HOSPITAL COST AND EFFICIENCY IN
A REGIME OF STRINGENT REGULATION

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INTRODUCTION

Hospital costs have resumed their upward trend at an unacceptably high rate after having slowed somewhat following the introduction during the mid-1980s of the Medicare Prospective Payment System, which sets payments to hospitals in advance based on the estimated complexity of each medical condition. Funded in part by rising hospital costs, the cost of the federal government's two main health insurance programs, Medicare for the elderly and Medicaid for the poor, has been rising at well above the general inflation rate. Efforts to balance the federal budget have focused on restraining the growth in health care costs. And a principal component of the effort to restrain costs is restricting reimbursement to hospitals and other health care providers. To a considerable degree, how such restrictions will impact the delivery of health care depends upon the efficiency of the nation's hospitals. Ironically, greater inefficiency means a greater potential to reduce costs without negatively impacting access or quality. Changes in incentive structures, institutional and managerial arrangements, and staffing procedures, for example, are possible ways of adjusting to cuts in funding. However, if hospitals are providing care in a least-cost manner, budget cutting will inevitably lead to a reduction in services.

This paper employs the increasingly popular stochastic frontier regression to estimate the extent of economic inefficiency of 219 general care hospitals in New York during 1991. New York is an interesting benchmark case because it has one of the oldest and most comprehensive system of hospital and healthcare regulation that includes fixing prices and limiting expansion to control costs [Rood, 1995]. It is one of a handful of states that comprehensively regulate hospital reimbursement rates, and an analysis of the impact of its policies may help predict the consequences of federal efforts to control costs by restricting reimbursement to hospitals.3

The regulatory environment in New York is illustrated by the fact that until recently hospitals were required to report how many vacant beds they had three times a day to the Health Department — even though they were all operating well below capacity. Installation of a new telephone system requires regulatory approval, too.
Hospital costs per state resident are the second highest in the nation, about 20 percent above the national average, and from 1982 to 1990 they grew faster than the national average (Rodat, 1985, 7). Between 1980-90, hospital expenses per adjusted admission grew only slightly less in New York than the national average rate: 152 percent vs. 160 percent [Agency for Health Care Policy Research, 1995]. Of course, high levels of expenditure on health care may simply reflect a large volume of output and is not necessarily indicative of inefficiency. But if comprehensive regulation also turns out to have been unsuccessful in promoting efficient and economical operation, policymakers may have to consider other options, such as market competition, in order to try and reduce the claim of health care upon the nation's resources.

We estimate that New York hospitals operate at about 15 percent above the least cost, a figure very similar to that estimated by Zuckerman, Hadley and Teziani (1984) for a national sample of 1,600 hospitals. Our result is important because it helps to establish a professional consensus regarding the degree of hospital inefficiency. Santerre and Bennett (1992) also find evidence of hospital inefficiency, although they do not quantify its magnitude. Using a sample of 276 Texas hospitals to fit a variable cost function, they find overuse of capital and doctors.

THE HOSPITAL SECTOR IN NEW YORK

A consensus exists among policymakers in New York that market forces could not control health care costs because of pervasive private and public insurance. Policy has therefore been aimed at directly controlling costs via rate regulation and limits on hospital expansion. New York pioneered Certificate of Need (CON) regulation requiring prior approval by state authorities for major capital expenditures and capacity expansion. The intent was to control costs by avoiding wasteful duplication and excess capacity. Since 1983 the state has set prospective reimbursement rates for most services offered by hospitals. Since 1983 it has used a Diagnostic Related Group (DRG) system of rate setting (discussed below) for the under-age-65 population, alongside the federal Medicare DRG system for the elderly.

