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1. Introduction

Most primary health professionals (physicians, dentists, and optometrists) supply a large portion of their services in fee for service, for profit health practices and fill the roles of manager, risk taker, and most productive input in the production process. Interest in the production processes of these firms has grown in recent years because of the concern over the rapid rise in expenditures for health services and because of the alleged shortage of physicians and other primary health professionals. As a result there is a rapidly expanding, if not yet substantial, health economics literature that examines the production processes of the private practices of primary health professionals in order to determine whether productive inputs are organized in an optimal way. The few completed studies have been of physician practices and have reached the same conclusion: physicians do not appear to be capably performing their entrepreneurial function. More specifically, physicians in private practice appear to be underemploying auxiliary manpower in the production process.

Reinhardt, for example, concluded from his estimated production function for physician services that the average American physician could employ profitably twice the number of assistants as he presently utilizes and by so doing, increase his hourly rate of output by 25 percent.[1]

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Smith, Miller, and Golladay 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.[2] 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 if not for the poor entrepreneurial performance of physicians.[3]

The purpose of this paper is to analyze the production process of optometrists in private practice. This study will then provide further evidence on the entrepreneurial performance of primary health professionals in private practice. 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.[4]

1.1 The Practice of Optometry: An Overview

The primary health services provided by optometrists are the examination of the eye and the prescription and provision of lenses to correct refractive error. Besides fitting, optometrists adjust and repair eyeglasses. The mean gross income of the 16 thousand self-employed optometrists in the United States from their professional practices is approximately 50 thousand dollars, implying that upwards of $800 million are spent annually on the services of self-employed optometrists.[5] Most optometrists are engaged in solo practices. About 17 percent of self-employed optometrists are in partnerships or group practices.[6] (The similar figure for physicians is 18 percent.[7])

2. Method of Analysis

2.1 Specification of the Production Functions

Continuous production functions will be estimated in this study in order to analyze the production process of optometrists in private practice. The production function estimates will then be used to examine the optimum input proportions, the utility and profit maximizing input levels, the productive efficiency of different inputs and the scale economies that characterize the production of optometric services.

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 specification that meets this requirement is the functional form used by Reinhardt in his analysis of the production of physician services. The general specification of this production function is

$$Q = A \prod_s [X_s^{\alpha_s} \; e^{\beta_s X_s}] \; e^{[\sum_j \gamma_j L_j + \theta \; (\sum_j L_j)^2]} \; U$$

where X_s denotes inputs that must be used in the production process and L_j denotes inputs that can be excluded from the production process. Besides permitting positive rates of output to occur when some inputs are not included in the production process, this functional form allows the factors to be characterized by both increasing and decreasing marginal products and does not constrain to constant values the elasticity of substitution or the returns to scale.[8]

Although the Reinhardt function seems well suited for an examination of the production process of health professionals in private practice, an alternative function should be estimated to test the sensitivity of the results to the specification of the production function. For this purpose the Cobb-Douglas production function is also estimated.[9]

2.2 The Data

The data base for this study is the 1964 American Optometric Association National Economic Survey. In 1965, nearly every member of the American Optometric Association (AOA) was 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 all AOA members.[10] The percent of AOA members responding to the survey by regional division of the United States ranged from 33 to 45 percent. In this survey, annual data was solicited from optometrists on their gross and net-before-tax income from practice, output (as measured by the number of visual 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 was collected on type of practice (group or solo).[11]

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 terms. Measuring inputs in value terms, however, is not an uncommon practice in the estimation of production functions.[12] One advantage of measuring inputs in this way 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 more productive workers receive higher wage payments. Measuring inputs in value terms does introduce potential bias, the size of which depends on how much variation exists in the factor prices that optometrists face. By controlling for city size in the estimated production functions, much of this bias may be eliminated.

The inputs measured in value terms that are included in the estimated production functions are the annual wages paid to assistants, the dollar amount of annual rent for office space, the flow of capital services,[13] and the imputed wage bill of assistants who worked without pay. An additional input, the number of hours worked per week by the optometrist was also collected in the survey. This variable, multiplied by 49.3 to approximate hours worked per year, is also included as an input in the production function.[14]

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

One other independent variable besides city size is included in the estimated production functions that is not formally an input. This is a dummy variable that takes on a value of one for those optometrists in group practices. This variable is entered into the production functions 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 are capable of generating 5.1 percent more office visits than solo practitioners from a given input bundle.

Before discussing the output measure, the specified Reinhardt and Cobb-Douglas production functions are summarized below.

Reinhardt:

$$Q = AH^{b_1} e^{b_2 H} D^{b_3} e^{b_4 D} R^{b_5 S} e^{b_6 R} e^{[b_7 W + b_8 W^2]} e^{b_9 GD} e^{b_{10} CS} U \quad (1)$$

Cobb-Douglas:

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

where:

Q = output

A = aide bill

H = optometrist's hours

GD = group dummy

D = capital flow

CS = city size

R = rent bill

2.5 Measuring Output

Measuring output--whether of a physician, a clinic, or a hospital--has been one of the most difficult problems confronting health economists. For example, the three output measures used by Reinhardt in his production analysis of physician practices, office visits, patient visits, and patient billings, all leave something to be desired. The problem with using visits as an output measure is the rather substantial variation that must exist in the quantity of services provided per visit. Patient billings would seem to take account of some of this variation in physician services per visit, but this measure can introduce bias depending upon the variation in fees charged by physicians for similar services. Reinhardt feels this variation may be quite substantial.[15]

The output of an optometric practice is generally a joint product, consisting of a visual examination and corrective lenses. Of course, optometrists also provide corrective lenses at times without a visual examination, such as in the case of providing a second pair of eye glasses. Fortunately, the AOA survey data contains information both on the annual number of eyeglasses and visual examinations supplied. As a result an output measure can be constructed from the data that is an accurate representation of the output of an optometric practice and should be a better measure of output than many health economists have had at their disposal in the past.

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 visual examinations provided. A single output measure can be constructed from this data by converting the wholesale value of lenses, frames and temples purchased to the number of eyeglasses sold[16] and then combining this measure with the number of visual exams provided, using, of course, an appropriate weighting scheme. Unfortunately, there is no explicit data available on the wholesale price of the eyeglass components that could be used to deflate their dollar value so as to render a quantity figure. To overcome this data problem, an informal survey of several optometrists in private practice in the New York metropolitan area was taken to gain their impression of the wholesale value of the materials in the average pair of eyeglasses provided by optometrists in 1964.[17] The concensus of the surveyed optometrists was that $10 was an accurate estimate of the 1964 wholesale value of the average pair, and this is the price used in this study to deflate the wholesale value of lenses and eyeglass components so as to approximate the physical quantity of eyeglasses provided.

Available data on the price of eyeglasses and visual examinations can be used to develop a weighting scheme so that the number of eyeglasses and eye examinations provided can be combined 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 that the average cost of eyeglasses alone was $28.23.[18] If the reasonable assumption is made that the relative values of a pair of eyeglasses and a visual 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 visual examinations supplied when combining the two quantities 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. Vision training is the only other significant service offered by optometrists besides visual examinations and corrective lenses, and this service comprises a very small portion of output.[19] This output measure should be an improvement over such output descriptions as patient visits or patient billings that have been used in studies of physician services. In using patient visits as an output proxie, for example, the assumption must be made that the variation that exists in the quantity of services provided per visit is not correlated with the size of the firm. If this assumption did not hold (and it probably does not) regression estimates of the parameters of the production relationship would be biased, as would the resulting calculation of returns to scale.[20] A primary advantage of studying the production of optometric services to learn more about the production of health services in fee for service for profit health practices 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.

