Title of Grant: Benchmarking Patient Safety and Quality in U.S. Hospitals: The Stochastic Frontier Approach

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ABSTRACT

Purpose: Systems for public reporting and value-based purchasing use averages or rankings of observed quality scores. An alternative set of measures is the gap between a hospital's observed and best possible quality scores. In this study, we estimated the gaps between the observed and best possible Hospital Compare outcomes scores and explored predictors of those gaps.

Scope: The sample was all hospitals that matched on data from sources listed below.

Methods: Stochastic Frontier Analysis (SFA) estimated the gaps between best possible and actual hospital quality measures. SFA inputs were indicators for capital, labor, and technology. SFA outputs were the best possible scores on six CMS Hospital Compare quality initiatives and the gaps between those scores and the hospital's actual scores. Poisson regressions were used to ascertain predictors of the gaps. Predictor variables were financial, organizational, and market indicators. Data were from the American Hospital Association Annual Survey, Area Resource File, and Centers for Medicare and Medicaid (CMS).

Results: Gaps distributions were as follows: 52-94% of hospitals had >10% quality and safety gaps, and 0-15% of hospitals had >50% quality and safety gaps. Payer mix, RN staffing, size, case mix index, accreditation, being a teaching hospital, market competition, urban location, and region were strong predictors of gaps. Results indicate that a significant percentage of hospitals have gaps between their best possible and actual quality scores. Ways to lower these gaps include increases in Medicaid and private insurance payments, higher RN/patient ratios, and assistance to rural and certain regional hospitals.

Key Terms:

- Benchmarking healthcare quality
- Stochastic Frontier Approach
- Hospital Compare
- Hospital quality measures
- Predictors of gaps in quality & safety

AIMS

Public reporting and value-based purchasing systems use measures of quality based on averages or rankings of observed quality scores (Lindenauer, et al., 2007; Ryan, 2009; Rosenthal and Frank, 2006). These methods provide a limited amount of information on how well hospitals are performing (Meddings and McMahon, 2008) and do not establish a “best practice” benchmark. A method that provides information about how hospitals meet their own best possible practices could be more informative. Hospitals could be compared based on this individualized quality rating, and benchmarks could be set based on the degree to which best practices are being reached. The gap estimation also could be used to assess factors that contribute to lower quality in hospitals.

One method for estimating gaps in performance is the Stochastic Frontier Analysis (SFA). SFA estimates the efficiency of a productive process by estimating the value of an unobservable best practice (i.e., frontier) outcome for each producer in the sample (Hofler and Folland, 2001). Comparing that estimated frontier amount with the actual amount reveals the extent of inefficiency or gap between the actual and best possible output. In healthcare, SFA has estimated efficiency in a number of settings, such as nursing homes and hospitals (Hofler and Folland, 2001; Mutter, Rosko and Wong, 2008; Rosko and Mutter, 2008).

SFA is usually used to estimate efficiencies in costs or production. To our knowledge, SFA has not been used to estimate gaps in quality. In this case, the equivalent of “efficiency” is the degree to which each hospital’s actual quality and safety scores approach its estimated best possible values. In other words, the SFA would estimate the gap between the observed (actual) and best possible (frontier) quality and safety scores.

This study uses SFA to estimate the gaps in seven Centers for Medicare and Medicaid Services (CMS) quality and safety indicators and explores the factors that contribute to those gaps. What financial resources and hospital and market characteristics affect gaps in quality and safety? Are there factors that can be influenced by policy?

SCOPE

Conceptual Framework

We use a framework first developed by Bazzoli and colleagues (Bazzoli, et al., 2007; Bazzoli, et al., 2008), adopting it to our analysis of gaps in quality and safety and their predictors. Figure 1 below illustrates this model. The inputs that directly affect quality include capital, labor, and technology (Bazzoli, et al, 2007). Capital inputs enhance quality through well-designed physical infrastructure and the financial resources to maintain and expand physical and human resources (Bazzoli, et al. 2008). Net revenue and system membership have been linked to quality and can be used as indicators of capital resources and infrastructure (Bazzoli, et al. 2007). Labor inputs, such as physicians, nurses, and other staff, enhance quality through their skills and expertise (Bazzoli, et al., 2007, 2008). Technology enhances quality by providing methods for employing the labor and capital inputs (Bazzoli, et al., 2007). 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 at an inefficient level in terms of quality. The SFA measures that gap between expected quality levels given inputs and the actual level of quality.

