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PART III

THE PRODUCTION OF HEALTH

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The Production of Health, an Exploratory Study

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INTRODUCTION: THE PROBLEM

The medical industry is one of the most important and one of the fastest-growing industries in the United States. Moreover, it is an industry in which government plays a large and increasing role.[1] Government activities now encompass the sponsorship or undertaking of most medical research, the financing of medical care and hospital construction, the regulation of the supply of personnel and the practice of medicine, and the financing of medical education. Government decisions

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All appendixes referred to and additional tables are available from the authors upon request.

[1] In recent years almost one-third of national health expenditure has been made by government. Total medical care spending is now running at an annual rate in excess of $50 billion. While employment in the United States has grown at a rate of 1.2 per cent per year since 1929, employment in the health industry has grown at 3.5 per cent.

affect the way in which resources are allocated between health and other goals, between medical services and other determinants of health, and among the various types of medical services. (The term "medical" services is used here to include public health activities.) If such allocation decisions are to be optimal it is necessary to know both the costs of and returns to each possible use. While in similar fields, such as education, information on returns has become increasingly available, in the health field work has largely centered on costs alone.

Recently some attempts have been made to evaluate the economic benefits of improvements in health.[2] However, as yet no one has answered in a satisfactory way the very basic question, "What is the contribution of medical services as opposed to environmental factors to changes in the health of the population?" (The term "environmental factors" is used here simply to refer to all factors other than medical and health services.) Certainly, more studies of the effects of specific therapeutic techniques on health and of the role of the factors of production in individual health programs are needed.[3] However, for broad policy questions, there is also a need for the measurement of the over-all effect of "medical services" on health and of the contribution of each of the factors of production which combine to produce "medical services."

Past studies of the factors influencing health have commonly dealt with a few variables at a time. Information on the effectiveness of medical services in improving health has typically been derived from the relatively few deliberate or "natural" experiments whose results were such as to make the impact of medical care easily discernible. The situations that were the subject of these experiments have been limited to a relatively small part of the health spectrum; most of them were in areas where medical accomplishments have been atypically great. Moreover, for a growing range of problems the importance of environmental conditions makes it impossible to determine adequately the impact of medical services on health solely in experimental circum-

[2] For example, see Selma J. Mushkin, "Health as an Investment," *Journal of Political Economy*, supplement, October 1962, pp. 129–57; Burton A. Weisbrod, *Economics of Public Health*, Philadelphia, University of Pennsylvania Press, 1961; Victor R. Fuchs, "Some Economic Aspects of Mortality in the United States," National Bureau of Economic Research, July 1965, mimeo.; Mary Lou Larmore, "An Inquiry into an Econometric Production Function for Health in the United States," Ph.D. dissertation, Northwestern University, August 1967.

[3] For a summary of some of these studies, see the first essay in this volume by Victor R. Fuchs.

stances. For these problems, a broad attempt to separate environmental effects from the impact of medical care on health is desirable, both as a policy guide and as an indicator of directions for further study. The influence of socioeconomic factors on health has frequently been considered apart from studies of the impact of medical care. In order to properly determine the role of medical care and other forces, both are best considered together.

The following sections describe variants of an econometric model designed to determine the causes of geographic variation in health, estimate the coefficients of the model, and consider some of their implications.

THE MODEL

Some of the most difficult problems in medical economics revolve around the definition and measurement of the output of the medical and health services industry. If we define output according to the services provided, our definition would imply such measures as physicians' visits and patient days in hospitals. Under such a definition, productivity analysis would be concerned with the production of medical services themselves. If, however, the production process is viewed as one that changes the health status of the population, medical services must be considered as an intermediate product in the "production" of health.[4] Because of our concern with the impact of medical services on health we take the latter approach. This deviates from the usual practice of defining output as a good or service. We define output as the result derived from the use of that good or service, because we are primarily interested in finding ways to improve health.[5] Moreover, because of consumer ignorance about the impact of medical services on health, the possibility that medical services are not competitively priced, and a conceivable divergence between private and social benefits we are not willing to assume that the optimum quantity of medical care is already being provided. Instead, we would like to

[4] See Victor R. Fuchs's first essay in this volume, pp. 3–38. See also Kenneth E. Boulding, "The Concept of Need for Health Services," *Milbank Memorial Fund Quarterly*, 44, October 1966, pp. 202–21.

[5] Defining the output of the medical industry by medical outcomes is similar to Lancaster's focus on attributes of goods and services and Becker's on characteristics. See Kelvin Lancaster, "A New Approach to Consumer Theory," *Journal of Political Economy*, 74, April 1966, and Gary S. Becker, "A Theory of the Allocation of Time," *Economic Journal*, 75, September 1965.

determine the benefits of medical care and compare them with costs, to arrive at judgments as to whether additional expenditures are warranted.

Given the amount of medical services that a group of individuals consumes and some socioeconomic variables, it should be possible to predict what the health of the group will be. We assume that genetic factors are either reasonably constant across states, or do not vary systematically with our independent variables, and that consequently the other variables are not influenced by genetic effects on health. Thus, we hypothesize that health will be a function of the amount of medical services (M) consumed in that state and of the following environmental variables.[6]

Per cent nonwhite (X_0). At a given level of income, education, et cetera, nonwhites may have poorer sanitation, housing, et cetera as a result of discrimination.

Income (X_1). It has been observed that higher-income people tend to consume higher-quality goods, better housing, et cetera, which may favorably affect their health. On the other hand, high incomes may permit a general style of life that is not conducive to health, particularly because the individual may be able to compensate for the adverse effects of his consumption pattern by simultaneously consuming more medical care. In addition, an increase in income may require entering those occupations which involve less exercise and/or more tension. This variable acts as a proxy for a host of factors for which we would prefer specific measures.