2.6 Estimation Bias

Ordinary least squares is used exclusively in this study to estimate the production functions for optometric services. The resulting estimates are biased unless inputs and outputs in optometric practices are not simultaneously determined. This assumption would be justified, for example, if optometrists choose current inputs on the basis of anticipated output, rather than current output. This is not an unlikely possibility.

Even if inputs and outputs are simultaneously determined in optometric practices the resulting estimation bias may not be large. Reinhardt 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.

This argument can be easily demonstrated. To illustrate the Cobb-Douglas production function will be employed, but the results apply equally to other specifications. It is helpful to assume that the firm is a profit maximizer and employs two inputs, K and L, in the production process. Profit, π, can be expressed as

$$\pi = PAK^{\alpha} L^{\beta} U - wL - rK \tag{1}$$

where P is price of output, U is the error term, and w and r are the factor prices. Maximizing (1) with respect to a factor input, say L, yields

$$\frac{\partial \pi}{\partial L} = PAK^{\alpha} \beta L^{\beta-1} U - w = 0 \tag{2}$$

The derived demand for L can be determined by solving 2 for L. This expression is presented in logarithmic form for ease of exposition.

$$\ln L = \frac{1}{1-\beta} (\ln P + \ln A + \alpha \ln K + \ln \beta + \ln U - \ln W) \qquad (3)$$

The simultaneous equation bias results from the correlation between an independent variable, in this case L, and the error term in the Cobb Douglas production function. Assuming that ln U is not correlated with ln P, ln K or ln W, the

$$E(\ln L, \ln U) = \frac{1}{1-\beta} \sigma^2_{\ln U} .$$

The implication of this result is that bias is introduced into the ordinary least squares (OLS) estimators of A, α and β. Note, however, that the bias is not large if E (ln L, ln U) is small. This would occur if variations in ln L could be explained predominantly by variations in other explanatory factors rather than ln U. This result is likely if there is substantial variation in the other explanatory variables in the derived demand equation. In this example these variables include ln P, ln W and ln K. Furthermore, we can add an additional variable, ln V to represent the error term in the derived demand equation. This expression would represent economic efficiency, or the ability or willingness of the entrepreneur to secure the profit maximizing input level. The greater the variation in this variable, as well as the others we have mentioned, the smaller should be the simultaneous equation bias. Reinhardt argues that variations in V are substantially greater than variations in U because physicians and other health professionals are fairly equal in technical ability because of their standardized training while they differ greatly in their ability or willingness to hire the profit maximizing levels of inputs. Some health professionals, for example, may prefer to keep their practices small with a minimum amount of task delegation even if they are aware that they could increase their profits by employing more aides and expanding output. In addition, the price of one of the inputs in the production functions of health professionals in private practice must necessarily vary a great deal. This is the price of the time of the health professional which must vary considerably across practitioners because it is a shadow price and depends on how the practitioner values his own time.[21]

The implication of these considerations is that the simultaneity bias may be quite small if the production functions for optometric services are estimated by OLS, even if the inputs and output of optometric practices are jointly determined.[22] It would be preferable, of course, to construct a model of the production of optometric services that included input decision equations as well as the production function in order to allow for the simultaneous determination of inputs and output. This more complete model cannot be specified, however, because the data does not contain variables that could be used to identify the structural equations.

3. A Framework for Examining the Optimal Employment of Inputs in the Production of Optometric Services

Before presenting the OLS estimates of production functions for optometric services, a framework for interpreting the regression results should be established. This is particularly necessary for an analysis of the optimal employment of inputs in the production process, which is an important emphasis of this research. As reviewed at the outset of this study, previous investigators have concluded that in the case of private medical practices physicians are underemploying auxiliary manpower and placing too low a value on their own input in the production of physician services. A primary purpose of this study is to evaluate how effectively optometrists organize inputs, including their own time, to produce optometric services. In order to do so, decision rules that are likely to govern the optometrist's practice must be derived.

3.1 The Utility Maximization Model

One reasonable approach to their formulation is to assume that the optometrist maximizes 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 non-employment income does not depend on time inputs of the optometrist.

More specifically, let

$$U = U\ (L,\ Y_1 + Y_2)$$

$$= U\ [\Omega - H,\ P \cdot Q(H,\ l_1,\ \ldots,\ l_n) - T\ C(l_1,\ \ldots\ l_n) + Y_2$$

where

L = hours of leisure

Y_1 = income from practice

Y_2 = income from other sources

Ω = a fixed amount of available hours

H = hours devoted to practice

P = price of output of the practice

$Q(H, l_i, \ldots, l_n)$ = the quantity of output produced by a production process using inputs $H, l_1, \ldots, l_n$

$TC(l_i, \ldots, l_n)$ = the total cost of the output produced which is determined by the quantity of inputs purchased in the market.

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

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

where

D = dollar value of capital used

W = wage bill

R = rent for office space

CS = city size

GD = group dummy

and the remaining variables have been previously defined. In order to maximize utility, the optometrist's employment of factor inputs must satisfy the following first order conditions:

$$\frac{\partial U}{\partial H} = -\frac{\partial U}{\partial L} + \frac{\partial U}{\partial Y} P \cdot \frac{\partial Q}{\partial H} = 0 \qquad (3)$$

$$\frac{\partial U}{\partial D} = \frac{\partial U}{\partial Y} (P \frac{\partial Q}{\partial D} - 1) = 0$$

$$\frac{\partial U}{\partial R} = \frac{\partial U}{\partial Y} (P \frac{\partial Q}{\partial R} - 1) = 0$$

$$\frac{\partial U}{\partial W} = \frac{\partial U}{\partial Y} (P \frac{\partial Q}{\partial W} - 1) = 0 \ . \qquad (4)$$

The first order conditions can be used to calculate the value or the shadow price that optometrists attach to their own time in terms of their employment of other productive inputs. For example, the shadow price which the average optometrist assigns to the value of an hour of his time in terms of his employment of auxiliary manpower would be[23]

$$\frac{\partial U/\partial L}{\partial U \ \partial Y} = P(\frac{\partial Q}{\partial H} - \frac{\partial Q}{\partial W}) + 1 \ . \qquad (5)$$

Equation (5) could also be derived from a profit maximization model where the optometrist assigns a shadow price to his own time.[24a]

Equation (5) can be used to determine the optimal wage bill of the average optometric practice if it is assumed that the shadow price equals the optometrist's opportunity cost or the market wage, and given the average rent and capital bills and the average number of hours worked by optometrists.

These calculations would provide evidence on the question of how effectively the optometrist is organizing his professional practice. Is the optometrist, for example, valuing his own time in the production process at a shadow wage which is close to the value it commands in the market?[24b] If not, it would appear that the optometrist in private practice is poorly organizing the production of optometric services.

4. The Estimated Reinhardt Production Function

OLS estimates of the Reinhardt production function specified in (1) are presented in Table 1. The AOA sample was edited down to 3,815 observations by deleting those cases where the optometrist was not self-employed or did not report either the number of visual exams provided or the wholesale value of the eyeglass components purchased during the year.[25] The difference between the pair of regressions presented in Table 1 is 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 (i.e., wives), while regression 2 only includes the actual annual wage bill. In both regressions results for the expressions $\ln e^{B_2 H}$ and $\ln e^{B_4 D}$ are not presented because the estimated coefficients were not statistically significant. The coefficients for the remaining variables are all highly significant. Estimates of the elasticity of substitution between optometrists and aides are discussed in Appendix A.

4.1 The Optimal Employment of Inputs--The Empirical Results

From the first order conditions of the utility maximization model developed in section 3.1, the following expression was derived for the shadow price that the average optometrist assigns to the value of an hour of his time in terms of his employment of auxiliary manpower:

$$\frac{\partial U/\partial L}{\partial U\ \partial Y} = P\ (\frac{\partial O}{\partial H} - \frac{\partial O}{\partial W}) + 1 \tag{5}$$

To compute the shadow price, values must be determined for the marginal products and for 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 determine the numerical value of the marginal products for different inputs. In the case of regression 1, the marginal product of the optometrist's hours is .83 and the marginal product of auxiliary manpower is .27. The price of output can be calculated from the sample data by taking a weighted average of the gross annual income per unit of output for each responding optometrist, where the weight is the number of units of output produced. This calculation yields a price per unit of output of $8.04 for the output measure used in regressions 1 and 2.

