DATA ENVELOPMENT ANALYSIS COMPARISON OF WASHINGTON STATE HOSPITAL EFFICIENCY AND QUALITY

By

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ABSTRACT

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The purpose of this thesis is to measure and assess the relationship between technical efficiency and quality in Washington State Hospitals using Data Envelopment Analysis (DEA). The study design is a non-randomized correlation analysis using a cross-sectional sample from 2007. Inputs for the DEA model include hospital size, operational expenses, total FTEs and total assets. Technical outputs consist of CMI adjusted admissions, outpatient visits and training FTEs, while quality outputs consist of percentage of pneumonia patients given initial antibiotic(s) within 6 hours of arrival, percentage of pneumonia patients given oxygenation assessment and percentage of pneumonia patients assessed and given pneumococcal vaccinations. An input oriented, constant returns to scale DEA model is used. Two separate DEA models are created, the first without the 3 quality outputs and the second model including the three quality outputs for a total of six outputs. These two models were then compared using a Spearman Rank Coefficient test.

Descriptive results from the correlations analysis show a positive and statistically significant correlation between the two models. This suggests that hospitals which are deemed

technically efficient are also more likely to rank highly when quality is considered into the equation as an output.

Managerial implications include the assurance that cost cutting measures such as Six Sigma or Lean Management do not have an effect on quality. This also adds credence to creating a balanced scorecard for hospitals which includes both quality and financial measures, since both these factors vary together.

This study has several limitations including a limited sample size of Washington State, the use of self-reported measures and the issue of multicolinearity.

Areas for future research include a replication of this study on a broader geographic sample.

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CHAPTER ONE

Introduction/Significance of Study

This chapter is divided into five sections. The first section examines the purpose of the study, while the second section defines the problem. The third section examines the significance of the study. The fourth section notes any gaps in the current literature and lastly the key research question is identified.

Introduction

Data Envelopment Analysis (DEA) is a quantitative technique developed by Charnes, Cooper and Rhodes that computes efficiency scores for decision making units (DMUs) relative to their peer inputs as shown in Figure 1.1 (Charnes, Cooper & Rhodes, 1978; Richards, 2008; Ozcan & Nayar, 2008).

Figure 1.1
General Formula for Efficiency

Measure	Formula
Efficiency	$= \frac{\text{Output}}{\text{Input}}$

This technique has been applied throughout the healthcare industry to assess quantitative outcomes, but not many attempts have been made to include quality as an output. This is mostly due to the fact that there is not a composite measure for quality that can incorporate all measures of quality and allow for a just comparison. However, in November 2001, the Quality Initiative was announced by the Department of Health and Human Services. Hospitals participating in this initiative voluntarily report on a set of clinical quality measures, which include process, outcome, and patient satisfaction measures. Coupled with the enactment of Section 501(b) of the

Medicare Prescription Drug, Improvement, and Modernization Act of 2003, participation is near universal in this –"voluntary"- program (Ozcan & Nayar, 2008). The act stipulates that hospitals which do not submit performance data will receive a 0.4 percentage point lower annual payment update than a hospital that submits data. The Deficit Reduction Act of 2005 later increased the reduction to 2.0 percentage points (Centers for Medicare & Medicaid Services, 2009). Centers for Medicare & Medicaid Services (CMS) also includes language allowing for increases in payment to be given to hospitals which are top performers based on their quality measures. Hospitals in the top 20% of quality for measured clinical areas will be given a financial payment as a reward for the quality of their care (Centers for Medicare & Medicaid Services, 2006). Hospitals in the top decile of hospitals for a given diagnosis will be provided a 2% bonus of their Medicare payments for the measured condition, while hospitals in the second decile will be paid a 1% bonus (Centers for Medicare & Medicaid Services, 2006). In FY 2007 nearly 95% of hospitals participated successfully in the reporting program and received the full market basket update for FY 2008 (Centers for Medicare & Medicaid Services, 2009). Market updates are provided by CMS to adjust reimbursement levels to accurately measure the price changes affecting providers.

The Hospital Quality Alliance (HQA) is a public-private collaboration led by the American Hospital Association (AHA), the Federation of American Hospitals, and the Association of American Medical Colleges that collects and reports hospital quality performance information and makes it available to consumers through CMS information channels (Ozcan & Nayar, 2008). The quality measures focus on three serious medical conditions: acute myocardial infarction (AMI), pneumonia and heart failure. Data from this program are publicly available on the CMS website.

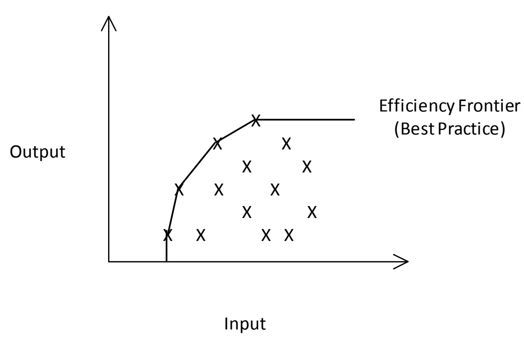
In an era of rising health care costs, pressures to contain costs within a hospital are tantamount to the financial viability of the institution (Ozcan, & Nayar, 2008). Compound this pressure with new initiatives emphasizing the importance of quality in the delivery of healthcare services, and hospital administrators can easily feel overwhelmed to address both these factors. One could imagine that increasing efficiency by cutting input costs can possibly impact the quality of care, but is this actually the case? Is there a trade-off between efficiency and quality in order to reach an optimal level of efficiency?

Purpose

The purpose of this thesis aims to address this exact question and examines the relationship between the efficiency, as measured using DEA, of Washington State hospitals with and without accounting for quality. DEA establishes a best case efficiency frontier for hospitals and allows comparison between them to determine where inefficiencies exist (Richards, 2008). The efficiency frontier is achieved when the greatest possible output per unit of input occurs, otherwise known as an absolute or optimum efficiency (Sherman & Zhu, 2006). Identifying these inefficiencies, allows the DEA model to establish a baseline efficiency measurement, thereby permitting a secondary analysis to examine factors associated with the variance of efficiency scores (Richards, 2008). When DEA was compared to other benchmarking models such as stochastic frontier analysis and regression models in analyzing cost structure, analysis incorporating DEA proved to be the most reliable (Fulton, Lasdon, McDaniel & Coppola, 2008) when analyzing hospital cost structure and forecasting costs. It is noteworthy that simple ratio analysis has also been tested against and compared to DEA, confirming that the two measuring techniques are closely related and consistent, but since DEA is more commonly used industry wide and the fact that this is a replication study, we will exclude simple ratio analysis as a benchmarking tool (Laspa & Priporas, 2008).

Data Envelopment Analysis is an extension of linear programming that is used to develop an efficiency frontier for the DMUs that operate with optimal performance patterns (Ozcan, & Nayar, 2008). The optimally efficient DMUs are given a score equal to one, and are considered on to be on the efficiency frontier. Any DMU with a score of less than one is considered inefficient. In order to increase efficiency hospitals must either decrease their inputs to obtain the same amount of outputs, or increase their outputs while maintaining constant inputs. For a detailed description regarding the DEA model used in this thesis please refer to the appendix (Sherman & Zhu, 2006).

Figure 1.2
DEA Efficiency Frontier



Problem

The problem examined here is: Does a hospital's technical efficiency ranking change when quality of care is added to the equation?

