# HOSPITAL STRUCTURE AND TECHNICAL EFFICIENCY IN THE PRODUCTION OF NUCLEAR MEDICINE

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HOSPITAL STRUCTURE AND TECHNICAL
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## PREFACE

Rising hospital costs are a national problem of growing concern. During the past decade economists have begun to examine certain relationships between hospital firm structure and production efficiency. This study focuses on some of these relationships in the context of a specific hospital sub-industry, nuclear medicine.

I am indebted to my major advisor, Dr. Joseph M. Jadlow, for his constructive evaluation and encouragement during the entire research effort. Also, I wish to express my appreciation to Dr. John C. Shearer for his guidance in the early stages of the study and to Dr. Michael J. Applegate for his suggestions regarding the statistical sections of the analysis. Dr. Germain B. Boer has contributed numerous comments which have added to the correctness and clarity of the presentation. Many other members of the faculty of the Department of Economics have provided assistance regarding particular problems of the study.

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# CHAPTER I

# INTRODUCTION

Amid rapidly rising hospital costs, a restructuring of the hospital service delivery system has been frequently suggested to stimulate production efficiency.[1] The American College of Radiology has particularly emphasized the importance of "the development of . . . a complete, workable, and efficient nuclear medicine service for patients and for training in nuclear medicine."[2] Proposals from the Committee for Economic Development (CED), and others, have suggested that hospital efficiency could be improved if the hospital industry were restructured in order to:

1. reduce capacity and service competition among hospitals,
2. develop profit and cost-risk incentives,
3. reduce service range and consolidate specialized services, and
4. reorganize in-house manpower training.[3]

Although such changes seem consistent with promoting cost efficiency, a paucity of data concerning the relationship of internal structure to technical efficiency makes the empirical significance of these proposals difficult to assess.

To relate empirically differences in hospital structure to technical production efficiency, comparable inputs and outputs must be identified. Since hospital care is a nonhomogeneous product, simple measures of efficiency are not available. Past studies of hospital efficiency have measured output in patient days, sometimes adjusted for case-mix.[4] Because it has remained impossible to define a homogeneous industry output, results obtained from these studies are tentative.

## Scope of the Study

This research utilizes an alternative approach for examining the relationship of hospital internal structure to production efficiency. The hospital industry consists of multiproduct firms selling various intermediate health care services in many markets. If separate industries can be identified for specific outputs, then a study of individual hospital subindustries is feasible. This research examines internal structure and performance relationships for a hospital subindustry, nuclear medicine. The objective is to measure the significance of specific elements of hospital structure on technical efficiency in the production of nuclear medicine. Although it is impossible to generalize the result over all areas of hospital production, the findings should supplement existing knowledge about efficiency in the hospital industry.

The nuclear medicine industry can be conceived as a set of production units operating as a part of a multi-product hospital firm. The industry's primary labor input is the nuclear medical technician/technologist occupational cluster. This group administers the diagnostic and therapeutic services and, in a majority of hospitals, is the only nonphysician manpower input. The capital input consists of specialized equipment designed to prepare, administer, monitor, and report on services produced. Service outputs consist of specialized diagnostic and therapeutic procedures. As these procedures require a standard format, they are substantially invariant among firms. Because inputs and outputs are relatively homogeneous and because little substitution is possible on either the input or output side, an industry made up of comparable firms is defined.

## Research Hypotheses

The research for this study tests four specific hypotheses relating hospital structure to production efficiency in nuclear medicine. The four research hypotheses are:

1. Increased competitive intensity reduces technical efficiency.
2. A lack of profit incentive reduces technical efficiency.
3. A broader service range reduces technical efficiency.

4. In-house training of technical personnel reduces technical efficiency.

First, because buyers of hospital services are not attracted on the basis of price, competitive pressures to minimize cost are reduced. Hospitals obtain customers from physician referrals and, therefore, may compete for staff physicians. This competition creates inefficiency if it induces overinvestment in staff and equipment. If the hypothesis is correct, then greater competition for staff physicians should be associated with reduced efficiency in the nuclear medical industry.

Second, hospitals that are subject to a profit constraint will tend to minimize costs of output to expand profit margins, thereby inducing increased efficiency. Without a profit motivation, the constraints to cost minimization and efficiency maximization are not imposed.

Third, it is argued that a hospital with a broad range of outputs is likely to be less efficient than one specialized in fewer services. A hospital which produces all services may be equipped to handle peak demands for each and may experience extended periods of excess capacity. If a specialized hospital can arrange a steadier flow of output, it will suffer less idle time. The hypothesis implies that specialized nuclear medicine producers should exhibit greater efficiency than non-specialized producers.

Fourth, because training is a joint output with nuclear medicine, a given service output might require more resource inputs in a training intensive hospital. If training programs do increase costs, then nuclear medicine units with relatively larger training programs should exhibit reduced production efficiency.

## Analytical Framework

The examination of these hypotheses requires a statistical method for making relative efficiency estimates. For efficiency comparisons a set of output response surfaces analogous to production functions is derived for firms operating under each structural condition, and the parameters of these functions are statistically compared. An output response function is a statement of the relationship between rates of input and output. Because firms cannot be assumed to minimize cost, the fitted function does not represent the maximum output possible from resource inputs. Therefore, it is not a true production function. The parametric constants identify the average output from given rates of input for the industry, or segment of the industry, under analysis. Significant differences in function parameters for firms operating under different structural conditions imply differences in technical efficiency.

Chapter II reviews selected literature relating hospital structure to efficiency and presents a theoretical statement of the hypotheses to be tested. Chapter III develops the technique of analysis and data measurement to be used for the empirical tests. Chapter IV presents the empirical findings and examines tests for the appropriateness of the statistical model. Chapter V summarizes the conclusions and recommendations of the research.

FOOTNOTES

[1]Karen Davis, "Rising Hospital Costs: Possible Causes and Cures," Brookings Reprint Series (Washington D. C., May, 1973), p. 1362.

[2]American College of Radiology, "Regionalization in Nuclear Medicine" (Washington D. C., 1973), p. 1.

[3]Committee for Economic Development, Building a National Health Care System (New York, April, 1973), p. 18.

[4]Judith and Lester Lave, "Economic Analysis for Health Service Efficiency," Applied Economics, I (1970), p. 293.

# CHAPTER II

# THE HOSPITAL INDUSTRY

This chapter introduces a concept of the hospital firm, reviews the problem of defining homogeneous hospital outputs, and examines current literature pertaining to hospital behavior, structure, and efficiency. This chapter develops a theoretical basis for evaluating the four hypotheses of the study, and in Chapter IV the a priori results developed in this chapter are compared with empirical statistical observations.

## The Hospital Firm

The hospital industry consists of 7,637 hospital units averaging 163 beds per unit. About three-fourths of the units are "short-term general hospitals."[1] Individual institutions range in size from under twenty to over five hundred beds and produce various intermediate health care services used in the production of a final product, medical care. Geographic market boundaries are determined by patient referral areas. While proprietary, private nonprofit, and government hospitals operate in the market, the dominant type by number, patient load, and bed capacity is the private nonprofit hospital.[2]

The concept of the firm has been difficult to define in hospital industry studies. The administrative unit of a hospital differs from the traditional firm decision maker in that it cannot determine the actual output of various services. The hospital management is limited to the creation of service capacity through its acquisition of production inputs. Actual output is dependent on physician choices of hospital services as they provide medical care for individual patients. Therefore, while the hospital administration selects the quantity of primary resources, the actual utilization of resources is not hospital decision. The relevant firm depends on a specification of inputs and outputs. The physician directs the use of hospital services as intermediate inputs for the final product, medical care.[3] The hospital management, however, selects the labor and capital resources as inputs to the production of the intermediate services. As this study is concerned with the choice of primary inputs acquired by hospitals for nuclear medicine production, the individual hospital management serves as the firm. The range, quality, and intensity of inputs utilized in providing service capacity is the primary determinate of the hospital cost function. An expansion in the range, quantity or quality of inputs available, other things constant, must increase the per unit cost of hospital services.

## Technical Efficiency

This study focuses on the technical efficiency with which hospitals under various structural conditions combine resources in the production of nuclear medicine. A concept of technical efficiency for a single firm in an industry requires the specification of input-output relationships, factor prices, and product prices. A production function is described by a responsive surface showing the relationship between various rates of resource utilization and the maximum rate of output, as:[4]

$$Q = f(X_1, X_2, X_3), \qquad (1)$$

where Q is output and $X_1$, $X_2$, and $X_3$ are input quantities. Given the output price, the set of factor prices, $r_1$, $r_2$, and $r_3$, and the budget constraint, C, the most efficient input-output combination can be found, where

$$C = X_1 r_1 + X_2 r_2 + X_3 r_3$$

and

$$Q = f(X_1, X_2, X_3) + \lambda\,(X_1 r_1 + X_2 r_2 + X_3 r_3 - C).$$

The first order condition for output maximization results in:

$$\frac{f_1}{r_1} = \frac{f_2}{r_2} = \frac{f_3}{r_3}\,. \qquad (4)$$

The $f_i$ are the marginal physical products of the resource inputs. Hence, Equation (4) represents the law of equi-marginal products. Necessary and sufficient conditions for constrained output maximization are:

$$\begin{vmatrix} 0 & r_1 & r_2 \\ r_1 & f_{11} & f_{12} \\ r_2 & f_{21} & f_{22} \end{vmatrix} > 0 \quad \text{and} \quad \begin{vmatrix} 0 & r_1 & r_2 & r_3 \\ r_1 & f_{11} & f_{12} & f_{13} \\ r_2 & f_{21} & f_{22} & f_{23} \\ r_3 & f_{31} & f_{32} & f_{33} \end{vmatrix} < 0.$$

To maximize technical efficiency firms must respond to and hire resources on the basis of marginal productivities per dollar of resource cost. Moreover, they must operate on the production function.[5]

Hospitals are believed to have little incentive to produce each intermediate service with maximum technical efficiency. Three sources of deviation are generally possible. First, there is a possibility of differences in technical production constraints among hospitals. If some hospitals are constrained to less efficient production techniques, then their observed output must lie below the production function of a more technically efficient institution. Because of rapid advances in medical technology, such a difference might be possible. Clarkson, however, comments that a large quantity of technical information reaches hospitals in well-developed channels.[6] Therefore, the state of technical knowledge tends to be common to all hospitals.

Second, and more likely, it is possible that some hospitals do not respond to changes in factor prices by equating marginal productivities per dollar of resource cost. Ogur states that the derivation of production functions for nonprofit hospitals is impossible from input price data.[7] Nonprofit hospitals ignore factor prices and choose input combinations based on nonprice variables. Clarkson has found that nonprofit hospitals do not seek and are unaware of market information about resource prices and that such hospitals will not respond to changes in prevailing factor prices.[8] Rice, alternatively, observes that hospitals do alter input utilization in response to changes in relative input prices.[9] In spite of conflicting opinions, the bulk of the literature and economic logic suggests that hospitals do respond to differences in factor prices. Even if the objective is not profit or net revenue maximization, other cost constraints may induce cost minimization.

The third and most commonly conceived form of inefficiency is the over-accumulation of inputs for the production of a given output. Over-accumulation of inputs provides the primary way in which a hospital can visually demonstrate, to the physician staff and to the community served, the quality of care that it offers. Because an output oriented concept of quality is difficult to observe, hospitals concentrate on the accumulation (and the over-accumulation) of input capacity. As Davis states, "The quantity of inputs used in the production of a given level of output is used to denote quality."[10]

Since a hospital is a multiproduct firm, it can avoid cost constraints for individual specialized outputs. However, if a hospital faced a break even constraint for each service, then revenue from the service would have to be sufficient to cover its production cost. If specialized but loss-producing services are desired as indicators of overall hospital quality, they can be covered by net revenue from "ordinary production" areas. The proposition set forth here is that divergences from the true nuclear medicine production function can be related systematically to specific elements of hospital structure. Such divergence would indicate differences in technical production constraints or in capacity accumulation incentives. With respect to the problem of hospital inflation, greater technical efficiency would reduce pressure on costs and prices.

## The Problem of Homogeneity

The most frequently cited empirical problem in studies of hospital efficiency is the specification of a homogeneous product. Commenting on the empirical analysis of the hospital industry, Clarkson states, "All hospitals do not produce the same product . . . [but] the implications require that the groups of firms tested produce similar outputs."[11] Several factors contribute to the heterogeneity of commonly used measures of hospital output. Variations in the quality of factor inputs may cause differences in units of specific intermediate outputs across hospitals. More significantly, however, the intensity of intermediate good utilization may vary substantially among diagnoses and patients. Because each hospital produces a variety of specialized goods used in treating many types of disorders, relatively few services are common to all patients. Even for specific disease categories, variations in care intensity, seriousness, and input utilization reduce hospital output homogeneity.

Four approaches have been used to define a homogeneous unit of hospital output for empirical study. First, and most common, is the measurement of total bed capacity or patient days. The use of available beds or patient days as the unit of hospital output is not satisfactory since a general hospital provides as many types of care as there are diseases.[12] Rafferty states:

> There is a general and growing displeasure with commonly used methods by which hospital output is measured, and, therefore, with methods of measuring hospital costs. This disaffection springs largely from the questionable assumption of homogeneity that is implied when output is measured in the traditional units (number of patients or patient days of care), for it is increasingly evident that output is not homogeneous in this respect.[13]

A second approach, used by Ingbar and Taylor, measures output for each patient as the sum of services performed for the patient.[14] The idea is to measure each output in dollar terms as the sum of its dollar intermediate service values. The methodology avoids the problem of variations in the intermediate good mix used for treatment of a specific patient or disorder category. However, Mann and Yett note that this procedure merely states a tautology. If output is defined in dollar terms as the sum of intermediate service values, then no variations in output per unit of input could be observed (except for statistical error). Since resources would appear to be used with equal efficiency in all cases, this approach has little empirical application to variations in technical efficiency.[15]

To avoid the problem of differences in the intermediate service mix, P. Feldstein and Carr have focused on specialized hospitals with similar production inputs. If similar input capacity indicates similar outputs, then the homogeneity problem is reduced. Lave and Lave point out that similarities in specialized facilities is consistent with significant variations in care type and intensity.[16] Even for the same input capacity, differences in case severity, cure procedure, or actual intermediate service utilization could imply different final products.

A fourth alternative suggests the adjustment of hospital patient days on the basis of diagnostic categories. To estimate a hospital production function, M. Feldstein has divided patient days into nine admittance categories, with patient days weighted according to a standard marginal cost of treatment.[17] Feldstein found that variations in case mix produce significant differences in resource utilization and cost. Rafferty has used three methods for diagnostic category adjustment. In each adjustment he found that case mix variations caused significant differences in resource intensity.[18] These results suggest that studies using patient days alone have not identified a homogeneous good. Although the adjusted patient day approach has been more favorably received for reducing final output heterogeneity, it does not overcome all the problems of differences within each case type. The assumption of a standard set of inputs for a single disorder is questionable. The definition of a series of output categories does not insure common intermediate service utilization even within those categories. Newhouse states, "This is an aggregation problem inherent in a multiproduct firm, since treatment of each diagnosis can be a separate product."[19]

The trade-off between data availability and degree of homogeneity is a particular problem in the empirical application of the adjusted patient day measure.[20] A detailed set of narrowly defined case types might produce reasonable homogeneity. However, the existence of thousands of diagnostic categories creates the statistical problems of small numbers, empty sets, and difficulty in obtaining data. The use of a smaller and more manageable set of diagnoses reduces the statistical problems at the cost of reduced homogeneity.

As an alternative, this research measures input and output rates in a single hospital subindustry. The hospital manager chooses among available input combinations to produce a specific intermediate hospital service, nuclear medicine. Since the input decision is made by the hospital manager in response to physician demand, observed differences in input-output relationships are directly related to managerial decisions. Moreover, the nuclear medicine industry produces a set of identifiable, relatively homogeneous outputs. Lee has suggested such an approach and conceives of specialized production functions for each intermediate hospital good. Newhouse adds, "Distinct cost and demand curves must be analyzed for each separate product."[21] Since units of nuclear medicine differ only to the extent of qualitative variations in primary resources, the major problem of patient care heterogeneity is avoided.

## The Nuclear Medicine Industry

Nuclear medicine is a specific hospital intermediate product. The nuclear medicine industry is a hospital subindustry in which radioactive isotopes and x-ray procedures are used to produce a set of diagnostic and therapeutic services. Approximately, 2,050 short-term general hospitals are known to produce nuclear medicine outputs.

The generalized production function for the nuclear medicine industry is $Q_i = f(L_i, K_i, M_i)$, where i is the ith output, Q is total quantity, and L, K, and M are labor, capital, and other inputs, respectively. Aside from physician input, the primary labor resource used in production is the nuclear medical technician/technologist occupational cluster. Although minimum employment standards vary, and associate or baccalaureate degree and clinical experience are normally required. Professional society registration and an internship period are frequently required. The capital input consists of a variety of specialized equipment designed to prepare, administer, monitor, and report on the services applied. The specialization of resource inputs precludes their substitution with non-specialized inputs. The industry output is a set of diagnostic and therapeutic procedures, with each requiring a standard routine and input of other resources. Although procedure formats are relatively standardized, there is considerable latitude for labor and capital substitution. The availability of labor saving devices offers hospital decision makers a choice of input combinations and production technologies.

Because output procedures follow standardized formats, and because output of each specific type provides a homogeneous intermediate input to the production of medical care, an industry is defined. The organization unit for firms in the industry are the individual hospital decision makers. The hospital managements acquire labor and capital inputs to provide nuclear medicine services in response to expected demands of physician users.

## Theories of Hospital Behavior

The effects of structural characteristics on hospital performance depend on the actions and objectives of hospital managers. Past studies of hospital production relationships have been handicapped by the absence of a generally accepted theory of hospital behavior. The problem results from difficulty in specifying property rights in an industry characterized as nonprofit and noncompetitive and is complicated by confusion over the relevant firm decision maker. The major theories of hospital behavior are reviewed, and each of the research hypotheses is examined in the context of the behavior models.

First, it has been suggested that hospitals attempt to maximize sales or output. Long has proposed a current output maximization objective. He states that the guiding principle for a hospital board of trustees is to "promote the social welfare by serving as many patients as possible."[22] The major constraint is that a hospital cannot run a deficit.[23] Reder suggests a modified output maximization objective where the number of patients treated per unit is "weighted by the prestige of the attending physicians."[24] Rice extends the output maximization hypothesis by assuming that a hospital is like a business firm in that it faces specific technical production constraints and will attempt to minimize the cost of its desired level of output. In addition, community pressure, professional requirements, and accreditation standards force the hospital to maximize its output of standard quality services. The minimum quality assumption is common to theoretical works suggesting output, profit, and net revenue maximization objectives. A final constraint induces production below the maximum rate in order to generate net returns (or surplus) for capacity expansion. If the desired surplus were greater than or equal to the maximum possible surplus, the profit maximizing output would be chosen. Rice's idea of a minimum surplus constraint provides a long-run version of the output maximization hypothesis by considering the need for capacity expansion.[25] The hypothesis that hospitals must generate a minimum surplus is consistent with the observation that about fifty percent of capacity expansion in non-profit hospitals is purchased with internally generated funds.[26] The model requires cost minimization for the desired volume of output, as a violation would impair the objective of maximum output subject to the minimum surplus constraint. Without further refinement, these constraints seem inconsistent with the excess capacity observed in many hospitals.

Alchian has suggested that the use of available resources involves more than constrained output maximization.[27] Hired managers may focus on a number of elements that affect their personal return. The sales maximization constraint alone is inconsistent with other economic theory and logic as it supposes that no reduction in sales, irrespective of its effect on profit or surplus, would be undertaken. Instead, the hired manager maximizes a personal utility function in which returns depend on several variables and include both pecuniary and nonpecuniary benefits. Pecuniary returns represent present and expected increases in personal wealth (e.g. salary, position security, and opportunity for advancement). Nonpecuniary returns (e.g. job satisfaction, pursuit of pleasant tasks, and attraction of congenial associates) enter the utility function and, within limits, are substitutes for pecuniary returns. The hired manager can increase his total utility while simultaneously increasing firm net returns or at the expense of net returns, particularly if his own reward does not depend on profit.