Substituting this datum and the computed marginal products for hours and aides in (5) yields a shadow price for an hour of optometrist's time of $5.50. Does this result indicate that optometrists in 1964 were valuing their time in terms of their employment of auxiliary manpower at approximately its market value? This question is difficult to answer because the optometrist's income from practice represents a return to physical capital, entrepreneurship and labor. The market value of an hour of the optometrist's time should be equal only to the return to labor component.

The hourly market wage or opportunity cost of self employed optometrists can be estimated from data in the 1964 AOA survey on the net-before-tax income, hours, and experience of optometrists employed by other optometrists and by physicians. A regression of the net-before-tax income of salaried optometrists divided by hours worked per week (Y/H) run on years of experience (E) and years of experience squared (E^2) yields the following results:

$$Y/H = 161.30 + \underset{(3.7)}{12.44E} - \underset{(-2.6)}{.22E^2} \tag{6}$$

$R^2 = .10$

$N = 164$

t statistics in parentheses.

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.[26]

The average market hourly wage for the labor of self-employed optometrists, or their opportunity cost of time, can be predicted from (6).

Because the mean years of experience of self employed optometrists in the AOA sample was 15.8, as opposed to the average experience of 10.5 years for salaried optometrists, the predicted market hourly wage for self employed optometrists is $6.15. Although this figure does not represent true opportunity cost because it is not net of tax payments, it is the relevant figure to compare to the shadow price previously calculated by inserting the marginal products and output price into equation (5). This is because these shadow prices are also not net of tax payments.[27]

The estimated $5.50 shadow price of an hour of the self employed optometrist's time in terms of his employment of auxiliary manpower is less than his opportunity cost of $6.15. This indicates that optometrists in 1964 were, on average, employing less than the optimal amount of assisting manpower. In fact, if the average optometrist valued his time at his opportunity cost, and if all other inputs were employed at their average level for optometric practices in 1964, the optimal wage bill (including the value of work performed by unpaid aides) would be $5,000, according to equation (5). This is substantially greater than the sample mean wage bill (including the value of unpaid work) of $3,620. This conclusion is consistent with those that have been reached concerning the optimal employment of aides by physicians in private practice. Optometrists too appear to have an opportunity to expand their employment of assisting manpower.

The shadow price of an hour of optometrist's time in terms of their employment of capital can be computed from (5), if $\frac{\partial Q}{\partial D}$ replaces $\frac{\partial Q}{\partial W}$.

The marginal product of capital is .52, if sample means are substituted into the marginal product expression and the parameter estimates of regression 1 are used. The computed shadow price is then \$3.49. This figure indicates that optometric services could be produced more efficiently if the substitution of capital for optometrist's hours was extended. From equation (5) it follows that the optimal capital bill 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 -.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 difficult to accept *primâ facie*. 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 inverse 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 assisting manpower is the actual annual wage bill paid by the optometrist. This measure does not include the value of the work of unpaid assistants, as did the measure of assisting manpower input 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 assisting manpower are slightly higher if the parameter estimates of 2 rather than those of 1 are inserted in the marginal product expressions. The marginal product of optometrist's hours increases to .86 and the marginal product of aides increase to .29. The marginal product of capital stays constant at .52.

Substituting the marginal products computed from regression 2 into equation (5) yields shadow values for an hour of optometrist's time of \$5.58 in terms of the optometrist's employment of aides and \$3.71 in terms of the employment of capital. These results are supportive of those previously discussed.

5. The Estimated Cobb-Douglas Production Function: The Sensitivity of the Calculated Optimal Input Levels to the Specification of the Production Function

Because the results just discussed may be sensitive to the specification of the production function, a comparison is made in this section of the shadow prices and optimal input levels that result from the estimation of a Cobb-Douglas production function with those that result from the estimation of the Reinhardt functional form. In order to make this comparison, the observations on optometric practices where no auxiliary manpower was employed must be deleted from the sample. This is 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. The deletion of these cases reduces the working sample from 3,814 to 2,782 observations.

In Table 2, regression results for the two production functions are presented. The rent variable is not statistically significant in the estimated Cobb-Douglas function, so this variable does not appear in regression 3. The calculated marginal products implicit in the results for the Reinhardt specification are .80, .20 and.44 for optometrist's hours, aides, and capital. The weighted average of the price of output in the abbreviated sample is $7.96. The marginal products and output price substituted as before into equation (5) yield shadow values of an hour of optometrist's time in terms of aide and in terms of capital input of $5.78 and $3.86. For the Cobb-Douglas specification, the marginal products for optometrist's hours, aides and capital are .81, .28, and .35. The shadow values of optometrist's time in terms of aides and capital are $5.21 and $4.66.

Given a market wage or opportunity cost of $6.16[28] for optometrists in the abbreviated sample, and assuming all other inputs are employed at their sample means, the optimal aide bill, including the value of unpaid work, according to equation (5) and the Reinhardt production function estimates is $5,600. The same procedure applied to the capital input yields on optimal flow of $2,300. The Cobb-Douglas estimates (regression 3) imply optimal levels of $6,100 and $2,100 for the aide and capital bills. The mean value for the abbreviated sample of the wage bill, including the value of unpaid work, is $4,668. The mean capital bill is $1,018.

The Reinhardt production function estimates, over both the full and abbreviated samples, have indicated that optometrists are undervaluing their time relative to what it is worth in the market in terms of their utilization of auxiliary manpower, given their employment of other inputs. An apparent opportunity also exists to increase substantially the use of capital in the production process. The Cobb-Douglas estimates over the abbreviated sample yielded similar results. These findings are not very sensitive to the weighting scheme used to combine visual examinations and the number of eyeglasses provided into a single output measure.[29]

6. <u>The Idle Time Hypothesis</u>

It may be possible that optometrists place a low value on their own time because some of their office hours are idle, or nearly so, but must be spent in the office waiting for patients, many of which are non-appointment. During this time they can complete much of the activities they would delegate to aides if they were busier. Similarly, they can 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 support for this hypothesis. Haffner found in his 1970 national survey of optometrists that 22 percent of all respondents felt their optometric practice under its present structure could accommodate greater than 30 percent more patients. The median respondent felt his optometric practice could accommodate 18 percent more patients under its present structure.[30]

The residual pattern for large and small output optometrists is also consistent with the idle time hypothesis. In Figure 1 the residual pattern is presented for the production functions estimated in this paper after arranging the observations in ascending order according to size of output. The predicted output of optometrists with small output exceeded actual output, while the opposite was true for optometrists with above average output. The Durbin-Watson statistics were all around .5, indicating significant positive autocorrelation, which is consistent with the residuals presented in Figure 1. Small output optometrists may appear less efficient because they are more likely to have idle inputs, such as the time of the optometrist, during the production period because of insufficient demand. If large output optometrists have a relatively small amount of idle capacity they should value their time close to its opportunity cost if the idle time hypothesis is the primary explanation of why the average optometrist undervalues his time in the production process.

