A New Approach to Evaluate and Measure Hospital Efficiency

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SSM Working Paper #1427-83
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Abstract

A new technique for identifying inefficient hospitals, Data Envelopment Analysis (DEA), is field tested by application to a group of teaching hospitals. DEA is found to provide meaningful insights into the location and nature of hospital inefficiencies as judged by the opinion of a panel of hospital experts. The insights about hospital efficiency provided by DEA are not generated from the widely used efficiency evaluation techniques of ratio analysis and econometric-regression analysis. DEA is, therefore, suggested as a means to help identify and measure hospital inefficiency as a basis for directing management efforts toward increasing efficiency and reducing health care costs.
1. Introduction

One approach that a hospital administrator or regulator can pursue to reduce health care costs is to reduce inefficiencies in hospital operations. Only after hospital inefficiencies are identified and measured can remedial action be taken to improve efficiency and thereby reduce hospital operating costs. This paper field tests a new approach to identify and measure hospital inefficiencies, Data Envelopment Analysis (DEA), which provides insights that are not available from currently used techniques and which can form the basis for managerial action to improve hospital operating efficiency.

The following section describes the need for applying such efficiency evaluation techniques to hospitals. Section 3 describes the weaknesses in currently used techniques for measuring hospital efficiency and the ways in which DEA circumvents these weaknesses. Section 4 describes the application of DEA to a set of teaching hospitals and the evaluation of the results by a panel of hospital experts and by management of one of the hospitals identified as inefficient. The final section 5 discusses the strengths and limitations of DEA and the ways it can be useful in future hospital application.

2. Efficiency Measurement Techniques are needed to help reduce health care costs

Rising health care costs are of widespread concern to government, individuals, and insurers. In the past, hospitals generally were reimbursed for services based on the cost of providing those services. This type of retrospective reimbursement does not provide strong incentives to reduce hospital costs, i.e., it allows hospitals to recover their costs regardless of
their level of efficiency. Recently, reimbursement systems have been attempting to reduce the rate of increase in hospital costs through prospective rate setting and reimbursement for hospital services [4] [15]. Prospective systems basically require a hospital to agree on a reimbursement rate structure for services to be rendered in the future based on budgets prepared by a hospital and accepted by the regulator and/or payor. While several studies (e.g., [4] and [15]) suggest that prospective reimbursement systems lead to lower rates of cost increases, they do not create the type of direct price competition which is expected to induce efficient behavior (in the microeconomic theory sense). Hospitals do compete on many dimensions for financing, donations, patients, and affiliations with medical schools and physicians, but success along these dimensions of competition would not necessarily result in efficient hospital operations. While the new prospective reimbursement mechanisms provide incentives to prevent a hospital from becoming less efficient, they do not assure that hospitals will become efficient partly because strategies to maximize reimbursement may not lead to improvement of efficiency and partly because prospective reimbursement systems are largely based on current cost levels which are not necessarily efficient cost levels. That is, prospective systems may only motivate a hospital to limit the rate of cost increases from an already inefficient cost level. Hence other more direct approaches to improve hospital efficiency are needed as one means of reducing health care costs.

Can hospitals reduce operating costs by improving operating efficiency? The answer to this question is, at worst, unclear and, at best, yes. The efficient amount of resources required to produce hospital services is not well understood or specifiable in any detail ([2], [15] and [9]). If the efficient amount of resources needed to produce each type of patient care were known, the efficient cost of providing hospital services could be directly
determined. Numerous studies (e.g., [9]) have attempted to identify the efficient hospital production relationships using econometric-regression techniques. These studies share a common methodological weakness in that they are based on estimating average input-output relationships based on data which includes both efficient and inefficient hospitals. They may provide good predictions of what costs will be assuming a constant level of inefficiency but they say nothing about efficient relationships ([14]).

Other studies suggest that many hospitals are operating with varying degrees of inefficiency which could be reduced by managerial action if the proper incentives existed. The U.S. General Accounting Office (GAO) study of U.S. hospitals [15] indicated that a large percent of these hospitals lack a number of good management practices which represented key ways of improving hospital operating efficiency. The GAO study suggests that many hospitals operate with distinct inefficiencies and that identifying and reducing these inefficiencies would be desirable because of the cost savings that would result. This result is quite believable. The absence incentives to maximize efficiency gives a hospital manager considerable latitude to emphasize concern for effectiveness of care to the detriment of efficiency.