The emphasis of the Alchian analysis is that both pecuniary and nonpecuniary returns are sought by firm decision makers. More important, the substitution rate between these returns is nonzero, and the return set can be altered by managerial use of resources.[28] Two lines of development for hospital behavior theory are implied. One line focuses on the determinants of managerial utility while the other line focuses on the differences in managerial constraints among hospitals.

Newhouse has specified a utility function in a theory of hospital behavior, where total managerial utility depends on pecuniary and nonpecuniary rewards.[29] The manager will manipulate hospital resources to receive personal income and job advancement rewards. He may simultaneously gain personal satisfaction from a sense of pride in serving the community interest, attracting staff of outstanding qualifications, or receiving professional recognition. Both forms of return are hypothesized to depend on the prestige of the hospital served. Prestige, in turn, depends on the measurable aspects of hospital performance, primarily output quantity and quality. Profit or surplus is not the usual standard for performance measurement and will be pursued only as a means of expanding quantity or quality.

Hospital behavior will differ from the quantity maximization model because quality explicitly enters the manager's utility function. Quality is pursued for two reasons. First, quality increases demand and actual output. Newhouse states, "Differences in quality levels generate demand."[30] Demand is increased because prestige attracts physicians and patient referrals. In addition, quality is desired since it produces utility independently of its effect on demand. The output of various price-quantity-quality combinations that a hospital would be able to sell implies a feasibility set from which the administrator chooses on the basis of his utility function.

In a similar vein Lee has presented a "Conspicuous Production" theory of hospital behavior.[31] Total managerial utility is dependent on the status of the hospital unit. Status must be demonstrated on the basis of visible objects or symbols, such as service capacity, input range, and input quality. Hence, attention is focused on the accumulation of status-producing assets.

Because of difficulty in measuring quality in an output sense, proponents of the utility maximization hypothesis have begged the question of defining output quality. Most of the quality maximization hypotheses interpret quality as the quantity of inputs per unit of hospital output. Newhouse has discussed several criteria indicative of quality, such as personnel and capital inputs per patient day.[32] Feldstein has called quality a "catchall term to denote the capacity for output and intensity of input as well as expenditure on professional staff."[33] Both of these interpretations emphasize the quantity of labor and capital inputs used for service production. Davis states, "the production of higher quality requires primarily capital [and] use of labor in producing a given level of output."[34] The probability of cure would provide a more meaningful concept of quality but is difficult to measure and has not been empirically applied.

Lee has summarized the importance of including quality as a separate utility variable. Given a budget constraint for the sum of its intermediate service capacities, a hospital will use funds so that the marginal dollar spent on each service area gives the same addition to managerial utility. Therefore, a change in relative resource prices would induce input substitution. However, since the utility added by marginal units of input may depend on the contribution to profit, output, and quality, a hospital cannot be supposed to minimize the cost of a given quantity of output alone.[35] A greater emphasis on the quality elements of status will lower average product and raise average cost because of overcapitalization and overstaffing.

An alternative application of the Alchian concepts provides a theory of hospital behavior which focuses on formal managerial constraints. Clarkson has observed that hospital objectives are not clearly defined and that performance is difficult to measure.[36] Sets of formal rules for managerial action are used as a substitute for profit incentives to guide the use of firm resources. Differences in hospital structure create systematic differences in the form of established rules, the behavior of hospital managers, and the efficiency of resource utilization.[37] Therefore, an analysis of formal operating rules is essential to an understanding of hospital behavior.[38]

This study is concerned with the relationship of specific elements of hospital structure to technical efficiency in the production of nuclear medicine. The theories of hospital behavior provide theoretical indications of the relationship between the four structural elements to be examined and technical efficiency.

## Competition

The first hypothesis of the study states that "increased competition reduces technical efficiency" in the production of nuclear medicine. Until recently, little attention has been given to the effect of competition on hospital behavior.[39] It has been assumed that most hospitals are voluntary, nonprofit institutions and that they have little incentive to compete for customers. "Because competitive pressures are reduced or absent, hospitals may not strive to attain minimum costs of production."[40] Some studies have gone so far as to equate the nonprofit status with noncompetitiveness.[41] Others have suggested a stimulus to hospital competition as an inducement to cost discipline.

Traditional microeconomic theory defines seller competition as the pressure exerted as each alternative seller tries to offer the most attractive alternative to potential buyers. Because sellers are forced to attract buyers on the basis of price, they seek to maximize technical efficiency and to minimize production costs. However, in the market for hospital care, individual patients are unable to choose from among available hospital alternatives. For the medical industry as a whole, individual hospital services are intermediate products. The physician selects the hospital and set of hospital services to be used in the production of medical care. Hence, the emphasis of hospital competition is on the attraction of staff physicians.[42] If some capacity is accumulated to attract physician staff, irrespective of actual use, then competition for staff reduces technical efficiency.

The sales maximization model implies two effects as the nuclear medicine capacity expands. A direct effect occurs if sales maximization and cost minimization are applied to nuclear medicine independently of other hospital outputs. More competitive hospitals are compelled to use more and better resources for nuclear medicine production in order to attract patient referrals. The degree of competitive challenge will determine the effect of changes in service quality and capacity on demand, as well as on cost and price. Since increased resource utilization has the effect of raising average cost, an output maximizing hospital will add to its nuclear medicine capacity as long as there is a corresponding increase in demand and output. Figures 1 and 2 show the expected effect of increased input intensity in noncompetitive and competitive hospitals, respectively. Price elasticities are assumed to be nonzero for both markets over the relevant range of demand.[43] The less competitive hospital is assumed to have a more inelastic demand since patients and physicians cannot readily choose other alternatives in response to price changes. Although average cost increases at the same rate for both as quality and capacity expand, little increase in demand is possible for the noncompetitive hospital. Its demand curve, by definition, represents the market demand. Since the competitive firm does not service the entire market, its demand can be increased by the attraction of staff

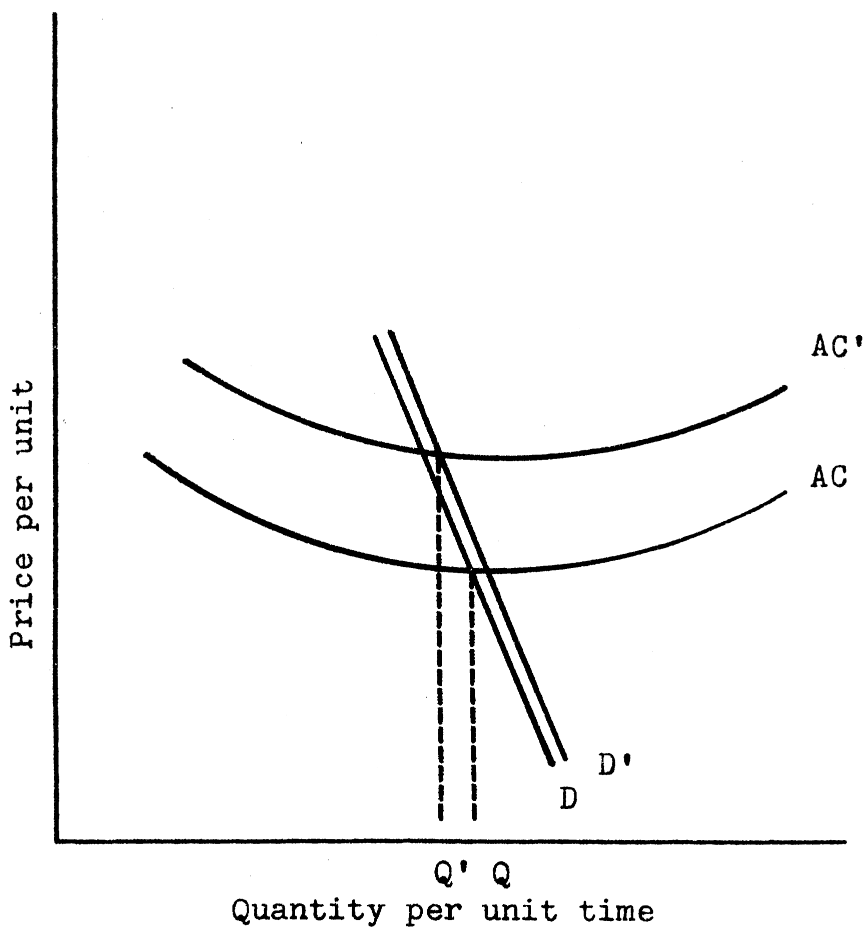



Figure 1. Quality Increases in Noncompetitive Markets

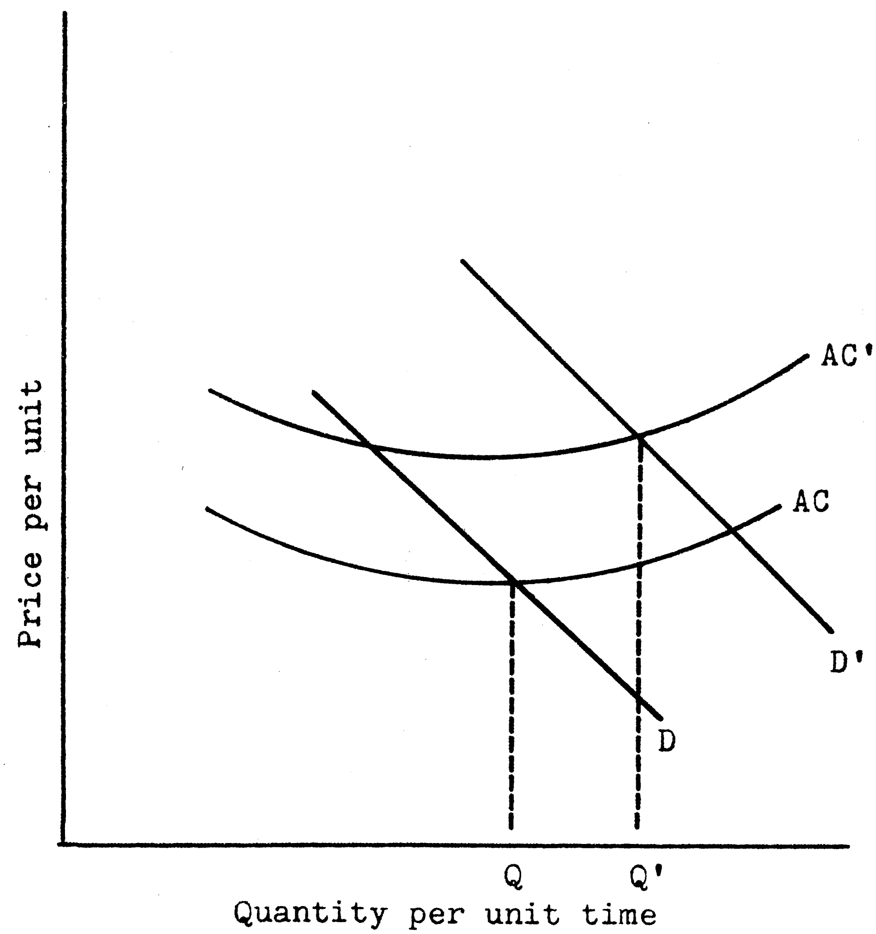


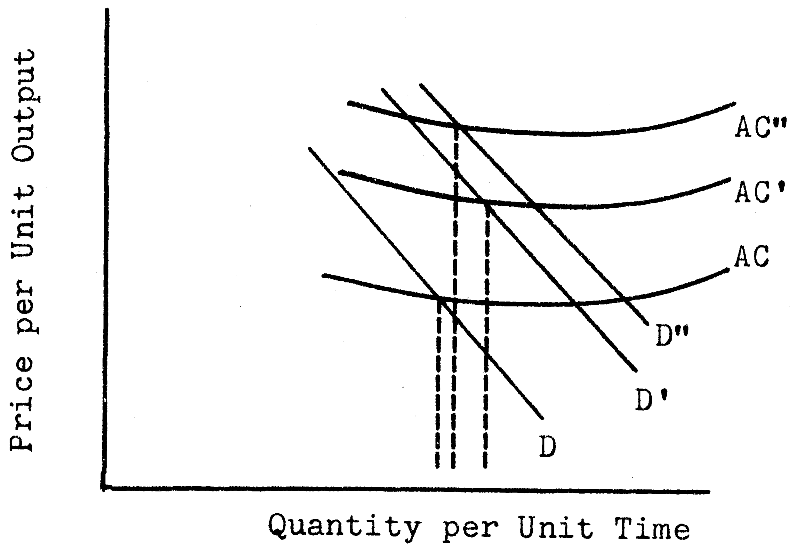

Figure 2. Quality Increases in Competitive Markets

physicians and their patient referrals. Average cost pricing is assumed in the figures, but the same result would apply to maximum profit or minimum cost constraint pricing.

Davis suggests that the availability of specialized inputs may increase the demand for other hospital products.[44] Because physicians serve on the staff of only one or two hospitals, the choice of association may depend on the capacity and range of service production. "The main way a hospital can attract more doctors is by increasing the specialized equipment it has."[45] Therefore, an increase in nuclear medicine capacity may have the additional effect of attracting staff and referrals for a range of hospital services. Although a noncompetitive hospital currently faces the market demand for each of its intermediate outputs, the competitive hospital may be able to expand the demand for services as its nuclear medicine capacity is increased.[46]

The utility maximization theory includes quality as an explicit variable which affects managerial return. The administrator's preferences for quantity and quality can be visualized as a quality-quantity indifference map. The feasible combinations of quality and quantity can be derived by varying quality and observing the effect on quantity sold. Quality can be interpreted as the accumulation of those inputs which enhance the apparent ability of the hospital to produce output (e.g. input intensity, variety, and complexity). Although initial increases in quality may expand patient referrals and demand, successive increases in costs and service prices will eventually reduce sales. Figure 3 shows the attainable quality-sales combinations under the assumption of average cost pricing. The relative movements of the demand and cost curves and the elasticity of demand will determine the new equilibrium quantity.[47]

The exact shape of the possibilities set is partially dependent on the degree of competition. Since a noncompetitive hospital faces the market demand for a particular output, higher quality will increase demand only if new customers are induced to participate in the market. Therefore, reductions in quantity demanded are likely to outweigh increases in demand. For the competitive firm an increase in quality will attract staff and patient referrals from other hospitals (if other hospitals do not alter input utilization). Hence, a given quality change would have a more expansionary effect on the sales volume of a competitive firm. Figure 4 illustrates the difference where F represents the noncompetitive feasibility locus and F' represents the competitive feasibility locus. $X_m$ represents the input combination meeting minimum standard quality for all hospitals, and $X_o$ represents the initial quality-quantity combination. Indifference curves I, II, and III represent the manager's preferences for quantity and quality. If preference orderings are similar for both administrators, the competitive hospital will choose a



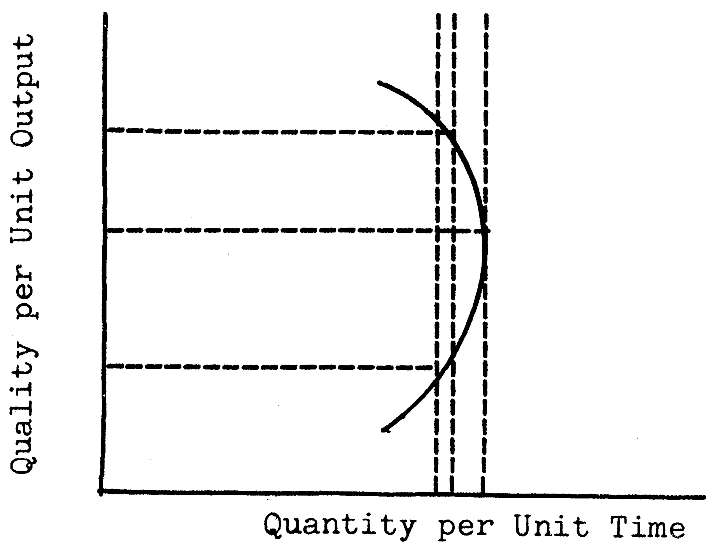




Figure 3. Quality-Quantity Feasibility Set

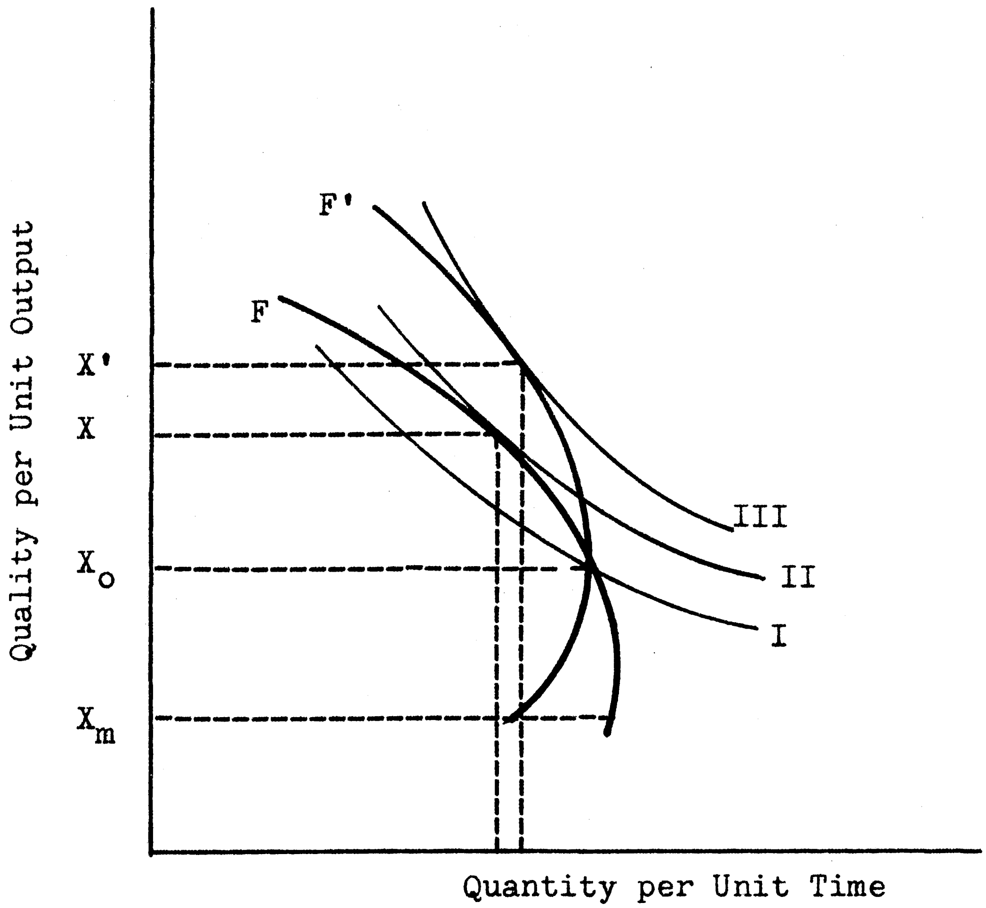



Figure 4. The Effect of Competition on the Quantity-Quality Feasibility Set

higher quality input combination, as illustrated in Figure 4. Lee describes such accumulation as offensive or independently motivated. The leading hospital in a market area attempts to enlarge or secure its current physician staff or to expand its status.

