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Hospital Cost Functions for Developing Countries

Adam Wagstaff
and
Howard Barnum

A critical survey of the techniques available for analyzing hospital costs and a review of the few hospital cost-function studies undertaken for developing countries.

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This paper — a product of the Health and Nutrition Division, Population and Human Resources Department — is part of a larger effort in the department to examine the efficiency of resource allocation for human services. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Otilia Nadora, room S6-065, extension 31091 (November 1992, 32 pages).

There is an extensive literature on hospital cost functions for industrial countries, and a small literature for developing countries. Yet the issues facing policymakers in all countries are much the same: Are hospitals overcapitalized, as is often claimed of U.S. hospitals? Are hospitals inefficient in other respects? Do hospitals vary in efficiency? Are private hospitals more efficient than their public counterparts? Should hospitals specialize or provide a broad range of services? Should costs be reduced by concentrating cases in fewer hospitals?

Wagstaff and Barnum critically survey the techniques available for analyzing hospital costs and review the few hospital cost-function studies undertaken for developing countries.

Although their paper is intended primarily for those working in developing countries, the discussion of cost function methodology has broad implications for interpreting econometric cost functions and for examining economies of scale and scope in both developing and industrial countries.

Their survey of econometric techniques is not uncritical. They question, for example, the validity of recent tests of overcapitalization undertaken on American hospitals. They also make general observations about the methods used to investigate economies of scope and economies of scale.

Hospital Cost Functions For Developing Countries

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1. Introduction

There is an extensive literature on hospital cost functions for industrialized countries, but a much smaller literature for developing countries.[1] Yet the issues facing policy-makers in both sets of countries are much the same: Are hospitals over-capitalized, as is often claimed of US hospitals? Are hospitals inefficient in other respects? Do hospitals vary in their degree of inefficiency? Are private hospitals more efficient than their public counterparts? Should hospitals specialize or provide a broad range of services? Could costs be reduced by concentrating cases in fewer hospitals? Such issues are as relevant to policy-makers in developing countries as to their counterparts in the industrialized world.

Moreover, it seems likely that the econometric techniques that have been used to such effect in the industrialized world would be equally capable of informing policy debate in the developing world. Our purpose in this paper is to provide a survey of these techniques and to summarize the work to date on developing countries. Though the paper is written primarily with developing countries in mind, it is hoped that it may be of some value to researchers in industrialized countries. Our survey of econometric techniques is not uncritical. We question, for example, the validity of recent tests of over-capitalization undertaken on American hospitals. We also make various general observations about the methods used to investigate economies of scope and economies of scale.

Section 2 provides a survey of the issues facing policy-makers in the hospital sector and the relevant econometric techniques. Sections 3 to 6 contain surveys of four recent studies of hospital costs in Kenya, Peru, Ethiopia and Nigeria. The final section contains our conclusions concerning both the studies undertaken to date and the methods for analyzing hospital costs.

2. Some economics and econometrics of hospitals

As indicated above, there are, broadly-speaking, four sets of policy issues that can be addressed using cost function analysis: (i) are hospitals over-capitalized?, (ii) are hospitals inefficient?, (iii) should hospitals specialize or provide a broad range of services?, and (iv) are there too many hospitals?

2.1 Are hospitals over-capitalized?

The issue is whether hospitals have a capital stock that is too large given their output level. In developed countries - especially the United States - it is often argued that this is the case, the

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[1]. For reviews of the American and British literature see Cowing, Holtmann and Peters (1983) and Wagstaff (1989a). Several of the more recent studies for industrialized countries are referred to in the present paper. To our knowledge there has been no survey of developing country studies.

implication being that hospitals ought to reduce their capital stock. It is important to realize that the issue of over-capitalization is different from the issue of economies of scale. The latter concerns the effect on costs of further expansion of output and therefore bears on the question of whether output levels are too high or too low. Authors of many early cost function studies confused the two issues. Writers such as Feldstein (1967) and Anderson (1980), for example, claim to address the issue of economies of scale, but in the event analyzed over-capitalization.[2]

The currently favored approach to over-capitalization dates back to Cowing and Holtmann (1983), who proposed analyzing the issue by reference to the parameters of the variable cost function. In the short-run, when the capital stock is fixed, short-run costs, CS, can be written as the sum of total fixed costs and total variable costs

(1) $C_S = F + C_V(y, w_V, K)$,

where $F = w_K K$ is total outlay on the fixed input, y is output, w_V is the price(s) of the variable input(s) and K is the stock of capital. It is worth noting that K enters CS twice: once as a determinant of fixed costs and once as a determinant of variable costs - an issue to which we return below. The long-run cost-minimizing capital stock, K^*, is that which minimizes costs at each level of output. Differentiating (1) with respect to K and setting the derivative equal to zero yields

(2) $-w_K = \delta C_V/\delta K$.

To test for over-capitalization Cowing and Holtmann suggest estimating the variable cost equation $C_V(y, w_V, K)$ and testing the hypothesis that $\delta C_V/\delta K = -w_K$.

The intuition here can be illustrated with fig 1, which shows three possible input mixes to produce a single output y. Without loss of generality set w_K equal to 1. Then the vertical intercept of each isocost line is equal to C_S, the value of K is equal to F and the vertical distance between C_S and F is equal to C_V. The long-run optimal stock of capital is K^*. At point '1', the capital stock is too small and a move from point '1' towards point '2' would cause total cost to fall. (Fixed costs would rise, but this rise would be more than offset by a fall in variable costs.) Hence at point '1' $\delta C_V/\delta K < -w_K$. At point '3', by contrast, the capital stock is too large and a reduction in capital towards K^* would reduce total cost. (Variable costs would rise, but this would be more than offset by the reduction in fixed costs.) Hence at point '3' $\delta C_V/\delta K > -w_K$. Only at point '2', where the capital stock is at its long-run equilibrium value, is $\delta C_V/\delta K$ equal to $-w_K$.

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[2]. That the approach used by Feldstein is ill-suited to the analysis of economies of scale was argued long ago by Davis (1968) and Mann and Yett (1968). That his approach is better suited to the analysis of over-capitalization has not, to our knowledge, been argued before.

In Cowing and Holtmann's study, as in most cost function studies in which a proxy for capital stock is included among the regressors, the derivative of cost with respect to capital is positive. Cowing and Holtmann interpret this as evidence of over-capitalization. However, this interpretation is, in fact, inconsistent with economic theory. An increase in capital ought always to reduce variable costs, because usage of variable inputs must decline if output is to remain unchanged. Hence $\delta C_V/\delta K$ ought always to be negative. That the derivative of cost with respect to capital is positive in such studies suggests that the dependent variable may not actually be variable costs, but may instead include some fixed costs. If, for example, all fixed costs are included in the cost variable, a positive $\delta C_S/\delta K$ makes perfect sense; indeed this is precisely the condition for over-capitalization.

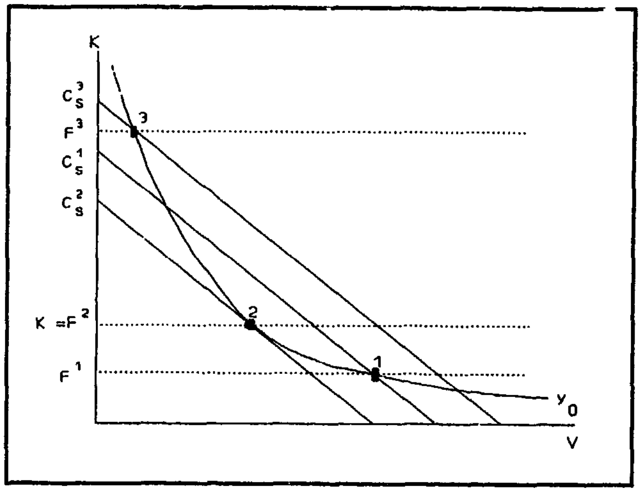

Figure 1

This suggests an alternative testing strategy, which addresses the fact that it will typically be difficult to purge cost data of fixed costs: estimate a short-run total cost equation and test the hypothesis that $\delta C_S/\delta K=0$. This is similar to the approach adopted long ago by Feldstein (1967), though he confusingly argued that he was investigating economies of scale rather than over-capitalization. From fig 1 it is evident that the partial relationship between short-run total (and average) cost and capital stock is U-shaped (fig 2). Moving along this curve is equivalent to moving from one short-run average cost curve to another (fig 3). At point '1' $\delta C_S/\delta K<0$ (and, by implication, $\delta C_V/\delta K<-w_K$), while at point '3' $\delta C_S/\delta K>0$ (and, by implication, $\delta C_V/\delta K>-w_K$). Hence if one estimates a short-run total (or average) cost function and finds that a hospital is operating to the right of the minimum point of the partial relationship between

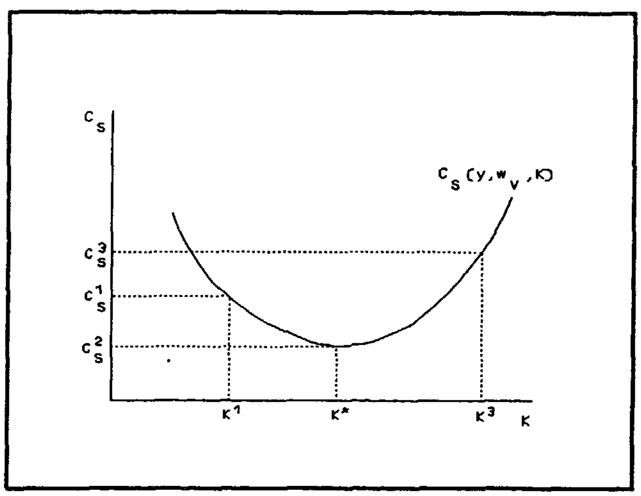

Figure 2

cost and capital stock, one can conclude that the hospital is over-capitalized.

