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## Analysis of Hospital Production and Cost: Economies of Scale and Scope

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# Analysis of Hospital Production and Cost: Economies of Scale and Scope

*Michael Alba*

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Estimating a Translog Variable Cost Function  
for Sixty-five Hospitals in the Philippines

A final report submitted to  
The Baseline Research for Health Care Financing Reform Project  
of the Department of Health and  
the Philippine Institute for Development Studies

*Costs are the obstacles that cause us to fulfill less than our full desires,  
so we need to investigate their nature.*

—George Stigler

*The cost function is the single most useful tool  
for studying the economic behavior of a firm.*

—Hal Varian

Michael M. Alba  
June 1995

## Executive Summary

In this study, a two-output transcendental logarithmic variable cost function and four (of five) share equations are jointly estimated by applying full-information maximum likelihood on a cross-section sample of 65 hospitals from seven provinces in the Philippines. The regression results comply with the inequality conditions (for the translog to be a proper cost function): The estimated function is found to be monotonic in both factor prices and outputs, concave in input prices, and convex in outputs.

Among the variable inputs, drugs and medical supplies are found to have the highest share (47.8%) of variable costs. The various personnel categories, such as medical residents, nurses, other medical staff, and non-medical staff, are estimated to have cost shares of between 11% and 15% percent. Of the two output indices, only the number of out-patient visits is measured to have a statistically significant impact on costs—although this may be inferred to be along the declining portion of the short-run average cost curve. (Specifically, the result indicates that doubling the number of out-patient visits would increase variable costs only by 54%, which implies that if hospitals expand the volume of their out-patient services, they may be able to reduce per unit costs.) The number of in-patient discharges is found not to have a significant impact on costs, although this may be due to measurement errors in the variable (in the sense that it does not capture variations in severity of illness and case mix across hospitals). Taken together, the regression results on input prices and outputs imply that costs are apparently driven by hospital inputs and may have little to do with the delivery of services.

Of the ten dummy variables which were included as regressors to capture cost variations arising from differences in hospital type, hospital ownership, and provincial location, only a hospital's being located in Bohol turned out to be statistically different from zero. Apparently, there are no systematic differences in variable costs due to facility level (or type), ownership, or provincial location.

What are the implications of the hospitals cost structure on the scale and scope of hospital operations? From the estimated translog cost function, it can be inferred that optimal bed capacity is about 81 hospital beds and that there are neither economies nor diseconomies of scope. The first result implies that if the scale of hospital operations were doubled, long-run per unit costs of hospitals with fewer than 81 beds would probably decrease, while those

with more beds are likely to see higher per unit costs. The second result means that it apparently would not cost more—though neither would it cost less—for out-patient and in-patient services to be provided in a single hospital as opposed to these services being offered in two *specialized* hospitals.

# I

## Introduction

Hospitals are perennially among the largest recipients of government and private funds for health care. Yet, in developing countries, the cost and production structure of hospitals remains poorly studied. In part, this neglect has been due to the prevailing thinking among researchers and policy makers (which is not without empirical basis) that primary health care as well as preventive and promotive health interventions are more cost-effective ways of delivering health services. But another aspect of this gap in research has been that, although the econometric technology to estimate structural cost functions for a hospital system has been available since the early 1980s,\* data sets with sufficiently detailed information on hospital costs in developing countries have been difficult to come by. Many hospitals still do not have good accounting systems in place; those that do follow different accounting practices, making it difficult to standardize costs.

Whatever the reasons for this oversight, the consequence has been that certain basic issues relevant to the efficient administration and effective planning of the hospital system, such as the substitutability or complementarity of hospital inputs, the optimal size of hospital operations relative to outputs, and the scale and scope of hospital services, have remained unanswered. Other important policy questions which require information on the structure of hospital costs, such as the appropriate allocation of resources between hospital and non-hospital activities and the viability of financing strategies, including cost recovery schemes and health insurance, cannot be addressed as well.

This study attempts to estimate a structural cost function for Philippine hospitals. As such, it represents an initial step at redressing both a research and a policy gap in the health sector of a developing country. In this exercise, a transcendental logarithmic variable cost function and four (of five) share equations are jointly estimated by applying full-information maximum likelihood on a cross-section sample of 65 hospitals from seven provinces in the Philippines. The results and interpretation of this regression are provided in chapter five. To set the stage for these estimates, an overview of the issues on hospital cost function

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\* Since the late sixties, there has been a torrent of studies on the estimation and interpretation of hospital cost functions in developed countries. Ellis (1992) estimates that in the last five years alone, at least 3,500 books and articles have been published on the subject.

estimation is undertaken in the next chapter. Chapter three then gives a brief technical exposition of the theoretical and empirical considerations involved in the estimation of a structural variable cost function—particularly one with a transcendental logarithmic form—and discusses some of the statistical inferences that can be drawn from such estimates. Chapter four provides some background information on the data set and the cost function variables. In chapter six, some counterfactual predictions on certain aspects of hospital costs and production for different types of hospitals are presented. These include the output elasticities of variable costs, indices of economies or diseconomies of scale and scope, and the economic efficiency of hospital operations. Finally, the significance and policy implications of this research activity are discussed in chapter seven.

## II

### An Overview of the Issues on Hospital Cost Function Estimation

This chapter is an attempt to take stock of recent developments in the econometric estimation of structural hospital cost functions. This attention on the literature of the last ten to fifteen years is notable because, over the same time period, there has been a marked shift in the approach used to study hospital costs. In the early seventies, hospital cost estimations were not much more than curve fitting exercises intended to forecast costs; since then, research has taken pains to use microeconomic theory as a basis for the specifications of cost functions. Given what remains a vast literature, however, it is foolhardy to undertake a full and detailed survey. Moreover, several excellent reviews are available, e.g., Cowing, Holtmann, and Powers (1983), Wagstaff and Barnum (1992), and Barnum and Kutzin (1993). Thus, the tact adopted here is to cull the issues as presented by the surveys and to provide a sense of what other issues have to be considered to improve future research efforts.

Recent econometric research on hospital cost functions has tried to address so many issues that it is helpful to review the basic intent of such investigations. In essence, the estimation and interpretation of hospital cost functions constitute an attempt to study, under a set of behavioral assumptions, the structure of costs and production of a set of hospitals. A sampling of the questions addressed by such exercises are: *How does average cost behave? Does cost per unit of output rise or decline as a hospital produces more output? What is the level of output at which cost per unit of output is at its lowest level? Are hospitals producing at this level of output?* Since costs are necessarily affected by the technology of the production process, hospital cost functions also afford another angle from which production-related issues can be examined. Some questions entertained along this line of inquiry are: *What is the optimal size of a hospital? How many beds should a hospital maintain? Relative to current output levels, do hospitals have too much capital equipment? Are hospitals technically efficient? (That is, do they obtain the maximum levels of output from their inputs?) Are they allocatively efficient? (That is, are they choosing the right combinations and levels of*

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\* Models of hospital behavior include standard cost-minimization as well as profit-, output- or utility-maximization (the last of the hospital administrator, of the hospital's board of trustees, or of doctors on the hospital staff). The emphasis here is on empirical work based on the cost-minimization theory of the firm, however, since this has been the approach generally used to study hospital cost functions over the last ten years.



*inputs, given their outputs?) On the basis of the patterns of their costs and production alone, should hospitals offer a wide range of medical services, or should they specialize? Are there hospital departments which are cheaper to operate jointly than if their services were otherwise provided separately in different, more specialized hospitals?*

Hospitals, however, do not fit the economist's standard notion of a firm, and this gives rise to a host of challenges in properly estimating the cost function of hospitals. As a starting point, consider that it is difficult to even pin down what it is that constitutes a hospital's output. If it is allowed (extending Grossman [1972]) that, in general, people avail of hospital services because their health stocks have fallen below some critical level, then perhaps the restoration of the health stock of its patients ought to be regarded as the outputs of a hospital (See Breyer [1987] and Ellis [1992], for instance). Even this measure falls short, however, in the cases of the terminally-ill, for whom the object of the hospital stay may be the management of pain before death,\* and of patients who undergo elective cosmetic enhancements, such as nose reconstructions and breast implants. Moreover, as Ellis (1992) points out, measuring the improvement in health stocks is difficult, if not virtually impossible, to implement empirically. Health status is multifaceted. Like all components of well-being, it is a nebulous concept that is not easy to define and measure in an operationally feasible manner, much less to compare and aggregate across patients.

Because of these problems, researchers have taken instead to using measures of throughputs or intermediate outputs, such as the number of cases treated, of patient-days served per hospital department, and of outpatient visitors. This strategy, however, summons a new set of problems related to the homogeneity of hospital outputs. Two aspects that have received widespread attention in particular are the case mix of hospitals and the quality of care that they provide.

A hospital's case mix refers to the variety of illnesses and diseases that are treated in a hospital setting. In relation to cost function estimation, the case mix of hospitals presents two problems: (a) Obviously, if hospitals do not administer to the same kinds of ailments (or if they follow radically different treatment protocols), then their production and cost structures are bound to be different, and they ought not to be regarded as belonging to the same class of firms. (b) The correct specification of the cost function requires the inclusion

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\* I am grateful to Orville Solop for this example. It can be argued, however, that assuming uncertain outcomes, there is always a last hope and the probability of recovery is never zero.

of *all* the outputs of hospitals in the set of regressors. Otherwise, the regression equation runs the risk of being misspecified.

Given the sheer numbers of diseases and conditions for which patients seek treatment in a hospital, however, some form of aggregation of the hospital throughputs is necessary to avoid running into a degrees of freedom problem (where the number of parameters to be estimated is greater than, or equal to, the number of observations in the data set) in the estimation of the hospital cost function. Unfortunately, the appropriate method of aggregation is still an unsettled issue in the literature, although there is no shortage of proposals.

Breyer (1987) suggests that the case mix issue be handled by grouping patients according to an arbitrary (manageable) number of diagnostic categories and specifying that each diagnostic group raise total costs only by a constant. In other words, given  $N$  diagnostic groups and  $y_1, y_2, \dots, y_N$  cases per group, the effect on total costs of these groups is given by  $\sum_{n=1}^N \delta_n y_n$ . Wagstaff and Barnum (1992) note, however, that this type of specification assumes away the possibility of economies of scope: The costs of jointly producing various classes of outputs cannot be lower than the costs of producing each output category separately if total costs are merely the sum of all outputs.

After pointing out that the approach used in other (more standard) markets (which is to deflate the price weighted sum of a subset of products by some price index in order to generate quantity indices of outputs) is inappropriate in the case of hospitals because of price and non-price distortions caused by different insurance schemes, Ellis (1992) claims that the usual technique in aggregating hospital throughputs has been to include a case mix index in the specification of the hospital cost function.\* This case mix index is supposedly generated by dividing the severity weighted sum of hospital admissions (in which diagnostic resource group [DRG] costs are used as measures of severity weights) by the total number of admissions. Ellis cautions, however, that a drawback in using such a case mix index is that, since DRG costs were designed to measure the cost of hospital resources used in each diagnostic group, the index infects output variables with measures of inputs.

As for schemes employed in actual hospital cost function studies, these range from simple breakdowns of cases into the number of out-patient visits and of in-patient admissions (*e.g.*, Wouters [1993]) to more elaborate stratifications, such as the number of in-patient days by hospital department and of emergency room visits, as in Cowing and Holtmann (1983),

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\* Ellis neglects to cite studies on cost function estimation that use this approach, however.

and frequencies of in-patient days by age group (child vs. non-child) and mode of payment (Medicare vs. non-Medicare), as in Conrad and Strauss (1983). However the case mix issue is handled, given the variety of suggested and implemented methods of aggregation, it is clear that they are not able to accommodate the same breadth of disease categories as a specification that is not based on microeconomic theory (See Caragay [1989], for example).

Like the case mix problem, the quality of care provided by hospitals has not been satisfactorily dealt with in the empirical literature. Obviously, as Ellis (1992) points out, hospitals with high mortality or readmission rates ought not to be regarded as having the same (quality of) outputs as hospitals with lower rates. Yet this misspecification is exactly what happens when quality measures are not included in the set of regressors of the cost function, since throughputs are used as the measures of hospital outputs (so that vital information is lost on the effectiveness of treatments). What the appropriate measures of quality are, however, is hard to say. Confounding the problem are (a) the inherent uncertainty in the outcomes of medical treatments, which makes mortality and readmission rates indicative but noisy measures of quality at best; (b) the bundling of (medical and non-medical or *hotel*) services in a hospital stay, each of which may have a qualitative aspect; and (c) the perception of patients, which arguably may be where quality of care ought ultimately to be judged. Some measures of quality that have been proposed or used in the literature are: the teaching status of hospitals, the number or proportion of specialists on the medical staff, the location and accessibility of the hospital, the attributes of amenities (*e.g.*, cleanliness of facilities, hospitality of the staff, quality of the food), and the occupancy rate of hospitals.\*

These problems notwithstanding, research on hospital cost function estimation (roughly since 1983) has generally proceeded under the assumption that hospitals are a class of multi-product firms whose common objective is to minimize costs subject to an output constraint. Cost-minimizing behavior is rationalized on the strength of the following arguments: (a) Many hospitals are constituted as non-profit organizations. As such, these hospitals may have objectives other than profit-maximization. (b) Cost-minimization is a necessary condition for profit- and (budget-constrained) output-maximization and is thus a legitimate objective under a wide variety of circumstances. (c) Hospitals do not control their

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\* The occupancy rate of hospitals was used by Friedman and Pauly (1981) as a measure of quality on the argument that as admissions approach hospital capacity, the resources of the hospitals have to be spread more thinly, thus resulting in lower overall quality of services provided.

output levels, but merely respond to the demand for medical care in their catchment areas. (d) It is contended that hospitals do not exercise monopsonistic powers over inputs.

The specific and technical details of hospital cost function estimation under the assumption of cost-minimization are discussed in the next chapter. This overview cannot be considered complete, however, without a brief discussion of the other issues pertinent to hospital cost function estimation that will have to be addressed if empirical work on the subject is to become more relevant. These are: the effects on hospital costs (a) of doctors' fees and the unique relationship that exists between doctors and their patients, (b) of various health insurance schemes, (c) of uncertainty in the contraction of illnesses, in diagnoses of the ailments, and in treatment outcomes, and (d) of alternative characterizations of hospitals.

