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Returns to scale in college and university student health centers: A Cobb-Douglas approach

Frank A Dieterich

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Returns to scale in college and university student health centers:
A Cobb-Douglas approach

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University of Nevada, Las Vegas, 1992
RETURNS TO SCALE IN COLLEGE AND UNIVERSITY STUDENT HEALTH CENTERS: A COBB-DOUGLAS APPROACH

by

Frank A. Dieterich

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Arts in Economics

Department of Economics University of Nevada, Las Vegas December 1992
Approval Page

The Thesis of Frank A. Dieterich for the degree of Master of Arts in Economics is approved.

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ABSTRACT

This study examined returns to scale for the production of health services in college and university student health centers. Estimation was done using the Cobb-Douglas production function. The results of this study present evidence that supports the hypothesis of decreasing returns to scale across the set of sampled observations of student health centers.
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Finally, I would like to express my heartfelt thanks to all concerned for their patience and encouragement throughout this arduous undertaking. I firmly believe that the personal attention and care for students that is shown by the professors and staff in the Economics department at UNLV has had a significantly positive influence on my academic career.
One of the unique aspects involving the study of student health centers on the College campus is the conspicuous absence of empirical information in the current literature. This statement naturally begs the question, why is there a need for such a study? The answer can be found in part by observing the escalating costs of health care services in the United States since the early 1970s. Recent estimates have placed total expenditures on health care at approximately 700 billion dollars annually, more than thirteen percent of the gross national product.1 Spiralling budget deficits in recent years have imposed further limitations on the ability of the federal government to provide additional funding for many social services, including health care and higher education. The cost of higher education has increased almost as rapidly as the cost of health care in the past decade,2 putting additional budget constraints on college administrations, and placing

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additional financial burdens on college students.

A survey of 411 campuses by the American Council on Education found that 57% of U.S. colleges and universities had to reduce their operating budgets in the 1991-92 academic year, even more than the 45% who did so in the 1990-91 school year. Public institutions suffered the most: 73% of public two-year colleges, 61% of public four-year colleges and 35% of private institutions endured midyear budget cuts. In all, nearly half of the public institutions had lower operating budgets in 1991-92 than they did the previous year.

Accounting for inflation, two-thirds of all public institutions lost financial ground during the past academic year. The result has been the elimination of many academic and intercollegiate programs from the college curriculum in an effort to cut costs wherever possible. For public and private institutions of all kinds, such choices may soon be at hand. Competition for limited resources is a distinct threat to the current size, structure, and function of student health centers (SHCs). Hence, the need for a study of returns to scale for the production of health services in college and university SHCs in terms of the resource inputs which are employed to produce the most efficient rate of output to meet the special needs of the student population.

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The American College Health Association (ACHA) was founded in 1917 by a group of physicians that provided medical care to college students. The ACHA listed 737 of the nation's public and private post-secondary schools among its membership in 1989. Recommended standards for student health services are issued by the ACHA's journal, the Journal of American College Health, six times each year, with peer-reviewed articles on subjects ranging from clinical problems to administrative issues. Major national initiatives of the ACHA over the past few years have included projects on immunization, alcohol and other substance abuse, acquired immunodeficiency syndrome, health promotion and disease prevention, health care for international students, and insurance coverage issues for young adults.

This study examines the relationship between inputs and outputs in a sample of ACHA member student health centers with an emphasis on returns to scale in the production of health care. An understanding of these relations is important in the determination of the optimal quantities of scarce resources to employ in order to provide health care services most efficiently.