The selected quantity-quality combination also represents a greater quality bias than in the output maximization model since quality gives real managerial utility. The difference in behavior is illustrated in Figure 5. If the administrator is faced with a minimum quality constraint but derives no direct utility from quality, his indifference map is represented by the L-shaped curves i, ii, and iii. On the other hand, if he derives utility from quality above the minimum standard, the more normally shaped curves (I, II, and III) describe his preference set. When quality gives independent satisfaction, it is likely that higher quality will be substituted for quantity, as illustrated. Davis states that a quality-quantity maximizing hospital will tend to offer a lower quantity of care than one emphasizing quantity alone, as Figure 5 shows. It will also use more inputs (to demonstrate higher quality) in providing any level of service.[48]

The assumption of unchanged resource utilization by other hospitals deserves consideration. If one hospital in a market area increases its stock of inputs, other hospitals may be expected to follow. Lee states that this defensive reaction might be a stronger incentive than the

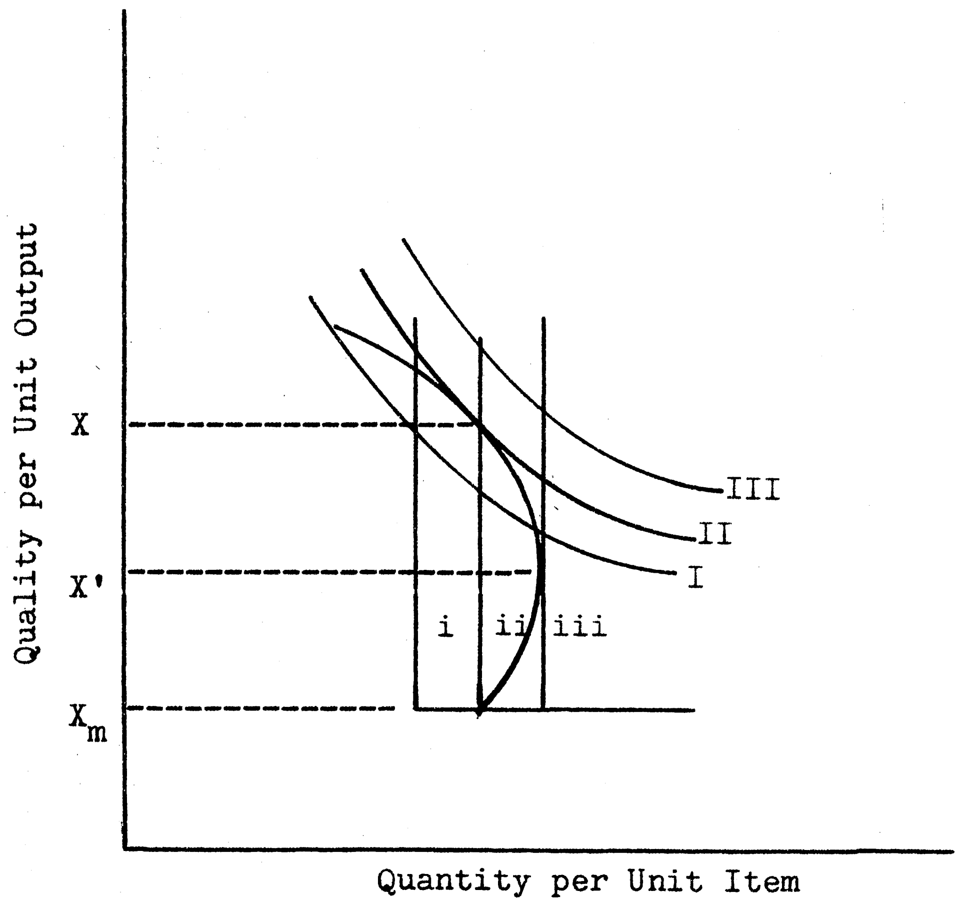



Figure 5. Quality Bias and Output Preference

offensive motivation for capacity accumulation in competitive hospitals.[49] A defensive accumulation response would alter the position of the quantity-quality feasibility locus for each competitive hospital. The expansion of demand created by offensive asset accumulation would be offset as other hospitals responded defensively. But the costs for all would rise as accumulation occurs. This result is pictured in Figure 6.

Irrespective of competitive intensity, the least cost resource combination for the desired quality-quantity combination might be chosen. However, since competition encourages a quality bias, competitive hospitals will exhibit higher input accumulations and costs per unit of output. Lee has shown that hospitals do overaccumulate some specialized inputs. Although the result was not systematically related to competition, Lee found that in 1961, thirty per cent of the 777 hospitals equipped to handle open heart surgery did not have a single case during the year.[50]

The managerial constraint model indicates a similar competitive effect. The primary objective for proprietary hospitals is the maximization of net returns. Since the managerial objective is clear and measurable, managerial action is guided without an extensive set of formal rules. In pursuit of returns the competitive proprietary firm has a stronger incentive to accumulate assets as long as marginal revenue increases more rapidly than marginal cost.

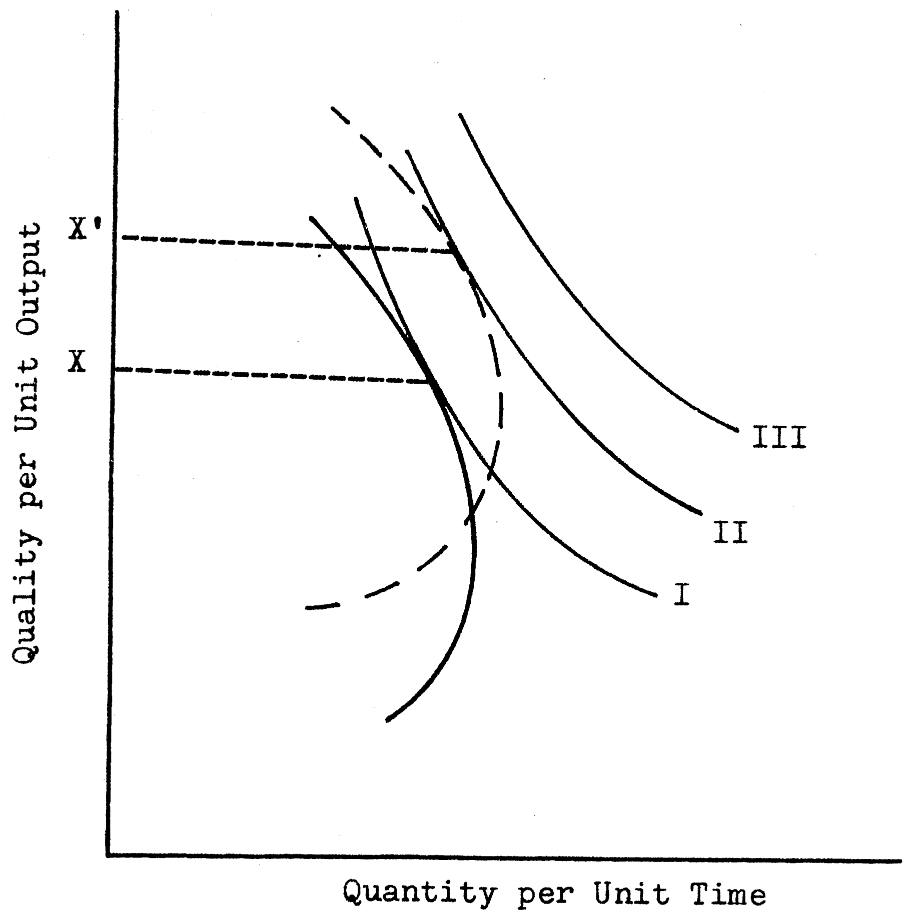



Figure 6. Defensive Behavior and the Feasibility Set

Long-run net revenue maximization may be consistent with overcapacity in a competitive environment. Moreover, if status in a competitive market provides an alternative managerial objective, the manager may try to accumulate visible status subject to a profit constraint.[51]

Clarkson has demonstrated that nonproprietary hospitals are more dependent on sets of formal regulations for managerial guidance.[52] If hospital trustees in competitive markets feel pressure to pursue the status objective, then the set of guidelines will be status oriented. Even if the emphasis of specific rules does not vary with competitive intensity, competition will create incentives for excess capacity accumulation, particularly if managerial performance is difficult to measure. The dependence of hospital behavior on the arrangement of formal rules is consistent with excess capacity and reduced technical efficiency in more highly competitive hospitals.[53]

## Profit Orientation

The second hypothesis of the study states that "a lack of profit incentive reduces technical efficiency." The bulk of the literature relating hospital structure to efficiency has concentrated on the effect of a profit orientation. Most studies rely on theoretical assertions about differences in resource use in proprietary and nonproprietary hospitals and present descriptive statistics for support.[54] Although few rigorous tests of profit incentives have been made, most proposals for improving hospital efficiency emphasize the importance of profit incentives. For example, the Committee for Economic Development has recommended a profit incentive in order to "provide a direct economic stake in successful and efficient operation of hospital services."[55]

The constrained sales maximization hypothesis suggests that nonproprietary hospitals diverge from the profit maximizing input-output combination for each intermediate service only if they are confronted with substantially different profit constraints. If a nonproprietary hospital attempts to maximize its surplus for facility expansion, then it behaves exactly like a profit maximizing proprietary hospital. Similarly, if the management of a profit oriented hospital has goals other than profit maximization, constrained by a minimum profit requirement, then it would act like a nonproprietary hospital with a similar surplus requirement.

If additional elements enter the administrator's utility function, a stronger probability of differences in technical efficiency emerges. Newhouse, Lee, and Ogur all point to the possibility of a pro-quality bias for nonprofit managers.[56] If nonproprietary managers are biased toward forms of return that induce excess capacity accumulation, then their firms will be less technically efficient. Ogur has depicted the effect in terms of complementary inputs.[57] Complementary inputs are defined as anything, besides the manager himself, used to increase quantity or to demonstrate quality. Additional complementary inputs will initially increase profit by expanding demand and revenue more rapidly than cost. However, at some point complementary input additions must reduce profit. Although a profit maximizing hospital would cease input accumulation at point A in Figure 7, a nonprofit hospital is more likely to add status-producing inputs beyond point A, thereby reducing efficiency.[58]

The managerial constraint model assumes that there are systematic differences in the rules imposed on proprietary and nonproprietary hospitals. In proprietary hospitals owners are assigned exclusive, saleable rights to the value of net returns from production. The owners appoint a manager who chooses the set of production inputs in order to maximize owner return. To insure adherence to the profit objective, various rules and controls over managerial action could be imposed.[59] However, because it is costly to detect and eliminate all undesirable deviations, the trustees can make managerial reward a positive function of profit. Bonuses, stock options, profit sharing, and position security are all possible inducements to profit maximization. "Assigning some of the residual claim to the individual who manages the hospital thus provides an additional way to monitor his activities."[60]

For nonproprietary hospitals a different kind of managerial constraint is required. The nonprofit hospital

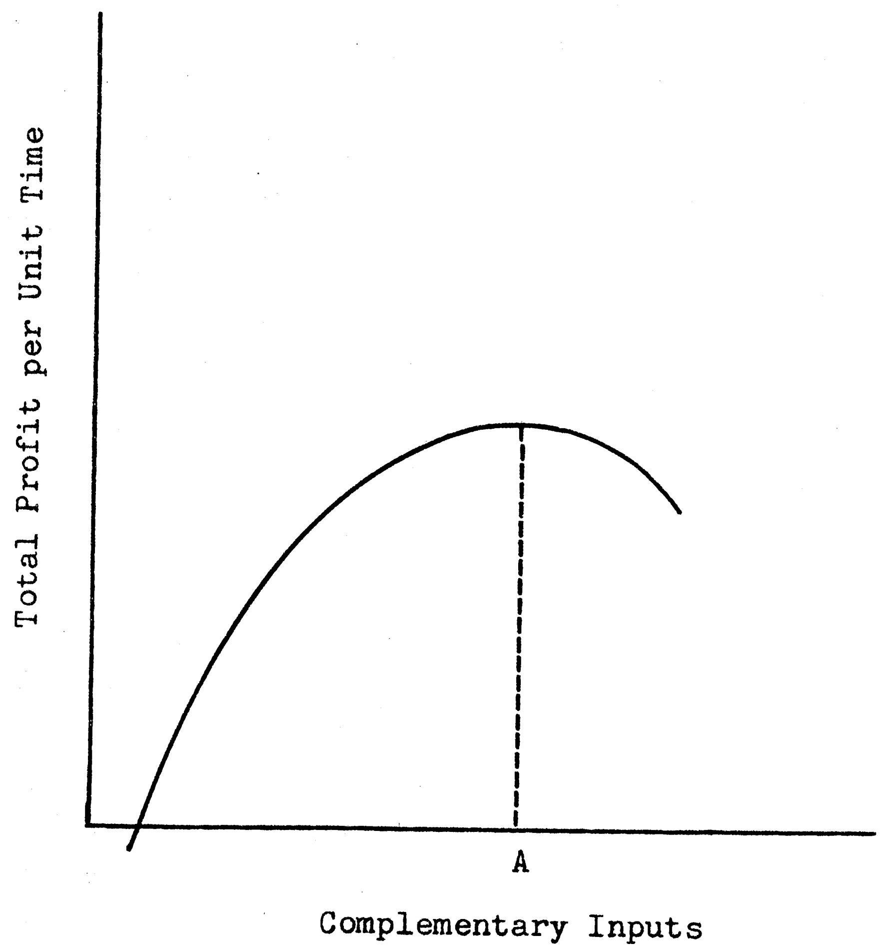



Figure 7. Complementary Inputs and Profit

trustees cannot claim or assign the flow of net returns. The absence of a connection between profit, firm objectives, and managerial return reduces the effectiveness of the profit incentive as a monitoring device. Since performance and managerial reward are not related to the current or future flow of net wealth, managers may seek other forms of return. To reduce potential abuses of managerial authority, trustees attempt to establish rules or guidelines governing specific managerial actions.[61] Even when explicit rules are established, performance may be difficult to measure. Therefore, managerial actions in nonproprietary hospitals are not effectively constrained to be cost minimizing. Clarkson has found that managers in nonproprietary hospitals are less concerned with input price information and more concerned with visible measures of quality than managers in profit oriented hospitals.[62]

Ogur has attempted to measure empirically the effect of profit orientation by testing the hypothesis that output per unit of input is lower in nonproprietary than in proprietary hospitals.[63] To test the effect of profit incentives, Ogur assumed that profit oriented hospitals combine resources to maximize profit. He found that the average product of labor was lower for nonproprietary than for proprietary hospitals and concluded that nonproprietary hospitals utilize resources less efficiently.[64] However, the conclusion is tentative because it fails to account for other structural differences in the hospitals tested.

First, because other production inputs were not directly included, the lower average products for labor might reflect differences in input mixes, resource prices, or technologies rather than efficiency. Second, Ogur points out that nonproprietary hospitals treat more severe cases which require more intensive care and more hospital services.[65] Even if resource utilization were equally efficient for both sets of hospitals, the use of patient days as the output measure would produce Ogur's result. Therefore, the evidence is consistent with, but cannot be taken as proof of, the assertion that profit oriented hospitals are systematically more efficient.

Other studies have found similar results but with similar problems. Davis found that production costs in short-term general hospitals were lower in profit oriented hospitals over the 1961 to 1969 period. Profit oriented hospitals employed fewer personnel per patient day and had a lower ratio of plant assets to daily census than nonprofit hospitals. However, both ratios increased more rapidly over the period in proprietary hospitals.[66] Wasyluka found that proprietary hospitals had fourteen percent fewer employees per patient than nonprofit hospitals.[67] Since variations in absolute costs may be caused by difference in care intensity or case complexity, it is impossible to attribute them to differences in technical efficiency.

Service Range

The third hypothesis states that "a broader service range reduces technical efficiency." Service range refers to the variety of specialized intermediate goods which a hospital can produce. Hospitals of a given bed or patient capacity may vary in the range of services offered as well as in the capacity for each type of service. Each intermediate service is associated with a production function which specifies the relationship of specialized and non-specialized inputs to the maximum possible rate of output. Therefore, the capacity for each hospital service depends on the set of resources chosen by the manager. Actual output, however, depends on patient referrals and physician decisions regarding the use of alternative therapies.[68]

As the range of services offered expands, the cost per unit of each individual service must increase, other things constant. For a given patient capacity, an expansion of the service range increases the variety of cases that can be treated and the therapies available. As the variety of cases and treatment alternatives increase, the number of patients using each specific service tends to decline, and input per unit of output tends to increase. With respect to nuclear medicine, higher nuclear medicine output intensity might allow more efficient resource utilization if a narrower case mix does increase the probability of capacity use.

Although the hypothesis implies that service range has an independent effect on technical efficiency, service range is often related to other elements of hospital structure. Just as input intensity for a particular type of output may be used to indicate quality, the range of services available also demonstrates quality. Therefore, the structural conditions that create a pro-quality bias are expected to induce greater service range accumulation and reduced technical efficiency for each intermediate service. First, competition is thought to induce a broader service range. Competition for staff and patient referrals implies a return to little used capacity that strengthens the general range of demand.[69] Therefore, given input capacity, nuclear medicine would be a smaller percentage of total output in more competitive hospitals. Second, nonprofit hospitals are assumed to acquire a broader service range and would be expected to exhibit a lower muclear medicine intensity (given capacity) than proprietary hospitals.[70] The service range hypothesis requires investigation with respect to its collinearity with other elements of hospital structure and with respect to its independent effect on technical efficiency.

## Training

The fourth hypothesis of the study states that "in-house manpower training reduces technical efficiency." Since training is a joint product with medical service, it is commonly assumed that a training program must increase resource requirements without a corresponding increase in output. The research hypothesis depends on two relationships concerning training intensity and hospital structure. First, Lave, Lave, and Silverman have assumed that training is most intensive in status biased hospitals.[71] Because competitive and nonprofit hospitals tend to be status biased, they are more likely to have training programs if such programs contribute to status and managerial utility. In order to examine the independent effect of training on efficiency, these relationships must be tested empirically.

The second relationship supposes that training reduces output efficiency. The actual relationship of training to efficiency depends on the definition of labor input and cost. Trainees produce medical outputs as a part of their training routine. Because their input represents the exhaustion of human resources with alternative potential uses, trainees represent part of the labor input in real terms. In a pecuniary sense, however, unpaid trainees may be treated as a free but productive resource. The actual cost imposed by training programs is not trainee-labor wages, but the cost of training equipment and teaching personnel. Areas requiring little direct trainee supervision may incur modest increases in labor costs. Areas requiring substantial supervisory personnel will experience larger money costs of training. Moreover, if training programs require technical personnel with higher qualifications, money costs will increase. The teaching cost is partially offset by the value of trainee output. The cost is also reduced to the extent that the training hospital retains its own trainees as employees. In this case the training cost could be treated (along with wages) as a cost of acquiring additional units of labor. Part of the cost would be recovered through the value of future production.

Training intensive hospitals will exhibit lower medical outputs per unit of paid labor input to the extent that output reductions are not compensated by the value of present or future trainee production. The observed divergence would, of course, increase if trainees were included in the input measure.

## Summary

This chapter has reviewed selected writings that pertain to the hypotheses of the study. The structure of the hospital industry and the concept of technical production efficiency were reviewed. The focus on nuclear medicine as a specific hospital subindustry was analyzed as a technique for avoiding the homogeneity problem common to hospital industry studies. Emphasis has been placed on the evaluation of the four structure-efficiency hypotheses within current theoretical models of the hospital industry. Available empirical evidence of the hypothesized relationships has been reviewed.

## FOOTNOTES

[1]Commission of Professional Hospital Activities, The Record (New York, 1970), p. 3.

[2]Ibid.

[3]Wayne Hales, "An Analysis of the Effects of Competitive Markets on Hospital Costs in Oklahoma" (Unpublished Dissertation, Oklahoma State University, Stillwater, Oklahoma, 1974), p. 5.

[4]Marc Nerlove, Estimation and Identification of Cobb-Douglas Production Functions (Chicago, 1965), p. 6.

[5]Taro Yamane, Mathematics for Economists (Englewood Cliffs, 1968), p. 475.

[6]Kenneth Clarkson, "Some Implications of Property Rights in Hospital Management," Journal of Law and Economics, XV (October, 1972), p. 374.

[7]Jonathan Ogur, "The Nonprofit Firm: A Test of the Theory for the Hospital Industry," Journal of Economics and Business, XI (Winter, 1974), p. 118.

[8]Clarkson, p. 376.

[9]Robert Rice, "An Analysis of the Hospital as an Economic Organism," Modern Hospital, CVI (April, 1966), p. 87.

[10]Karen Davis, "Economic Theories of Behavior in Non-profit Private Hospitals," Economic and Business Bulletin, XXIV (Winter, 1972), p. 3.

[11]Clarkson, p. 363.

[12]Maw Lin Lee and Richard Wallace, "Some Problems in Estimating Multicost Production Functions," Western Economic Journal, XI (September, 1973), p. 351.

[13]John Rafferty, "Measurement of Hospital Case Mix," Applied Economics, V (Winter, 1973), p. 301.

[14]Mary Ingbar and Lester Taylor, Hospital Costs in Massachusetts (New York, 1968), p. 1.

[15]Judith Mann and Donald Yett, "The Analysis of Hospital Costs," The Journal of Business, LV (1968), p. 194.

[16]Judith Lave and Lester Lave, "Economic Analysis for Health Service Efficiency," Applied Economics, I (1970), p. 294.

[17]Martin Feldstein, "Hospital Cost Variations and Case Mix Difference," Medical Care, III (April, 1971), p. 95.