STOCHASTIC FRONTIER ESTIMATION

Empirical estimation of inefficiency is fairly recent. The methodology employed here was first introduced into the literature by Aigner, Lovell and Schmidt (1977). Their idea was that inefficiency could be captured by the error term of a regression model if that error term was composed of two parts, the usual error term e that captures random statistical noise and a systematic component u that measures inefficiency. Management might be efficient yet firms could be observed above or below their cost frontiers for stochastic and uncontrollable reasons such as weather, strikes, ill-health, natural disasters, and pure good or bad luck. That type of inefficiency is measured by the term u, with a zero mean, which also captures measurement error in the dependent variable. On the other hand, systematic and persistent inefficiency might be the result of weak management, incompetence, or rent-seeking behavior. This sort of inefficiency would not have a zero mean because random favorable events would not just offset unfavorable ones. Thus the composed error e + u would be normally distributed with zero mean only if firms were efficient on average. A skewed composed error, consisting of a zero mean of e plus a non-zero mean of u is taken to indicate the presence of economic inefficiency.

Hospitals pursue several objectives: survival and growth, perceived quality leading to community and peer group prestige, as well as narrow economic objectives like profit maximization or rent seeking by managers, doctors, and hospital employees. In addition, the practice of medicine is strongly influenced by peer review and custom — partly as a defense against malpractice litigation. These hospital characteristics are not conducive to cost-minimizing behavior, especially where the regulatory environment is geared to hospital survival and price competition is negligible. Indeed, hospital managers may find that manipulating reimbursement codes in order to extract more revenues for given levels of care is a more attractive option than the often contentious process of improving efficiency. Failure to minimize costs means either that too many inputs are employed relative to output (technical inefficiency) or inputs are used in the wrong proportions (allocative inefficiency). Underutilization of diagnostic equipment is an example of technical inefficiency, and using too many registered nurses compared to licensed practical nurses illustrates allocative inefficiency. The estimate of inefficiency used here contains both types but does not separate them. Traditionally, economists have assumed that units of control such as the business firm are efficient because profit maximization requires cost minimization. The appeal of the stochastic frontier model is that it allows us to test the validity of that assumption in a rigorous fashion. The model may be specified in general form as follows:

\[ C = CY(y, w, Z) + e + u \]

where C is total cost, Y is a vector of outputs, w a vector of input prices and Z a vector of environmental variables, such as for-profit versus not-for-profit status. Conceptually, CY(·) represents the cost-minimizing frontier, and the u error term captures inefficient departures therefrom. The price to be paid for using the stochastic frontier model is that one must specify a functional form for CY(·) and a distribution for the u inefficiency variable. A cost function, rather than a production function, is the preferred way to model the problem at hand because it implies one dependent variable, total cost, and one equation. All the right-hand side variables are basically exogenous: output is supplied "on demand" and non-storable, and its price is regulated. Likewise, input prices are determined by collective bargaining or market forces, making them statistically independent, too.

The translog model was the starting point for our search for an appropriate form of the cost function. It fits the data rather poorly. The model does not converge after 50 iterations and only 3 of 24 coefficients are statistically significant. In contrast, the old-fashioned Cobb-Douglas cost function, which is nested within the translog provides an excellent fit and is quite robust to alternate specifications of Y, w and Z.
TABLE 1
DATA USED TO ESTIMATE FRONTIER COST FUNCTION
(N = 219)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$97,51 mill.</td>
<td>$115,65 mill.</td>
</tr>
<tr>
<td>Patient Days</td>
<td>4775</td>
<td>7712</td>
</tr>
<tr>
<td>Case-mix Index</td>
<td>1.09</td>
<td>0.284</td>
</tr>
<tr>
<td>Technology Index</td>
<td>3.05</td>
<td>2.65</td>
</tr>
<tr>
<td>Occupancy Rate</td>
<td>0.70</td>
<td>0.144</td>
</tr>
<tr>
<td>Emergency Room Visits</td>
<td>2253</td>
<td>2839</td>
</tr>
<tr>
<td>Outpatient Clinic Visits</td>
<td>5807</td>
<td>7397</td>
</tr>
<tr>
<td>Teaching Hospitals</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Wages Registered Nurses</td>
<td>$11,479 yr</td>
<td>$6,330</td>
</tr>
<tr>
<td>Wages Radiologists</td>
<td>$30,239 yr</td>
<td>$5,525</td>
</tr>
</tbody>
</table>