Significance/Importance of Study

It is essential to consider not only hospital efficiency but also quality in an acute care hospital setting. While managers and policy makers should not utilize DEA alone, it is a valuable method of assessing efficiency worth considering when assessing hospitals (Richards, 2008). Outside financial pressure from primarily uncontrollable forces—the potential bundling of Medicare reimbursements to hospitals and non-payments for readmissions and adverse events, to name a few—have compelled healthcare organizations to spend more time looking inward to fine-tune existing capabilities (Birk, 2010). Establishing the relationship between hospital efficiency and quality metrics is of critical interest to health services researchers, purchasers, and policy-makers seeking to improve the U.S. health care system's effectiveness while simultaneously controlling costs—collectively increasing value (Huerta, Ford, Peterson & Brigham, 2008).

Although DEA has increasingly been used in hospital efficiency analysis, it has only rarely incorporated quality or patient safety variables (Mark, Jones, Lindley & Ozcan, 2009). In fact, the AHRQ evidence calls quality measures in efficiency reports "silent" and recommends that studies of efficiency also contain quality measures (Mark et al, 2008; McGlynn, 2008).

Gaps in the Literature

There have been many studies which have examined the technical efficiency of hospitals but few which have incorporated quality into the equation. Quality is a growing focus and component of DEA based studies in the healthcare field, because of its increased importance in policy setting and ties to the reimbursement.

Key Research Question

The null hypothesis of this thesis is that there is a positive relationship between hospital quality and hospital efficiency in Washington State. Evidence supporting the null hypothesis would show that hospitals which are technically efficient will also be efficient when quality is incorporated as an output. On the other hand, some hospitals which are technically efficient will be inefficient when quality is incorporated. There are two alternative hypotheses: 1) That no relationship exists between hospital efficiency and quality and 2) that a negative relationship exists, which would support the tradeoff theory between efficiency and quality as suggested in non-healthcare studies (Sherman & Zhu, 2006).

Summary

With the growing focus of quality in healthcare delivery being tied to reimbursement, it is important for research to examine the relationship quality has with technical efficiency. This study aims to add to the scarce amount of literature focusing on how quality and technical efficiency are linked, which can have important implications from both the policy and managerial perspective.

CHAPTER TWO

This chapter is divided into three sections. The first section is a discussion behind the methodology used in the literature review. The next section is a theoretical basis for data envelopment analysis discussing the various techniques which are in use today, including the method used in this thesis. The last section is a comprehensive literature review of all the studies related to healthcare which include quality and efficiency analysis, grouped into 4 different sections including world health, nursing home, practitioner, and hospital applications.

Literature Review

In conducting a literature review, sources were obtained from the EBSCO database, limited by peer-reviewed articles only. Only articles since the development of DEA in 1978 were included in the time period reference. Relevant articles were selected based off their focus on healthcare and the incorporation of DEA. Key search terms used were “hospital”, “DEA”, “Data Envelopment Analysis”, “healthcare”, and “quality”. After conducting the search using the above state inclusion criteria, a total of 78 studies were identified. Exclusion criteria, such as not using DEA as a research tool in the healthcare setting, reduced the number of relevant articles to 39.

Methodology of Literature Review

Many healthcare DEA models have compared technical efficiency across a set of hospitals, but few have addressed the aspect of quality as an output measure. Furthermore, there are several techniques of how to incorporate quality into the DEA model. Three widely used techniques will be discussed in this section: (1) the two-model approach, (2) the combined quality and efficiency model with weight restrictions and (3) the multiple objective DEA (MODEA) model.

In the two-model approach, two separate DEA models are developed to compare hospitals, one with quality outputs and the other with operating efficiency outputs. After the results are obtained, operating and quality efficiency are placed on the same graph, separated in four quadrants. Only the results that fall within the high quality, high operating efficiency quadrant would be considered best practice units and used as a reference for inefficient DMUs (Shimshak et al., 2008). An extension of this model is the quality-adjusted DEA (Q-DEA), in which operating efficiency is analyzed without quality measures and then compared to service quality based on customer evaluations. An example of such a model was used in measuring the efficiency of bank branches. Only bank branches that scored high on both operating efficiency and quality were kept as the benchmark set. Thus, those branches whose productivity was high enough to offset and possibly disguise low quality (perhaps sacrificing quality to achieve lower costs) were removed from the set of benchmark branches (Shimshak et al., 2008; Sherman & Zhu, 2006).

A popular approach used in DEA has been simply to add quality measures into the model as outputs (Shimshak et al., 2008). This approach is referred to above as the combined quality and efficiency model with weight restrictions. However, DEA can assign such low weights to some inputs and/or outputs that the quality output variables are effectively ignored (Shimshak et al., 2008). The most common way to overcome this problem is by placing weight restrictions on the input or output measures. The problem with this method lies in the subjectivity of the restrictions, relying essentially on what administrators deem as appropriate.

Lastly, the MODEA model accounts for the fact that some 100% efficient entities may not have optimal levels for some inputs or outputs, essentially allowing only one output or input to bring a 100% efficiency rating. To overcome the shortcomings of single-objective DEA, MODEA permits the creation of multiple models, one for each objective, using different combinations of measures as inputs and outputs (Shimshak et al., 2008).

In a study by Shimshak and colleagues (2008), the researchers found that the two-model approach is the easiest technique to understand and to apply. This is important, in that administrators are the ones who directly benefit from such research, allowing them to know where they are deficient and to take action in increasing quality or focusing on operating efficiency if quality benchmarks are already being met. The problem with this technique, however, is that the manager must eventually decide whether to focus on quality or operating efficiency, either of which will likely require different staffing targets (Shimshak et al., 2008). For the purposes of this thesis, a two-model approach similar to the Q-DEA proposed by Sherman and Zhu (2006) will be used.

Quality Integrated Applications in Healthcare

DEA has been around since the late 1970's but has just recently been applied to the healthcare industry. Most research in the healthcare industry has focused on technical efficiency, which is a model of data envelopment analysis which does not include quality measures within its outputs (Hollingsworth, 2008). Less than ten percent of the articles examined compared hospital quality and DEA. The remainder of the articles examined incorporating quality and DEA in other sectors of healthcare, including the nursing home industry and practitioner productivity.

World Health Applications

With much emphasis on health reform and the amount of GDP that the United States spends on healthcare per year, articles have examined the cross country efficiency between nations. One study highlighted that the most important secondary variables affecting the efficiency of care are gross national income and the proportion of old people in the respective country's population (Huang, Wang & Chen, 2008). The quality measures incorporated into these DEA models included infant mortality rates and life expectancies.

Nursing Home Applications

The 1987 Omnibus Budget Reconciliation Act (OBRA) defined a Minimum Data Set (MDS) for nursing facilities which requires facilities to submit the resident data to the state, and, in turn the state provides reports of performance on benchmarks in a defined set of quality indicators to each facility to facilitate the comparison with similar facilities (Bott, Gajewski, Lee, Piamjariyakul & Taunton, 2007). This data set has allowed researchers to incorporate both technical efficiency measures and quality measures in DEA models to benchmark nursing home care facilities against one another.