[18]Rafferty, "Measurement of Hospital Case Mix," p. 303.

[19]Joseph Newhouse, "Toward a Theory of Nonprofit Institutions: An Economic Model of a Hospital," American Economic Review, XXXVII (March, 1970), p. 68.

[20]John Rafferty, "Hospital Output Indices," Economic and Business Bulletin, XXIV (1972), p. 21.

[21]Newhouse, p. 68.

[22]Millard Long, "Efficient Use of Hospitals," in The Economics of Medical Care (Ann Arbor, 1964), p. 212.

[23]Ibid.

[24]Melvin Reder, "Some Problems in the Economics of Hospitals," American Economic Review, LV (May, 1965), p. 401.

[25]Rice, p. 88.

[26]Ibid., p. 89.

[27]Armen Alchian, "The Basis of Some Recent Advancements in the Theory of Management of the Firm," Journal of Industrial Economy, LI (November, 1965), p. 32.

[28]Ibid., p. 34.

[29]Newhouse, p. 65.

[30]Ibid., p. 64.

[31]Maw Lin Lee, "A Conspicuous Production Theory of Hospital Behavior," Southern Economic Journal, XXXIX (July, 1971), p. 48.

[32]Newhouse, p. 64.

[33]Feldstein, p. 10.

[34]Davis, "Economic Theories of Behavior in Nonprofit Private Hospitals," p. 3.

[35]Lee, p. 46.

[36]Clarkson, p. 366.

[37]Ibid., p. 365.

[38]Ibid., p. 364.

[39]Hales, p. 2.

[40]Committee for Economic Development, Building a National Health Care System (New York, April, 1973), p. 46.

[41]Ibid., p. 10.

[42]Hales, p. 15.

[43]Davis, "Economic Theories of Behavior in Nonprofit Private Hospitals," p. 4.

[44]Ibid.

[45]Ibid., p. 2.

[46]Lee, p. 52.

[47]Newhouse, p. 69.

[48]Ibid., p. 67.

[49]Lee, p. 54.

[50]Ibid.

[51]Clarkson, p. 369.

[52]Ibid., p. 366.

[53]Ibid.

[54]Ogur, p. 118.

[55]Committee for Economic Development, p. 14.

[56]Ogur, p. 119.

[57]Ibid.

[58]Ibid.

[59]Clarkson, p. 364.

[60]Ibid., p. 369.

[61]Ibid., p. 366.

[62]Ibid.

[63]Ogur, p. 118.

[64]Ibid., p. 117.

[65]Ibid.

[66]Davis, "Rising Hospital Costs: Possible Causes and Cures," p. 1364.

[67]Ray Wasyluka, "New Blood for Tired Hospitals," Harvard Business Review, LXXII (September, 1970), p. 67.

[68]Lee and Wallace, p. 353.

[69]Ibid., p. 354.

[70]Davis, "Economic Theories of Behavior in Nonprofit Private Hospitals," p. 10.

[71]Judith Lave, Lester Lave, and Lester Silverman, "Hospital Cost Estimation Controlling for Case Mix," Applied Economics, IV (1972), p. 166.

CHAPTER III

# METHODOLOGY

The analysis in Chapter II indicates that the market mechanism fails to promote technical efficiency in the hospital industry and in specific hospital subindustries. The primary source of the inefficiency is hypothesized to be the capacity accumulation bias created by four elements of firm structure. This chapter presents a methodology for investigating the relationship of competition, profit incentives, service range, and training intensity to relative efficiency in the production of nuclear medicine.

A commonly applied device for estimating and comparing the relative efficiency of firms in a particular industry is an industry production function.[1] This chapter discusses the data source and methodology for constructing a set of nuclear medicine production functions for groups of hospitals operating under different structural circumstances. Specific methods for hospital grouping and hypothesis testing are developed. The interpretations of an estimated production function and its use in comparing relative efficiencies are reviewed. A technique for constructing a production frontier as an alternative test of relative firm efficiency is outlined. Finally, this chapter discusses criteria for the selection of a particular production function.

## Sources of Data

Most of the data which are employed in this study are from the American College of Radiology (ACR) and Energy Research and Development Administration (ERDA) Census of Nuclear Medicine.[2] The census format was developed during 1973 and the data were collected and made available in 1974. Although the primary purpose of the census is to provide information for regional planning in nuclear medicine, much of the data is applicable to the construction of a set of production functions. Questionnaires were sent to all of the 2,050 short-term general hospitals known to have a nuclear medicine facility. Of the questionnaire responses, 1,362 are usable for this study. The specific elements of data to be used are listed below:

1. Hospital identification by American Hospital Association number.
2. Hospital location by city, county, and state.
3. Hospital bed capacity.
4. Patient referral radius.
5. Administrative control.
6. Quantities of each nuclear medicine procedure performed.
7. Kinds and quantities of nuclear medicine equipment owned.

8. Numbers of part-time and full-time nuclear medicine personnel.
9. Number of trainees.
10. Personnel education and training information.

In addition to the data provided by the ACR-ERDA census, the following data are also available:

1. Service price data for each nuclear medicine procedure is available on a statewide basis from the "Professional Service Index" of Blue Cross and Blue Shield Plans.
2. Capital equipment price data are available from six manufacturers of nuclear medicine equipment.

## The Production Function

The primary empirical construct for this research is the estimation of a set of production functions for nuclear medicine. A microeconomic production function is a technical relationship which describes the maximum rate of output that can be produced from various rates of resource utilization.[3] This definition suggests that production is a physical process in which inputs are transformed into outputs. The production function is not limited to a single production technology but includes the range of input-output combinations for conceivable methods of production. In this context the production function sets the highest limit on the output which a firm can hope to obtain with a certain combination of resource inputs during the production period at the given state of technical knowledge. Given the technical possibilities that are set up by the production function, the choice of a production method is a matter of other economic considerations, such as relative resource prices.[4] As demonstrated in Chapter II, maximum technical efficiency requires operation on the production function for the chosen rates of resource input.

A commonly used empirical form of the production function is the Cobb-Douglas specification,

$$Q = AL^{\alpha} K^{\beta}, \qquad (5)$$

where Q is output per unit time, L and K are the respective labor and capital inputs per unit time, and A, $\alpha$ , and $\beta$ are the parametric constants to be estimated. $\alpha$ and $\beta$ are the "input elasticities", which describe the relationship of the respective labor and capital inputs to the rate of output. A is the "scale parameter" which shows the relative height of the production surface and indicates the state of technical knowledge.[5] By specifying Equation (5) in logarithmic form and by using empirical data for labor, capital, and output, a least squares regression program can be used to estimate the parameters of a nuclear medicine production function.

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K \qquad (6)$$

The $\alpha$ and $\beta$ represent the slope terms and ln A represents the intercept term.

The empirical form of the estimated production function does not correspond perfectly to the theoretical definition. Because the multiple linear regression technique minimizes the sum of squared deviations of actual from predicted firm outputs, some observed output levels will lie above the estimated production function. However, the true production function requires that all outputs must lie on or below the production surface. An output level above the function would define a new state of the arts in production. Instead of the precise theoretical definition, some economists have suggested that "the estimated production function represents the average production surface for the industry."[6]

The concept of an average production surface has generated several interpretations. One possible explanation is that the estimated function represents an average industry technology. This view assumes that firms face different physical production constraints. Another explanation assumes that the average production function shows the maximum sustainable output rate over some time period. Production divergences above the sustainable output would reflect random and uncontrolled production shocks. Because such shocks cannot be controlled or predicted, they cannot be treated as production inputs. Aigner and Chu refer to "random fluctuations due to 'lucky' coincidences of good weather, sunspots, etc."[7] Devoid of the random disturbances, no divergences above the production function would be observed.

A third explanation, used by Aigner and Chu, provides an important application of the estimated production function to this study.

> From a more practical standpoint, if, for instance, we wish to estimate how much output on the average could be obtained from a firm in the industry with a certain set of inputs, then the average concept would obviously be the correct one to employ.[8]

Significant differences in production surface parameters would reflect differences in expected average output from a given input combination. Such differences in expected average output would imply differences in technical efficiency.

This interpretation suggests that an estimated production function could be used as a measure of relative efficiency in the production of nuclear medicine. The firms in the hospital industry can be divided into segments based on the four structural elements to be examined, and an average production surface can be estimated for each segment. A comparison of the estimated parameters would provide a test of relative efficiency. To apply such a technique to the four hypotheses of the study requires two sets of specifications. First, an appropriate method of segmenting the industry in accordance with each hypothesis is required. Second, labor, capital, and output for each firm must be specified from the available data in a suitable form for estimation in Equation (6).

## Test Groupings and Parameter Comparisons

The test of each hypothesis is performed independently. Each test requires a division of the industry into data subsets based on the structural element under observation. To test the hypothesis "increased competitive intensity reduces technical efficiency," a measure of hospital competition is required. The most commonly used measures of competition and concentration are market share proportions and concentration ratios. Unfortunately, such measures are difficult to obtain for the hospital industry because there are a large number of separate geographic markets. Although a few hospitals draw patient referrals on a national basis for a few specialized services, most hospitals have a patient referral radius limited by feasible physician and patient transportation distances.[9]

For the hospital industry, then, measures besides concentration are related to firm competition. First, there is the size of the geographic area from which the hospital draws patients, measured as the patient referral radius. Other things constant, a larger patient referral radius increases the number of hospitals with which the firm conceives itself to be in competition.[10] Second, the density of hospitals within the geographic area effects competition by altering the number of alternatives available. Third, the density of population within the market area is likely to be associated with the total volume of hospital production and the intensity of competition. The index of competitive intensity, CI, will be:

CI = ( referral radius ) x ( hospital density ) x ( population density ).

Such an index might be inadequate if the purpose were to construct a precise continuum of competitive intensity. However, as the purpose is to segment firms into aggregate categories, the procedure is less prone to serious distortions. On the basis of the competition index, hospitals will be divided into three groups, and an average production surface will be estimated for each group. The theoretical analysis anticipates lower production surface parameters as competition increases.

To test the hypothesis "a lack of profit incentive reduces technical efficiency," firms will be divided into three categories. These are proprietary hospitals, private nonprofit hospitals, and government hospitals. Production surface parameters will be estimated for each group. On a theoretical basis lower parameters are expected for the nonprofit groups.

A priori reasoning suggests that the elements of service range and in-house manpower training are systematically related to competitive intensity and profit incentives. Therefore, the following hypotheses are tested before the structural categories are defined:

1. High competitive hospitals have greater average

service ranges than low competitive hospitals.

2. Nonprofit hospitals have greater average service ranges than proprietary hospitals.
3. High competitive hospitals have higher average training levels than low competitive hospitals.
4. Nonprofit hospitals have higher average training levels than proprietary hospitals.

The appropriate t-statistic for comparing mean values taken from two data subsets is:[11]

$$t = \frac{(u_1 - u_2) - (U_1 - U_2)}{(s_1^2 + s_2^2)^{\frac{1}{2}}} \quad ,$$

where $U_1 - U_2 = 0$. The sample means for the data subsets are $u_1$ and $u_2$. The true means are $U_1$ and $U_2$, respectively, and the standard errors of the sample means are $s_1$ and $s_2$, respectively. Adjustments for competition and profit orientation are based on these test results and precede an examination of the structure-efficiency hypotheses.

To test the hypothesis that "a broader service range reduces technical efficiency," a method of approximating the variety of services offered by individual hospitals is required. A uniform measure for service range is not available in a consistent form. Instead, service range is approximated by the intensity of nuclear medicine production. Given a hospital bed capacity and a capacity for a single specialized service, Lee and Wallace argue that a broader service range would reduce the share of total output produced by the single service.[12] Similarly, a broader service range would reduce the utilization of a given nuclear medicine capacity since fewer beds would be occupied by patients using nuclear medicine outputs. Nuclear medicine production intensity can be measured as the ratio of nuclear medicine output to total bed capacity, and hospitals can be divided into groups for testing. The expected theoretical result is lower production surface parameters for lower nuclear medicine intensity hospitals (i.e. those with a broader service range).

To test the hypothesis "in-house manpower training reduces technical efficiency," hospitals will be grouped on the basis of their relative training program sizes. Either a relative or an absolute training level measure could be used. The relative measure is preferred since the effect of an additional trainee would depend on the size of the nuclear medicine unit. Relative training level is measured as the ratio of trainees to full-time nuclear medicine personnel. High training level hospitals are expected to exhibit lower production surface parameters.

The four hypotheses of the research are examined separately. For each hypothesis test the hospital population is divided into subsets on the basis of the structural classifications developed above. Then, a production surface of the form in Equation (6) is derived for each data subset. If the estimated coefficients are significantly different, then a relationship between the particular structural element and technical efficiency is implied.[13]

Two statistical tests can be applied to compare the coefficients associated with different subsets. First, the Chow Test provides a test of different estimations of the same regression model. The Chow Test is based on a comparison of the sum of the squared residual terms for pooled data and for separate data subsets. If the pooled data coefficients fit each of the individual subsets (within error), then no additional explanatory power is gained from the subset division. The appropriate F-statistic for the Chow Test is:[14]

$$F_{(K,\ T_1 + T_2 - 2K)} = \frac{(Q_p - Q_1 + Q_2) \div K}{(Q_1 + Q_2) \div (T_1 + T_2 - 2K)},$$

where K is the number of parameters in the regression model, and $Q_p$, $Q_1$, and $Q_2$ are the sums of squared residuals for pooled data, the first subset, and the second subset, respectively. $T_1$ and $T_2$ are the number of observations in the respective subsets.

Although the Chow Test provides an overall indicator of the similarity of differences among subset coefficients, it does not directly examine the individual model parameters, $\ln \hat{A}$, $\hat{\alpha}$, and $\hat{\beta}$. A second test can be applied to compare corresponding parameters from different data subsets. The test statistic for comparing an individual model parameter from two separate estimations (e.g. ) is:

$$t = \frac{(\hat{\alpha}_1 - \hat{\alpha}_2) - (\alpha_1 - \alpha_2)}{(s_1^2 + s_2^2)^{\frac{1}{2}}} ,$$

where $\alpha_1 - \alpha_2 = 0$. $\alpha_1$ and $\alpha_2$ are the actuals values of the parameter for the two data subsets. $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are the corresponding predicted values, and $s_1$ and $s_2$ are the standard deviations for the respective subset coefficients.[15] If the calculated t-statistic exceeds the tabulated value corresponding to a selected significance level, then a difference in input-output relationships among the subsets is identified.

## The Data Format

The production function form in Equation (6) requires data for L, K, and Q. The primary labor input for the nuclear medicine industry is the nuclear medical technologist. The nonphysician labor input for each hospital is measured as the sum of full-time nuclear medicine personnel plus one half the sum of part-time nuclear medicine personnel, as measured by the ACR-ERDA census. For each hospital the capital input is measured as the summed quantities of each type of nuclear medicine equipment, weighted by the current market prices for equipment inputs. This is described by

$$K = \sum_{i=1}^{47} k_i R_i \quad ,$$

where K is the hospital capital stock, $k_i$ is the number of units of the $i^{th}$ type of equipment, and $R_i$ is the current dollar price of the $i^{th}$ type of equipment. Therefore, the capital input is measured in dollars.

The nuclear medicine industry output consists of fifty-eight diagnostic and therapeutic procedures. The total output of each hospital is measured as the quantity of each procedure, weighted by an index price for each procedure. This is represented by

$$Q_j = \sum_{i=1}^{58} P_i Q_{ij} \quad ,$$

where $Q_j$ is the total nuclear medicine output for the $j^{th}$ hospital, $P_i$ is the index price for the $i^{th}$ procedure, and $Q_{ij}$ is the number of procedures in the $i^{th}$ category performed by $j^{th}$ hospital. The index price for each procedure is measured from state level price data as the weighted average price of the output. This is shown by

$$P_i = \sum_{m=1}^{43} P_{im} Q_{im} \div \sum_{m=1}^{43} Q_{im} \quad ,$$

where m is the $m^{th}$ state, $P_{im}$ is the state level price for the $i^{th}$ output, and $Q_{im}$ is the total state quantity of the $i^{th}$ output.[16]

## The Production Frontier

Although the average production surfaces provide a basis for comparing relative technical efficiencies, it is not clear that an average production surface is the best efficiency benchmark. The true production function may not be a neutral transformation of the estimated average function. Substantial divergences of true and estimated input elasticities would reduce the validity of efficiency comparisons based on the average production surfaces.[17] The estimated function, in such a case, misspecifies the actual shape of the production surface. A second method for comparing relative firm efficiency under the four hypotheses of the study utilizes an estimation of a nuclear medicine production frontier. The production frontier better represents the theoretical concept of a production function because all observed firm outputs are constrained to lie on or below the surface. Since the uncontrolled production factors (e.g. weather) are likely to be insignificant to nuclear medicine production, serious random shocks are unlikely. Therefore, a production frontier conceptually exists showing the maximum output for each possible set of inputs.

A nuclear medicine production function can be estimated with linear programming techniques by constraining all firm outputs to lie on or below the frontier. The linear programming method takes the highest observed output value for each input combination as the standard for that input set. Parameter estimates result in a production surface on which the set of one hundred percent efficient firms would lie. The estimation of such a "deterministic frontier" has become relatively common in empirical production studies.[18]

For convenience in developing the linear programming format, the following matrices and vectors are defined:[19]

$$A = \underset{1362 \times 3}{\begin{pmatrix} 1 & \ln L_1 & \ln K_1 \\ \vdots & \vdots & \vdots \\ 1 & \ln L_i & \ln K_i \\ \vdots & \vdots & \vdots \\ 1 & \ln L_n & \ln K_n \end{pmatrix}}$$

$$b = \underset{1362 \times 1}{\begin{pmatrix} \ln Q_1 \\ \vdots \\ \ln Q_i \\ \vdots \\ \ln Q_n \end{pmatrix}}$$

$$c = \underset{3 \times 1}{\begin{pmatrix} 1 \\ \overline{\ln L} \\ \overline{\ln K} \end{pmatrix}}$$

$$x = \begin{pmatrix} \ln\hat{A} \\ \hat{\alpha} \\ \hat{\beta} \end{pmatrix}_{3 \times 1}$$

$$e = \begin{pmatrix} e_1 \\ \cdot \\ \cdot \\ e_i \\ \cdot \\ \cdot \\ e_n \end{pmatrix}_{1362 \times 1}$$

$$v = \begin{pmatrix} 1 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{pmatrix}_{n \times 1}$$

where $L_i$, $K_i$, and $Q_i$ are labor input, capital input, and output, respectively, for the $i^{th}$ hospital. The industry average values for the logarithm of labor, capital, and output are $\overline{\ln L}$, $\overline{\ln K}$, and $\overline{\ln Q}$. The estimated values of the production function parameters are $\hat{A}$, $\hat{\alpha}$, and $\hat{\beta}$. For a given set of estimated parameters, the residual terms for each hospital form the e vector. The v vector is a "sum vector" as described by Hadley, to be used for finding the sum of the elements in any specific vector.[20]

To estimate the Cobb-Douglas production function in Equation (5), all divergences from the estimated surface can be forced to lie below the production function, such that

$$Ax \geq b. \tag{7}$$

Because an infinite set of estimated parameters would satisfy the inequality in Equation (7), the production surface must be forced to lie as closely as possible to the set of observed points. To be most consistent with the multiple linear regression format, the model could be specified to minimize the sum of the squared residual terms. Hence, the problem is to minimize $e'e$, subject to Equation (7). However, a quadratic objective function places an emphasis on the extreme observation values. Since the linear programming technique already focuses on extreme observations, this objective function is undesirable. Instead, Aigner and Chu suggest the minimization of the sum of the residual terms. Timmer points out that "minimizing the linear sum of the divergence terms avoids the additional weighting of extreme observations."[21] By constraining each residual term to be non-negative, Equation (7) becomes,

$$Ax - e = b.$$

The estimation technique then, is to minimize $e'v$,

subject to $Ax \geq b$,

and subject to $x > 0$.