Theory suggests various restrictions that need to be placed on a short-run cost function and it is worth spelling these out. First, the equation could be additive in fixed and variable costs. If, as is often the case, the shadow price of capital is unknown, the fixed cost component of the equation ought not to contain an intercept and instead capital ought to be entered as a regressor; its coefficient would then be interpreted as the shadow price of capital. Second, assuming convexity of isoquants, total variable costs ought to be decreasing in capital stock with the derivative approaching zero asymptotically. In other words, as substitution of labor for capital gets harder and harder, an ever increasing share of the extra cost associated with increases in capital stock will be taken up by extra fixed costs. The partial relationship between short-run total cost and capital stock ought, as indicated above, to be U-shaped.

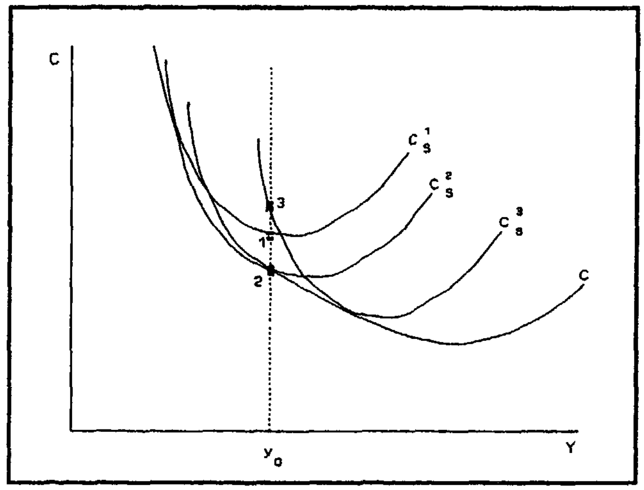

Figure 3

2.2 Are hospitals inefficient?

A distinction is normally made between technical inefficiency (failing to produce the maximum possible output from a given bundle of inputs) and allocative inefficiency (employing inputs in the wrong proportions given their prices and productivity at the margin). The issue of over-capitalization examined above is, of course, one aspect of allocative efficiency. In principle both types of inefficiency might be present in the hospital sector and it is useful for policy-makers to know the extent of any such inefficiency in the hospital sector as a whole, as well as any variation across hospitals. It is also of interest, of course, to know whether there is any variation between one sub-sector (eg the private sector) and another (eg the public sector).

Technical efficiency can be analyzed using either non-statistical approaches[3], such as data envelopment analysis, or statistical methods,

[3]. For an example of the non-statistical approach in the context of the hospital sector see Grosskopf and Valdmanis (1988).

such as the frontier production function[4]. We focus here on the latter.

Suppose for simplicity that the production function is Cobb-Douglas:

(3) $\ln y_i = \beta_0 + \Sigma_j \beta_j \ln x_{ij} + u_i$

where y is output, the x_j are inputs, the β's are output elasticities and u is an error term. Feldstein (1967) suggested that the residuals of eq (3) might be used as estimates of technical inefficiency, so that a hospital with a zero residual is said to be of average technical inefficiency, while a hospital with a positive (negative) residual is said to be of above-average (below-average) technical efficiency.[5] A disadvantage of this approach is that it provides no information on the level of efficiency. Clearly, it is important to know whether inefficient hospitals are very inefficient or only marginally so. This defect can be overcome using the deterministic frontier model (DFM) of Aigner and Chu (1968), which differs from eq (3) in that it constrains the error term to be non-positive. Hospitals can thus operate on or below the production frontier but not above it, and the extent of technical inefficiency is indicated by the estimated residuals, $\hat{u}_i$. The DFM can be estimated using a variety of methods, the simplest of which is Corrected Ordinary Least Squares: this involves shifting up the OLS estimate of the intercept until one residual is zero and all the rest are negative.[6]

There is, however, a second problem with Feldstein's approach, which is not overcome by the DFM, namely that it implicitly assumes that all cross-sample variation in the error term of the estimating equation is due to variation in efficiency. In reality the residuals are also likely to reflect random influences outside the hospital's control, as well as statistical 'noise'. A better tool is the stochastic frontier model (SFM) [cf eg Aigner et al. (1977)]:

(4) $\ln y_i = \beta_0 + \Sigma_j \beta_j \ln x_{ij} + v_i + u_i \qquad u_i \leq 0,$

so that the error term v_i+u_i is composed of two parts, v_i being two-sided and capturing random shocks and statistical noise, and u_i being one-sided and reflecting inefficiency, which is constrained to be

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4. For surveys of parametric and non-parametric approaches to efficiency measurement see Schmidt (1986) and Barrow and Wagstaff (1989).

5. The rationale behind this is that the output of a hospital with a residual equal to zero is exactly the output that would be expected of it given its input utilization and the average estimated productivity of the inputs. By contrast, a hospital with a positive (negative) residual produces more (less) than it would have been expected to produce on the basis of its input usage and the estimated parameters of the production function.

6. Cf. Forsund, Lovell and Schmidt (1980) and Schmidt (1986).

non-positive. Inefficiency is measured relative to the stochastic frontier ($\beta_0+\Sigma_j\beta_j x_{ij}+v_i$). There are, broadly-speaking, two approaches to estimation of the SFM. One involves making an assumption about the distribution of the u_i in a cross-section, the most common assumption being that the u_i are half-normal. The model can then be estimated by supplementing the information normally used in the estimation of the regression model with information on the extent of skewness in the residuals [see Schmidt and Lovell (1979)].[7] One then ends up with a residual for each hospital, an estimate of the mean of the u_i, but not an estimate of u_i. What one can estimate, however, is $E(u_i|v_i+u_i)$ - the expected value of u_i, given the value of the composite error [see Jondrow et al. (1982)]. The alternative estimation approach involves the use of panel data and assumes that inefficiency remains constant over time [cf Schmidt and Sickles (1984)]. By working with data in terms of deviations from temporal means, one can eliminate the unobservable inefficiency term, which can then be recovered once the parameters of the production function have been estimated.

The detection of allocative inefficiency is, in principle at least, relatively straightforward. Allocative efficiency requires that for each pair of inputs j and m

(5) $MP_j/MP_m = w_j/w_m$

where MP_j is the marginal product of the jth input and w_j is its price. In the case of the Cobb-Douglas production function this condition becomes

(6) $\beta_j/\beta_m = w_j x_j/w_m x_m$,

i.e., the ratio of expenditures on the two inputs equals the ratio of their output elasticities. Because the β_j are invariant with respect to the amount of each of the inputs employed, the left-hand side of eq (6) can be treated as a datum. Any discrepancy between the ratio of output elasticities and the expenditure ratio is therefore to be attributed to incorrect usage of one or both of the inputs. Once one has estimates of the β_j, one can determine whether one input is over- or under-employed relative to another. If, for example, the right-hand side of (6) is larger than the left-hand side, the kth input is being over-employed relative to the jth. For other functional forms - such as the translog - allocative efficiency can be assessed by comparing the ratio of marginal products with the ratio of input prices.[8]

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[7]. An alternative to this so-called moments estimator is a maximum likelihood (ML) estimator [see eg Greene (1980, 1982)].

[8]. The standard shares equation approach in this context is clearly inappropriate, since it assumes that the residuals of the shares equations have zero mean [cf Wagstaff (1989b)].

One possible way of <u>measuring</u> allocative inefficiency is to calculate by how much a hospital's output would increase if it optimally reallocated its budget and use the ratio of actual output to feasible output as the measure of allocative inefficiency [cf Feldstein (1967)]. Alternatively, in the two-input case, one might employ the index proposed by Goldman and Grossman (1983):

(7) $AI_i = \left|(MP_{1i}/MP_{2i})\cdot(w_2/w_1)-1\right|$,

which in the case of the Cobb-Douglas becomes

(7′) $AI_i = \left|(\beta_1/\beta_2)\cdot(w_2x_{2i}/w_1x_{1i})-1\right|$.

Allocative efficiency gives a zero value of AI, while allocative inefficiency results in AI being positive.

The effect of both technical and allocative inefficiency is, of course, to raise a hospital's costs above their feasible minimum. It is instructive, therefore, to consider the relationship between a hospital's production function and its cost function in the presence of such inefficiency, not least because doing so ought to help establish how the estimation of <u>cost</u> functions might shed light on the issue of efficiency. Consider the case of the Cobb-Douglas production function (4). If hospitals are technically and allocatively efficient, so that the u_i in eq (4) are zero for all hospitals, the associated cost function takes the form

(8) $\ln C_i = M + (1/r)\ln y_i + (1/r)\Sigma_j\beta_j\ln p_{ji} - (1/r)v_i$,

where $r=\Sigma_j\beta_j$ denotes returns to scale (RTS) and M is a function of the parameters of the cost function.[9] Suppose now that hospitals are both technically inefficient and allocatively inefficient. Thus $u_i<0$ for some i and instead of eq (6) we have

(9) $\ln p_1x_{1i} - \ln p_mx_{mi} + \ln(\beta_m/\beta_1) = \delta_{mi} \qquad m=2,\ldots,J.$

Thus δ_{mi} represents the amount by which the mth first-order condition for allocative efficiency fails to hold in the ith hospital. Schmidt and Lovell (1979) show that this gives rise to a cost function of the form

(8′) $\ln C_i = M + (1/r)\ln y_i + (1/r)\Sigma_j\beta_j\ln p_{ji} - (1/r)[v_i-u_i] + (E_i-\ln r)$,

where

$$E_i = \Sigma_j(\beta_j/r)\delta_{ji} + \ln[\beta_1+\Sigma_{j\neq 1}\beta_j\exp(-\delta_{ji})].$$

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[9]. M is, in fact, given by
$M = \ln r - (1/r)\beta_0 - (1/r)\ln[\pi_i\beta_i^{\beta_i}]$
[see eg Schmidt and Lovell (1979, p347)].