Practitioner Applications

Hospitals and HMOs have used DEA as a benchmarking tool to evaluate the pool of physicians that they employ and establish best-practice targets to develop resource utilization control strategies (Chilingerian & Sherman, 1996). Considering that over 80% of every dollar spent on healthcare is controlled by physician decision-making, this area of DEA has many cost savings applications in any area of healthcare whether it be hospitals, nursing homes, or physician practice organizations (Chilingerian & Sherman, 1996). One study found three implications of incorporating quality into DEA: 1) Anywhere from 12 – 30% cost savings by employing best practice physicians only, 2) specialists provided more efficient care than primary care physicians, modifying current perception that reducing specialists is the most effective way to achieve low cost practice patterns, and 3) distinct groups of resource patterns were identified allowing for opportunities to manage high cost groups (Chilingerian & Sherman, 1996). In another study that documented the variation of care provided for similar diagnoses for otitis media, excessive resource consumption was noted by inefficiency primary care physicians, which suggests that clinical practices need retooling by examining the practice patterns of efficient providers, or by continuing education and adherence to established clinical guidelines (Ozcan, 1998).

Hospital Applications

Many studies have examined the association between hospitals and technical efficiency using DEA, but few have incorporated quality or patient safety variables in their efficiency analysis. Empirical data usually incorporates risk-adjusted mortality rates as the main indicator of hospital quality, for example, 25 out of the 37 studies on the link between hospital ownership and quality of care reviewed by Eggleston et al. (2008) use mortality as the indicator of quality (Chua, Palangkaraya & Yong, 2009). Readmission rates are now a popular measure to benchmark quality and have increased emphasis in tying reimbursement rates to these quality measures. In fact, with the passing of the Patient Protection and Affordable Care Act in 2010, readmission rates will now be linked directly to reimbursement rates and those facilities with high severity-adjusted readmission rates, will have access to quality improvement tools provided by their local accountable care organization (HR 3590, 2009). One study, using DEA found that including quality as an output actually impacts the disparity between hospitals when comparing efficiency (Chua, Palangkaraya & Yong, 2009). In other words, hospitals when benchmarked against one another using DEA were more like to show a greater disparity between best practice (efficiency frontier) and least efficient hospitals when quality was included as an additional output. This study further emphasizes the importance that quality has when developing a benchmarking tool to compare hospitals against one another. Hospitals which are technically efficient are more than likely to show their efficiency when quality is included as an output. Those that are already inefficient, are more than likely to be even more inefficient when quality is accounted for as an output in the DEA model. This concept was further supported by a study that showed hospitals with lower technical efficiency are associated with poorer risk-adjusted quality outcomes (Clement, Valdmanis, Bazzoli, Zhao & Chukmaitov, 2008). Interestingly, those hospitals which were the most efficient, still had room to increase their inputs (such as FTEs), which perhaps could further accentuate the difference in scores by allowing more personnel and to be devoted to quality improvement initiatives to further increase quality scores (Fraser, Encinosa & Glied, 2008). In another study examining 1,377 urban hospitals, low-quality hospitals could be improved by increasing labor inputs, in contrast to high-quality outputs (Valdmanis, Rosko & Mutter, 2008). This adds to the importance and focus of quality improvement initiatives in improving quality incorporated efficiency scores. Making sure the goals of quality improvement and cost reduction are complementary to one another is a difficult task and this is depicted in a study which found no evidence that low-cost providers provide better care (Jha, Orav, Dobson, Book & Epstein, 2009). This study noted that hospitals with the lowest-risk adjusted costs were more often for-profit, had more Medicare patients and had lower nurse-to-census ratios (Jha et al, 2009). Though Ozcan and Nayar showed that quality and technical efficiency are linked, mandating quality benchmarks can actually produce counterproductive outcomes. Examining the California nurse-to-staffing ratio law passed in this past decade was a study by Mobley and Magnussen which showed that actually implementing quality laws such as the nursing staff requirements would penalize the larger, more efficient urban hospitals, by forcing them to increase staffing when they were already at the efficiency frontier (Mobley & Magnussen, 2002).

DEA use is extensive in the health services research, but the incorporation of quality is still quite rare. Ozcan and Nayar (2008) is the only article which uses quality as an output in measuring and comparing technical efficiency and quality of hospitals. Their study used hospitals in the state of Virginia to address the same research question that is posed in this paper. The evidence from their study found that the quality outcomes were not being compromised by the technically efficient hospitals. (Ozcan & Nayar, 2008). This thesis is a replication study using the same methodology that Ozcan and Nayar (2008) used, which is an extension of the DEA tools demonstrated by Sherman and Zhu (2006). The goal of this paper is to supplement Ozcan and Nayar's (2008) analysis by using a Washington State database comparison of hospitals and quality. Also, with the lack of material on this topic, this thesis aims to contribute further to the realm of knowledge of DEA incorporating quality and further discredit the conception that there is an efficiency-quality tradeoff between hospitals or to strengthen it by showing a difference between technical efficiency with and without the use of quality as an output.

Summary

Though there is a great deal of literature discussing DEA applications in healthcare, there have been few studies which have actually assessed the relationship between quality and efficiency. For hospitals the key study findings from the few DEA studies in the literature is a positive relationship between efficiency and quality. The main reason this study was conducted was to add to the sparse literature regarding incorporating quality measures as outputs in efficiency models such as DEA within the healthcare sector. This study intends to examine the relationship between two separate DEA models where quality is and is not included as an output.

CHAPTER THREE

Methods/Study Design

This chapter is divided into 5 sections. First the study design of the thesis is discussed. Second, the study sample is defined. Third, the measures used for outputs and inputs are operationally defined. Fourth, the data analysis strategy and the breakdown of the two DEA models are given. Lastly, a short discussion on slack analysis is given.

Study Design

The study design is non-randomized correlational analysis with a cross-sectional sample from 2007 that includes all hospitals in Washington State. Though 2008 data was available from the Washington State Department of Health, CMS Cost Report, and Hospital Compare database, the data were incomplete; not all hospitals had submitted data for the fiscal year for these respective databases. The sample is from all Washington State hospitals. Data for this thesis are extracted from three secondary databases including the CMS Hospital Compare database, the CMS Cost Report database, and the Washington State Department of Health statistical database. All quality data will be extracted from the CMS Hospital Compare database and the remaining data will be from the CMS Cost Report database and Washington State Department of Health statistical database.

Sample

All Washington State hospitals with non-missing data from the CMS Hospital Compare database will be included in the analysis. Of these, only the hospitals with complete CMS Cost Report and Washington State Department of Health statistical database data will be incorporated into the thesis. There were 92 acute care hospitals listed on the Washington Department of Health database with complete financial information, as shown in Table 3.1. Of these 92, there were 37 hospitals which did not have complete quality data available on the Hospital Compare database, so the final sample was limited to 55 hospitals, approximately 60% of the original sample, as listed in table 3.2.