Education (X_2). Higher levels of education may be associated with relatively more medical care at preventive stages. In addition, the better educated may provide more care for themselves or members of their families, or simply be more willing to take the doctor's advice.

Standard Metropolitan Statistical Areas (SMSA's), per cent of population inside SMSA's (X_3). Urbanization may have adverse effects on health because of such factors as air and water pollution, congestion, et cetera.

Per cent employed in manufacturing (X_4). This index of industrialization was found to be significant by Fuchs. It may reflect patterns of work or simply general air pollution.

Alcohol consumption per capita (X_5) *and cigarette consumption per capita* (X_6). These two consumption items are included explicitly because of their special interest and our ability to measure them.

[6] The sources and methods used are given in Appendix A.

Per cent in white-collar occupations (X_7). This is a proxy variable for factors like stress and exercise.

Females not in the labor force (*per cent of females not in the labor force, married, with husband present*) (X_8). If labor force activity is more adverse to health than household activity, this variable will be positively related to health. In addition, women out of the labor force provide medical services to other members of their families. It may not be highly skilled care, but it is personal and in the right place at the right time. If there is important variation in such home production, the variable will also tend to have a positive relation to health.

We also add a variable indicating the effectiveness of medical care:

Medical school (*a dummy variable coded* 1 *for states with medical schools and* 0 *for those without*) (X_9). It is hypothesized that the quality of medical care will be higher and the technology more advanced in hospitals associated with medical schools than in others. Also, it is assumed that medical schools disseminate information and provide continuous training to physicians in the community.

Specifically, we write the following production function for health:[7]

$$H = A_1 M^{\sigma_0} \prod_{i=1}^{9} X_i^{\sigma_i} e^{\epsilon_1} \qquad (1)$$

where ϵ_1 is a random disturbance term which is assumed to be normally distributed. We intend in this formulation (Model I) to measure M by expenditures on medical care per capita (E). The price elasticity of demand for medical services appears to be very close to zero. Price variation may therefore act similarly to measurement error in an independent variable which, if uncorrelated with the dependent variable,

[7] This equation involves two further assumptions: first, that the amount of medical services produced in an area equals the amount consumed there; second, that health is a function of this year's medical services only, i.e., that the state of the group's health is not affected by the amount of medical services or environmental factors prevailing over the lifetimes of members of the group. Correlations for the various variables by state between the years 1940, 1950, and 1960 are very high, indicating that relative conditions in each state have not changed greatly over time. As a test of whether this is a source of serious bias, a migration variable was introduced into the production equation. The results (not shown) were not materially affected. Inclusion of variables for the years in question would introduce a high degree of multicollinearity into our estimates. The adverse effects of this would most likely outweigh the benefits from improved specification. The related problem of selective migration was examined by comparing the difference between deaths by state of residence and deaths by state of occurrence with residuals from early runs and found unimportant.

would bias the regression coefficient of expenditures downward. An alternative formulation will be considered later.

The primary purpose of this paper is to estimate σ_0, the elasticity of health with respect to medical services. This could be done directly by estimating equation (1) by ordinary least squares. However, to do so would result in biased estimates owing to the simultaneous nature of the problem. This can be illustrated by considering the meaning of the coefficient of physicians in an equation relating it and other variables to health. One is tempted to interpret this coefficient as a measure of the effect of doctors on health. Consider, however, that where health is poor, ceteris paribus, the demand for doctors will tend to be high. If doctors move around the country in such a way as to equalize returns to medical practice, then areas with poor health will tend to attract a greater than average number of doctors per capita. Or, to put the matter more precisely, not only does the coefficient in question measure the elasticity of health with respect to doctors, but also the elasticity of doctors with respect to health. In order to deal with the simultaneity, estimates are obtained by using two-stage least squares. This technique involves the replacement of each independent endogenous variable in equation (1) by predicted values obtained by regressing that variable on all of the exogenous variables in the model.[8] Equations for the demand for medical services, and the supplies of physicians, paramedical personnel,[9] and hospital capital[10] were specified. These equations, together with equation (1), give us the following set of exogenous variables:

X_0 Per cent nonwhite
X_1 Income
X_2 Education
X_3 Per cent of population inside SMSA's
X_4 Per cent employed in manufacturing
X_5 Alcohol consumption per capita
X_6 Cigarette consumption per capita
X_7 Per cent in white-collar occupations
X_8 Married women out of the labor force
X_9 Medical school
X_{10} Per cent of population more than sixty years old
X_{11} Birth rate

[8] See J. Johnston, *Econometric Methods,* New York, McGraw-Hill Book Co., 1963, chap. 9.

[9] All persons employed in the industry "medical and other health services," with the exception of physicians and surgeons.

[10] The derivation and estimation of these equations are contained in Appendixes C and D, and the basic data, in Appendixes F and G.

X_{12} Per cent foreign born
X_{13} Per cent of health expenditures financed by health insurance
X_{14} Per cent of health expenditures in state and local governmental short-term hospitals
X_{15} Per cent of population rural
X_{16} Per cent of population in SMSA's of 1 million or more
X_{17} Ratio of 1960 to 1950 population
X_{18} Total property income
X_{19} Labor force participation rate of females

The classification of variables as endogenous or exogenous is necessarily somewhat arbitrary and is dictated in part by the completeness of our model. Consideration of classifications implied by other models is beyond the scope of this article.