To apply the available linear programming package, the sum of the residual terms must be expressed as a function of lnA, $\alpha$, $\beta$, L, and K. This can be done as:

$$e'v = (Ax)'v - b'v \quad (9)$$

For any given set of data, b'v must be a constant and can be dropped from Equation (9) without consequence. Since (Ax)'v represents the total of the predicted logarithm of output values for all firms, it can be shown that,

$$(Ax)'v = (c'x)n, \quad (10)$$

where n is a scalar equal to the number of firms in the data universe. Therefore,

$$e'v = (c'x)n \quad (11)$$

Equation (11) provides an expression for e'v that is suitable as a linear programming objective function. For computational purposes it is desirable to divide Equation (11) by the number of observations in the sample.[22] The model for the estimation of lnA, $\alpha$, and $\beta$ is:

Minimize

$$c'x$$

subject to $Ax \geq b$

and subject to $x > 0$.

The estimated production function parameters describe a production surface consistent in the theoretical definition requiring maximum output per unit of input.

## Estimating a Probabilistic Frontier

The linear programming technique is of value because it provides an alternative estimate of the true production function. However, the technique is subject to two problems of particular importance. First, if there are no firms in the industry that are actually achieving technical efficiency, then even the deterministic frontier will not represent the true production function. The problem, however, does not invalidate the methodology for this research since the frontier is to be used as an efficiency datum of the correct shape. Essentially, the most efficient firms are defined as one hundred percent efficient.

The shape of the estimated production frontier is a more serious concern. The procedure takes set of highest output values for each resource combination as the standard. Strange results could occur if a few hospitals exhibit unusually high output rates that are not sustainable, or if errors in data reporting have occurred. The problem is complicated by the fact that the linear programming procedure provides no goodness-of-fit measures for the estimated parameters. These limitations lead to the second problem, the possibility of a significant error in the estimated input elasticities. If the input elasticities are incorrectly estimated, the shape of the production frontier will not correspond to the actual shape. Timmer states, "Because only extreme observations are used, the estimation is subject to errors."[23] Since no check on the adequacy of the estimates is provided through goodness-of-fit statistics, serious estimation errors might not be obvious from the parameter calculation alone. If the estimated surface shape is not a reliable estimator of the true production function, then the technique fails to provide an appropriate efficiency datum.

To reduce the likelihood of allowing extreme observations to distort the estimated frontier, Timmer has added an additional step in the linear programming procedure. "To avoid the problem of spurious errors in extreme observations, it is desirable to fit a probabilistic frontier."[24] This can be done by translating Equation (5) into a probability statement of the form

$$\Pr\,(\hat{A}\,L_i^{\hat{\alpha}}\,K_i^{\hat{\beta}} \quad Q_i) > \; P,$$

where P is an externally specified probability. For the deterministic frontier, P is equal to one. Aigner and Chu have also referred to such a device. "One may pursue less than one hundred percent efficient frontiers using chance constraint programming ideas . . . with a specified probability constraint which is to hold."[25] By throwing out the most efficient firms, the chance of serious distortions of the production surface shape is reduced.

There may be no way to judge the appropriate probability level to be specified for the given data set. An arbitrary value for P could, of course, be chosen. As an alternative to the arbitrary selection of P, Timmer has utilized a gradual reduction of P in small increments until the estimated parameters stabilize. The technique discards the most efficient observations slowly until those creating the apparent distortion are eliminated. Timmer argues that once the parameters have stabilized, "it is likely that the estimation errors created by the focus on extreme observations have been largely overcome."[26]

## A Test of Relative Efficiency

Unlike the multiple linear regression format, the linear programming technique does not imply an average input-output relationship. Since no hospital output can exist above the production frontier, it can be used as an efficiency datum. Relative firm efficiency can be evaluated as the percentage divergence from the production frontier. The index of efficiency divergence is measured by

$$D_i = (\hat{Q}_i - Q_i) \div \hat{Q}_i.$$

For a one hundred percent efficient firm, the index would be zero. As the divergence from the frontier function increases, the index of efficiency divergence will increase. For the set of nuclear medicine producers, the observed efficiency divergences can be regressed on the four structural elements of concern: Competitive intensity, profit incentive, service range, and training level.

$$D = B_0 + B_1 CI + B_2 NMI + B_3 TR + B_4 G + B_5 P,$$

where: D = efficiency divergence index

CI = competitive intensity index

NMI = nuclear medicine intensity index

TR = relative training level

G = a dummy variable for government hospitals

P = a dummy variable for proprietary hospitals

## Selection of a Production Function

The Cobb-Douglas form of the production function has been used for this study for two primary reasons. First, the estimation format allows the use of physical data for inputs and outputs. Because the use of actual input-output data does not require the assumption of cost minimization, it is not necessary to suppose that firms acquire resources on the basis of factor prices. Since it is not clear that hospitals act to minimize production costs, the avoidance of such a constraint is desirable. Moreover, physical input and output data are available for individual hospitals. Before the data could be used to estimate a production function form requiring factor price data, statewide aggregates would be required. This would be particularly undesirable for a study focusing on the efficiency and structure relationships for individual firms, and would reduce the advantage to be gained from the availability of individual firm data.

Second, the Cobb-Douglas function does not require that the input elasticities must sum to unity. If the industry is characterized by increasing or decreasing returns to scale over the relevant range of output, then production function formats restricting the input elasticity values would be less desirable.

The most important criterion for choosing a production function is the true form of the input-output relationship. However, there is no a priori basis for selecting the most suitable description of nuclear medicine production. The empirical validity of the Cobb-Douglas form for the nuclear medicine industry is examined in Chapter IV.

## Summary

This chapter has presented the sources of data and an estimation technique for constructing a set of nuclear medicine production surfaces. Use of the average production surface was examined as an efficiency comparison device. Frameworks for firm grouping and hypothesis testing and for the estimation of a nuclear medicine production frontiers as an alternative efficiency datum were developed. Problems and criteria involved in selection of the Cobb-Douglas production function were discussed.

FOOTNOTES

[1]J. S. Cramer, Empirical Econometrics (Amsterdam, 1971), p. 210.

[2]American College of Radiology, Regionalization in Nuclear Medicine (Washington, D. C., 1973), pp. 1-30.

[3]Cramer, p. 211.

[4]Ibid., p. 212.

[5]Alpha C. Chaing, Fundamentals of Mathematical Economics (New York, 1967), p. 381.

[6]D. J. Aigner and C. F. Chu, "On Estimating the Industry Production Function," American Economic Review, LVIII (September, 1968), p. 829.

[7]Ibid., p. 830.

[8]Ibid.

[9]Wayne Hales, "An Analysis of the Effects of Competitive Markets on Hospital Behavior in Oklahoma" (Unpublished Dissertation, Oklahoma State University, Stillwater, Oklahoma, 1974), p. 15.

[10]Ibid.

[11]Harry Alder and Edward Roessler, Probability and Statistics (San Francisco, 1964), p. 143.

[12]Maw Lin Lee and Richard Wallace, "Problems in Estimating Multicost Production Functions," Western Economic Journal, XI (September, 1973), p. 353.

[13]James L. Murphy, Introductory Econometrics (Homewood, 1973), p. 238.

[14]Ibid.

[15]Ibid.

[16]Price data is available for only forty-three states.

[17] C. P. Timmer, "Using a Probabilistic Production Frontier to Measure Technical Efficiency," Journal of Political Economy, LXXIX (1971), p. 782.

[18] Ibid., p. 781.

[19] G. Hadley, Linear Programming (Reading, 1962), p. 39.

[20] Ibid., p. 25.

[21] Timmer, p. 785.

[22] Ibid.

[23] Ibid., p. 784.

[24] Ibid.

[25] Aigner and Chu, p. 833.

[26] Timmer, p. 782.

# CHAPTER IV

## EMPIRICAL ANALYSIS

This chapter presents an empirical analysis of the four hypotheses pertaining to hospital structure and technical efficiency in the production of nuclear medicine. The analysis includes a comparison of the theoretical expectations already developed with results obtained from empirical statistical models.

The first section of the chapter examines the significance of differences in average production surface parameters for each structural segment of the nuclear medicine industry. These were estimated using the multiple linear regression technique. The second section of the chapter presents the linear programming estimate of the nuclear medicine production frontier and examines the relationships of hospital structure to technical efficiency divergence. The third section of the chapter compares qualitative differences in resources among structural groups. The fourth section of the chapter examines specific problems of production function estimation.

## Average Production Function Results

### Competition

A theoretical examination of the hypothesis, "Increased competitive intensity reduces technical efficiency," anticipates lower production surface parameters for competitive hospitals due to over-accumulation of production inputs. The empirical validity of the hypothesis can be examined from the three sets of production surface parameters listed in Table I. The $R^2$ values for the regression equations are .85, .88, and .90, indicating that all but ten percent to fifteen percent of output variations are explained on the basis of input capacity.

Frequently, fitted production functions explain as much as ninety-seven to ninety-nine percent of output variations.[1] Compared to these results, the estimated nuclear medicine production surfaces provide a relatively poor data fit. However, an optimal fit requires that "no significant management biases exist to affect technical efficiency."[2] In this case the fit is very good since the only structural element for which adjustment was made is competitive intensity. If other structural differences also affect output efficiency, then a perfect fit would be impossible from input data alone. The estimates for the nuclear medicine industry provide a better fit than most production function estimates for the hospital industry.[3]

The Chow Test F-statistic, 365.7, is statistically

TABLE I

PRODUCTION SURFACE PARAMETERS

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| | | Low Competitive Intensity, $R^2$: .88 | | | |
| ln L | 1.04 | .69 | .020 | .55 | 31.4 |
| ln K | 1.56 | .47 | .016 | .33 | 27.8 |
| ln A | | 2.78 | .048 | | |
| | | Middle Competitive Intensity, $R^2$: .84 | | | |
| ln L | 1.14 | .70 | .018 | .68 | 37.7 |
| ln K | 1.80 | .39 | .016 | .15 | 22.8 |
| ln A | | 2.60 | .049 | | |
| | | High Competitive Intensity, $R^2$: .90 | | | |
| ln L | 1.67 | .70 | .034 | .81 | 21.4 |
| ln K | 2.50 | .36 | .033 | .09 | 10.8 |
| ln A | | 2.41 | .052 | | |

significant at the .0001 level. Therefore, it appears that the amount of variation explained by the pooled data is much smaller than the combined amount from the three separate estimations.

In each of the equations, the scale parameter and input elasticity terms are statistically significant. As expected on an a priori basis, the scale parameter is significantly higher for less competitive hospitals. This result holds for a comparison of any two of the groups at the .01 significance level. In other words, the production surface for a less competitive hospital would lie above the surface for a more competitive hospital. For any set of resource prices, the production surfaces can be translated into cost functions. The average cost function would appear to shift down as competitive intensity is reduced. Figure 8 illustrates the relative shapes of average cost functions corresponding to the three production surfaces.

The estimated input elasticities provide further comparisons of technical efficiency. Summed input elasticities are 1.16, 1.09, and 1.06, respectively, for low, middle, and high competitive intensity hospitals. Although slight economies of scale appear in each estimate, the degree of scale economies declines as competition increases. In terms of the average cost curves in Figure 8, a reduction in competition increases the negative steepness of the function. This result supports the conclusion that

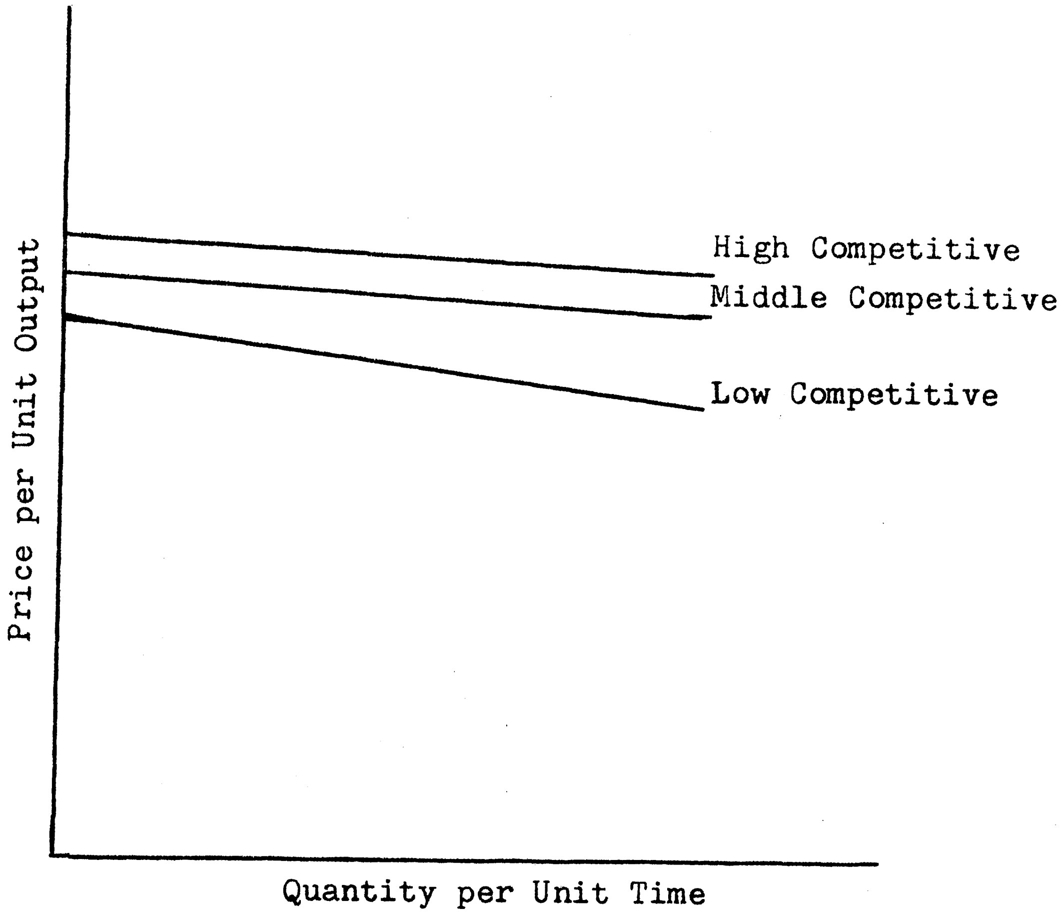



Figure 8. Long Run Average Cost
by Competitive Intensity

a unit of input is more productive when applied in a less competitive hospital. A possible interpretation of the result, suggested by the theoretical analysis, is that non-competitive hospitals acquire inputs to meet expected demands for output. Competitive pressures create incentives not directly related to demand, thereby causing input redundancies and reduced technical efficiency.

The most significant difference in resource input elasticities appears for the capital input. The capital input elasticity of the low competitive group exceeds those of the higher competitive groups at the .001 statistical significance level. The difference in capital input elasticities between the middle and high competitive groups is not statistically significant at the .1 level. The labor input elasticities are not significant at the .1 level but are slightly higher for more competitive hospital groups. These results imply that most of the over-accumulation of resources is in equipment rather than in personnel inputs. If more competitive hospitals do acquire excess equipment, then increases in the capital stock would add less to total output in these hospitals. However, the excess supply of capital would allow an additional unit of labor to be more productive, hence, the higher labor input elasticity in more competitive hospitals.

In the same vein Table I shows the proportion of output variation which is explained by each input. In the more competitive hospitals the capital input adds much less to the predictive power of the equation than in the low competitive hospital group. Variations in capital inputs account for only nine percent and fifteen percent of output variations in the high and middle competitive intensity groups. In the low competitive group the capital input explains thirty-three percent of output variations. This result is expected if competitive hospitals are thought to acquire excess equipment irrespective of use.

Overall, the evidence from the set of average production surfaces is consistent with, and provides empirical support of, the theoretical expectation of reduced efficiency in more competitive hospitals. The over-accumulation of capacity seems to be concentrated in the capital input.

## Profit Orientation

The hypothesis, "Profit incentives increase technical efficiency", is examined from the three sets of production surface parameters listed in Table II. The regression $R^2$ values range from .81 to .90. The poorer data fit for private nonprofit hospitals is partly due to differences in competitive intensities among the three groups. The average competitive intensities are not significantly different for the three groups. However, there is a greater dispersion of competitive intensities for private nonprofit hospitals. Table III reports the average competitive intensities and their standard deviations.

Since competition appears to affect technical

TABLE II

PRODUCTION SURFACE PARAMETERS

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| | | Proprietary Hospitals, $R^2$: .86 | | | |
| ln L | .83 | .58 | .052 | .33 | 11.1 |
| ln K | 1.36 | .66 | .040 | .53 | 16.2 |
| ln A | | 3.11 | .054 | | |
| | | Private Non-Profit Hospitals, $R^2$: .81 | | | |
| ln L | 1.11 | .72 | .017 | .64 | 42.4 |
| ln K | 1.70 | .41 | .014 | .17 | 28.1 |
| ln A | | 2.71 | .046 | | |
| | | Government Hospitals, $R^2$: .90 | | | |
| ln L | 1.23 | .67 | .017 | .76 | 39.8 |
| ln K | 1.88 | .33 | .014 | .14 | 24.1 |
| ln A | | 2.64 | .049 | | |

TABLE III

AVERAGE COMPETITIVE INTENSITIES

| Administrative Orientation | Average Competitive Intensity | Standard Deviation |
|---|---|---|
| Proprietary | 125 | 60 |
| Private Non-profit | 166 | 158 |
| Government | 155 | 68 |

efficiency, the larger variation in competition would cause a poorer data fit. The poorer data fit associated with greater variation in competitive intensity is evidence of the importance of competitive intensity to technical efficiency.

The Chow Test F-statistic for the three data subsets is 439.6 and indicates that the division of data on the basis of profit orientation provides a much better fit than can be obtained from pooled data. In each of the equations, the scale parameters and input elasticities are highly significant. The scale parameter is nearly twenty percent larger for proprietary hospitals than for either of the nonprofit groups. The difference in the nonprofit private and government group scale parameters is not statistically significant at the .1 level. The summed input elasticities are 1.24, 1.13, and 1.00 for proprietary, private nonprofit, and government hospitals, respectively. Economies of scale appear in both private groups, and constant returns to scale appear for the government group. The cost curve shapes associated with the production surfaces are in Figure 9. These results are consistent with the theoretical expectation of greater technical efficiency in profit oriented hospitals. The proprietary hospital production surface lies above the nonprofit surfaces, and the degree of divergence increases with higher output.

The labor input elasticity is significantly higher for the private nonprofit group at the .001 statistical significance level when compared with either of the other groups. The labor input elasticity is higher in government than in proprietary hospitals at the .01 significance level. The term accounts for sixty-four percent of output variations in the private nonprofit group and for seventy-six percent of output variations in the government group. It accounts for only thirty-three percent of output variations in the proprietary hospital group.

The results are reversed for the capital input. The capital input elasticity is greater for proprietary hospitals than for either nonprofit group at the .001 statistical significance level. It is also greater in the private nonprofit group than in the government group at the .01 significance level. Variations in capital inputs explain only fourteen and sixteen percent of output differences in private nonprofit and government hospitals,

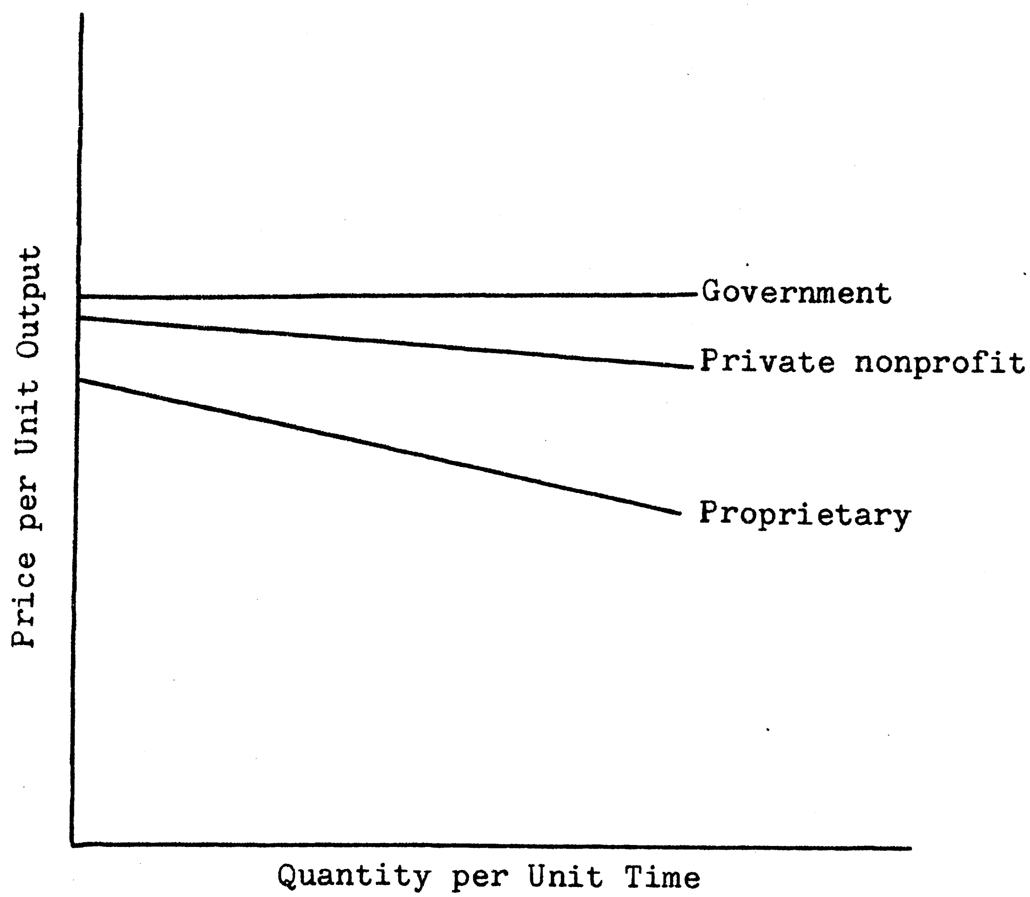



Figure 9. Long Run Average Cost by Profit Orientation

respectively. In the proprietary group the capital input accounts for fifty-two percent of output differences.