Table 3.1
Washington State Hospitals

#	Hospital Name	#	Hospital Name
1	Swedish Medical Center - Seattle	47	St. Clare Hospital
2	Swedish Medical Center - Providence	48	Island Hospital
3	Klickitat Valley Hospital	49	Lincoln Hospital
4	Virginia Mason Medical Center	50	Stevens Healthcare
5	Children's Hospital and Regional Medical Center	51	Holy Family Hospital
6	Newport Community Hospital	52	Kittitas Valley Community Hospital
7	Lourdes Medical Center	53	Dayton General Hospital
8	Okanogan-Douglas County Hospital	54	Harrison Medical Center
9	Peacehealth St. John Medical Center	55	St. Joseph Hospital-Bellingham
10	Providence Gen Med Center - Pacific	56	Mid-Valley Hospital
11	Harborview Medical Center	57	Coulee Community Hospital
12	St. Joseph Medical Center - Tacoma	58	Mason General Hospital
13	Enumclaw Community Hospital	59	Whitman Hospital and Medical Center
14	Ballard Community Hospital	60	Valley Medical Center
15	Deaconess Medical Center	61	Whidbey General Hospital
16	Olympic Medical Hospital	62	St. Luke's Rehabilitation Institute
17	Kennewick General Hospital	63	Cascade Medical Center - Leavenworth
18	Walla Walla General Hospital	64	Providence St. Peter Hospital
19	Columbia Basin Hospital	65	Kadlec Medical Center
20	Prosser Memorial Hospital	66	Sacred Heart Medical Center
21	St. Mary Medical Center	67	Evergreen Healthcare
22	Forks Community Hospital	68	Lake Chelan Community Hospital
23	Willapa Harbor Hospital	69	Ferry County Memorial Hospital
24	Yakima Valley Memorial Hospital	70	Central Washington Hospital
25	Grays Harbor Community Hospital	71	Group Health Eastside
26	Samaritan Healthcare	72	Southwest Washington Medical Ctr
27	Ocean Beach Hospital	73	Pullman Regional Hospital
28	Odessa Memorial Hospital	74	Morton General Hospital
29	Good Samaritan Community Healthcare	75	Mary Bridge Children's Hospital & Health Ctr
30	Garfield County Hospital District	76	Tacoma General Hospital
31	Providence Everett Medical Center	77	Valley Hospital and Medical Center
32	Jefferson General Hospital	78	Auburn Regional Medical Center
33	Community Hospital	79	Mark Reed Hospital
34	Skyline Hospital	80	Providence Centralia Hospital
35	Yakima Regional Medical Center	81	Mount Carmel Hospital
36	Valley General Hospital	82	St. Joseph's Hospital-Chewelah
37	Cascade Valley Hospital - Arlington	83	Snoqualmie Valley Hospital
38	North Valley Hospital	84	Capital Medical Center
39	Tri-State Memorial Hospital	85	Sunnyside Community Hospital
40	East Adams Rural Hospital	86	Toppenish Community Hospital
41	Othello Community Hospital	87	St. Francis Hospital
42	Highline Community Hospital	88	Wenatchee Valley Hospital
43	University of Washington Medical Ctr.	89	United General Hospital
44	Quincy Valley Medical Center	90	Skagit Valley Hospital
45	Northwest Hospital	91	Legacy Salmon Creek Hospital
46	Overlake Hospital Medical Center	92	Fairfax Hospital

Note. Group Health Central, Affiliated Health Services, Allenmore Community Hospital, Kindred Hospital Seattle, Dear Park Health Center & Hospital, Regional Hospital for Respiratory & Complex Care, Seattle Cancer Care Alliance, Lourdes Counseling Center, West Seattle Psychiatric Hospital, and Puget Sound Behaviorial Health not included in study sample despite being listed on the Washington State Department of Health hospital database.

Table 3.2
Washington State Hospitals included in study sample, n=55

DMU #	Hospital Name
1	Swedish Medical Center - Seattle
2	Swedish Medical Center - Providence
3	Virginia Mason Medical Center
4	Lourdes Medical Center
5	Peacehealth St. John Medical Center
6	Harborview Medical Center
7	St. Joseph Medical Center - Tacoma
8	Deaconess Medical Center
9	Olympic Medical Hospital
10	Kennewick General Hospital
11	Walla Walla General Hospital
12	St. Mary Medical Center
13	Willapa Harbor Hospital
14	Yakima Valley Memorial Hospital
15	Grays Harbor Community Hospital
16	Samaritan Healthcare
17	Good Samaritan Community Healthcare
18	Providence Everett Medical Center
19	Jefferson General Hospital
20	Yakima Regional Medical Center
21	Valley General Hospital
22	Cascade Valley Hospital - Arlington
23	Highline Community Hospital
24	University of Washington Medical Ctr.
25	Northwest Hospital
26	Overlake Hospital Medical Center
27	St. Clare Hospital
28	Island Hospital
29	Stevens Healthcare
30	Holy Family Hospital
31	Harrison Medical Center
32	St. Joseph Hospital-Bellingham
33	Mason General Hospital
34	Valley Medical Center
35	Whidbey General Hospital
36	Kadlec Medical Center
37	Sacred Heart Medical Center
38	Evergreen Healthcare
39	Lake Chelan Community Hospital
40	Central Washington Hospital
41	Southwest Washington Medical Ctr
42	Pullman Regional Hospital
43	Tacoma General Hospital
44	Valley Hospital and Medical Center
45	Auburn Regional Medical Center
46	Providence Centralia Hospital
47	St. Joseph's Hospital-Chewelah
48	Snoqualmie Valley Hospital
49	Capital Medical Center
50	Sunnyside Community Hospital
51	Toppenish Community Hospital
52	St. Francis Hospital
53	United General Hospital
54	Skagit Valley Hospital
55	Legacy Salmon Creek Hospital

Measures

Output measures

Technical efficiency

Hospitals will be assumed to produce three types of outputs: adjusted admissions, total outpatient visits, and training full-time equivalents (FTEs). Adjusted admissions are the total number of hospital inpatient admissions for 2007, adjusted using the Medicare case mix index for that hospital for the respective year. Total outpatient visits include all visits to the Emergency Room and outpatient facilities for 2007. Training FTEs include all medical and dental trainee FTEs and other professional FTEs trained for 2007. The training FTEs were the only data that was pulled from the CMS Cost Report database, the remainder of the technical efficiency outputs were taken from the Washington DOH database.

Quality

The quality measures that are derived from the CMS website include measures that gage the quality of processes, outcome, and patient satisfaction. The same measures that Ozcan and Nayar (2008) used: (1) percent of patients given initial antibiotic timing, (2) percent of patients given oxygenation assessment, and (3) percent of patients given pneumococcal vaccination, will be incorporated into the quality model. These three quality measures were chosen, because they had the highest percentage of completion rate compared to all the other measures. All these measures are readily available on the CMS Hospital Compare website, which are downloadable into a Microsoft Access spreadsheet for further analysis.

Input measures

The input measures included in this thesis are hospital size (staffed beds), supply (operating expenses), total FTEs, and total assets. Hospital size is measured by the total number of hospital beds set up and staffed for 2007. Supply is measured by operational expenses, which did not include payroll, capital, or depreciation expenses. Total FTEs are the amount of full-time and part-time staff that is employed combined. Lastly, total assets is based off the submitted line item on the year-end report. This information is provided by the Washington State Department of Health statistical database, which is an unaudited source of information and is subject to inaccuracies posed by any public information prior to audit.