Physicians play a curious role in the provision of hospital care. As noted by Cowing, Holtmann, and Powers (1983), although doctors supply what may be considered indispensable inputs in the treatment of patients in a hospital setting, they are often paid separately (either by the patients themselves or by the health insurance companies) so that the costs of their services are usually not reflected along with those of other production factors in hospital cost figures. In addition, physicians enjoy privileged relationships with their patients, which allow them a wide degree of latitude in the choice of treatment procedures. It has been alleged that such special bonds may even cause physicians to induce demand for particular procedures, *e.g.*, deliveries by caesarian section for women with higher paying capacities. Furthermore, there is evidence that the qualifications and reputations of doctors in the medical staff of hospitals increase both the costs of and the demand for care in those hospitals. All these aspects pose important questions for the correct analysis of hospital costs.

The existence of various health insurance schemes also has wide ranging implications on hospital costs. The payment or reimbursement schemes (*e.g.*, whether by capitation or fee-for-service) and what is allowed or disallowed under different insurance plans influence the strategic behavior of both doctors and hospitals in the provision of medical care. For instance, if Medicare ceilings are raised, it is possible that laboratory fees and other prices may simply follow suit, rising up to the levels of the ceilings. Or, the frequency distribution

of medical treatments may very well be heavily skewed toward those procedures that are covered by Medicare or other insurance plans.\*

The pervasiveness of uncertainty in health is another factor whose impact on hospital costs has not been fully explored. The time during which an illness is contracted, how accurately an illness is diagnosed, and the efficacy of various types of treatment all exert significant influences on hospital costs. As Friedman and Pauly (1981) hypothesize, when the number of admitted cases approaches a hospital's bed capacity, the quality of its services may suffer: less time and resources may be devoted to each patient, thereby increasing the probability of a wrong diagnosis or decreasing the efficacy of treatments. For a given illness, a hospital patient may thus be worse off during epidemics.

Finally, it is not clear that hospitals solely minimize costs; they may also be pursuing other goals, *e.g.*, maximizing the welfare of doctors on their staffs and satisfying the desires of donors or trustees which, under cost-minimization, would appear as technical or allocative inefficiencies. As has already been pointed out, hospitals have peculiar aspects that rankle against an economist's standard notion of a firm. It is difficult to characterize what exactly hospitals produce. Payments to an important input—namely, doctors' services—are not customarily considered part of hospital costs. Possibly, all these imply that it is more appropriate to consider hospitals not as firms but as marketplaces, where a patient who needs some form of *critical* health care goes for the bundling of the particular service that he needs from the diverse set of inputs selling their wares in that marketplace.

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\* This argument is also another reason why a well-designed method of disaggregating or aggregating the case mix of hospitals is important in the specification of a hospital cost function.

### III

#### Hospital Cost Function Estimation: Some Theoretical Considerations and the Translog Variable Cost Function

This chapter provides a brief exposition of some relevant aspects of the theory of cost-minimization and discusses in some detail how these considerations enter in the estimation of a transcendental logarithmic variable cost function for a cross-section of hospitals.

##### A. Theoretical Considerations

It is posited that a hospital is a multiple output firm whose objective is to minimize the cost of producing given levels of outputs. The programming problem of such a firm may be stated as:

$$\begin{aligned} \min_x \quad & w \cdot x \\ \text{subject to} \quad & T(x, y^0) = 0 \end{aligned} \quad (1)$$

where  $x$  is the vector of all inputs;  $w$  is the vector of all exogenous factor prices;  $y^0$  is an  $N$ -vector of all outputs, the magnitudes of whose elements are set at  $[y_n^0]_{n=1}^N$ ; and  $T(\cdot)$  is an implicit function which represents the efficient transformation of inputs into outputs.

Under rather minimal assumptions about the firm's technology (see Varian [1992], for instance), the solution to the programming problem (1) consists of a set of conditional factor demands  $x^*$ , which jointly minimize the cost of producing outputs  $y$  at prices  $w$ . That is,

$$x^* = x(w, y). \quad (2)$$

Returning these conditional demand functions to the cost equation  $w \cdot x$  yields the cost function:

$$\begin{aligned} w \cdot x(w, y) &= c(w, y) \\ &= c(w_1, w_2, \dots, w_I, y_1, y_2, \dots, y_N). \end{aligned} \quad (3)$$

Thus, the cost function gives the minimum cost of producing outputs  $y$  at prices  $w$ . Given the assumptions on the firm's technology, the cost function is linearly homogeneous and concave in factor prices, convex in outputs, and nondecreasing and continuous in both outputs and factor prices.

### Long-Run and Short-Run Cost Functions

By construction, the vector  $x^*$  in equation (2) contains the cost-minimizing levels of demand for *all* inputs. Consequently, equation (3) may be viewed as a long-run cost function in which all inputs are assumed to be variable. Some inputs, such as buildings and machines, however, are *long-lived* and are difficult to change over short periods of time. It is therefore useful analytically to define a restricted cost function

$$c^v = c^v(w^v, y, k) \quad (4)$$

where  $c^v$  is the minimal variable cost,  $w^v$  is the vector of variable input prices, and  $k$  is a vector of fixed inputs—in which all variables are defined for a given reference period, say, a year. The variable cost function (4) is completely analogous to equation (3), except that it assumes cost minimization with respect to a subset rather than the full set of inputs.

How is the variable cost function (4) related to the long-run cost function (3)? Observe that total (though not necessarily minimal) costs can always be written as the sum of variable and fixed costs

$$\begin{aligned} E &= w \cdot x \\ &= w^v \cdot x^v + w^k \cdot k \\ &= c^v(w^v, y, k) + w^k \cdot k \end{aligned} \quad (5)$$

where  $E$  is the value of total costs,  $x^v$  is the vector of variable inputs, and  $w^k$  is the vector of prices of the fixed factors.

Minimizing the total cost equation (5) with respect to each element of the fixed input vector  $k$  and setting these to zero yield the minimal total cost function. That is,  $E = c(w, y)$  if and only if

$$\begin{aligned} \frac{\partial E}{\partial k_i} &= \frac{\partial c^v(w^v, y, k)}{\partial k_i} + w_{k_i} = 0 \\ \frac{\partial c^v(w^v, y, k)}{\partial k_i} &= -w_{k_i}. \end{aligned} \quad (6)$$

Equation (6) is the envelope condition. It states that long-run costs are minimized when the amounts of fixed inputs are such that  $(-\partial c^v / \partial k_i)$ —the savings in variable costs brought about by the last unit of the  $i$ th fixed input hired—are just equal to  $w_{k_i}$ —the marginal cost of that fixed input. Hence, equation (6) gives the condition for the optimal level of fixed inputs  $k^*$ : To minimize long-run costs, fixed inputs  $k$  should be employed at levels

such that equation (6) is satisfied. A second implication of equation (6) is that it provides a link between the variable cost function and its long-run kin: When equation (6) holds so that, in the short-run, fixed factors are hired at levels that minimize long-run costs, the cost function (3) can in principle be derived from the variable cost function (4).

An issue in the hospital cost literature concerns which cost function is the more appropriate one to estimate. Cowing, Holtmann, and Powers (1983) recommend using the variable cost function, particularly when the estimation is performed on cross-section data. They argue that it is improbable that in the short-run all firms would be employing all inputs at their long-run cost-minimizing levels or, which is the same thing, that equation (6) holds for all firms at any given point in time.\* On the other hand, Wagstaff and Barnum (1992) point out that it is difficult to cleanse total cost data of all fixed costs. They claim that this is possibly the reason why  $\partial c^v/\partial k$  is positive and significant in Cowing and Holtmann's (1983) study: For given input prices and a combination of output levels, the employment of variable factors and their costs should decrease as a hospital acquires and employs more of the fixed factors—unless variable costs are not rid of all fixed costs. Consequently, Wagstaff and Barnum suggest using the total cost equation (5) instead, where the fixed factors enter the specification twice—as arguments of the variable cost function  $c^v$  and as components of fixed costs  $w^k \cdot k$ .\*\* Then, to determine whether hospitals use fixed inputs at their cost-minimizing levels, statistical tests can be performed on whether the estimated fixed cost coefficients of the fixed inputs  $\hat{w}^k$  are significantly different from zero.†

### Duality and Shephard's Lemma

An important aspect about the cost function is that by the principle of duality, given any cost function, it is possible to recover the technology that may have generated the cost function. In other words, information about the firm's technology is embedded in the cost

\* In fact, whether or not equation (6) holds can be subjected to statistical testing procedures after the variable cost function is estimated. For instance, given a set of values for  $w_{k_t}$ ,  $t = 1, \dots, T$ , an F-test can be performed to test the hypothesis that  $\partial c^v(w, y, k)/\partial k_t = -w_{k_t}$  for all  $t$ .

\*\* A problem with this specification, though, is that it may be subject to serious collinearity problems, since indices of the fixed factors enter twice in the cost equation.

† Note that if  $\hat{w}^k = 0$ , then  $\partial c/\partial k_t = \partial c^v(w^v, y, k)/\partial k_t = 0$ , which implies that the amounts of the fixed assets employed are consistent with their long-run cost-minimizing levels. But if  $\hat{w}^k > 0$  ( $\hat{w}^k < 0$ ), then  $\partial c/\partial k_t = 0 > \partial c^v(w^v, y, k)/\partial k_t$  ( $\partial c/\partial k_t = 0 < \partial c^v(w^v, y, k)/\partial k_t$ ), which implies that hospitals underemploy (overemploy) fixed inputs. Thus, Wagstaff and Barnum also interpret the test as one on the appropriateness of the levels of fixed assets given the hospitals' output levels.



function, so that it is possible—sometimes even easier—to study the characteristics of the production process using the cost function.

This proposition—that under cost-minimization the cost function is merely the dual representation of the firm's technology—is proven for the general case using the mathematical theory of convex sets. In practice, however, the recovery of the technology from a specific form of the cost function is customarily done using Shephard's lemma, which states that the partial derivative of the (variable) cost function with respect to the price of the  $i$ th input is equal to the the firm's conditional factor demand for that factor:

$$\frac{\partial c(w, y)}{\partial w_i} = x_i(w, y, k) \quad \text{for } i = 1, \dots, I. \quad (7)$$

Given the  $I$  input demand equations in (7), the firm's transformation function  $T(x, y^0) = 0$  can then be solved, in principle, by eliminating the input prices.

In the context of structural cost function estimation, however, Shephard's lemma serves another purpose. The theorem is used to obtain conditional factor demand functions which, being functional transformations of the cost function, share many of its parameters. Treating the cost function and the conditional demand functions as a system of equations and applying system estimation procedures, such as generalized least squares or full-information maximum likelihood then allow efficiency gains to be achieved in the estimation of cost function parameters.

### *B. The Transcendental Logarithmic Variable Cost Function*

From the theory of cost-minimization, the econometrician can glean the arguments of the variable cost function. Without any prior knowledge of the functional form of the hospital's underlying transformation function, however, he runs the risk of misspecifying the form of the regression equation. One way to get around this problem is to use flexible functional forms which are second-order Taylor series expansions that can locally approximate any differentiable function. The idea behind the estimation of flexible functional forms is the following: Assuming that the data collected are those of firms minimizing costs for given levels of outputs, input prices, and fixed factors, then if the specification of the regression equation is such that it can approximate any functional form, it may be possible to allow the true structure of the variable cost function to emerge as a result of the estimation,

provided that the list of regressors is complete. The drawback, however, is that, being *local* expansions, flexible functional forms yield estimation results that are not valid globally, but only in the neighborhood of the expansion points (Vita, 1990).

The most widely used flexible functional form, perhaps because it requires the least number of parameters to estimate, is the transcendental logarithmic (translog) variable cost function. The translog variable cost function is a second-order Taylor series expansion of the natural logarithm of a normalized variable cost function about the point  $(\ln w^*, \ln y^*, \ln k^*) = (0, 0, 0)$ , where  $w^* = (w_1^*, \dots, w_J^*)$ ,  $y^* = (y_1^*, \dots, y_N^*)$ , and  $k^* = (k_1^*, \dots, k_T^*)$  are vectors of factor prices, outputs, and fixed factors about which expansion is performed.

#### Derivation of the Translog Variable Cost Function

One procedure for deriving the translog variable cost function is as follows: Transform the variable cost function  $c^v(\cdot)$  of a firm by dividing the value of the function as well as the variables that enter as arguments by their industry averages (or sample means in the case of a cross-section sample):

$$c^{v*} = c^v(w_1^*, \dots, w_J^*, y_1^*, \dots, y_N^*, k_1^*, \dots, k_T^*)$$

where

$$\begin{aligned} c^{v*} &= c^v / \bar{c}^v; \\ w_i^* &= w_i / \bar{w}_i \quad \text{for } i = 1, \dots, J; \\ y_n^* &= y_n / \bar{y}_n \quad \text{for } n = 1, \dots, N; \\ k_t^* &= k_t / \bar{k}_t \quad \text{for } t = 1, \dots, T; \end{aligned}$$

and where  $\bar{w}_i$  is the mean of the  $i$ th factor price,  $\bar{y}_n$  is the mean of the  $n$ th output, and  $\bar{k}_t$  is the mean of the  $t$ th fixed factor.