In the literature the three most frequently assumed distributions of u are the half-normal truncated at zero (i.e., a mode of zero), the half-normal truncated at a non-zero point and the exponential distribution. Each represents an alternative assumed pattern in the size distribution of inefficient firms [Stevenson, 1980]. As pointed out by two of the originators of the frontier model, "It seems to us that the only real solution is to try various alternative distributions for u, and see which fits best" [Schmiedl and Lovell, 1979, 349]. The exponential distribution yields a lower estimate of mean u of 0.167 vs. 0.303 for the half-normal truncated at zero. Since the half-normal and exponential models are nonnested there is no obvious specification test to guide the selection between them. However, the variance of the composed error is less for the exponential model than for the half-normal (0.048 vs. 0.064), suggesting the former better fits the data. Both distribution functions are characterized by the mass of the density function concentrated near zero inefficiency. All results presented below are therefore based on the exponential model. 8

THE DATA

Table 1 presents the descriptive statistics of the data used in the estimation of the stochastic frontier cost function. All data was collected by the New York State Department of Health (1991). The universe of non-federal, general surgical-medical hospitals is 554. 35 hospitals were eliminated leaving 219 observations. Output is measured along six dimensions, three of which measure the volume of medical treatment and three of which gauge the scope and complexity of care. The volume of activity is measured by patient days, emergency room visits, and outpatient clinic visits. This is in accord with Ashby and Altman who maintain that, "The most comprehensive definition of hospital output is a completed admission" [1992, 80]. They use this measure and adjust for the complexity of patients treated to measure hospital productivity. (Note that our output variable *patient days = admissions x length of stay.*)
TABLE 2
FRONTIER ESTIMATION OF TOTAL HOSPITAL COSTS

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.877</td>
</tr>
<tr>
<td>Log Patient Days</td>
<td>0.914</td>
</tr>
<tr>
<td>Log Outpatient Clinic Visits</td>
<td>0.111</td>
</tr>
<tr>
<td>Log Emergency Room Visits</td>
<td>0.088</td>
</tr>
<tr>
<td>Log Case-mix Index</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Occupancy Rate</td>
<td>-0.469</td>
</tr>
<tr>
<td>Teaching Hospital</td>
<td>0.230</td>
</tr>
<tr>
<td>Technology Index</td>
<td>0.020</td>
</tr>
<tr>
<td>Log Wages Registered Nurses</td>
<td>0.101</td>
</tr>
<tr>
<td>Log Wages Radiologists</td>
<td>0.319</td>
</tr>
<tr>
<td>G (inefficiency parameter)</td>
<td>5.64*</td>
</tr>
</tbody>
</table>

* Significant at 95 percent; N = 319; log likelihood = 52.31; σ²/σ = 0.026; σ² = 0.026. Mean value of G = 0.167; mean inefficiency = 0.371 (i.e., 18 percent).

lower estimate overlaps their basic case, suggesting that the difference is more illusory than real and that the additional variables are largely redundant. With regard to input prices, we use the wages of registered nurses and of radiologists. These are selected from five different wages available for all hospitals in our data set. The two included wage variables were selected with the aid of Factor Analysis because of the high correlation between the different wages. The two included wages account for 85 percent of the total variance of the five wage variables. A cost of capital proxy, property expenses per square foot of building space, was tried. It was always highly insignificant and its omission caused no discernible effect on estimated parameters or inefficiency.

Differences in cost and efficiency owing to differences in type of hospital ownership is of great interest to economists and policymakers. 85 percent of the 219 hospitals analyzed are private not-for-profit organizations, another 10 percent are operated by local governments, and 5 percent are for-profit operations. The frontier was estimated with and without dummy variables for ownership. There was no significant difference in the estimated inefficiency and the ownership coefficients were not significant and were dropped.

ECONOMETRIC RESULTS

Economic theory indicates that positive coefficients are to be expected on the output variables and the input prices: higher levels of output increase costs while holding input prices fixed, and increased input prices raise costs given specified levels of output. Table 2 displays the estimated stochastic frontier cost function. In the exponential model, the mean of the inefficiency residual u is equal to 1/0, where G is the parameter of the distribution function (see note 5) [Greene, 1992, 622]. From Table 2, 1.0 = 0.167 + u. This is derived from the composed error since the mean of u is zero by assumption. This translates into 15 percent inefficiency because of the log-log specification of the model. This is very close to the 0.188 estimated by Zuckerman, et al. for their basic cost function case [1994, Table 4]. It seems reasonable to conclude that New York hospitals are neither more nor less efficient than other hospitals in the United States.