Table 3.3
DEA Model Input and Output Variables & Definitions

#	Variable	Operational Definition
	Inputs	
1	Hospital Size	The daily average complement of beds (excluding bassinets) fully staffed during the reporting period. Staffed beds are those beds set up, staffed, equipped, and in all respects ready for use by patients remaining in the hospital overnight. Hospitals typically staff those beds currently occupied by inpatients, plus an increment for unanticipated admissions (WDOH, 2009).
2	Supply	An expense incurred in conducting the ordinary major activities of an enterprise, usually excluding "nonoperating" expense or income deductions (WDOH, 2009).
3	FTEs	An objective measurement of the personnel employed in an institution in term of full-time labor capability. To calculate the number of full-time equivalent employees, sum all hours for which employees were paid (whether worked or not) during the year and divide by 2080 (WDOH, 2009).
4	Total Assets	Any owned physical object (tangible) or right (intangible) having economic value to its owner; an item or source of wealth expressed, for accounting purposes, in terms of its cost, depreciated cost, or, less frequently, some other value; hence, any cost benefiting a future period (WDOH, 2009).
	Outputs	
Technical Efficiency		
1	Adjusted Admissions	Total Admissions x Case Mix Index
2	Outpatient Visits	isits to the hospital by patients who are not lodged in the hospital while receiving medical, dental, or other services. Multiple services provided during a single encounter are recorded as one outpatient visit (WDOH, 2009).
3	Training FTEs	The total number of FTE residents. Compute this amount in accordance with 42 CFR 413.86(f), (g), and (h) (CMS Cost Report, 2010)
Quality		
4	Antibiotics	Percent of Pneumonia Patients Given Initial Antibiotic(s) within 6 Hours After Arrival
5	Oxygenations	Percent of patientes given oxygenation assessment
6	Vaccinations	Percent of Pneumonia Patients Assessed and Given Pneumococcal Vaccination

Data Analysis Strategy

Analysis of technical efficiency and quality

Two separate models are needed in order to compare efficiencies with or without the use of quality as an output. Model 1 (Figure 3.1) consists of the four inputs stated above (hospital size, supply, total assets and staffing FTEs) and three outputs (adjusted discharges, total outpatient visits, and training FTEs). Model 2 (Figure 3.2) incorporates quality. It has the same inputs as Model 1, but has three additional outputs (the three quality measures) plus the three outputs included in model 1, making a total of six outputs. After data are analyzed under both models, it will be plotted to depict distribution. A non-normal distribution is expected so a Spearman rank correlation coefficient will be computed. A negative coefficient will be obtained if the alternative hypothesis proves true and a positive coefficient if efficiency and quality vary together in the same direction as the null hypothesis would indicate.

DEAfrontier software developed by *Sherman and Zhu* was used to perform the calculations for DEA (Sherman & Zhu, 2006). This decision came after examining the various capabilities of all the DEA software from a state-of-the-art survey put together by Richard Barr (Barr, 2003).

Figure 3.1
Model 1: Technical Efficiency

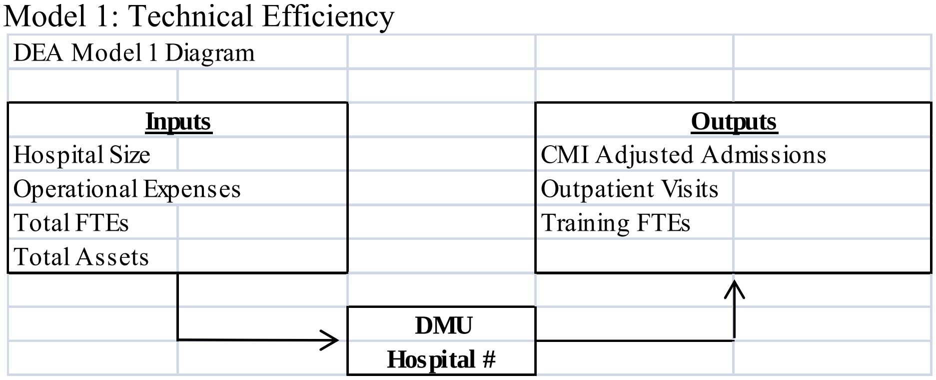
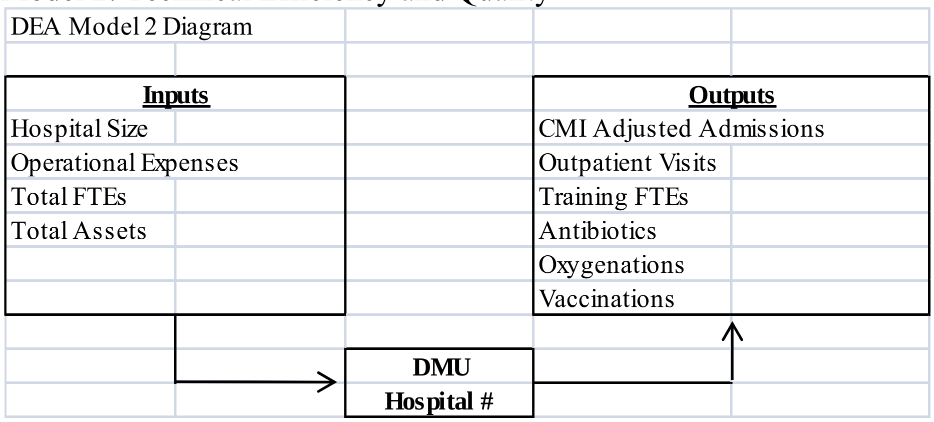


Figure 3.2
Model 2: Technical Efficiency and Quality



Slack Analysis

In performing a slack analysis, inefficient hospitals inputs and outputs are analyzed to see how they would need to change in order to help the hospital reach the efficiency frontier, which is the optimal level of efficiency. This is especially a useful tool for managers who are benchmarking themselves against their competition and want to see how they can best raise their DEA scores to the efficiency frontier. As a corrective action, inputs need to be decreased while outputs need to increase. Examining the slack analysis for each hospital may show opportunities for improvement in inputs or outputs or both. Aligning your strategic goals and budget with benchmarks based on your slack analysis allows for practical application of DEA for benchmarking purposes to help reach the efficiency frontier (Stewart, 2010).

Summary

This study is a replication of Ozcan and Nayar and compares two models, Model 1 which examines technical efficiency, and Model 2, which has the same inputs and outputs as Model 1, but incorporates an additional 3 outputs associated with quality. These two models are then correlated using a Spearman Rank Coefficient test to examine if any relationship exists between technical efficiency and quality.

CHAPTER FOUR

This chapter is divided into three sections. The first section discusses the results from Model 1. The next section discusses the results of Model 2 and compares them to Model 1 including a Spearman Rank Coefficient test. Lastly, the slack analysis was conducted on Model 2.

Results/Analysis

Out of the 92 acute care hospitals in Washington State, only 55 of them had complete quality data for 2007 as reported from the Hospital Compare database. This sample of 55 hospitals comprised the data set used for analysis.

Analysis of Technical Efficiency and Quality

Model 1: Technical Efficiency, CRS & Input Oriented

When the 55 DMUs that had complete data available for 2007 were incorporated into the four input/three output model, it was found that 12 DMUs were efficient (efficiency score = 1) and 43 DMUS (efficiency < 1) were inefficient (Table 4.1). The average efficiency score for the inefficient DMUs was 0.80 for 2007. The overall average efficiency score for the entire sample was 0.85 for 2007.

The average inputs for the efficient hospitals for 2007 were 165.2 beds, $212,540,967 operating expenses, 1,273.7 total FTEs, and $200,674,632 total assets (Table 4.2). The efficient hospitals outputs for 2007 were 20,965 CMI adjusted admissions, 220,708 outpatient visits, and 39.0 training FTEs. On the inefficient side, the average inputs for the hospitals for 2007 were 169.0 beds, $185,026,293 operating expenses, 1,196.0 total FTEs, and $226,269,713 total assets.

