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DOI: 10.1111/1475-6773.12468
RESEARCH ARTICLE

Predictors of Gaps in Patient Safety and Quality in U.S. Hospitals

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Objective. To explore predictors of gaps between observed and best possible Hospital Compare scores in U.S. hospitals.

Data Sources. American Hospital Association Annual Survey; Area Resource Files; Centers for Medicare and Medicaid Services Medicare Provider and Analysis Review; and Hospital Compare data.

Study Design. Using Stochastic Frontier Analysis and secondary cross-sectional data, gaps between the best possible and actual scores of Hospital Compare quality measures were estimated. Poisson regressions were used to ascertain financial, organizational, and market predictors of those gaps.

Data Extraction. Data were cleaned and matched based on hospital Medicare IDs. All U.S. hospitals that matched on analysis variables in 2007 were in the study (1,823–2,747, depending upon gap variable).

Principal Findings. Most hospitals have a greater than 10 percent gap in quality indicators. Payer mix, registered nurse staffing, size, case mix index, accreditation, being a teaching hospital, market competition, urban location, and region were strong predictors of gaps, although the direction of the association with gaps was not uniform across outcomes.

Conclusions. A significant percentage of hospitals have gaps between their best possible and observed quality scores. It may be better to use gap scores than observed scores in payments systems. More SFA research is needed to know how to lower gaps through changes in hospital and market characteristics.

Key Words. Stochastic Frontier Analysis, predictors of gaps in hospital quality

Public reporting and value-based purchasing systems use measures of quality based on averages or rankings of observed quality scores (Rosenthal and Frank 2006; Lindenauer et al. 2007; Ryan 2009). These methods provide a limited amount of information on how well hospitals are performing (Meddings and McMahon 2008). A method that provides information about how closely each hospital approaches its own best possible quality scores (or, alternatively, best possible outcomes) could provide additional information, especially to payers. Hospitals could be compared based on this rating, changes in

their performance could be tracked over time, and benchmarks could be set based on the degree to which hospitals were achieving their own best possible quality scores given their resources. For payers, the method would be superior to one that ranks hospitals based on external criteria because it would not penalize hospitals that have fewer resources, but would instead reward them based on how they perform *given* their resources. In addition, once a hospital's individualized quality ratings are determined, the results could also be used to assess factors that contribute to the gap in quality (difference between the observed quality score and the best possible score) to reduce that gap.

One method for estimating gaps in quality is Stochastic Frontier Analysis (SFA). SFA assesses gaps in performance by analyzing the extent to which a producer makes best use of a given a set of inputs (capital, labor, and technology) in the productive process. "Productive process" is one that generates outcomes for a "producer"—the entity that engages in production. The measured gap between what the producer is capable of and the actual performance is called technical inefficiency, and it is due to unmeasured managerial decisions, employee actions, and technical problems within the firm.

SFA deviates from standard regression models by having two error terms, the usual one which indicates noise, and a second one which represents the gap and is notated as u_i . SFA starts with the idea that an actual outcome (e.g., a quality score or, for instance, a 30-day readmission rate) equals the sum of the best possible outcome and u_i . So, estimating a u_i for each hospital indicates the gap between what each hospital is capable of doing (its best possible outcome, also called the "frontier") and its actual outcome.

SFA is most commonly used to estimate efficiency, but it has also been used to estimate quality gaps in non-health care areas. Examples include performance gaps in investment (Reis 2005), management (Chen 2007), and national governance (Owen 2013). It has also been used to estimate other types of gaps (neither quality or efficiency) such as market effort by women (Hofler and Sen forthcoming); employer and employee information in the labor market (Polachek and Yoon 1987); choosing recreational destinations (Hofler et al. 2010); alliances in biotechnology markets (Kinukawa and Moto-

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hashi 2010); optimism and pessimism (Groot and van den Brink 2007); and job satisfaction (Poggi 2010).

In health care, SFA has estimated efficiency gaps in nursing homes and hospitals (Hofler and Folland 2001; Mutter, Rosko, and Wong 2008; Rosko and Mutter 2008), but to our knowledge, it has not been used to estimate quality gaps. This study uses SFA to estimate the gaps in seven Centers for Medicare and Medicaid Services (CMS) hospital quality and safety indicators (part one), and it explores the factors that contribute to those gaps (part two).

BACKGROUND

Use of Stochastic Frontier Analysis to Measure Gaps in Hospital Quality

Two factors must be at work for SFA to be applicable to estimating hospital quality gaps (Kumbhakar and Lovell 2003). First, hospitals must be utilizing inputs (capital, labor, and technology) to optimize (maximize or minimize) some outcome, such as minimizing 30-day readmissions. Second, hospital employees make decisions, take actions, and/or fail to do certain things that lead to a failure to optimize that outcome (technical inefficiency).

Both of these conditions are met for estimating gaps in quality in hospitals. Capital, labor, and technology are used to maximize quality patient outcomes and minimize patient adverse events (Bazzoli et al. 2007, 2008). Capital inputs in hospitals are the physical and monetary resources of the organization. Labor inputs are the human resources such as physicians, nurses, technicians, and other staff. Technology is the state of clinical or scientific knowledge embodied in a hospital, as well as available diagnostic equipment and procedures.