As an alternative to measuring medical services by expenditures, we can specify a production function for medical services. Specifically, we can write

$$M = A_1 D^{\alpha_1} N^{\alpha_2} K^{\alpha_3} R^{\alpha_4} G^{\alpha_5} X_9^{\alpha_0} e^{\epsilon_2} \qquad (2)$$

where

D = number of physicians per capita,
N = number of paramedical personnel per capita,
K = medical capital per capita,
R = prescription drug expenditures per capita,
G = per cent of practicing physicians in group practice, and
X_9 = medical school.

Note that in addition to the four input measures, two efficiency variables—group practice and medical school—are included. Many people believe that medical care produced in group practice (G) tends to have a more favorable end result because the care is more continuous and there is better exchange of information between the physicians. We expect a positive coefficient for this variable in equation (2) and a negative coefficient in equation (3) below. Substituting equation (2) into equation (1) yields

$$H = (A_1 A_2^{\sigma_0}) (D^{\alpha_1} N^{\alpha_2} K^{\alpha_3} R^{\alpha_4} G^{\alpha_5} X_9^{\alpha_6})^{\sigma_0} \prod_{i=1}^{4} X_i^{\sigma_i} e^{\epsilon_1 + \epsilon_2}.$$

If we then impose the restriction that $\sum_{i=1}^{4} \alpha_i = 1$, that is, that the production function of medical services exhibits constant returns to scale, we can obtain an estimate of σ_0 by summing the coefficients of D, N, K, and R; that is,

$$\sigma_0\alpha_1 + \sigma_0\alpha_2 + \sigma_0\alpha_3 + \sigma_0\alpha_4 = \sigma_0 \sum_{i=1}^{4} \alpha_i = \sigma_0 . \qquad (3)$$

Equation (3) together with the exogenous variables listed for Model I will be referred to as Model II; Models I and II will enable us to investigate the impact of medical services and environmental factors on health. This will be done by an analysis of interstate differences in health in 1960.[11]

MEASUREMENT OF HEALTH

The growing awareness that as the incomes of nations grow, medical services are devoted to an increasing number of problems—disability, mental illness, problems of aging, et cetera—has caused researchers to devise an ever increasing number and variety of measures to supplement the use of death rates. Among these are measures of the prevalence of chronic conditions and activity limitations, and measures of work loss and bed disability.

Measures of mortality possess a number of properties which make them suitable for health research. They are objectively measured, reasonably accurate, readily available, and universally understood. Their use in any new study has the feature of comparability with earlier work.[12] However, even within the class of mortality measures,

[11] The use of individuals rather than states as the unit of observation would present many problems because of transitory influences. For example, high-income individuals might have better health because those with poor health can work less frequently or earn lower wages. The use of states requires attention to the distribution of characteristics and resources among individuals because relationships among aggregates may depend on them. However, it reduces the importance of transitory factors. One reason for this is that health is likely to vary much less relative to variation in income across states than across individuals. Another advantage of using states is that medical knowledge probably varies less across them than over time or across countries, at least for recent years, when the death rate has changed little. Finally, with states, variations in reporting practices and in the accuracy of information, which may be serious at the individual level, tend to average out.

[12] Fuchs points out that the ranks across geographic divisions of measures of mortality and morbidity tend to be correlated in spite of inadequacies in the morbidity measures. The lowest correlations are with measures indicating the presence of chronic conditions. For example, the rank correlation of age-adjusted death rates with age-adjusted average work-loss days per person seventeen years and older is 0.65, while it is only 0.08 with the age-adjusted percentage of persons with one or more chronic conditions and some activity limitation. See "Some Economic Aspects of Mortality," Table 2.

many indices have been used in the past. These indices differ according to whether they are crude death rates or rates standardized to a common age distribution, or whether they are death rates for specific age groups or for all age groups combined. In some cases life expectancy has been used.[13]

Age- and sex-specific death rates are preferred in principle, but not enough information was available to derive measures of the amount of medical care each age or sex group receives. It did not seem reasonable to assume that the relative use of medical services per capita in each age group was the same in every state, in spite of variations in relative income, education, et cetera. The decision was made to examine age–sex-adjusted death rates.

The use of age-adjusted death rates as the measure of health for the purpose of determining the impact of medical services presumes that a constant proportion of medical services is devoted to prolonging life as opposed to reducing pain or other health-related goals. The use of an insufficiently comprehensive measure of health can lead to biased measurement of the impact of medical services on health. For example, we might understate the effect of medical care on mortality if a relatively large proportion of medical services tended to be used

[13] Different patterns of age-specific death rates can result in the same average age at death; even when they do, people may prefer one pattern over another. Average life expectancy is in principle superior to age-adjusted death rates, since it takes into account not only variation in the average age at death but also differences in patterns of age-specific death rates. Once the importance of the entire distribution of age-specific death rates is recognized, a number of other measures of aspects of health are immediately suggested. For any given average age at death, a greater or lesser dispersion of the average age at death across individuals, or other characteristics of the distribution, may be considered desirable. Persons who weigh more immediate improvements more heavily than later ones may at any given age feel better off from a reduction in age-specific death rates in age groups which they are immediately approaching than from an even larger reduction in the future, even though that larger reduction has a greater effect on average life expectancy. This suggests still another measure: a "discounted life expectancy" that gives greater weight to more immediate gains.

The difference in geographic patterns between life expectancy and age-adjusted death rates (adjusted to the U.S. age distribution by the indirect method) is small in the United States at the present time. The correlation coefficient between the two measures across states in 1960 is 0.96. The life expectancy data were supplied by Harley B. Messenger.