The inefficient outputs for 2007 were 16,586 CMI adjusted admissions, 158,974 outpatient visits, and 9.1 training FTEs.

Table 4.1

Model 1. Constant returns to scale input oriented technical efficiency
2007

Hospitals	Number	Percentage	Average Efficiency Score
Efficient	12	21.8%	1.00000
Inefficient	43	78.2%	0.80404
All	55	100.0%	0.84680

Table 4.2

Input and Output Data of Efficient vs. Inefficient Facilities; Model 1 (n = 55)
2007

	Outputs			**Inputs**			
	Adjusted Admissions	Outpatient Visits	Training FTEs	Total Beds	Operating Expenses (in 000's)	Total FTEs	Total Assets (in 000's)
All Facilities							
Mean	17,541	172,443	15.6	168.2	191,029	1,212.9	220,685
SD	15,633	167,249	54.1	139.0	184,255	1,138.3	243,340
Efficient							
Mean	20,965	220,708	39.0	165.2	212,541	1,273.7	200,675
SD	20,142	232,241	90.8	119.0	210,940	1,276.3	223,777
Inefficient							
Mean	16,586	158,974	9.1	169.0	185,026	1,196.0	226,270
SD	14,271	144,869	37.5	145.4	178,401	1,112.6	250,742

Model 2: Technical Efficiency and Quality, CRS & Input Oriented

When the 55 DMUs that had complete data available for 2007 were incorporated in the four input/six output model, it was found that 17 DMUs were efficient (efficiency score = 1) and 43 DMUS (efficiency < 1) were inefficient. The average efficiency score for the inefficient DMUs was 0.84 for 2007. The overall average efficiency score for the entire sample 0.89 for 2007.

Table 4.3

Model 2. CRS input orientation technical efficiency and quality
2007

Hospitals	Number	Percentage	Average Efficiency Score
Efficient	17	30.9%	1.00000
Inefficient	38	69.1%	0.83952
All	55	100.0%	0.88912

The average inputs for the efficient hospitals for 2007 were 114.5 beds, $150,252,373 operating expenses, 894.4 total FTEs, and $141,494,555 total assets. The efficient outputs for 2007 were 14,433 CMI adjusted admissions, 161,741 outpatient visits, 27.5 training FTEs, 100.0% oxygenation quality score, 94.6% antibiotics quality score, and 73.9% vaccination quality score. On the inefficient side, the average inputs for the hospitals for 2007 were 191.1 beds, $209,363,168 operating expenses, 1354.3 total FTEs, and $255,753,471 total assets. The inefficient outputs for 2007 were 18,985 CMI adjusted admissions, 178,442 outpatient visits, 10.3 training FTEs, 100.0% oxygenation quality score, 94.2% antibiotics quality score, and 73.7 vaccination quality score.

Table 4.4

Input and Output Data of Efficient vs. Inefficient Facilities model 2
technical efficiency and quality model (n=55)
2007

	Outputs						**Inputs**			
	Adjusted Admissions	Outpatient Visits	Training FTEs	Oxygenation	Antibiotics	Vaccination	Total Beds	Operating Expenses (in 000)	Total FTEs	Total Assets (in 000)
All Facilities										
Mean	17,578	173,280	15.6	100.0	94.3	73.8	167.4	191,093	1,212.2	220,437
SD	15,597	166,526	54.1	0.1	5.1	15.5	139.7	184,208	1,139.1	243,552
Efficient										
Mean	14,433	161,741	27.5	100.0	94.6	73.9	114.5	150,252	894.4	141,495
SD	19,169	213,637	77.5	0.0	6.9	18.1	119.4	198,501	1,184.2	206,567
Inefficient										
Mean	18,985	178,442	10.3	100.0	94.2	73.7	191.1	209,363	1,354.3	255,753
SD	13,767	143,692	39.8	0.2	4.2	14.4	143.0	177,130	1,104.6	252,933

The magnitude of correlation between the efficiency scores for each DMU in the quality model and the technical efficiency model was measured by using the spearman rank correlation coefficient. The coefficient obtained was 0.54 for 2007 from SPSS.

Table 4.5

Model 1 & Model 2 Spearman Rank Coefficient for 2007

Year		Spearman Rank Coefficient
2007	=	0.542

Slack Results

The slack results indicate that only 18.2% of the hospitals were efficient in both model 1 which did not incorporate quality and model 2 which incorporated quality as an output (Table 4.6). There were 16.3% of hospitals which were efficient according to one model but not the other, of which 3.6% were efficient using model 1 and 12.7% were efficient using model 2. The majority of the hospitals were inefficient according to both models at 65.5%. Furthermore, the magnitude of the changes is important to note, in that when quality was incorporated as an output, the average DEA score increased (Table 4.7). This may or may not be a product of adding more outputs which is theoretically proven to increase DEA scores (Sherman & Zhu, 2006).

Further breaking down the number of hospitals that were inefficient for specific measures as incorporated in model 2 (both quality and efficiency outputs), we can see that there is a large disparity in the quality and efficiency outputs as far as the number which could be improved (Table 4.8). The number of hospitals which could decrease their inputs to become efficient for model 2 as a percentage of the total sample were as follows: Staffed beds 14.5%, Operating expense 20.0%, Total FTEs 12.7%, and Total Assets 30.9%. The number of hospitals which could increase their outputs to become efficient for model 2 as a percentage of the total sample were as follows: Adjusted admission 5.5%, Outpatient visits 52.7%, Training FTEs 29.1%, Oxygenation 67.3%, Antibiotics 63.6%, and Vaccinations 63.6%.

Table 4.6

Comparison of Model 1 and 2 for Efficiency

2007

Hospitals Efficiency	Number	Percentage
TE & Q Efficent	10	18.2%
TE but NOT Q Efficient	2	3.6%
Q Efficient but NOT TE	7	12.7%
Not Efficient in either model	36	65.5%
n =	55	

Table 4.7

Magnitude of Efficiency

Magnitude of Efficiency

2007

	Model 1		**Model 2**	
Efficiency Level	Hospitals	%	Hospitals	%
1.0	12	21.8%	17	30.9%
>= 0.9	13	23.6%	13	23.6%
>= 0.8	13	23.6%	15	27.3%
>= 0.7	5	9.1%	5	9.1%
>= 0.6	7	12.7%	3	5.5%
>= 0.5	4	7.3%	2	3.6%
>= 0.4	1	1.8%	0	0.0%
Total	55	100.0%	55	100.0%

Table 4.8

Model 2. Inefficient Hospital Inputs/Outputs Slack Distributions

2007

Measures	**Number Inefficient**	**Percentage**
Inputs		
Staffed Beds	8	14.5%
Operating Expenses	11	20.0%
Total FTEs	7	12.7%
Total Assets	17	30.9%
Outputs		
Technical Efficiency		
Adj Admissions	3	5.5%
OP Visits	29	52.7%
Training FTEs	16	29.1%
Quality		
Oxygenation	37	67.3%
Antibiotics	35	63.6%
Vaccination	35	63.6%

