Volume Title: Explorations in Economic Research, Volume 4, number 2

Volume Author/Editor: NBER

Volume Publisher: NBER

Volume URL: http://www.nber.org/books/smit77-1

Publication Date: June 1977

Chapter Title: The Optimal Employment of Inputs in Fee-For-Service, For-Profit Health Practices: The Case of Optometrists

Chapter Author: Douglas Coate

Chapter URL: http://www.nber.org/chapters/c9097

Chapter pages in book: (p. 316 - 330)

4

DOUGLAS COATE
National Bureau
of Economic Research
and Rutgers University, Newark

The Optimal Employment of Inputs in Fee-for-Service, for-Profit Health Practices: The Case of Optometrists

ABSTRACT: In this paper, I examine the employment of inputs by optometrists in private practice. The principal finding derived from the utility maximization model and production function estimates is that the hypothesis that optometrists are employing the optimal amount of aide input cannot be rejected. This is in conflict with findings from similar research on physician practices. The productive efficiency of optometrists in group and solo practice is also compared.

[1] INTRODUCTION

Most primary health professionals (physicians, dentists, and optometrists) supply a large portion of their services in fee-for-service, for-profit private practice.

NOTE: This research was supported by grants to the National Bureau from the Robert Woods Johnson Foundation and the National Center for Health Services Research (PHS Grant P 01 HS00451). I thank Isaac Ehrlich, Michael Grossman, and Mark Pauly for helpful comments, Christy Wilson for research assistance, and Catherine Grant for typing the manuscript.

They fill the combined roles of manager, risk taker, and most productive input in the production process. Interest in the production processes of their "firms" has grown in recent years because of concern over the rapid rise in expenditures for health services and because of the alleged shortage of primary health professionals. As a result there is a rapidly expanding, if not yet substantial, health economics literature in which the production processes of primary health professionals in private practice are examined to determine whether productive inputs are organized in an optimal way. The few completed studies have been of physician practices, and the same conclusion has been reached in all of them: physicians do not appear to be capably performing their managerial function. More specifically, physicians in private practice appear to be under-employing auxiliary manpower in the production process.

Reinhardt, for example, concluded from his estimated production function for physician services that the average American physician could profitably employ twice the number of assistants he presently utilizes and, by so doing, increase his hourly rate of output by 25 percent (Reinhardt 1972). Smith, Miller, and Golladay (1972) used a linear activity model to analyze the production of medical services by physicians in private practice and found that the efficient use of physician assistants would increase physician productivity by 49 to 74 percent.[1] If these results are correct, a substantial portion of the present inflation in the price of physician services and of the alleged shortage of health services could be avoided but for the poor managerial performance of physicians.[2]

My purpose in this paper is to analyze the production process of optometrists in private practice and to provide further evidence on the managerial performance of primary health professionals. If optometrists also appear to be using inefficient production techniques, further questions can be raised about organizing the delivery of health services around fee-for-service, for-profit private practices.

[1.1] The Practice of Optometry: An Overview

The primary health services provided by optometrists are eye examinations and the prescription and sale of lenses to correct refractive errors. Besides fitting, optometrists adjust and repair eyeglasses. The mean gross income from professional practice of the sixteen thousand self-employed optometrists in the United States is approximately $50,000, implying that upward of $800 million is spent annually on their services.[3] Most optometrists are engaged in solo practice. About 17 percent of self-employed optometrists are in partnerships or group practice (HEW 1973, p. 14).

[2] METHOD OF ANALYSIS

[2.1] Specification of the Production Functions

To produce their services, optometrists in private practice generally combine their own time with the time of aides, capital, office space, and other inputs. Some optometrists, however, do not employ auxiliary manpower in the production process. Therefore, the production function specification should reflect the fact that positive rates of output can occur when some inputs are not used in the production process. A functional form that meets this requirement was used by Reinhardt in his analysis of the production of physician services: The general specification of that function is

$$Q = A\prod_{s} (X_s^{\alpha_s} e^{\beta_s \lambda_s}) \exp \{\sum_{j}\gamma_j L_j + \Theta(\Sigma L_j)^2 + u\}$$

where X_s denotes inputs that must be used in the production process and L_j, inputs that can be excluded. The inputs can have either increasing or decreasing marginal products, and the elasticity of substitution and returns to scale are not constrained to constant values.[4]