A number of readers have mentioned the possibility of omitting violent deaths. These are intended to be influenced by medical care, as are "natural" deaths. In any event, they are a small part of the total and their exclusion would have little effect.

for goals other than to prolong life in states using large amounts of medical care per capita. This problem is considered further in discussing the results.

THE RESULTS

Determinants of Death Rates—Model I

Initially, we attempted to determine the production relationship for whites and nonwhites combined. Table 8-1 presents Model I results for this specification, estimated by ordinary least squares. The large positive coefficient of color would imply that nonwhites experience higher death rates than whites, holding constant both the levels of socioeconomic variables and the quantity of medical care. Percentage nonwhite is correlated with many of the other variables, making it difficult to separate their effects from variation associated with color and introducing some doubt as to the accuracy of the estimated effect of the color variable itself. For example, the partial correlation between color and education, given income, is 0.44. Because differences between whites and nonwhites are great for many of the other independent variables, treating whites and nonwhites together raises the intercor-

TABLE 8-1
Production of Health, Total Population, Model I,
Ordinary Least Squares

		Linear		Log	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Intercept		6.776	.783	.860	.164
Per cent nonwhite	(X_0)	.054	.008	.048	.009
Income	(X_1)	.057	.029	.023	.084
Education	(X_2)	−.152	.086	−.153	.138
Per cent in SMSA's	(X_3)	−.002	.003	−.012	.006
Per cent in manufacturing	(X_4)	.008	.007	.049	.020
Alcohol consumption per capita	(X_5)	.060	.197	.031	.046
Cigarette consumption per capita	(X_6)	−.019	.011	.141	.063
Health expenditures per capita	(E)	−.084	.007	−.084	.081
Medical school	(X_9)	−.020	.158	−.020	.011
R^2		.761		.674	

relation among these variables. Because color may interact with other variables, there is also a possibility of specification error. When whites are considered alone, correlation between education and income falls from 0.73 to 0.55 (see Table 8-2) and between education and medical care, from 0.67 to 0.47. On the basis of the above considerations, it was decided to restrict the analysis to whites.

Table 8-3 presents Model I estimates by ordinary least squares for

TABLE 8-2
Correlation Coefficients, White Population, Logarithms

	Age–Sex-adjusted Death Rate (H')	Income (X'_1)	Education (X'_2)	Per Cent in SMSA's (X'_3)	Per Cent in Manufacturing (X'_4)
Income (X')	.447				
Education (X'_2)	−.044	.551			
Per cent in SMSA's (X'_3)	.112	.265	−.112		
Per cent in manufacturing (X'_4)	.381	.278	−.195	.273	
Alcohol consumption per capita (X_5)	.378	.671	.330	.172	.021
Cigarette consumption per capita (X_6)	.478	.463	.224	.050	.116
Health expenditures per capita (E)	.166	.680	.467	.230	.061
Medical school (X_9)	.100	.085	.161	.352	.611

TABLE 8-3
Production of Health, White Population, Model I,
Ordinary Least Squares

		Linear		Log	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Intercept		.957	.099	−.196	.152
Income	(X'_1)	.003	.002	.204	.076
Education	(X'_2)	−.016	.011	−.218	.112
Per cent in SMSA's	(X'_3)	−.000	.000	−.000	.005
Per cent in manufacturing	(X'_4)	.002	.001	.040	.018
Alcohol consumption per capita	(X_5)	.013	.027	−.002	.038
Cigarette consumption per capita	(X_6)	.002	.002	.102	.056
Health expenditures per capita	(E)	−.001	.001	−.065	.065
Medical school	(X_9)	−.042	.021	−.023	.010
R^2		.517		.539	

whites, in both linear and logarithmic forms. In the logarithmic form, the regression coefficients are elasticities. Variables for whites were used where possible. These are indicated by a "prime" over the variable number. It was necessary to assume that the per capita usage of medical services by whites in a state is the same as for the entire population. Fuchs experimented with the assumption that the share of medical services received by whites is the same as their share of income, and found that the regression coefficients of the modified measures of medical services differed little from the original ones. This was found for our study also.

More than 50 per cent of the variation among states in age–sex-adjusted death rates is associated with the combination of medical and environmental variables. The sign of health expenditures is negative, contrary to the positive zero order correlation. A 10 per cent increase reduces mortality by two-thirds of a per cent in the logarithmic form. Income is positively related to the death rate, while education has a negative association. This finding is not the result of intercorrelation between the two variables. The coefficient for income remains positive after the education variable is omitted. The same signs appear even in the simple correlations. Also, the use of the age-adjusted income and education measures does not change the results. Urbanization does not appear to be important when other factors are held constant, either in the form shown or when alternative measures are used. However, the index of industrialization—percentage of employment in manufacturing—is positively related to mortality. Cigarette consumption per capita exhibits a positive association with mortality, but alcohol consumption does not have a consistently positive sign.[14] The effect of per capita medical services appears to be small, but, as was indicated in the previous section, estimates of the effect of medical services on

[14] Alternative estimates of the coefficients of alcohol, cigarettes, and percentage in manufacturing were derived from the demand estimating equation in Appendix C. These are 0.006, 0.200, and 0.029, respectively; all three are very similar to those presented in this section. In the case of alcohol, some measure of the distribution of its use might be helpful. While we have hypothesized a positive coefficient for urbanization, it should be noted that the single most important variable explaining interstate differences in motor vehicle accident death rates is population density—with a negative sign. See Victor R. Fuchs and Irving Leveson, "Motor Accident Mortality and Compulsory Inspection of Vehicles," *Journal of the American Medical Association,* 201, August 28, 1967, pp. 657–61. Since we include accidental deaths and since population density is positively related to urbanization, urbanization may be measuring two things with opposite effects on "health," i.e., pollution and speed of cars.

