medical care -- than the less efficient.[5] It has generally been observed that more educated persons are more efficient producers of money earnings than less educated persons. Since education improves market productivity it is reasonable to expect that it improves nonmarket productivity as well. This implies a positive relationship between education and the health production process. Thus an increase in education would increase the amount of health produced from given amounts of medical care and time. Since earnings are related to production efficiency, it would appear that the more efficient (educated) while using less of both inputs, for a given output, would use relatively less of their own time in the production of health.

Consider the following production function:

$$(1) \quad H = A_1 e^{a_1 E} M^{\alpha_1} T^{\alpha_2} u_1$$

where H is the amount of health produced, E stands for the education level, and M and T are the medical care and time input, respectively. The term A_1 is a constant, a_1 is the education coefficient, α_1 is the elasticity of health with respect to medical care (proportional change in health production resulting from a proportional change in medical care input), α_2 is the elasticity of health with respect to time, and u_1 is a random error term. If it is further assumed that $\alpha_1 + \alpha_2 = 1$, or $\alpha_2 = 1-\alpha_1$, the implication is that if medical care and time are increased, say 10 per cent, then output is also increased 10 per cent. This is known as constant returns to scale. The form of production function depicted in (1) is called Cobb-Douglas.[6,7] The non-consumption commodities input is not included in (1) as it is difficult to measure and since this input largely reflects life styles and environmental factors, its effect is likely to be absorbed by the education variable.

The primary purpose of this paper is to estimate α_1. Direct estimation of equation (1) by ordinary least squares would result in biased estimates owing to the simultaneous nature of the health production process. The medical care coefficient can be interpreted as a measure of the effect of medical care on health. But the feedback of H on M and T must be considered. Medical care and time are not exogenous but are influenced by the current level of health stock. Thus the medical care coefficient could also be interpreted as the effect of health on the demand for medical care. In order to deal with the simultaneity, estimates are obtained by using two-stage least squares.

The full model, referred to above,[8] suggests that the demand for medical care and the demand for the time input each depend on income and education. Income reflects the economic determinants and education reflects production efficiency and attitudinal variables. The following demand specification is proposed:

$$(2) \quad T/M = A_2 e^{a_2 E + a_3 I} u_2,$$

where I is income, A_2 is a constant, and u_2 is the error term. If the production coefficients in equation (1)--α_1 and α_2-- are restricted to sum to unity, both equations (1) and (2) would be exactly identifiable and estimation by indirect least squares, two-stage least squares and quasi-information maximum likelihood would all yield the same consistent and efficient estimates.[9]

Noting the restriction on α_1 and α_2, dividing (1) through by M, and converting (1) and (2) into logarithms, we obtain the following two equation system;

$$\text{(3a)}\quad \log H/M = \log A_1 + (1-\alpha_1)\log (T/M) + a_1E + b_1S_1 + b_2S_2 + b_3S_3 + \log u_1$$

$$\text{(3b)}\quad \log T/M = \log A_2 + a_2E + a_3I + c_1S_1 + c_2S_2 + c_3S_3 + \log u_2$$

The data are obtained from a four strata sample of households. To allow for possible shifts in intercept among the strata, dummy variables are included in each equation; S_i is set equal to unity if the observation is from stratum i and set to zero otherwise.

III. The Data

The data used to test the above model were obtained in the Yolo County Health Survey.[10] Data were gathered on 1100 households (3400 individuals)--a four percent sample. A two-stage stratified sampling procedure was employed. The study area was divided into four strata--Davis (Stratum 1), Woodland (Stratum 2), East Yolo (Stratum 3), and Rural Yolo (Stratum 4). Stratum 4 is the most rural of the strata. The other strata are characterized by higher population density and relatively less agricultural employment.

Definitions of Variables

1) M: Gross personal medical expenditures. This includes annual (1969-70) out-of-pocket expenditures by individuals for services of physicians, dentists and other health manpower; hospital care; nursing home care; x-ray and laboratory tests; and medical appliances. To this sum, "Adjusted Insurance Premiums" is added. This is an approximation of the individual's share of the household's expense for health insurance. "Adjusted Insurance Premiums" is calculated by dividing total annual household health insurance premiums by the number of equivalent adults in the household. This term is calculated by counting all children under 12 and the second adult as one-half. All other adults are counted as one.[11,12] Due to the form of equations (3a) and (3b), the analysis is restricted to persons for whom M is not zero.