Because the results may be sensitive to the specification of the production relationship, a Cobb-Douglas production function is also estimated in this study.[5]

[2.2] The Data

The data base for this study is the 1964 National Economic Survey of the American Optometric Association (AOA). In 1965, nearly all members of the AOA were mailed a questionnaire that solicited 1964 data on the economics of conducting their optometric practices. About 70 percent of practicing optometrists are AOA members. The number of questionnaires returned, coded, and punched by the AOA totaled 4,750, which represented approximately 40 percent of its members.[6] The proportion of members responding to the survey by regional division of the United States ranged from 33 to 45 percent. In this survey, annual data were solicited from optometrists on their gross and net-before-tax income from practice, output (as measured by the number of eye examinations produced and wholesale value of eyeglasses sold), wages and rent paid, the imputed or shadow wage bill of assistants who worked without pay (e.g., family members), the dollar size of capital stock, hours worked, and city size. In addition, data were collected on type of practice (group or solo).[7]

[2.3] Measuring Inputs

One problem with the data solicited in the survey is that most of the productive inputs are measured in value terms rather than physical units. Measuring inputs in value terms, however, is not an uncommon practice in the estimation of production functions (see, for example, Feldstein 1967, Chap. IV). One advantage of doing so is that a built-in quality adjustment is provided. For example, the input hours of higher-quality or more productive workers are more heavily weighted than the hours of lower-quality labor to the extent that the former receive higher wages. Measuring inputs in value terms does introduce a potential bias, the size of which depends on the amount of variation in the factor prices optometrists face. By controlling for city size in the estimated production functions, much of this bias can be eliminated.

The following inputs are measured in value terms: annual wages paid to assistants, dollar amount of annual rent for office space, flow of capital services,[8] and imputed wage bill of assistants who worked without pay. Data on the number of hours worked per week by the optometrist were also collected in the survey. Those figures, multiplied by 49.3 to approximate the number of hours worked per year, were also included as an input in the production function.[9]

[2.4] The Group Practice Variable and a Summary of the Production Function Specifications

Besides city size, one other independent variable that is not formally an input is included in the estimated production functions. It is a dummy variable that equals 1.0 for optometrists in group practice. It is included because many observers of the health care industry have argued that health services can be more efficiently delivered in group rather than solo practice settings. Reinhardt's production function results showed, for example, that group practitioners were capable of generating 5.1 percent more office visits from a given input bundle than solo practitioners.

Before I discuss the output measure, I summarize the specified Reinhardt and Cobb-Douglas production functions below:

Reinhardt:

$$Q = AH^{b_1} e^{b_2 H} D^{b_3} e^{b_4 D} R^{b_5} e^{b_6 R} e^{(b_7 W + b_8 W^2)} e^{b_9 CD} e^{b_{10} CS} U$$

Cobb-Douglas:

$$Q = AH^{b_1} D^{b_2} R^{b_3} W^{b_4} e^{b_5 CD} e^{b_6 CS} U$$

where:

Q = output
H = optometrist's hours
D = capital flow
R = rent bill
W = aide bill
CD = group dummy
CS = city size

[2.5] Measuring Output

The explicit output measures solicited in the AOA survey were the wholesale value of lenses, temples, and frames purchased by the optometrist during the year and the annual number of eye examinations provided. A single output measure can be constructed from this data by converting the wholesale value of eyeglass components and lenses to number of eyeglasses sold and then combining this measure with the number of eye exams provided by using an appropriate weighting scheme. An informal survey of optometrists in the New York metropolitan area revealed that in 1964 the approximate wholesale value of the average pair of eyeglasses provided by optometrists was $10.[10] This price was used to deflate the AOA wholesale value figure so as to approximate the physical quantity of eyeglasses provided.