A methodology that would locate inefficient hospitals, indicate the magnitude of the inefficiency and the general location of that inefficiency could be used to help hospital managers analyze and implement programs to improve efficiency. In addition, it might be possible to study the management techniques found in the more efficient hospitals and transfer them to the less efficient hospitals as a means of improving their efficiency. Regulators could use this information to encourage and even subsidize the less efficient hospitals to obtain appropriate consulting services to help reduce their inefficiencies. A stronger use of these insights would be to actually penalize the less efficient hospitals by reducing their reimbursement rates to
levels of more efficient hospitals or by limiting their capital expansion as a way of applying direct pressure to improve efficiency.

Data Envelopment Analysis is a technique recently developed by A. Charnes, W. W. Cooper, and E. Rhodes ([5], [6], and [7]) which compares organizations that use multiple inputs (such as labor, capital, materials) to produce multiple outputs (such as various types of patient care, teaching, research). It compares these organizations and identifies those which are relatively inefficient as well as the magnitude of these inefficiencies. This study represents the first field application and test of DEA in hospital evaluations. The motivation for use of DEA in the health sector is twofold. 1) The multiple outputs of hospital and specifically the case mix can be directly accommodated with DEA and 2) the alternative techniques are less reliable and definitive in their ability to identify hospital inefficiencies.

3. Efficiency measurement techniques for hospitals

There are two widely used approaches to evaluate hospital efficiency:

1. Ratio Analysis (i.e., "rules of thumb") - use of various ratios for a group of comparable hospitals to locate relationships which are abnormally high or low such as cost per patient day, cost per patient, personnel full-time equivalents per patient. Examples of this type of ratio data are Monitrend reports of the American Hospital Association and the Massachusetts Rate Setting Commission ratios used for cost audits [11].

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1DEA has been shown to be theoretically sound [5], [6], and [7] and has been found to be reliable in controlled applications [13] and has also been used in areas such as education and court systems efficiency evaluations.
2. Econometric regression techniques - used to estimate hospital cost relationships and production relationships. Examples of this type of study are numerous. Feldstein's study of hospitals [9] reflects many of the more traditional alternatives using econometric-regression techniques. These approaches attempt to estimate marginal cost per patient, the breakdown of fixed versus variable cost, existence of economies of scale, and the efficient rates of substitution between inputs.

Both ratio analysis and regression methodologies have distinct limitations with respect to evaluating hospital efficiency. These limitations, may be summarized as follows.

**Ratio analysis - Problems in evaluating hospital efficiency**

Ratio analysis calculates and attempts to understand relationship between two variables such as cost per day, cost per patient, etc. By their nature, each ratio is limited to one output and cannot easily accommodate multiple outputs and inputs. If a hospital treated only two types of patients and trained residents, it would have three outputs. Assume, for example, that cost per patient day is calculated as total number of patient days / total costs. This ratio would be biased by the lack of recognition that there are two different types of patients being treated and because training outputs are ignored. Hence, a higher cost per patient day could be due to the case mix, the intensity of training activity, excessive prices paid for resources used, or excessive amounts of resources used (generally referred to as operating or technical inefficiency).

The efficient cost is not known for most hospital services. Consequently, when comparing hospitals, those hospitals with cost per patient or cost per
day some distance above the mean cost might be considered potentially inefficient. There currently is no way, however, to determine objectively how far above the mean is inefficient or even if the mean is efficient. It is conceivable that all the hospitals operating at the mean cost per patient day are also inefficient. To compensate for the unidimension of a single ratio, large sets of ratios are developed as in Monitrend reports. One hospital may appear relatively efficient on one group of ratios and inefficient on another while another hospital may have the opposite result for the same ratios. There is no objective means of assigning relative weights to these ratios. Consequently, it is difficult to conclude which hospitals are inefficient using ratio analysis. Ratio analysis may be very useful in identifying what aspect of a hospital's operation is out of line with the norm, but it is of limited help in locating the inefficient hospitals among a large group of hospitals.