Capital inputs provide a well-designed physical infrastructure and the financial resources to maintain and expand physical, technical, and human resources (Bazzoli et al. 2008). Net revenue, profit margin, payer mix, and system membership are capital resources that have been linked to quality (Bazzoli et al. 2007; Mutter, Valdmanis, and Rosko 2010; Carretta et al. 2013; Eappen et al. 2013; Jiang, Friedman, and Jiang 2013). Labor inputs enhance quality by putting to use the capital and technology inputs, and through their skills and expertise (Bazzoli et al. 2007, 2008). Total personnel, physician and RN/patient ratio, and nurse skill mix (RNs/total nurses) are indicators of labor inputs that could impact quality (Aiken et al. 2003; Unruh 2003; Cho and Yun 2009). Technology enhances quality by providing methods for employing the labor and capital inputs (Bazzoli et al. 2007). Technology

indices have been linked to quality in some studies (Mukamel, Zwanziger, and Tomaszewski 2001; Volpp et al. 2005; and Bazzoli et al. 2007, 2008).

The attempt to maximize quality (minimize adverse events) may be negatively affected by factors such as administrative decision making and employee actions. These factors can be sources of inefficiencies in the use of the inputs in the production of quality. In other words, given input amounts, quality is dependent upon the decisions and actions in using those inputs. This is the source of the quality gap.

Quality is also affected by factors outside the control of the organization. These are environmental (background) effects that can create either better or worse operating situations, which affects the ability to optimize the outcome. One example is additional reporting requirements by a governmental agency (e.g., CMS) that takes time away from providing quality health care. Another example might be a requirement that a hospital prove meaningful usage of electronic health records, a time-consuming and nonproductive process. In regression analysis, these factors are considered to be noise and are captured in the error term. When assessing gaps in quality using SFA, these effects are not counted in the gap, but rather, like regression analysis, they go into a symmetric error term.

Studies of Predictors of Quality and Safety

Although this is the first study of predictors of *gaps* in quality and safety in hospitals, a number of studies examine influences on quality and safety. Organizational characteristics of hospitals that are often included in studies of quality are case mix index (CMI), ownership, RN staffing, nurse skill mix, region of operation, size, teaching status, and urban or rural setting. CMI is thought to affect quality negatively, as higher case mix indicates sicker patients with greater risk for poorer outcomes. However, if the quality measures are also risk-adjusted, it may not be significantly related to quality. Research tends to show a nonsignificant relationship (Bazzoli et al. 2007, 2008).

Research results for ownership, size, teaching status, region of operation, and urban or rural setting have been mixed. These characteristics are positively related to quality in some studies (Gowrisankaran and Town 2003; Unruh 2003; Escarce, Jain, and Rogowski 2006; Rogowski, Jain, and Escarce 2007; Harrison, Lambiase, and Zhao 2010; Carretta et al. 2013; Jiang, Friedman, and Jiang 2013), but negatively or nonsignificantly related in other studies (Bazzoli et al. 2007, 2008; Rogowski, Jain, and Escarce 2007; Chukmaitov

et al. 2009; Harrison, Lambiase, and Zhao 2010; Mutter, Valdmanis, and Rosko 2010; Maeng and Martsolf 2011; Smith et al. 2012).

RN staffing is usually measured as the number of RNs given the number of patients, patient days, or hours of patient care. Nurse skill mix is the proportion of RNs to the total number of all nurses. Greater values of these measures are fairly consistently related to higher quality (Bazzoli et al. 2007; Cho et al. 2009; Harrison, Lambiase, and Zhao 2010; Mark et al. 2004; Unruh 2003).

Joint Commission accreditation is not a common measure of predictors of quality. Being accredited by the Joint Commission could be a factor in a hospital's pursuit of quality as well as reimbursement, and therefore would be positively associated with quality. One study that examined this factor did find a positive relationship with quality (Gowrisankaran and Town 2003).

Market factors that have appeared in studies of hospital quality include hospital competition, Health Maintenance Organization (HMO) market share or penetration, and the percentage of hospitals that are for-profit in the area. Hospital competition and HMO market share or penetration tend to show a positive or nonsignificant relationship with quality (Gowrisankaran and Town 2003; Rogowski, Jain, and Escarce 2007; Bazzoli et al. 2008; Harrison, Lambiase, and Zhao 2010; Mutter, Valdmanis, and Rosko 2010; Maeng and Martsolf 2011; Jiang, Friedman, and Jiang 2013). Results are mixed for the percentage of hospitals that are for-profit in the area (Bazzoli et al. 2007).