2) I: Adjusted income. This is total household income for 1969, before taxes, per equivalent adult.

3) T: Time input. Because of recall problems with this item, it was decided to use work-loss days for the expenditure period as a proxy. Thus the entire analysis is restricted to employed adults. It should be noted that this is a poor measure of time devoted to health production and is strongly influenced by economic factors.[13]

4) E: Education. This is an eight-point scale. The values are shown in Table 1.

Table 1. Education Intervals

Highest Level of Education	Value
No formal school	0
Some grade school	1
Completed grade school	2
Some high school	3
Completed high school	4
Vocational training	5
Some college	6
Completed college	7
Post graduate study	8

5) H: Health Status. This is a weighted sum of medical conditions checked by respondents.[14] The conditions and their corresponding weights are shown in Table 2. An index value of "zero" implies "perfect" health while a value of 128 is the poorest. The major difficulty with the variable is that it is a proxy for health stock and not the amount of health produced.

IV. Results

The two stage least-squares estimates are shown below;

$$\text{(3'a)}\quad \log H/M = 2.5199 - 0.0341E + 1.3733\, T/M^{*} - 0.4445\, S_1^{*} - 0.1220\, S_2 - 0.0284\, S_3 \qquad R^2 = 0.175,\ N = 569$$

$$\text{(3'b)}\quad \log T/M = -3.2639 - 0.0745\, E^{*} - 0.0001\, I^{**} - 0.0649\, S_1 - 0.0258\, S_2 - 0.1850\, S_3 \qquad R^2 = 0.065,\ N = 569$$

where (*) and (**) indicate statistical significance at the .05 and .01 levels respectively. If u_2 is normally distributed with zero mean and constant variance, the t tests are valid for (3'b) as all the regressors are exogenous. In (3'a) the t test is not appropriate but the t values are shown to indicate the relative sizes of standard errors.

Equation (3'b) indicates that education and income each have a negative effect on T/M. Thus persons with more education and persons with more income have a less "time intensive" production process than do their less educated and lower income counterparts. This is a reflection of the relative value of their own time.

Since our proxy for health status is an inverse measure, the coefficients stated in (1) and (3a) must be reinterpreted. The elasticity of health with respect to medical care is to be interpreted as $-\alpha_1$ and that with respect to time as $\alpha_1 - 1$, both summing to -1 instead of 1, as they did previously. From (3'a) the estimate of $-\alpha_1$ is -2.3733. Thus a 10 percent increase in medical care results in a 24 percent decrease in our inverse health status variable or a 24 percent <u>increase</u> in health status. This implies that med-

Table 2. Conditions and Weights Used in Construction of "Health Status Index" (Adults)

Condition	Weight	Condition	Weight
High blood pressure	4	Frequent cramps in legs	4
Heart condition	2	Pain in heart or tightness in chest	4
Stroke	4	Trouble breathing or shortness of breath	4
Bronchitis	2	Swollen ankles or feet	4
Asthma or hay fever	2	Pains in the back or spine	2
Arthritis or rheumatism	4	Repeated pains in stomach	2
Epilepsy	4	Frequent headaches	2
Sugar diabetes	4	Constant coughing or frequent heavy chest colds	2
Cancer or tumor	4	Blurred, haziness or clouding of vision	4
Tuberculosis	4	Stiffness, swelling, or aching in any joint or muscle	4
Emotional or mental illness	4	Getting very tired in a short time	4
Stomach or duodenal ulcer	4	Blind spots in vision	2
Gall bladder trouble	4	Seeing double	4
Liver trouble	4	Episode of fainting	5
Hernia or rupture	4	Feelings of lightheadedness or dizziness	5
Kidney trouble	4	Trouble hearing	2
Back trouble	2	Now unable to carry on normal activities	4
Trouble passing urine	4	Injury in past 12 mo. restricting normal activities	6

ical care makes a strong positive contribution while time makes a negative contribution (1.3733) --a 10 percent increase in time devoted to health maintenance results in a 14 percent decrease in health status. It is possible that the data inadequacies, noted in Section III, could account for this disturbing result.[15] The result could also indicate that time and medical care are really not substitutable, on the average, and that a certain minimum amount of medical care is necessary and without this minimum amount of care, time has a negative effect on health status. This would indicate that the longer one attempts to treat a medical problem by remaining at home but not obtaining necessary medical care, the more aggravated the problem will become.