In order to investigate this possibility, the Reinhardt production function was estimated over large output optometrists, or those optometrists in the AOA sample with outputs above the median level. These results are presented in Table 3. The calculated marginal products implied by the Reinhardt function estimated over the half sample of above median output optometrists and the subsample means are .56, .14, and .28 for optometrist's hours, aides and capital. The shadow prices of an hour of optometrist's time in terms of aide and capital employment can be calculated from equation (5), as before, given the price of output, and the marginal product expressions. The weighted average of output price in the subsample of large output optometrists is \$6.66, implying a shadow price of optometrist's time of \$3.79 and \$2.86 in terms of aides and capital, respectively. The average years of experience of optometrists with above median outputs is 16.4 years. Using equation (6), and the weeks worked figure of 49.3, the predicted market hourly wage or opportunity cost of self employment for these optometrists is \$6.21. Therefore, the results for a group of optometrists that should have a relatively small amount of idle time indicate an opportunity for these optometrists to substantially expand their employment of aides and capital. The results are similar if the sample is further divided so that only those optometrists with outputs in the top third of the sample are analyzed.

Besides enabling an investigation of the idle time hypothesis, stratifying the sample by firm size also enables the production technology to vary between large and small firms. For optometrists with below median outputs computations similar to those made for large output optometrists yield shadow prices of an hour of optometrist time of \$2.41 and \$2.74 in terms of aides and capital.

The computed shadow prices of optometrist's time in terms of the employment of aides and capital are then even lower when allowing for variation in production technology between large and small firms than was the case when all firms were restrained to the same production function.

Additional empirical results will be considered before extending the discussion of these findings.

7. Additional Interpretations of the Residual Pattern

Another possible explanation of the residual pattern in Figure 1 is that returns to scale decline with size of output. Figure 2 shows for the case of a production function with a single input how an inverse relationship between returns to scale and size of firm could account for the residual configuration. The estimates in Table 3 for above and below median output optometrists support the hypothesis that an inverse relationship exists between returns to scale and size of output. A 10 percent increase in the employment of all inputs by small output optometrists would increase their output by 4.4 percent; a 10 percent increase in input levels by large scale optometrists would increase output by 3.6 percent.[31]

Differences in returns to scale may not be the only feature distinguishing optometrists with large outputs from small output optometrists. If the mean values of the factor inputs and other independent variables for optometrists with above median output are inserted into the estimated Reinhardt production function for below median output optometrists, the parameter estimates yield a predicted natural log of output of 7.56. Yet the same values inserted into the estimated production function for large output optometrists yields predicted log output of 8.63. It is possible then that large output optometrists employ a superior production technique.

Figure 3 shows how differences in production technology, as well as an inverse relationship between returns to scale and size of firm, could have generated the observed residual pattern. To examine this possibility, the Reinhardt production functions were re-estimated after adding a dummy variable to the specifications which took on a value of one for those optometrists with above the median level of output. These results are presented in Table 4. The size dummy indicates that optometrists with outputs of above median size are capable of generating 68 percent more output than smaller scale optometrists from a given bundle of inputs. An examination of the input ratios of small and large scale optometrists also gives evidence of differences in the organization of the production process. Larger output optometrists employ significantly more capital and aides per hour of own time, and their capital-aide ratio is higher than smaller output optometrists as well (see Table 5). Perhaps the larger optometrists more extensive use of capital per unit of other inputs explains their technological superiority.

8. The Technical Efficiency of Optometrists in Group and Solo Practices

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 aides receiving no pay, indicates that the optometrist in group practice produced, on average, about 5 percent more output than optometrists in solo practice from a given input bundle (see Table 1, regression 1).[32] When the size dummy is added to this production function, the group dummy coefficient falls to .03 and the t-statistic falls from 2.3 to 1.6 (see Table 4, regression 1). Because optometrists with large outputs are more likely to be in group practices than optometrists with smaller outputs, the group dummy picks up some of the apparent efficiencies of large output optometrists previously discussed when the size dummy is not included in the specification.

This group dummy coefficient does not imply that the average group practitioner produced 3 percent more output on an annual basis than the solo practitioner. In fact, the output level of the group practitioner in 1964 was about 20 percent greater than his counterpart in solo practice. However, the average input levels of the group practitioner were considerably higher than for the solo practitioner (see Table 6).

The superior technical efficiency of the group practitioner explicit in the results of regression 1, Table 1 and regression 1, Table 4 is not apparent in regression 2, Table 1, and regression 2, Table 4, where aide input is measured as the wages paid to assisting manpower, and does not include the wages imputed to assistants who worked without pay. In both of these regressions the coefficient of the group dummy falls to .02 and is not significantly different from zero at accepted confidence levels. The reason for this change can be seen in Table 6. In 1964, optometrists in solo practice used $500 worth of non-paid help while optometrists in group practice used $250 worth. By having $250 more of unmeasured aide input than the group practitioner, the solo practitioner can appear to be as equally technically efficient.

Newhouse has presented empirical support for the hypothesis that physicians in solo practice produce services at lower cost than physicians in group practice because scale economies in the production of physician services are offset by X-inefficiency. Newhouse argues that the cost sharing arrangements that characterize group practices result in individual physicians becoming more "wasteful" as the number of physicians with whom they practice increases, and that this increase in X-inefficiency is likely to more than offset any scale economies.[33]

This hypothesis would appear to be as relevant to optometric practices as to physician practices, although it is not supported in general by the estimated production functions for optometric services. The results do support the notion, however, that optometrists in solo practice are more cost conscious than optometrists in group practice. Solo optometrists appear to have a greater reluctance to hire salaried aides and a greater propensity to use non-salaried aides (undoubtedly family members) in the production of optometric services. A plausible explanation of this behavior is that optometrists are more likely to hire aides if the wage bill is shared, other things equal, and less likely to volunteer the non-salaried labor of family members if the returns to this labor are shared with other practice members.

To summarize this section, the regression results show that optometrists in group practice are more technically efficient than optometrists in solo practice. For given input levels, group practitioners appear to generate about 3 percent more output than solo practitioners. However, this is not to say that a group practitioner would produce a given output at lower out-of-pocket cost than a solo practitioner. Because the solo practitioner makes greater use of non-salaried aides, he can be less technically efficient than the group practitioner, yet produce a given output at approximately the same out-of-pocket cost.

9. Interpretation of the City Size Variable

In all of 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 optometrists in smaller cities are more efficient producers of optometric services than optometrists in larger cities. However, this is undoubtedly an illusion. The more reasonable interpretation is that the prices of productive inputs are lower in smaller cities. If so, holding the dollar value of inputs constant in the production function is not holding 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.

10. Concluding Remarks

One of the primary goals of this study was to provide additional evidence on how efficiently primary health professionals in fee for service, for profit practices organize the production of health services. The results derived from the utility model and estimated production functions indicate that optometrists are undervaluing their own time relative to what it is worth in the market and are employing considerably less than the optimal amounts of aides and capital.

Reasonable explanations of this finding are limited. One assumption implied in the analysis is that optometrists can sell all the services they want at the going market price. This may not be realistic, particularly if optometrists were to expand, say, their employment of aide input to a level near that which appears to be optimal, given the optometrist's opportunity cost of time. If the average optometrist increased aide input to $5,000, the optimal level implied by the full sample results, industry output would expand by about 10 percent.[34] It is highly unlikely that such an expansion could take place without affecting market price. The optimal input levels would exceed the actual levels by amounts less than those implied by the utility maximization analysis, depending upon the extent to which market price is sensitive to shifts in the supply curve.