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This paper has seven component parts. The first part contains the introduction and purpose for the study; the second part gives a brief description and background of student health centers; part three is a review of production function literature; part four specifies the model used in the analysis of student health centers; part five examines the sampled set of observations used in the study; part six is a discussion of the results; and part seven presents the summary and conclusions.
II. STUDENT HEALTH CENTERS

Colleges and universities have provided health care to students in a variety of forms since the mid-19th century. Health education has also been an integral part of College health services since 1859, when Amherst College in Massachusetts became the first American College to employ a physician as professor of hygiene to provide student health services, although it was oriented largely to the promotion of physical fitness and treatment of athletic injuries. In the 1890s, the larger and more affluent colleges engaged local physicians who would visit the campus periodically. In 1906, the University of California at Berkeley organized a general medical service offering comprehensive care.6 From earliest efforts to improve the student's health by means of physical fitness and education, through years of providing infirmary care on campuses across the country, to the existence of impressive ambulatory clinics today, the field of college health practice has created a remarkable model to treat, teach, support, and counsel college students and their families.

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There are approximately 12.4 million students at more than 3,253 institutions of higher education. This number includes virtually every state system of higher education, including postsecondary and technical schools. Nearly all four-year institutions and the majority of two-year junior and community colleges assume some responsibility for the health care of their students. Combined, they enroll approximately 80% of the nation's college students at a cost of over one billion dollars annually. This figure may well underestimate total costs, since it does not include major expenses, such as upkeep and depreciation. On most campuses these costs are absorbed in general University operating expenses, although some are accounted for differently.

Student health centers may serve any combination of students, staff, faculty, and their dependents and may accept as their overall mission anything from simple first aid and emergency needs to the complete management of personal and public health problems. Student health centers typically exist as freestanding ambulatory, or outpatient, care facilities rather than inpatient care facilities. They are staffed by physicians, mid level practitioners, nurses,

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medical assistants, and clerical staff. The health center director is often a nurse practitioner or a registered nurse, as contrasted with the traditional clinical environment where physicians direct the operations of the facility. Support services such as laboratory, roentgenogram, physical therapy, pharmacy, and dental services may be offered on-site.

Financing of student health care consists of a mix of prepaid health fees, financed either directly by student health fees, over and above tuition; fee-for-service revenues; insurance reimbursement; or general University funds. Health insurance is an especially important issue because college students are among the least likely individuals to be insured. It is well known that student participation is very low in voluntary health insurance plans. This problem is compounded when one considers that student status often renders people ineligible for public medical assistance. Thus, SHCs may be the only medical resource financially accessible to college students.

The role of health education and health promotion activities has expanded more in the University health

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setting than in any other environment. The type and extent of health promotion activity varies greatly among institutions. However, on moderate to large campuses, one or more health educators might be employed to work in such areas as nutrition; tobacco, drug and alcohol abuse; stress management; exercise and fitness; sexuality; contraception, family planning, and sexually transmitted diseases.

Two methods of organization of mental health care services predominate on campuses, one in which psychiatric care is provided by physicians in or under the jurisdiction of the SHC and one in which mental health services are linked with other personal, developmental, and career counseling services in a facility organizationally separate from the student health center.

Perhaps the greatest strength of student health care is the opportunity to favorably alter risk factors for many causes of premature morbidity and mortality. There is little question that education has played a significant role in making society more aware of the risks involved with respect to indiscriminate actions, and more responsible about behavior and life-style changes. Prevention has become a major focus of health care delivery to students.


\(^{12}\)Patrick, p. 3302.
The integration of behavioral change processes into the ambulatory care setting and into community-based health promotion programs is the ultimate goal of many health care professionals.\textsuperscript{13}
III. REVIEW OF PRODUCTION FUNCTION LITERATURE

Since the original production function studies of Cobb and Douglas in the late 1920s\textsuperscript{14} many similar studies have been undertaken.\textsuperscript{15} Using time-series data, production functions have been developed for entire economies (for example, the United States, Norway, Finland, New Zealand), geographical regions (Massachusetts, and Victoria and New South Wales in Australia), and major sectors of the economy (manufacturing, mining, agriculture). Also, Cobb-Douglas functions have been estimated for various sectors of an economy using cross-sectional industry data (the United States, Australia, Canada) and for various industries using cross-sectional data on firms within an industry (railroads, coal, clothing, chemicals, electricity, milk, and rice).