Noting that a second-order Taylor series expansion of a function  $f(x_1, \dots, x_Z)$  about the point  $\mathbf{a} = (a_1, \dots, a_Z)$  is given as

$$f(x_1, \dots, x_Z) = f(a_1, \dots, a_Z) + \sum_{z=1}^Z \frac{\partial f}{\partial x_z} (x_z - a_z) + \frac{1}{2} \sum_{z=1}^Z \sum_{\zeta=1}^Z \frac{\partial^2 f}{\partial x_z \partial x_\zeta} (x_z - a_z)(x_\zeta - a_\zeta),$$

let  $f(\cdot) = \ln c^v$  and  $\mathbf{a} = (\ln \bar{w}^*, \ln \bar{y}^*, \ln \bar{k}^*)$ . Then, the expansion of the function  $\ln c^v$  at the point  $(\ln \bar{w}^*, \ln \bar{y}^*, \ln \bar{k}^*)$  can be written as

$$\begin{aligned}
& \ln c^{v*}(\ln w_1^*, \dots, \ln w_J^*, \ln y_1^*, \dots, \ln y_N^*, \ln k_1^*, \dots, \ln k_T^*) \\
&= \ln c^{v*}(\ln \bar{w}_1^*, \dots, \ln \bar{w}_J^*, \ln \bar{y}_1^*, \dots, \ln \bar{y}_N^*, \ln \bar{k}_1^*, \dots, \ln \bar{k}_T^*) + \sum_{i=1}^I \frac{\partial \ln c^{v*}}{\partial \ln w_i^*} (\ln w_i^* - \ln \bar{w}_i^*) \\
&+ \sum_{n=1}^N \frac{\partial \ln c^{v*}}{\partial \ln y_n^*} (\ln y_n^* - \ln \bar{y}_n^*) + \sum_{t=1}^T \frac{\partial \ln c^{v*}}{\partial \ln k_t^*} (\ln k_t^* - \ln \bar{k}_t^*) \\
&+ \frac{1}{2} \sum_{i=1}^I \sum_{j=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln w_j^*} (\ln w_i^* - \ln \bar{w}_i^*) (\ln w_j^* - \ln \bar{w}_j^*) \\
&+ \frac{1}{2} \sum_{n=1}^N \sum_{m=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln y_m^*} (\ln y_n^* - \ln \bar{y}_n^*) (\ln y_m^* - \ln \bar{y}_m^*) \\
&+ \frac{1}{2} \sum_{t=1}^T \sum_{s=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln k_t^* \partial \ln k_s^*} (\ln k_t^* - \ln \bar{k}_t^*) (\ln k_s^* - \ln \bar{k}_s^*) \\
&+ \sum_{i=1}^I \sum_{n=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln y_n^*} (\ln w_i^* - \ln \bar{w}_i^*) (\ln y_n^* - \ln \bar{y}_n^*) \\
&+ \sum_{i=1}^I \sum_{t=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln k_t^*} (\ln w_i^* - \ln \bar{w}_i^*) (\ln k_t^* - \ln \bar{k}_t^*) \\
&+ \sum_{n=1}^N \sum_{t=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln k_t^*} (\ln y_n^* - \ln \bar{y}_n^*) (\ln k_t^* - \ln \bar{k}_t^*).
\end{aligned}$$

But by definition  $\bar{w}_i^* = \bar{y}_n^* = \bar{k}_t^* = 1$  for all  $i$ ,  $n$ , and  $t$ , so that  $\ln \bar{w}_i^* = \ln \bar{y}_n^* = \ln \bar{k}_t^* = 0$  for all  $i$ ,  $n$ , and  $t$ . Hence, the translog variable cost function can be expressed as

$$\begin{aligned}
& \ln c^{v*}(\ln w_1^*, \dots, \ln w_J^*, \ln y_1^*, \dots, \ln y_N^*, \ln k_1^*, \dots, \ln k_T^*) \\
&= \ln c^{v*}(0, \dots, 0) + \sum_{i=1}^I \frac{\partial \ln c^{v*}}{\partial \ln w_i^*} \ln w_i^* + \sum_{n=1}^N \frac{\partial \ln c^{v*}}{\partial \ln y_n^*} \ln y_n^* + \sum_{t=1}^T \frac{\partial \ln c^{v*}}{\partial \ln k_t^*} \ln k_t^* \\
&+ \frac{1}{2} \sum_{i=1}^I \sum_{j=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln w_j^*} \ln w_i^* \ln w_j^* + \frac{1}{2} \sum_{n=1}^N \sum_{m=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln y_m^*} \ln y_n^* \ln y_m^* \\
&+ \frac{1}{2} \sum_{t=1}^T \sum_{s=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln k_t^* \partial \ln k_s^*} \ln k_t^* \ln k_s^* + \sum_{i=1}^I \sum_{n=1}^N \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln y_n^*} \ln w_i^* \ln y_n^* \\
&+ \sum_{i=1}^I \sum_{t=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln k_t^*} \ln w_i^* \ln k_t^* + \sum_{n=1}^N \sum_{t=1}^T \frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln k_t^*} \ln y_n^* \ln k_t^*; \tag{8}
\end{aligned}$$

and the regression equation to be estimated can be written as

$$\begin{aligned}
\ln c^{v*} = & \alpha_0 + \sum_{i=1}^I \alpha_i \ln w_i^* + \sum_{n=1}^N \beta_n \ln y_n^* + \sum_{t=1}^T \gamma_t \ln k_t^* \\
& + \frac{1}{2} \sum_{i=1}^I \sum_{j=1}^I \alpha_{ij} \ln w_i^* \ln w_j^* + \frac{1}{2} \sum_{n=1}^N \sum_{m=1}^N \beta_{nm} \ln y_n^* \ln y_m^* + \frac{1}{2} \sum_{t=1}^T \sum_{s=1}^T \gamma_{ts} \ln k_t^* \ln k_s^* \quad (9) \\
& + \sum_{i=1}^I \sum_{n=1}^N \rho_{in} \ln w_i^* \ln y_n^* + \sum_{i=1}^I \sum_{t=1}^T \delta_{it} \ln w_i^* \ln k_t^* + \sum_{n=1}^N \sum_{t=1}^T \theta_{nt} \ln y_n^* \ln k_t^*,
\end{aligned}$$

where

$$\begin{array}{ll}
\alpha_0 & = \ln c^{v*}(0, \dots, 0); \\
\alpha_i & = \partial \ln c^{v*} / \partial \ln w_i^* \quad \text{for } i = 1, \dots, I; \\
\beta_n & = \partial \ln c^{v*} / \partial \ln y_n^* \quad \text{for } n = 1, \dots, N; \\
\gamma_t & = \partial \ln c^{v*} / \partial \ln k_t^* \quad \text{for } t = 1, \dots, T; \\
\alpha_{ij} & = \partial^2 \ln c^{v*} / (\partial \ln w_i^* \partial \ln w_j^*) \quad \text{for } i = 1, \dots, I \text{ and } j = 1, \dots, I; \\
\beta_{nm} & = \partial^2 \ln c^{v*} / (\partial \ln y_n^* \partial \ln y_m^*) \quad \text{for } n = 1, \dots, N \text{ and } m = 1, \dots, N; \\
\gamma_{ts} & = \partial^2 \ln c^{v*} / (\partial \ln k_t^* \partial \ln k_s^*) \quad \text{for } t = 1, \dots, T \text{ and } s = 1, \dots, T; \\
\rho_{in} & = \partial^2 \ln c^{v*} / (\partial \ln w_i^* \partial \ln y_n^*) \quad \text{for } i = 1, \dots, I \text{ and } n = 1, \dots, N; \text{ and} \\
\theta_{nt} & = \partial^2 \ln c^{v*} / (\partial \ln y_n^* \partial \ln k_t^*) \quad \text{for } n = 1, \dots, N \text{ and } t = 1, \dots, T.
\end{array}$$

### Equality and Inequality Restrictions

For equation (9) to be a proper cost function, recall from Section A that it must be linearly homogeneous and concave in factor prices, convex in outputs, and nondecreasing and continuous in both outputs and factor prices. In econometric estimations of the translog variable cost function, the convention has been to impose restrictions on certain parameters to ensure that the equality conditions—namely, homogeneity of degree one in prices and continuity in both prices and outputs—are satisfied and to check that the estimated model complies with the inequality conditions of monotonicity in both outputs and prices, concavity in prices, and convexity in outputs.\* The details of these restrictions are discussed below.

Continuity of the variable cost function in prices and outputs implies that the function is non-negative for all non-negative outputs and prices and for given levels of fixed inputs  $\bar{k}$ . That is,

$$c(w, y, k) \geq 0 \quad \text{for } w \geq 0, y \geq 0, \text{ and } k = \bar{k}.$$

\* Because of the widespread failure of estimated translog cost functions to show the required properties, however, Antle and Capalbo (1988) report that there is an ongoing trend to develop algorithms which satisfy these restrictions. It should be noted, though, that this failure in estimation can also mean that (a) cost-minimization is not the correct behavioral model that generated the data observed or that (b) there are sampling, measurement, or specification errors. Moreover, as Nimfa Mendoza notes in her review of an earlier version of this report, imposing concavity restrictions effectively eliminates the flexibility of the translog function. If concavity is an important consideration, some other functional form such as the generalized McFadden, should be used instead.

Given data that are usually observed on costs, factor prices, outputs, and fixed inputs, this condition is satisfied trivially. The practice in the estimation of the translog cost functions, however, has been to make use of Young's Theorem which provides sufficient, though not necessary, conditions for continuity, perhaps in order to reduce the number of parameters to be estimated:

**Young's Theorem.** *If a function is twice differentiable,\* then its cross partial derivatives are equal:*

$$\frac{\partial^2 c^v}{\partial w_i \partial w_j} = \frac{\partial^2 c^v}{\partial w_j \partial w_i} \quad \text{for all } i \text{ and } j \text{ and} \quad \frac{\partial^2 c^v}{\partial y_n \partial y_m} = \frac{\partial^2 c^v}{\partial y_m \partial y_n} \quad \text{for all } n \text{ and } m.$$

For the translog variable cost function, the equivalent conditions for Young's theorem are

$$\begin{aligned} \frac{\partial^2 \ln c^{v*}}{\partial \ln w_i^* \partial \ln w_j^*} &= \frac{\partial^2 \ln c^{v*}}{\partial \ln w_j^* \partial \ln w_i^*} && \text{for all } i \text{ and } j \text{ and} \\ \frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln y_m^*} &= \frac{\partial^2 \ln c^{v*}}{\partial \ln y_m^* \partial \ln y_n^*} && \text{for all } n \text{ and } m. \end{aligned} \quad (10)$$

Since  $\alpha_{ij} = \partial^2 \ln c^{v*} / (\partial \ln w_i^* \partial \ln w_j^*)$  and  $\beta_{nm} = \partial^2 \ln c^{v*} / (\partial \ln y_n^* \partial \ln y_m^*)$ , the set of equations in (10) imply that the coefficients of the interactions between factor prices and between outputs are symmetric.\*\* That is,

$$\alpha_{ij} = \alpha_{ji} \quad \text{for all } i \text{ and } j \text{ and} \quad \beta_{nm} = \beta_{mn} \quad \text{for all } n \text{ and } m. \quad (11)$$

Linearly homogeneity in factor prices is formally described as

$$c^v(\lambda w, y, k) = \lambda c^v(w, y, k) \quad \text{for all } \lambda > 0.$$

In the case of the translog variable cost function, this requires that

$$\sum_{i=1}^I \alpha_i + \sum_{i=1}^I \sum_{j=1}^I \alpha_{ij} + \sum_{i=1}^I \sum_{n=1}^N \rho_{in} + \sum_{i=1}^I \sum_{t=1}^T \delta_{it} = 1.$$

\* Differentiability of a function at a point implies continuity of the function at the point. The translog function, being a second-order expansion, is twice differentiable in the neighborhood of the point of approximation and therefore continuous at that point, so that Young's Theorem holds locally.

\*\* When multiple indices of fixed factors are used and these are assumed to be continuous in the neighborhood of the point of expansion of the translog function, symmetry may be imposed on the coefficients of their interactions as well. Then,  $\partial^2 \ln c^{v*} / (\partial \ln k_i^* \partial \ln k_s^*) = \partial^2 \ln c^{v*} / (\partial \ln k_s^* \partial \ln k_i^*)$  and  $\gamma_{is} = \gamma_{si}$  for all  $i$  and  $s$ . Care should be exercised on this issue, however, because fixed factors are assumed to be discrete variables in the variable cost function and, theoretically, a different variable cost function obtains as amounts of fixed factors are incremented.

But the custom has been to impose the following restrictions:

$$\begin{aligned}
 \sum_{i=1}^I \alpha_i &= 1, \\
 \sum_{j=1}^I \alpha_{ij} &= 0 \quad \text{for } i = 1, 2, \dots, I, \\
 \sum_{i=1}^I \rho_{in} &= 0 \quad \text{for } n = 1, 2, \dots, N, \text{ and} \\
 \sum_{i=1}^I \delta_{it} &= 0 \quad \text{for } t = 1, 2, \dots, T.
 \end{aligned} \tag{12}$$

Parenthetically, note that if the coefficients of the interaction terms,  $\alpha_{ij}$ ,  $\beta_{nm}$ ,  $\gamma_{ts}$ ,  $\rho_{in}$ ,  $\delta_{it}$ ,  $\theta_{nt}$ , are all equal to zero, the translog variable cost function takes on a Cobb-Douglas form. Thus, whether or not the Cobb-Douglas variable cost function is consistent with a given data set on costs, input prices, and fixed factors can be subjected to statistical testing procedures.

A variable cost function that is monotonically nondecreasing in factor prices has the property that

$$c^v(w, y, k) \geq c^v(w', y, k) \quad \text{for all } w \geq w'.$$

Assuming the variable cost function to be continuous, this condition is equivalent to

$$\frac{\partial c^v(w, y, k)}{\partial w_i} \geq 0 \quad \text{for } i = 1, 2, \dots, I.$$

Since, by Shephard's lemma,  $\partial c^v / \partial w_i = x_i(w, y, k)$ , monotonicity also implies that the value of conditional factor demand functions are non-negative:  $x_i \geq 0$  for  $i = 1, 2, \dots, I$ . Hence, for the translog variable cost function, monotonicity implies that

$$\begin{aligned}
 \frac{\partial c^v}{\partial w_i} &= \frac{c^v}{w_i} \frac{\partial \ln c^v}{\partial \ln w_i} \\
 &= \frac{c^v}{w_i} s_i \geq 0 \quad \text{for } i = 1, 2, \dots, I
 \end{aligned}$$

where  $s_i$  is the share of the  $i$ th input in total variable costs.