It may also be true that many optometrists employ less than the optimal level of inputs calculated in this study because they prefer to keep their practices small or fear a compromise in the quality of care they provide if substitution of other inputs for their own time in the production process is extended. Another explanation of the findings is that optometrists are unaware of the value of their own time or of the value of other inputs in the production process and poorly organize the production of optometric services as a result. This could result from a standardized training that optometrists receive in their professional schools that does not emphasize the substitution of other inputs for the time of the optometrist in the production process when possible.[35]

APPENDIX A

The Elasticity of Substitution Between Optometrists and Aides

The elasticity of substitution between optometrists and aides in the estimated Reinhardt production function varies with the amount of aide input. Values for the Allen elasticity of substitution as the amount of aide input increases from \$2,500 to \$3,620 (the sample mean) to \$4,500 are 2.7, 2.1, and 1.9, according to the results of regression 1, Table 1. (For the derivation of the relevant formula see Reinhardt, 1970, p. 184. The elasticity does not vary with the number of hours worked by the optometrist because the $\ln e^{b_2 H}$ term was insignificant in the production function.) These values are similar to those computed by Reinhardt for the elasticity of substitution between physician hours and aides. The elasticity between physician hours and aides for physicians who worked between 40 and 60 hours per week and employed one aide ranged from 1.6 to 2.2. The elasticity of 1.9 for optometrists with approximately one assistant (wage bill = \$4,500) falls within this range.

APPENDIX B

Because the optimal input levels and the shadow values of an hour of optometrist's time in terms of their employment of different inputs may be sensitive to the weighting scheme used to combine visual examinations and the number of eyeglasses provided into a single output measure, alternative production function estimates are presented here with output measures calculated from different weighting schemes. It should be kept in mind, however, that the output measure used in the text, which was the natural log of the sum of visual examinations supplied plus 2.8 times the number of eyeglasses sold, was in no sense arbitrary. The weight of 2.8 was derived from available data on the price of visual examinations and eyeglasses.

The output measure in regression 1A of Table A-1 is the natural log of the sum of the number of visual examinations supplied and 2.3 times the number of eyeglasses sold. The weight is 3.3 in regression 2. These Reinhardt specifications were estimated over the full sample.

The price of output for the output measure used in regression 1, or the average gross annual income per unit of output for each responding optometrist, weighted by the units of output produced, is \$9.29. The computed marginal products for optometrist's hours, aides, and capital are .76, .23, and .45, respectively. It follows from (5) that the shadow values of an hour of optometrist's time in terms of aide and in terms of capital inputs are \$5.92 and \$3.87. Given the hourly market after tax wage or opportunity cost of optometrist's time of \$6.15

and the assumption that all other inputs were employed at their average level for optometric practices in 1964, the parameter estimates of regression 1 indicate an optimal aide bill (inclusive of unpaid labor) of $5,000. The same procedure applied to the capital input yields on optimal flow of $1,900. Using the regression results for 2 in a similar manner yields shadow values of an hour of optometrist's time in terms of aide and capital inputs of $5.45 and $3.40. The optimal wage and capital bills are $5,200 and $2,100, respectively.

It is evident that the optimal input levels are not too sensitive to the different weighting schemes used to construct the output measure.

This is also true for the Cobb-Douglas results. In regression 3, the number of eyeglasses sold is weighted by 2.3 before being added to visual examinations provided. The marginal products explicit in this Cobb-Douglas function are .70, .24, and .30 for optometrist's hours, for aides, and for capital. The shadow values of an hour of optometrist's time are $5.27 and $4.71 in terms of the wage bill (inclusive of the value of unpaid labor) and capital bill. The optimal aide and capital bills are $5,900 and $1,800. In regression set 3, eyeglasses are weighted by 3.3. The marginal products for hours, aides and capital are .91, .32, and .40. The shadow prices of optometrist's time in terms of the aide and capital bills are $5.16 and $4.60. The optimal capital and aide bills are $6,100 and $2,000.

FOOTNOTES

[1]U. Reinhardt, "A Production Function for Physician Services," Review of Economics and Statistics, v. 54, February 1972, pp. 55-66.

[2]K. R. Smith, M. Miller, and F. L. Golladay, "An Analysis of the Optimal Use of Inputs in the Production of Medical Sercices," Journal of Human Resources, Vol. 7, No. 2, Sp. 72, p. 218. Physician assistants is not used generally in this instance but refers to a category of para-professionals specifically trained to perform a variety of tasks.

[3]It should be noted that other investigators have concluded that auxiliary manpower is over employed relative to physician input in hospitals and clinics. Feldstein 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. (See M. Feldstein, Economic Analysis for Health Services Efficiency: Econometric Studies of the British Health Service, North Holland Publishing Co., 1967, pp. 100-101.)

Boaz, in her production analysis of 19 family planning clinics, found that the clinics should expand their employment of physicians for "the high fee charged by the physician is more than offset by his high marginal productivity compared to other personnel." (See R. F. Boaz, "Manpower Utilization by Subsidized Family Planning Clinics: An Economic Criterion for Determining the Professional Skill Mix," Journal of Human Resources, Vol. 7, No. 2, Spring 1972, p. 204.

[4]Many observers have already concluded that health services should not be delivered by small firms on a fee for service basis, where the primary health providers perform the entrepreneurial function. These observers encourage a movement away from the present organization of private health practices towards a system where a more comprehensive range of health services are provided on a per capita payment basis to an enrolled population (i.e., a system of HMO's).

[5]In 1968, there were 18,299 optometrists in active practice. Self-employed optometrists totaled 16,218. (National Center for Health Statistics, Optometrists Employed in Health Services, United States, 1968, Department of HEW publication No. (HSM) 73-1803, Vital Health Statistics - Series 14, No. 8). In 1969, the mean annual gross income of practicing optometrists was $46 thousand. (Fred Chipman, "AOA 1969 Economic Survey, Part IV," Journal of The American Optometric Association, Vol. 41, No. 6, June 1970, p. 551.)

[6]National Center for Health Statistics, Optometrists Employed in Health Services, p. 14.

[7]Steven Vahovich, Profiles of Medical Practice, American Medical Association, 1973. The figure cited is the percentage of non-federal physicians in group practice in 1969.

[8]For a more complete description of the properties of this production function, see U. E. Reinhardt, "An Economic Analysis of Physician Practices," unpublished Ph.D. dissertation, Yale University 1970, Appendix C.

[9]Because the Cobb-Douglas function does not allow for positive rates of output to occur when an input is not included in 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.

[10]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.

[11]The AOA sample is further described in the following issues of the Journal of the American Optometric Association: April 1966, pp. 364-366; May 1966, pp. 477-481; June 1966, pp. 566-570; July 1966, pp. 683-685; August 1966, pp. 781-785; September 1966, pp. 883-886; October 1966, pp. 955-957.

[12]See, for example, Martin Feldstein, Economic Analysis for Health Service Efficiency: Econometric Studies of the British Health Service, North Holland Publishing Co., 1967, Chapter IV.

[13]Depreciation figures were not explicitly collected in the AOA survey. The flow of capital is approximated by taking 10 percent of the reported value of the capital stock.

[14]The average weeks worked per year figure 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 as reported in, "A Survey of Optometrists," Journal of the American Optometric Association, Vol. 40, No. 12, December 1969, p. 1194.

[15]Reinhardt, 1972, p. 56.

[16]Optometrists fit and provide contact lenses as well as eyeglasses. Because the optometrists reported only the total value of lenses (including contacts) and eyeglass components they purchased during 1964, it is impossible to separate out the portions of this expense devoted to contact lenses and to eyeglasses. Any bias that results from optometrists providing contact lenses in different proportions should be small, however, because the provision of contact lenses comprises a small part of the practice of optometry. In the United States in 1965, for example, only 1 percent of the U.S. population had contact lenses while more than 47 percent had eyeglasses. (National Center for Health Statistics, "Characteristics of Persons with Corrective Lenses, United States - July 1965 - June 1966," Vital Health Statistics, Series 10, No. 53, 1969, p. 16.) Further evidence of the small portion of optometric services accounted for by the provision of contact lenses is the small number of optometrists who specialize in the fitting and provision of contact lenses. In 1970, one one-half of 1 percent of practicing optometrists had "primarily or exclusively a contact lens practice." (See Alden N. Haffner, A National Study of Assisting Manpower in Optometry, U.S. Department of Labor Contract DL-81-34-70-11, August 1971, p. 31.)