The coefficient estimates in Table 2 are all in accord with a priori reasoning. For example, the elasticity of total cost with respect to patient days is 0.014, which does not bracket unity at the 95 percent confidence level. Economies of scale thus appear to exist along this dimension, which is consistent with Vitaliano's estimate [1987] of a (non-frontier) cost function for New York hospitals using just beds to measure output. However, the sum of the three output volume coefficients—patient days, emergency room visits and outpatient clinic visits—is 1.11 indicating overall decreasing returns to scale. Total costs increase 1.1 percent as a result of a 1 percent increase in each of the three outputs.

The occupancy rate is in log form, so the -0.449 coefficient is an elasticity and indicates that costs could be lowered significantly if hospital occupancy were to rise. This is consistent with the estimates of Gaynor and Anderson [1995, 310]. At present, all Certificate-of-Need approved capital projects have their costs included in the rate structure, thereby providing little incentive to reduce excess capacity. Inefficient overuse of capital may be a long-run equilibrium: time may not correct the situation without some change in the regulatory framework. The situation would appear to correspond to a hospital operating at a point on its short-run average cost curve to the left of the point of tangency with the long-run average cost curve. The tangency point would be the optimal occupancy rate for the existing hospital plant. Thus the same output could be produced at lower cost with a smaller facility operated more intensively.

Scale economies and occupancy rates deal with the shape of the long-run cost function and each hospital's location along it, and are distinct from efficiency, which involves the position of the cost function in the cost-output space. Evaluated at the means of the variables, the marginal cost of a patient day is $1,014, $296 for an emergency room visit, and $78 for an outpatient clinic visit. The slightly higher marginal cost for an outpatient visit seems consistent with the shift from inpatient to outpatient care noted above.

A more complex case mix, a teaching hospital, and more advanced medical technologies are all expected to raise costs; thus the positive coefficients on each of these variables is reasonable. Other things equal, a teaching hospital has over 25 percent higher costs. And each of the 14 advanced technologies raises costs by 2 percent (or $2 million per year at the mean of total costs). The positive intercept is consistent with the relevant theory since it incorporates the various parameters of the underlying production function as well as any input prices that do not vary [Vitaliano, 1987, 508].

In addition to the overall mean level of hospital inefficiency, we are interested in hospital-specific estimates so that we can identify patterns and discover policy implications.
BRIEFLY, the frontier model determines individual inefficiency by first adding mean inefficiency to the fitted cost for each hospital, that amount is then subtracted from actual costs to produce an estimated \( e + u \) component error, which is then decomposed based on the shape of the distribution of the inefficiency residual. The resulting estimates of inefficiency are used in the next part of the paper.

ANALYSIS OF HOSPITAL INEFFICIENCY

The degree of economic efficiency of a hospital is the outcome of a complex interplay of various, often conflicting, goals and the effectiveness with which they are realized. This is in contrast to the textbook, perfectly competitive firm that single-mindedly seeks to maximize profit and failing that is forced out of business. Among New York hospitals, for-profit ownership is rare and discouraged, Certificate-of-Need regulation limits entry, and rate-setting acts as a price-fixing arrangement since most insurers are forbidden from negotiating prices with hospitals. And in common with other states, geographic monopolies exist and consumer ignorance is widespread. In many ways the entire situation is reminiscent of classic regulatory capture, hospitals and their unions have a cost-pass-through mechanism with little resistance on the other side because of almost universal third-party payment. Consumer-patients bear directly a small fraction of the cost of health care, the regulating state government bears only 25 percent of Medicaid costs, and employers attempt to shift higher premiums for health care onto workers via reduced or more slowly growing monetary compensation. Medicare is paid by the federal government. All of this is politically viable because policymakers and the media apparently do not recognize or care about rent-seeking behavior unrelated to profit. Legislators are keen to preserve local hospitals, which exist in almost every county, even if that means additional taxpayer or insurer costs to keep uneconomic units operating. Only recently has the state government begun to try to control health-care costs via regulatory reform and by proposing that hospital rates be negotiated rather than set by regulation. The industry has responded with outcries and lawsuits. [Times Union, 28 October 1995]