Conceptual Framework

Based on the studies above, we developed a framework for an SFA of gaps in hospital quality (part one of the study), and predictors of those gaps (part two). Figure 1 illustrates this model. In part one, the inputs into quality are capital, labor, and technology (Bazzoli et al. 2007). Capital inputs are net revenue, profit margin, payer mix, and system membership. Labor inputs that capture both the quantity and quality of labor are total personnel expenses/patient admission and nurse skill mix (RNs/total nurses). Technology inputs are represented by an index of services the hospital provides (e.g., angioplasty, cardiac catheterization) (Harrison & Sexton, 2006).

In part one of the study, given a hospital's direct inputs, it could be expected to produce a certain level of quality. If that level of quality is not achieved, the hospital is operating in a way such that its actual quality and safety scores fall short of its estimated best possible values; that is, it has a quality gap. The SFA measures that gap between the expected best possible quality level, given inputs, and the actual level of quality.

Figure 1: Gaps and Predictors of Gaps in Quality and Safety

Other factors indirectly affect quality and safety through their influence on the process that leads to a gap. In our analysis, this relationship is analyzed in a separate second step after the gaps are estimated (part two of the study). Factors that are hypothesized to affect gaps in quality are the hospital's organizational characteristics and its market environment (Bazzoli et al. 2007, 2008). Hospital ownership, size, urban or rural setting, and other characteristics can affect production decisions and outcomes. For-profit hospitals, for example, may be less likely to use inputs in a way that promotes quality. Market factors affecting hospital quality could include HMO market share. Hospitals in areas with high HMO market share may compete to keep costs down, which may negatively affect the use of inputs and, therefore, quality (Bazzoli et al. 2007).

METHODS

Measures

Table 1 lists the measures for the two parts of this study, their operational definitions, and their data sources. First, the inputs and the observed quality and safety measures used in the SFA are listed. Next, the table presents the predictors of gaps in quality and safety, which are explanatory variables in the second step of the analysis. Finally, the estimated gaps in quality and safety from the SFA are listed. These form the response variables in the second step of the analysis.

Inputs and Observed Quality and Safety in SFA Analysis. Inputs were indicators of capital, labor, and technology. Capital indicators were net revenue/patient day, profit margin, payer mix (percent Medicare patients), and system membership (yes or no). For profit margin, we used the total margin: net income from total revenue/total revenue. Labor inputs were total personnel expenses/patient admission and RN full-time equivalents (FTEs)/total nurse FTEs. We were unable to include physician inputs due to lack of data. The technology indicator was a count of 12 technologies, which are listed in the table (Blegen, Vaughn, and Vojir 2008). To account for the possibility of a non-linear relationship between inputs and quality, we included squared terms for all of the continuous variables (net revenue, profit margin, total personnel expenses, nurse skill mix).

Observed quality and safety measures were seven CMS quality and safety measures from Hospital Compare: 30-day mortality and readmissions for heart failure and pneumonia, a composite patient safety indicator (PSI), and composite inpatient quality indicators (IQIs) for mortality due to surgical procedures and medical conditions (CMS, 2010, 2013). Thirty-day mortality and readmissions for heart failure and pneumonia are the risk-adjusted deaths or readmissions in the hospital in the population at risk divided by the population at risk (Krumholz et al. 2006; Keenan et al. 2008). The measures have been used as outcomes in several studies (Krumholz et al. 2006; Lindenauer et al. 2007; Keenan et al. 2008).

IQIs and PSIs are risk-adjusted hospital rates of mortality and patient safety events obtained from software that identifies the events based on ICD-9-CM diagnoses and procedures noted in the patient's discharge record (Elixhauser, Pancholi, and Clancy 2005; Laditka, Laditka, and Cornman 2005).

Table 1: Study Variables

	Variable	Definition	Source
Inputs in SFA capital	Net revenue	Net revenue/adjusted patient day	MCR
	Profit margin	Net income/revenue (revenue = total revenue from pt services + contributions + income investment)	MCR
	Payer mix	% Medicare patients	AHA
	System member	System membership, yes = 1, no = 0	AHA
Labor	Nurse skill mix	RN FTEs/total of all nurse FTEs (all nurses = RNs + licensed practical nurses + nursing assistants)	AHA
	Total personnel expenses	Total personnel expenses/patient admission	MCR & AHA
	Technology Index	Count of 12 technologies: angioplasty, cardiac catheterization, open heart surgery, trauma center, lithotripter, hemodialysis services, CT scanner, diagnostic radio-isotope, MRI, PET scan, SPECT tomography, transplant surgery. The transplant surgery technology is comprised of 7 items.	AHA
Observed quality and safety indicators in SFA	Heart failure mortality	Risk-adjusted number of deaths in heart failure patients/number of heart failure patients	CMS
	Pneumonia mortality	Risk-adjusted number of deaths in pneumonia patients/number of patients with pneumonia	CMS
30-day readmissions	Heart failure readmission	Risk-adjusted number of readmissions in heart failure patients/number of heart failure patients	CMS
	Pneumonia readmission	Risk-adjusted number of pneumonia readmissions/number of patients with pneumonia	CMS
PSI composite	PSI composite of complications	Weighted average of reliability and risk-adjusted rates of adverse events, such as pressure ulcers, postoperative respiratory failure, and postoperative sepsis	CMS