Thus, in the case of the Cobb-Douglas technology, technical and allocative inefficiency leave the shape of the cost function unaffected, but give rise to two non-negative hospital-specific effects, $(1/r)u_i$ and $(E_i-\ln r)$, the values of which indicate the percentage by which the ith hospital's costs exceed their feasible minimum due to technical and allocative inefficiency respectively.

Various points emerge from the above. First, it suggests alternative measures of technical and allocative inefficiency, namely $(1/r)u_i$ and $(E_i-\ln r)$. Second, it is clear that one cannot obtain separate estimates of technical and allocative inefficiency by estimating only a cost function; information from the production function or the first-order cost-minimization conditions (9) is also required. By contrast, separate estimates of technical and allocative inefficiency can be obtained by estimating only the production frontier, since this provides all the information required to compute the two inefficiency indices $(1/r)u_i$ and $(E_i-\ln r)$. Third, if one is content merely to have an estimate of technical and allocative inefficiency combined, estimation of a cost function would suffice. But note that since both types of inefficiency increase costs ($(1/r)u_i$ and $(E_i-\ln r)$ are both non-negative), the appropriate model is a cost frontier which explicitly takes into account this fact.[10] Including in one's cost function variables other than input prices and output in an attempt to capture inefficiency [cf eg Breyer (1987)] is a less reliable strategy.

2.3 Should hospitals specialize?

Another important issue confronting policy-makers is whether hospitals should be encouraged to specialize or to provide a broad range of services. Should hospitals, for example, provide both inpatient and outpatient care? Should hospitals providing inpatient services aim to treat most casetypes, or should they specialize?

Analysis of this issue dates back to Evans and Walker (1972), who employed information theory to derive an index of inpatient specialization, which they then included in their cost function for Canadian hospitals. Their index involved a comparison between a hospital's overall share of cases casemix proportions and the province's proportions, with the index increasing in the degree of divergence between a hospital's actual casemix proportions and the province's proportions. Thus a small hospital that is unable to treat the full range of inpatient casetypes would typically have a high specialization index. Evans and Walker found that larger hospitals tended to be less specialized (though the correlation was fairly low) and that, holding constant the stock of beds, casemix, length of stay, occupancy rate,

[10]. See Wagstaff (1989c) for an empirical comparison of various cost frontier models estimated on a sample of Spanish hospitals.

caseflow and outpatient expenditures, a high degree of specialization raised average costs.[11]

More recent work on specialization and hospital costs [cf eg Cowing and Holtmann (1983), Grannemann, Brown and Pauly (1986), Vita (1990)] has built on the literature on economies of scope that emerged in the 1980s [cf eg Baumol, Panzar and Willig (1982)]. Economies of scope are said to exist if the joint output of a single organization is greater than the output that could be achieved by several separate organizations each producing one product but together employing the same amount of input. In this context, inpatient and outpatient care might be treated as two different products, and one might treat different inpatient casetypes as different products. An implication of economies of scope is that production costs can be reduced by producing products jointly, rather than specializing. Thus in the two-product case (the generalization to three or more products is straightforward), economies of scope can be measured as

$$S_C = [C(y_1^*,0)+C(0,y_2^*)-C(y_1^*,y_2^*)]/C(y_1^*,y_2^*),$$

where $C(y_1^*,0)$ and $C(0,y_2^*)$ are the costs that would be incurred if y_1^* units of y_1 and y_2^* units of y_2 were produced separately, and $C(y_1^*,y_2^*)$ is the cost that would be incurred if the same quantities of y_1 and y_2 were to be produced jointly. With economies of scope, the joint cost is less than the sum of the individual costs, so that $S_C>0$. With diseconomies of scope, $S_C<0$. If both products have positive marginal costs, it can be shown that $S_C<1$.

In order to establish whether economies of scope exist, and if so to what extent, it is necessary to estimate a multiproduct cost function. Moreover, the functional form must yield plausible estimates of the costs that would obtain if only one product were produced at any one time. In principle this is straightforward. Eq (1) might, for example, be generalized to a multiproduct setting by treating y as a vector rather than a scalar. In practice cost functions are often specified in a way that prejudges the issue of economies of scope. Suppose, for example, that the estimated cost function involves cost per case expressed as a linear function of a casemix vector[12]

$$(9) \quad C/N = \beta_0 + \Sigma_{i=1}^{n-1}\beta_i p_i + e,$$

where C/N is cost per admission and p_i is the proportion of cases falling into the ith casemix category (there being n categories altogether). Multiplying through by N gives the total cost counterpart of eq (9), namely

[11]. Cf. Barer (1982), who obtained a negative but insignificant coefficient in his equations.

[12]. Such an equation was used by Feldstein (1967).

(10) $C = \Sigma_{i=1}^{n} \tau_i N_i + e^*$

where $\tau_i = \beta_0 + \beta_i$ for $i=1,\ldots,n-1$, $\tau_n = \beta_0$ and $e^* = e \cdot N$. It is evident that the average cost function (9) implicitly assumes that there are no economies of scope, because overall total cost is simply the sum of the product-specific total costs.[13]

The estimated cost function must therefore be sufficiently general to allow for either or both of the two possible sources of economies of scope: (1) fixed or quasi-fixed[14] costs that are not product-specific and, (2) cost complementarities. Suppose, for example, that treating the various inpatient categories requires use of some central facility, and that the associated cost is invariant with respect to the hospital's level of activity. Then eq (10) would include a constant term (which may or may not become zero when all outputs fall to zero) and S_C would become positive. If, by contrast, each product line simply had its own quasi-fixed costs which could be avoided by ceasing production of the product in question, fixed costs would not generate any economies of scope. The alternative source of economies of scope is cost complementarities: a situation where the marginal cost of one product is a decreasing function of the amount being produced of other products. This is evidently not the case in eq (10), because the marginal cost of casetype i is τ_i, which is a constant. To allow for cost complementarities the cost function would need to include interaction terms between the various outputs.

2.4 Too many hospitals?

A further important issue facing policy-makers in developed and developing countries alike is whether the current number of hospitals should be increased or reduced to cope with the existing workload.

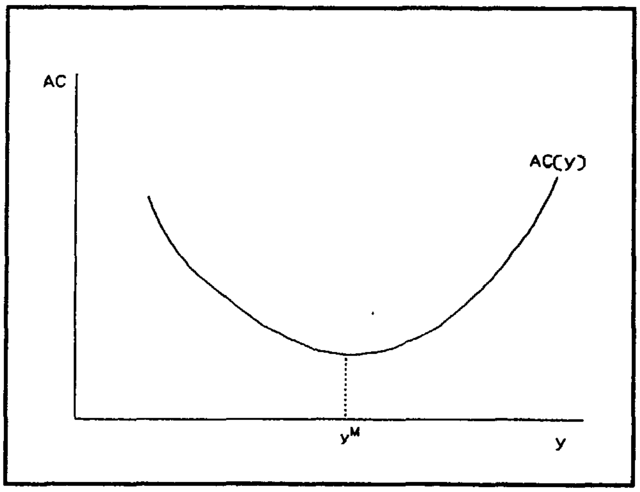

Figure 4

In the case of a single-product industry with a U-shaped average cost curve it is straightforward to determine the cost-minimizing number of producers for the industry in question. If y^I is industry

[13]. This conclusion is unaffected by the inclusion of variables such as the stock of beds and caseflow in eq (9).

[14]. By "quasi-fixed costs" we mean costs that do not vary with the level of output but which are only incurred if production is positive [cf Baumol and Willig (1981)].

output, and if y_m is the minimum point of the average cost curve (cf fig 4), the cost-minimizing number of producers, m^*, is equal to y^I/y_m [Baumol et al. (1982; 23)]. If this is not an integer, m^* is either the integer just below y^I/y_m or the integer just above it. The intuition is straightforward. Suppose that $y^I=y_m$. Then getting two firms to produce $\frac{1}{2}y^I$ each would cost more than getting one to produce the whole amount by itself.

Evidently when y^I is sufficiently large relative to y_m, each producer will, in the cost-minimizing industry structure, operate at the minimum point of its average cost curve. Hence the interest in the hospital cost literature in economies of scale. In the single-product case these are measured by the elasticity of total cost with respect to output:

$$\epsilon = (\delta C/C)/(\delta y/y) = (\delta C/\delta y)\cdot y\ (1/C) = \delta \ln C/\delta \ln y,$$

which is equal to the ratio of marginal cost to average cost. If economies of scale exist, $\epsilon<1$ and average cost is falling, while $\epsilon>1$ implies diseconomies of scale and a rising average cost. It is customary to measure economies of scale using the reciprocal of ϵ: thus

$$(11) \quad S = AC/MC = C \ / \ (\delta C/\delta y)\cdot y \ = 1/(\delta \ln C/\delta \ln y),$$

which is positive if economies of scale exist and negative if diseconomies of scale exist.