Research into the production function has a long history. In 1928 Charles W. Cobb of Amherst College and Paul H. Douglas of the University of Chicago sought to


develop a formula that would measure the relative effect of labor and capital upon output. The original model they fitted for this purpose was of the form:

\[ P = \beta L^k C^{1-k} \]

Where \( P \) is an index of physical production in manufacturing, \( \beta \) is an index of the firm's technology, \( L \) and \( C \) are indices of labor and capital inputs, and \( k \) and \( 1-k \) are exponents measuring the relative contribution of labor and capital to output. This model was later modified as a result of an excellent critical article by Durand, in which he urged that the restricted formula be abandoned for one in which the exponent for capital is independently determined. It would then be possible for the sum of the exponents to be either greater or less than unity and hence to show true increasing and decreasing as well as constant returns to scale. The modified formula then took the form:

\[ P = \beta L^k C^j \]

where the contribution of capital to output (\( j \)) was determined independently of the value of labor's share.


\footnote{David Durand, "Some Thoughts on Marginal Productivity with Special Reference to Professor Douglas' Analysis," \textit{Journal of Political Economy}, 45 (December 1937): 740-758.}
By 1948 Douglas\(^{18}\) (originally economics professor and subsequently U.S. Senator) was able to identify nearly forty different studies that used the Cobb-Douglas model. Since then, numerous studies in manufacturing, utilities, and agriculture have utilized the Cobb-Douglas function.

In a more recent study of returns to scale, Moroney used cross-sectional data to estimate Cobb-Douglas production functions for eighteen U.S. manufacturing industries.\(^{19}\) Using aggregated data on established plants located within each state, the three variable model was fitted as:

\[
Q = \alpha L_p^{\beta_1} L_n^{\beta_2} K^{\beta_3} \quad (\alpha, \beta_1, \beta_2, \beta_3 > 0)
\]

where \(Q\) is the value added by the production plants, \(L_p\) is production worker work-hours, \(L_n\) is nonproduction work-years, and \(K\) is gross book value of depreciable and depletable assets.\(^{20}\) The sum of the exponents \((\beta_1 + \beta_2 + \beta_3)\), i.e., elasticities, ranged from a low of 0.947 for the petroleum and coal industry to a high of 1.109 for the

---

\(^{18}\)Douglas, p. 6.


\(^{20}\)"Book values" of assets are the historic values of these assets as they appear on the balance sheet of the firm. Book values may differ significantly from current replacement values and hence may overstate or understate the actual amount of capital employed in the firm.
furniture industry. In thirteen of the eighteen industries studied, the statistical tests showed that the sum of the exponents was not significantly different from unity. This evidence supports the hypothesis that most manufacturing industries exhibit constant returns to scale.

In a similar study, Maskus and Bohara used cross sectional data to estimate a Cobb-Douglas production function for Nepalese industry. Their study provided an initial analysis of an aggregate technology for Nepalese manufacturing for the years 1965, 1972-73, and 1976-77. They employed two models for the study consisting of a simple two-factor Cobb-Douglas specification, and a four-input function (capital, labor, raw materials, and fuel). A third specification pooled the data across the years of the analysis.

The first model of a simple two-factor Cobb-Douglas specification examined the contribution of capital and labor to the production of value added:

\[ VA_i = AK_i^a L_i^b e^{u_i} \]  

where for industry \( i \), \( VA \) is real value added, defined as real output (deflated by the price index), less inputs of raw materials and fuel; \( K \) is physical capital stock, and \( L \)
is total employment. A disturbance term in exponential form was attached to the model in order to make double-log estimation of equation (1) feasible. The parameter $A$, generally considered to be an indicator for the state of technological progress in time series analysis is taken to indicate an average technological parameter across the set of industries in each year. The coefficients $a$ and $b$ represent the elasticities of value added production with respect to capital and labor, respectively; the coefficient on capital is presumed independent of the coefficient on labor in order to examine the state of returns to scale.

The second specification for the four-input production function is of the form:

$$ Q_i = A K_i^a L_i^b R_i^c F_i^d e^{u_i} $$

(2)

where $Q$ is real gross output, $R$ is raw materials, and $F$ is fuel inputs used by the $i$th industry.