continued

Table 1. Continued

Variable	Definition	Source
IQI composites	Weighted average of reliability and risk-adjusted rates of mortality following a number of procedures	CMS
Explanatory variables: Predictors of gaps in quality and safety	Weighted average of reliability- and risk-adjusted rates of mortality following number of medical conditions	CMS
Organizational characteristics	CMS case mix index	CMS
	Accreditation by Joint Commission	AHA
	Whether hospital is for-profit, not-for-profit, private, government	AHA
	1. New England: ME, NH, VT, MA, RI,	AHA
	2. Mid-Atlantic: NY, NJ, PA	AHA
	3. South-Atlantic: DE, MD, DC, VA, WV, NC, SC, GA, FL	AHA
	4. East North Central: OH, IN, IL, MI, WI	AHA
	5. East South Central: KY, TN, AL, MS	AHA
	6. West North Central: MN, IO, MI, ND, SD, NB, KS	AHA
	7. West South Central: AR, LA, OK, TX	AHA
	8. Mountain: MN, ID, WY, CO, NM, AZ, UT, NV	AHA
	9. Pacific: WA, OR, CA, AK, HI	AHA
RN staffing	RN FTEs/ acuity and outpatient adjusted patient days	AHA
Size	Number of acute-care staffed beds	AHA
Teaching status	Member of Council of Teaching Hospitals of the Association of American Medical Colleges	AHA
Urban versus rural location	Urban—rural continuum—9 levels based on size of population and relation to metropolitan (metro) area	ARF
	1—1 million or more in metro area	
	2—250,000—1,000,000 in metro area	
	3—<250,000 in metro area	
	4—20,000, adjacent to metro area	

continued

Table 1. Continued

Variable	Definition	Source
	5—20,000, not adj. to metro area	
	6—2,500–19,999, adj. to metro area	
	7—2,500–19,999, not adj. to metro	
	8—<2,500 adjacent to metro area	
	9—<2,500 not adjacent to metro area	
Market conditions	Herfindahl–Hershman Index: the sum of the squares of the market share of each hospital in the county.	AHA
	$HHI = \Sigma(APD_i/APD_{total})^2$ where APD = adjusted patient days and i = individual hospital	
	No. of hosp. for-profit in county/total no. of hosp. in the county	AHA
Response variables: Gaps in quality and safety		
Gaps in 30-day mortality	% hosp for-profit	SFA
	Gap in heart failure mortality	SFA
	Gap in pneumonia mortality	SFA
Gaps in 30-day readmissions	Gap in heart failure readmission	SFA
	Gap in pneumonia readmission	SFA
Gaps in Composite PSI	Gap in PSI composite of complications	SFA
Gaps in composite IQIs	Gap in IQI composite of mortality d/t surgical procedure	SFA
	Gap in IQI composite of mortality d/t medical condition	SFA

AHA, American Hospital Association Annual Survey; ARF, Area Resources Files; CMS, Centers for Medicare and Medicaid Services; MCR, Medicare Cost Report; SFA, obtained from Stochastic Frontier Analysis.

The composite IQIs and PSIs were constructed from individual indicators. IQI indicators were rates of risk-adjusted mortality following certain hospital procedures and for some patient conditions. PSI indicators were rates of adverse events such as pressure ulcers, postoperative respiratory failure, and postoperative sepsis. The composites were the weighted average of the scaled reliability-adjusted indicators for that composite (Inpatient Quality Indicators, 2008; Patient Safety Indicators, 2010).

Predictors of Quality and Safety. Hospital organizational measures were CMI, Joint Commission accreditation, ownership, RN staffing, size, teaching status, region, and urban or rural setting. CMI was the hospital's average CMI for all acute-care patients. Joint Commission accreditation was a dichotomous variable indicating whether the hospital was accredited by the Joint Commission or not. Ownership was measured through three categorical dichotomous variables: for-profit or not, nonprofit private or not, and nonprofit government or not. RN staffing was the number of RN FTEs/patient days, which are adjusted for patient acuity and outpatient care (RN FTE/acuity-adjusted patients days [AAPD]). Size was measured through the number of acute-care staffed beds. Teaching status was a dichotomous variable of whether the hospital is a member of the Council of Teaching Hospitals (COTH) or not. Regional location divides the United States into nine areas such as New England, Mid-Atlantic, and so on. Urban or rural location was measured by nine categories of an urban–rural continuum, which starts with the most urban location and ends with the most rural location. These last two measures were transformed into dichotomous variables for each category.

Market factors included the Herfindahl–Hirschman Index (HHI) and the percentage of hospitals in the county that are for-profit, both continuous variables. HHI is the sum of the squares of each hospital's adjusted patient days divided by the county total. The range is from 0 to 1: 0 indicates a high degree of competition, and 1 a monopoly. The second market variable was the number of for-profit hospitals divided by the total number of hospitals in the county.