In the light of the result above concerning the optimal number of producers, and the definition of S, it is understandable that authors whose results point towards the existence of economies of scale conclude that too many hospitals exist, while those whose results point towards diseconomies of scale conclude that too few hospitals exist.[15] There is, however, a complication that needs to be borne in mind that is often overlooked, namely that the issue of whether there are too few or too many hospitals is necessarily a long-run problem and hence economies of scale should be evaluated in the context of the long-run, as is envisaged in the traditional textbook definition of economies of scale. Thus in eq (11) AC should be interpreted as long-run average cost and MC as long-run marginal cost.

Because of this, it is tempting to try to estimate a long-run cost curve directly. It is often assumed that this can be achieved simply by omitting capital from the cost function [cf eg Granneman et al. (1986)]. The problem with this approach is obvious: only in the rather unlikely event that hospitals have adjusted their capital stock to its long-run equilibrium value will a hospital be operating on its long-run cost

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[15]. Although this conclusion is sound when y^I is large relative to y_m, it is evident that when y^I is small relative to y_m, it may well be optimal for a small number of producers to be producing to the left or right of y_m. The presence of economies or diseconomies of scale is not necessarily indicative therefore of there being too many or too few hospitals.

curve. If hospitals have not adjusted their capital stocks to the long-run optimal level, their actual average costs will exceed LAC and their actual marginal costs will differ from LMC. Attempting to estimate a long-run equation in this context will yield unreliable estimates of LMC and LAC and hence of S.

Some authors have instead sought to infer economies of scale from the variable cost function $C_V(y,w_V,K)$. Cowing and Holtmann (1983), for example, compute S as the reciprocal of $\delta lnC_V/\delta lny$. As Vita (1990) notes, this does not in fact capture economies of scale. Eq (2) above can be solved to obtain the long-run equilibrium level of capital

(12) $K^* = K^*(y,w_K,w_V)$,

which can then be substituted into (1) to obtain the long-run cost curve

(13) $C(y,w_K,w_V) = w_K K^*(y,w_K,w_V) + C_V(y,w_V,K^*(y,w_K,w_V))$.

The partial derivative $\delta C_V/\delta y$ is equal to short-run marginal cost, while what is required is the total derivative of total cost with respect to y. The latter, unlike the former, takes into account the effects of output changes on the optimal capital stock and the effects of these changes in capital on fixed and variable costs. What the derivative $\delta lnC_V/\delta lny$ does show is whether a hospital has exploited all possible returns to the variable input(s) and therefore whether the hospital is operating to the left or right of the minimum point of its short-run average cost curve. This may be of some interest in its own right, but it does not bear on the issue of economies of scale.

It is possible, however, to draw inferences about economies of scale from a variable cost curve by invoking the envelope condition. As is reported in, for example, Braeutigam and Daughety (1983), S can be computed as

(11′) $S_V = (1-\delta lnC_V/\delta lnK)/(\delta lnC_V/\delta lny)$.

In this formula the derivatives ought in principle to be evaluated at K^* [cf Friedlaender and Spady (1981)]. In his analysis of American hospitals Vita (1990) does not have access to the price of the fixed input and hence cannot compute K^*; he therefore evaluates the derivatives at the actual value of K, an approach suggested by Caves et al. (1981). This, like the approach of Cowing and Holtmann, hinges on the assumption that the dependent variable in the cost equation is indeed C_V. If, as suggested above, the reported costs include some element of fixed costs, one's inferences concerning economies of scale will be unreliable. An alternative would be to estimate a short-run total cost equation, which is additive in fixed and variable costs, and then compute S_V using eq (11′) and differentiating that part of the cost function that captures variable costs, or compute S using eq (11) and bearing in mind that K* depends on y [cf eq (13)].

Thus far we have assumed that hospitals produce just one product. Yet as the discussion above of economies of scope makes clear, such an assumption is unwarranted. This raises the issue of what determines the cost-minimizing number of hospitals in a multi-product context. The appropriate cost concept in such a situation is ray average costs (RAC). Along the ray R in fig 5 the output mix is unchanged. The RAC at each point on this ray is equal to the slope of the chord drawn from the origin to the total cost surface above the ray. In the case illustrated, RAC reaches its minimum at y_m on the ray R. Evidently for each such ray there exists a different RAC curve and hence, assuming each is U-shaped as in fig 5, a different output combination at which the RAC reaches its minimum.

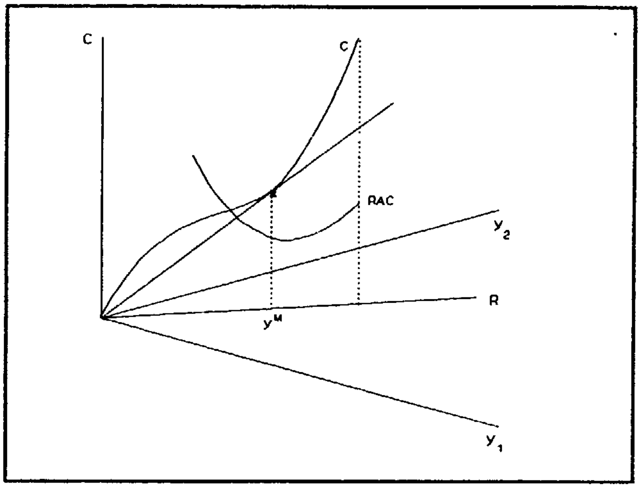

Figure 5

The locus of such output combinations is shown in fig 6 and is termed the M locus [Baumol et al. (1982)]. Let y^l be the current output vector on ray R and let $t \cdot y^l$ be the output level at which the RAC for ray R reaches its minimum point. Given the logic of the single-product case, one might expect the cost-minimizing number of producers in the multi-product case to be equal to 1/t if this an integer, or to the integer just below or just above 1/t. Thus if RAC reaches its minimum at one tenth of industry output, one might reasonably expect the cost-minimizing number of producers to be equal to 10. As Baumol et al. (op cit) show, however, this is not necessarily the case. The lower and upper bounds that can be derived for the cost-minimizing number of producers are, it turns out, relatively wide. Moreover, their calculation requires information on the location of y_m for output mixes other than the current mix.

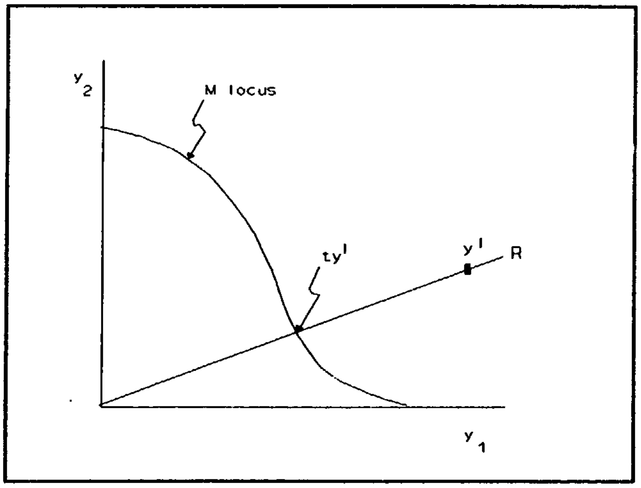

Figure 6

In these calculations the shape of the RAC surface is crucial, though the relationship between this and the optimal number of producers is far from straightforward. Empirically the output mixes at which the RACs reach a minimum can be investigated using the multi-product analogue of economies of scale, ray economies of scale, defined as

(14) $S_N = C \,/\, \Sigma_i(\delta C/\delta y_i)\cdot y_i = 1/\Sigma_i\epsilon_i$,

where ϵ_i is the elasticity of cost with respect to output i. Ray economies (diseconomies) are said to exist if S_N is greater (less) than unity. Since S_N can be shown to be equal to the reciprocal of one plus the elasticity of RAC(t·y) with respect to t, it follows that ray economies (diseconomies) of scale imply that RAC is decreasing (increasing) [cf Baumol et al. (1982)]. As in the single product case, the formula for economies of scale needs to be modified if a variable cost equation or a short-run total cost equation has been estimated. In the case of the former the appropriate formula for S_N is

(14′) $S_N = (1-\delta \ln C_V/\delta \ln K))/\Sigma_i\epsilon_i$,

which ought to be evaluated at K^*, while in the case of the latter one can proceed using either of the approaches suggested above for the single product case.

The extent of any ray economies of scale can be shown to depend in part on economies of scope and in part on product-specific economies of scale. The latter indicate what happens to cost when one alters the level of production of one product, holding the other output levels constant. The incremental cost of product 1 in the two-product case is defined as

(15) $IC_1 = [C(y_1,y_2)-C(0,y_2)]$,

which indicates the addition to the producer's costs resulting from the current level of output of product 1. The average incremental cost of producing y_1 is then defined as

(16) $AIC_1 = IC_1/y_1$

and indicates the extra cost associated with producing product 1 averaged over the amount of y_1 produced. Product-specific economies of scale in the production of product 1 are then measured as

(17) $S_1 = AIC_1/MC_1$,

where, as before, an index value that is greater (less) than one indicates economies (diseconomies) of scale. It can be shown [cf eg Baumol et al. (op cit)] that

(18) $S_N = [wS_1 + (1-w)S_2] \,/\, (1-S_C)$,

where $w=y_1MC_1/[y_1MC_1+y_2MC_2]$. Thus if economies of scope are sufficiently strong, ray economies can exist even if there are no product-specific economies. Indeed, sufficiently strong economies of scope might generate ray economies of scale even in the presence of product-specific diseconomies. Conversely, sufficiently strong diseconomies of scope might result in ray diseconomies of scale even if product-specific economies of scale exist. Evidently, since product-specific economies of scale, like ray economies of scale, are a long-run concept, AIC and MC ought to be evaluated using a long-run cost function.