For 1965, the simple two factor production function showed that both capital and labor inputs contributed significantly to value added. However, when the model was expanded to include raw materials and fuels the capital coefficient was negative and became insignificant, and the labor coefficient was cut in half, although it retained its significance. The negative and insignificant coefficient on capital suggests that that coefficient was estimated imprecisely, possibly due to multicollinearity between the
two regressors, capital and raw materials.

Multicollinearity increases the probability of a Type II error, the acceptance of a false null hypothesis. Maskus and Bohara dealt with this problem subsequently in their third specification by pooling the data. The coefficient on raw materials input of 0.632 is consistent with the fact that most Nepalese industry is of the processed primary goods variety. The explanatory power of the expanded equation with an $R^2$ of .98 is significantly higher than that of the simple two factor production function with an $R^2$ of .88."

The results for 1972-73 were substantially the same as the equations for 1965 with the exception that the intercept terms dropped somewhat, indicating a reduction in the technological efficiency of Nepalese industry. The fuel coefficient increased substantially from 0.094 in 1965 to 0.159 in the 1972-73 period, possibly reflecting government policy to subsidize energy use in Nepalese industry.

Equations for the period 1976-77 revealed that in the four-input specification capital retained its importance while the labor coefficient lost its significance. The parameters that were estimated for each period were then tested under the assumption of unity based on two-sided alternatives so as to allow for either increasing or

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22The $R^2$s are not strictly comparable, however, because of the different specifications of the dependent variable in the two equations.
decreasing returns to scale. The results showed that in each case the hypothesis of constant returns to scale could not be rejected. The coefficients on factor inputs may thus be interpreted as input shares and therefore factor intensities.

The third specification of the models employed by Maskus and Bohara in their study of Nepalese industry pooled the data across the three years under investigation in order to produce a more precise estimate of the Cobb-Douglas production specification. This is possible only if there is overall homogeneity in the regression coefficients in the three years of the study. Homogeneity was tested for by means of an F-test for a common relationship. This involved comparing the residual sums of squares which resulted from pooled regression with coefficients constrained to be equal across years, with the residual sums of squares available in the unconstrained annual regressions.\textsuperscript{23}

Allowing for separate time intercepts, in each model they could not reject the hypothesis of homogeneity. Therefore, pooling of the data was possible. In both the simple two factor equation and the expanded four-input specification, Maskus and Bohara found evidence of constant returns to scale, confirming their previous results. Pooling of the data also corrected the problem of

multicollinearity between capital and raw materials in equation (2) by increasing the sample size, and therefore the degrees of freedom. The coefficient on capital became positive again, but it remained insignificant, while the coefficient on raw materials was highly significant, providing further evidence that most Nepalese industry is of the processed, primary goods variety.

Little empirical information has been found in the literature that deals directly with returns to scale in student health centers. However, increasing concern over rising health care costs has lead many researchers to examine returns to scale and internal economies in similar ambulatory or outpatient settings.

The ACHA undertook a survey of student health service programs throughout the country in 1977. Questionnaires were sent to all member institutions in the Association (about 400), plus a sample of non-member colleges to yield a mailing list of 728. Returns were received from 225 colleges and universities. This response represented a sample of the population of more than 2,700 institutions in the country at the time of the survey.

Generally speaking, the survey found that larger and older universities, offering at least four-year academic degrees, tend to have more well developed ambulatory care

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systems. Smaller four-year colleges offering less than full degree programs (typically for two years) often provide health services from a nurse or nurse practitioner, with one or more physicians being on call.

The ACHA survey claimed evidence of economies of scale, implying that institutions with larger enrollments realize lower average costs when the planned rate of output is increased. Their findings suggest increasing returns to factor inputs for the typical SHC. The rate of ambulatory service utilization was about equal for both the larger and smaller institutions at 2.5 encounters per student per year. Although the scope of these services is highly variable, College and University health care programs constitute a significant source of organized ambulatory care for young adults in America.
IV. THE ECONOMETRIC MODEL

The student health care center is viewed as a producer of health care, transforming two fundamental factors of production (labor and capital) and a variety of other inputs into an output as measured by the average daily case load of students tested, evaluated, or counseled.