Gaps in Quality and Safety. Table 1 lists the outcome measures in the predictor part of the study. The gaps in quality and safety were obtained by performing SFA (procedure described below) on the seven CMS quality and safety measures described above.

Data Sources

The last column in Table 1 presents the data sources. Data for the input variables came from the American Hospital Association (AHA) Annual Report and the CMS's Medicare Cost Report (MCR). Data for the quality and safety indicators were posted publically on the CMS Hospital Compare website in 2010 (CMS, 2010). The 30-day mortality and readmission measures came from the CMS's Acute Myocardial Infarction Heart Failure file. The PSI and IQIs came from the CMS's Reporting Hospital Quality Data for Annual Payment Update files. Data for the predictor variables came from the AHA, CMS, and the Area Resource Files. The gap variables were derived from the SFA.

The most up-to-date data that could be matched for the same year in all datasets was 2007. The number of complete observations in the final dataset depended upon the hospitals that matched across all datasets given the particular dependent variable being analyzed. That number is reported in Table 4.

Procedures

Stata version 12.1 was used for all analyses. Descriptive statistics were generated for the inputs, observed quality and safety, and predictor variables. Next, the SFA model was used to estimate the value of the unobserved best possible value for each outcome in each hospital.

The SFA model was:

$$y_i = \beta x_i + v_i + u_i \quad (1)$$

where y_i is the observed outcome; β is a vector of coefficients; x_i is a vector of correlates with y_i ; v_i is a random error ("noise") distributed as $N(0, \sigma_v^2)$; and u_i is a one-sided error term distributed as a $N(0, \sigma_v^2)$ truncated from below at zero and with a half-normal distribution (Kumbhakar and Lovell 2003). The observed outcome amount was $y_i = \beta x_i + v_i + u_i$, whereas the unobserved best possible value was $y_i^* = \beta x_i + v_i$. As we are assessing negative outcomes (e.g., mortality), a hospital wants to minimize them. So the best possible value is always less than or equal to the actual value. The gap was the amount of the observed outcome minus the estimated best possible amount of that outcome.

When there is no quality gap (i.e., when the observed outcome y_i = the best possible outcome y_i^*), then $y_i = \beta x_i + v_i + u_i$ equals $y_i^* = \beta x_i + v_i$, which means that $u_i = 0$. A standard practice in SFA is to truncate the $N(0, \sigma_v^2)$ distribution from below at zero so that the error term u is ≥ 0 . It is this truncation that

enables the SFA to estimate the gap between observed outcome y_i and best possible outcome y_i^* .

The SFA used each of the seven quality outcomes measures listed in Table 1 as Y variables and the “inputs into quality” measures as X variables. One model was estimated for each of the seven Y measures. We accounted for heteroskedasticity by bootstrapping our standard errors.

For descriptive purposes only, we transformed the estimated gaps into percentage gaps, defined as the gap amount divided by the best possible score. We did this because the gap amount is not weighted, and therefore comparing gaps can be misleading. As can be seen in the results section in Table 3, gap amounts may appear to be similar, but because the base amounts differ the percentage gaps are quite different and values can be reversed. A dramatic example in our sample involves comparing heart failure readmission rates and mortality due to surgical procedures, in which the gap amounts are 0.16 and 1.64 but the gap percentages are 28 and 7 percent, respectively. For the prediction analysis, however, gap percentages were not used because the results reflect the relationship between the predictors and each of the gaps separately.

For the prediction analysis, gap amounts were regressed on explanatory variables hypothesized to be related to these gaps, as in the following functional model:

$$\text{Gap} = f(\text{organizational indicators, market indicators})$$

where organizational indicators = CMI, Joint Commission accreditation, ownership type, RN staffing, region, size, teaching status, urban or rural location; market indicators = market competition, HMO penetration, percent of hospitals that are for-profit.

Due to possible nonlinear relationships with the dependent variable, we squared three of the predictor variables in the model: RN FTE/AAPD, size, and HHI. Prior research with RN FTE/AAPD has indicated that negative patient outcomes are reduced at a decreasing rate as RN FTE/AAPD increases (Mark et al. 2004). Prior research with size and HHI has often used categorical variables to allow for nonlinearity (Gowrisankaran and Town 2003; Chukmaitov et al. 2009; Carretta et al. 2013; Jiang, Friedman, and Jiang 2013).

The analysis of the predictors of gaps used a Poisson regression with robust standard errors because the distributions of the gaps were skewed close to zero. Such a skewed distribution violates the assumption of a normal distri-

bution needed to use ordinary least squares regression. A Poisson distribution is a better match and Poisson regression is one of the recommended types of regression for this type of data (Gourieroux, Monfort, and Trognon 1984; Greene 2011).

RESULTS

Descriptive statistics for the input and predictor variables in the study are presented in Table 2. Table 3 shows the means for the observed quality and safety scores, the best possible scores, the gaps, and the percentage gaps. On average hospitals had a greater than 10 percent gap on most of seven Hospital Compare quality and safety indicators. Patient complications had the highest percentage gap, followed by mortality due to surgical procedures. Gaps were lowest for heart failure and pneumonia readmissions.