These results imply that nonprofit hospitals acquire capital resource inputs irrespective of actual utilization, and then acquire labor resource inputs as capacity is actually used. As a result, labor input appears to be a very good predictor of output. The lower labor productivity in proprietary hospitals suggests that these hospitals economize on capital inputs by using labor intensive production techniques. Less capital investment would allow more short-run flexibility and less excess capacity. The results support the hypothesis concerning profit incentives and efficiency and imply that excess capital accumulation is a primary source of technical inefficiency in nonprofit hospitals.

## Service Range

Competition and profit incentives have been hypothesized to affect both the intensity of input accumulation for specific services and the range of services offered. The hypothesis, "a broader service range reduces technical efficiency," is concerned with the independent effect of the breadth of service offerings on technical efficiency. Two empirical problems of the hypothesis test were discussed in Chapter III. First, service range is difficult to measure, and must be approximated as the intensity of nuclear medicine production. Second, hospitals that have a status bias (particularly competitive and nonprofit hospitals) may tend to acquire broader service ranges. To test for the independent effect of service range, it is necessary to adjust for these managerial biases.

The t-statistic to be used for comparing the mean values taken from two samples was defined in Chapter III. The universe of nuclear medicine producers was divided separately on the basis of competitive intensity and profit orientation, and an average nuclear medicine intensity was computed for each data subset. Finally, the corresponding subsets were tested for differences in average nuclear medicine intensities.

The division of data on the basis of competitive intensity produced a computed t-statistic of 1.99, indicating that there is a significant difference in nuclear medicine intensity in competitive and noncompetitive hospitals. The t-statistic for the division based on profit orientation was .96, and is not significant at the .1 level. Therefore, it is necessary to adjust for competitive intensity but not for profit orientation.

Since competitive hospitals have systematically lower nuclear medicine intensities (indicating broader service range), two separate groups are examined. One group compares the effect of nuclear medicine intensity in low competitive hospitals. The other group compares the same effect among high competitive hospitals. Table IV shows the estimated production coefficients for low and high

TABLE IV

PRODUCTION SURFACE PARAMETERS

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| | | **Low Competitive Hospitals** | | | |
| | | **Low Nuclear Medicine Intensity, $R^2$: .83** | | | |
| ln L | 1.18 | .71 | .038 | .59 | 18.7 |
| ln K | 1.83 | .54 | .030 | .24 | 18.1 |
| ln A | | 2.65 | .050 | | |
| | | **High Nuclear Medicine Intensity, $R^2$: .81** | | | |
| ln L | .91 | .67 | .024 | .52 | 27.7 |
| ln K | 1.43 | .44 | .021 | .21 | 20.1 |
| ln A | | 2.87 | .052 | | |
| | | **High Competitive Hospitals** | | | |
| | | **Low Nuclear Medicine Intensity, $R^2$: .82** | | | |
| ln L | 1.43 | .70 | .025 | .82 | 28.7 |
| ln K | 2.24 | .34 | .025 | .08 | 13.5 |
| ln A | | 2.67 | .047 | | |

TABLE IV (Continued)

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| High Nuclear Medicine Intensity, $R^2$: .82 | | | | | |
| ln L | 1.13 | .68 | .022 | .66 | 31.1 |
| ln K | 1.75 | .34 | .019 | .16 | 18.6 |
| ln A | | 2.62 | .055 | | |

nuclear medicine intensive producers after adjusting for competitive intensity.

In each equation all of the regression coefficients are highly significant. The $R^2$ values range from .82 to .91. The Chow Test F-statistic for the low competitive subsets is 3.9 and is statistically significant at the .01 level. The F-statistic for the high competitive subsets is 2.0 and is not statistically significant at the .1 level. Although dividing the low competitive group on the basis of nuclear medicine intensity adds to the explanatory power of the equation, there is no additional explanatory power gained by dividing the high competitive group.

For the low competitive hospitals the high nuclear medicine intensity group has a significantly higher scale parameter. However, the scale parameters are not significantly different for the high competitive subsets. It has already been observed that competitive hospitals acquire more excess capacity. That observation, coupled with these results, implies that service range has very little impact on efficiency when other status biases exist. On the other hand, service range does appear to have an impact when hospitals are not capacity biased.

For the group of low competitive hospitals, the high nuclear medicine intensity subset has lower input elasticities for both labor and capital. Therefore, as output expands the production surfaces for the high and low nuclear medicine intensity, subsets appear to converge.

The average cost curves corresponding to these production surfaces are shown in Figure 10. It should be noted that the high nuclear medicine intensity production surface is higher over the entire relevant range of output. None of the hospitals in the data universe used an input combination that would show a higher predicted output rate on the low nuclear medicine intensity function.

For the high competitive hospital subsets the input elasticities were not significantly different for either resource. It appears that service range has little efficiency impact in these hospitals. The cost curves corresponding to the high competitive intensity data subsets are in Figure 11.

Overall, these results indicate that the importance of service range to technical efficiency depends, first, on the existence of other capacity accumulation incentives, and, second, on the absolute volume of output. As other capacity biases are reduced, service range appears to be of greater significance to technical efficiency. Moreover, a broader service range hospital can add a nuclear medicine facility with less efficiency loss if it expects to produce a relatively large volume of output.

## Training

To test the hypothesis, "In-house manpower training reduces technical efficiency," the proprietary hospitals were deleted from the data universe. Only five of the

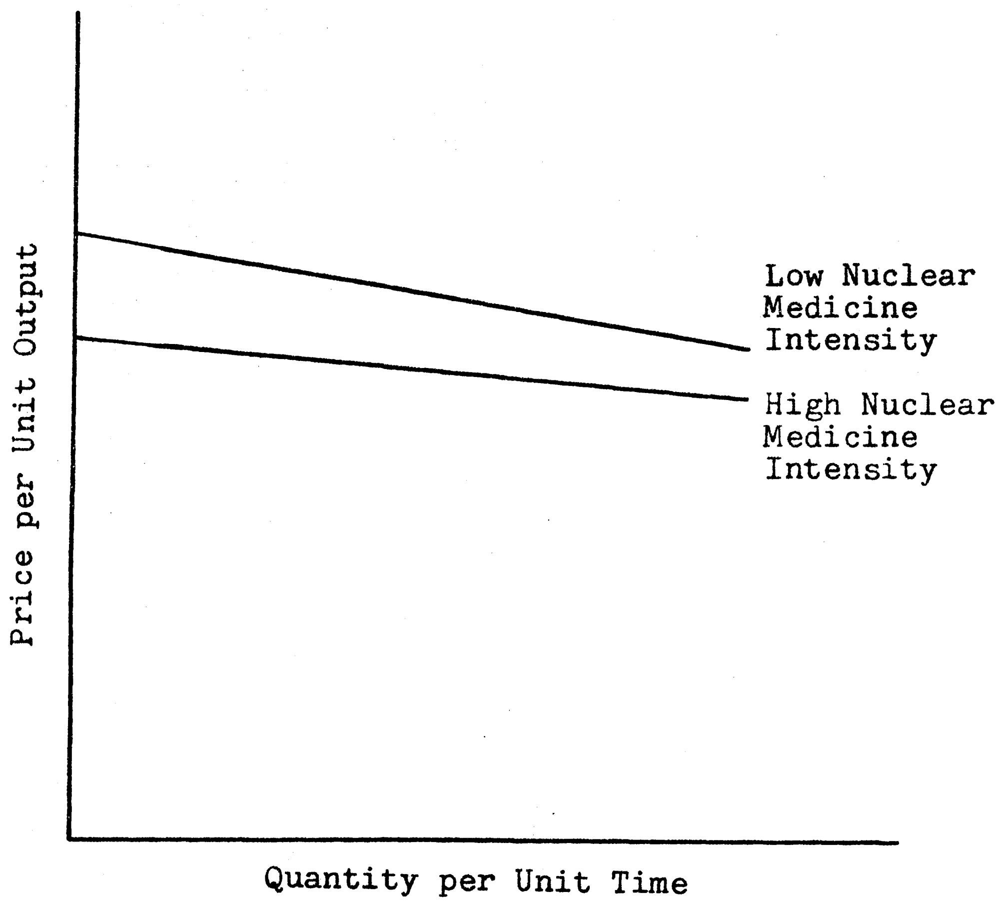



Figure 10. Long Run Average Cost for Low Competitive Hospitals

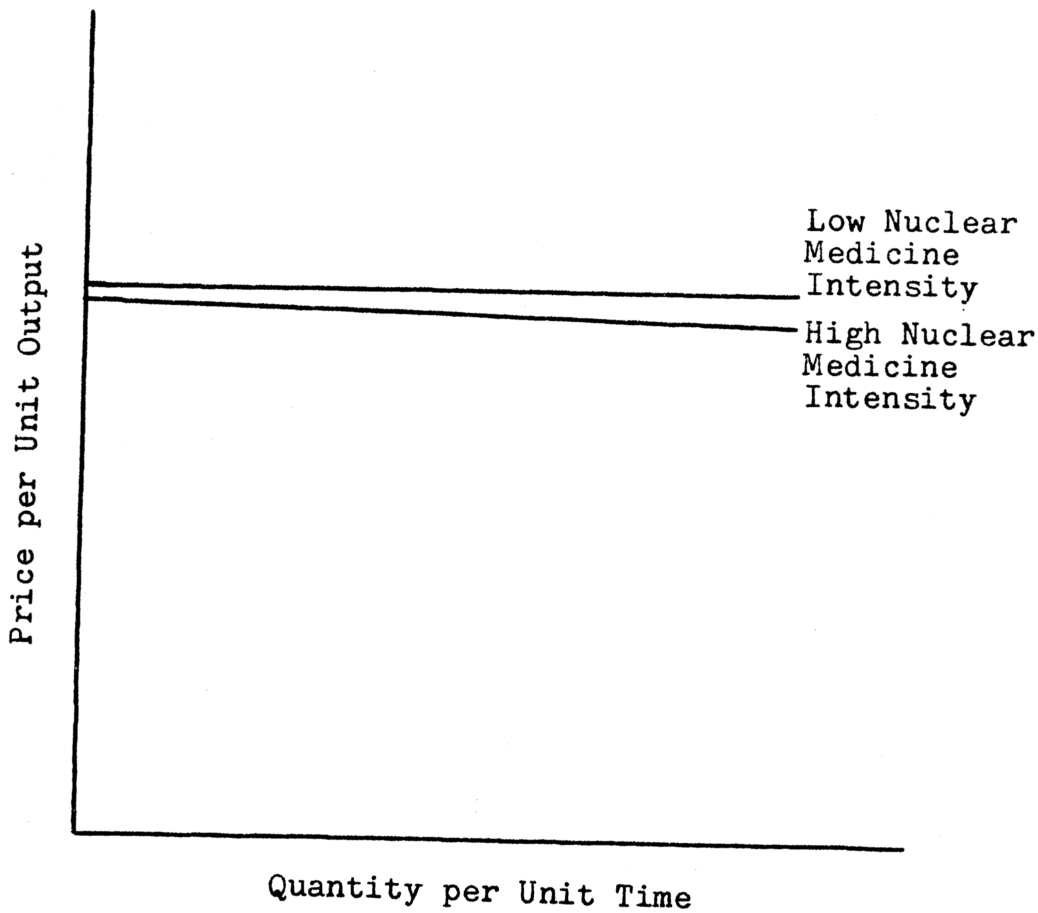



Figure 11. Long Run Average Cost for High Competitive Hospitals

seventy-three proprietary hospitals reported training of technical personnel. Since proprietary hospitals were found to be more efficient, their inclusion in the analysis would give an efficiency bias to nontraining hospitals. The five proprietary hospitals that do produce training do not constitute a sufficient sample for estimation of a separate production surface.

To avoid the inclusion of other managerial biases in the hypothesis test, data subsets were separated on the basis of competition and administrative orientation. The average training level was computed for each subset. The computed t-statistic for comparing average training levels in competitive and noncompetitive hospitals was .37. Therefore, an adjustment for competitive intensity is not required. The t-statistic for comparing average training levels in private nonprofit and government hospitals was 2.3, indicating that the average training level is significantly higher in private nonprofit hospitals. The test of the effect of training intensity on efficiency was made after adjusting for administrative orientation.

Table V lists the parameter estimates for each of the production surfaces. The $R^2$ values are from .81 to .92. The adjustment for training intensity did little to improve the predictive power of the regression equations for either the government or private nonprofit group. The Chow Test supports this observation. The F-statistics for the private nonprofit and government hospital subsets were 1.3

TABLE V

PRODUCTION SURFACE PARAMETERS

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| | | **Nonprofit Private Hospitals** | | | |
| | | **Low Training Intensity, $R^2$: .81** | | | |
| ln L | 1.05 | .70 | .020 | .62 | 37.5 |
| ln K | 1.53 | .46 | .018 | .19 | 24.7 |
| ln A | | 2.66 | .058 | | |
| | | **High Training Intensity, $R^2$: .81** | | | |
| ln L | 1.27 | .70 | .033 | .66 | 21.9 |
| ln K | 2.08 | .44 | .072 | .15 | 14.9 |
| ln A | | 2.66 | .051 | | |
| | | **Government Hospitals** | | | |
| | | **Low Training Intensity, $R^2$: .85** | | | |
| ln L | 1.07 | .65 | .022 | .69 | 29.3 |
| ln K | 1.58 | .35 | .021 | .16 | 17.0 |
| ln A | | 2.53 | .049 | | |

TABLE V (Continued)

| VAR | MEAN | REG COEFF | STD ERROR REG COEFF | PROP VAR INCREMENT | t-STAT |
|---|---|---|---|---|---|
| | | High Training Intensity, $R^2$: .92 | | | |
| ln L | 1.54 | .71 | .021 | .80 | 33.8 |
| ln K | 2.45 | .30 | .017 | .11 | 18.1 |
| ln A | | 2.46 | .050 | | |

and 2.3, respectively. The pooled data for each group predicts as well as if individual subsets are used.

The scale parameters are not significantly different for the private nonprofit production surfaces at the .1 statistical significance level, but the term was slightly higher for the low training group. Therefore, the direction of the efficiency divergence was as expected. The labor input and capital input elasticities are not significantly different between the subsets. Figure 12 depicts the average cost curves corresponding to the estimated production surfaces.

For the government hospital subsets the low training scale parameter exceeds the high training scale parameter at the .01 statistical significance level. The summed input elasticities are unity for both groups. The labor input elasticity is significantly higher for the high training group, while the capital input elasticity is significantly higher for the low training group. The average cost curves corresponding to these production surfaces are shown in Figure 13.

The observed difference in labor productivity may result from an undercounting of labor in real terms in training oriented hospitals. Although unpaid trainees were not counted as part of the labor input, they may contribute to total service output. Therefore, even if paid personnel divide their time between training activities and service production, a part of their forgone output is recompensed

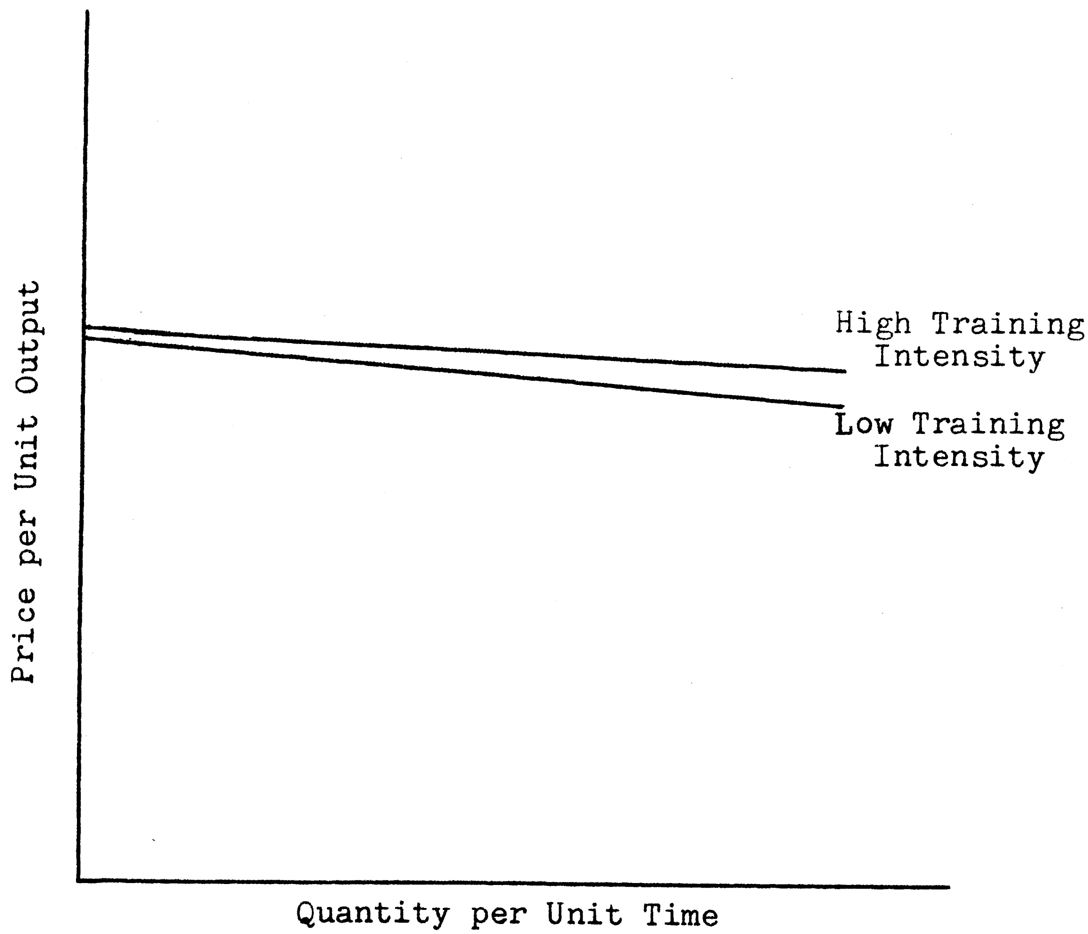



Figure 12. Long Run Average Cost for Private Nonprofit Hospitals

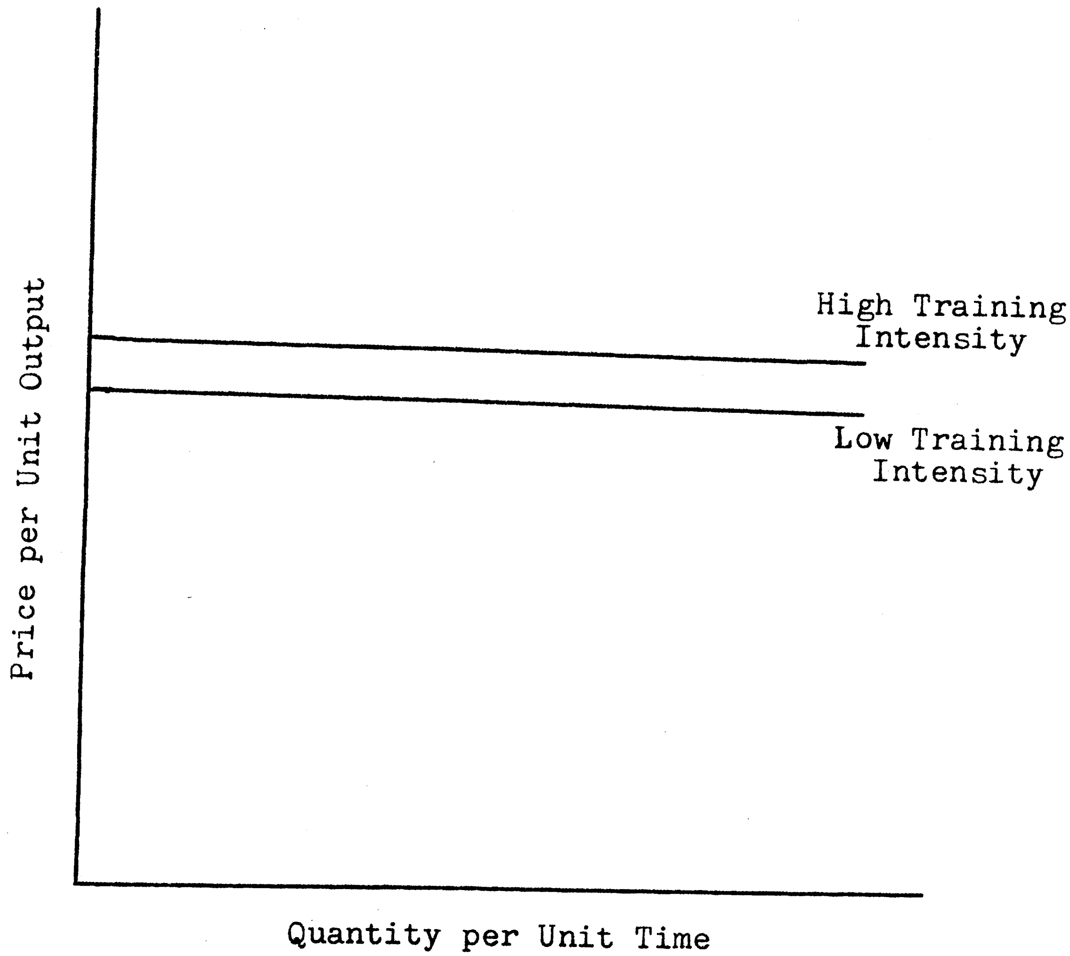



Figure 13. Long Run Average Cost for Government Hospitals

by trainee production. The accompanying reduction in capital productivity would occur because the capital devoted to training is not supplemented by output from a cost-free capital resource. In effect, the real quantity of capital available for the production of nuclear medicine is overstated in training hospitals. Overall, the analysis suggests that training, as a joint product with nuclear medicine output, has a slight but distinguishable effect on technical efficiency.