The model selected for this study is a Cobb-Douglas production function, chosen for its relative ease of estimation by ordinary least squares (OLS) procedures. The multiplicative, or power function transformed into natural double-log (ln) form is fitted as:

$$\ln Q_i = \beta_0 + \beta_1 \ln L_i + \beta_2 \ln K_i + \epsilon_i$$

where for student health center $i$;

- $Q_i$ is output as measured by the average daily case load observed across the sampled SHCs.
- $\beta_i$ is a vector of production parameters, including a constant term to be estimated.
- $L_i$ represents labor's input as measured by the size of the medical staff (medical staff providing hands-on care), clerical, administrative, and other health services support staff.
KAP is represents capacity utilization; combining capital inputs (as measured by the number of examination rooms) with the number of hours of operation per week per student health center.

\( \epsilon \) is a vector of random error (disturbance) terms in exponential form, attached to the model in order to make the log-linear estimation possible.

In order to convert the stock of available examination rooms to a concept of capacity utilization, the number of examination rooms were multiplied by hours of operation per week to obtain the capital utilization variable, KAP. Estimation of the production parameters yields \( \beta_0 \), which is the constant (intercept) term. Parameters \( \beta_1 \) and \( \beta_2 \) are interpreted as elasticities (or percentage change) in output with respect to a percentage change in inputs; and \( \epsilon \) is a random disturbance term assumed to have constant variance and to be independently distributed about a mean of zero. The a priori expectation is that the estimated elasticities have values between zero and one, and that they sum to one. Returns to scale is measured by the percentage change in output resulting from a common percentage change in all inputs.\(^2\) Increasing returns to scale mean that output changes by a greater proportion than the common percentage change in all inputs; constant returns to scale result when

the percentage change in output equals the common percentage change in all inputs; and decreasing returns to scale occur when output changes by a smaller percentage than the common percentage changes in all inputs. Returns to scale can be calculated by summing the output elasticities for all inputs. The specific nature of returns to scale will be found in whether the elasticity coefficients on the independent variables are greater than, less than, or equal to unity.

Input elasticity coefficients are constrained to homogeneity by this specification, i.e., an increase in one input factor is matched by a proportionate increase in all other inputs. This simplifying assumption of the technical efficiency for factor inputs is a necessary constraint imposed on this model since the precise amount of a variable input to be used in order to achieve economic efficiency cannot be determined without knowledge of the relative costs of inputs. Therefore, the assumption of constant factor prices is made and input substitution is constrained to unity.
V. THE DATA

The source of the data for this study was compiled by means of a survey of 250 student health centers in the United States in the summer of 1991. The sample of institutions was chosen at random from a population of 646 public and private colleges and universities listed as "Institutional Members" of the ACHA in 1988. Eighty questionnaires of the one-hundred schools that responded to the survey provided usable data for this study. Of particular interest for this study is information regarding average daily case load, levels of staffing of medical, administrative, and support personnel, and the number of functional examination rooms combined with the hours of operation per facility, in order to measure the capital utilization per student health center.

26American College Health Association, Membership Directory (Rockville, Maryland: American College Health Association, 1990).

Selected Characteristics of the SHCs

Selected characteristics of the SHCs with means and standard deviations are presented in Table 1. The average student enrollment is 9,686 students with a standard deviation of 9,368 students. Eighty-two percent of the sampled observations are four-year schools, while eighteen percent are two-year community colleges. Sixty-five percent are public schools while thirty-five percent are private. Fifteen percent of the sampled institutions have medical schools on campus. The average student health center is open for operation fifty-two hours per week, is a facility with six examination rooms, and services a daily caseload of eighty-two patients. The data with respect to services provided indicate that 97 percent of the health centers offer clinical care, 40 percent provide mental health care, 95 percent make health education available, and 6 percent render dental care services. Additionally, 55 percent of the health centers are nurse-directed facilities, 30 percent are centers directed by physicians, and 15 percent are directed by nonmedical institutional administrators.