Table 4 presents the results of the prediction analysis. All predictor variables except for percent of for-profit hospitals in the region were statistically significantly related to at least one quality indicator gap, but several of the predictors' relationships were not consistent across different quality indicator gaps. Consistent predictors of gaps in quality were Joint Commission accreditation, nonprofit private ownership, RN FTE/AAPD, teaching status, and urban-rural continuum. Joint Commission accreditation was associated with a higher gap for five of the seven outcomes (heart failure readmission, pneumonia mortality and readmission, and mortality due to selected surgical procedures and selected medical conditions). Being a nonprofit private hospital was associated with lower gaps for two of the outcomes (PSI and mortality due to selected surgical procedures). Taking into account the nonlinear relationship, hospitals with higher RN FTE/AAPD had lower gaps for five of the outcomes (heart failure and pneumonia mortality and readmission, and mortality due to selected medical procedures). Being a teaching hospital was associated with higher gaps for all but two outcomes (heart failure mortality and mortality due to selected medical conditions). For four outcomes (heart failure and pneumonia readmission, PSI, and mortality due to selected medical conditions), hospitals in more urban areas had lower gaps compared to the most rural hospitals.

Predictors that were not consistently related to the gaps were CMI, size, region, and HHI. Hospitals with higher CMI had lower gaps in heart failure and pneumonia readmission, but higher gaps in heart failure and pneumonia mortality and mortality due to selected surgical procedures and medical con-

Table 2: Descriptive Statistics for Inputs into Quality and Safety and Predictors of Gaps

Inputs into quality	Mean	SD
Net revenue/adjusted patient day	\$112	\$1,153
RNs/total nurses	71	12
Percentage of Medicare patients	27	10
Profit margin	−0.06	4.03
Technology index (count of 12 technologies)	6.30	3.45
Total personnel expenses/patient admission	\$8,222	\$14,795
	Frequency	Percent
System membership, yes	1,809	59.62
Predictors of the gaps in quality and safety		
Organizational characteristics	Mean	SD
CMI	1.37	0.26
RN FTE/AAPD	0.003	0.001
Size (beds, total)	221.11	199.44
	Frequency	Percent
Joint Commission accreditation	2,648	87.22
Ownership, for-profit	600	19.76
Ownership, nonprofit government	528	17.39
Ownership, nonprofit private	1,908	62.85
Region		
1. New England: ME, NH, VT, MA, RI	135	4.45
2. Mid-Atlantic: NY, NJ, PA	360	11.87
3. South-Atlantic: DE, MD, DC, VA, WV, NC, SC, GA, FL	517	17.04
4. East North Central: OH, IN, IL, MI, WI	467	15.39
5. East South Central: KY, TN, AL, MS	310	10.22
6. West North Central: MN, IO, MI, ND, SD, NB, KS	239	7.88
7. West South Central: AR, LA, OK, TX	458	15.10
8. Mountain: MN, ID, WY, CO, NM, AZ, UT, NV	191	6.30
9. Pacific: WA, OR, CA, AK, HI	357	11.77
Teaching hospital (member COTH)	260	8.56
Urban–rural continuum		
1. 1 million or more in metro area	1,180	38.87
2. 250,000–1,000,000 in metro area	571	18.81
3. <250,000 in metro area	374	12.32
4. ≥20,000, adjacent to metro area	259	8.53
5. ≥20,000, not adj. to metro area	122	4.02
6. 2,500–19,999, adj. to metro area	288	9.49
7. 2,500–19,999, not adj. to metro	191	6.29
8. <2,500 adjacent to metro area	22	0.72
9. <2,500 not adjacent to metro area	29	0.96
Market characteristics		
HHI	0.46	0.35
Percent of for-profit hospitals in the region	25.00	28.99

Table 3: Quality and Safety Scores

<i>Observed, Best Possible, Gap, and Percentage Gap in Quality and Safety Scores</i>	<i>Observed (Y)</i>		<i>Best (Y*)</i>		<i>Gap (Y – Y*)</i>		<i>% Gap*</i>	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
30-day mortality								
Heart failure mortality	11.06	1.61	9.70	0.57	1.38	1.19	13.84	11.54
Pneumonia mortality	11.51	1.92	9.73	0.58	1.78	1.49	17.76	14.38
30-day readmission								
Heart failure readmission	24.59	2.20	22.91	1.02	1.64	1.40	7.00	5.82
Pneumonia readmission	18.29	1.78	16.64	0.60	1.63	1.32	9.61	7.62
Inpatient Quality Indicator Composite								
Mortality d/t surgical procedure	0.73	0.08	0.57	0.02	0.16	0.08	28.33	14.35
Mortality for sel. medical condition	0.64	0.10	0.56	0.05	0.08	0.07	13.85	11.61
Patient Safety Indicator Composite								
Patient complications	1.11	0.21	0.85	0.07	0.25	0.18	29.2	20.85

Notes. *% Gap = (Y – Y*)/Y*, where Y = observed score, and Y* = best possible score from SFA.

ditions. Larger hospitals had higher gaps for two of the outcomes (heart failure and pneumonia readmission) and a lower gap for heart failure mortality. Most regions had lower gaps compared to the Pacific for five outcomes, but there were higher gaps for some regions compared to the Pacific for heart failure and pneumonia readmission. Hospitals in areas with lower competition (higher HHI) had lower gaps in heart failure and pneumonia readmission and patient safety but higher gaps in heart failure and pneumonia mortality and mortality due to selected medical conditions.