For  $c^v \geq 0$  and  $w_i \geq 0$ , a necessary and sufficient condition for the translog variable cost function to be monotonically nondecreasing in factor prices is therefore that  $s_i \geq 0$ , which implies that for each  $i$ ,

$$\frac{\partial \ln c^{v*}}{\partial \ln w_i^*} = s_i = \alpha_i + \sum_{j=1}^I \alpha_{ij} \ln w_j^* + \sum_{n=1}^N \rho_{in} \ln y_n^* + \sum_{t=1}^T \delta_{it} \ln k_t^* \geq 0.$$

Recall, however, the translog variable cost function is expanded at the point  $\ln \bar{w}_i^* = \ln \bar{y}_n^* = \ln \bar{k}_i^* = 0$ . Thus, if  $s_i$  is evaluated at the mean of the sample, the condition for monotonicity in prices of the translog cost function translates into

$$s_i = \alpha_i \geq 0 \quad \text{for } i = 1, 2, \dots, I. \quad (13)$$

Analogously, if the translog variable cost function is to be monotonically nondecreasing in outputs, then a necessary and sufficient condition, given the point of expansion of the function, is that

$$\frac{\partial \ln c^v}{\partial \ln y_n} = \beta_j \geq 0 \quad \text{for } n = 1, 2, \dots, N. \quad (14)$$

Concavity of the variable cost function in factor prices requires that the Hessian matrix of cross-price derivatives of the conditional demand functions be negative semidefinite. That is,

$$H_{ww} = \begin{bmatrix} \frac{\partial^2 c}{\partial w_1^2} & & & \\ \frac{\partial^2 c}{\partial w_1 \partial w_2} & \frac{\partial^2 c}{\partial w_2^2} & & \\ \vdots & \vdots & \ddots & \\ \frac{\partial^2 c}{\partial w_1 \partial w_I} & \frac{\partial^2 c}{\partial w_2 \partial w_I} & & \frac{\partial^2 c}{\partial w_I^2} \end{bmatrix} = \begin{bmatrix} \frac{\partial x_1}{\partial w_1} & & & \\ \frac{\partial x_1}{\partial w_2} & \frac{\partial x_2}{\partial w_2} & & \\ \vdots & \vdots & \ddots & \\ \frac{\partial x_1}{\partial w_I} & \frac{\partial x_2}{\partial w_I} & \dots & \frac{\partial x_I}{\partial w_I} \end{bmatrix} \leq 0.$$

For the translog variable cost function, it can be established that, at the point of approximation, the diagonal elements of the Hessian matrix can be expressed as

$$\frac{\partial^2 c^v}{\partial w_i^2} = \frac{c^{v*}}{w_i^{*2}} (\alpha_{ii} - \alpha_i + \alpha_i^2) \quad \text{for } i = 1, 2, \dots, I, \quad (15)$$

and the off-diagonal elements can be given as

$$\frac{\partial^2 c^v}{\partial w_i \partial w_j} = \frac{c^{v*}}{w_i^* w_j^*} (\alpha_{ij} + \alpha_i \alpha_j) \quad \text{for } i \neq j. \quad (16)$$

If it is supposed that  $c^v > 0$  and  $w_i > 0$  for all  $i$ , then the sign of each element in the Hessian matrix  $H_{ww}$  is determined solely by the terms inside the parenthesis in equations (15) and (16). Let

$$H_{ww}^* = \begin{bmatrix} \alpha_{11} - \alpha_1 + \alpha_1^2 & & & \\ \alpha_{12} + \alpha_1 \alpha_2 & \alpha_{22} - \alpha_2 + \alpha_2^2 & & \\ \vdots & \vdots & \ddots & \\ \alpha_{1I} + \alpha_1 \alpha_I & \alpha_{2I} + \alpha_2 \alpha_I & \dots & \alpha_{II} - \alpha_I + \alpha_I^2 \end{bmatrix}$$

Then the Hessian matrix  $H_{ww}$  is negative semidefinite if and only if  $H_{ww}^*$  is negative semidefinite.

Finally, conditions for convexity of the cost function in outputs are developed in a manner similar to that of concavity in factor prices. Convexity in outputs requires that the Hessian matrix of second-order partial derivatives of the cost function with respect to outputs be positive semidefinite. That is,

$$H_{yy} = \begin{bmatrix} \frac{\partial^2 c}{\partial y_1^2} & & & \\ \frac{\partial^2 c}{\partial y_1 \partial y_2} & \frac{\partial^2 c}{\partial y_2^2} & & \\ \vdots & \vdots & \ddots & \\ \frac{\partial^2 c}{\partial y_1 \partial y_N} & \frac{\partial^2 c}{\partial y_2 \partial y_N} & \cdots & \frac{\partial^2 c}{\partial y_N^2} \end{bmatrix} \geq 0.$$

At the point of approximation of the translog variable cost function, the diagonal elements of this Hessian matrix  $H_{yy}$  can be expressed as

$$\frac{\partial^2 c^v}{\partial y_n^2} = \frac{c^{v*}}{y_n^{*2}} (\beta_{nn} - \beta_n + \beta_n^2) \quad \text{for } n = 1, 2, \dots, N, \quad (17)$$

and the off-diagonal elements can be given as

$$\frac{\partial^2 c^v}{\partial y_n \partial y_m} = \frac{c^{v*}}{y_n^* y_m^*} (\beta_{nm} + \beta_n \beta_m) \quad \text{for } n \neq m. \quad (18)$$

If  $c^v > 0$  and  $y_n > 0$  for all  $n$ , the sign of each element in the Hessian matrix  $H_{yy}$  is determined solely by the terms inside the parenthesis in equations (17) and (18). Let

$$H_{yy}^* = \begin{bmatrix} \beta_{11} - \beta_1 + \beta_1^2 & & & \\ \beta_{12} + \beta_1 \beta_2 & \beta_{22} - \beta_2 + \beta_2^2 & & \\ \vdots & \vdots & \ddots & \\ \beta_{1N} + \beta_1 \beta_N & \beta_{2N} + \beta_2 \beta_N & \cdots & \beta_{NN} - \beta_N + \beta_N^2 \end{bmatrix}$$

Then the Hessian matrix  $H_{yy}$  is positive semidefinite if and only if  $H_{yy}^*$  is positive semidefinite.

### Estimation

The translog variable cost function (9) is converted into a regression equation by appending to it an additive stochastic disturbance term  $\epsilon$ . The sequence of random variables  $\{\epsilon_\ell\}$ ,  $\ell = 1, \dots, L$  (where  $L$  stands for the size of the regression sample), is usually assumed to be (identically) normally and independently distributed (NID) with mean zero and variance  $\sigma_\epsilon^2$ . Ordinary least squares (OLS) can be applied on this regression equation to estimate the parameters of the translog variable cost function. As mentioned in Section A (on duality and Shephard's lemma), however, additional information may be obtained from the translog



variable cost function, which can result in efficiency gains in estimation. This takes the form of the share equations of the inputs, which is derived using Shephard's lemma:

$$\frac{\partial \ln c^{v*}}{\partial \ln w_i^*} = s_i = \alpha_i + \sum_{j=1}^I \alpha_{ij} \ln w_j^* + \sum_{n=1}^N \rho_{in} \ln y_n^* + \sum_{l=1}^L \delta_{il} \ln k_l^* \quad \text{for } i = 1, 2, \dots, I \quad (19)$$

where  $s_i = w_i^* x_i / c^{v*}$  is the share of the  $i$ th input in total variable costs. Adding to each share equation  $s_i$  a disturbance term  $\nu_{i\ell}$  for  $i = 1, 2, \dots, I$  and  $\ell = 1, 2, \dots, L$  with the following distributional assumptions

$$\begin{bmatrix} \varepsilon_\ell \\ \nu_{1\ell} \\ \vdots \\ \nu_{I\ell} \end{bmatrix} \sim \text{NID}(0, \Sigma)$$

where

$$\Sigma = \begin{bmatrix} \sigma_\varepsilon^2 & & & \\ \sigma_{1\varepsilon} & \sigma_1^2 & & \\ \vdots & \vdots & \ddots & \\ \sigma_{I\varepsilon} & \sigma_{I1} & \dots & \sigma_I^2 \end{bmatrix}$$

results in a model with a seemingly unrelated regression (SUR) structure.

With the equality restrictions (equation (11)) imposed on its parameters, the translog variable cost function and any set of  $I - 1$  share equations may be estimated as a system of equations using full-information maximum likelihood.\*

### Inferences on the Structure of Costs and Production

Several aspects of hospital costs and production are usually investigated using the estimated translog cost function. These include economies (or diseconomies) of scale and scope, the substitutability between inputs, and whether or not fixed inputs are employed according to their long-run cost-minimizing levels. How these issues are measured and studied is discussed below.

Economies of scale are the cost function analog of the elasticity of scale. They are meant to answer the question, would unit costs increase, decrease, or stay constant as hospital operations expand? For multiple output firms, the most commonly used concept of economies

\* One share equation has to be thrown away to avoid singularity in the error terms since the intercept of the share equations sum to unity. Because of the invariance property of full-information maximum likelihood, it does not matter which share equation is deleted.

\*\* Given this intent, Wagstaff and Barnum (1992) argue that scale economies are properly analyzed only from a long-run perspective where all inputs are allowed to adjust to unit increases in output levels. This contention is made in reaction to Gowing and Holtmann (1983) who examined what they called the short-run economies of scale.

of scale is the ray or overall economies of scale, which measure the relative increase in total costs of increasing all outputs of the firm by the same proportion.\* When the evaluation is done on the variable cost function, the index of ray scale economies may be given as

$$\epsilon = \frac{1 - \sum_{t=1}^T \frac{\partial \ln c^v}{\partial \ln k_t^*}}{\sum_{n=1}^N \frac{\partial \ln c^v}{\partial \ln y_n}}$$

where  $k_t^*$  is the long-run optimal level of the  $t$ th fixed input.

In the translog variable cost function, this translates to

$$\epsilon = \frac{1 - \left[ \sum_{t=1}^T (\gamma_t + \gamma_{tt} \ln k_t^{*'} + \sum_{i=1}^I \delta_{it} \ln w_i^* + \sum_{n=1}^N \theta_{nt} \ln y_n^*) + \frac{1}{2} \sum_{t=1}^T \sum_{s=t+1}^T \gamma_{ts} \ln k_s^{*'} \right]}{\sum_{n=1}^N (\beta_n + \beta_{nn} \ln y_n^* + \sum_{i=1}^I \rho_{in} \ln w_i^* + \sum_{t=1}^T \theta_{nt} \ln k_t^*) + \frac{1}{2} \sum_{n=1}^{N-1} \sum_{m=n+1}^N \beta_{nm} \ln y_m^*} \quad (20)$$

where  $k_t^{*'}$  and  $k_s^{*'}$  are the mean-scaled long-run optimal levels of the  $s$ th and  $t$ th fixed inputs. Since  $\ln w_i^* = \ln y_n^* = \ln k_t^* = 0$  for all  $i$ ,  $n$ , and  $t$  at the point of approximation, however, the index of ray scale economies at that point reduces to

$$\epsilon = \frac{1 - (\sum_{t=1}^T \gamma_t + \sum_{t=1}^T \gamma_{tt} \ln k_t^{*'} + \frac{1}{2} \sum_{t=1}^{T-1} \sum_{s=t+1}^T \gamma_{ts} \ln k_s^{*'})}{\sum_{n=1}^N \beta_n} \quad (21)$$

Using the ray scale index, economies of scale (or declines in long-run unit costs with the expansion of hospital operations) are said to exist if  $\epsilon > 1$ ; diseconomies of scale (or increases in long-run average costs associated with the expansion of hospital operations) are said to exist when  $\epsilon < 1$ . Hence, based on considerations about economic efficiency alone, a policy implication that may be drawn from measures of economies of scale is that each hospital should expand (contract) operations, when scale economies (diseconomies) exist.

A concept specific to multiple product firms, economies (diseconomies) of scope are said to exist if the costs of jointly producing different outputs are less (greater) than if outputs are produced separately. Formally, scope economies exist if

$$c(y_1, y_2, \dots, y_N) > c(y_1, 0, \dots, 0) + c(0, y_2, \dots, 0) + \dots + c(0, 0, \dots, y_N),$$

and diseconomies of scope are said to exist when the direction of inequality goes the other way.

\* Cowing, Holtmann, and Powers (1983) note, however, that a problem with this concept is that when the firm's scale of operations expand, outputs along the same ray may no longer be in the firm's least cost path.

In the case of the translog variable cost function, however, it is not appropriate to evaluate costs where some outputs are set at zero, since the estimated variable cost function only has local properties (Vita, 1990). Consequently, the issue is judged using an indicative measure: Scope economies are inferred to exist if

$$\frac{\partial^2 c^v}{\partial y_n \partial y_m} < 0 \quad \text{for } n \neq m,$$

i.e., if the marginal cost of producing  $y_n$  declines as another output  $y_m$  is produced in greater quantities. On the other hand, scope diseconomies are inferred to exist if the direction of the inequality goes the other way.

In the case of the translog variable cost function, the necessary and equivalent condition for scope economies may be written as

$$\frac{\partial^2 \ln c^{v*}}{\partial \ln y_n^* \partial \ln y_m^*} + \frac{\partial \ln c^{v*}}{\partial \ln y_n} \frac{\partial \ln c^{v*}}{\partial \ln y_m} < 0 \quad \text{for } n \neq m,$$

or, in terms of its parameters,

$$\begin{aligned} & \beta_{nm} + \left( \beta_n + \beta_{nn} \ln y_n^* + \beta_{nm} \ln y_m + \sum_{i=1}^I \rho_{in} \ln w_i^* + \sum_{t=1}^T \theta_{nt} \ln k_t^* \right) \\ & \left( \beta_m + \beta_{mm} \ln y_m^* + \beta_{nm} \ln y_n + \sum_{i=1}^I \rho_{im} \ln w_i^* + \sum_{t=1}^T \theta_{mt} \ln k_t^* \right) < 0 \quad \text{for } n \neq m. \end{aligned} \quad (22)$$

Evaluated at the point of approximation of the translog variable cost function, the condition for scope economies simplifies to

$$\beta_{nm} + \beta_n \beta_m < 0 \quad \text{for } n \neq m. \quad (23)$$

The policy implication of scope economies is straightforward. Hospital departments (e.g., obstetrics and pediatrics or surgery and emergency care) or output categories that are cheaper to produce jointly should be available in one hospital. Hospital departments that are more expensive to maintain jointly should be offered in different specialized hospitals.

The extent of substitutability or complementarity in production between pairs of variable inputs may be studied using the Allen elasticity of substitution (AES), which can be computed from the variable cost function according to the following formula:

$$e_{ij} = \frac{c^v \partial^2 c^v / (\partial w_i \partial w_j)}{(\partial c^v / \partial w_i)(\partial c^v / \partial w_j)} \quad \text{for } i = 1, 2, \dots, I \text{ and } j = 1, 2, \dots, I.$$

In a translog variable cost function, the AES indices evaluated at the point of expansion are given by

$$e_{ij} = \begin{cases} \frac{\alpha_{ii} + \alpha_j^2 - \alpha_i}{\alpha_i} & \text{for } i = j \\ \frac{\alpha_{ij} + \alpha_i \alpha_j}{\alpha_i \alpha_j} & \text{for } i \neq j. \end{cases} \quad (24)$$

When  $e_{ij} > 0$  ( $e_{ij} < 0$ ), inputs  $i$  and  $j$  are said to be Allen substitutes (complements).

The policy relevance of AES indices is that they allow decision makers to anticipate possible changes in the mix of inputs used by hospitals as a result of changes in factor price ratios. When inputs  $i$  and  $j$  are Allen substitutes (*i.e.*,  $e_{ij} > 0$ ), an increase in the price of input  $i$  causes hospitals to decrease their employment of input  $i$  and hire more of input  $j$ . When a pair of inputs are Allen complements (*i.e.*,  $e_{ij} < 0$ ), an increase in the price of either input results in a decrease in employment of both factors.

Given the widespread concern on the escalation of medical care costs, one other issue that has been investigated using hospital cost functions is whether hospitals employ fixed inputs according to their long-run cost-minimizing levels. Specifically, this line of inquiry has been directed at whether or not hospitals have too much capital equipment or too many doctors on their medical staffs—not surprisingly, the two factors which are often blamed for the increasing costs of hospital care.