The large standard deviations relative to their means are caused by the great variation in the size of the sampled institutions.
## TABLE 1

SELECTED CHARACTERISTICS OF STUDENT HEALTH CENTERS  
(N = 80)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institutions:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Enrollment</td>
<td>9,686</td>
<td>9,368</td>
</tr>
<tr>
<td>Dummy (four-year school=1)</td>
<td>.82</td>
<td>.38</td>
</tr>
<tr>
<td>Dummy (public school=1)</td>
<td>.65</td>
<td>.48</td>
</tr>
<tr>
<td>Hours of operation per week</td>
<td>52.26</td>
<td>29.34</td>
</tr>
<tr>
<td>Number of examination rooms</td>
<td>6.00</td>
<td>7.10</td>
</tr>
<tr>
<td>Average daily case load</td>
<td>82.40</td>
<td>89.35</td>
</tr>
<tr>
<td><strong>Services Provided:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical care (%)</td>
<td>.9750</td>
<td>.1571</td>
</tr>
<tr>
<td>Mental health care (%)</td>
<td>.4000</td>
<td>.4930</td>
</tr>
<tr>
<td>Health Education (%)</td>
<td>.9500</td>
<td>.2193</td>
</tr>
<tr>
<td>Dental care (%)</td>
<td>.0625</td>
<td>.2436</td>
</tr>
<tr>
<td><strong>Director:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician (%)</td>
<td>.3000</td>
<td>.4611</td>
</tr>
<tr>
<td>Nurse (%)</td>
<td>.5500</td>
<td>.5006</td>
</tr>
<tr>
<td>Other (%)</td>
<td>.1500</td>
<td>.3593</td>
</tr>
<tr>
<td><strong>Staff:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physicians (FTE)</td>
<td>1.86</td>
<td>3.34</td>
</tr>
<tr>
<td>Nurse practitioners (FTE)</td>
<td>1.21</td>
<td>1.92</td>
</tr>
<tr>
<td>Registered nurses (FTE)</td>
<td>2.86</td>
<td>3.18</td>
</tr>
<tr>
<td>Licensed vocational nurses (FTE)</td>
<td>0.79</td>
<td>2.47</td>
</tr>
<tr>
<td>Mental health personnel (FTE)</td>
<td>0.76</td>
<td>1.73</td>
</tr>
<tr>
<td>Health educator (FTE)</td>
<td>0.79</td>
<td>2.38</td>
</tr>
<tr>
<td>Dentists (FTE)</td>
<td>0.04</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Observations on staff, expressed in full time equivalent (FTE) terms are 1.86 for physicians, 1.21 for nurse practitioners, and 2.86 for registered nurses, respectively. Licensed vocational nurses, mental health personnel, health educators, and dentists are represented at less than one FTE provider of health services.

\[29\text{ Where full time equivalent is 40 hours per week.}\]
VI. RESULTS OF THE STUDY

An initial approach in the estimation of factor inputs involved the use of an additive model using simple linear regression techniques. The relative influence of medical staff, support staff, number of functional examination rooms, and hours of operation on average daily case load was examined. Two indicator (dummy) variables were also added to the model, representing two-year and four-year colleges, and private versus public institutions, to determine their separate effect on output.

Heteroscedasticity was highly suspect in the linear model due to the wide range of the standard deviations about their respective means. To test for this possibility the data were first sorted by size of enrollment from the smallest to largest institutions. A plot of the residuals against the dependent variable (average daily case load), showed an expansion path that is typical of data in which the variance of the error term is not constant for all observations in one or more of the independent variables.