When assessing these results from the perspective of the gaps, it can be seen that most of the gaps were related to a large number of predictors. Heart failure and pneumonia mortality and heart failure readmissions were related to nearly all of the organizational predictors and HHI. Mortality due to selected surgical procedures and mortality due to selected medical conditions were also related to nearly all organizational predictors.

DISCUSSION

It is important to reiterate that this study investigates *gaps* between actual and best possible hospital quality and safety rather than actual quality and safety. Having a gap means that the hospital is not meeting its *best possible* quality and

Table 4: Predictors of Gaps in Quality and Safety

	Heart Failure Mortality (n = 2,706) Coefficient	Heart Failure Readmission (n = 2,716) Coefficient	Pneumonia Mortality (n = 2,718) Coefficient	Pneumonia Readmission (n = 2,718) Coefficient	Patient Safety Indicator, Composite (n = 2,784) Coefficient	Mortality d/t Selected Surgical Procedures (n = 1,823) Coefficient	Mortality d/t Selected Medical Conditions (n = 2,747) Coefficient
CMI	0.39***	-0.92***	0.23*	-0.66***	-0.13	0.07	0.22**
Joint Com. accreditation	-0.02	0.24***	0.12*	0.12*	-0.01	0.13*	0.18***
Ownership, for-profit ^a	0.09	0.10	-0.00	0.04	-0.11*	-0.08	0.20**
Ownership, nonprofit, private ^a	0.02	-0.03	-0.07	-0.04	-0.13***	-0.11**	-0.03
RN FTE/AAPD	70.91**	77.91***	43.16*	22.47	0.57	15.20	57.34**
RN FTE/AAPD ²	-4,000.64**	-4,569.54***	-1,781.04*	-2,970.74*	-46.81	-1,954.56	-3,821.50***
Size (no. beds)	0.00	0.00***	-0.00	0.00***	-0.00	0.00	0.00
Size ² (no. beds ²)	-0.00*	-0.00*	-0.00	-0.00**	-0.00	-0.00	-0.00
Teaching (member COTH)	-0.03	0.40***	0.19**	0.30***	0.24***	0.15**	0.12
Region [†]							
1. New England	-0.46***	0.11	-0.42***	0.38***	-0.33***	-0.05	-0.12
2. Mid-Atlantic	-0.35***	0.32***	-0.20**	0.41***	-0.01	-0.10*	0.09
3. South-Atlantic	-0.43***	0.03	-0.23***	0.23***	-0.02	-0.12**	-0.30***
4. East North Central	-0.36***	0.14*	-0.42***	0.26***	-0.25***	-0.15***	-0.54***
5. East South Central	-0.30***	0.16*	-0.22***	0.31***	-0.06	-0.02	-0.05
6. West North Central	-0.32***	0.13	-0.40***	0.22***	-0.26***	0.02	-0.22**
7. West South Central	-0.19**	0.05	-0.27***	-0.06	-0.18***	-0.07	-0.18**
8. Mountain	-0.26***	-0.23**	-0.30***	-0.21*	0.03	-0.08	-0.35***
Urban-rural continuum [‡]							
1. >1 million metro area	-0.15	-0.24	-0.16	-0.25	-0.16	0.00	-0.33*
2. 250,000-1 mill metro	0.13	-0.53***	0.05	-0.41**	-0.21	0.06	-0.15
3. 2,500,000 metro	0.19	-0.45**	-0.02	-0.41**	-0.39*	0.08	-0.03
4. ≥20,000 adj. metro	0.16	-0.40**	0.05	-0.31*	-0.36*	0.05	0.06

continued

Table 4. *Continued*

	Heart Failure Mortality (n = 2,706) Coefficient	Heart Failure Readmission (n = 2,716) Coefficient	Pneumonia Mortality (n = 2,718) Coefficient	Pneumonia Readmission (n = 2,718) Coefficient	Patient Safety Indicator, Composite (n = 2,784) Coefficient	Mortality d/t Selected Surgical Procedures (n = 1,823) Coefficient	Mortality d/t Selected Medical Conditions (n = 2,747) Coefficient
5. ≥20,000 not adj. metro	0.25	-0.27	0.25	-0.29	-0.29	0.13	0.30
6. 2,500–19,999, adj metro	0.07	-0.29*	-0.01	-0.17	-0.22	0.02	-0.04
7. 2,500–19,999, not adj. metro	-0.03	-0.21	-0.17	-0.14	-0.27	0.00	0.09
8. <2,500 adj. metro	0.16	-0.61*	-0.12	-0.34	-0.25	0.00	-0.01
HHI	1.19***	-0.74**	0.61*	-1.13***	-0.69***	0.14	0.66**
HHI ²	-0.77***	0.49*	-0.35	0.75***	0.47**	-0.11	-0.39
% for-profit hosp. in reg.	0.03	-0.10	0.01	-0.10	0.08	0.04	-0.10

Notes: A positive coefficient, lower quality; a negative coefficient, higher quality.