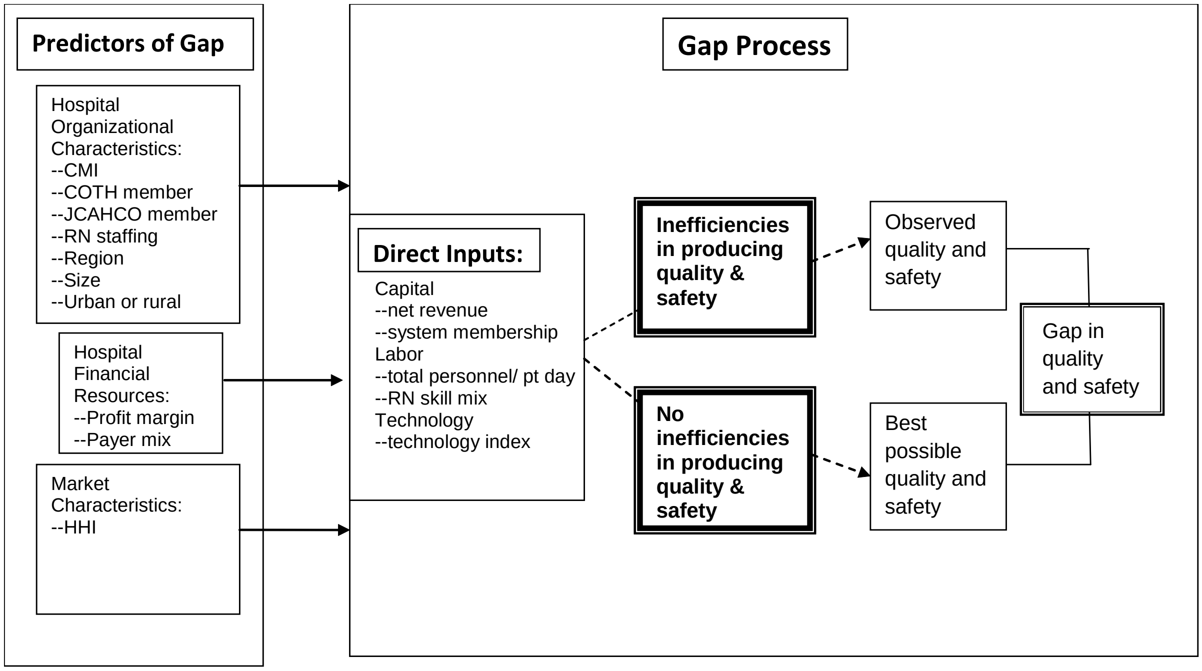

Figure 1. Predictors of Gaps in Quality and Safety

Other factors in this model indirectly affect quality and safety, primarily through their influence on the direct inputs and on the efficiency in applying these inputs. In our analysis, these indirect influences are the predictors of the gap between the best possible and actual quality. These factors are the hospital's organizational characteristics and financial resources as well as the characteristics of the hospital's market (Bazzoli, et al., 2007; Bazzoli, et al., 2008). An example of a financial resource that may play a role in operational decisions is profit margin. Hospitals with lower profit margins may have to cut back on essential inputs in order to maintain operations (Bazzoli, et al., 2008; Stone, et al., 2007). On the other hand, high profit margin may have been obtained by keeping costs down, resulting in the use of too few inputs and lower quality. Payer mix is another indicator of financial status. Because Medicare and private insurance pay more for services than Medicaid does, it is expected that a higher percentage of Medicare patients will be associated with more revenues and thus a better ability to provide higher quality of care.

Hospital ownership, size, urban or rural setting, and other characteristics can also affect production decisions and outcomes. For-profit hospitals, for example, may be more likely to cut the labor force, which might have a negative impact on quality. Larger hospitals in urban settings may have more physical and labor resources and more sophisticated technology than smaller rural hospitals. Market factors affecting hospital quality could include HMO market share. Hospitals in areas with high HMO market share may compete to keeps costs down, which may negatively affect inputs and therefore quality (Bazzoli, et al., 2007).

Studies of Predictors of Quality and Safety

The conceptual framework of predictors of gaps in quality and safety is informed by a number of studies that examine influences on quality and safety. As indicated in the model, predictors can be categorized as financial resources, hospital characteristics, or market characteristics (Bazzoli, et al., 2007, 2008). Studies of profit margin, a common measure of financial resources, are inconsistent, as the conceptual framework would suggest. Some find that higher profit margin is positively related to quality (Eappen, et al., 2013), some indicate a negative relationship (Eappen, et al., 2013; Stone, et al., 2007), and others find that it is not significantly related (Bazzoli, et al., 2008; Harrison, Lambiase, and Zhao, 2010; Stone, et al., 2007).

Regarding payer mix, another financial resource, most studies find that the percentage of Medicare patients is positively related to some patient outcomes, and the percentage of Medicaid patients is negatively related to some patient outcomes, but these relationships do not hold for other outcomes (Bazzoli, et al., 2007; Carretta, et al., 2013; Jiang, Friedman and Jiang, 2013; Muttner, Valdmanis, and Rosko, 2010).

Organizational characteristics of hospitals that are often included in studies of quality are case mix index (CMI), nurse staffing, ownership, region of operation, size, teaching status, and urban or rural setting. Case mix index is thought to affect quality negatively, because 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).