Econometric-Regression Analysis - Problems in evaluating hospital efficiency

Regression analyses is more comprehensive than ratios because it can accommodate multiple outputs and inputs, but other significant problems are encountered. The use of least square regression techniques result in estimates of average (or central tendency) relationships which are not necessarily efficient relationships as noted above.

A second problem is an estimate of the hospital cost function using this technique results in a mean relationship which does not directly locate inefficient hospitals. Designation of the relatively inefficient hospitals again requires that hospitals with costs some arbitrary distance from the mean be labelled as potentially inefficient. More importantly, numerous econometric-regression types of hospital studies have been used to identify economies of scale, marginal costs of patient care and rates of substitution
among outputs and inputs. These results say nothing, however, about what the efficient rates of substitution, efficient scale size, and efficient rates of transformation are because they are based on an average of the behavior of efficient and inefficient hospitals combined. Use of regression techniques would only provide insights into efficient hospital behavior if all the hospitals in the study were known to be efficient. While this problem was noted early on by Feldstein [9], econometric-regression techniques are among the most accessible and have consequently been widely used in hospital industry cost studies.

Data Envelopment Analysis

DEA addresses the limitations associated with ratio analysis and regression techniques. It is explicitly able to consider the multiple outputs and inputs of a hospital. Specifically, the multiple outputs reflected in the case mix and the multiple resources used to produce these services to gain an overall evaluation of hospital efficiency. In addition, it can incorporate other hospital outputs like teaching, research, and community education programs to gain a comprehensive efficiency measure of hospital performance.

Data Envelopment Analysis is a linear programming technique which compares a set of an organization's actual inputs used to produce their actual output levels. DEA locates those units that are the relatively more and less efficient and measures the inefficiency compared with the more efficient units in the set. Inefficient units are those with an efficiency ratio of less than 1 \( (E < 1) \) and those units are strictly inefficient compared to other units in the set. Units with an efficiency ratio of 1 \( (E = 1) \) are not necessarily absolutely inefficient but rather represent the "best practice" group of units which means that they are not clearly inefficient compared to other units in the set. This situation arises because the identity of absolutely efficient
hospitals is not known because of lack of knowledge of the truly efficient input-output relationships. Hence a hospital that is found to be relatively efficient may also be able to improve its operating efficiency. A hospital that is found to be inefficient will have true inefficiencies at least as large as the amount located with DEA. An inefficient hospital, as identified by DEA, is defined to have the ability to produce its same level of outputs (patient care, teaching) with fewer inputs based on the actual output-input levels of hospitals that were compared with the inefficient hospital.

The DEA model is described in the appendix to this paper. (See exhibit 3.)

To apply DEA, it is necessary to identify and obtain the data for set of outputs and inputs relevant to the hospitals' operations. Each of the outputs and inputs need only be measured in their natural physical units without the need to use a homogeneous measurement unit like dollars. For example, DEA can include as outputs the number of each patient diagnosis type treated and the number of each type of individual trained, and it can include inputs measured in units of full-time equivalents of each personnel type, number of beds available, etc.

4. Field Test of DEA to evaluate Teaching Hospital Efficiency

A set of teaching hospitals in Massachusetts were used to evaluate the ability of DEA to locate relatively inefficient hospitals. This researcher had no a priori knowledge about which of these hospitals were relatively inefficient nor was any accepted benchmark available that independently indicated which of these hospitals were more or less efficient. In lieu of an absolute benchmark of efficiency, a panel of hospital experts including regulators, managers, and hospital management consultants that were familiar with the hospitals in the state were enlisted to evaluate the accuracy of the
DEA results and to help identify the outputs and inputs that were relevant for the efficiency evaluation. (The procedures followed are described in greater detail in [14].)