*reference group = nonprofit, government.

†reference group = 9, the most rural.

‡reference group = 9, Pacific.

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

safety given the capital, labor, and technology available to it, but it does not necessarily indicate that actual quality and safety are low. This study found that gaps of 8–23 percent exist between hospitals' actual and best possible patient outcomes, indicating that hospitals are not performing at their best possible level given their resources. Significant predictors of gaps were payer mix, RN staffing, size, CMI, Joint Commission accreditation, teaching status, urban location, region, and market competition, although with some predictors the direction of the association was not consistent across outcomes.

Better RN staffing and being in an urban area tended to be associated with lower gaps in quality and safety. RN staffing may be associated with lower gaps through an efficient use of resources that contributes to quality care. Urban hospitals may have infrastructures that enable hospitals to make good use of resources.

Joint Commission accreditation and being a large and/or teaching hospital were associated with higher gaps (with the exception of heart failure for teaching hospitals). Accredited hospitals may have higher gaps because the accreditation only signifies that the hospital has met quality standards, but it may not reflect how well the hospital used resources in achieving that quality. With larger hospitals, which tend to be in urban areas, one would expect a strong infrastructure to help manage their resources, but they may instead be more disorganized (due to the difficulty of managing a large organization, perhaps) or may have other inefficiencies that affect the utilization of resources in the quality of care. Teaching hospitals may have a higher gap because they have exceptional resources that are not being used efficiently. In sum, hospitals with any or all of these factors may not be meeting their quality potential; therefore, they may have higher gaps than nonaccredited, nonteaching, or small hospitals that make better use of their inputs. This hypothesis could be tested in future research by comparing the gaps with the quality outcomes in each hospital given hospital characteristics.

The reversed sign between gaps in mortality and readmissions for a number of predictors (payer mix, case mix, region, HHI) is important to explore further. It indicates that hospitals with different characteristics use resources in different ways to prevent mortality compared to preventing readmissions. Hospitals with a greater number of Medicare patients as their payer mix had a better use of resources to prevent mortality compared to readmissions, while hospitals with higher case mix and lower competition (higher HHI) had a worse use of resources for preventing mortality compared to readmissions.

Limitations of the Study

Limitations of this study relate to the validity of both the gap and predictor models and the use of SFA itself. The SFA models used to estimate the gaps contained a parsimonious number of inputs. It is possible that the best possible values, and therefore the gap amounts, would have been better predicted if more or different inputs had been included in the models. Some of the predictor variables might be important to include in the gap model. It may also be that the use of truncated SFA to establish the gap was not the optimum statistical method, so other analyses for estimating gaps, such as Data Envelopment Analysis, should be explored.

Policy and Research Implications

This study found significant gaps between hospitals' observed and best possible quality and safety indicators, suggesting that, based on their existing capital, labor, and technology, hospitals have room for improving the quality of care. The study also found that several organizational characteristics and market conditions of hospitals impacted those gaps. However, given the lack of uniformity of results across predictors of these gaps, it is too early for specific policy recommendations to be made based on these predictors.

The main policy issue raised by the study is whether it is preferable to compare and reward hospitals on their observed quality and safety indicators or on their ability to meet their resource-based best possible quality. A P4P system based on meeting *observed* quality does not help hospitals with low quality (that may also be resource-poor but making the most of those resources) to make improvements, nor does it motivate hospitals that have high quality but that are not meeting their quality potential to do better. A P4P system based on meeting a hospital's own *best possible* quality (minimizing gaps) could help hospitals with low gaps to receive more resources and motivate hospitals with high gaps to do better to meet their potential. This could reduce perverse consequences of reward systems that further starve resource-poor hospitals that have lower quality indicators.

More research is needed to further explore the use of SFA to establish hospital gaps in quality and safety and to understand the effect of hospital organizational and market characteristics on those gaps. Gap analyses of important CMS quality and safety indicators should be conducted on new data in national samples. The gap models in those studies could explore alternative measures for the capital, labor, and technology inputs. A useful study

would be to compare gap results using alternative measures of inputs on the same quality and safety indicators with the same data. If the gap results are similar across models, this would indicate that the SFA model is robust across different input measures. If it is not, studies need to be designed to determine the most reliable and valid input measures. Future research of predictors of the gaps needs to be conducted along similar lines.

ACKNOWLEDGMENTS

Joint Acknowledgment/Disclosure Statement: This research was supported through a grant from the Agency for Healthcare Research and Quality. Authors also thank anonymous reviewers for their helpful comments on this paper.

Disclosures: None.

Disclaimers: None.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.