An interesting special situation exists in the Rochester, New York area, where medical costs are reported to be 20 percent lower than in the rest of the nation. [Times Union, 1 March 1996]. For many years major employers in the Rochester area, led by the Kodak Company, have used monopoly power to hold down costs. Seven of the eight hospitals in the Rochester area are included in our analysis. Their mean is 0.135 and is less than 0.10 excluding one observation. Indeed, two large tertiary care facilities that offer the most advanced research and treatment are among the most efficient in our entire sample. The regional buyers' cooperatives that were the centerpiece of President Clinton's unsuccessful 1993 health care reform plan were modeled after the Rochester plan.

Variables measuring ownership and market structure could help to explain inefficiency, subject to the proviso that we are able to measure only within-state variation. Hospital ownership type and unionization are obvious candidate variables. The number of hospitals by county is one measure of competition. In addition, hospitals usually argue that Medicare payments are relatively stingy as compared to the cost of treatment, and some observers feel that the industry in New York has greater influence over non-Medicare reimbursement. Thus the incentive to act efficiently may be affected by a hospital's sources of revenues. Efficiency is also a function of management's skill in running a hospital, and the size of a facility may influence the situation if larger hospitals are able to attract better trained or more experienced managers. Apart from managerial competences, inefficiency also relates to medical skills in producing favorable treatment outcomes. One measure of inept medical management is the extent of malpractice liabilities paid by a hospital. In keeping with the preceding discussion, a least-squares regression was estimated, with estimated inefficiency for each hospital as the dependent variable. Exploratory variables include a union dummy, two size of hospital dummies, ownership dummies, sources of reimbursement and the amount of malpractice payments. Summary statistics are presented in Table 3 and the preferred results in Table 4. Alternate specifications of the model that include market competition variables were tested, but they gave substantially the same results. Most of the hospitals (189) were unionized and, as shown in Table 4, the presence of a union increases inefficiency about 5 percentage points. Although the union coefficient is significant at only the 90 percent confidence level, this is a considerable effect when set against the mean value of \( a \) of 0.167. The results in Table 4 indicate that hospital efficiency increases with size. The value of \( u \) for small (under 120 beds) hospitals is 0.125 higher (i.e. more inefficient) than the default group (between 120 and 300 beds), which in turn is less efficient than the group of large hospitals (over 300 beds) whose \( u \) is 0.07 less than the default group. Since the frontier controls for the occupancy rate, it is unlikely that fuller utilization of fixed capacity is the cause of greater efficiency. Economies of scale is a
TABLE 4
ANALYSIS OF INEFFECTIVENESS RESIDUALS OF HOSPITALS
(dependent variable $u$, estimated in frontier)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.200</td>
</tr>
<tr>
<td>Union</td>
<td>0.045</td>
</tr>
<tr>
<td>Over 300 beds</td>
<td>-0.070</td>
</tr>
<tr>
<td>Under 120 beds</td>
<td>0.126</td>
</tr>
<tr>
<td>Medicare Professionals</td>
<td>0.7372-88</td>
</tr>
<tr>
<td>Medicaid Percent</td>
<td>-0.157</td>
</tr>
<tr>
<td>Medicare Percent</td>
<td>-0.374</td>
</tr>
<tr>
<td>Blue Cross Percent</td>
<td>0.080</td>
</tr>
<tr>
<td>Government Hospital</td>
<td>0.027</td>
</tr>
<tr>
<td>For-Profit Hospital</td>
<td>-0.006</td>
</tr>
</tbody>
</table>

a. Significant at 95 percent; b = significant at 90 percent.
N = 219. R² = .14

possible reason, but Cowing and Holtmann (1983) finds little evidence of it in New York. To the extent that we do not completely measure output, it is the more complex output of larger hospitals that is more likely to be mis-measured as inefficiency, which makes the results presented here more persuasive. Thus the possibility of better management at larger hospitals cannot be ruled out.