[17] A telephone survey of several optometrists in private practice in the New York metropolitan area, selected randomly from telephone directories, elicited enthusiastic responses, most unhallowed, and none usable. These optometrists were apparently reluctant to give any information that could be used to determine the mark-up 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. Their consensus was that $10 was an accurate figure.

This figure is more than twice the value of all eyeglass components at the manufacturing level in 1963. The average value of a pair of vision lenses at the manufacturing level in 1963 (calculated by dividing total value of shipments by quantity of lenses) was $1.91. The average value of a set of temples and frames was $2.21. The average value of eyeglass components at the manufacturing level in 1963 was then $4.12. Computations from data published in <u>1963 Census of Manufacturing</u>, U.S. Department of Commerce.

[18]These figures were compiled by Benham from data collected in the 1963 National Health Survey that provided the data base for the book by Ronald Andersen and Odin W. Anderson, A Decade of Health Services: Social Survey Trends in Use and Expenditure, University of Chicago Press, 1967. The mean price of eyeglasses and examination were computed from a sample of 383 individuals. The mean price of eyeglasses alone were computed from a sample of 177 individuals. This data is reported in Lee Benham, "The Effect of Advertising on the Price of Eyeglasses," Journal of Law and Economics, October 1972.

[19]One indication of this is that in 1970, less than one-third of 1 percent of optometrists devoted their practice hours "primarily or exclusively to vision training." (Haffner, p. 31.)

[20]It is likely that larger physician firms do provide more services per visit than smaller firms because a wider range of anciliary services, such as X-rays and laboratory tests, are offered. As a result, patients can receive these services on the premises rather than being referred to, say, a commercial laboratory, as would be the case for a visit to a smaller physician firm that could not efficiently utilize sophisticated laboratory equipment.

[21]These arguments are presented in a more complex fashion in Uwe E. Reinhardt, "Manpower Substitution and Productivity in Medical Practice: Review of Research," Health Services Research, Fall 1973, pp. 205-210.

[22]Simply stated, the conclusion that simultaneity bias may be small in the OLS estimates rests on the assertion that the variation in ln U is small, at least relative to the variation in some of the other variables in the derived demand equations and relative to the variation in the error terms of the derived demand equations.

There is one caveat that has not been mentioned that would imply a more substantial variation in ln U than was implicit in the discussion in the text. This would occur if there are substantial errors in the measurement of the optometrists' input in the production process. This is possible because optometrists, whose work effort is self regulated in their private practices, would supply different amounts of true input per unit of measured input. For example, if the measured input of optometrists was hours devoted to practice and if optometrists varied in their work effort per hour, then true input would differ from measured input. Since the input of optometrists is likely to have a high output elasticity in the production of optometric services, the variation in ln U resulting from errors in measurement is likely to be substantial. To show this, let us assume that output Q is produced only by one input H, which is measured with error. Let

$$Q = bH + V,$$

and let

$$h = H + c \quad E(c) = 0,$$

where h is the reported measure of the true input, H. It follows that

$$Q = bh - bc + V.$$

The error term in the production relation is bc + V. The variance of the error term will increase the larger the measurement error and the larger the output elasticity.

[23]From equations (3) and (4), it follows that

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

Equation (5) falls easily from this expression.

[24a]Profit, π, would be expressed as

$$\pi = P \cdot Q(H, D, W, R) - D - W - R - u H$$

where u is the shadow price of optometrist's time and all other variables have been defined previously. Since

$$\frac{\partial \pi}{\partial H} = P \cdot \frac{\partial Q}{\partial H} - u = 0 \quad \text{and}$$

$$\frac{\partial \pi}{\partial W} = P \cdot \frac{\partial Q}{\partial W} - 1 = 0 ,$$

$$u = P \left(\frac{\partial Q}{\partial H} - \frac{\partial Q}{\partial W}\right) + 1 .$$

[24b]It will be assumed throughout this paper that the optometrist should value his time in the production process at his opportunity cost or market wage. The market wage actually underestimates, or is at best a lower bound of, the value of the time of the self employed optometrists in the production of optometric services. This is because the supervisory and organizational responsibilities of self-employed optometrists, which are an important input in the production process, likely exceed those of salaried optometrists.

[25]Mean values were inserted for missing observations on inputs used in the production process.

[26]The annual weeks worked figure of 49.3 is the same as that figure derived for self employed optometrists (see note 14).

[27]There would not be much difference in the tax rates applied to the salaried or to the self-employed income. The 1964 average annual incomes of self-employed optometrists in the AOA survey, net of business expenses but before tax payments, was slightly under $15,000. Federal income tax payments by individual proprietors in 1964 amounted to about 15 percent of adjusted gross incomes of $15,000. (Statistics of Income, 1964, U.S. Business Tax Returns, U.S. Treasury, Internal Revenue Service, p. 49.) The state and local tax bite should have been an additional 9 percent of income. This combined average tax rate of 24 percent is slightly lower than the estimated federal, state and local government take of 27 percent from salaried incomes of $12,000, which would be the approximate annual income of employed optometrists with an hourly wage of $6.15. (The state and local tax estimate and the combined federal, state, and local tax figure on the salaried income are for 1965 and were from the Economic Report of the President, 1969, as summarized by Joseph A. Pechman in "The Rich, The Poor, and the Taxes They Pay," The Public Interest, No. 17, Fall 1969, p. 33.)

[28]The mean years of experience of optometrists in the abbreviated sample is 15.9. Using (6), the predicted market wage or opportunity cost of these optometrists is $6.16, assuming 49.3 weeks worked in 1964.

[29] See Appendix B for a presentation of production function estimates, optimal input levels and shadow prices of optometrist's time under different assumptions about the weighting scheme used to construct the output measure.

[30] Haffner, p. 32.

[31] The scale estimates for the Reinhardt production function results were derived from the elasticity of output with respect to scale, which is equal to

$$\hat{\alpha}_H + \hat{\alpha}_D + \hat{\alpha}_R + \hat{\beta} R + \gamma W + 2 u_1 W^2,$$

where α's are the estimated coefficients for the logs of hours, capital flow and rent, β is the coefficient of rent, γ is the coefficient of aide input and u_1 is the coefficient of aide input squared. For the derivation of the elasticity of output with respect to scale, see Reinhardt, 1970, p. 183. The scale estimates for small and large output optometrists are significantly different at the 30 percent confidence level in a two-tailed test.

[32] The results can be interpreted in this fashion because the group practitioners that were surveyed were asked to prorate the inputs and outputs of the group practice by practitioner, and to report only that portion which applied to themselves.

[33]Joseph P. Newhouse, "The Economics of Group Practice," Journal of Human Resources, No. 7, Winter 1973, pp. 37-56.

[34]The wage elasticity for the Reinhardt specification is $b_6 w + b_7 w^2$. The elasticity at the mean wage bill is equal to .26 according to the full sample production function estimates. An increase in the level of aide employment by the average optometrist to $5,000 would represent a jump of 38 percent.

[35]Bailey has provided a similar argument to explain why internists do not appear to extend the substitution of capital or aides for their own time as practice size increases. He feels this is the case because the medical school, internship and residency training received by these physicians dictated uniform treatment techniques to be used in the delivery of their services. (Richard M. Bailey, "Economics of Scale in Medical Practice," Empirical Studies in Health Economics, H. Klarman, ed., John Hopkins Press, 1970, pp. 255-73.