3. Hospital costs in Kenya

Anderson (1980) reports the results of a cost function estimated on data for 51 provincial and district public hospitals in Kenya in 1975/76. His estimating equation takes the form

$$(19) \quad \ln(C/I) = \alpha_0 + \alpha_1 \ln B + \alpha_2 \ln R + \alpha_3 \ln S + \alpha_4 \ln(OUTP/I) + \alpha_5 \ln SAT + \alpha_6 PROV + v,$$

where C is total cost, B is the stock of beds, R is the occupancy rate, I is inpatient days, S is mean length of stay, OUTP is outpatient visits, SAT is the number of associated sub-hospital facilities, PROV is a dummy taking a value of one if the hospital is a provincial hospital and zero if it is a district hospital and v is an error term. If we substitute $R=I/(365 \cdot B)$ and $S=I/A$, where A is admissions, eq (19) can be rearranged as a total cost function of the form

$$(19') \quad \ln C = \alpha_0^* + (\alpha_1-\alpha_3)\ln B + (1+\alpha_2+\alpha_3-\alpha_4)\ln I - \alpha_3 \ln A + \alpha_4 \ln OUTP + \alpha_5 \ln SAT + \alpha_6 PROV + v.$$

The equation estimated (eq 19) implies an elasticity of cost with respect to inpatient days of one minus the elasticity of cost with respect to outpatient visits if occupancy rate and length of stay are not allowed to change. The total cost form allows R and S to change, but the interrelationship of the coefficients in the total cost form remains, of course, entirely the artifact of the equation estimated. Note too that this Cobb-Douglas-type cost function implies that if either output is zero, cost is automatically zero, which is consist t with the equation being interpreted as a variable cost equation. Anderson's estimates of the parameters of eq (19) are shown in table 1.

Table 1: Parameter Estimates of Anderson's Equation

Variable	Parameter	Value
Constant	α_0	6.57
lnB	α_1	-0.20
lnR	α_2	-0.44
lnS	α_3	-0.07
ln(OUTP/I)	α_4	0.29
lnSAT	α_5	0.19
PROV	α_6	0.28
Adjusted R^2	0.75	

Note: Dependent variable is ln(C/I). Parameters taken from column labelled R-4 of Anderson's table 1.

3.1 Are Kenyan hospitals over-capitalized?

The negative coefficient on beds in Anderson's study, coupled with the lack of fixed costs in the equation, suggests that the estimated equation can indeed be interpreted as a variable cost equation. Hence the Cowing-Holtmann test for over-capitalization would be applicable. Notwithstanding Anderson's claims to the contrary, the negative coefficient does not of itself imply under-capitalization. Only if $\delta C_V/\delta K$ is less than $-w_K$ can one conclude that "cost savings could be obtained by expanding existing facilities" [Anderson (op cit, p233)]. Since Anderson does not report an estimate of w_K, or the mean values of C_V and K, one cannot establish from his paper whether Kenyan hospitals are indeed under-capitalized.

3.2 Inefficiency in Kenyan hospitals

Although Anderson does not explicitly address the issue of efficiency, it might be argued that he does so implicitly by including several variables that are not required by economic theory. One problem with this line of argument is, of course, that it is difficult in the context of the hospital sector to determine whether a variable is an 'additional' variable, or whether it is included in attempt to capture better inter-hospital variations in output. Another problem is that, as emphasized above, no account is taken in this non-frontier approach of the fact that inefficiency is cost-increasing.

In the Kenyan study four variables are potentially 'additional' variables: the occupancy rate, length of stay, the number of associated hospital sub-facilities, and the province/district dummy. Inclusion of occupancy rate cannot be rationalized in terms of its being a proxy for output. The implication of the results in table 1 are that hospitals with low occupancy rates are inefficient. It is also hard to justify viewing length of stay as an output proxy, given that inpatient days are used as the output measure for inpatient care and these already reflect length of stay. The relevant coefficient is not, however, significant. Whether variations in the number of associated hospital sub-facilities reflects output variations is unclear. The province/district dummy probably does reflect - at least in part - differences in output, since it is likely that provincial hospitals end up treating more complicated cases. This may explain at least partly the positive and significant coefficient on the province/district dummy.

3.3 Economies of scope in Kenyan hospitals

The Cobb-Douglas functional form adopted by Anderson implies that costs fall to zero whenever the production level of either output falls to zero. As Baumol et al. (1982:449) note, this implies that industry costs can (ostensibly) be driven to zero by dividing outputs among specialized producers. The Cobb-Douglas specification automatically gives rise to cost anti-complementarities if the cost elasticities are positive (as they are in the present case) and hence (in the absence of fixed costs) results in diseconomies of scope. The Cobb-Douglas cost function is thus insufficiently flexible to test for economies of scope in a multiproduct environment.

3.4 Too many hospitals in Kenya?

Ignoring for the moment the long-run nature of economies of scale, in the case of eq (19') we have

$$S_I = 1 + \alpha_2 + \alpha_3 - \alpha_4 = 0.2$$

and

$$S_{OUTP} = \alpha_4 = 0.3$$

so that both outputs have product-specific diseconomies of scale. Given the result in eq (18) above, we would expect ray economies of scale to exist if these product-specific economies are sufficiently strong to offset the assumed diseconomies of scope. In fact

$$S_N = 1 \;/\; (1 + \alpha_2 + \alpha_3) = 2.0.$$

This does not takes into account that the estimated equation is not a long-run equation, but rather a variable cost function. Because of this it is more appropriate to compute S_N using eq (14') rather than eq (14). Ideally $\delta lnC_V/\delta lnK$ would be evaluated at K^*, but since there is insufficient information in Anderson's paper to calculate K^*, we evaluate S_N at the actual value of K. This gives

$$S_N = (1-\alpha_1 + \alpha_2)/(\alpha_4 + (1 + \alpha_2 + \alpha_3 - \alpha_4) = 1.55,$$

implying mild ray economies of scale.[16] The implication is that the ray average cost curve is downward sloping and that product-specific economies of scale are also larger than the short-run estimates above suggest. However, as indicated above, the fact that ray economies exist in a multiproduct setting does not necessarily mean that there ought to be fewer hospitals. Moreover, given the restrictions in the estimated equation, the fact that S_N points towards ray economies of scale ought to be treated with some caution.

4. Hospital costs in Peru

Dor (1987) reports the results of a cost function estimated on data for 19 urban public hospitals in Peru in 1984. His equation bears a close resemblance to the equations estimated by Feldstein (1967) and takes the form

$$(20)\quad C/A = \alpha_0 + \alpha_1 F + \alpha_2 F^2 + \alpha_3 OUTP + \alpha_4 \%DEL + \alpha_5 \%SURG + \alpha_6 MIN + v,$$

---

16. Anderson also concluded that hospitals in his sample exhibited economies of scale. However, his conclusions were based on the value of the coefficient on the stock of beds, which, as we argued above, bears on the issue of over-capitalization rather than economies of scale.

where A is the number of admissions, %DEL is the proportion of admissions taken up by deliveries, %SURG is the proportion of cases receiving surgery and MIN is a dummy taking value of one if the hospital is under the control of the ministry. Eq (20) implies a total cost function of the form

$$(20') \quad C = \alpha_0 A + \alpha_1 A \cdot F + \alpha_2 A \cdot F^2 + \alpha_3 A \cdot OUTP + \alpha_4 DEL + \alpha_5 SURG + \alpha_6 A \cdot MIN + v^*,$$

where DEL is the number of deliveries, SURG is the number of inpatients admitted for surgery and $v^*=A \cdot v$. It is evident that if admissions are zero, total cost is zero, irrespective of whether any outpatients are being seen or not. This, coupled with the fact that the stock of beds does not appear as a regressor in the estimating equation, suggests that eq (20') is probably best interpreted as a long-run total cost function. Dor's parameter estimates are shown in table 2.

Table 2: Parameter Estimates of Dor's Equation

Variable	Parameter	Value
Constant	α_0	12076.94
F	α_1	-6168.90
F^2	α_2	961.16
OUTP	α_3	0.003
%DELIV	α_4	802.30
%SURG	α_5	-562.45
MIN	α_6	-1635.38
Adjusted R^2	0.98	

Note: Dependent variable is cost per admission. Weighted Least Squares estimates taken from column (2.9) of Dor's table 2.

4.1 Are Peruvian hospitals over-capitalized?

Since Dor's estimating equation is a long-run equation, it is assumed implicitly that the stock of capital is at its long-run optimal value. No test for over-capitalization is therefore possible.

4.2 Inefficiency in Peruvian hospitals

Like Anderson, Dor does not analyze efficiency explicitly but might be said to do so implicitly by including various 'non-traditional' variables in his cost function. Clearly one would not include among these the outpatient variable and the two casemix variables, which reflect output. This leaves three variables that might be argued to be 'additional': the affiliation dummy, caseflow and its square. Whether the affiliation dummy (which takes a value of one if the hospital is operated by the Ministry of Health and zero if operated by the social security system) might capture output variations is unclear. If it does not, the results in table 2 suggest that hospitals operated by the Ministry of Health are more efficient. Turning to the effects of caseflow, it is evident that the partial relationship between average cost and caseflow is U-shaped, reaching a minimum at 3.2 cases per bed per month, which is above the sample average of 2.8. The inference drawn by Dor is that most hospitals have unnecessarily high costs because their caseflows are too low. Much the same conclusion was reached by Feldstein (1967), who found that the 'inefficient' hospitals with the below-average caseflows tended to be the larger hospitals and tended to have low caseflows because of above-average lengths of stay. Several writers have, however, questioned Feldstein's conclusion: it may well be that larger hospitals may have an above-average mean length of stay and hence a below-average caseflow because they treat the more severe cases [cf Barlow (1968), Fuchs (1969), Lave and Lave (1970)]. The same note of caution would seem appropriate in the context of Dor's study, if low caseflows are due to long lengths of stay rather than to low occupancy rates.