the death rate by ordinary least squares are subject to simultaneous equations bias. States with medical schools tend to have lower mortality rates than those without them. A coefficient of —0.02 in the logarithmic form implies that states with medical schools, all other things being equal, have lower death rates by 4.5 per cent than states without medical schools.[15] A related variable—percentage of physicians in active practice under age thirty-five (excluding interns and residents)—was also tested. It was intended to measure the vintage of the available technology. The effects of the variable, however, disappeared when the medical school variable was introduced. Another efficiency parameter considered was hospital size, which was thought a possible reflection of quality of care. However, it did not show the expected sign, while it increased problems of multicollinearity.

Table 8-4 presents estimates for Model I using two-stage least squares (2SLS). The standard errors cannot be clearly interpreted, since when 2SLS is used, the underlying distributions are not known. They may nevertheless serve as a guide. As expected, the coefficient of per capital medical expenditures was increased (to —0.116, with a standard error of 0.082).[16] The other coefficients were essentially unchanged.

TABLE 8-4
Production of Health, White Population, Model I,
Two-Stage Least Squares, Logarithms

		Regression Coefficient	Standard Error
Intercept		−.135	.162
Income	(X'_1)	.212	.075
Education	(X'_2)	−.194	.114
Per cent in SMSA's	(X'_3)	−.000	.005
Per cent in manufacturing	(X'_4)	.039	.018
Alcohol consumption per capita	(X_5)	.014	.041
Cigarette consumption per capita	(X_6)	.099	.056
Health expenditure per capita[a]	(E)	−.116	.082
Medical school	(X_9)	−.021	.010
R^2		.551	

[a] Endogenous.

[15] A continuous form of this variable performed less satisfactorily. The dummy variable is still coded zero and one in logarithmic equations but is interpreted as the log of a variable coded one and ten.

[16] This probably results not only from the removal of simultaneous equation bias but also in part from the elimination of measurement error in the medical expenditures variable by the use of the instruments in the first stage.

In Table 8-5 two variables are added to the two-stage least squares equation. At this point, it should be emphasized that, with the nature of the data available, improved specification often comes at the price of a radical increase in multicollinearity. While the increase in multicollinearity from the addition of the white-collar and labor-force variables is not very destructive in this case, it would be if they were included in Model II. The proportion of workers in white-collar occupations is positively associated with death rates, while the proportion of married females with husband present and out of the labor force is negatively associated with mortality. The inclusion of these two variables appreciably increases the coefficient of determination at the same time as it reduces the estimated effect of medical care on mortality.[17]

Determinants of Death Rates—Model II

Model II disaggregates medical services into four components. It is expected that this disaggregation will raise the estimate of the effect of medical services on the death rate. In the form "medical expenditures," part of the variation results from variations in price as distinguished from quantity, the former having no relevance for the death rate. To the extent that price variation operates as a kind of random measurement error, variation in expenditures will tend to overstate the true variation in quantity and result in an understatement of the regression coefficient.[18] All Model II equations are in logarithmic form. Table 8-6

[17] Two hypotheses can be advanced to explain the effect of the female labor force variable. Labor market activity may be less favorable to health than nonmarket activity. Also, females at home may provide unmeasured medical services. The former would suggest that the relationship would hold for females; the latter that it would hold for males. In fact, the coefficient is very close to zero in regressions against the white male age-adjusted death rate, but is quite large for females. However, this cannot be clearly interpreted as support for the market activity hypothesis. In states where the death rate of males relative to females is high, relatively more females will be widowed and/or working. The female labor force variable, therefore, is in part a proxy for the ratio of the male to the female death rate which is correlated with the sex-specific death rates in such a way as tend to produce the observed result. On the other hand, relatively more women will be out of the labor force where the health of women is poor. The net effect of these two biases is not known.

[18] Even if price did not vary, the expenditure variable, which as measured here is essentially total cost, would only be an error-free measure of the quantity of medical services if the production function were homogeneous of degree one and factors of production were being combined in a cost-minimizing way. The latter, in particular, is not necessarily true in a nonprofit industry.

TABLE 8-5

Production of Health, White Population, Two-Stage Least Squares, Logarithms

		White-Collar Workers		Females Not in Labor Force		White-Collar Workers and Females Not in Labor Force	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Intercept		−.287	.175	.232	.251	.126	.240
Income	(X'_1)	.168	.076	.226	.074	.177	.072
Education	(X'_2)	−.243	.113	−.244	.113	−.312	.110
Per cent in SMSA's	(X'_3)	−.002	.005	.000	.005	−.003	.004
Per cent in manufacturing	(X'_4)	.048	.018	.025	.019	.034	.018
Alcohol consumption per capita	(X_5)	.014	.040	.006	.040	.004	.038
Cigarette consumption per capita	(X_6)	.099	.054	.084	.054	.080	.051
White-collar workers	(X'_7)	.145	.075			.173	.072
Females not in labor force	(X'_8)			−.233	.124	−.281	.119
Health expenditures per capita[a]	(E)	−.096	.080	−.090	.081	−.061	.077
Medical school	(X_9)	−.028	.010	−.016	.010	−.023	.010
R^2		.591		.589		.645	

[a] Endogenous in two-stage least squares runs.