Table 4.9

Washington State Hospital Model Efficiency Comparison, n=55

DMU #	Hospital Name	TE	TE & Q
1	Swedish Medical Center - Seattle	0.62	0.62
2	Swedish Medical Center - Providence	1.00	1.00
3	Virginia Mason Medical Center	1.00	1.00
4	Lourdes Medical Center	0.99	0.97
5	Peacehealth St. John Medical Center	0.93	0.93
6	Harborview Medical Center	0.92	0.92
7	St. Joseph Medical Center - Tacoma	0.80	0.79
8	Deaconess Medical Center	1.00	1.00
9	Olympic Medical Hospital	0.89	0.89
10	Kennewick General Hospital	0.97	0.88
11	Walla Walla General Hospital	0.57	1.00
12	St. Mary Medical Center	1.00	1.00
13	Willapa Harbor Hospital	0.68	1.00
14	Yakima Valley Memorial Hospital	0.84	0.83
15	Grays Harbor Community Hospital	0.93	0.91
16	Samaritan Healthcare	0.63	0.68
17	Good Samaritan Community Healthcare	0.74	0.74
18	Providence Everett Medical Center	0.86	0.85
19	Jefferson General Hospital	1.00	1.00
20	Yakima Regional Medical Center	1.00	1.00
21	Valley General Hospital	0.89	0.80
22	Cascade Valley Hospital - Arlington	0.88	0.88
23	Highline Community Hospital	1.00	1.00
24	University of Washington Medical Ctr.	1.00	1.00
25	Northwest Hospital	0.95	0.95
26	Overlake Hospital Medical Center	0.83	0.83
27	St. Clare Hospital	0.94	0.92
28	Island Hospital	1.00	1.00
29	Stevens Healthcare	0.92	0.85
30	Holy Family Hospital	1.00	0.97
31	Harrison Medical Center	0.83	0.82
32	St. Joseph Hospital-Bellingham	0.83	0.82
33	Mason General Hospital	0.70	1.00
34	Valley Medical Center	0.83	0.83
35	Whidbey General Hospital	1.00	1.00
36	Kadlec Medical Center	0.89	0.89
37	Sacred Heart Medical Center	0.80	0.80
38	Evergreen Healthcare	0.57	0.57
39	Lake Chelan Community Hospital	0.59	1.00
40	Central Washington Hospital	0.85	0.82
41	Southwest Washington Medical Ctr	0.71	0.71
42	Pullman Regional Hospital	0.63	0.96
43	Tacoma General Hospital	0.57	0.57
44	Valley Hospital and Medical Center	1.00	0.96
45	Auburn Regional Medical Center	0.99	0.96
46	Providence Centralia Hospital	0.94	0.94
47	St. Joseph's Hospital-Chewelah	0.76	1.00
48	Snoqualmie Valley Hospital	0.46	0.85
49	Capital Medical Center	0.78	0.77
50	Sunnyside Community Hospital	0.68	1.00
51	Toppenish Community Hospital	0.93	0.96
52	St. Francis Hospital	0.86	0.84
53	United General Hospital	0.97	1.00
54	Skagit Valley Hospital	0.93	0.93
55	Legacy Salmon Creek Hospital	0.69	0.69

CHAPTER FIVE

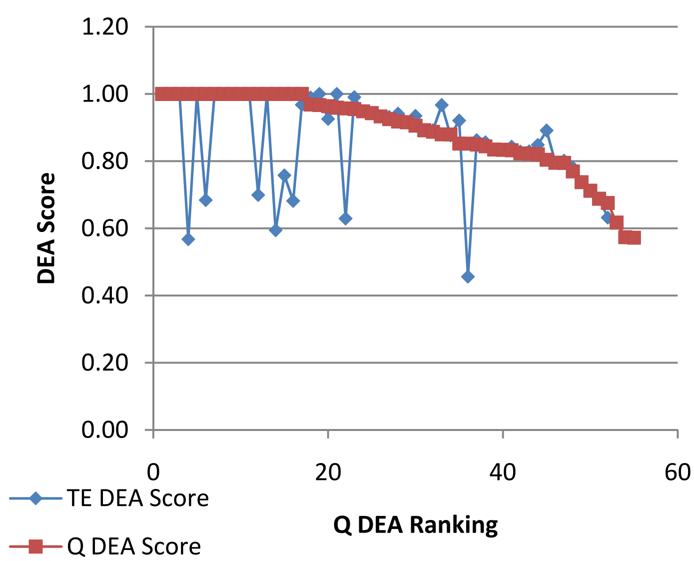
Conclusion

Discussion of Key Thesis Findings

The most important finding that came out of this research was a validation of Ozcan and Nayar showing that indeed, hospitals which were efficiently producing quantitative outputs (adjusted admissions, outpatient visits and training FTEs), were also shown to produce quality outcomes efficiently as well (% of pneumonia patients receiving oxygenation assessments, initial antibiotics timely and pneumococcal vaccinations).

As shown in Figure 5.1, there is a positive relationship between Model 1 of technical efficiency and Model 2 of quality, thus providing evidence that there is no quality-efficiency trade-off, but rather hospitals which are technically efficient are also efficient in terms of quality as well. This bodes well for the current push by CMS and payers to provide financial incentives to providers for high quality outcomes to the patients served.

Figure 5.1
Comparison of Technical Efficiency and Quality
2007



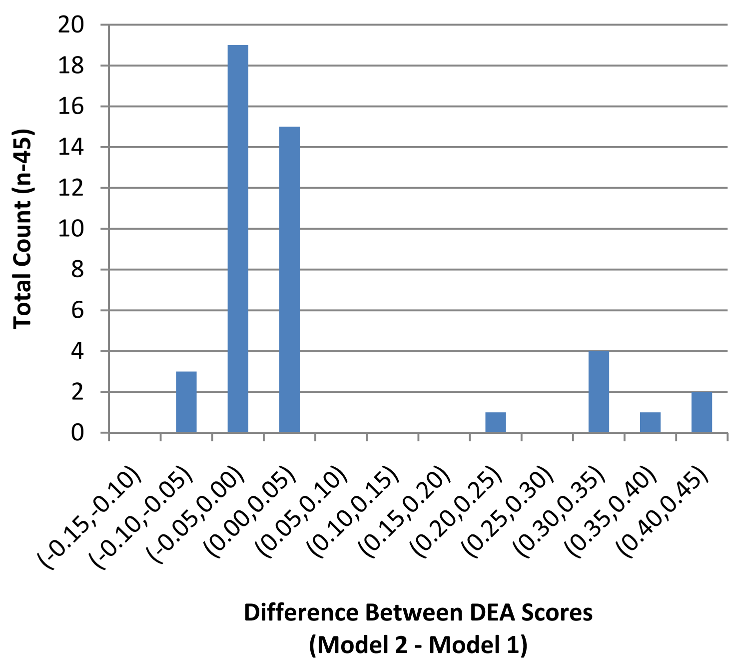
Rank	TE DEA Score	Q DEA Score	Rank	TE DEA Score	Q DEA Score
1	1.00	1.00	29	0.92	0.92
2	1.00	1.00	30	0.93	0.91
3	1.00	1.00	31	0.89	0.89
4	0.57	1.00	32	0.89	0.89
5	1.00	1.00	33	0.97	0.88
6	0.68	1.00	34	0.88	0.88
7	1.00	1.00	35	0.92	0.85
8	1.00	1.00	36	0.46	0.85
9	1.00	1.00	37	0.86	0.85
10	1.00	1.00	38	0.86	0.84
11	1.00	1.00	39	0.83	0.83
12	0.70	1.00	40	0.83	0.83
13	1.00	1.00	41	0.84	0.83
14	0.59	1.00	42	0.83	0.82
15	0.76	1.00	43	0.83	0.82
16	0.68	1.00	44	0.85	0.82
17	0.97	1.00	45	0.89	0.80
18	0.99	0.97	46	0.80	0.80
19	1.00	0.97	47	0.80	0.79
20	0.93	0.96	48	0.78	0.77
21	1.00	0.96	49	0.74	0.74
22	0.63	0.96	50	0.71	0.71
23	0.99	0.96	51	0.69	0.69
24	0.95	0.95	52	0.63	0.68
25	0.94	0.94	53	0.62	0.62
26	0.93	0.93	54	0.57	0.57
27	0.93	0.93	55	0.57	0.57
28	0.94	0.92			