Available data on the prices of eyeglasses and visual examinations can be used to develop a weighting scheme for combining the numbers of eyeglasses and eye examinations provided into a single output measure. Lee Benham reports that in 1963 the average combined cost of eyeglasses and an eye examination in the United States was $38.32 and the average cost of eyeglasses alone was $28.23.[11] If the reasonable assumption is made that the relative values of a pair of eyeglasses and an eye examination were the same in 1964, the data indicate that the number of eyeglasses sold should be weighted 2.8 times as heavily as the number of eye examinations supplied when the two quantities are combined into a single output measure.

The physical measure of output derived from this procedure is a nearly complete description of the output of an optometric practice. This measure should be an improvement over such output descriptions as patient visits or patient billings, which have been used in studies of physician services. In using patient visits, for example, the assumption must be made that variation in the quantity of services provided per visit is not correlated with the size of the firm. If, as is probable, this assumption does not hold, regression estimates of the parameters of the production relationship will be biased, as will the resulting calculation of returns to scale.[12] One advantage of studying the production of optometric services to learn more about the production of health services in fee-for-service, for-profit practice is that the limited range of services offered by optometrists (as compared to physicians) can be measured quite readily in physical terms and assumptions such as the one just discussed need not be made.

[3] A FRAMEWORK FOR EXAMINING THE OPTIMAL EMPLOYMENT OF INPUTS IN THE PRODUCTION OF OPTOMETRIC SERVICES

Before presenting the estimates of the production functions for optometric services, a framework must be established for interpreting the regression results. It is particularly necessary for an analysis of the optimal employment of inputs in the production process. As reviewed at the outset of this study, previous investigators have concluded that physicians in private practice are under-employing auxiliary manpower and placing too low a value on their own input in the production of their services. Since the primary purpose of this study is to evaluate how effectively optometrists organize productive inputs, including their own time, the decision rules that are likely to govern the optometrists' practices must be derived.

[3.1] The Utility Maximization Model

One reasonable approach to the formulation of these decision-making rules is to assume that optometrists maximize a utility function in income and leisure and that income is derived from professional practice and other sources. It is also assumed that income cannot be generated from professional practice without inputs of the optometrist's time, and that nonemployment income does not depend on time inputs of the optometrist.

More specifically, let

$$U = U(L, Y_1 + Y_2)$$
$$= U[\Omega - H, P \cdot Q(H, I_1, \ldots, I_n) - TC(I_1, \ldots, I_n) + Y_2]$$

where

L = hours of leisure
Y_1 = income from practice
Y_2 = income from other sources
Ω = fixed amount of available hours
H = hours devoted to practice
P = price of output of the practice
$Q(H, I_1, \ldots, I_n)$ = quantity of output produced by a production process using inputs $H, I_1, \ldots, I_n$
$TC(I_1, \ldots, I_n)$ = total cost of the output produced as determined by the quantity of inputs purchased in the market

Because the inputs of labor, capital, and office space in the AOA survey were measured in value terms and the input hours of the optometrist, in physical terms, the utility function for optometrists can be written as

$$U = U[\Omega - H, P \cdot Q(H, D, W, R, CS, GD) - (D + W + R) + Y_2]$$

In order to maximize utility, the optometrist's employment of factor inputs must satisfy the following first-order conditions:

$$\frac{\partial U}{\partial H} = -\frac{\partial U}{\partial L} + \frac{\partial U}{\partial Y} P \frac{\partial Q}{\partial H} = 0$$

$$\frac{\partial U}{\partial i} = \frac{\partial U}{\partial Y} (P \frac{\partial Q}{\partial i} - 1) = 0; \quad i = D, R, W$$

The first-order conditions can be used to calculate the value or shadow price optometrists attach to their own time in terms of their employment of other productive inputs. For example, the shadow price the average optometrist assigns to the value of an hour of his time in terms of his employment of auxiliary manpower would be

$$(3.1) \quad \frac{\partial U/\partial L}{\partial U/\partial Y} = P\left(\frac{\partial Q}{\partial H} - \frac{\partial Q}{\partial W}\right) + 1$$

Equation 3.1 could also be derived from a profit maximization model in which the optometrist assigns a shadow price to his own time.