An interesting result is the effect of payer type upon the estimated level of inefficiency. All states follow the Medicare prospective reimbursement system outlined above. What distinguishes New York is its regulation of rates paid by other payer types. The percent of discharges in the three main categories are included regressors: Medicare (51 percent), Medicaid (16.5 percent), and Blue Cross (15 percent). The remainder of discharges are paid by health maintenance organizations, workers’ compensation, commercial insurance, charity care, etc.

The coefficient on the Medicare Percent variable in Table 4 is significantly negative and large: each percentage-point increase in the proportion of patients covered by Medicare is associated with a 0.37 percentage-point reduction in inefficiency. Bryson, Johnson and Jones (1992) also find that hospitals that rely more heavily on Medicare are more efficient, as measured by the ratio of administrative staff to admissions. Since Medicare patients are usually more seriously ill, the negative coefficient is unlikely due to mismeasurement of output. In New York, the average length of stay for Medicare patients is approximately six days, which is about one-half the stay for non-Medicare patients (Bédat, 1995, 8). This difference could account for the effect of Medicare on estimated inefficiency. The Medicaid coefficient in Table 4 is also negative, but it is not statistically significant; nor is the Blue Cross variable’s coefficient.

The dollar amount of malpractice claims paid in 1991 has a statistically significant effect in raising inefficiency, although it amounts to only a one percentage point increase when evaluated at the mean for the 129 units who paid any malpractice claims. Ownership type is not associated with efficiency differences. This is consistent with the results of Vitaliano and Toren (1994), who use frontier analysis to estimate efficiency of nursing homes in New York State and find no significant difference in efficiency across types of ownership. As far as hospitals are concerned, Zuckerman, Hadley and Lessen (1984, 373) find no difference nationally in efficiency between private nonprofit and government hospitals, while for-profit units are somewhat more efficient. It may be more difficult to assess the impact of ownership accurately in New York because of the small number of for-profit and government hospitals.

Although only a fraction of estimated inefficiency is “explained” in Table 4, hospital size, Medicare, and unionization all appear to play significant roles. Union negotiated staffing and work rules seem to cause inefficient use of labor. But policymakers face formidable resistance in trying to change such practices. More promising perhaps is the potential for economies from hospital consolidation. Not only would that save money by eliminating excess capacity, but it is likely to yield efficiencies from better management.

QUALITY OF CARE

We believe that the results presented here are not contaminated by omitting explicit measures of hospital quality. As part of other research, one of the authors constructed dummy variables indicating whether or not a hospital provides above or below average quality of care in 12 medical specialties, such as coronary disease, cancer, etc. Quality is measured using peer reputation, outcomes, and resources in each specialty. When these indicator variables were added to the explanatory variables in Table 4 all were statistically insignificant and an $F$ test for inclusion could not reject the null hypothesis that all the betas were zero. These variables were used alone (as a group) they were again insignificant.

CONCLUSION

The natural and man-made barriers to least-cost operation of hospitals are formidable. New York’s hospital costs are among the highest in the nation and they are just as inefficient. An average level of cost inefficiency of 18 percent is estimated for 219 hospitals during 1991. This raises questions about the effectiveness of the existing state regulatory system in controlling costs.

Those facilities with larger Medicare populations are more efficient. Hospitals are found to be more efficient in the Rochester area, where employers who provide health insurance have exercised monopoly power. Thus, efforts to control federal health care costs by more stringent reimbursement restrictions on suppliers may prove useful. Hospitals with over 300 beds are found to be measurably more efficient. Excess bed capacity adds significantly to the level of hospital costs, and unionization appears to account for a considerable degree of inefficiency, apart from any direct effect in raising wages.
The finding that federal Medicare and local Rochester area restraints do enhance efficiency at the same time that hospitals overall in New York state are just as inefficient as elsewhere in the nation is consistent with regulatory capture. New York specific rate and capacity regulation does not appear to restrain output nor does it affect the efficiency with which it is produced.