Wagstaff and Barnum (1992) note a fine point on this issue: The problem is not whether outputs should be expanded to fully utilize the fixed inputs, which is a question of economics of scale, but whether optimal amounts of the fixed inputs are employed *given the output levels of hospitals*. In other words, the question is whether hospitals are allocatively efficient in their use of the fixed factors.

To examine this point, Cowing and Holtmann (1983) propose checking whether  $\partial c^v / \partial k$  is not statistically different from  $-w_k$ .<sup>\*</sup> If  $-\partial c^v / \partial k < w_k$  ( $-\partial c^v / \partial k > w_k$ ), *i.e.*, the savings in variable costs on the margin due to the employment of an additional unit of capital are less than (greater than) the marginal cost of capital, then fixed input  $k$  is said to be overemployed (underemployed).

If hospitals are found to overemploy (underutilize) fixed factors, the policy implication is obviously to nudge them to adjust their employment of these factors according to allocatively efficient levels.

<sup>\*</sup> The objection of Wagstaff and Barnum (1992) and our comment on their suggestion were discussed earlier on p. 11.

This completes the exposition of the theoretical and empirical considerations in econometrically estimating a variable cost function for a system of hospitals. In the next chapter, the data set and variables used are described briefly. The regression results are then presented and interpreted in chapter five.

## IV

### Data Set and Variables

Michael M. Alba and Maria Theresa A. Bugayong

Our data set comes from the Hospital Administrators Survey of the Baseline Studies for Health Care Financing Reform Project, a research initiative consisting of about 26 studies whose primary aim is to formulate a consistent set of policies intended to reform the country's health care financing system. The project is being undertaken jointly by the Department of Health (DOH) and the Philippine Institute for Development Studies (PIDS) under a grant from the World Bank.\*

Five surveys were commissioned by the Baseline Studies project to gather information on various aspects of the Philippine health sector. These included a survey of (a) households, of (b) patients and (c) medical practitioners in free-standing and hospital-based clinics, and of hospital (d) patients and (e) administrators. Conducted between 1991 and 1992, the surveys covered four regions of the country: Region II was selected to represent a low-income area, Region VII to represent a high-income area, Region X to represent a middle-income area, and the National Capital Region (NCR) to represent a highly urbanized area. In each of the regions with the exception of NCR, one high- and one low-income province were selected. Cagayan and Quirino were picked as the high- and low-income provinces in Region II. Cebu as a high-income province and Bohol as a low-income province were chosen for Region VII. And Misamis Oriental (high-income) and Surigao del Norte (low-income) were the provinces selected for Region X.\*\*

The survey of hospital administrators was based on stratified random sampling methods with hospital ownership (*i.e.*, whether the hospital was a private or public institution) as the stratifying variable. Some 188 hospitals from various provinces of the country were requested to participate in the survey. Of these, 159 hospital administrators or their representatives allowed themselves to be interviewed. Unfortunately, due to gaps in information provided by these respondents, only 65 met the data requirements of our study. These 65 hospitals constitute our regression sample.

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\* Orville Solon serves as director of the Baseline Studies project.

\*\* For more detailed information on these surveys, see Mendoza (1992) and TRENDS (1993).

The variables in our data set and their descriptive statistics for the sample as a whole and for various categories of hospitals are presented in Tables 1 and 2a to 2m. As shown in those tables, about a third of the hospitals in our sample are located in Metro Manila, whereas Cebu and Bohol hospitals each comprise about a fifth of the sample, with the rest located in Cagayan, Misamis Oriental, Quirino, and Surigao del Norte. Close to one half of the hospitals in the sample are secondary hospitals; a quarter are primary hospitals; and 30% are tertiary (non-teaching or teaching) hospitals. Privately-owned hospitals comprise about 46% of the sample.

In this study, variable costs are defined as the sum of a hospital's expenditures on labor services as well as on drugs and medical supplies. Other expenses, including those for depreciation, interest, rents, water and electricity, transportation and communication, and repairs and maintenance—most of which went unreported—are assumed to be (quasi-)fixed costs. Annual wages are calculated for four categories of labor inputs—medical residents, nurses, other medical personnel, and non-medical personnel\*—as the total annual gross compensation of the staff divided by the number of full-time personnel in that labor category. Information necessary to construct a quantity-weighted price index of drugs and medical supplies dispensed was unavailable. In its stead we used the value of drugs and medical supplies per patient, which is defined as annual expenditures on drugs and medical supplies divided by the total number of patients served.

Our measures of hospital outputs are the number of in-patient discharges and the number of out-patient consultations. Although finer distinctions in in-patient services would have been desirable (to explore scope economies more satisfactorily, for example), our data were riddled by missing observations when in-patient discharges were disaggregated by hospital department or when the number of in-patient days was used as the measure of in-patient output.

The number of hospital beds is our proxy indicator for fixed inputs. Given the heterogeneity of fixed factors, this variable is likely to be measured with error. Unfortunately, there is no other measure that would give us as large a sample as bed capacity.\*\*

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\* *Wages* are used as a generic term for compensation. In the case of medical residents, *stipend* is the more legally correct term.

\*\* In the regression runs, when the number of medical specialists was specified as a second measure of fixed inputs, serious collinearity problems were encountered, resulting in the failure of maximum likelihood algorithms to converge.

Table 1  
Descriptive Statistics of Variables for All Hospitals

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 19,284.90 | 41,668.30          | 311.33    | 249,421.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 9,973.25  | 20,451.00          | 241.33    | 131,608.00 |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 69,867.22 | 47,719.80          | 680.40    | 318,532.50 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 39,273.73 | 16,757.13          | 712.88    | 139,495.78 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 33,757.19 | 16,786.86          | 10,233.82 | 145,446.66 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 30,691.53 | 9,989.12           | 9,767.59  | 58,048.80  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 102.54    | 121.26             | 0.63      | 746.79     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 3,976.57  | 4,955.00           | 276       | 24,608     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 41,487.38 | 120,924.05         | 759       | 934,794    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 87.20     | 149.04             | 8         | 1,044      |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.3385    | 0.4769             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.1846    | 0.3910             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.1077    | 0.3124             | 0         | 1          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.2000    | 0.4031             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0462    | 0.2115             | 0         | 1          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0462    | 0.2115             | 0         | 1          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.0769    | 0.2685             | 0         | 1          |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.4615    | 0.5024             | 0         | 1          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.2462    | 0.4341             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.4615    | 0.5024             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.2000    | 0.4031             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0923    | 0.2917             | 0         | 1          |
| Number of Observations = 65         |   |           |                    |           |            |



Table 2a  
Descriptive Statistics of Variables for Primary Hospitals

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum   |
|-------------------------------------|---|-----------|--------------------|-----------|-----------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 1,664.91  | 1,089.61           | 311.33    | 4,034.22  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 1,037.97  | 481.44             | 241.33    | 2,089.60  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 63,687.15 | 18,701.25          | 15,000.00 | 84,000.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 38,371.94 | 9,881.39           | 12,000.00 | 47,616.00 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 32,587.78 | 7,226.12           | 18,577.50 | 50,400.00 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 29,411.78 | 10,366.04          | 10,079.76 | 43,815.43 |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 62.57     | 64.31              | 9.01      | 263.55    |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 1,026.19  | 491.20             | 276       | 2,095     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 6,447.63  | 5,562.92           | 786       | 20,717    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 15.56     | 5.78               | 8         | 27        |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.1250    | 0.3416             | 0         | 1         |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.1875    | 0.4031             | 0         | 1         |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.1875    | 0.4031             | 0         | 1         |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.1875    | 0.4031             | 0         | 1         |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.1250    | 0.3416             | 0         | 1         |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0625    | 0.2500             | 0         | 1         |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.1250    | 0.3416             | 0         | 1         |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.25      | 0.45               | 0         | 1         |

Number of Observations = 16

**Table 2b**  
**Descriptive Statistics of Variables for Secondary Hospitals**

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 4,628.37  | 3,504.80           | 603.10    | 15,941.70  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 2,410.54  | 1,420.44           | 396.95    | 6,239.52   |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 72,271.71 | 45,256.09          | 36,000.00 | 280,088.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 36,524.30 | 9,356.07           | 12,480.00 | 47,588.40  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 28,812.94 | 9,238.85           | 10,233.82 | 44,552.00  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 28,296.08 | 8,499.89           | 9,767.59  | 51,200.00  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 78.77     | 63.08              | 4.22      | 234.03     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 2,708.43  | 3,404.99           | 421       | 16,768     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 11,349.40 | 7,173.81           | 759       | 35,040     |
| Number of Beds                      | Total Number of Hospital Beds                                 | 37.03     | 17.68              | 10        | 75         |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.2667    | 0.4498             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.2000    | 0.4068             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.1333    | 0.3458             | 0         | 1          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.2667    | 0.4498             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0333    | 0.1826             | 0         | 1          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0333    | 0.1826             | 0         | 1          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.0667    | 0.2537             | 0         | 1          |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.5333    | 0.5074             | 0         | 1          |
| Number of Observations = 30         |   |           |                    |           |            |

Table 2c  
Descriptive Statistics of Variables for Non-Teaching Hospitals

| Variables                           | Description   | Mean       | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|------------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 59,288.80  | 71,612.50          | 668.01    | 249,421.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 29,301.10  | 35,672.20          | 1,045.44  | 131,608.00 |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 83,434.54  | 77,946.39          | 680.40    | 318,532.50 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 47,025.95  | 32,728.63          | 712.88    | 139,495.78 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 45,341.07  | 31,812.99          | 16,360.00 | 145,446.66 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 35,830.48  | 11,868.45          | 15,660.00 | 58,048.80  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 146.40     | 149.78             | 0.63      | 419.07     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 8,865.38   | 6,692.71           | 2,035     | 24,608     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 133,427.38 | 249,312.07         | 3,993     | 934,794    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 235.54     | 267.27             | 50        | 1,044      |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.6154     | 0.5064             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.1539     | 0.3755             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.0000     | 0.0000             | 0         | 0          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.0769     | 0.2774             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0000     | 0.0000             | 0         | 0          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0769     | 0.2774             | 0         | 1          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.0769     | 0.2774             | 0         | 1          |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.3846     | 0.5064             | 0         | 1          |
| Number of Observations = 13         |   |            |                    |           |            |

Table 2d  
Descriptive Statistics of Variables for Teaching Hospitals

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 52,879.30 | 45,206.40          | 15,235.00 | 113,546.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 29,737.30 | 15,762.00          | 9,934.74  | 52,286.50  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 44,929.15 | 16,009.67          | 23,600.00 | 71,424.00  |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 38,629.19 | 4,256.85           | 31,894.36 | 43,237.41  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 36,498.44 | 4,170.85           | 32,282.39 | 42,078.59  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 34,947.05 | 8,227.12           | 19,927.20 | 42,045.30  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 232.98    | 254.89             | 97.79     | 746.79     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 7,592.50  | 4,843.49           | 1,084     | 13,668     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 86,413.33 | 61,840.54          | 30,589    | 191,198    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 207.67    | 69.58              | 150       | 329        |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.6667    | 0.5164             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.1667    | 0.4083             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.0000    | 0.0000             | 0         | 0          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.1667    | 0.4083             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0000    | 0.0000             | 0         | 0          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0000    | 0.0000             | 0         | 0          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0          |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.8333    | 0.4083             | 0         | 1          |
| Number of Observations = 6          |   |           |                    |           |            |

**Table 2e**  
**Descriptive Statistics of Variables for Private Hospitals**

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 16,890.40 | 32,327.80          | 476.00    | 113,546.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 10,915.70 | 17,722.90          | 396.95    | 58,008.60  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 65,677.32 | 52,615.32          | 23,600.00 | 318,532.50 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 37,347.42 | 21,817.33          | 11,700.00 | 139,495.78 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 34,014.75 | 23,324.89          | 10,800.00 | 145,446.66 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 30,396.47 | 12,070.08          | 12,654.55 | 58,048.80  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 126.42    | 163.05             | 1.72      | 746.79     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 4,272.83  | 4,417.44           | 276       | 16,768     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultation                     | 27,333.80 | 41,737.23          | 759       | 191,198    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 74.20     | 80.76              | 8         | 329        |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.5667    | 0.5040             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.2000    | 0.4068             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.0333    | 0.1826             | 0         | 1          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.1667    | 0.3791             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0333    | 0.1826             | 0         | 1          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0000    | 0.0000             | 0         | 0          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.1333    | 0.3458             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.5333    | 0.5074             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.1667    | 0.3791             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.1667    | 0.3791             | 0         | 1          |
| Number of Observations = 30         |   |           |                    |           |            |

Table 2f  
Descriptive Statistics of Variables for Public Hospitals

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 21,337.30 | 48,656.30          | 311.33    | 249,421.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 9,165.47  | 22,757.80          | 241.33    | 131,608.00 |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 73,458.57 | 43,548.02          | 680.40    | 280,088.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 40,924.85 | 10,793.05          | 712.88    | 67,064.00  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 33,536.42 | 8,142.06           | 10,233.82 | 63,532.14  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 30,944.44 | 7,963.73           | 9,767.59  | 43,815.43  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 82.07     | 63.78              | 0.63      | 263.55     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 3,722.63  | 5,424.72           | 454       | 24,608     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 53,619.03 | 160,346.06         | 786       | 934,794    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 98.34     | 189.67             | 10        | 1,044      |
| Manila                              | 1 if located in Metro Manila, 0 otherwise                     | 0.1429    | 0.3550             | 0         | 1          |
| Bohol                               | 1 if located in Bohol, 0 otherwise                            | 0.1714    | 0.3824             | 0         | 1          |
| Cagayan                             | 1 if located in Cagayan, 0 otherwise                          | 0.1714    | 0.3824             | 0         | 1          |
| Cebu                                | 1 if located in Cebu, 0 otherwise                             | 0.2286    | 0.4260             | 0         | 1          |
| Misamis Oriental                    | 1 if located in Misamis Oriental, 0 otherwise                 | 0.0571    | 0.2355             | 0         | 1          |
| Quirino                             | 1 if located in Quirino, 0 otherwise                          | 0.0857    | 0.2840             | 0         | 1          |
| Surigao del Norte                   | 1 if located in Surigao del Norte, 0 otherwise                | 0.1429    | 0.3550             | 0         | 1          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.3429    | 0.4816             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.4000    | 0.4971             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.2286    | 0.4260             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0286    | 0.1690             | 0         | 1          |
| Number of Observations = 35         |   |           |                    |           |            |