4.3 Economies of scope in Peruvian hospitals

Dor has, in effect, four outputs in his equation: deliveries, surgical procedures, other inpatient care, and outpatient visits. Denoting by OTH non-surgery and non-delivery admissions, eq (20') becomes

$$(21)\quad C = (\alpha_0+\alpha_4)DEL + \alpha_1 F\cdot DEL + \alpha_2 F^2\cdot DEL + \alpha_3 DEL\cdot OUTP + \alpha_6 DEL\cdot MIN$$

$$+ (\alpha_0+\alpha_5)SURG + \alpha_1 F\cdot SURG + \alpha_2 F^2\cdot SURG + \alpha_3 SURG\cdot OUTP + \alpha_6 SURG\cdot MIN +$$

$$+ \alpha_0 OTH + \alpha_1 F\cdot OTH + \alpha_2 F^2\cdot OTH + \alpha_3 OTH\cdot OUTP + \alpha_6 OTH\cdot MIN + v^*,$$

Overall economies of scope can then be calculated as

$$S_C = [C(DEL,0,0,0)+C(0,SURG,0,0)+C(0,0,OTH,0)+C(0,0,0,OUTP)$$

$$-C(DEL,SURG,OTH,OUTP)]/C(DEL,SURG,OTH,OUTP),$$

which, in this case, turns out to be equal to

$$S_C = -\alpha_3(DEL+SURG+OTH)\cdot OUTP \;/\; C(DEL,SURG,OTH,OUTP).$$

Since the estimate of α_3 is positive, $S_C<0$ and there are therefore diseconomies of scope. From the point of view of economies of scope, however, Dor's specification is highly restrictive. Given that A and OUTP are both positive, the sign of S_C depends entirely on the sign of α_3. But since A is positive, α_3 is also the sole determinant of the sign of the marginal cost of an outpatient visit (ie $\alpha_3 A$). Given that a negative marginal cost is implausible, Dor's specification in effect constrains S_C to being negative. As in Anderson's study, therefore, the issue of economies of scope is prejudged by the model specification.

4.4 Too many hospitals in Peru?

Since eq (21) is to be interpreted as a long-run equation, economies of scale can be inferred directly from it. It is apparent from eq (21) that the average incremental cost and marginal cost of each output are by construction equal to one another. Hence the value of the product-specific economies-of-scale index S_i is by construction equal to one for all outputs. Thus Dor's specification prejudges the issue of product-specific economies of scale, as well as the issue of economies of scope. Given the relationship between these two concepts and the concept of ray economies of scale, it is clear that Dor's specification must also prejudge the latter issue. Substituting the marginal costs of the four outputs into eq (14) yields

$$S_N = C / [C + \alpha_3(DEL+SURG+OTH)\cdot OUTP],$$

which is less than unity, given $\alpha_3>0$. The implication is that there are ray diseconomies of scale in the Peruvian sample. This result is, of course, prejudged by the model specification. Only in the implausible case where the marginal cost of an outpatient visit is negative can S_N be larger than one. Since the weights in the multiproduct analogue of eq (18) sum to one, the relationship between ray economies of scale and economies of scope in this case is

$$S_N = 1 / (1-S_C),$$

which, given the expression for S_C derived above, confirms the earlier expression for S_N. Thus, because product-specific economies are ruled out by assumption, it is the diseconomies of scope that give rise to the ray diseconomies of scale. But since the specification is compatible only with diseconomies of scope, this finding is uninteresting.

5. Hospital costs in Ethiopia

Bitran and Dunlop (1989) report estimates of a cost function estimated from an unbalanced panel of 38 observations on 15 public hospitals in Ethiopia in the mid-1980s. Their estimating equation is similar to that of Granneman et al. (1986), except that the stock of beds is included and there are no cubic terms. Their equation is of the form

$$(22)\quad \ln C = \alpha_0 + \alpha_1 B + \beta_1 I + \beta_2 I^2 + \beta_3 OUTP + \beta_4 OUTP^2 + \beta_5 I\cdot OUTP + \beta_6 DELIV + \beta_7 SURG + \beta_8 LAB + v,$$

where LAB is the number of lab tests and the other variables are as defined above. The parameter estimates of eq (22) are shown in table 3.

5.1 Are Ethiopian hospitals over-capitalized?

The positive estimate of α_1 suggests that the equation estimated by Bitran and Dunlop is not a variable cost equation but rather a short-run total cost function. The Cowing-Holtmann test for over-capitalization would therefore seem to be inappropriate and points towards the use of the alternative Feldstein-type test proposed above. The fact that $\delta C_S/\delta K>0$ in this study implies that hospitals in the sample are too large, given their current output levels. One ought, however, to be wary about taking this conclusion at face value. The estimating equation does not satisfy the restrictions required of a short-run total cost function: it is not additive in fixed costs and variable costs, and variable costs are not a decreasing function of the stock of capital.

Table 3: Parameter Estimates of Bitran and Dunlop's Equation

Variable	Parameter	Value
Constant	α_0	5.45
B	α_1	4.71E-3
I	β_1	2.18E-5
I^2	β_2	-1.65E-12
OUTP	β_3	1.91E-6
$OUTP^2$	β_4	1.42E-10
I•OUTP	β_5	-7.50E-10
DELIV	β_6	1.68E-4
SURG	β_7	3.21E-6
LAB	β_8	7.63E-6
Adjusted R^2	0.96	

Note: Dependent variable is lnC.

5.2 Inefficiency in Ethiopian hospitals

Bitran and Dunlop do not analyze efficiency explicitly. Nor do they include any 'non-traditional' variables in their cost function which might be said to capture inefficiency implicitly.

5.3 Economies of scope in Ethiopian hospitals

Bitran and Dunlop have, in effect, five different outputs in their cost function: inpatient days, outpatient visits, deliveries, surgical procedures and lab tests. In calculating the economies of scope associated with eq (22) it is important to be clear about which fixed costs would be incurred and which would avoided in each scenario. An extreme and clearly implausible assumption would be that all outputs would, if produced alone, require the same level of beds as at present. In this case projected stand-alone production costs are those indicated in column 1 of table 4. The projected costs incurred by the average hospital at present are 1006231 Birr [Bitran and Dunlop (op cit, table A.3)]. The overall degree of economies of scope are therefore

$$S_C = [3155873-1006231]/1006231 = 2.136,$$

which implies economies of scope. If, instead, one assumes that producing outpatient visits and lab tests alone would not necessitate any beds, the stand-alone production costs are those indicated in column 2 of table 4 and the implied degree of economies of scope is equal to

$$S_C = [2527777-1006231]/1006231 = 1.512,$$

which, unsurprisingly, is smaller than in the previous case. But even this probably overstates the true degree of economies of scope, the reason being that the production of each of the inpatient outputs alone is unlikely to require the full amount of beds currently being used. This highlights a weakness of the specification used by Bitran and Dunlop, namely that unlike the flexible fixed cost functional form proposed by Baumol et al. (op cit), it does not allow for the possibility that each production 'line' has its own quasi-fixed costs that are avoided if the production of that output ceases.

5.4 Too many hospitals in Ethiopia?

Suppose we ignore for the moment the long-run nature of economies of scale and calculate ray economies of scale using eq (14). The cost elasticity of output i is equal to $(\delta \ln C/\delta y_i)y_i$. If these are evaluated at the means given in appendix 1 of Bitran and Dunlop, the cost elasticities obtained are those indicated in table 4. The large and negative cost elasticity of outpatient visits suggests a serious model misspecification and therefore the results below ought to be treated with caution. The elasticities imply that

$$S_N = 1 / 0.296 = 3.38,$$

and hence imply substantial ray economies of scale. This is despite the fact that none of the outputs with positive marginal costs are characterized by product-specific economies of scale [cf table 4]. The implication is that the ray economies of scale exist despite these product-specific diseconomies and are to be attributed to the economies of scope noted earlier.

The ray economies uncovered above ignore the fact that the equation estimated is not a long-run equation. Nor apparently is it a variable cost function. One cannot therefore treat the derivative of the cost function with respect to beds as reflecting $\delta \ln C_V/\delta \ln K$ and use eq (14), as was done above in the discussion of Anderson's results. Moreover, since the estimated equation is not additive in fixed and variable costs, one cannot recover $\delta \ln C_V/\delta \ln K$ from the estimated equation. Nor, given the lack of additivity, would it make sense to try to solve for K^*, even if information on the shadow price of beds were reported in the study, which it is not. The upshot of this is the results in table 3 cannot be used to infer the true extent of ray economies of scale.