A Goldfeld-Quandt test provided further evidence of heteroscedasticity. Although this test is less robust than others, it failed to accept the null hypothesis of
heteroscedasticity in the error term at the ninety-five percent level of confidence. A Park test provided more conclusive evidence of heteroscedasticity at the five percent level of significance.\footnote{Michael J. Brennan and Thomas M. Carroll, \textit{Quantitative Economics and Econometrics} (Fourth Edition; Cincinnati: South-Western Publishing Co., 1987), pp. 432-435.} Solving for heteroscedasticity involved taking the log of the squared residuals and regressing against the log of a scalar, (support staff in this case).\footnote{I estimated the correlation between the squared residual and each of the independent variables, and found that support staff was the most likely cause of the heteroscedasticity.} The resulting coefficient was then used to transform the variables, and a weighted least squares regression was run. The adjusted R-squared was lowered to .726, compared to .861 in the original regression. The F-statistic of 112.54 indicates that the model is an adequate fit to the data, i.e., that the independent variables are useful in explaining average daily case load in student health centers. The F-test is also a useful tool for diagnosing multicollinearity in the data. It tests the null hypothesis that none of the regressors has a significant effect on the dependent variable against the alternative that at least one regressor is significant. When all t-statistics are insignificant, but the F-statistic for the equation is significant, multicollinearity is the probable cause; the result of inflated standard error terms...
of the slope coefficients. A negative sign on the coefficient for support staff and insignificant t-statistics for five of the six regressors implied the presence of some troubling multicollinearity among the independent variables, support staff, medical staff, and the number of examination rooms. This problem is dealt with in the multiplicative, Cobb-Douglas production function.

Coefficients on both indicator variables for the two-year and four-year schools, and for private versus public institutions continued to be insignificant, implying that these variables had no meaningful effect on average daily case load for the typical SHC. They were subsequently dropped from the model.

The second model employed the multiplicative Cobb-Douglas function. As a power function, the Cobb-Douglas production function is actually estimated by linear regression techniques, since the multiplicative function can be transformed into a log-linear specification.\(^3\) By first transforming measures of capital (usually measured in dollar value of machines or assets) and labor (measured in workers or man-hours) into natural logarithms, the Cobb-Douglas function can be measured with relatively simple ordinary least squares techniques.

Utilizing the log-linear model effectively eliminated heteroscedasticity because the data were standardized to a

\(^3\)Carroll, p. 223.
percentage basis, thereby, reducing the wide range of the standard errors of the regression. The capital input variable was combined with hours of operation in order to get some measure of the capital utilization for SHCs.

Multicollinearity was still present, however, due to the high degree of correlation between the medical staff and support staff variables. These two variables were combined into a single "staff" variable. This appeared to be a more meaningful choice of variable for the estimation of the relative contribution of labor to average daily case load.

Table 2 presents results of regressions of the Cobb-Douglas production function as applied to all student health centers under consideration. Both output elasticity parameter estimates have values greater than zero and less than one, as expected. A one percent increase in staff, holding constant the number of examination rooms and hours of operation is associated with a .4883 percent increase in output, or average daily case load. By comparing the coefficient of the staff variable against its standard error, it can be seen that this regressor is significant at the one percent level of significance. The contribution of capital utilization, (defined as the product of the number of examination rooms and hours of operation), to output of health services, is .2892 percent; also significant at the one percent level.

The adjusted R-squared of .811 indicates that
**TABLE 2**

REGRESSION RESULTS

DEPENDENT VARIABLE = ln Q
(N = 80)

\[ \ln Q_i = \beta_0 + \beta_1 lnL_i + \beta_2 lnKAP_i + \epsilon_{ui} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Regression Coefficients</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_0 )</td>
<td>1.5289 (.3535)</td>
<td>4.325**</td>
</tr>
<tr>
<td>( \beta_1 )</td>
<td>0.4883 (.1151)</td>
<td>4.243**</td>
</tr>
<tr>
<td>( \beta_2 )</td>
<td>0.2892 (.1067)</td>
<td>2.709**</td>
</tr>
</tbody>
</table>

R-squared: 0.8158
Adjusted R-squared: 0.8110
S.E.: 0.4211
F-statistic: 170.5331

Note: standard errors in parenthesis.
** significant at the 1 percent level of significance.
approximately eighty-one percent of the variation in average
daily case load can be explained by the variation in the
independent variables. The F-statistic of 170.53 indicates
that the model is a reasonably good fit to the data, i.e.,
that the ratio of the explained to the unexplained variance
in the dependent variable is significant. The staff
coefficient of .4883 showed that it had a greater influence
on output than capital utilization rates, implying that SHCs
are labor intensive.