TABLE 8-6
Production of Health, Model II, Without Composites

		Ordinary Least Squares		Two-Stage Least Squares	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Intercept		−.065	.157	.037	.251
Income	(X'_1)	.105	.079	.183	.116
Education	(X'_2)	−.161	.121	−.288	.216
Per cent in SMSA's	(X'_3)	−.001	.005	−.001	.005
Per cent in manufacturing	(X'_4)	.051	.023	.042	.040
Alcohol consumption per capita	(X_5)	−.002	.037	.013	.044
Cigarette consumption per capita	(X_6)	.094	.053	.097	.058
Drug expenditures per capita[a]	(R)	−.070	.040	−.076	.066
Physicians per capita[a]	(D)	.143	.064	.044	.111
Paramedical per capita[a]	(N)	−.190	.076	−.031	.195
Capital per capita[a] (plant assets)	(K)	−.004	.048	−.109	.141
Group practice[a]	(G)	.007	.012	.007	.021
Medical school	(X_9)	−.034	.012	−.024	.019
R^2		.639		.586	
Elasticity of the death rate with respect to medical services (σ_0)		−.121		−.172	

[a] Endogenous in two-stage least squares runs.

presents estimates of Model II by ordinary least squares and instrumental variables. Capital is measured by the value of plant assets. (The problem of capital measurement is discussed in Appendix B.) As was to be expected, the instrumental variables estimation yields a higher estimate of σ_0 than ordinary least squares; higher values for σ_0 are also obtained vis-à-vis Model I. The coefficients of the environmental variables differ little between the top models. While σ_0, the sum of the coefficients of the factors of production, is fairly constant between alternative formulations, determination of the effects of individual factors of production is hampered by the high intercorrelations among these factors. The highest degree of correlation is between paramedical personnel and capital. In an attempt to eliminate this, the two variables were combined by linearly regressing the total number of paramedical personnel on capital and combining the factors according to the estimated conversion.[19] Estimates using this "composite" are shown in Table 8-7. The elasticity of the death rate with respect to medical services is —0.134 in the two-stage least squares run, and the positive coefficient of physicians is reduced to zero. The environmental coefficients are essentially unchanged.[20] In such gross comparisons, no impact of group practice on mortality is discernible.

An attempt was made to deal more adequately with variations in the quality of physicians, in particular between general practitioners and specialists. A fixed weight composite of G.P.'s and specialists based on the national difference in their earnings was used. In addition,

TABLE 8-7
Production of Health, Model II, Composite of Capital and Paramedical Personnel

		Ordinary Least Squares		Two-Stage Least Squares	
		Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Intercept		.018	.181	−.044	.213
Income	(X'_1)	.165	.075	.183	.080
Education	(X'_2)	−.263	.108	−.231	.116
Per cent in SMSA's	(X'_3)	−.002	.005	.000	.006
Per cent in manufacturing	(X'_4)	.035	.023	.039	.029
Alcohol consumption per capita	(X_5)	−.014	.038	.008	.044
Cigarette consumption per capita	(X_6)	.108	.055	.098	.059
Drug expenditures per capita[a]	(R)	−.062	.042	−.051	.064
Physicians per capita[a]	(D)	.089	.061	.003	.090
Composite of capital and paramedical per capita[a] (plant assets)	$(K + N)$	−.124	.061	−.086	.072
Group practice[a]	(G)	.001	.012	.001	.017
Medical school	(X_9)	−.028	.012	−.022	.015
R^2		.595		.557	
Elasticity of the death rate with respect to medical services (σ_0)		−.097		−.134	

[a] Endogenous in two-stage least squares runs.

[19] The relationship indicated fixed proportions.

[20] In an attempt to treat incomes as an endogenous variable, the endogenous form was more highly correlated with other variables and its coefficient increased.

composites of paramedical and alternative measures of capital input were considered. The use of the physicians' composite had no effect on the results. All coefficients remain basically unchanged. Use of alternative measures of capital had a relatively negligible effect on the estimate of σ_0. However, the estimates of the individual effects of the various medical inputs did appear to be quite sensitive to alternative measures of capital. Clearly, further research is called for before the productivity of individual factors of production can be ascertained.

Attempts were made at various points in the investigation to add distribution parameters such as variables for low income and low education. It was found that in the cases considered, the explanatory power of the measures of the variables could not be improved upon by replacing them with the distribution parameters, and serious multicollinearity resulted when both forms were introduced simultaneously.

Discussion

Both models indicate that a 1 per cent increase in the quantity of medical services is associated with a reduction in mortality of about 0.1 per cent. Environmental conditions are a more important determinant of interstate variation in death rates. Among these, income and education play the greatest role. The effect of income on mortality is positive while that of education is negative. Urbanization is not important, but a number of labor force variables are. There is also some indication of harmful effects from cigarette smoking.

The positive coefficient of income is particularly interesting since it is contrary to gross relationships in most data. It should be borne in mind that the analysis holds constant the effects of medical care and education, variables that increase with income. Also, use of state averages, unlike use of individual observations or data grouped by income, greatly reduces the extent to which observed patterns are influenced by the tendency for some persons to have low income because their health is poor. Abstracting from these considerations, there are many reasons why income and mortality might be positively related.

We view persons as simultaneously determining consumption patterns, occupation, and life styles. As incomes rise, they might choose more adverse diets, faster cars, less exercise, et cetera. Also, occupations with less exercise, more strain, high risk of accident, et cetera might be selected in order to obtain higher income. The results of this study suggest that both occupation- and consumption-related factors may be important.

The education variable may also represent quite complex forces.