**Table 2g**  
**Descriptive Statistics of Variables for Hospitals in Bohol**

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 5,944.62  | 9,319.66           | 476.00    | 32,756.00  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 2,976.50  | 5,080.90           | 396.95    | 18,733.30  |
| Wage of Medical-Residents           | Average Annual Stipend of Full-Time Medical Residents         | 70,397.00 | 25,971.05          | 36,000.00 | 143,928.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 31,934.12 | 12,361.66          | 11,700.00 | 47,328.00  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 29,129.80 | 12,199.61          | 10,800.00 | 50,400.00  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 24,620.22 | 8,234.10           | 12,654.55 | 41,096.00  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 87.54     | 76.41              | 1.72      | 263.55     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 1,961.17  | 978.82             | 908       | 4,313      |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 10,081.33 | 14,168.25          | 759       | 51,162     |
| Number of Beds                      | Total Number of Hospital Beds                                 | 51.42     | 48.90              | 19        | 200        |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.5000    | 0.5222             | 0         | 1          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.2500    | 0.4523             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.5000    | 0.5222             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.1667    | 0.3893             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0833    | 0.2887             | 0         | 1          |
| Number of Observations = 12         |   |           |                    |           |            |

Table 2h  
Descriptive Statistics of Variables for Hospitals in Cagayan

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum   |
|-------------------------------------|---|-----------|--------------------|-----------|-----------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 2,894.11  | 2,393.99           | 1,086.21  | 7,202.46  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 1,923.44  | 1,489.53           | 679.27    | 4,272.02  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 67,126.63 | 5,569.08           | 60,000.00 | 77,064.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 40,736.05 | 6,131.73           | 30,000.00 | 47,588.40 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 32,945.16 | 5,124.82           | 26,997.00 | 42,169.85 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 28,781.19 | 6,155.78           | 19,066.67 | 35,640.00 |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 38.98     | 37.98              | 4.22      | 93.80     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 1,475.43  | 562.87             | 925       | 2,660     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 11,933.29 | 4,983.67           | 6,724     | 16,974    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 24.57     | 12.61              | 10        | 50        |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.1429    | 0.3780             | 0         | 1         |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.4286    | 0.5345             | 0         | 1         |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.5714    | 0.5345             | 0         | 1         |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.0000    | 0.0000             | 0         | 0         |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0         |
| Number of Observations = 7          |   |           |                    |           |           |



Table 2i  
Descriptive Statistics of Variables for Hospitals in Cebu

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 8,134.14  | 7,148.61           | 835.19    | 23,408.00  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 6,301.81  | 10,642.80          | 691.25    | 40,119.30  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 80,357.63 | 61,422.38          | 41,142.86 | 280,088.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 42,926.08 | 3,009.31           | 37,500.00 | 48,800.00  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 32,874.53 | 6,348.99           | 22,138.29 | 42,078.59  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 32,842.83 | 6,010.20           | 22,153.85 | 42,593.00  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 116.21    | 103.03             | 10.55     | 384.96     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 3,053.54  | 4,269.53           | 483       | 13,668     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 21,285.62 | 32,417.23          | 3,893     | 127,192    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 53.38     | 61.91              | 10        | 246        |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.3846    | 0.5064             | 0         | 1          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.2308    | 0.4385             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.6154    | 0.5064             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.0769    | 0.2774             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0769    | 0.2774             | 0         | 1          |
| Number of Observations = 13         |   |           |                    |           |            |

Table 2j  
Descriptive Statistics of Variables for Hospitals in Misamis Oriental

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum   |
|-------------------------------------|---|-----------|--------------------|-----------|-----------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 3,046.94  | 2,902.02           | 311.33    | 6,090.76  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 1,773.97  | 1,401.73           | 241.33    | 2,990.98  |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 36,388.80 | 19,977.71          | 15,000.00 | 54,566.40 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 32,200.00 | 7,358.25           | 23,874.00 | 37,830.00 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 30,900.09 | 10,713.93          | 18,577.50 | 38,012.00 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 27,084.59 | 14,731.85          | 10,079.76 | 35,980.00 |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 57.49     | 69.32              | 11.43     | 137.22    |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 1,370.33  | 837.12             | 454       | 2,095     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 11,109.67 | 9,291.51           | 2,170     | 20,717    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 29.33     | 15.                | 15        | 46        |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.3333    | 0.57               | 0         | 1         |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.6667    | 0.5774             | 0         | 1         |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.3333    | 0.5774             | 0         | 1         |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.0000    | 0.0000             | 0         | 0         |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0         |
| Number of Observations = 3          |   |           |                    |           |           |

Table 2k  
Descriptive Statistics of Variables for Hospitals in Metro Manila

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 44,583.30 | 64,511.90          | 663.46    | 249,421.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 21,750.70 | 31,010.30          | 572.62    | 131,608.00 |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 66,587.35 | 63,139.73          | 680.40    | 318,532.50 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 41,455.30 | 25,743.94          | 712.88    | 139,495.78 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 38,584.12 | 25,930.18          | 18,933.33 | 145,446.66 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 32,870.24 | 11,861.21          | 14,200.00 | 58,048.80  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 137.58    | 175.93             | 0.63      | 746.79     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 7,168.64  | 6,640.24           | 276       | 24,608     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 92,701.14 | 198,759.64         | 1,480     | 934,794    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 165.14    | 230.82             | 8         | 1,044      |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.7727    | 0.4289             | 0         | 1          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.0909    | 0.2942             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.3636    | 0.4924             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.3636    | 0.4924             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.1818    | 0.3948             | 0         | 1          |
| Number of Observations = 22.        |   |           |                    |           |            |

Table 21  
Descriptive Statistics of Variables for Hospitals in Quirino

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum    |
|-------------------------------------|---|-----------|--------------------|-----------|------------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 6,715.15  | 7,319.03           | 1,272.23  | 15,035.70  |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 3,964.97  | 4,372.36           | 844.86    | 8,962.50   |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 86,227.27 | 22,351.70          | 71,892.00 | 111,981.82 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 43,015.10 | 1,671.64           | 41,085.00 | 44,000.31  |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 34,541.89 | 3,315.21           | 31,858.67 | 38,248.00  |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 36,304.12 | 6,967.25           | 29,070.67 | 42,970.50  |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 80.63     | 61.61              | 36.91     | 151.09     |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 2,556.33  | 2,083.17           | 922       | 4,902      |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 17,165.33 | 11,453.43          | 5,234     | 28,072     |
| Number of Beds                      | Total Number of Hospital Beds                                 | 46.00     | 47.15              | 13        | 100        |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.0000    | 0.0000             | 0         | 0          |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.3333    | 0.5774             | 0         | 1          |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.3333    | 0.5774             | 0         | 1          |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.3333    | 0.5774             | 0         | 1          |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0          |
| Number of Observations = 3          |   |           |                    |           |            |

Table 2m  
Descriptive Statistics of Variables for Hospitals in Surigao del Norte

| Variables                           | Description   | Mean      | Standard Deviation | Minimum   | Maximum   |
|-------------------------------------|---|-----------|--------------------|-----------|-----------|
| Total Cost                          | Total Cost of Operations (in Thousand Pesos)                  | 9,212.81  | 11,294.10          | 1,583.69  | 28,838.00 |
| Variable Cost                       | Total Cost less Fixed Cost (in Thousand Pesos)                | 4,284.50  | 5,805.08           | 861.47    | 14,459.50 |
| Wage of Medical Residents           | Average Annual Stipend of Full-Time Medical Residents         | 69,860.00 | 19,080.75          | 37,404.00 | 82,120.00 |
| Wage of Nurses                      | Average Annual Wage of Full-Time Nurses                       | 37,745.96 | 13,974.72          | 13,200.00 | 47,616.00 |
| Wage of Other Medical Personnel     | Average Annual Wage of Full-Time Other Medical Personnel      | 28,299.58 | 10,316.54          | 10,233.82 | 35,824.98 |
| Wage of Non-Medical Personnel       | Average Annual Wage of Full-Time Non-Medical Personnel        | 31,554.08 | 13,454.85          | 9,767.59  | 43,815.43 |
| Value of Drugs and Medical Supplies | Annual Expenditures on Drugs and Medical Supplies Per Patient | 77.97     | 25.83              | 46.47     | 109.49    |
| Total In-Patient Discharges         | Annual Number of In-Patient Discharges                        | 3,085.80  | 3,389.08           | 649       | 8,912     |
| Total Out-Patient Visits            | Annual Number of Out-Patient Consultations                    | 18,241.60 | 25,635.86          | 2,784     | 63,605    |
| Number of Beds                      | Total Number of Hospital Beds                                 | 65.20     | 62.78              | 10        | 163       |
| Privately Owned Hospital            | 1 if a privately owned hospital, 0 otherwise                  | 0.0000    | 0.0000             | 0         | 0         |
| Primary Hospital                    | 1 if a primary hospital, 0 otherwise                          | 0.4000    | 0.5477             | 0         | 1         |
| Secondary Hospital                  | 1 if a secondary hospital, 0 otherwise                        | 0.4000    | 0.5477             | 0         | 1         |
| Tertiary Non-Teaching Hospital      | 1 if a tertiary non-teaching hospital, 0 otherwise            | 0.2000    | 0.4472             | 0         | 1         |
| Tertiary Teaching Hospital          | 1 if a tertiary teaching hospital, 0 otherwise                | 0.0000    | 0.0000             | 0         | 0         |
| Number of Observations = 5          |   |           |                    |           |           |

## V

### Regression Results

The regression results of the translog variable cost function for the hospitals in the sample are presented in Table 3.\* Except for dummy variables intended to capture intercept changes due to hospital type, hospital ownership, and the location of hospitals, the form of the variable cost function whose parameter estimates are reported in Table 3 is identical to equation (9) of chapter three,\*\* with  $I = 5$ ,  $N = 2$ ,  $T = 1$ , and  $L = 65$ .

To improve the precision of the estimates (as well as to increase the degrees of freedom), the translog variable cost function itself and four of the five share equations were specified as a system of equations and full-information maximum likelihood (FIML) procedures (in TSP386) were used in the estimation. One share equation had to be omitted from the equation system to avoid singularity in the error terms; this was the cost share of drugs and medical supplies. The equality conditions for continuity in both outputs and input prices (equation (11)) as well as linear homogeneity in input prices (equation (12)) were imposed as prior restrictions, following standard practice in translog cost function estimations.

#### Inequality Restrictions

In general, the regression results seem sound. They meet the inequality conditions for the translog variable cost function specified in chapter three: The coefficients of the natural logarithm of input prices ( $\alpha_i$  for  $i = 1, \dots, 5$ ) are all estimated to be positive and highly significant, and the coefficients of the natural logarithm of the outputs ( $\beta_n$  for  $n = 1, 2$ ) are at least non-negative, in effect fulfilling the conditions for monotonicity in factor prices and outputs as stipulated in equations (13) and (14). Concavity in input prices and convexity in outputs are also satisfied. The Hessian matrix  $H_{ww}$  is (weakly) negative semidefinite with

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\* Attempts at estimating other specifications were unsuccessful. These include (a) stochastic frontier cost functions and (b) an unoptimized cost equation in which, following the suggestion of Wagstaff and Barnum (1992), the fixed factor enters twice—as a parameter of the optimized variable cost function as well as of the fixed cost equation. In the stochastic frontier specification, the residual variance of the cost function could not be decomposed into that of the one-sided disturbance term (which is intended to measure the magnitude of technical and allocative inefficiency) and of the two-sided error term (which is meant to account for the effects on costs of truly random factors)—a result that is consistent with the Monte Carlo studies of Aigner, Lovell, and Schmidt (1977) for sample sizes smaller than 100 observations. In the cost equation specification, including the fixed factor twice in the set of regressors led to serious collinearity problems.

\*\* All equations referred to are those of chapter three.

Table 3  
Translog Hospital Variable Cost Function

| Variables                                | Parameters | Coefficient Estimates | Student t-Statistic |
|--|------------|-----------------------|---------------------|
| <i>constant</i>                          | $\alpha_0$ | -0.19235              | -2.202              |
| <i>al</i>                                |            | -0.16877              | -2.148              |
| <i>nyan</i>                              |            | -0.03963              | -0.454              |
|  |            | -0.10205              | -1.566              |
| <i>mis Oriental</i>                      |            | -0.13197              | -1.203              |
| <i>ino</i>                               |            | -0.11892              | -1.116              |
| <i>gno del Norte</i>                     |            | -0.14123              | -1.550              |
| <i>ary Hospital</i>                      |            | 0.01659               | 0.224               |
| <i>ary Non-Teaching Hospital</i>         |            | 0.08951               | 1.059               |
| <i>ary Teaching Hospital</i>             |            | 0.12960               | 1.197               |
| <i>te Hospital</i>                       |            | 0.06174               | 1.146               |
| <i>(age of Medical Residents)</i>        | $\alpha_1$ | 0.13072               | 13.506              |
| <i>(age of Nurses)</i>                   | $\alpha_2$ | 0.14494               | 18.492              |
| <i>(Wage of Other Medical Personnel)</i> | $\alpha_3$ | 0.11032               | 13.797              |
| <i>(Wage of Non-Medical Personnel)</i>   | $\alpha_4$ | 0.13585               | 14.775              |
| <i>(Price of Drugs)</i>                  | $\alpha_5$ | 0.47817               | 35.945              |
| <i>(Total In-Patient Discharges)</i>     | $\beta_1$  | 0.05554               | 1.307               |
| <i>(Total Out-Patient Visits)</i>        | $\beta_2$  | 0.54369               | 8.388               |
| <i>(Number of Beds)</i>                  | $\gamma_1$ | 0.41926               | 5.295               |