[4] THE ESTIMATED REINHARDT PRODUCTION FUNCTION

Estimates of the Reinhardt production function specified above are presented in Table 1.[13] The results shown were obtained exclusively by ordinary least squares. The results are biased unless inputs and outputs are not simultaneously determined. This assumption would be justified, for example, if optometrists chose current inputs on the basis of anticipated, rather than current, output. Even if inputs and outputs are simultaneously determined, the resulting estimation bias may not be large. Reinhardt (1973, pp. 205-210) has concluded that the OLS estimates of health care production functions are not biased to a great degree by the simultaneity problem because physicians and other primary health professionals differ greatly in their ability or willingness to maximize profits and face substantially different product and input prices.

[4.1] The Optimal Employment of Inputs—the Empirical Results

The pair of regressions presented in Table 1 differ in the index of aide input. Regression 1 measures aide input as wages paid to assistants plus the imputed wage for work performed by unpaid aides (e.g., spouses); regression 2 includes only the actual annual wage bill. Results for optometrist's hours and for capital flow (ln e^{b_2H} and ln e^{b_4D}) are not presented for either regression because the estimated coefficients were not statistically significant. The estimated coefficients for the remaining variables are all highly significant. The coefficients and statistical significance of the city size and group dummy variables are discussed in Appendix A.

To compute the shadow price the average optometrist assigns to an hour of his time in terms of his employment of auxiliary manpower as defined in equation 3.1, values must be determined for the marginal products and the price of output. If the mean sample values for all variables are substituted into the marginal product expressions, the regression estimates can be used to deter-

TABLE 1 Regression Coefficients for Production[a] of Optometric Services, Reinhardt Functional Form (figures in parentheses are *t* values)

Independent Variables	Regression 1	Regression 2
ln optometrist's hours	0.423	0.426
	(12.4)	(12.5)
ln capital flow	0.123	0.120
	(9.5)	(9.2)
ln rent bill	0.118	0.122
	(4.3)	(4.4)
Rent	-0.033×10^{-3}	-0.033×10^{-3}
	(−2.6)	(−2.6)
Aide value[b]	0.077×10^{-3}	
	(27.5)	
Aide value[b] squared	-0.11×10^{-8}	
	(−11.0)	
Aide bill		0.080×10^{-3}
		(28.6)
Aide bill squared		-0.11×10^{-8}
		(−11.0)
City size	0.055	0.054
	(11.0)	(11.0)
Group dummy	0.057	0.029
	(2.3)	(1.2)
Constant	2.92	2.91
R^2	0.33	0.34
F ratio	235.8	246.4
N	3,814	3,814

[a]Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.
[b]Aide value is equal to the aide bill plus the value of work performed by unpaid assistants.

mine the numerical value of the marginal products for the different inputs. For regression 1, the marginal product of the optometrist's hours is 0.83 and the marginal product of auxiliary manpower is 0.27. Output price is calculated from the sample data by taking a weighted average of the gross annual income per unit of output of each responding optometrist, where the weight is the number of units of output produced. The resulting price per unit of output is $8.04. Substituting this figure and the computed marginal products into (3.1) yields a shadow price of $5.50 for an hour of optometrist's time. This result must be compared with optometrists' "true" value of time to determine whether their time is optimally valued in terms of their employment of auxiliary manpower. One approximation of the "true" value is market wage.[14] The hourly market wage of salaried optometrists can be estimated from data in the

1964 AOA survey on the before-tax net income, hours, and experience of optometrists employed by other optometrists and by physicians. A regression of the before-tax net annual income of salaried optometrists divided by hours worked per week (Y/H) run on years of experience (E) and E^2 yields the following results (t statistics in parentheses):

$$(3.2) \quad \underset{}{Y/H} = 161.30 + \underset{(3.7)}{12.44E} - \underset{(-2.6)}{0.22E^2}$$

$$R^2 = 0.10; \; N = 164$$

The mean hourly earnings of optometrists employed by physicians and other optometrists in 1964 was \$5.00, assuming salaried optometrists on average worked 49.3 weeks per year.[15]

The average market hourly wage for the labor of self-employed optometrists can be predicted from (3.2). Because the mean years of experience of self-employed optometrists in the AOA sample was 15.8, compared to 10.5 years for those on salary, the predicted market hourly wage for self-employed optometrists is \$6.15.