## The Production Frontier

Since the estimated production surfaces allow some observations to lie above each production surface, a true production function for nuclear medicine has not been represented. It is not possible to select any of the surfaces to represent the actual state of the arts in nuclear medicine production on an objective basis. The purpose of the linear programming model is to estimate a production frontier above which no actual observations lie. The constraint is then relaxed to allow some extreme output rates to lie above the surface until the parameters stabilize.

Results of the one hundred percent, ninety-eight percent, ninety-six percent, ninety-five percent, ninety-four percent, and ninety percent frontiers are listed in Table VI. The one hundred percent efficient frontier lies above all of the observed input-output combinations. It is characterized by a very high scale parameter (over twice the value of the scale parameter in the regression estimations). The sum of the input elasticities, .83, indicates decreasing returns to scale. This is also inconsistent with the observation of increasing returns to scale in the regression estimates.

TABLE VI

LINEAR PROGRAMMING PRODUCTION SURFACE PARAMETERS

| Variable | Alternative Production Frontiers | | | | | |
|---|---|---|---|---|---|---|
| | 100% | 98% | 96% | 95% | 94% | 90% |
| ln L | 6.51 | 4.39 | 3.66 | 3.58 | 3.54 | 3.50 |
| ln K | .50 | .59 | .70 | .68 | .68 | .67 |
| ln A | .33 | .44 | .51 | .50 | .49 | .46 |

As the most efficient firms are deleted from the estimation allowing them to lie above the estimated surface, the result becomes more consistent with the earlier estimates. The ninety-eight percent estimation removed twenty-six firms from the sample. The scale parameter for the ninety-eight percent efficient production surface is thirty-five percent lower than the one hundred percent frontier, and its summed input elasticities indicate slight economies of scale. The ninety-six percent, the ninety-five percent, the ninety-four percent, and the ninety percent frontiers exhibit considerable stability, and the parameters estimates are fairly consistent with the regression solutions. Average cost curves associated with the production frontiers are in Figure 14.

By the estimation of the ninety percent frontier, 127 firms were dropped from the solution. Therefore, the production surface parameters were not determined by proprietary firms alone. Although the regression equations indicate that proprietary firms are the most efficient, forty-six remained by the ninety percent estimation. The remaining comparisons of technical efficiency utilize the ninety percent efficient production function as an efficiency datum.

A simple test of structure-efficiency relationships utilizes a comparison of average deviations from the production frontier.[4] A significant difference would be an indication of a structural element affecting hospital technical efficiency. For the $i^{th}$ hospital the index of efficiency divergence is:

$$D_i = (\hat{Q}_i - Q_i) \div \hat{Q}_i$$

The average divergences for each hospital subset are

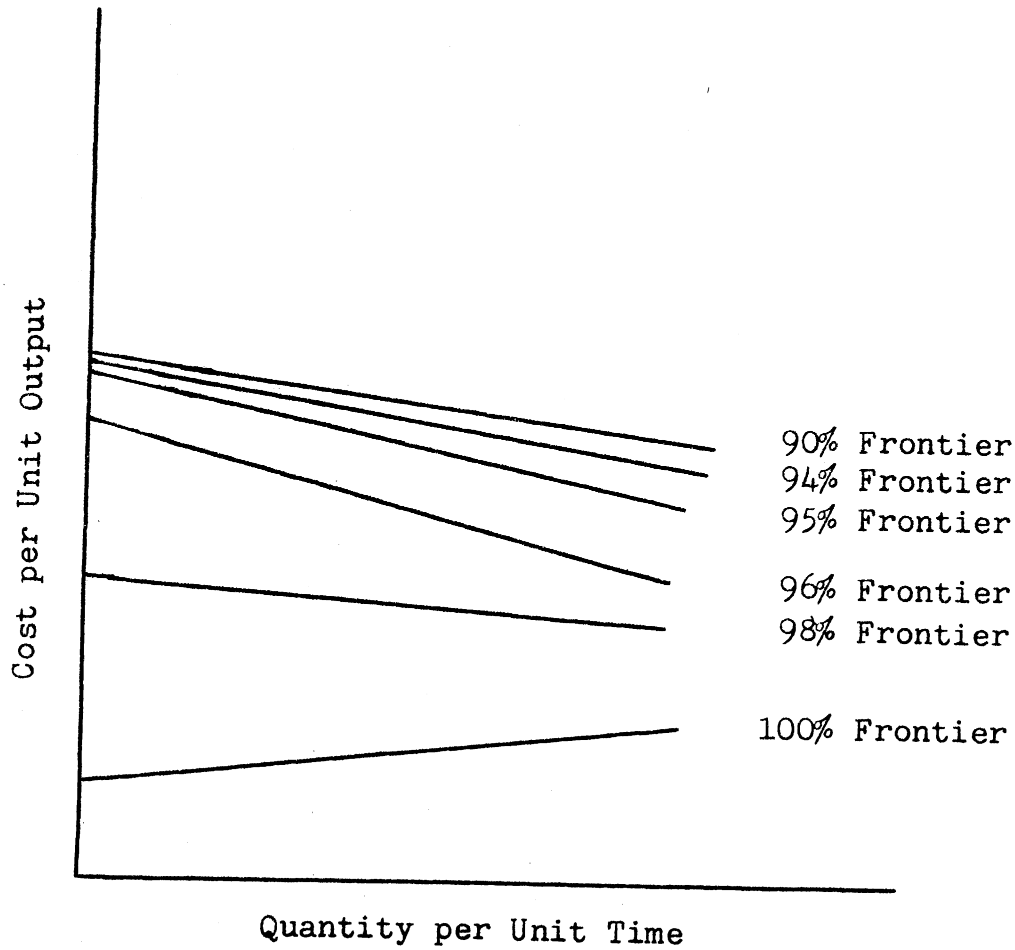



Figure 14. Production Frontier Estimates for Long Run Average Cost

reported in Table VII. Any two groups of firms could be compared using the following t-statistic:

$$t = \frac{(D_1 - D_2)}{(s_1^2 + s_2^2)^{\frac{1}{2}}} \quad ,$$

where $D_1$ and $D_2$ are the average efficiency deviations for the segments of the industry under investigation, and $s_1$ and $s_2$ are the standard errors of the respective divergence terms.

A comparison of the efficiency divergences for the competitive intensity data grouping indicates that low competitive hospitals have smaller average efficiency divergences at the .001 statistical significance level. This is consistent with the average production function observations.

For the profit orientation grouping, proprietary hospitals have a lower average efficiency divergence than either nonprofit group at the .001 significance level. Private nonprofit hospitals have a lower average efficiency divergence than government hospitals at the .01 significance level.

Low service range hospitals in the high competitive data set have lower average efficiency divergences than the high service range group. The difference between the two barely misses significance at the .01 level. Low service range hospitals in the low competition data set have significantly lower efficiency divergence than the high

TABLE VII

TECHNICAL EFFICIENCY DIVERGENCES

| Structural Element | Efficiency Divergence | Standard Error |
|---|---|---|
| Low Competitive | 10.5 | 1.9 |
| High Competitive | 21.8 | 1.8 |
| Proprietary | 5.2 | 1.0 |
| Private Nonproprietary | 13.4 | 1.7 |
| Government | 18.8 | 1.3 |
| | <u>Low Competitive Intensive</u> | |
| Low Service Range | 8.4 | 2.1 |
| High Service Range | 12.8 | 2.3 |
| | <u>High Competitive Intensive</u> | |
| Low Service Range | 21.0 | 3.9 |
| High Service Range | 22.1 | 4.0 |
| | <u>Private Nonproprietary</u> | |
| Low Training | 12.6 | 3.8 |
| High Training | 14.5 | 3.9 |
| | <u>Government</u> | |
| Low Training | 16.9 | 2.5 |
| High Training | 20.8 | 2.4 |

service range group at the .1 statistical significance level.

Neither private nor government hospitals exhibit a difference in efficiency divergence on the basis of training intensity at the .1 statistical significance level. Therefore, training intensity appears to have no statistically significant impact on technical efficiency.

Timmer states, "the extent of technical efficiency in an industry is important. Knowledge of any sources of inefficiency is doubly important."[5] The final empirical task concerning the examination of the research hypotheses is to measure the proportion of technical efficiency divergences related to each of the four structural elements central to the study. This was done by computing the percentage divergence from the ninety percent frontier for each hospital and by regressing the divergence terms on the four structural elements. Two separate regressions were run. The first included all of the hospitals in the data universe, and the second included only the observations falling on or below the ninety percent frontier. The standard error for each coefficient is in parentheses.

$$D = \underset{(.88)}{9.8} + \underset{(.001)}{.028}\,CI - \underset{(.004)}{.011}\,NMI + \underset{(.220)}{.310}\,TR + \underset{(.28)}{3.0}\,G - \underset{(.56)}{5.9}\,P$$

$$D = \underset{(.96)}{10.2} + \underset{(.001)}{.027}\,CI - \underset{(.004)}{.016}\,NMI + \underset{(.222)}{.213}\,TR + \underset{(.29)}{3.4}\,G - \underset{(.66)}{4.6}\,P$$

For the equation, CI represents the index of competition; NMI represents nuclear medicine intensity as a proxy for service range; TR represents relative training level; G is a dummy variable for government hospitals; and P is a dummy variable for private proprietary hospitals. The regression $R^2$ values are .53 and .55, respectively. The four structural elements under investigation explain over half of variations in efficiency divergence.

The better data fit for the observations falling on or below the ninety percent frontier indicates the unusual nature of the deleted observations. The odd production occurrences that created strange results for the one hundred percent and ninety-eight percent frontiers have reduced the predictive power of the regression equation.

The implications of this evidence regarding the relationship of hospital structure to technical efficiency are substantially the same as for the preceding analysis in this chapter. Therefore, a brief summary of the results is reported below.

As expected, the competitive intensity coefficient has a positive sign and is statistically significant at the .0001 level. The competitive intensity term accounts for thirty-two to thirty-four percent of variations in efficiency divergence. This result reinforces the importance of competitive intensity to technical efficiency that was found in the average production surface comparisons.

The dummy variables for proprietary and government hospitals are both statistically significant at the .001 level. The negative sign on the proprietary hospital term indicates that efficiency divergences are substantially lower when a profit incentive exists. Government hospitals exhibit systematically greater efficiency divergences than other hospitals. Taken together, the administrative orientation variables account for twenty-two to twenty-five percent of variations in hospital efficiency.

The nuclear medicine intensity term has a negative affect on efficiency divergence at the .05 statistical significance level. The result here supports the weaker evidence of the effect of service range from the average production function comparisons. The average production surface estimations showed that service range has a greater impact in lower competitive hospitals. Since over half of the hospitals in the data universe were in the low competition group, these results are consistent. In spite of collinearity with competitive intensity, service range has exhibited an independent impact on efficiency. The nuclear medicine intensity term accounts for about one percent of variations in efficiency divergence.

Relative training level has a small, positive impact on technical efficiency divergence. The training coefficient is not statistically significant at the .1 level. The lack of significance for the term may be partly a result of collinearity with the administrative orientation variables. However, the result is consistent with the average production function comparisons which showed only slight efficiency differences on the basis of training intensity. The training variable contributes less than .3 percent to the explanatory power of the equation.

## Structure, Quality Bias, and Efficiency

Labor and capital have been assumed to be homogeneous resource categories. However, it is probable that some hospitals have a quality bias in their resource selection. If higher quality inputs are more productive and more costly, then resource inputs have been understated for quality biased hospitals. Resource quality is, to some degree, a substitute for resource quantity. Given equal rates of input quality, differences in resource quality should be reflected in output rates.

Indications of capital input quality might include equipment age, maintainence expenditure, equipment brand, or equipment price. Since individual hospital data is not available for these indicators, no comparison is possible.

Labor input quality depends on the human capital embodiment of the labor set. Human capital resource embodiment is normally measured in terms of education and experience. To compare the quality of labor inputs among nuclear medicine producers, the average years of education and experience requirements were computed for technicians in each hospital.[6] These are reported in Table VIII on the basis of the four structural elements of the study.

More competitive hospitals have slightly higher education and experience requirements, but the difference is not

TABLE VIII

AVERAGE EDUCATION AND EXPERIENCE LEVELS

| Structural Element | Education Level (Standard Error) | Experience Level (Standard Error) |
|---|---|---|
| Low Competitive | 2.9 (.53) | 4.7 (1.0) |
| Middle Competitive | 2.9 (.54) | 4.2 (1.3) |
| High Competitive | 3.1 (.41) | 4.9 (0.9) |
| Proprietary | 1.8 (.45) | 2.6 (0.8) |
| Private Nonproprietary | 3.0 (.71) | 5.9 (1.0) |
| Government | 3.2 (.55) | 4.7 (1.2) |
| Low Competitive Intensive | | |
| Low Service Range | 2.7 (.83) | 5.4 (1.5) |
| High Service Range | 3.4 (.75) | 3.6 (1.1) |
| High Competitive Intensive | | |
| Low Service Range | 3.1 (.43) | 5.8 (1.0) |
| High Service Range | 3.2 (.66) | 3.5 (1.4) |
| Private Nonproprietary | | |
| Low Training | 2.8 (.55) | 4.1 (1.3) |
| High Training | 4.3 (.89) | 6.2 (1.6) |
| Government | | |
| Low Training | 3.0 (.65) | 3.7 (.95) |
| High Training | 4.6 (.52) | 5.4 (1.2) |

significant at the .1 level. Therefore, no additional cost or efficiency bias would result from input quality differences.

Proprietary hospitals have significantly lower education and experience requirements than either of the non-profit groups. This quality bias suggests that the actual efficiency divergence on the basis of profit orientation may exceed the divergence observed in this study.

Higher nuclear medicine intensity hospitals have greater average experience requirements in both the high and low competitive comparisons. Education requirements are not significantly different. If higher quality increases resource costs, then the production and cost advantages observed for high nuclear medicine intensity hospitals would be partially offset by higher labor costs. Hence, the advantages appearing for high nuclear medicine intensity hospitals would be reduced if labor quality were included as a separate input.

Training hospitals, as expected, require higher quality labor inputs. The difference in education and experience levels on the basis of training intensity is significant at the .05 level. The use of higher quality inputs in training hospitals implies that the actual labor input was undercounted for training hospitals. The inclusion of the quality difference would add to the technical efficiency and cost divergence between training and non-training hospitals.

## Production Function Considerations

The analysis of technical efficiency in the production of nuclear medicine has utilized a comparison of estimated production surface parameters for various groups of hospital firms. The selected production function fit a homogeneous production relationship characterized by a unitary elasticity of substitution but not constrained to constant returns to scale. Feldstein assumed a linear homogeneous production function in his analysis of the hospital industry.[7] Ogur, on the other hand, applied a Constant Elasticity of Substitution (C.E.S.) production function to proprietary hospitals and found that the elasticity of substitution was significantly less than one.[8]

If hospitals attempt to minimize production costs, then a change in relative resource prices would lead to an adjustment of the input proportions employed. This effect is measured by the elasticity of substitution. The Cobb-Douglas production function assumes that the elasticity of substitution is equal to one. Cramer states, "a significant deviation from this value should be taken as evidence in favor of an alternative formula."[9]

In order to examine the empirical validity of the Cobb-Douglas fit of nuclear medicine data, a C.E.S. production function was estimated. Of particular importance is the elasticity of substitution term. If it appears to have a value significantly different from one, then the conclusions based on the Cobb-Douglas function comparisons would be suspect.

## The C.E.S. Production Function

The C.E.S. production function can be stated in a general form that is homogeneous of degree one and has a constant elasticity of substitution (not necessarily one). A common specification of the C.E.S. production function is:[10]

$$Q = g \left[ (1 - c)\, L^{-h} + cK^{-h} \right]^{\frac{-1}{h}} . \qquad (12)$$

The scale parameter, g, plays the same role as A in Equation (5), and the distribution parameter, (1 - c), has the same significance as $\alpha$. The substitution parameter, h, determines the value of the elasticity of substitution. Chaing has demonstrated that the elasticity of substitution, 2, is:[11]

$$s = \frac{1}{1 + h} .$$

Under the assumption that firms acquire resources to equate their marginal products per unit of cost, Equation (11) can be reduced to:

$$Q/L = \left[ g^{h}/(1 - c) \right]^{s} W^{s}. \qquad (13)$$

In logarithmic form, the equation can be estimated as a multiple linear regression model from data on firm output, labor input, and wage rates:

$$\ln(Q/L) = \ln \left[ g^h / (1 - c) \right]^s + s \ln W \qquad (14)$$

The cost minimization assumption for the derivation of Equation (13) requires that firms act to maximize profit. Since it is clear that all hospitals do not attempt to maximize profit, only the proprietary firm data are included in the C.E.S. production function estimation.

Wage data for the estimation of Equation (14) is available on a statewide basis from the American College of Radiology. Therefore, statewide aggregates of proprietary hospital labor input, nuclear medicine output, and wage data were used. Forty states have one or more hospitals which produce nuclear medicine.

The fit of the C.E.S. production function resulted in the following equation, with standard error terms in parentheses:

$$\ln(Q/L) = \underset{(.38)}{2.3} + \underset{(.15)}{.86}\, W \quad .$$

The regression $R^2$ value of .52 is considerably worse than for the Cobb-Douglas fit of proprietary firm data. The poorer fit may be partly caused by statewide aggregations, the smaller sample size, and the constraint to constant returns to scale. (The Cobb-Douglas fit showed significant economies of scale.)