| Variables   | Parameters    | Coefficient Estimates | Student's t-Statistics |
|---|---------------|-----------------------|------------------------|
| $(\text{Wage of Medical Residents})^2$  | $\alpha_{11}$ | 0.09312               | 7.642 **               |
| $(\text{Wage of Nurses})^2$   | $\alpha_{22}$ | 0.09163               | 6.354 **               |
| $(\text{Wage of Other Medical Personnel})^2$  | $\alpha_{33}$ | 0.05538               | 3.864 **               |
| $(\text{Wage of Non-Medical Personnel})^2$  | $\alpha_{44}$ | 0.08150               | 6.199 **               |
| $(\text{Price of Drugs})^2$   | $\alpha_{55}$ | 0.16631               | 19.302 **              |
| $(\text{Total In-Patient Discharges})^2$  | $\beta_{11}$  | 0.20460               | 2.712 **               |
| $(\text{Total Out-Patient Visits})^2$   | $\beta_{22}$  | 0.16188               | 3.258 **               |
| $(\text{Number of Beds})^2$   | $\gamma_{11}$ | 0.24806               | 2.067 *                |
| $\text{Wage of Medical Residents} \times \ln(\text{Wage of Nurses})$                      | $\alpha_{12}$ | -0.03910              | 3.576 *                |
| $\text{Wage of Medical Residents} \times \ln(\text{Wage of Other Medical Personnel})$     | $\alpha_{13}$ | -0.01314              | 1.444                  |
| $\text{Wage of Medical Residents} \times \ln(\text{Wage of Non-Medical Personnel})$       | $\alpha_{14}$ | -0.01362              | 1.472                  |
| $\text{Wage of Medical Residents} \times \ln(\text{Price of Drugs})$                      | $\alpha_{15}$ | -0.02728              | 5.136 *                |
| $\text{Wage of Nurses} \times \ln(\text{Wage of Other Medical Personnel})$                | $\alpha_{23}$ | -0.00840              | 0.805                  |
| $\text{Wage of Nurses} \times \ln(\text{Wage of Non-Medical Personnel})$                  | $\alpha_{24}$ | -0.01483              | 1.499                  |
| $\text{Wage of Nurses} \times \ln(\text{Price of Drugs})$                                 | $\alpha_{25}$ | -0.04609              | 0.315 *                |
| $\text{Wage of Other Medical Personnel} \times \ln(\text{Wage of Non-Medical Personnel})$ | $\alpha_{34}$ | -0.00538              | 0.465                  |
| $\text{Wage of Other Medical Personnel} \times \ln(\text{Price of Drugs})$                | $\alpha_{35}$ | -0.04526              | 9.964 *                |
| $\text{Wage of Non-Medical Personnel} \times \ln(\text{Price of Drugs})$                  | $\alpha_{45}$ | -0.04768              | 9.098 **               |
| $(\text{Total In-Patient Discharges}) \times \ln(\text{Total Out-Patient Visits})$        | $\beta_{12}$  | -0.03384              | -0.623                 |
| $(\text{Total In-Patient Discharges}) \times \ln(\text{Wage of Medical Residents})$       | $\rho_{11}$   | -0.02331              | -2.039                 |
| $(\text{Total In-Patient Discharges}) \times \ln(\text{Wage of Nurses})$                  | $\rho_{12}$   | 0.00832               | 0.920                  |
| $(\text{Total In-Patient Discharges}) \times \ln(\text{Wage of Other Medical Personnel})$ | $\rho_{13}$   | 0.01051               | 1.168                  |



| Variables   | Parameters    | Coefficient Estimates | Student's t-Statistics |
|---|---------------|-----------------------|------------------------|
| <i>Total In-Patient Discharges</i> ) × ln( <i>Wage of Non-Medical Personnel</i> ) | $\rho_{14}$   | -0.01389              | -1.289                 |
| <i>Total In-Patient Discharges</i> ) × ln( <i>Price of Drugs</i> )                | $\rho_{15}$   | 0.01837               | 0.967                  |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Wage of Medical Residents</i> )        | $\rho_{21}$   | -0.00847              | -0.977                 |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Wage of Nurses</i> )                   | $\rho_{22}$   | -0.01412              | -1.999 *               |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Wage of Other Medical Personnel</i> )  | $\rho_{23}$   | -0.02811              | -4.045 **              |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Wage of Non-Medical Personnel</i> )    | $\rho_{24}$   | -0.03960              | -4.762 **              |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Price of Drugs</i> )                   | $\rho_{25}$   | 0.09029               | 6.730 **               |
| <i>Wage of Medical Residents</i> ) × ln( <i>Number of Beds</i> )                  | $\delta_{11}$ | 0.04773               | 3.881 **               |
| <i>Wage of Nurses</i> ) × ln( <i>Number of Beds</i> )                             | $\delta_{12}$ | 0.02748               | 2.721 **               |
| <i>Wage of Other Medical Personnel</i> ) × ln( <i>Number of Beds</i> )            | $\delta_{13}$ | 0.00574               | 0.583                  |
| <i>Wage of Non-Medical Personnel</i> ) × ln( <i>Number of Beds</i> )              | $\delta_{14}$ | 0.04073               | 3.471 **               |
| <i>Price of Drugs</i> ) × ln( <i>Number of Beds</i> )                             | $\delta_{15}$ | -0.12169              | -6.324 **              |
| <i>Total In-Patient Discharges</i> ) × ln( <i>Number of Beds</i> )                | $\theta_{11}$ | -0.05391              | -1.057                 |
| <i>Total Out-Patient Visits</i> ) × ln( <i>Number of Beds</i> )                   | $\theta_{12}$ | -0.13884              | -2.183 *               |
|   |               |                       | 0.985                  |
| log-likelihood Function   |               |                       | 451.561                |
| Number of Observations  |               |                       | 65                     |

\* significant at 95% confidence interval.  
 \*\* significant at 99% confidence interval.

principal minors:  $h_1^w = -0.2051$  and  $h_2^w = \dots = h_6^w = 0$ , while the Hessian matrix  $H_{vv}$  is (weakly) positive semidefinite with principal minors:  $h_1^v = 0.1521$  and  $h_2^v = 0$ .\*

### Cost Shares, Cost Elasticities of Outputs, and Consistency with the Cobb-Douglas Form

Turning to the interpretation of the individual parameters, recall that the input price coefficients  $\alpha_i$ s are the intercepts of the cost share equations (equation (19)). Since the variables in the translog variable cost function are mean-scaled, however, when the share equations are evaluated at the sample means of the regressors, the coefficient estimates also represent the cost shares of the various input categories. As such, the  $\alpha_i$ s ought to take on estimated values that lie in the unit interval—which they do in the results. Among the variable inputs, drugs and medical supplies have the highest estimated cost share (47.8%), although labor services as a whole account for about 52.2% of variable costs. Surprisingly, the cost shares of the various personnel categories are relatively even, on average accounting for 11 to 15 percent of variable costs.

In the case of the output coefficients,  $\beta_1$  and  $\beta_2$ , their estimates can be interpreted as the output elasticities of variable costs (which are monotonic transforms of marginal costs) when the evaluation is performed at the sample means of the variables. In this light, the lack of statistical significance of  $\hat{\beta}_1$  and the significant but small magnitude of  $\hat{\beta}_2$  can be taken to mean that variable costs are relatively unresponsive to small increases in outputs. What  $\hat{\beta}_2 = 0.544$  implies, for instance, is that if the number of out-patient visits to hospitals doubles, variable costs, on average, would increase only by about 54%. In terms of the more customary cost curves, this result suggests that on average the hospitals in the sample are operating at the decreasing portion of their average variable cost curves.\*\*

\* Wald tests conducted for each principal minor indicate that only  $h_1^w$  and  $h_1^v$  are different from zero at 10% level of significance.

\*\* This interpretation follows from the well-known result that

$$\frac{\partial c^v}{\partial y} \left\{ \begin{array}{l} < \\ = \\ > \end{array} \right\} \frac{c^v}{y} \quad \text{as } c^v/y \text{ is } \left\{ \begin{array}{l} \text{decreasing,} \\ \text{at its minimum level, or} \\ \text{increasing.} \end{array} \right\}$$

Multiplying through by  $y/c^v$  gives the result in terms of the output elasticity of variable cost:

$$\frac{d \ln c^v}{d \ln y} \left\{ \begin{array}{l} < \\ = \\ > \end{array} \right\} 1 \quad \text{as } c^v/y \text{ is } \left\{ \begin{array}{l} \text{decreasing,} \\ \text{at its minimum level, or} \\ \text{increasing.} \end{array} \right\}$$

Does the estimated cost function have a Cobb-Douglas form? Recall from chapter three that the translog variable cost function takes on the form of a Cobb-Douglas function when the coefficients of the interaction terms,  $\alpha_{ij}$ ,  $\beta_{nm}$ ,  $\gamma_{ll}$ ,  $\beta_{in}$ ,  $\delta_{it}$ , and  $\theta_{nt}$  (for  $i, j = 1, \dots, 5$ ;  $n, m = 1, 2$ ; and  $l = 1$ ), are found to be jointly not significantly different from zero. Using the Wald test to test this composite hypothesis yields a test statistic of  $\chi^2_{19} = 429.45$ . Hence, the hypothesis that the estimated cost function is no different from a Cobb-Douglas cost function is to be rejected for any given significance level.

#### Does Hospital Type, Ownership, or Location Matter?

Ten dummy variables were included as regressors of the variable cost function to capture intercept shifts in variable cost arising from differences in hospital type, hospital ownership, and provincial location.\* But of these dummy variables, only a hospital's being located in Bohol turned out to be significantly different from zero. This implies that on average there are no significant differences in the intercepts of the variable cost functions of secondary hospitals and of other types of hospitals, of government-owned and of private hospitals, and of hospitals located in Manila and of those located in other provinces with the exception of Bohol. In the case of Bohol hospitals, the intercept of their variable cost functions turns out to be lower than that of Manila hospitals.

#### Are there Economies (Diseconomies) of Scale?

Would average variable costs decline, increase, or keep pace with outputs if hospitals were to expand the scale of their operations (while maintaining the relative proportions of their outputs)? As discussed in chapter three, this question is answered using the index of ray scale economies  $\epsilon$  at the long-run optimal level of the fixed input. For  $T = 1$  and  $N = 2$ ,

Incidentally, note too that

$$\frac{d \ln c^v}{d \ln y} \left\{ \begin{array}{l} < \\ = \\ > \end{array} \right\} 0 \quad \text{as marginal cost is} \quad \left\{ \begin{array}{l} \text{decreasing,} \\ \text{at its minimum level, or} \\ \text{increasing.} \end{array} \right\}$$

\* Secondary hospitals, public hospitals, and hospitals located in Metro Manila were selected as the left-out categories.

the ray scale index may be expressed as:

$$\epsilon = \frac{1 - (\hat{\gamma}_1 + \hat{\gamma}_{11} \ln k_1^*)}{\sum_{n=1}^2 \hat{\beta}_n}$$

or in terms of the estimated parameters

$$= \frac{1 - (0.41926 + 0.24806 \ln k^*)}{0.05554 + 0.54369}$$

Thus, the value of  $\epsilon$  depends on the value of  $k^*$ , the mean-scaled long-run optimal number of hospital beds, which unfortunately is not known. Since  $k^*$  is the only variable with an unknown value on the right hand side of  $\epsilon$ , however, the value of  $k^*$  can be solved for  $\epsilon = 1$  to derive relative ranges of economies or diseconomies of scale. Using the sample mean of hospital beds (87.2), it can be calculated that

$$\epsilon \begin{cases} > \\ = \\ < \end{cases} 1 \quad \text{when} \quad k' \begin{cases} < \\ = \\ > \end{cases} 80.9.$$

In other words, if the long-run optimal size of hospitals in the regression sample is about 80 beds, then doubling the scale of hospital operations would correspondingly double their unit variable costs. If the long-run optimal number of beds turns out to be much less than 80, then doubling outputs would increase variable costs, but by less than the increase in outputs. Finally, if  $k' \gg 80$ , average variable costs of hospitals in the sample would more than double if demand for their services doubled.

#### Are there Economies (Diseconomies) of Scope?

Should hospitals offer both in-patient and out-patient care? The index of scope economies given in equation (23) is calculated to be  $-0.0007$ , but by the Wald test is found to be insignificantly different from zero ( $\chi_1^2 = 0.0003$ ). Thus, it is apparently not cheaper and neither is it more expensive for hospitals to offer both in-patient and out-patient services jointly.

#### Which Pairs of Inputs are Substitutes(Complements)?

Table 4 presents the matrix of Allen elasticities of substitution (AES) for the five variable input categories considered in the cost function estimation.\* Of the statistically significant

\* These Allen elasticities are calculated at the point of approximation of the translog variable cost function using equation (24).

Table 4  
Allen Elasticities

|                            | Medical Residents    | Nurses              | Other Medical Personnel | Non-Medical Personnel | Drugs and Medical Supplies |
|----------------------------|----------------------|---------------------|-------------------------|-----------------------|----------------------------|
| Medical Residents          | -1.2003<br>3.364*    |                     |                         |                       |                            |
| Nurses                     | -1.0635<br>3.027*    | -1.5379<br>4.711**  |                         |                       |                            |
| Other Medical Personnel    | 0.0892<br>0.019      | 1.5251<br>5.319**   | -3.5145<br>8.898***     |                       |                            |
| Non-Medical Personnel      | 0.2333<br>0.194      | 0.2467<br>0.245     | 0.6413<br>0.697         | -1.9450<br>6.956***   |                            |
| Drugs and Medical Supplies | 0.5636<br>304.294*** | 0.3349<br>86.732*** | 0.1420<br>5.216**       | 0.2660<br>28.684***   | -0.3697                    |

The numbers below the Allen elasticities are Wald test statistics for  $\chi^2_1$

- \*—significant at 10% level.
- \*\*—significant at 5% level.
- \*\*\*—significant at 1% level.

AES indices, the category, drugs and medical supplies, turns out to be an Allen substitute of all four categories of labor. Medical residents and nurses turn out to be Allen complements, while nurses are Allen substitutes of other medical personnel. That drugs and medical supplies are Allen substitutes of labor services in hospitals and that nurses are Allen substitutes of other medical personnel perhaps suggest that treatment protocols become more capital intensive as wage rates of hospital personnel rise. For instance, for a given admission, bed rest and *being under observation* which require intensive nursing services may be discouraged in favor of more diagnostic tests, which require more drugs and medical supplies, when nurses' time becomes more expensive. Why medical residents and nurses are Allen complements is perhaps because they tend to work in teams. When treatment protocols move away from nursing services, demand for the services of medical residents also decline.

#### Do Hospitals have Too Much Bed Capacity?

As discussed in chapter three, the issue of whether there is too much capital stock in the hospital system *given the levels of outputs of hospitals* is usually investigated by comparing the value of  $-\partial c^v/\partial k$  with the optimal return on investment in the fixed factor. The hypothesis on this issue is that  $\partial c^v/\partial k < 0$  (or, equivalently,  $\partial \ln c^v/\partial \ln k = \gamma < 0$ ), since along the same isoquant (*i.e.*, holding outputs fixed), the utilization of variable inputs must decrease as amounts of the fixed factor are incremented.

Table 3 reports a statistically significant  $\hat{\gamma} = 0.419$ . Cowing and Holtmann (1983), who got a similar result, interpret this to mean that hospitals are overcapitalized. But Wagstaff and Barnum (1992) disagree. Noting that it is  $\partial c/\partial k > 0$  (the partial derivative of *total costs* with respect to capital stock) that indicates overcapitalization, they argue that  $\partial c^v/\partial k > 0$  is instead evidence that variable costs have not been totally rid of fixed costs.