Managerial Implications and Slack Analysis

As quality and technical efficiency are shown to vary together, managers should take notice. A manager who can objectively demonstrate superior level of performance or efficiency in the delivery of demonstrably higher quality of care outputs, that manager could be in a stronger position to compete for business opportunities in the healthcare marketplace (Galterio, Helton, Langabeer & DelliFraine, 2009). Thus DEA should be incorporated in the scorecards that most hospitals use to benchmark themselves against other hospitals. It is noteworthy to mention that this analysis was done at a hospital level and that departmental managers may want to consider using different, department specific, measures to assess and benchmark their efficiency relative to other similar departments (Magnussen & Nyland, 2008). Hospital managers typically examine profitability, services offered, and patient populations served, which then is compared with resources consume to evaluate organization efficiency, but most of the time this analysis tends to take place at the hospital level, which ignores the fact that some departments managers, like nursing managers, would want to benchmark themselves only against other nursing units. Of course, the availability of such data may limit opportunities for departmental analysis, but at in a large health system this may be possible especially with the ever increasing technological capabilities of information technology. Thus, DEA can assist managers in making a fairer assessment of operational efficiency when traditional operating metrics might not reflect the true operating efficiency (Galterio et al, 2009).

An important point needs to be made regarding the magnitude of DEA scores and their distribution. When accounting for only the hospitals which were inefficient in one or both of the models (n = 45) and calculating the difference between Model 2 and Model 1, to assess the role that quality played in the difference, we find the following distribution in Figure 5.2. This bimodal distribution with the first mode centered around 0.00 and the second centered around 0.30, further emphasizes the importance of focusing on quality improvement. Hospitals which had low DEA scores in Model 1, made a big jump in Model 2 when quality was incorporated. These hospitals are dedicating resources (inputs) at the expense of their technical efficiency, hence the lower score in Model 1, but when their DEA score is calculated in Model 2, their efficiency increases. This may be a reflection of the push by CMS to start rewarding hospitals based on quality rather than volume. This should be encouraging news to the manager of a hospital who appeared to be technically efficient, but when quality was incorporated increased their efficiency scores dramatically, and bodes well to the competitiveness of such hospitals in an environment that is endeavoring to reward more and more based on quality rather than quantity.

Figure 5.2
Distribution of DEA Score Difference Between Model 2 and Model 1



Limitations

There are four main limitations to this thesis. First, the findings of this study are based on Washington State only, and may not be externally valid to other states or the country as a whole, because of the non-uniform distribution of costs as emphasized in the Dartmouth Atlas studies regarding the variability of cost and quality of care. Secondly, all the measures included in the models are self-reported which may bring about some form of response bias. Thirdly, the analysis was limited to only pneumonia process measures and may not be generalizable to all hospitals. Lastly, the issue of multicolinearity is a potential problem with the similar output variables between the two models. Statistically this may skew the results to show a false-positive relationship when indeed one does not exist. A third model was constructed, with only quality measures as outputs and after running a spearman rank coefficient against the first model, a result of -0.031 was generated, which means that there is no relationship between quality and efficiency. Though this is a significant finding, it should be noted that this study's focus was on replicating *Ozcan and Nayar's* paper, which chose this model as a benchmarking and real-world application tool for managers. Having a single model to compare your hospital as a manager against other hospitals has much more application than having two separate models for efficiency and quality, especially as the trend in healthcare is towards reimbursing on a quality basis.

Though this study focuses on examining the relationship between quality and efficiency, it is noteworthy to mention that benchmarking a hospital at a single point in time may be misleading because the unit may perform well in one time period but under-perform over the long-run (Weng, Wu, Blackhurst & Mackulak, 2009). Therefore, if time is not considered, the efficiency results can be biased (Weng et al, 2009).

Nevertheless, this study was able to achieve significant explanatory power despite the limitations discussed above. The study was able to add to the field of knowledge regarding the relationship of quality and efficiency by showing that there is a positive correlation between the two.

Future Studies

Further research should focus on developing tools for decision makers to use in helping improve healthcare efficiency. The federal government recognized the importance of a uniform distribution of research by devoting over a billion dollars to the Agency of Healthcare Research and Quality to focus on comparative effectiveness research. Developing a network of information channels to help disseminate and standardize healthcare delivery can help hospitals in reacting more quickly and helping them reach the efficiency frontier. Implicit in this argument is the reduction of waste. Many quality improvement initiatives like Toyota's lean approach, total quality management, and six sigma are readily adopted by hospitals, but at what point is the investment in increasing quality actually affecting your overall efficiency, because of the increased resources needed to employ such programs? Further studies examining this trade-off are important as well, because letting managers know the importance in quality is not enough. Lastly, studies performed on a national level with bigger sample sizes are needed to provide more validity to this study's conclusion.

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Appendix

APPENDIX A

Table A1
DEA Model used

DEA linear programming model developed by Charnes, Cooper, and Rhodes (1978):

$$\max E_k = \sum_{r=1}^{s} w_r Y_{rk}$$

$$\text{subject to} \quad \sum_{i=1}^{m} \mu_i X_{ik} = 1$$

$$\sum_{r=1}^{s} w_r Y_{rj} - \sum_{i=1}^{m} \mu_i X_{ij} \leq 0$$

$$w_r \geq \varepsilon, \mu_r \geq \varepsilon$$

where, Ek : the measure of productivity or efficiency of hospital "k," the hospital in the set of j : 1,. . .,55 hospitals rated relative to the others for the hospital efficiency analysis; Yrk : The amount of output "r" produced by hospital "k" during the period of observation; Xik : The amount of input "i" used by hospital "k" during the period of observation; Yr j : The amount of output "r" produced by hospital "j" during the period of observation; Xi j : The amount of input "i" used by hospital "j" during the period of observation; wr : The coefficient or weight assigned to output r computed in the solution to the DEA model; μi : The coefficient or weight assigned to input i computed in the solution to the DEA model; m : The number of inputs used by the hospitals (four in the hospital application); s : The number of outputs produced by the hospitals (three in model 1 and six in model 2 in the hospital application); ε : An infinitesimal positive number that constrains the input and output coefficients to be positive, eliminating the possibility that they will be given a zero relative value in the DEA results.

The objective function of this model maximizes the productivity or efficiency rating E for hospital k. This is subject to the constraint that when the same set of w and coefficients are applied to all hospitals being compared, no hospital will be more than 100 percent efficient and the coefficient values will be positive and non zero.

Adapted from Zhu and Sherman, 2006