6. Health care costs in Nigeria

Wouters (1990) reports the results of a cost function estimated on 24 Nigerian health care institutions, of which eight are health centers, seven are maternity units and nine are dispensaries. Her estimating equation is of the form

$$(23) \quad \ln C = \alpha_0 + \alpha_1 \ln A + \alpha_2 \ln OUTP + \alpha_3 \ln(\%DRUGS) + \alpha_4 \ln w_{HW} + \alpha_5 \ln w_{NHW} + \alpha_6 D_{BEDS} + \alpha_7 D_{BEDS} \cdot \ln B + \alpha_8 \ln AI + v,$$

where C is total cost, %DRUGS is the percentage of drugs available, w_{HW} and w_{NHW} are the wages of health workers and non-health workers respectively, D_{BEDS} is a dummy taking a value of one if the facility has beds and AI is an index of allocative inefficiency calculated from

Table 4: Economics of scope and scale-Bitran-Dunlop study

Output	Cost of each output alone		MC	Cost Elasticity	AIC	S	y	y•MC
	With All Beds	Only IP beds						
Inpatient days	883532	883532	2.582	0.073	2.534	0.981	28410	73361
Outpatient visits	548476	268063	-12.226	-0.310	-19.542	n.a.	25520	-311995
Deliveries	564877	231544	169.047	0.171	155.407	0.919	1016	171752
Surgical procedures	478934	478934	3.230	0.006	3.221	0.997	1758	5678
Lab tests	680054	332371	7.678	0.356	6.459	0.841	46691	358472
Sum	3155873	2527777		0.295				297268
Projected cost of avg. beds	1006231							
Economies of scope (all beds)	2.136							
Econs. of scope (only IP beds)	1.512							
Ray econs of scale (SR)	3.385							
Elasticity of cost wrt beds	0.716							
Ray economies of scale (LR)	0.962							

estimates of a production function (see section 2.2 above).[17] Like Anderson's equation, this Cobb-Douglas type equation implies that cost is zero if either output is zero.

6.1 Are Nigerian health care institutions over-capitalized?

The positive estimates of α_6 and α_7 suggests that Wouters' equation, notwithstanding her claims to the contrary, is best interpreted as a short-run total cost function rather than as a variable cost equation. As in the Ethiopia study, these positive coefficients imply over-capitalization. But once again one ought to be wary about taking this conclusion at face value, since the estimating equation does not satisfy the restrictions required of a short-run total cost function.

6.2 Inefficiency in Nigerian health care institutions

Of the four studies included in this survey, Wouters' is the only one which analyses efficiency explicitly. She explores both technical and allocative inefficiency. Her method differs slightly from that outlined in section 2.2 above. Rather than estimating a SFM, she first divides her sample into efficient and inefficient facilities on the basis of the number of visits per health worker per year and then estimates a conventional Cobb-Douglas production function on the 'efficient' subsample. The shortcomings of this approach are obvious: it is arbitrary and fails to provide any evidence on variation in technical inefficiency <u>within</u> each group. Nonetheless, it does have an advantage over the frontier production function approach in that whereas the frontier approach models technical efficiency simply as a shift factor, Wouters' approach allows the <u>shape</u> of the production function to differ between 'efficient' and 'inefficient' facilities. Moreover, it is interesting to note that almost all of the private facilities in Wouters' sample fall below the relatively generous cutoff point for inclusion in the 'efficient' subsample.

Table 5: Parameter Estimates of Wouters's Equation

Variable	Parameter	Value
Constant	α_0	1.63
lnA	α_1	0.01
lnOUTP	α_2	0.60
ln(%DRUGS)	α_3	-1.36
$\ln w_{HW}$	α_4	0.59
$\ln w_{NHW}$	α_5	0.39
D_{BEDS}	α_6	0.22
$D_{BEDS} \bullet \ln B$	α_7	0.09
lnAI	α_8	-0.16
Adjusted R^2	0.91	

Note: Dependent variable is lnC.

[17]. Because of zero values admissions and beds are, in fact, not entered in logarithms but are instead transformed using the Box-Cox metric (L=0.10). The interpretation of the coefficients is much the same as for variables expressed in logarithms.

Wouters' analysis of allocative inefficiency is more conventional. From her estimates of the Cobb-Douglas production function estimated on the 'efficient' subsample, she finds that the ratio of the marginal product of non-health workers to that of health workers is less than the relevant wage ratio, implying that non-health workers are, on average, over-employed relative to health workers. Allocative inefficiency is then measured by AI in eq (7). Interestingly, the index is smaller in value in the private sector than in the public sector, suggesting that at least among the technically efficient facilities, allocative inefficiency is lower in the private sector.[18] Finally, Wouters includes the log of her inefficiency index in her cost function as a regressor. Surprisingly, its coefficient is negative (though not significant), implying literally that allocative inefficiency reduces costs.

6.3 Economies of scope in Nigerian health care institutions

Like Anderson's estimating equation, eq (23) implies that costs fall to zero whenever the production level of either output falls to zero. The specification therefore automatically implies diseconomies of scope and an S_C value of -1.

6.4 Too many health care institutions in Nigeria?

Ignoring for the moment the long-run nature of economies of scale, eq (14) gives a value of S_N equal to

$$S_N = 1 / \alpha_1+\alpha_2 = 1.645,$$

which implies ray economies exist. This is despite the fact that, as noted above, Wouters' cost function automatically results in diseconomies of scope. The implication is that these diseconomies of scope are offset by sufficiently strong product-specific economies of scale. This is indeed the case. From Wouters' estimating equation and table 5 we obtain

$$S_I = 1 / \alpha_I = 90.909$$

and

$$S_{OUTP} = 1 / \alpha_2 = 1.675,$$

so that both outputs enjoy product-specific economies of scale. The marginal costs of admissions and outpatient visits are $\alpha_1(C/A)$ and $\alpha_2(C/OUTP)$ respectively, and therefore the weights in eq (18) are $\alpha_1/(\alpha_1+\alpha_2)$ and $\alpha_2/(\alpha_1+\alpha_2)$ respectively. Eq (18) thus becomes

$$S_N = [0.018\cdot 90.91 + 0.982\cdot 1.645] / 2 = 1.630,$$

18. The sample size is, however, very small, the number of private facilities being only 3.

which is close to the value of S_N obtained above and confirms that the product-specific economies of scale more than offset the (assumed) diseconomies of scope.

These estimated ray economies ignore, however, the fact that the equation estimated is not a long-run equation but rather a short-run total cost equation. As in the case of Bitran-Dunlop study above, this means that one cannot obtain a true measure of ray economies of scale from the results reported in Wouters' paper.

7. Conclusions

It is evident from the above, and not surprising perhaps, that none of the studies of hospital costs in developing countries would appear to provide reliable evidence on all of the issues of interest to policy-makers.

Although the issue of over-capitalization is clearly important in its own right, it also has implications for the investigation of other issues. Thus even if one's interest lies with, say, economies of scale, the issue of over-capitalization cannot be ignored, since if hospitals are not in a long-run equilibrium, the estimated parameters will not provide reliable evidence on economies of scale. Estimating a short-run cost function, irrespective of whether or not one is interested in over-capitalization, which is the practice advocated by Cowing, Holtmann and Powers (1983), seems eminently sensible. It is therefore unfortunate that Dor, in his study of hospital costs in Peru, elected to estimate a long-run cost function. With regard to testing for over-capitalization, we have argued that since in practice it is difficult to separate fixed costs from variable costs, the test proposed by Cowing and Holtmann (1983) is unlikely in general to be appropriate, since it relies on the estimated equation being a variable cost function. Of the three short-run cost functions included in this survey, only in Anderson's was the sign of $\delta C/\delta K$ consistent with the equation being interpreted as a variable cost equation. But although the Cowing-Holtmann test seems valid in this case, the negative value of $\delta C/\delta K$ and the absence of information on the shadow price of capital make testing for over-capitalization impossible. In the case of the other two studies, where the positive value of $\delta C/\delta K$ suggests that the equation estimated is a short-run total cost equation, we argued that a more appropriate test would be to test whether $\delta C/\delta K=0$. In both studies $\delta C/\delta K$ was positive, which interpreted literally implies over-capitalization. We argued, however, that this conclusion ought not to be taken at face value, since the estimated equations are not, as theory requires, additive in fixed and variable costs.

Of the studies included in this survey, only Wouters' analyses the issue of efficiency explicitly. Although her method for investigating technical inefficiency is somewhat ad hoc and falls short of the frontier production function approach, her approach to allocative inefficiency is fairly conventional. She finds evidence in her sample of under-employment of health workers relative to non-health workers, and that the degree of allocative inefficiency is greater in the private sector. Her finding that allocative inefficiency reduces costs must, however, cast some doubt on these findings. Since two of the other studies include 'non-traditional' variables in their cost function, it might be argued that they too address the issue of inefficiency, albeit implicitly. The results of these studies suggest, for example, that low occupancy rates are a sign of inefficiency, and that hospitals operated by the Peruvian Ministry of Health are more efficient than those operated by the Peruvian Social Security. It is apparent from the above that the large and growing econometric literature on efficiency measurement has remained virtually untapped by the authors of hospital cost functions in developing countries, as indeed is true of researchers in industrialized countries. Much more research could usefully be done on this topic.