Finally, returns to scale, the central focus of this
paper, was determined by summing the output elasticity
coefficients and testing the assumption of unity (constant
returns to scale), against the alternative hypothesis of
non-constant returns to SHCs. If \( \beta_1 + \beta_2 > 1 \), the
function exhibits increasing returns to scale; when \( \beta_1 + \beta_2
= 1 \), constant returns to scale are indicated; while \( \beta_1 + \beta_2
< 1 \), implies decreasing returns to scale. Table 3
reveals the results of the statistical tests which were
performed. The sum of the estimated parameters is shown to
be .7774, suggesting decreasing returns to SHCs at a rate of
approximately 2.226 percent for a 10 percent increase in all
factor inputs. The calculated t-statistic is shown to be
highly significant at 5.226, resulting in a failure to
accept, at the ninety-nine percent level of confidence, the
null hypothesis of unity, i.e., that SHCs exhibit constant
returns to scale, in favor of the alternative hypothesis of
### TABLE 3

**RETURNS TO SCALE RESULTS**

<table>
<thead>
<tr>
<th>$\epsilon_s$</th>
<th>$\epsilon_n$</th>
<th>Sum of Elasticities</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4883</td>
<td>0.2892</td>
<td>0.7774 (5.226)</td>
<td>Decreasing Returns to Scale</td>
</tr>
</tbody>
</table>

Note: t-statistic in parenthesis.
decreasing returns to scale for this two-tailed test." A Wald test for parameter restrictions generated an equivalent F-statistic of 27.3151, producing the same conclusion.

The inference of decreasing returns to scale is also revealing of economies of scale since they have readily recognized similarities. Economies of scale refers to the firm's ability to reduce average costs by increasing the planned rate of output. A firm realizes scale economies when it operates along the downward sloping part of its average cost curve, and diseconomies along the upward sloping part of its average cost curve. Decreasing returns to scale imply that the typical SHC operates along the upward sloping part on its average cost curve. Increasing the size of SHCs in order to provide more health services would increase total operating costs, but would increase average costs at a greater rate; assuming constant factor intensities and input prices.

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VII. SUMMARY AND CONCLUSIONS

The purpose of this study was to examine returns to scale for the production of health services in college and university student health centers. A Cobb-Douglas production function in log-linear form was fitted to the data to estimate parameters for labor inputs and capital utilization rates. The a priori expectation was that the elasticity coefficients would have values between zero and one. The null hypothesis was that the sum of the estimated parameters would not be significantly different from unity, implying constant returns to scale. Econometric techniques which were employed confirmed the a priori expectation that the coefficients would have values between zero and one, but rejected the null hypothesis of constant returns to scale for the production of health services at the one percent level of significance.

This study views the SHC from the perspective of technical efficiency, holding factor input prices and intensities constant, rather than from the perspective of economic efficiency which also calculates input prices in the determination of an optimal mix of the factors of production.
As the costs of health care continue to escalate, and as increasing numbers of public and private institutions of higher education are constrained to smaller operating budgets, college administrations and SHC directors will be faced with increasingly difficult choices in determining the optimal mix of scarce resources to employ in order to provide health care services most efficiently. This study finds that student health centers operate under conditions of decreasing returns to scale, and concludes that, *ceteris paribus*, smaller scale operations are more efficient in the production and delivery of health care services than the larger scale SHCs. However, these results might be due to the heterogeneous output of health services. Larger SHCs provide more extensive services, so the average daily case load does not increase proportionately with factor inputs. Further research in this area will assist college administrators and SHC directors in selecting the most efficient and productive combinations of factor inputs to meet the needs of college students.
BIBLIOGRAPHY