Here, still another interpretation is suggested. Note that the output measures used in the regression do not control for treatment procedures. As new capital equipment becomes available in hospitals, however, it may well be that doctors change the procedures they prescribe in favor of using the new machines. If so, even variable costs would be positively affected by increasing the hospitals' stock of capital.\* In other words, it is possible that when a hospital purchases new equipment, it does not only increase the hospital's capital

\* Formally, let  $q$  be some index of quality (*e.g.*, diagnostic accuracy) which has a positive influence on the employment of variable inputs  $x_v$  (*e.g.*, the services of medical technologists) and is itself increasing in fixed

stock but also changes the hospital's technology. As a result, new isoquants prevail, and to produce the same output levels, even variable costs increase.

This completes the presentation and interpretation of the regression results. In the next section, the results of some simulation exercises (which were undertaken to investigate the structure of costs and production of different categories of hospitals) are presented.

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factors  $k$  (e.g., more expensive machines). Then,

$$\frac{\partial c^v}{\partial k} = w_v \left( \frac{\partial x_v}{\partial k} + \frac{\partial x_v}{\partial q} \frac{\partial q}{\partial k} \right),$$

where  $\partial x_v / \partial k$  is the direct effect of  $k$  on the employment of variable inputs and  $(\partial x_v / \partial q)(\partial q / \partial k)$  is the effect through quality. It is therefore possible for fixed factors to have a net positive effect on variable costs: their impact on variable costs through quality just has to be stronger than their direct effect.

## VI

### Counterfactual Simulations

In chapter five, the regression results reported in Table 3 were interpreted and statistical inferences were made *at the point of approximation* of the translog variable cost function. In those tasks, the effort was greatly simplified by the fact that the translog variable cost function is a Taylor series expansion at vector point 0 of natural logarithms of mean-scaled variables. For at the sample means, the natural logarithms of these variables are zero and drop out of the formulas and indices used to investigate various aspects of hospital cost and production. This simplification came at the cost, however. *Away from the sample means*—where specific categories of hospitals that made up the regression sample are observed to be—it is not clear what the picture of costs and production that emerges from the regression looks like.

To (partly) redress this shortcoming, this chapter reports and interprets the results of six simulation exercises which were performed (using the estimated parameters of the translog variable cost function reported in Table 3) in order to analyze and compare certain aspects of costs and production of different categories of hospitals.\*\* The results of these exercises are presented in Table 5.

#### Output Elasticities of Variable Cost

How would hospital (variable) costs behave when demand for a category of output services doubles, holding the levels of other services constant? This question may be answered by calculating the output elasticity of variable cost, which may be roughly defined as measuring the percent change in variable cost resulting from a one percent change in an output category, holding all other variables fixed. In terms of the more customary cost curves, it can be easily shown that the output elasticity of variable cost is less than, equal to, or greater

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\* Had there been sufficiently many hospitals in each category of interest (tenet by type and ownership), separate regression runs could have been performed and comparisons (across hospital type and ownership) of the structure of hospital costs and production would then have been possible from the separate runs.

\*\* The reader is cautioned that these results are to be taken as being suggestive of rather than the last word on the true cost and production structure of hospitals. Because the regression was performed on a pooled sample of hospitals of different types and ownership (due to the small number of observations), a not-too-realistic assumption underlying the estimated cost function is that hospitals in the sample (whether public or private, whether primary, secondary, or tertiary) all have the same structure of cost and production beyond differences in intercept terms (most of which did not turn out to be statistically significant anyway).



Table 5  
Results of Simulation Exercises

|                                 | Number of Hospitals | Output Elasticity<br>In-patient Discharges | Output Elasticity<br>Out-patient Visits | Long-Run<br>Optimal<br>Bed Size | Economies<br>of Scope | Capital<br>Elasticity | Technical<br>Inefficiency |
|---------------------------------|---------------------|--|---|---------------------------------|-----------------------|-----------------------|---------------------------|
| <i>Hospital Type</i>            |                     |  |   |                                 |                       |                       |                           |
| Primary Hospitals               | 16                  | -0.0876                                    | 0.4115                                  | 6.29                            | -0.0699               | 0.4575                | 0.4375                    |
| Secondary Hospitals             | 30                  | -0.0090                                    | 0.4100                                  | 20.95                           | -0.0375               | 0.5005                | 0.5000                    |
| Tertiary Non-Teaching Hospitals | 13                  | 0.1196                                     | 0.4348                                  | 280.91                          | 0.0182                | 0.5510                | 0.4600                    |
| Tertiary Teaching Hospitals     | 6                   | 0.0848                                     | 0.5459                                  | 340.05                          | 0.0125                | 0.4518                | 0.5000                    |
| <i>Hospital Ownership</i>       |                     |  |   |                                 |                       |                       |                           |
| Private Hospitals               | 30                  | 0.0374                                     | 0.4044                                  | 47.84                           | -0.0187               | 0.5066                | 0.5000                    |
| Public Hospitals                | 35                  | -0.0209                                    | 0.4480                                  | 67.51                           | -0.0432               | 0.4861                | -0.4571                   |

than zero when the marginal cost of producing the output is decreasing, at its minimum level, or increasing. Moreover, it can just as easily be shown that the output elasticity of variable cost is less than, equal to, or greater than unity when marginal cost is below, intersects, or is above the average variable cost of producing the output.

In the second and third columns of Table 5, the output elasticities of in-patient discharges and out-patient visits are reported for the four hospital types as well as for private and public hospitals (at the sub-sample means of the hospital categories). The computed elasticities are all below unity, indicating that the system of hospitals comprising the regression sample has cost structures that are not very responsive to increases in service delivery. Apparently, the hospitals are operating at output levels where average variable costs are declining. Moreover, the in-patient cost elasticities of primary, secondary, and public hospitals are shown to be negative, suggesting that hospitals in these categories may be operating at the declining portions of their marginal cost curves.\*

A possible explanation for the results on in-patient elasticities is that the number of in-patient discharges may be a poor measure of hospital in-patient services. It does not account for both the patients' length of stay and the hospital department to which they were admitted. These errors-in-variable are known to bias coefficient estimates toward zero, which may have driven the simulation results.

#### Economies (Diseconomies) of Scale

How would hospital costs behave when the scale of hospital operations expand (holding the services offered in the same proportions)? As mentioned in chapter three, this question is answered by the index of ray scale economies or diseconomies  $\epsilon$ , where economies (diseconomies) of scale are said to exist if  $\epsilon > 1$  ( $\epsilon < 1$ ).

A problem in calculating the value of  $\epsilon$ , however, is that, as shown in equations (20) and (21), it requires the value of the long-run optimal level of the fixed input  $k_i^*$ , which is generally not known. To surmount this difficulty, the strategy adopted in the simulations is to solve for the value of  $k_i^*$  for  $\epsilon = 1$ , given the sub-sample means of bed capacity of the different hospital categories. The numbers provided in the fourth column of Table 5 thus

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\* This result is inconsistent with a fundamental prediction of the microeconomic theory of costs, which states that firms (operated by rationale managers) will not be observed operating at the downward sloping portion of their marginal costs because, at these output levels, the incremental contribution of additional outputs to revenues would be greater than their incremental contribution to costs.

indicate the long-run optimal number of beds in each hospital category if there are unit elasticities of scale (*i.e.*, there are neither economies or diseconomies of scale). If the long-run optimal bed capacities are thought to be lower (higher) than the numbers reported, economies (diseconomies) of scale are indicated.

The long-run optimal number of beds implied by unit elasticities of scale for primary and secondary as well as private and government hospitals (of Table 5) turns out to be lower than their (sub-)sample means for bed capacity (see Tables 2a and 2b and 2e and 2f). This suggests that if the scale of operations is expanded in these hospital categories, long-run unit costs are likely to increase. On the other hand, the (sub-)sample means for bed capacity of tertiary hospitals (see Tables 2c and 2d) are lower than their long-run optimal bed capacities at unit elasticity of scale. This indicates that economies of scale may be realized if hospital operations of tertiary hospitals are expanded.

#### Economies of Scope

On the basis of their cost structure, should hospitals offer both in-patient and out-patient services, or is it cheaper for hospitals to specialize in one type of service delivery? The indices of scope economies shown in the fifth column of Table 5 indicate that scope economies may exist for primary and secondary hospitals as well as for public and private hospitals, but not for the tertiary hospitals. The magnitudes of the indices are quite small, however, and may not be significantly different from zero. Hence, there may be neither economies nor diseconomies in the hospitals' offering in-patient and out-patient services jointly.

#### Capital Elasticity of Variable Cost

The issue being investigated by the capital elasticity of variable cost is whether hospitals have too much capital equipment or bed capacity relative to their output levels. The expectation here is that the elasticities would be negative since variable costs and the use of variable inputs are predicted to decrease as hospitals employ more of the fixed factors. Just as in the regression results, however, the measured impact of increasing bed capacity on variable costs is positive across all categories of hospitals. Because case mix and treatment protocols have not been adequately controlled for in the regression and because the regression sample consists of cross-section data (so that the rates at which new technology is being acquired by hospitals is unaccounted for), what this result means is difficult to say.

That increasing capital equipment raises variable cost is not at issue. What is whether this increase in variable cost is actually due to improvements in technology (which result in hospitals having enhanced capability to prevent more deaths and treat a wider range of ailments) rather than to sheer overexpansion in the hospitals' capital stock. Unfortunately, this is a decomposition that cannot be explored with cross-section data.

#### Technical Inefficiency

Technical inefficiency is customarily and more appropriately studied using stochastic frontier function estimates. Unfortunately, with less than a hundred observations in the sample, efforts to estimate a stochastic frontier hospital cost function were unsuccessful. Consequently, what was done instead was to compare a hospital's actual variable cost and the value predicted by the translog variable cost function estimated. A hospital was deemed to be technically efficient if its actual variable costs were lower than or equal to predicted variable cost; it was considered to be technically inefficient if its actual variable costs were higher than costs predicted by the estimated cost function. A shortcoming of this method, however, is that since the error term of the cost function is assumed to be identically and independently distributed as a normal random variable with mean zero, the variable cost function estimated is an *average* variable cost function with approximately half of the hospitals in the sample having actual variable costs that are greater than values that would be predicted by the estimated cost function.

The numbers reported in the last column of Table 5, in fact, show this to be the case: 50% of secondary, tertiary teaching, and private hospitals are deemed to be technically inefficient. Primary, tertiary non-teaching, and public hospitals are reported to have only slightly smaller percentages.

## VII

### Conclusion

This report presented and interpreted the regression results of a translog variable cost function that was estimated using a cross-section sample of 65 Philippine hospitals of various types, ownership, and provincial location. Statistical inferences and simulations which were based on these regression results were also provided to give some sense of the structure of costs and production of hospitals in the Philippines. What are we to make of its results?

Note from Table 1 that, relative to the estimation requirements, the size of the regression sample at 65 observations is quite small. This imposes rather severe constraints on the estimation exercise. Ideally, given that in an econometric estimation of a cost function all the firms that constitute the regression sample are assumed to have the same structure of costs and production, regressions ought to be performed on hospitals that are as much alike as possible (*e.g.*, in terms of size and ownership), so that the same case mixes, technology, and behavioral modes would prevail in the sample. Performing regression runs on subsamples of hospitals in the data set, however, would have cut deeply into the degrees of freedom and the precision of the parameter estimates.

In addition, it ought to be realized that, relative to their theoretical constructs, the cost function variables in the data set are measured with error. For instance, variable costs do not include outlays for quasi-fixed inputs such as utilities and for a miscellany of other items. The annual wage of a typical member of each labor category is derived as the wage bill of that category of labor divided by the number of full-time staff. The price of drugs and medical supply is really the ratio of expenditures on those items (including inventories) to the number of both in-patient discharges and out-patient visits. The measures of outputs themselves do not take account of illness severity, case mix, and aggregation (across hospital departments) issues. And the number of beds is a poor proxy of the capital stock of hospitals (but one that maximized sample size).

Nonetheless, the regression results generally seem reasonable. The variable cost function that was estimated conforms to the (unimposed) theoretical requirements of a cost function: Statistical tests reveal it to be monotonically nondecreasing in input prices and outputs, concave in factor prices, and convex in outputs. Key coefficient estimates, such as the cost share of inputs  $\hat{\alpha}_i$  and the output elasticity of variable costs  $\hat{\beta}_n$ , have the expected signs with

magnitudes that are within the range required by theory. What this suggests is that there may be enough of a common cost structure shared by hospitals of different sizes, geographical location, and management styles, so that the estimation effort is not totally invalidated.

Unexpected results can also be explained. For instance, why  $\hat{\beta}_1$ , the coefficient estimate of the natural logarithm of in-patient discharges, is not statistically significant and why the output elasticities for in-patient services of primary, secondary, and public hospitals are negative in the simulation results may be attributed to the poor measurement of the output variable. Relative to its theoretical construct (which is intended to measure in-patient service delivery), the number of in-patient discharges assigns a uniform weight to patients even if they are afflicted with different types as well as severity of illness and even though they may be using hospital resources at different levels of intensity. With such errors-in-variable, it is well-known that the coefficient estimate tends to be biased toward zero.

Why the estimate of  $\gamma_1$ , the coefficient of the natural logarithm of the number of beds, is positive and significant has been previously explained as a probable consequence of the different rates at which hospitals are adopting new technology as they expand operations. In other words, hospital investments may not be affecting the scale alone, such as when more machines are purchased or when more beds or rooms are provided, but may also have an impact on the quality of capital equipment, such as when the new machines allow more accurate diagnoses or earlier detection of illnesses. Since the case mix of hospitals (or the range as well as the seriousness of illnesses handled) and differences in treatment protocols of hospitals were not adequately controlled for, it is hard to tell whether the escalation of hospital variable costs arising from expansions of capital stock is due to overcapitalization or to technological improvements.

What policy implications may be drawn from the regression results and the simulation exercises? The most important message is that policy makers and hospital administrators need to rationalize the structure of hospital costs and operations. Hospital costs *must* be related to performance. As it is, (the regression and simulation results show that) supply-side factors, such as labor services and medical supplies, are what drive hospital costs. Services offered by hospitals apparently have little or no impact on costs. It may not even be cheaper to maintain out-patient and in-patient departments jointly in one hospital. As for the production structure of hospitals, policy makers need to address whether it is reasonable that (a) expenditures on drugs and medical supplies should take up about half of hospital

variable costs and (b) primary and secondary hospitals are apparently operating at output levels where long-run unit costs are likely to rise if hospital operations are expanded, while tertiary hospitals may be operating on the downward sloping portion of their long-run unit cost curves.

Two initiatives make reforms in the structure of hospital costs imperative. Under the devolution of health services delivery, public hospitals need to prove to local government units their economic viability as well as responsiveness to the health needs of their catchment areas. With national health insurance impending, an increasingly important concern for the government is that hospital costs do not escalate unless there is at least a corresponding increase in value for the services offered. Both initiatives need a detailed understanding of the nature of hospital costs and production, such as those provided by structural cost function estimates.

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