We do not know if we have isolated effects of the educational process or simply greater ability or willingness to learn. Even if what we have found does represent the effects of education, it is not clear whether general education or specific health training, such as in hygiene classes and exposure to school health programs, is relevant. There are many unanswered questions as to the patterns of care to which learning leads. The more educated may seek more preventive care, obtain medical care at earlier stages of an illness, have a better follow-up on drugs prescribed and referrals, or receive more continuous care. The last factor may be related to differences in the year-to-year variability of income between the more and less educated.

In comparisons among both developed and underdeveloped countries, Irma Adelman estimated the elasticity of the death rate with respect to the number of physicians per capita for specific age groups.[21] Her estimates of the impact of medical services on health are remarkably close to those in our study. Income, the rate of growth of income, and the proportion of the labor force employed outside agriculture were held constant. It seems likely that in international comparisons the number of physicians per capita is a good index of the total quantity of death-related medical services. Furthermore, since there is limited international factor mobility, it is probable that her estimates are relatively unbiased by her use of a single equation procedure. Her negative coefficient for income may reflect such factors as education, public health, and sanitation. Also, the effect of income may not be the same at all levels. She reports no significant difference between the coefficients for underdeveloped and developed countries, which may not hold true when education is added. Education has a positive sign in the Adelman study. Across countries, it may be associated with many of the factors with which income is associated across states. The income results with education included are not reported.

IMPLICATIONS AND CONCLUSIONS

One application of our results is to provide a possible explanation of recent trends in mortality in the United States. The age-adjusted death rate has not declined appreciably between about 1955 and 1965 (see Table 8-8), in spite of a substantial increase in the quantity of medical services produced per capita and probably some technological change as well. If we deflate national health expenditures by the Consumer

[21] See "An Econometric Analysis of Population Growth," *American Economic Review*, 53, June 1963, pp. 314–39.

TABLE 8-8

Contribution of Selected Medical Services and Environmental Factors to Changes in the Age-adjusted Death Rate, 1955–65

	Percentage Change in Variable	Percentage Change in Mortality per Percentage Change in Variable	Percentage Change in Mortality
Actual change in U.S. death rate			−3.9%
National health expenditures per capita deflated by CPI for medical care	+35%	−0.1%	−3.5%
Median family income deflated by CPI for all items	+32%	+0.2%	+6.4%
Education	+17%	−0.2%	−3.4%
Cigarette consumption per capita	+18%	+0.1%	+1.8%

Source: U.S. Bureau of the Census, *Statistical Abstract of the United States, 1967*, various tables.

Price Index for medical care, we find an increase in real expenditures per capita of 35 per cent between 1955 and 1965. This alone would lead us to expect a decline in the death rate of about 4 per cent. The effect of the medical school variable over time cannot be similarly derived, because its effects will be spread out and depend more on the past rather than on the present growth of the schools. What, then, has offset the expected decline? The answer is provided by the environmental factors, although a literal application of the estimated coefficients to time series may not be fully justified. The growth of education would have led to a decline of about 3 per cent. On the other hand, changes in real family income would have increased mortality. With a literal application of the estimates, the effect of income is 6 per cent. However, occupation will tend to vary less with income over time than in cross sections, because technological change also contributes to changes in income. This suggests that a smaller estimate of the effects of income on changes in mortality is appropriate. Changes in cigarette consumption per capita would have led to a further increase of 2 per cent, although this is a case for which changes over a longer period are clearly more appropriate. Our results, then, would imply that adverse environmental factors have been offsetting the advantages of increases in the quantity and quality of medical care. We can estimate the effects of improvements in the effectiveness of medical services as all changes not attributable to either changes in the quantity of medical care or environment. Literal predictions based on the variables in Table 8-8 would imply that in the period 1955–65 technological change reduced mortality by —3.9 minus 1.3 per cent, or a total of 5.2 per cent. Converted to an annual rate, this change is a change in mortality due to technology of 0.5 per cent per year. Allowing for the effects of medical schools and modifying the coefficient of income would produce an even smaller estimate of the contribution of technology change in the 1955–65 period. What may be an appropriate explanation since 1955 is not likely to be one for a longer period of time since in prior years the death rate fell precipitously. Unless the marginal effectiveness of medical care is substantially lower than in the past, one would have to infer that a slowdown in technological advance occurred.

It is also interesting to examine the implications of our results for white-nonwhite mortality differentials. In 1960, the white death rate was only 69 per cent of the nonwhite death rate when both are adjusted to the U.S. age distribution. Medical care spending and education would account for a large part of the difference, with small offsets from cigarette and possibly alcohol consumption. The application of the results on income to this problem seems highly questionable, since income may represent different variables at different ends of the income distribution. The color differential in mortality could be "explained" by our equations only if the predicted effect of income were omitted. We shall return to this point in a moment.

Some useful cost-benefit implications can be derived from the results. Dorothy P. Rice has estimated the economic cost of mortality using the present discounted value of future earnings as a measure of the loss of production to the economy. For 1963, she estimates these costs alternatively as $49.9 billion and $40.6 billion, depending on whether a 4 per cent or a 6 per cent rate of discount is used.[22] If the effect of a 1 per cent increase in medical expenditures is to reduce death rates by 0.1 per cent, as our estimate suggests, the benefit in increased production would be $40–50 million. Adding an equal percentage reduction in the loss from morbidity would bring the benefits to about $60–70 million. In 1963, however, national health expenditures were $32.9 billion, so that the costs of a 1 per cent increase in medical services would have been $329 million. While this comparison implies that costs exceed benefits, it should be noted that we have only considered economic losses due to the loss of productive time. No allowance has been made either for the loss of productivity due to

[22] Dorothy P. Rice, *Estimating the Cost of Illness*, U.S. Public Health Service Publication No. 947–6, May 1966, Tables 31 and 32.

illness or for the large psychic costs resulting from poor health. Also, the percentage effect of an across-the-board increase in the quantity of medical care may reduce morbidity losses by a very different percentage than mortality losses. We have examined the impact of variation in medical care generally. This type of cost-benefit comparison is relevant to a general increase in the quantity of medical care such as results from increased health insurance coverage. Specific programs may be able to select problems and areas with higher returns.