TABLE 1

Production of Optometric Services, Reinhardt Functional Form

Independent Variables	Regression Number 1		Regression Number 2	
	Regression Coefficient	t-value	Regression Coefficient	t-value
Log optometrist's hours	.423	12.4	.426	12.5
Log capital flow	.123	9.5	.120	9.2
Log rent bill	.118	4.3	.122	4.4
Rent	$-.033 \times 10^{-3}$	-2.6	$-.033 \times 10^{-3}$	-2.6
Aide value[a]	$.077 \times 10^{-3}$	27.5		
Aide value[a] squared	$-.11 \times 10^{-8}$	-11.0		
Aide bill			$.080 \times 10^{-3}$	28.6
Aide bill squared			$-.11 \times 10^{-8}$	-11.0
City size	.055	11.0	.054	11.0
Group dummy	.057	2.3	.029	1.2
Constant	2.92		2.91	
R^2	.33		.34	
F ratio	235.8		246.4	
N	3814		3814	

Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

[a]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

TABLE 2

Production of Optometric Services, Reinhardt and Cobb-Douglas Functional Forms, Abbreviated Sample

Independent Variables	Regression Number 1		Regression Number 2		Regression Number 3	
	Regression Coefficient	t-value	Regression Coefficient	t-value	Regression Coefficient	t-value
Log optometrist's hours	.356	9.5	.334	9.15	.334	9.15
Log capital flow	.102	7.6	.074	5.6	.074	5.6
Log rent bill	$.084 \times 10^{-3}$	2.8	$.002 \times 10^{-3}$	.14		
Log aide value[a]			.275	24.6	.275	25.0
Rent	$-.024 \times 10^{-3}$	-2.0				
Aide value[a]	.051	18.2				
Aide value[a] squared	$-.06 \times 10^{-8}$	-6.1				
City size	.046	8.8	.047	9.4	.047	9.8
Group dummy	.047	2.0	.048	2.1	.049	2.2
Constant	4.01		2.88		2.90	
R^2	.25		.29		.29	
F ratio	112.8		186.3		223.7	
N	2782		2782		2782	

[a]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE 3

Production of Optometric Services, Reinhardt Functional Form, Separate Estimates for Above and Below Median Output Optometrists

Independent Variables	Above Median Output Optometrists		Below Median Output Optometrists	
	Regression Coefficients	t-value	Regression Coefficients	t-value
Log optometrist's hours	.192	6.0	.278	7.7
Log capital flow	.049	4.5	.048	3.2
Log rent bill	.046	2.0	.118	3.5
Rent	$-.01 \times 10^{-3}$	-1.1	$-.065 \times 10^{-3}$	-4.1
Aide value[a]	$.025 \times 10^{-3}$	12.5	$.089 \times 10^{-3}$	15.4
Aide value squared	$-.024 \times 10^{-8}$	-6.0	$-.27 \times 10^{-8}$	-11.7
City size	.038	7.3	.049	7.6
Group dummy	.072	3.8	-.059	-2.0
Constant	6.36		4.45	
R^2	.21		.17	
F ratio	61.3		48.8	
N	1906		1908	

[a] Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE 3 (continued)

Production of Optometric Services, Cobb-Douglas Functional Form, Separate Estimates for Above and Below Median Output Optometrists

Independent Variables	Above Median Output Optometrists		Below Median Output Optometrists	
	Regression Coefficients	t-value	Regression Coefficients	t-value
Log optometrist's hours	.141	4.3	.106	2.6
Log capital flow	.055	4.4	.007	.4
Log aide value[a]	.139	14.1	.081	5.9
City size	.034	7.2	.048	2.9
Group dummy	.063	3.8	-.023	-.8
Constant	6.02		6.52	
R^2	.22		.03	
F ratio	100.6		11.4	
N	1395		1387	

[a]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE 4

Production of Optometric Services, Reinhardt Functional Form, with Size Dummy

Independent Variables	Regression Number 1		Regression Number 2	
	Regression Coefficient	t-value	Regression Coefficient	t-value
Log optometrist's hours	.239	9.6	.242	9.6
Log capital flow	.053	5.9	.055	5.8
Log rent bill	.082	4.1	.084	4.2
Rent	$-.028 \times 10^{-3}$	-3.1	$-.028 \times 10^{-3}$	-3.0
Aide value[a]	$.035 \times 10^{-3}$	17.5		
Aide value squared	$-.043 \times 10^{-8}$	-8.6		
Aide bill			$.036 \times 10^{-3}$	15.9
Aide bill squared			$-.042 \times 10^{-8}$	-8.4
City size	.053	8.1	.054	8.0
Group dummy	.029	1.6	.018	.9
Size dummy	.683	61.8	.680	61.9
Constant	4.98		4.94	
R^2	.64		.64	
F value	763.3		762.5	
N	3814		3814	

[a]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE 5

Average Levels of Inputs and Output for Optometrists with Above and Below Median Outputs, 1964

	Above Median Output	Below Median Output
Optometrist's hours	2,034	1,921
Capital flow	$1,090	$758
Rent bill	$2,514	$2,120
Aide value[a]	$5,234	$2,014
Output[b]	5,880	2,649
Capital/hour ratio	.53	.39
Capital/aide value ratio	.54	.38
Aide value/hour ratio	2.57	1.05

[a]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

[b]Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE 6

Average Level of Inputs and Output for Optometrists in Group and Solo Practice, 1964

	Solo	Group[a]
Optometrist's hours	1,977	1,986
Capital flow	$898	$1,170
Rent bill	$2,260	$2,930
Aide value[b]	$3,411	$5,760
Aide bill	$2,919	$5,510
Output[c]	3099	3885

[a]Optometrists in group practice prorated the inputs and outputs of the practice by practitioner and reported only that portion which applied to themselves.

[b]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

[c]Output is the log of the sum of visual exams and 2.8 times the wholesale value of lenses and frames.

TABLE B-1

Production of Optometric Services, Reinhardt Functional Form, Different Output Measures

Independent Variables	Regression Number 1[a]		Regression Number 2[b]	
	Regression Coefficient	t-value	Regression Coefficient	t-value
Log optometrist's hours	.425	12.8	.422	12.4
Log capital flow	.122	9.4	.124	9.5
Log rent bill	.116	4.1	.120	4.2
Rent	$-.032 \times 10^{-3}$	-2.5	$-.033 \times 10^{-3}$	-2.6
Aide value[c]	$.077 \times 10^{-3}$	27.6	$.077 \times 10^{-3}$	27.6
Aide value[c] squared	$-.11 \times 10^{-8}$	-11.0	$-.11 \times 10^{-8}$	-10.9
City size	.054	11.0	.056	11.2
Group dummy	.055	2.2	.057	2.2
Constant	2.79		3.03	
R^2	.33		.33	
F ratio	235.9		235.3	
N	3814		3814	

(continued on next page)

TABLE B-1 (continued)

Production of Optometric Services, Cobb-Douglas Functional Form, Different Output Measures

Independent Variables	Regression Number 3[a]		Regression Number 4[b]	
	Regression Coefficient	t-value	Regression Coefficient	t-value
Log optometrist's hours	.339	9.4	.332	9.0
Log capital flow	.073	5.6	.075	5.7
Log rent bill	*		*	
Log aide value[c]	.275	25.5	.277	25.2
Group dummy	.046	2.0	.051	2.2
City size	.046	9.6	.048	9.8
Constant	2.76		3.06	
R^2	.29		.29	
F ratio	225.2		221.9	
N	2782		2782	

*Variable statistically insignificant when included in estimated production function.

[a]Output is the log of the sum of visual exams and 2.3 times the wholesale value of lenses and frames.

[b]Output is the log of the sum of visual exams and 3.3 times the wholesale value of lenses and frames.

[c]Aide value is equal to aide bill plus the value of work performed by unpaid assistants.