Choice of Sample

The state rate setting commission had already adopted a ratio analysis approach to evaluate hospitals whereby a hospital over one standard deviation above the mean cost per day or mean cost per patient was deemed potentially inefficient [11]. This ratio analysis was applied within groups of hospitals that were designated as "comparable" groups. These comparable groups were developed by the rate setting commission using cluster analysis modified by discussions with the hospitals. One of these comparable groups of hospitals, a set of teaching hospitals, was selected for this study and the data used was from reports required to be submitted annually to the rate setting commission by each hospital in the state [12]. Data was available for seven of the nine hospitals in this group, so the DEA was used to evaluate just those seven hospitals. The study focused on one part of the hospital, the medical surgical area as defined in [12], to reduce the complexity of analyzing the efficiency in an entire hospital and because this represented the largest single cost area separately reported on by hospitals in the state. Data from 1976 was used because it was believed that some of the negative connotations of being labelled "inefficient" would be diffused if the study tested DEA using a prior year. The study began in 1979 so that the 1976 year of operations was not so old as to have faded from the memory of those familiar with these hospitals.

Identification of relevant outputs and inputs

The identification of the relevant outputs and inputs had to be based on an understanding of what resources are used to provide the types of services
offered in the Medical Surgical (MS) area. In this study, the variable selection was also tempered by the data that would be available from public reports from these hospitals.

The outputs and inputs used are described in table 1.

The elaborate process of defining these outputs and inputs is described in exhibit 1 in the appendix. The process began with a list of all the identifiable and relevant direct outputs and inputs of the medical surgical area. This list was refined by eliminating input measures like square feet of building space which was believed to be less directly associated with efficiency and which was already reflected in part by one of the input measures used—bed days available. The most problematic compromise was the use of only two case types, over and under 65 year of age rather than the more direct and complete measures like diagnostic related groups (DRG's) [3].

While age does appear to be a key factor in the resource required to treat a patient [3] [13], age alone is an incomplete measure. Proceeding with only age as a case mix breakdown would mean that the DEA results might be skewed because other case mix dimensions of the hospitals' outputs are not accounted for. This problem is somewhat reduced in the set of hospitals used because they were already believed to be "comparable", i.e., all of these hospitals had a relatively severe (resource intensive) set of patient diagnoses characteristic of these teaching hospitals. In addition, the Medical Surgical area was moderated in its case mix complexity because patients were generally admitted to this area only after being stabilized in the intensive care, emergency care, or operating recovery room areas. DEA would evaluate these hospitals' use of the three inputs in table 1 to produce patient care and training as measured by the four outputs in table 1. To the extent that there are other outputs and inputs not included, the DEA results may be less than comprehensive. The experts agreed that the data that was specified in table 1
Table 1

The inputs and outputs selected and used for the DEA analysis were as follows:

**INPUTS**

<table>
<thead>
<tr>
<th>(1) FTE's</th>
<th>Full-time Non-Physician Equivalents specifically employed in the Medical Surgical (MS) area during Fiscal Year 1976 (FY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) Supply $'s</td>
<td>Total dollar value of supplies and purchased services used in MS area during FY 1976</td>
</tr>
<tr>
<td>(3) Bed days</td>
<td>Number of bed days available in MS area during FY 1976</td>
</tr>
</tbody>
</table>

**OUTPUTS**

| (1) Patient days with age ≥ 65 | Number of patient days of care in MS area for patients 65 or over during FY 1976 |
| (2) Patient days age < 65 | Number of days of care for patients under 65 during FY 1976 |
| (3) Nurses trained | Number of nursing students trained during FY 1976 in their first, second or third years of the hospitals' nursing schools |
| (4) Interns/Residents trained | Number of interns and residents receiving one year of training at the hospital during FY 1976 |
was a reasonable list of relevant outputs and inputs that characterize medical-surgical area activities but that a more detailed case mix measure would have been a desirable addition if it were available.

The actual output and input data used are reported in exhibit 2 of the appendix.

**DEA results versus the use of ratio analysis**

The DEA results are summarized in Table 2 which indicates that hospital D and G are relatively inefficient compared with the other hospitals in the data set, i.e. efficiency rating of less than 1.0. (The hospital names are disguised but these names were made available to the expert panel.)

The rate setting commission's ratio analysis suggested that only hospital C (and specifically not hospitals D and G) may be relatively inefficient in the prices they pay for inputs and/or the amount of inputs used (Table 2, columns 4 and 5). DEA goes beyond these ratios and suggests that hospitals D and G are also relatively inefficient and that compared to other hospitals in this group, these inefficient hospitals should be able to produce their same level of services (outputs) with fewer inputs and, therefore, at lower cost.

**Interpretation of DEA results**

The meaning of the inefficient rating derived from DEA can be understood by examining the results for hospital D. DEA indicates that hospital D is inefficient with an efficiency rating of .88 based on comparison of hospital D with all seven hospitals. More specifically, DEA indicates that the inefficiency was located and measured by comparing hospital D with its efficiency reference set hospitals A, C, and E, noted in table 2. This information is a direct output of DEA. By identifying the efficiency reference set, DEA allows one to focus on a subset of these hospitals to better understand the inefficiencies present. This comparison is illustrated in table 3 which indicated that a weighted composite of the efficiency
reference set hospitals would yield a hypothetical hospital that produces as much or more outputs as the inefficient hospital D but also uses less inputs than D. In this example, the composite is constructed by applying the weights, (the dual variables from the DEA-linear program), of 0.138, 0.296, and 0.498, respectively, to the actual outputs and inputs of hospitals A, C, and E. Columns (4), (5), and (6) of table 3 indicate that a combination of the actual operations of these three hospitals would result in a hypothetical hospital that would use 55 fewer FTE's, $182,330 fewer supply dollars, and 9090 fewer bed days to produce the same amount of patient care and 34 additional units of training.

**Experts assessment of DEA results**

The experts agreed that the two hospitals identified as inefficient, D and G, was a reasonable and believable result though one expert expressed some doubt about the magnitude of the inefficiency found in hospital D.

The reaction of the experts provides added insights into the need for techniques like DEA. These experts were not able to provide a ranking of relative efficiency before the DEA results were obtained for two reasons: (a) they do not generally evaluate hospital performance based on output-input efficiency criteria but rather were more aware of cost per patient and cost per day types of data, and (b) the experts were not as knowledgeable about an individual department like Medical Surgical but rather had general impressions of these hospitals' overall performance. Their reaction to the validity of the DEA findings were, nevertheless, very strong and they indicated that the two hospitals identified as inefficient reflect a believable result based on knowledge of these hospitals and the quality of their management. DEA effectively located two inefficient hospitals that would not be so identified or measurable with commonly used techniques.
### Table 2

Comparison of teaching Hospitals' Medical Surgical (MS) area

<table>
<thead>
<tr>
<th>Hospital**</th>
<th>DEA Efficiency Rating (2)</th>
<th>Efficiency Reference Set (ERS) (3)</th>
<th>MS Cost Per Patient Day (4)</th>
<th>MS Cost Per Patient (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0</td>
<td>-</td>
<td>$34</td>
<td>$408</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
<td>-</td>
<td>38</td>
<td>418</td>
</tr>
<tr>
<td>C</td>
<td>1.0</td>
<td>-</td>
<td>39</td>
<td>429</td>
</tr>
<tr>
<td>D</td>
<td>0.88</td>
<td>A, C, E</td>
<td>32</td>
<td>407</td>
</tr>
<tr>
<td>E</td>
<td>1.0</td>
<td>-</td>
<td>27</td>
<td>243</td>
</tr>
<tr>
<td>F</td>
<td>1.0</td>
<td>-</td>
<td>29</td>
<td>348</td>
</tr>
<tr>
<td>G</td>
<td>0.93</td>
<td>E</td>
<td>36</td>
<td>324</td>
</tr>
</tbody>
</table>

Average Cost: $34.29 | $368.14

Standard Deviation: $4.27 | $62.45
<table>
<thead>
<tr>
<th>Column (5)</th>
<th>Hospital D - Compositive (6)</th>
<th>(1976 actual)</th>
<th>Equivalent (1.984+Z5696+4986)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,090</td>
<td>21</td>
<td>92</td>
<td>26</td>
</tr>
<tr>
<td>32,320</td>
<td>92</td>
<td>26</td>
<td>47</td>
</tr>
<tr>
<td>160</td>
<td>92</td>
<td>26</td>
<td>47</td>
</tr>
<tr>
<td>94,900</td>
<td>26</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>316,700</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>290</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>182,300</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>9,090</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>26</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
</tbody>
</table>

Comparison of Hospital D with the efficiency reference set hospitals A, C, and E.

Table 3
Evaluation of DEA results by management of inefficient hospital D

To further test the validity of these results, they were reviewed with the director and financial officer of inefficient hospital D. They agreed that the medical surgical areas of these seven hospitals were comparable and that the outputs and inputs selected reasonably captured the key inputs and outputs of the area. While the case mix data was questioned, they did not feel that their case mix was more severe or resource consuming than others in the group so that this was not believed to be the cause of the inefficiency identified in hospital D.

They located three potential explanations for the inefficiencies identified by DEA.

- The supply cost data was found to be overstated by $141,000 due to an accounting transfer that appears elsewhere in the report to the rate setting commission and which was subsequently determined to be a peculiarity that affected hospital D's report but did not affect the data for the other six hospitals.

- The bed days was determined by management to be excessive and were reduced subsequent to 1976 by 6935 bed days as was verified by examining subsequent years' agency reports.

- Personnel levels of hospital D were compared with other hospitals in the group and noted that they were somewhat higher than comparable hospitals by about 5.4 FTE's, but that this was a result of a conscious decision to maintain a somewhat larger staff to provide more personalized patient care.

In summary, management of hospital D found a data problem, an excessive level of bed days available which was subsequently adjusted and an excess FTE
level that continued to exist.

The DEA evaluation was rerun with the corrected supply dollar level and with the reduced level of beds to determine if these adjustments would make hospital D efficient compared with the other six hospitals. It was found that hospital D was still inefficient compared to the other six hospitals, but with a higher efficiency rating of .96 instead of the original rating of .88.

Hence, hospital D remained inefficient and this was believed to be due in part to personnel levels. Another DEA evaluation which reduced FTE's by the amount calculated by management (5.4 units) and also reflected the above adjustments were found to be adequate to make hospital D efficient.

Hospital D could become relatively efficient by making adjustments to its inputs of a lower magnitude than was indicated by DEA as indicated in table 4. This reflects the existence of a number of alternative paths that any inefficient hospital may select to become relatively efficient. A number of alternative paths including the one noted in column 1, table 4 is available directly from DEA. Other paths that are considered more practical by management may also make a hospital relatively efficient. The ability of these other alternative paths to make an inefficient hospital become relatively efficient can also be evaluated using DEA for sensitivity analysis as was described above. In the case of hospital D, the adjustments that management considered necessary to make it efficient as represented in column 2 of table 4 was found to be one adequate path to relative efficiency.
Table 4

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive Inputs</td>
<td>Input Adjustments and Excesses Noted by Hospital D Management</td>
<td>Cause of Excess Inputs</td>
<td></td>
</tr>
<tr>
<td>based on DEA evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of Hospital D (Table 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FTE's 55</td>
<td>5.4</td>
<td>Intentionally richer staffing</td>
</tr>
<tr>
<td></td>
<td>Bed days</td>
<td></td>
<td>Reduction of 19 beds to compensate for low occupancy rate</td>
</tr>
<tr>
<td></td>
<td>Available 9090</td>
<td>6935</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supply $182,230</td>
<td>141,000</td>
<td>Transfer due to unique accounting system</td>
</tr>
</tbody>
</table>
Conclusion of the field application of DEA to hospitals

The key results of this field study may be summarized as follows:

- DEA accurately located two inefficient hospitals that would not be identifiable using the types of ratio analysis used by the state rate setting commission.

- DEA could explicitly consider different outputs measured in their natural units and was able to identify as well as measure the relative magnitude of inefficiency present, i.e., the amount of potential resource reduction possible if these inefficient hospitals attained the operating efficiency of the relatively more efficient hospitals in the study.

- DEA results could be understood, interpreted, and accepted by administrators familiar with these hospitals to help locate the source of the inefficiency. This could lead to managerial action to reduce these inefficiencies and/or to clarify the magnitude of the inefficiencies or slack that management chose to incorporate into their operating plans.

5. Future Use of DEA for Hospital Efficiency Evaluations

The field test result of this study buttressed by the theoretical formulation and other tests of DEA described in [5], [7] and [13] suggest that DEA is a promising tool to evaluate hospital efficiency. These studies indicate that DEA is reliable in the location of relatively inefficient units and in its ability to suggest the general magnitude of input reductions required to make an inefficient unit relatively efficient. It is particularly useful in hospital applications because it can simultaneously accommodate multiple outputs and inputs and does not require specific knowledge of the efficient amount of inputs required for each hospital output.
Operational issues in applying DEA to hospitals

Input-Output specifications -- a key ingredient in the DEA evaluation is the location and measurement of the relevant inputs and outputs. The advantage of DEA over other techniques is that each input and output can be measured in their natural physical units without the need to apply a weighting system to collapse these different units into dollars or any other single unit measure. Hence, it is sufficient to know, for example, how many patients of each diagnosis was treated as an output measure and how many FTE's of each personnel type are utilized to produce the outputs. This is of major significance because it means that case mix can be explicitly considered in the efficiency evaluation by considering each case type (e.g., diagnostic related group case type) to be a separate output.

Defining and measuring the relevant physical inputs and outputs may require additional effort, since many hospital information systems tend to emphasize and collect only the dollar cost of inputs due to the importance of the reimbursement systems and the widespread concern about the dollar cost of health care. Similarly, comprehensive case mix output data are only beginning to be captured in a form which is useable for assessment of hospital efficiency via DEA or other techniques. These data collection efforts are needed to help identify a path to reducing inefficiency and costs, regardless of the methodology to be used. Specifically, a hospital located as inefficient using this data with DEA will be strictly inefficient and consequently will have the ability to produce the same level of outputs with a reduced level of inputs which can translate into lower costs.

Use of DEA to hospitals to improve technical efficiency

Based on this pilot study, DEA may be applied to hospitals in the following ways.

- Segments of hospitals like the Medical Surgical area as well as an
entire hospitals' operation may be compared to locate the relatively inefficient hospitals.

- Location of relatively inefficient hospitals can be used to allocate resources to reduce these inefficiencies, i.e., remedial resources can be focused on the hospitals most likely to have inefficiencies that can be reduced by in depth study of their operations. This may provide a basis for regulators or insurers to encourage and perhaps subsidize the hiring of consultants or auditors to evaluate ways of increasing the inefficient hospitals' efficiency levels which should ultimately translate into lower operating costs or increased service levels.

- DEA results can be used by managers or regulators to compare techniques used in relatively more and less efficient hospitals and to identify techniques used by more efficient hospitals that can be transferred to and adopted by the inefficient hospitals. As suggested in the field study, DEA not only locates the inefficient units but it also locates the relatively efficient hospitals against which that hospital was most directly found to be inefficient. In this way, the group of hospitals to be compared is significantly reduced from the original size of the groups being evaluated. In this study, hospital D needed only be compared to three hospitals (A, C, and E) rather than all of the six hospitals and hospital G needed only be compared with hospital E.

- Regulatory organizations can use DEA to select out the more efficient hospitals as a basis for rate setting. They could require that less efficient hospitals receive no more than the rates required to reimburse the more efficient hospitals for similar services. This might provide an
incentive for less efficient hospitals to become at least as efficient as the relatively more efficient hospitals in the data set.

- Use of DEA can encourage managers to specifically consider physical input-output efficiency as distinct from other performance dimensions such as maximization of reimbursement revenues and minimizing of material costs and salary levels as a direct means of reducing health care costs. This suggests that DEA has capabilities not found in other measurement techniques such as ratio analysis. At the same time, other techniques can address efficiency dimensions not addressed by DEA such as the cost per FTE, cost per unit of a drug. DEA is, therefore, a useful complement to other techniques rather than a replacement for other techniques.
Both variances are available but were not used.
.. on in some future study.

injury, which eventually will be treated as both inputs and

An output of the area where more attention and training occur.

averted by attending to the area.

for same mix for HS in teaching hospitals. but clearly important to

averted by attending to the area.

... tions he void in lack of ability to explain it on a computer, or even

the model as presented. the model as presented could not be used in

DNG, are currently one of the most potential output measures. For

level and the model output almost directly.

contacted between society levels of resource utilization

there is also no report that these secrets. there is also no report that these

tions of manpower by medical vs medical care, dealable but

ated[set] than adoptions tolerated.

was not used because many mix matched model able to make

a rest of the system which does not reflect length of stay. It

the number of patients treated and length of stay. In the future

additional output measures which can be measured.

atively output around a price above. 

this is a basic output measure of medical care. unbiased for case

based on the wage was available.

duction of our model. 

output.

and allocation to different levels of care. 

research on out hospital wage rate in the area.

were not available. the output needs to be reflected in the area.

need an approximation of the unit volume.

in the absence of a unit measure of output, the output measures in

came into existence which were born out of the supply of goods.

not satisfy. All hospitals in the area and all regions of the country

information on physical units of output per sector output. 

which does not reflect the actual number utilized in the HS area.

the data quality is deceptively superficial. note, too, the deceptiveness

expectation extends to the only available measure and many hospitals

N
An objective quality rating for teaching programs is not available. Quality, possibly varying by quality by department. All teaching hospital areas believed to be generally high. There is no available quality rating by hospital or by hospital area. Amount of student time spent in the HS area. Breakdown is not available and there is no systematic record of the HS area for each hospital. Receipt and throughput the same percentage of all training occurs in this. Therefore, this is amount of training in HS vs. other areas. Therefore, this is added to the HS area. No breakdown is available to this teaching occurs in the HS area (as well as other areas) training.
Appendix — Exhibit 3

The DEA Model

DEA measures the efficiency of hospital o compared with the n hospital in the data set as follows:

Objective:

\[
\max_{E_o} \quad \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{m} \sum_{i=1}^{l} v_i x_{io}}
\]

where o is the hospital being evaluated in the set of \( j = 1, \ldots, n \) hospitals. (This analysis is run repetitively with each hospital in the objective function to derive an efficiency rating for each of the n hospitals).

Constraints:

Less than Unity:

\[
0 < u_r \quad ; \quad r = 1, \ldots, s
\]

\[
0 < v_i \quad ; \quad i = 1, \ldots, m
\]

Data:

Outputs: \( y_{rj} \) = observed amount of \( r \)th output for the \( j \)th hospital

Inputs: \( x_{ij} \) = observed amount of \( i \)th input for the \( j \)th hospital

The data used for each hospital are the \( y_{rj} \) outputs; and the \( x_{ij} \) inputs.

The \( u_r, v_i \) values are determined from the data by the above model. DEA provides an ex post evaluation of how efficient each hospital was with the actual inputs \( x_{ij} \) used to produce its outputs \( y_{rj} \) without explicit knowledge of the input-output relationships it used. The weights in the form of the \( u_r \) and the \( v_i \) are not known or given a priori. They are, instead, calculated as \( (u_r, v_i) \) values to be assigned to each input and output in order to maximize the efficiency rating \(-E_o^-\) of the hospital being evaluated. That is, the solution sought is the set of \( (u_r, v_i) \) values that will give the hospital being rated the highest
efficiency ratio, $E^*$, but not result in an input-output ratio exceeding 1 (100% efficiency) when applied to any and all other hospitals in the data set. (See [5] and [7] for further details).

Applying DEA to a set of hospitals' results in an efficiency rating for each hospital of 1 (relatively efficient) or less than 1 (relatively inefficient). These ratings, however, represent relative efficiencies based on comparison of hospitals in the data set ($j = 1...n$ hospitals). A hospital that is found to be inefficient ($h_o < 1$) is strictly inefficient compared to other hospitals in the data set as is shown in [13].

Note that the $u_r$, $v_i$ values calculated by DEA are objectively determined weights which may not correspond to relative values that a hospital would assign to outputs and inputs. This is actually a strength and not a weakness of DEA. A hospital located as efficient using DEA is so identified only after all possible weights have been considered to give that hospital the highest rating possible consistent with the constraint that no hospital in the data set can be more than 100% efficient. Hence, any other set of weights applied to all hospitals would only make an inefficient hospital appear less efficient, i.e., DEA gives the benefit of the doubt to each hospital in calculating the efficiency value.

The DEA evaluation also provides insights far beyond the identification of the inefficient hospitals (see [13]) as is illustrated in the hospital application in table 3 and further described in [13].
References