The poorer data fit may also indicate that proprietary hospitals do not acquire factor inputs in response to relative resource prices. If hospitals do not select the least cost combination of resources, then reliance on an estimation technique requiring factor price data is subject to serious estimation error. "If the equality of marginal product values to the wage rate no longer applies . . . there can be no question of estimating input elasticities from their relative rewards."[12]

An important result for this study is that the elasticity of substitution term, .86, is not different from unity at the .1 significance level. Therefore, the estimation of the C.E.S. production function offers no grounds for rejecting the Cobb-Douglas assumption of a unitary elasticity of substitution. This observation, along with the superior data fit for the Cobb-Douglas estimation, supports the adequacy of the selected model.

Collinearity among the labor and capital inputs provides additional evidence of the possibility of factor substitution. Production processes with little substitution flexibility would exhibit considerable collinearity among the input variables. Since one resource could not be easily substituted for another, both would have to change to alter the volume of output. Little collinearity between labor and capital variables was observed in any of the average production surface regressions. The partial correlation coefficients between labor and capital for each of the regression estimations are listed in Table IX. The

TABLE IX

PARTIAL CORRELATION COEFFICIENTS

| Structural Element | Correlation Coefficient Between L and K |
|---|---|
| Low Competitive | .263 |
| Middle Competitive | .321 |
| High Competitive | .358 |
| Proprietary | .101 |
| Private Nonproprietary | .327 |
| Government | .297 |
| Low Competitive Intensive | |
| Low Service Range | .305 |
| High Service Range | .567 |
| High Competitive Intensive | |
| Low Service Range | .161 |
| High Service Range | .390 |
| Private Nonproprietary | |
| Low Training | .233 |
| High Training | .427 |
| Government | |
| Low Training | .238 |
| High Training | .467 |

degree of collinearity between labor and capital cannot be used to assign a value to the elasticity of substitution, but the observation of low correlation coefficients is consistent with relative flexibility in the resource mix.

<u>Other Estimation Problems</u>

Critics of production function estimates for the hospital industry have cited five primary estimation problems.[13] The significance of the criticisms are discussed below in the context of this study.

First, the assumption of cost minimization may be invalid. If hospitals do not attempt to select the cost minimizing production technique, then the true production function cannot be identified from firm production data. This identification problem is not of particular importance to this study since the only use of the estimated production functions is for efficiency comparisons among various structural groups. The use of physical input-output data in the Cobb-Douglas framework avoids the necessity of a cost minimization assumption for establishing the average production surfaces.

Second, constraints placed on production surface parameters may create distortions in the shape of the estimated production surface. Although it is impossible to avoid some such constraints, tests have been made regarding the importance of the constraints imposed. Since the summed input elasticities were significantly greater than one in most of the average production surface estimates, a constraint to linear homogeneity would be undesirable. On the other hand, the elasticity of substitution term does not appear to be significantly different from unity. Its restriction should not distort the production surface estimates.

Third, the relevant range of predictive significance for an estimated production function may be limited. Lave and Lave have emphasized the importance of the relevant range of predictive significance.[14] If different production surfaces were estimated over small ranges of output, a better fit might be obtained. Severe problems of identifying the relevant output range are avoided by allowing variations in returns to scale. All production function comparisons were made over comparable output ranges.

Fourth, the nonhomogeneity of inputs and outputs reduces the validity of empirical results. The major problem of output homogeneity has been avoided by the focus on nuclear medicine as a specific set of hospital outputs. The possibility of qualitative differences in resource inputs, and the corresponding effect on technical efficiency, was discussed.

Fifth, the required statistical data may not be comparable for all firms. This problem is particularly important if firm data comes from a variety of sources. It is less serious in this study because all of the primary data are drawn from the ACR-ERDA census of nuclear medicine producers. Differences in data would occur only to the extent of hospital reporting errors.

## Summary

This chapter has presented empirical test statistics for an examination of the research hypotheses. Substantial support was found for the hypotheses concerning competition and profit incentives. Support for the hypotheses concerning service range and training was much weaker, although the directions of their affects were consistent with the a priori reasoning. The regression of the four structural elements on efficiency divergence strongly indicates that profit incentives and competition account for the bulk of efficiency variations. Overall, the four structural elements have explained over half of efficiency variations among producers of nuclear medicine.

The possibility of variations in resource quality among different structural groups was also considered. Quality biases in competitive, nonprofit, and training intensive hospitals would increase the efficiency divergence related to these elements. It appears that the quality bias observed for high nuclear medicine intensive hospitals would reduce the efficiency advantage that was observed for those groups.

The examination of the C.E.S. production function showed that the elasticity of substitution term is not significantly different from one. The Cobb-Douglas production function also appears to provide a better data fit than the C.E.S. form. Finally, other problems of production function estimation were evaluated within the context of this study.

## FOOTNOTES

[1]Parameters estimated from cross-section data typically provide a poorer data fit than those estimated from time series data.

[2]C. P. Timmer, "Using a Probabilistic Production Frontier as a Measure of Technical Efficiency," Journal of Political Economy, LXXIX (1971), p. 782.

[3]Jonathan Ogur, "The Nonprofit Firm: A Test of the Theory for the Hospital Industry," Journal of Economics and Business, XI (Winter, 1974), p. 118.

[4]Ibid., p. 119.

[5]Timmer, p. 777.

[6]Data is available from the ACR-ERDA census of nuclear medicine producers.

[7]Martin Feldstein, "Hospital Cost Variations and Case Mix Differences," Medical Care, IV (April, 1971), p. 95.

[8]Ogur, p. 117.

[9]J. S. Cramer, Empirical Econometrics (Amsterdam, 1971), p. 245.

[10]Alpha C. Chaing, Fundamentals of Mathematical Economics (New York, 1967), p. 381.

[11]Ibid.

[12]Cramer, p. 250.

[13]Judith Lave and Lester Lave, "Economic Analysis for Health Service Efficiency," Applied Economics, IV (1970), p. 300.

[14]Ibid.

# CHAPTER V

## SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The theoretical and empirical evidence presented in this study implies that hospital structure has an important impact on technical efficiency. This chapter summarizes the conclusions and implications of the theoretical and statistical evidence and puts them in perspective relative to other studies of the hospital industry. The chapter also recommends other lines for empirical study that might extend from this analysis.

The primary limitation on the findings of the study is the restriction to nuclear medicine production relationships. A broader analysis of the hospital industry, and an in depth study of any particular proposal, should precede specific policy action.

### Conclusions

The most significant conclusion of the study is that over half of the observed variations in technical efficiency in the production of nuclear medicine are attributed to the four structural elements under investigation. The measured impact of each element was consistent with reasoning from the theoretical models of hospital behavior. The conclusions presented below are related to the CED efficiency proposals.

Competition for staff physicians reduces technical efficiency. Competitive hospitals were found to accumulate excess capital resources. Personnel inputs are apparently adjusted in response to actual service requirements even in status-biased hospitals. The degree of efficiency divergence between low and high competitive intensity hospitals increases as the output of nuclear medicine increases. This observation suggests that the accumulation of excess capital becomes increasingly important as output expands. The American College of Radiology is currently considering the effect of regional planning and cooperation for nuclear medicine production. Such planning might reduce the importance of nuclear medicine capacity for the attraction of staff physicians, thereby reducing the incentive to acquire excess capacity. The evidence of this research indicates that a substantial improvement in technical efficiency would be possible. If regional planning also induces fewer but larger nuclear medicine producers, an additional efficiency benefit would be the economies of scale that were observed for the industry.

Profit incentives also have a significant efficiency impact. Although some of the evidence indicates that proprietary hospitals do not equate marginal productivities with resource prices, there was considerable evidence that they achieve higher output levels per unit of input. Therefore, the emphasis on creations of profit incentives offers a promising method for improving technical efficiency.

Service range had less than the expected affect on technical efficiency, particularly when qualitative differences in resource are also considered. The independent effect of service range was most important in the absence of capacity accumulation biases. If competition on the basis of excess capacity could be reduced, then reductions in service range could also produce efficiency gains.

The output effect of in-house manpower training, coincident with the production of nuclear medicine, was observed to be fairly unimportant. Any attempt to reorganize the training system would require a comparison of the relative impacts of alternative systems. Under the current system, it appears that trainee productivity largely compensates for the teaching and supervisory efforts of regular nuclear medicine personnel. Moreover, the value of firm expenditures on trainees should be compared to future firm productivity. Current training expenditures might reflect, in part, a wage bill allocation to hiring and training expense. Since the current training system has a minimal impact on technical efficiency, possible changes in the system do not suggest major efficiency gains.

## Consistency with Other Studies

The analysis of nuclear medicine provides a unique view of structure-efficiency relationships in the hospital industry. The common problem of output heterogeneity was avoided by focusing on a relatively standardized intermediate hospital product. Firm efficiency was directly related to hospital managerial behavior since hospital decisions link the measured input and output variables. Some of the results support other empirical findings; some contradict other findings; and some suggest new lines of interpretation for other findings.

As is consistent with other works, both competition and profit incentives were found to have considerable effect on technical efficiency. Other studies have asserted relationships between both of these and technical efficiency.

Two fairly unique observations appeared. First, significant economies of scale were observed for most of the production surface estimates. Many studies of the hospital industry have found little evidence of scale economies for hospital services. Lave and Lave are "skeptical of evidence showing no economies of scale because of the heterogeneity of services offered."[1] This study sheds some light on possible reasons for the lack of measured scale economies in other studies of hospital production. Economies of scale in the nuclear medicine industry were least significant in those hospitals with the strongest capacity biases. Since previous analysis has concentrated on capacity biased hospitals, their conclusions would apply only within the set of technically inefficient producers.

The second unexpected observation concerns the relative unimportance of service range and training intensity. Davis has noted that service range and training are important efficiency determinants which give an efficiency bias to proprietary hospitals.[2] This reasoning has been used to cast doubts on studies of efficiency in proprietary hospitals. In this study, service range was not significantly different for proprietary and nonproprietary hospitals. Moreover, the independent affect of service range on efficiency was small. Similarly, the effect of training appeared to be insignificant. These results lend support to the observation of greater technical efficiency in proprietary hospitals as found in other studies.

The findings of this study also indicate the validity of various theories of hospital behavior. Competition and profit incentives both effect the intensity of input accumulation. This evidence of status biased behavior implies that some hospitals do not attempt to maximize output or net revenue. The status biases are best explained on a theoretical basis within the utility maximization model. The accumulation of excess capacity is most consistent with the maximization of some quantity-quality combination. The poor data fit of the C.E.S. production function is not consistent with cost minimization with respect to output alone, but is consistent with regard to cost minimization of some quantity-quality combination.

## Recommendations for Further Study

Two general areas for additional study of the hospital industry could extend from this analysis. First, there is a need for more evidence concerning the general behavior of hospitals. The identification and examination of other specialized hospital services could be used to supplement the evidence from this study. An efficiency comparison format similar to the one applied to nuclear medicine might be employed.

Further investigations of scale economies in hospital production are also suggested. An attempt could be made to adjust for the status biases of individual hospitals. The observations of scale economies were most significant in the hospitals with lowest status biases, thereby demonstrating the importance of such an adjustment.

Finally, further investigations of the impact of in-house manpower training on technical efficiency should be developed. The result of this research is inconsistent with the commonly held view that training hospitals are less efficient.

The second area for additional study is the nuclear medicine industry itself. A more detailed investigation of production relationships would be a useful decision making tool for hospital managers. A larger set of resource categories could be defined, and the alternative input sets for each potential output level could be specified. Then a linear programming model could be used to describe the technical production constraints. For any given set of resource prices, the optimum input combination could be found.

## Summary

This study has attempted to measure the impact of four elements of hospital structure on technical efficiency in the production of nuclear medicine. The research hypotheses have stated that systematic differences in hospital efficiency are related to the level of competition, the profit incentives, the service range, and the training intensity of hospitals. Theoretical and empirical evidence has revealed a substantial relationship between these structural elements and technical efficiency. The findings have also contributed to the understanding of current theories of hospital behavior and other hospital production relationships. The results indicate that technical efficiency gains could be achieved through reduced competitive intensity, stronger profit orientation, and reduced service range in the hospital industry.

## FOOTNOTES

[1]Judith Lave and Lester Lave, "Economic Analysis for Health Service Efficiency," Applied Economics, IV (1970), p. 279.

[2]Karen Davis, "Economic Theories of Behavior in Non-profit Private Hospitals," Economic and Business Bulletin, XXIV (Winter, 1972), p. 4.

# BIBLIOGRAPHY


Aigner, D. J., and S. F. Chu. "On Estimating the Industry Production Function." American Economic Review, LVIII (September, 1968), 827-33.

Alchian, Armen. "The Basis of Some Recent Advancements in the Theory of Management of the Firm." Journal of Industrial Economics, XIV (November, 1965), 30-33.

Arrow, Kenneth J. "The Economics of Moral Hazard: Further Comment." American Economic Review, LVIII (June, 1968), 537-39.

__________. "Uncertainty and the Welfare Economics of Medical Care." American Economic Review, LIII (December, 1963), 941-73.

Baird, Charles W. "On Profits and Hospitals." Journal of Economic Issues, V (March, 1971), 57-66.

Berry, Ralph E., Jr. "Product Heterogeneity and Hospital Cost Analysis." Inquiry, VII (March, 1970), 67-75.

Brown, Max, Jr. "An Economic Analysis of Hospital Operations." Hospital Administration, XV (Spring, 1970), 60-74.

Chaing, Alpha C. Fundamentals of Mathematical Economics. New York: McGraw Hill, 1967.

Clarkson, Kenneth W. "Some Implications of Property Rights in Hospital Management." Journal of Law and Economics, XV (October, 1972), 363-84.

Commission of Professional Hospital Activities. The Record. New York: American Hospital Association, 1974.

Committee for Economic Development. Building a National Health Care System. Washington: Committee for Economic Development, 1973.

Cramer, J. S. Empirical Econometrics. Amsterdam: North Holland Publishing Company, 1971.

Davis, Karen. "Economic Theories of Behavior in Nonprofit Hospitals." Economic and Business Bulletin, XXIV (Winter, 1972), 1-13.

__________. "Relationship of Hospital Prices to Costs." Applied Economics, IV (1971), 115-25.

__________. "Rising Hospital Costs: Possible Causes and Cures." Brookings Reprint Series, CCLXII (May, 1973), 1359-68.

__________, and Louise B. Russell. "The Substitution of Hospital Outpatient Care for Inpatient Care." Review of Economics and Statistics, LIV (May, 1972), 109-20.

Feldstein, Martin S. "An Econometric Model of the Medicare System." The Quarterly Journal of Economics, LXXXV (February, 1971), 1-20.

__________. "Hospital Cost Inflation: A Study in Non-profit Price Dynamics." American Economic Review, LXI (December, 1971), 853-72.

__________. "Hospital Cost Variations and Case Mix Differences." Medical Care, III (1971), 95-99.

Feldstein, Paul J., and Sander Kelman. "An Econometric Model of the Medical Care Sector." Empirical Studies in Health Economics. Edited by Herbert E. Klarman. Baltimore: The Johns Hopkins Press, 1970, 63-72.

Fuchs, Victor R., ed. Essays in the Economics of Health and Medical Care. New York: National Bureau of Economic Research, 1972.

Garfield, Sidney R. "The Delivery of Medical Care." Scientific American, CCXXII (April, 1970), 15-23.

Ginzberg, Eli. Men, Money, and Medicine. New York: The Columbia University Press, 1969.

Hadley, G. Linear Programming. Reading: Addison-Wesley, 1962.

Hales, Wayne. "An Analysis of the Effects of Competitive Markets on Hospitals in Oklahoma." (Unpublished Ph.D. dissertation, Oklahoma State University, 1974.)

Joseph, Hyman. "Hospital Insurance and Moral Hazard." Journal of Human Resources, VII (Spring, 1972), 152-61.

Kessel, Reuben A. "Price Discrimination in Medicine." Journal of Law Economics, I (October, 1958), 20-53.

Klarman, Herbert E. The Economics of Health. New York: The Columbia University Press, 1965.

Ingbar, Mary, and Lester Taylor. Hospital Costs in Massachusetts. New York: The Columbia University Press, 1968.

Lave, Judith R., and Lester B. Lave. "Economic Analysis for Health Service Efficiency." Applied Economics, I (1970), 293-305.

__________. "Hospital Cost Functions." American Economic Review, LX (June, 1970), 379-95.

__________, Lester B. Lave, and Lester Silverman. "Hospital Cost Estimation Controlling for Case Mix." Applied Economics, IV (1972), 166-72.

Lee, Maw Lin. "A Conspicuous Production Theory of Hospital Behavior." Southern Economic Journal, XXXIX (July, 1971), 48-58.

__________, and Richard Wallace. "Some Problems in Estimating Multi-cost Production Functions." Western Economic Journal, XI (September, 1973), 350-58.

Lindsay, Cotton M. "Medical Care and the Economics of Sharing." Economica, XXXVI (November, 1969), 351-62.

Long, Millard. "Efficient Use of Hospitals." The Economics of Health and Medical Care. Ann Arbor: University of Michigan Press, 1964.

Mann, Judith, and Donald Yett. "The Analysis of Hospital Costs." Journal of Business, XLI (1968), 191-96.

Muller, Charlotte F., and Paul Worthington. "Factors Entering into Capital Decisions of Hospitals." Empirical Studies in Health Economics. Edited by Herbert E. Klarman. Baltimore: The Johns Hopkins Press, 1970, 75-81.

Nerlove, Mark. Estimation and Identification of Cobb-Douglas Production Functions. Chicago: Rand McNally, 1956.

Newhouse, Joseph P. "A Model of Physician Pricing." Southern Economic Journal, XXXVII (October, 1970), 174-83.

__________. "Toward a Theory of Nonprofit Institutions." American Economic Review, LX (May, 1970), 64-74.

Ogur, Jonathan D. "The Nonprofit Firm: A Test of the Theory for the Hospital Industry." Journal of Economics and Business, XXVI (Winter, 1974), 117-23.

Pauly, Mark V. "The Economics of Moral Hazard: Comment." American Economic Review, LVIII (June, 1968), 531-37.

__________, and David F. Drake. "Effect of Third-Party Method of Reimbursement on Hospital Performance." Empirical Studies in Health Economics. Edited by Herbert E. Klarman. Baltimore: The Johns Hopkins Press, 1970, 82-90.

__________, and Michael Redisch. "The Not For-Profit Hospital as a Physicians' Cooperative." American Economic Review, LXIII (March, 1973), 87-89.

Rafferty, John. "Hospital Output Indices." Economic and Business Bulletin, XXIV (Winter, 1972), 68-75.

__________. "Measurement of Hospital Case Mix." Applied Economics, IV (1972), 300-305.

Reder, M. W. "Economic Theory and Nonprofit Enterprise: Some Problems in the Economics of Hospitals." American Economic Review, LV (May, 1965), 472-80.

Rice, Dorothy P., and Barbara S. Cooper. "National Health Expenditures, 1929-71." Social Security Bulletin, XXXV (January, 1972), 3-18.

Rice, Robert G. "Analysis of the Hospital as an Economic Organism." Modern Hospital, CVI (April, 1966), 87-91.

Scitovsky, Anne A. "Changes in the Costs of Treatment of Selected Illnesses, 1961-65." American Economic Review, LVII (December, 1967), 1182-95.

Stevens, Carl M. "Hospital Market Efficiency: The Anatomy of the Supply Response." Empirical Studies in Health Economics. Edited by Herbert E. Klarman. Baltimore: The Johns Hopkins Press, 1970, 16-24.

Taylor, Ryland A. "Principles of the Economic Behavior of Hospitals." Nebraska Journal of Economics and Business, XI (Spring, 1972), 45-53.

Timmer, C. P. "Using a Probabilistic Frontier to Measure Technical Efficiency." Journal of Political Economy (1971), 781-88.

Wallace, T. D., and V. G. Ashar. "Sequential Methods in Model Construction." Review of Economics and Statistics, LIV (May, 1972), 172-78.

Wasyluka, Ray. "New Blood for Tired Hospitals." Harvard Business Review, XLVIII (September, 1970), 65-74.

Yamane, Taro. Mathematics for Economists. Englewood Cliffs: Prentice Hall, 1968.

# VITA

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