Statements regarding the merits of increments to educational spending relative to medical care can be made with less concern about the problems of benefit measurement. The effects of education on mortality are about double those of medical care, according to our estimates. Increases in education would presumably save medical resources as well. Yet a 1 per cent increase in the quantity of education involves only about one and one-half times the additional dollars. This would suggest that the tradeoff favors education, although again we need to know the relative effects on morbidity.[23,24] In view of the many other benefits of education, however, this result strongly suggests that the return on expenditures for additional education are far greater than on additional expenditures for medical care.

It is possible to integrate a great many of our findings, and in particular the observed effect of income on health, into a coherent, although somewhat conjectural, framework. Let us begin with the empirical observation that the gross relationship between health and income has the form H_T in Figure 8–1, ascending at a decreasing rate until it becomes approximately level over a wide range. This has been found to be the case for a large number of health measures, e.g., 365 minus the number of the disability days per person per year.[25] The beneficial

[23] The value of the effect on education of improvement in health attributable to an increase in medical care is likely to be much smaller than the saving in medical care due to an increase in education. See Irving Leveson, Doris Ullman, and Gregory Wassall, "Effects of Health on Education and Productivity," *Inquiry*, 6, December 1969, pp. 3–11.

[24] This comparison might overstate the merits of increasing education because forgone earnings of students may be greater than forgone earnings of medical patients. Also, to some extent, interstate differences in education may reflect interstate differences in native ability which would not be increased when education is increased over time.

[25] For example, see U.S. Public Health Service, *Medical Care, Health Status, and Family Income, United States*, National Center for Health Statistics Report, Series 10, No. 9, Washington, May 1964.

Our assumptions about the shape of H_T are derived from inspections of health measures individually. If each measure had a similar shape, but, as incomes effects of medical care and education on health, both of which rise with income, are represented by H_{M+E}, which is monotonically increasing at perhaps a decreasing rate. H_T can be considered as resulting from H_{M+E} and the effects of factors other than medical care and education which are associated with income, H_Y. Alternatively, H_Y can be derived as a residual by subtracting H_{M+E} from H_T. In effect, we can consider H_Y to represent approximately the same factors as the income variable in our regressions. H_Y rises steadily and reaches a maximum at relatively low levels of income, declining continuously thereafter. The rising portion represents the effects of factors such as basic nutrition, sanitation, and housing, while the declining portion represents such factors as diet, exercise, and stress.[26]

This model is consistent with our finding of an adverse effect of income and also with the findings of Irma Adelman across countries, because of the unique income level of the United States. More generally, the model tends to explain the difference between our results and those of other studies concentrating on low income groups. It should also

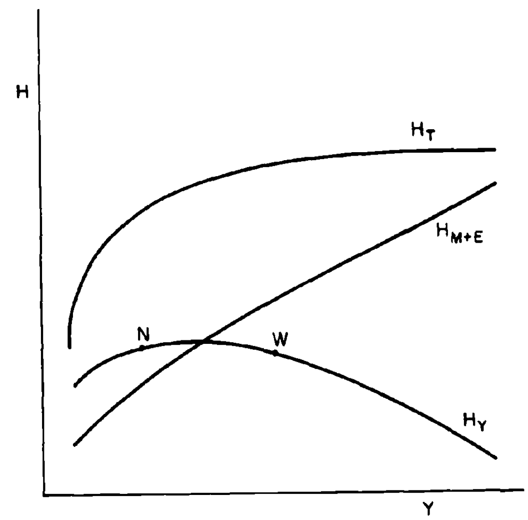

FIGURE 8-1
The Effects of Income, Education, and Medical Care on Health

rose, the weight in a combined health index shif:ed to measures that level off at higher incomes, the following remarks would hold only for mortality and not for health generally.

[26] If this is correct, then by fitting a monotonic relationship to H_Y one tends to underestimate the adverse effects of factors associated with income on health.

be noted that replacing the mean-income variable by the percentage of persons with low income would give a greater weight to the rising portion of the curve. When this was done, a smaller adverse effect of income was found.

Now consider the attempt to explain the white-nonwhite differential. We noted that a reconciliation could be made only if the predicted effects of income were not included. Suppose, however, that the average income of whites was at a point on H_Y such as *W* and those of nonwhites at *N*. Factors associated with income would then have both positive and negative effects on the differential. If these canceled, the reconciliation of the color difference would be succesful. If the income effect were not important in explaining the color differential, however, its impact on the total death rate ought to be much smaller than on white mortality. This view is supported by the results in Table 8-1.

At this point we are tempted to speculate that those factors which account for the declining portion of H_Y are also responsible for the higher death rates in the United States than in many European countries. Perhaps in that comparison, differences in the way people make a living, spend money, and allocate their time more than outweigh the effects of medical care and education. We might also expect that adverse effects of stress, exercise, and diet associated with income will not apply to infants. This model would therefore predict the negative association between income and infant mortality which has commonly been found. Again, the speculative nature of these remarks needs emphasis.