Of the four studies covered in the present survey only one employs a specification that is sufficiently general not to prejudge the issue of economies of scope. Both Anderson and Wouters employ a multiproduct Cobb-Douglas production, which, as Baumol et al. (1982) note, implicitly assumes cost anti-complementarities and hence assumes diseconomies of scope unless there are sufficiently strong offsetting fixed costs. Dor's specification is less rigid but is consistent with economies of scope only in the implausible case where the marginal cost of an outpatient visit is negative. Only in the Bitran-Dunlop study is the model specification sufficiently general not to prejudge the issue of economies of scope. In the event the authors' results imply overall economies of scope. The extent of these economies is reduced, but are still positive, if it is assumed, not unreasonably, that beds are required only in the provision of inpatient services. However, although the Bitran-Dunlop specification is much less restrictive than the specifications adopted in the other studies, it still has the disadvantage that it does not take into account that each output may have its own quasi-fixed costs. Both of the aforementioned estimates of the economies of scope index assume that if a hospital were to provide no outpatient services and only one line of inpatient services (eg deliveries), it would still require all the beds it currently uses, even if the number of cases treated in the retained line were no greater than the current number. This is clearly unrealistic. A more sensible functional form is the flexible fixed cost function proposed by Baumol et al. (1982), in which the quasi-fixed costs of each product line are distinguished from one another.[19]

Turning finally to economies of scale, we have seen that of the three studies that prejudge the issue of economies of scope, two also prejudge the issue of economies of scale. In Anderson's specification the cost elasticities sum to unity by construction. Thus if one calculates S_N using eq (14), the specification guarantees a value of S_N

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[19]. A disadvantage of this functional form is that the separate quasi-fixed costs are identifiable only in samples where not all producers produce all outputs.

of one. If instead the equation is treated as a variable cost function (which is consistent with the value of $\delta C/\delta K$), the value of S_N depends solely on the value of $\delta lnC/\delta lnK$. Dor's specification also prejudges the issue of ray economies of scale by implicitly assuming that the product-specific economies-of-scale index S_i is equal to one for all outputs. Given this, the link between ray economies of scale, economies of scope and product-specific economies of scale, and that the specification in effect rules out economies of scope, it follows that the specification forces ray diseconomies of scale. Neither of the remaining two studies prejudge the issue of ray economies of scale. Bitran and Dunlop find slight product-specific diseconomies of scale (although the negative marginal cost of one output suggests a model misspecification) but find ray economies of scale. The implication is that these stem from the economies of scope noted above. Wouters also finds ray economies of scale but in contrast to Bitran and Dunlop finds product-specific economies. The economies-of-scale estimates of both studies ought, however, to be treated with some caution, since these results are calculated from equations which are probably best interpreted as short-run total cost equations, albeit equations that do not meet the theoretical requirement of being additive in fixed and variable costs. At best the results indicate the effects of moving along short-run cost curves.

We feel that it would be unwise to try to draw firm policy conclusions from the four studies included in this survey. In several studies the issues being investigated are in effect prejudged by the model specifications. Where this is not the case, the model specifications are often inconsistent with economic theory. Some authors claim, for example, to estimate a variable cost equation and yet the parameter estimates are inconsistent with this interpretation. Nor are the specifications consistent with being interpreted as short-run total cost functions, since the equations are not additive in fixed and variable costs.

We believe, however, that certain firm conclusions <u>can</u> be drawn about the methodology of hospital cost function estimation. These conclusions would appear to be relevant to the estimation of hospital costs functions in industrialized countries. First, since hospitals may well not be employing their long-run equilibrium quantities of capital, it seems sensible to follow the line taken by Cowing et al. (1983) and estimate a short-run cost function. If capital is not wholly exogenous, the obvious answer is to employ simultaneous equation techniques. One cannot, we believe, convincingly argue, as Granneman et al. (1986) seek to, that the possible endogeneity of capital justifies the estimation of a long-run equation. Second, given the difficulty of purging fixed costs from variable costs, it may be best to estimate a short-run total cost equation, rather than a variable cost equation. This ought to be additive in fixed and variable costs, as required by economic theory, and variable costs ought to be a decreasing function of the stock of capital.[20] One can then test for over-capitalization by testing to see whether $\delta C_S/\delta K$ is positive. Third, since hospitals may well be technically and allocatively inefficient, and since cost frontier models are relatively straightforward to estimate, it seems desirable that greater use should be made of these models in future work in this area. Disentangling technical and allocative inefficiency via a frontier production function analysis also seems desirable. Fourth, as the studies in this survey indicate it is all too easy to specify a cost function in a way that prejudges the issues that are of interest to policy-makers. Equations must be specified sufficiently flexibly to allow the data rather than the model specification to indicate the extent of any economies of scope, product-specific economies of scale, and hence ray economies of scale. Ideally these specifications would allow one to determine the extent of any quasi-fixed costs associated with each product line. Finally, since economies of scale are a long-run phenomenon, this needs to be borne in mind when calculating their extent. If a short-run cost function is estimated, this will necessitate the calculation of the optimal capital stock, which will in turn require data or estimates of the shadow price of capital.

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[20]. Barer's (1982) specification meets the first of these requirements but not the second.

References

Aigner, D.F. and S.F. Chu, 1968, On estimating the industry production function, American Economic Review 58, 226-239.

Aigner, D.J., C.A.K. Lovell and P. Schmidt, 1977, Formulation and estimation of stochastic production function models, Journal of Econometrics 6, 21-37.

Anderson, D.L., 1980, A statistical cost function study of public general hospitals in Kenya, Journal of Developing Areas 14, 223-235.

Barer, M., 1982, Casemix adjustment in hospital cost analysis: Information theory revisited, Journal of Health Economics 1, 53-80.

Barlow, R., 1968, Review of Economic analysis for health service efficiency, Economic Journal 78, 921-923.

Barrow, M. and A. Wagstaff, 1989, Efficiency measurement in the public sector: An appraisal, Fiscal Studies 10, 72-97.

Baumol, W.J. and R.D. Willig, 1981, Fixed costs, sunk costs, entry barriers, and sustainability of monopoly, Quarterly Journal of Economics 95, 405-431.

Baumol, W.J., J.C. Panzar and R.D. Willig, 1982, Contestable markets and the theory of industry structure (Harcourt Brace Jovanovich, NY).

Bitran-Dicowsky, R. and D.W. Dunlop, forthcoming, The determinants of hospital costs: An analysis of Ethiopia, in: A. Mills and K. Lee, eds., Health Economics Research in Developing Countries, (Oxford University Press, Oxford).

Braeutigam, R. and A. Daughety, 1983, On the estimation of returns to scale using variable cost functions, Economics Letters 11, 25-31.

Breyer, F., 1987, The specification of a hospital cost function: A comment on the recent literature, Journal of Health Economics 6, 147-158.

Caves, D., L. Christiansen and J. Swanson, 1981, Productivity growth, scale economies, and capacity utilization in U.S. railroads, 1955-1974, American Economic Review 71, 994-1002.

Cowing, T.G. and A.G. Holtmann, 1983, Multiproduct short-run hospital cost functions: Empirical evidence and policy implications from cross-section data, Southern Economic Journal 49, 637-653.

Cowing, T.G., A.G. Holtmann and S. Powers, 1983, Hospital cost analysis: A survey and evaluation of recent studies, in: R.M. Scheffler and L.F. Rossiter, eds., Advances in health economics and health services research Vol. 4 (JAI Press, Greenwich, CT).

Davis, K., 1968, Review of Economic analysis for health service efficiency, American Economic Review 58, 1488-1490.

Dor, A., 1987, Estimates of cost functions for the Peruvian hospital sector: Some policy implications, Unpublished report, The Urban Institute.

Evans, R.G. and M.D. Walker, 1972, Information theory and the analysis of hospital cost structure, Canadian Journal of Economics 4, 198-215.

Feldstein, M.S., 1967, Economic analysis for health service efficiency: Econometric studies of the British National Health Service (North-Holland, Amsterdam).

Forsund, F.R., C.A.K. Lovell and P. Schmidt, 1980, A survey of frontier production functions and their relationship to efficiency measurement, Journal of Econometrics 13, 5-25.

Friedlaender, A. and R. Spady, 1981, Freight transport regulation: Equity, efficiency, and competition in the rail and trucking industries (MIT Press, Cambridge, MA).

Fuchs, V.R., 1969, Review of Economic analysis for health service efficiency, Health Services Research 3, 242-250.

Goldman, F. and M. Grossman, 1983, The production and cost of ambulatory care in community health centers, in: R.M. Scheffler and L.F. Rossiter, eds., Advances in health economics and health services research Vol. 4 (JAI Press, Greenwich, CT).

Grannemann T.W., R.S. Brown and M.V. Pauly, 1986, Estimating hospital costs: A multiple-output analysis, Journal of Health Economics 5, 107-127.

Greene, W.H., 1980, Maximum likelihood estimation of econometric frontier functions, Journal of Econometrics 13, 27-56.

Greene, W.H., 1982, Maximum likelihood estimation of stochastic frontier production models, Journal of Econometrics 18, 285-289.

Grosskopf, S. and V. Valdmanis, 1987, Measuring hospital performance: A non-parametric approach, Journal of Health Economics 6, 89-108.

Jondrow, J, C.A.K. Lovell, I. Materov and P. Schmidt, 1982, On the estimation of technical inefficiency in the stochastic frontier production function model, Journal of Econometrics 19, 233-238.

Lave, J.R. and L.B. Lave, 1970, Economic analysis for health service efficiency: A review article, Applied Economics 1, 293-305.

Mann, J.K. and D.E. Yett, 1968, The analysis of hospital costs: A review article, Journal of Business 41, 191-202.

Schmidt, P., 1986, Frontier production functions, Econometric Reviews 4, 289-328.

Schmidt, P. and C.A.N. Lovell, 1979, Estimating technical and allocative efficiency relative to stochastic production and cost frontiers, Journal of Econometrics 9, 343-366.

Schmidt, P. and R. Sickles, 1984, production frontiers and panel data, Journal of Business and Economic Statistics 2, 367-374.

Vita, M.G., 1990, Exploring hospital production relationships with flexible functional forms, Journal of Health Economics 9, 1-22.

Wagstaff, A., 1989a, Econometric studies in health economics: A survey of the British literature, Journal of Health Economics 8, 1-51.

Wagstaff, A., 1989b, The measurement of hospital efficiency: A comment, Social Science and Medicine 28, 13-15.

Wagstaff, A., 1989c, Estimating efficiency in the hospital sector: A comparison of three statistical cost frontier models, Applied Economics 21, 659-672.

Wouters, A., forthcoming, The cost and efficiency of public and private health facilities in Ogun State, Nigeria, Health Economics.

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