The education coefficient in (3'a) has the expected sign, indicating that more educated persons are more efficient producers of health than their less educated counterparts. It was expected that rural individuals, owing to lower earnings and inaccessibility of medical services, would have a more time intensive production process and a less efficient production process than urban individuals. The coefficients of the stratum dummy variables did not confirm this.[16] Furthermore, an analysis of variance of T/M among strata showed no significant differences.

V. Conclusion

A model of the production of health was tested on data obtained from a rural health survey. The results imply that, in general, time and medical care are not substitutable in treating a medical condition and that medical care is the most productive of the two inputs. Production efficiency is positively affected by education. Individuals with high income and individuals who are more educated have a less time intensive production process than their less educated and lower income counterparts. The time-medical care ratio does not significantly differ between the urban and rural regions of the study area.

NOTES

[1]This method of viewing consumer theory is similar to that developed by G.S. Becker, "A Theory of the Allocation of Time," Econ. Jour., 1965; and K. Lancaster, "A New Approach to Consumer Theory," Jour. of Polit. Econ., 1966. This is an application of a method set forth by R.R. Wilson, "The Theory of Consumer Behavior: Production and the Allocation of Time," Winter Meeting (1969), Econometric Society, New York.

[2]The complete model, including the derivation of demand functions, is presented in H.W. Zaretsky, "The Demand for Health Care," Ph.D. Dissertation in progress, Department of Economics, University California, Davis, 1970.

[3]See M. Grossman, "The Demand for Health: A Theoretical and Empirical Investigation," National Bureau of Economic Research, 1970.

[4]See R.W. Shepard, Theory of Cost and Production Functions, Princeton, 1970.

[5]M. Grossman, op.cit.

[6]R. Auster, I. Leveson, and D. Saracheck in their, "The Production of Health, An Exploratory Study," Jour. of Hum. Resources, (Fall 1969), used a Cobb-Douglas production function with constant returns to scale to explain variations in mortality rates across states.

[7]There are two major difficulties inherent in this form of production function: (1) If any input is zero, output must be zero. (2) This form requires the "elasticity of substitution" to be unity. The implication is that if the ratio of the price of time to the price of medical care would increase by 10 percent, the ratio of time to medical input would decrease by this same amount. Alternative forms are being considered for further study. There has developed a substantial literature on production functions and their estimation. A useful survey can be found in A. Walters, "Production and Cost Functions: An Econometric Survey," Econometrica (January-April, 1963).

[8]H.W. Zaretsky, op.cit.

[9]See E. Malinvaud, Statistical Methods of Econometrics, Amsterdam, 1966.

[10]This was a comprehensive health survey conducted during June 1970 by the Department of Community Health, School of Medicine, University of California, Davis.

[11]This method was used in W.J. McNerney, et al., Hospital and Medical Economics, Chicago, 1962.

[12]In conducting the survey we were not permitted the luxury of verifying medical expenses. Since consumer recall or even knowledge of that portion of the medical bill paid by insurance or other third parties was poor, only the net or out-of-pocket expenditures could be used. To approximate the individual's total expenditure, his expense for prepayment was added.

[13]See M. Silver, "An Economic Analysis of Variations in Medical Expenses and Work-Loss Rates," Empirical Studies in Health Economics, H. E. Klarman ed., Baltimore, 1970.

[14]This is a modification of an index developed by A.I. Kisch, J.W. Kovner, F.J. Harris, and G. Kline in "A New Proxy Measure for Health Status," Health Services Research (Fall, 1969).

[15]It should be noted that the simple correlations between H and T and between H and M are each positive (each about .1). There is reason to suspect that M and T are each alternative measures of health status. Furthermore, as indicated above, the variable H should measure amount of health produced (change in health status) while our measure of H is a proxy for current health status or level.

[16]The coefficient of S_1 (Davis) in (3'a) is absolutely larger than the coefficients of the other dummy variables and has the expected sign. This would indicate that Davis residents, with the education level held constant, are relatively more efficient producers of health. Although the standard error of the coefficient in question is less than half the size of the coefficient, it must be noted again that the t tests are not appropriate here.