NOTES

A preliminary version of this paper was presented at the meetings of the Eastern Economic Association in New York City, March 17, 1999. The views expressed in this paper are the sole responsibility of the authors and do not represent the official position of the organizations with which they are affiliated.

1. The Journal of Health Economics [Oct/Nov 1994] featured a Symposium on frontier estimation in health care, for example. At one point in the 1950s, editors were reported to have stopped accepting frontier-related papers because as many had already been received. Other applications include Diller and Kendrick (1954), who analyzed local and maintenance and Ferrier and Leidy (1960) who studied commercial banks’ efficiency.

2. Eight states have adopted mandatory regulation of hospital expenses since 1970: Connecticut, Maryland, New Jersey, New York, Massachusetts, Wisconsin, and Rhode Island (Agency for Health Care Policy and Research, 1999). All but New York and Maryland have recently abandoned rate setting for non-Medicare candidates.

3. One of the authors recently received a brochure for a piece of computer software whose stated purpose is to maximize reimbursement revenue. It points out that even small changes in reimbursement can result in thousands of dollars of extra revenue to the hospital for exactly the same course of medical treatment.

4. Zucker et al. (1996) employ a tunneling. But only a few coefficients estimated are statistically significant. For example, the simple Cobb-Douglas could have been used instead.

5. The tunneling form of the total cost function in log form is \( \ln y = \alpha + \beta x + \beta_0 \ln x + \beta_1 \ln y + \beta_2 \ln y^2 + \beta_3 \ln y^3 + \beta_4 \ln y^4 + \beta_5 \ln y^5 + \beta_6 \ln y^6 \). This suggests that the test statistic is the null hypothesis that the slope is 1.

6. The tunneling is a problem because the test statistic is \( F \approx \frac{R^2}{n - v - 1} \), where \( R^2 \) is the sum of the squared residuals of the restricted and unrestricted estimates, as the number of restrictions, \( b \) the number of parameters in the unrestricted expression, and \( n \) the sample size. With a sample size of 1600 (3) there would be a problem to reject the “basic” model or “basic” cost function, regardless of how trivial the additional explanatory power of their unrestricted model. This problem is reflected in the fact that two-thirds of their parameters are insignificant. Indeed, the authors concede in their concluding section that more detailed output measure are unnecessary (Zuckerman, Hsley, and Leoni, 1994, 274).

7. Factor analysis was performed on wage (annual earnings) of registered nurses, licensed practical nurses, aides, pharmacists and radiologists, using maximum likelihood methods. Two principal components were identified with wages of registered nurses, aides and LPNs having about the same factor loadings (correlations) of over 0.90, indicating any one of these is a suitable candidate to represent the first component. We have selected registered nurses. The highest loading in the second principal component is radiologists. Wage rates may be highly correlated because 68 percent of the hospitals are unionized. Zuckerman, Hsley and Leoni also used two input prices, average annual salaries for all labor and interest and depreciation per bed.

8. Cost and input prices are not normalized by dividing through by one of the input prices because our list of input prices is not exhaustive.

9. A separate frontier for the dominant not for-profit sector was also estimated. The mean value of the dependent variable 0 was 5.86 (standard error 0.05), which is not significantly different from the pooled estimate of Table 2. There are too few observations to estimate separate frontiers for government or for-profit hospitals.

10. The sample of actual to least cost for the logarithmic specification may be written as \( S(x) = e^{\alpha + \beta x} \) (since \( e = 0 \) then \( S = 0 \). Thus if \( u = 0.167, v = 0.178 \) the median of the distribution is that of the hospital with the highest estimate of the bias of their paper except to remark that the two estimates were almost perfectly correlated.

11. Examination of individual hospital inefficiency estimates reveals three clear outliers, with estimated u’s of 0.04, 0.90 and 1.00. The latter is a 75 bed rural hospital affiliated with another hospital, suggesting possible misclassification of costs. The other two are highly specialized facilities whose output may not be adequately measured by our variables, although some of them are recorded as having an occupancy rate of only 20 percent which could account for its high level of inefficiency. Mean u is 0.164 if these outliers are deleted.