The difference between the estimated shadow price of \$5.50 and the calculated market wage is not statistically significant. A precise significance test cannot be formulated because the shadow price is determined in part from marginal product expressions that consist of the product of a relatively large number of random variables. A crude but informative statistical test can be conducted, however, by observing the sensitivity of the shadow price to variations in the estimated production function parameters. For example, if the coefficient of the log of optometrist's hours is allowed to increase by one standard deviation, the estimated shadow price increases to \$7.50. Thus, even if the variation is eliminated by assumption in all parameters but one, a shift in that one coefficient within the bounds of statistical error is sufficient to yield a shadow price in excess of the market wage. Equation 3.1 and the production function estimates indicate the optimal wage bill is \$5,000, given the optometrist's market wage of \$6.15 and assuming other inputs are employed at their sample means. Although this value is 38 percent greater than the sample mean wage bill (including the value of unpaid work) of \$3,620, the discrepancy is not statistically significant given the foregoing considerations.

The shadow price of an hour of optometrist's time in terms of capital employment can be computed from (3.1) if $\partial Q/\partial W$ is replaced by $\partial Q/\partial D$. The marginal product of capital is 0.52 if sample means are substituted into the marginal product expression and the estimates of regression 1 are used. The computed shadow price is then \$3.49, which is substantially less than the market wage of \$6.15, although the difference cannot be considered statistically significant. The gap between market wage and shadow price is reduced markedly by allowing variations in a single parametric estimate. If the coefficient of the log of optometrist's hours is again allowed to increase by one standard error, the shadow price of optometrist's time in terms of capital employment increases to almost \$5.00. Equation 3.1 and the production function estimates indicate that the optimal capital flow is \$2,000, given the optometrist's opportunity cost of \$6.15 and assuming other inputs are employed at their sample means. The average capital bill in the AOA sample was \$922.

The calculated marginal product of office space is −0.05 if the regression results of (1) are used in conjunction with the sample means in the marginal product expression. This result is questionable and not only because a negative marginal product is inherently difficult to accept. Bias is introduced because the rent bill is not an adequate index of the physical quantity of floor space. Rents per unit of space vary for a variety of reasons that are not related to the productivity of the space in the production process. One example is the direct relationship between rent per unit of space and access to population concentrations. Because of the bias introduced when using rents as a proxy for floor space, a discussion of an optimal rent bill is omitted.

In regression 2 the measure of aide input is the actual annual wage bill paid by the optometrist. The value of the work of unpaid assistants is not included, as it is in the aide input measure in regression 1. Because not all of the auxiliary manpower input is accounted for, the inputs should appear more productive than they actually were. The calculated marginal products for optometrist's hours and aide input are slightly higher if the parametric estimates of (2) rather than (1) are used. The marginal product of optometrist's hours increases to 0.86 and the marginal product of aides increases to 0.29. The marginal product of capital stays constant at 0.52.

Substituting the marginal products computed from (2) into (3.1) yields shadow values for an hour of optometrist's time of \$5.58 in terms of aide input and \$3.71 in terms of capital employment. These results are similar to those previously discussed.

[5] THE ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION

Because the results just discussed may be sensitive to the specification of the production function, the shadow prices and optimal input levels obtained from estimation of a Cobb-Douglas production function are compared with results from the Reinhardt form. For this comparison, the observations on optometric practices where auxiliary manpower was not used must be deleted from the sample because a constraint of the Cobb-Douglas functional form is that a positive rate of output can occur only if all inputs are used in the production process. Deletion of those cases reduces the working sample from 3,814 to 2,782 observations.