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

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, negatively related in other studies, and nonsignificant in yet other studies (Bazzoli, et al., 2007, 2008; Carretta, et al., 2013; Gowrisankaran, & Town, 2003; Harrison, Lambiase and Zhao, 2010; Jiang, Friedman, and Jiang, 2013; Maeng, and Martsolf, 2011; Muttner, Valdmanis, and Rosko, 2010; Rogowski, Jain, and Escarce, 2007; 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 and therefore would be positively associated with quality. The 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, 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 (Bazzoli, et al., 2008; Gowrisankaran, and Town, 2003; Harrison, Lambiase and Zhao, 2010; Jiang, Friedman, and Jiang, 2013; Maeng, and Martsolf, 2011; Muttner, Valdmanis, and Rosko, 2010; Rogowski, Jain, and Escarce, 2007). Results are mixed for the percentage of hospitals that are for-profit in the area (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 were divided into capital, labor, and technology. Capital indicators were net revenue/patient day and system membership (yes or no). Labor inputs were total personnel expenses/admissions and nurse skill mix (RNs/total nurses). The technology indicator was an index of a count of 12 technologies.

Inputs and observed quality and safety in SFA analysis

Observed quality and safety measures were seven CMS quality and safety measures: 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).

Table 1. Study Variables

Inputs in SFA

	Variable	Definition	Source
Capital	Net revenue	Net revenue/adjusted patient day	MCR
	System member	System membership, yes = 1, no =0	AHA
Labor	% RNs	# RNs/# total nurses	AHA
	Total personnel expenses	Total personnel expenses/ patient admission	MCR & AHA
Techno-logy	Technology Index	Count of 12 technologies	AHA

Observed Quality and Safety Indicators in SFA

	Variable	Definition	Source
30-day mortality	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 readmis-sions	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
IQI Composites	IQI composite of mortality d/t surgical procedures	Weighted average of reliability and risk-adjusted rates of mortality following a number of procedures.	CMS
	IQI composite of mortality d/t medical cond.	Weighted average of reliability- and risk-adjusted rates of mortality following number of medical conditions.	CMS

Explanatory Variables: Predictors of Gaps in Quality and Safety

	Variable	Definition	Source
Financial Resources	Payer mix	% Medicare patients	AHA
	Total margin	Net income /revenue (revenue = total revenue from pt services + contributions + income investment)	MCR
	CMI	CMS case mix index	CMS
	JCAHO	Accreditation by JCAHO	AHA
Organiza-tional charac-teristics	Ownership	Whether hospital is for profit, not-for-profit private, government	AHA
	Region	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

Organizational characteristics	Region	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 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 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	ARF
Market Conditions	Market competetion	Herfindahl Hershman Index: the sum of the squares of the market share of each hospital in the county. $HHI = \Sigma(APD_i/APDtotal)^2$ where APD = adjusted patient days and i = individual hospital	AHA
	% hosp for-profit	# hosp for-profit in county/total # hospitals in the county	AHA

Response Variables: Gaps in Quality and Safety

	Variable	Definition	Source
Gaps in 30-day mortality	Gap in heart failure mortality	Gap between actual and best possible score on heart failure 30-day mortality rate	SFA
	Gap in pneumonia mortality	Gap between actual and best possible score on pneumonia 30-day mortality rate	SFA
Gaps in 30-day readmissions	Gap in heart failure readmission	Gap between actual and best possible score on heart failure 30-day readmission rate	SFA
	Gap in pneumonia readmission	Gap between actual and best possible score on pneumonia 30-day readmission rate	SFA
Gaps in Composite PSI	Gap in PSI composite of complications	Gap between actual and best possible score on PSI Composite (patient safety complications)	SFA
Gaps in composite IQIs	Gap in IQI composite of mortality d/t surgical proced.	Gap between actual and best possible score on IQI composite (mortality for selected surgical procedures)	SFA
	Gap in IQI composite of mortality d/t medical cond.	Gap between actual and best possible score on IQI composite (mortality for selected medical conditions)	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

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 (Keenan, et al., 2008; Krumholz, et al., 2006). The measures have been used as outcomes in several studies (Keenan, et al., 2008; Krumholz, et al., 2006; Lindenauer, et al., 2007).

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 Common, 2005). 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 averages of the scaled reliability-adjusted indicators for that composite (Inpatient Quality Indicators, 2008; Patient Safety Indicators, 2010).

Predictors of quality and safety

Indicators of financial resources were profit margin and payer mix. For profit margin, we used the total margin: the net income from total revenue divided by total revenue. Total revenue was the revenue from patient services, contributions, and income investment. Payer mix was the percentage of Medicare patients, with all other types of payers as the reference group. Hospital organizational measures were nurse staffing, ownership, size, case mix index, Joint Commission accreditation, teaching status, urban or rural setting, and region. Nurse staffing was the ratio of the number of full-time equivalent RNs to patient days, which are adjusted for patient acuity and outpatient care (RN/AAPD). Ownership was measured through three categorical dichotomous variables: for-profit or not, non-profit private or not, and non-profit government or not. Size was measured through the number of acute-care staffed beds. