Measuring Hospital Operating Efficiencies for Strategic Decisions

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Abstract

This paper measures and benchmarks the operating efficiency of a regionally-based hospital in Colorado using Data Envelopment Analysis (DEA). Results compare increases in revenue versus reduction of operating expenses for future strategic decisions.

Keywords: measuring hospital efficiency, data envelopment analysis, strategic decisions

1. Introduction

Global competition has created new challenges for many industries and the health care industry is no exception. However, as pointed out by Ozcan (2008) the health care industry has lagged behind other industries in terms of more objective performance evaluation and decision making needed to compete in this global marketplace. Historically, health care providers struggled beginning in the 1980's in response to decreases in reimbursements for Medicare patients. Initial reactions were to cut costs or avoid cases that would lose money. However, administrators realized that in the long run, the only way to survive the new competitive frontier would be to improve performance.

There are several perspectives on the performance of health care operations. For example, performance can be viewed from the perspective of patients, hospital administrators, or society's policymakers. Regulatory agencies are concerned with economizing the resources being used to provide health care services to citizens. This is the case in countries such as the United Kingdom or Canada where health care service is predominantly nationalized. Although health care is a privatized industry in the United States, there remains tremendous pressures to contain costs and improve services. Simultaneously, health care facilities are realizing they are competing with one another for human resources (e.g., skilled surgeons and nurses) as well as for patients. This paper measures and benchmarks the operating efficiency of a regionally-based hospital in Colorado using Data Envelopment Analysis (DEA) in order to more fully understand the relationship among the variables affecting hospital performance.

2. Measuring hospital efficiency

Numerous empirical studies have examined the strategic importance of efficiency in hospitals. However, Ancarnai, Di Mauro, and Giammanco (2009) point out that hospital efficiency has been far overlooked in the research literature. Their study examined the relationships between decision making processes of a hospital ward and technical efficiency using Data Envelopment Analysis (DEA). Results indicate that both decisions internal to the hospital and exogenous re-organizations affect the hospital's efficiency. Coyne, Richards, Short, Shultz, and Singh (2009) measured efficiency and cost indicators in relationship to hospital size and ownership. Their research shows that small and large not-for-profit hospitals appear to achieve higher efficiency levels than government-owned hospitals, but that larger hospitals of both ownership types report greater efficiency than achieved by small hospitals.

Other researchers have examined the different ownership forms of hospitals and efficiency performance of Taiwanese hospitals (Hsu & Hu, 2007; Hu and Huang, 2004; Wei, 2006). Hu and Huang (2004) found that public ownership significantly worsens a hospital's efficiency, while higher ward capacity utilization helps improve efficiency. Huerta, Ford, Peterson, and Brigham (2008) found that for-profit institutions had a significant and negative impact on efficiency, supporting the contention that publicly run and nonprofit hospitals may be more efficient than privately run hospitals. Harrison and Sexton (2006) documented that religious, not-for-profit hospitals are becoming more efficient in management of resources and highlighted the importance of the hospital's unique mission to the community in order to ensure continuing support. Friesner, Roseman and McPherson (2008) examined whether or not hospital efficiency is affected by seasonal inefficiency. Results indicate that hospital efficiency does vary over time, but that the type of inefficiency depends on the specific efficiency being measured. The impact of mergers on technical efficiency has also been studied (Groff, Lien, & Su, 2007).

Using non-parametric Data Envelopment Analysis (DEA), these researchers indicate that there are no apparent improvements in efficiency in the first year after the merger, but that efficiency improved significantly in the second year following the merger. This finding is consistent with the merger and acquisition literature that indicates a time lag may occur before the intended results of the merger are realized. Organizational design (structural process) has been studied as well. Vera and Kuntz (2007) found that a high degree of process-based organizational structure has a moderate, yet significant, positive effect on efficiency of hospitals. Related to organizational structure, Sikka, Luke, and Ozcan (2009) measured the efficiency of hospital-based clusters, that is, hospitals that were members of multihospital systems. Results were mixed, but findings suggest that regional patterns of distributing service across clusters might contribute to measured performance. Harrison and Coppola (2007) examined the relationship between hospital quality and numerous independent variables related to hospital efficiency. Using DEA methodology and regression analysis, their research shows a positive relationship between quality and efficiency, supporting the premise that hospital leadership, through effective allocation of resources and development of high-performance work processes, is essential to improve quality of care. For a comprehensive, cross-national comparison and taxonomy of hospital efficiency studies, see O'Neill, Rauner, Heidenberger and Kraus (2008).

3. Measuring operating efficiencies using DEA

DEA was first introduced into the literature by Charnes, Cooper, and Rhodes (1978). Based on linear programming (LP), Data Envelopment Analysis (DEA) is a non-parametric programming technique that develops an efficiency frontier by optimizing the weighted output/input ratio of each provider, subject to the data set. In health care, the first application of DEA dates to 1983 in the work of Nunamaker and Lewin (1983) who measured nursing service efficiency. Since then, DEA has been used widely in the assessment of hospital technical efficiency in the United States as well as around the world at different levels of business and public sector operations. What differentiates DEA from other methods of descriptive statistics is that it identifies optimal performance rather than the averages. In today's competitive health care market, no health care institution can afford to be an average performer.

DEA is a comparative approach for identifying performance or its components by considering multiple resources that are used to achieve outputs. These evaluations can be conducted not only at the organization level, but also in sub-units, such as departmental comparisons, so that a department can improve its performance either by saving certain elements of inputs or by improving its output. In summary, DEA can help health care managers to:

- Assess their organization's relative performance
- Identify top performance in the health care market
- Identify ways to improve performance

4. Data and methodology

4.1 Efficiency model

The variables selected for this study are some of the most commonly used for input and output variables affecting hospital efficiency as found in the published research. We consider the number of doctors (D) and nurses (N) as input variables, and the number of inpatients (Ip), outpatients (Op), and the revenue (R) as output variables as summarized in Table 1. Hence the Efficiency to measure in this paper is given as:

$$Efficiency = \frac{\sum Ip + Op + R}{\sum D + N}$$

Table 1. Input and output variables and operating definitions

Input Variables	Operating Definitions
Number of Physicians	The total number of physicians who are full-time employees during September 2007 to August 2009
Number of Nurses	The total number of nurses who are full-time employees during September 2007 to August 2009
Output Variables	**Operating Definitions**
Number of Outpatients	The total number of patients to emergency rooms and outpatient department during September 2007 to August 2009
Number of Inpatients	The total number of patients receiving inpatient treatment services during September 2007 to August 2009
Revenue	The income the hospital receives for provided services measured in US dollars

It is obvious that although efficiency is indicated in a mathematically simple way, we cannot calculate an efficiency figure directly from this formula because of the differences in units of the input and output variables. For example, in the case of output, R is measured in monetary terms (dollars) whereas Ip and Op are simple whole numbers and hence the summation of these variables is meaningless or misleading at best. In this case, the use of DEA as a research tool is effective in resolving this dilemma due to its nonparametric nature. The DEA model defines the efficiency of DMU (Decision Making Unit) as the 'maximum ratio of weighted outputs to weighted inputs' subject to the condition that the ratios for every DMU are less than or equal to unity. The model is mathematically presented as:

$$\text{Max } h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \quad (1)$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \; ; \; j = 1,\ldots, n \quad (2)$$

$$u_r, v_i \geq 0; \; r = 1,\ldots,s \; ; \; i = 1,\ldots, m \quad (3)$$

Where:

y_{rj} , x_{ij} are the unknown outputs and inputs of *j*th DMU and

u_r, v_i are the variable weights, assigned to output r and input i, respectively.

There are four different ways to get the optimized solutions depending on whether to minimize input or to maximize output and whether to assume constant returns or variable returns to scale. The results are identical between the input minimization and output maximization models. The constant returns to scale and the variable returns to scale models produce different results, however. In order to examine whether the hospital in this study increased the output of resources while keeping the level of inputs constant, this study used an output oriented model with a constant returns to scale assumption. For computing efficiency, we use three DEA models such as SBM, CCR, and BCC models. The efficiency scores computed by the DEA models are between zero and one due to its very nature dictated by the mathematical models.

4.2 Data

The data were collected at a medium-sized, regionally-based hospital in Colorado for the period of two years, September 2007 - August 2009. Table 2 shows the descriptive statistics for the operations of the emergency room at the hospital.

Table 2. Descriptive statistics of input and output

Input	Maximum	Minimum	Average	Standard Deviation
Physicians	28	20	23.66667	2.640497
Nurses	73	50	61.125	7.758396
Output				
Inpatient	745	600	672.875	37.18682
Outpatient	4697	3825	4248.958	230.6587
Revenue	5,605,260	4,523,760	5,043,922	270122.3

5. Results

5.1 Efficiency Scores

Table 3 shows the efficiency scores. SBM scores are the most restrictive measure of efficiency. December 2007 and January and July 2008 show 100 percent efficiency, but since September 2008, efficiency begins to decrease rapidly. Noticeably, the efficiency dropped to 65.05 percent in July 2009. In comparison to the SBM model, the BCC model shows 100 percent efficiency in December 2007, January 2007 and July 2008. Then, since September 2008, it also begins to decrease rapidly, the worst of it being 67.90 percent in July 2009. The CCR model shows 100 percent efficiency in September, October, November and December 2007, and also in January, March, and July 2008.

The relationship between CCR, SBM and BCC models are as follows:

CCR efficiency= [BCC efficiency] x [Scale Efficiency or SE]

SBM efficiency = [MIX efficiency] x [BCC efficiency] x [Scale Efficiency or SE]

SBM efficiency = [MIX efficiency] x [CCR efficiency]

Benchmarking is a management approach used to implement the best practices found in similar industries, or even in different industries, in order to improve the performance of an organization. We can suggest that December 2007 and January and July 2008 can be a benchmark because each of these months shows 100 percent efficiency in all DEA models; that is, implying the best practices in managing resources.

Table 3. Efficiency scores

Year	Month/Year	SBM	CCR(TE)	BCC(PTE)	MIX	SE
2007	September 07	97.45	97.73	100.00	99.71	97.73
	October 07	93.49	97.13	100.00	96.25	97.13
	November 07	95.95	98.23	100.00	97.68	98.23
	December 07	100.00	100.00	100.00	100.00	100.00
2008	January 08	100.00	100.00	100.00	100.00	100.00
	February 08	97.42	97.57	98.22	99.85	99.33
	March 08	97.60	98.74	100.00	98.85	98.74
	April 08	90.57	90.60	93.80	99.97	96.59
	May 08	95.10	95.15	96.37	99.95	98.74
	June 08	95.05	95.07	95.21	99.98	99.85
	July 08	100.00	100.00	100.00	100.00	100.00
	August 08	96.35	96.39	96.89	99.96	99.48
	September 08	79.50	83.24	95.98	95.51	86.73
	October 08	77.03	79.16	90.34	97.31	87.63
	November 08	75.50	75.60	88.95	99.86	85.00
	December 08	76.42	76.89	90.46	99.40	85.00
2009	January 09	73.98	75.59	88.86	97.86	85.07
	February 09	72.67	79.35	93.36	91.58	85.00
	March 09	79.19	79.43	93.15	99.70	85.27
	April 09	71.26	76.49	94.36	93.17	81.06
	May 09	69.94	71.83	89.53	97.36	80.23
	June 09	67.59	71.96	91.54	93.92	78.61
	July 09	65.05	67.90	88.19	95.81	76.99
	August 09	65.66	69.86	90.74	93.99	76.99

5.2 Measures to improve efficiency

Table 4 shows potential improvements computed by the SBM model. The following indicates improvement in output variables such as inpatient, outpatient, and revenue.

Table 4. Potential improvement (%) for SBM model

Year	Month/Year	Inpatients	Outpatients	Revenue
2007	September 07	1.93%	3.03%	2.88%
	October 07	13.65%	2.96%	4.28%
	November 07	9.99%	0.76%	1.93%
	December 07	0.00%	0.00%	0.00%
2008	January 08	0.00%	0.00%	0.00%
	February 08	6.94%	0.04%	0.96%
	March 08	0.68%	3.54%	3.14%
	April 08	10.47%	10.37%	10.39%
	May 08	6.73%	4.20%	4.54%
	June 08	6.32%	4.53%	4.78%
	July 08	0.00%	0.00%	0.00%
	August 08	5.31%	2.85%	3.19%
	September 08	36.74%	19.25%	21.37%
	October 08	25.77%	32.32%	31.39%
	November 08	32.77%	32.27%	32.34%
	December 08	32.15%	30.06%	30.33%
2009	January 09	28.76%	39.13%	37.65%
	February 09	41.59%	26.02%	45.23%
	March 09	25.83%	26.54%	26.44%
	April 09	28.25%	47.84%	44.88%
	May 09	38.02%	46.03%	44.91%
	June 09	34.98%	56.03%	52.85%
	July 09	45.31%	58.90%	56.94%
	August 09	41.22%	59.15%	56.50%

On the basis of the study results, we find that increases in inpatient, outpatient and revenue have contributed to improved organizational performance. Except for September, October, November, and December 2007, all other months should have improved output variables. To improve the efficiency, we recommend that revenue will have to increase over 50 percent beginning August 2009 because reducing operating expense will only show short-term improvement.

6. Summary and conclusions

This study has presented the development of models designed to measure and benchmark operating efficiencies in a medium-sized regional hospital in order to examine strategic performance measures of efficiency. Findings indicate that revenue will need to increase for the future because reducing operating expenses will result in only a short-term improvement. While this study concentrated on revenue and efficiency measures, future research should also include other performance measures such as patient wait times, patient satisfaction, service quality, as well as other financial measures.

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