TABLE 2 Regression Coefficients for Production[a] of Optometric Services, Reinhardt and Cobb-Douglas Functional Forms, Abbreviated Sample (figures in parentheses are *t* values)

Independent Variables	Reinhardt Regression 1	Cobb-Douglas Regression 2	Cobb-Douglas Regression 3
ln optometrist's hours	0.356	0.334	0.334
	(9.5)	(9.15)	(9.15)
ln capital flow	0.102	0.074	0.074
	(7.6)	(5.6)	(5.6)
ln rent bill	0.084	0.002×10^{-3}	
	(2.8)	(0.14)	
ln aide value[b]		0.275	0.275
		(24.6)	(25.0)
Rent	-0.024×10^{-3}		
	(−2.0)		
Aide value[b]	0.051×10^{-3}		
	(18.2)		
Aide value[b] squared	-0.06×10^{-8}		
	(−6.1)		
City size	0.046	0.047	0.047
	(8.8)	(9.4)	(9.8)
Group dummy	0.047	0.048	0.049
	(2.0)	(2.1)	(2.2)
Constant	4.01	2.88	2.90
R^2	0.25	0.29	0.29
F ratio	112.8	186.3	223.7
N	2,782	2,782	2,782

[a]Output is the log of the sum of eye exams and 2.8 times the wholesale value of lenses and frames.
[b]Aide value is equal to the aide bill plus the value of work performed by unpaid assistants.

Regression results for the two production functions are presented in Table 2. Since the rent variable was not statistically significant in the estimated Cobb-Douglas function, it does not appear in the corresponding regression. The calculated marginal products implicit in the results for the Reinhardt specification are 0.80, 0.20, and 0.44 for optometrist's hours, aides, and capital. The weighted average of the price of output in the abbreviated sample is \$7.96. Substituting marginal products and output price into equation 3.1, as before, yields a shadow price of \$5.78 for an hour of optometrist's time in terms of aides and \$3.86 in terms of capital input. For the Cobb-Douglas specification, the marginal products for optometrist's hours, aides, and capital are 0.81, 0.28, and 0.35, and the shadow prices of optometrist's time in terms of aides and capital are $5.21 and $4.66. As before, the shadow prices computed from the abbreviated sample are lower than the market wage of $6.16,[16] but the differences cannot be considered statistically significant.

IMPLICATIONS AND CONCLUDING REMARKS

The most striking characteristic of these results is that the hypothesis that optometrists are employing the optimal amount of aide input cannot be rejected.[17] It may be true, as Reinhardt reported, that physicians could profitably expand their employment of aides, but that does not appear to be true for optometrists.[18] One reason why optometrists may be able to organize their practices more efficiently than physicians is that the latter may have a greater fear of compromising the quality of care they provide if they increase the substitution of other inputs for their own time in the production process. It is true that malpractice claims have become a relatively common occurrence in medicine, but they remain very rare in optometry.

Although the principle finding of this research is that optometrists may indeed be employing the optimal amounts of aide input, it is also true that strong support for the postulate that optometric practices are efficiently organized is not evident. Each estimate of the shadow price of optometrists' time in terms of aide and capital input has been less than their estimated market wage. Optometrists could be operating efficiently and at the same time placing a relatively low value on their own time in the production process if some of their working hours must be spent in the office waiting for patients, many of whom come without an appointment. During this time they could be completing many of the activities they would delegate to aides if they were busier. Similarly, they could afford to spend a substantial portion of time with each patient they do serve and would be less concerned with task delegation in the treatment process. There is some evidence for this idle time hypothesis. Haffner (1971, p. 32) found in his 1970 national survey of over 2,000 optometrists that 22 percent of all respondents felt their optometric practices under their present structure could accommodate over 30 percent more patients. The median respondent felt his optometric practice could accommodate 18 percent more patients under its present structure.