FIGURE 1

Residual Pattern from Estimated Production Functions for Optometric Services

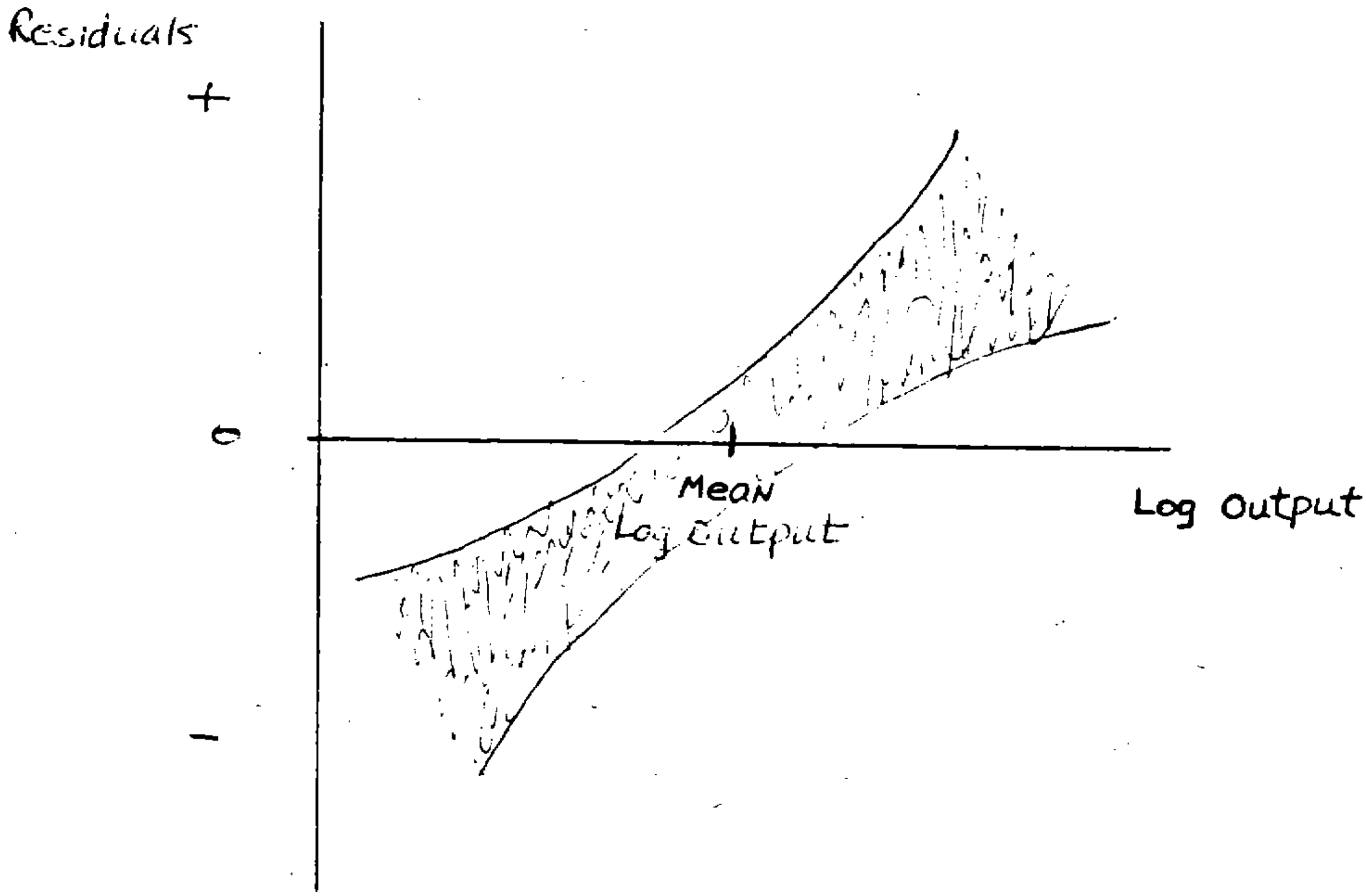

FIGURE 2

How the Residual Pattern Could Have Developed Because of an Inverse Relationship Between Size of Output and Returns to Scale; the Case of a Single Input

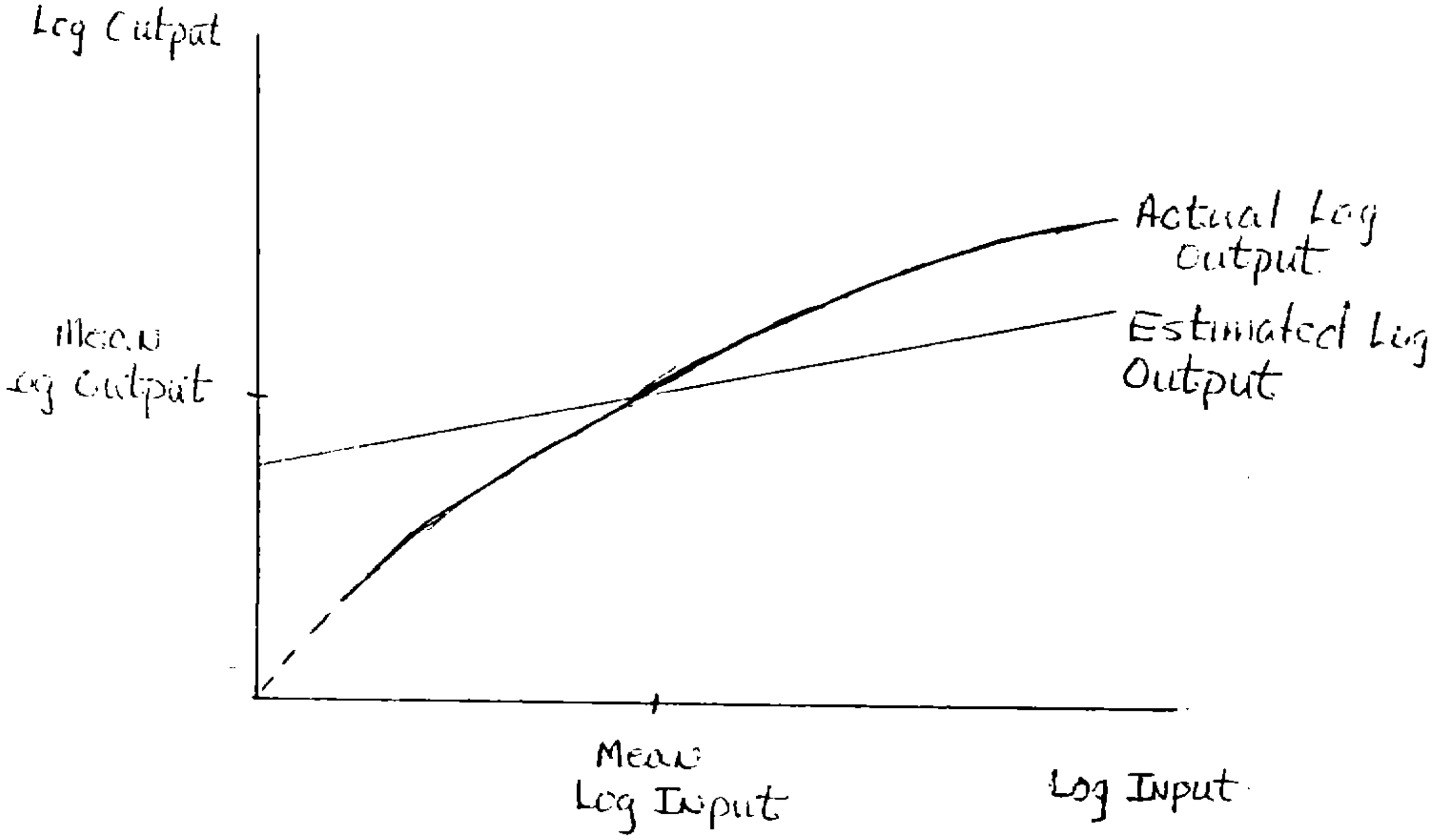

FIGURE 3

How the Residual Pattern Could Have Developed Because of an Inverse Relationship Between Size of Output and Returns to Scale Given a Technological Superiority for Large-Output Producers; the Case of a Single Input