12. A referee questioned why we estimated a long-run rather than a short-run cost function. Our primary reason is to make our results comparable with Zuckerman, et al. In addition, we are not confident of our ability to accurately measure capital stock or separate variable from total costs. In any event, our results with respect to occupancy rate appear to be similar to what would result with a short-run cost function: inefficient excess of capital. Hospital beds is a proxy for capital stock. Zuckerman and Bennett, 1990, and that is consistent in the occupancy rate variable.

13. Zuckerman, Hsley and Leoni do not include emergency room visits in their model and their outpatient visits variable has a statistically insignificant coefficient. In fact, their list of hospital level output measures is rather different from those employed here: percentage of beds in intensive care, percentage of outpatient visits that do not involve surgery, percentage of long-term admissions, ratio of births to deaths, measures says index, inpatient surgery per admission and an index of each hospital’s specialties available (1984, 269). The close correspondence in results suggests that alternate output vectors perform equally well (or poorly) in explaining hospital cost and efficiency.

14. The model is specified by selecting 1 from the set of the coefficients.

15. For the semi-logarithmic model the decomposition is based on the following expression (with subscript for each observation suppressed): \( \ln y = \alpha + \beta_0 \ln x + \beta_1 \ln y + \beta_2 \ln y^2 + \beta_3 \ln y^3 + \beta_4 \ln y^4 + \beta_5 \ln y^5 + \beta_6 \ln y^6 \), where \( \epsilon \) is the estimated composed error.
and \( z = \frac{x - \mu}{\sigma} \) where \( \mu \) is the probability density function of the standard normal and \( \phi \) is the cumulative density function, \( \sigma \) is the distribution parameter and \( \sigma^2 \) is the variance of \( \sigma \) (Greene, 1992, 666).

17. Expansion of hospital capacity is subject to a "used" review that hinges primarily upon the existing number of beds locally represent a population based estimate of demand. Thus if excess beds exist, either or expansion will typically be blocked even if the new supplier might have lower costs.

18. The Breusch-Pagan test indicated the presence of heteroskedasticity but White's corrected test changed the significance of only one coefficient: malpractice expenses become significant, which suggests that the problem is not serious. The correction does not change parameter coefficients, however. Table 4 presents the corrected results.

19. We use the number of hospitals in each county and projected excess bed capacity (as estimated by the Health Department) by county as the two measures of the vigor of competition. The first yielded a small positive coefficient significant at the .80 percent level, which suggests non-price competition to attract patients. Santoro and Bennett (1986, 216) find that greater numbers of hospitals in a county raises costs for private nonprofit hospitals, which dominate our data set, which they suggest is due to a "medical arms race."

The excess bed capacity variable's coefficient was not statistically significant, perhaps because the frontier already controls for occupancy rate. Only the union and malpractice variables were affected by inclusion of these market structure indicators: the union coefficient increased to .070 and its \( p \)-value was 2.93 when excess beds was included, and malpractice payments were not significant when number of hospitals was added to the regression.

20. The 319 hospitals were sorted by efficiency level and divided into quintiles. The mean bed size of the most efficient group (whose \( z \) ranges from .038 to .264) is 414 and the mean bed size of the least efficient group (whose \( z \) ranges from .380 to 1.207) is 510. This illustrates the danger of drawing conclusions about relationships based on two-way comparisons as compared to multiple regression techniques.

The usual definition of scope economies is that an increase in one output reduces the marginal cost of another output.

22. Only 85,000 Medicaid clients were enrolled in health maintenance organizations statewide during 1991 versus 485,000 in 1990. This dramatic shift towards managed care could alter our conclusions. Blue Cross is the dominant insurer in the Rochester market, so the lack of a statewide effect supports the notion of something spatial there. Zuckerman, Holley and Leshem (1994) include Medicare discharges in their frontier and it has a negative coefficient, but they do not discuss it.

Zuckerman, et al. find that inclusion of quality of care variables has no effect on estimated inefficiency (1994, Table 4).

REFERENCES