APPENDIX A: THE VARIABLES FOR GROUP PRACTICE AND CITY SIZE

The group dummy variable in the Reinhardt production function estimated over the full sample, with aide input measured as the actual wage bill plus the value of work performed by unpaid aides, indicates that the optometrist in group practice produced, on average, about 5 percent more output than optometrists in solo practice for a given input bundle (see Table 1, regression 1). A superior technical efficiency of the group practitioner is not apparent in regression 2, Table 1, where aide input is measured as wages paid to assisting manpower and does not include imputed wages of unpaid assistants. In this regression the coefficient of the group dummy falls to 0.02 and is not significantly different from zero at accepted confidence levels. The reason for the difference in these results is that solo optometrists used $500 worth of unpaid help while group optometrists used only $250 worth. Since the solo practitioner had $250 more of unmeasured aide input than the group practitioner, the former can appear to be as technically efficient as the latter.

In all the estimated production functions, the city-size variable is highly significant. The measure of city size consists of seven different population categories, with higher values of the variable being associated with smaller-size cities. The regression results then appear to indicate that the smaller the city, the more efficient is the production of optometric services. However, this is undoubtedly an illusion. The more reasonable interpretation is that the prices of productive inputs are lower in small cities than in large ones. If so, holding the dollar value of inputs constant in the production function does not hold the physical quantities constant. Optometrists in smaller cities would appear to be more productive if they have more inputs to work with per dollar of expenditure.

NOTES

1. "Physician assistant" refers to a category of paraprofessionals specifically trained to perform a variety of medical tasks.
2. It should be noted that other investigators have concluded that auxiliary manpower is overemployed relative to physician input in hospitals and clinics. Feldstein (1967, pp. 100-101) concluded from his estimated production function for British hospitals that "too much is being spent on nurses, catering and other supplies and not enough on doctors, drugs and dressings." Feldstein recommended that the number of doctors in British hospitals be increased relative to other inputs. Pauly (1975), using data on rural hospitals in the Midwest also concluded that hospital inputs are overused relative to physician inputs in the production of hospital services. Boaz (1972, p. 204), in her production analysis of nineteen family-planning clinics, concluded that the clinics should expand their employment of physicians, for "the high fee charged by the physician is more than offset by his marginal productivity compared to other personnel."
3. In 1968, there were 18,299 optometrists in active practice. Self-employed optometrists totaled 16,218 (HEW 1973). In 1969, the mean annual gross income of practicing optometrists was $46,000 (Chipman 1970, p. 551).
4. For a more complete description of the properties of this production function, see Reinhardt (1970, App. C).
5. Because the Cobb-Douglas function does not allow positive rates of output to occur when an input is omitted from the production process, the data set is restricted for the Cobb-

Douglas estimates to those optometrists who employed at least some of each measured input. These results are compared with estimates of the Reinhardt function over the same abbreviated sample.

6. This response rate is not unusually low. For example, the 1973 *Medical Economics* survey of office-based physician practices also yielded a working sample that consisted of 40 percent of the surveyed population. See "Will Self-Employed Physicians Net Out Ahead," *Medical Economics* (October 15, 1973), p. 251.
7. The AOA sample is further described in the monthly issues of the *Journal of the American Optometric Association* for April through October 1966.
8. Depreciation figures were not explicitly collected in the AOA survey. The flow of capital was approximated by taking 10 percent of the reported value of the capital stock.
9. The figure for average weeks worked per year was computed by the author from data collected in the 1968 survey of optometrists conducted by the National Center for Health Statistics. The calculation was based on the data reported in JAOA (1969, p. 1194).
10. A telephone survey of several optometrists in private practice in the New York metropolitan area, randomly selected from telephone directories, was not successful. The optometrists were apparently reluctant to give any information that could be used to determine the markup on eyeglasses from the wholesale to retail level. Because of the difficulty in conducting the telephone survey, four optometrists on the faculty of the School of Optometry, State University of New York, with private practice experience, were asked their estimate of the 1964 wholesale value of the materials in the average pair of eyeglasses.
11. These figures were compiled by Benham (1972) from data collected in the 1963 National Health Survey that provided the data base for Andersen and Anderson (1967).
12. It is likely that large physician firms do provide more services per visit than small ones because the former offer a wider range of on-premises ancillary services such as X rays and laboratory tests. A small physician firm may be unable to utilize sophisticated laboratory equipment efficiently and would be compelled to refer its patients to, say, a commercial laboratory for those services.
13. The AOA sample was edited down to 3,815 observations by deleting respondents who were not self-employed or did not report either the number of eye exams provided or the wholesale value of the eyeglass components purchased during the year. Mean values were inserted for missing observations on inputs used in the production process.
14. The use of the market wage of optometrists as an indicator of the value of the self-employed optometrist's time entails the assumption that similar technologies govern the production of optometric services by salaried and self-employed optometrists. It must also be assumed that the average and marginal wages of salaried optometrists are equal because the market wages computed in this paper are average wages while the shadow value of optometrist's time is computed at the margin.

    The calculation of the market wage is also helpful when considering the question of efficiency from a different perspective. It could be argued that if market opportunities dictate specialization, then optometrists are making efficient choices as long as their average wage from self-employment exceeds their average wage from salaried employment. It can be shown that the (marginal) shadow price of optometrist's time can be compared with the market wage to analyze efficient occupational choice under the assumptions that optometrists are identical in all respects but specialize in either self- or salaried-employment and that the production function for optometric services is linear homogeneous.
15. The annual weeks worked figure of 49.3 is the same as the figure derived for self-employed optometrists.
16. The mean years of experience of optometrists in the abbreviated sample is 15.9. Using (3), the predicted market wage of these optometrists is \$6.16, assuming 49.3 weeks worked in 1964.

17. This finding is not sensitive to the weighting scheme used to combine eye examinations and number of eyeglasses sold into a single output measure. Production function estimates and computed shadow values of optometrist's time resulting from different assumptions about the weighting scheme used to construct the output measure are available on request to the author.
18. It is possible that Reinhardt's findings are a statistical artifact that results from imperfect measures of physician output. The use of physician visits as an output measure may produce an upward bias in the ratio of the marginal productivity of aides relative to that of physicians. In other words, aides may be more productive in producing an office visit, relative to physicians, than they are in the production of true physician services. Reinhardt's use of patient billings as an alternative output measure would at least partially correct for this bias, however. And his findings when using this output measure still indicated a substantial opportunity for aide expansion.

REFERENCES

Andersen, Ronald, and Odin W. Anderson. 1967. *A Decade of Health Services: Social Survey Trends in Use and Expenditure.* Chicago: University of Chicago Press.

Benham, Lee. 1972. "The Effect of Advertising on the Price of Eyeglasses." *Journal of Law & Economics*, October.

Boaz, R. F. 1972. "Manpower Utilization by Subsidized Family Planning Clinics: An Economic Criterion for Determining the Professional Skill Mix." *Journal of Human Resources*, Spring.

Chipman, Fred. 1970. "AOA 1969 Economic Survey, Part IV." *Journal of the American Optometric Association*, June.

Feldstein, M. 1967. *Economic Analysis for Health Services Efficiency: Econometric Studies of the British Health Service.* Amsterdam: North-Holland.

Haffner, Alden N. 1971. "A National Study of Assisting Manpower in Optometry." U.S. Department of Labor Contract DL-81-34-70-11 August.

HEW [U.S. Department of Health, Education and Welfare]. 1973. National Center for Health Statistics. *Optometrists Employed in Health Services, 1968.* Vital Health Statistics Series 14, no. 8 (HSM) 73-1803.

JAOA. 1969. "A Survey of Optometrists." *Journal of the American Optometric Association*, December.

Pauly, Mark. 1975. "The Role of Physicians in the Production of Hospital Output." Processed. Working Paper 73. New York: National Bureau of Economic Research.

Reinhardt, Uwe E 1970. "An Economic Analysis of Physician Practices." Ph.D. dissertation. Yale University.

———. 1972. "A Production Function for Physician Services." *Review of Economics and Statistics*, February.

———. 1973. "Manpower Substitution and Productivity in Medical Practice: Review of Research." *Health Services Research*, Fall.

Smith, K. R.; M. Miller; and F. L. Golladay. 1972. "An Analysis of the Optimal Use of Inputs in the Production of Medical Services." *Journal of Human Resources*, 1972.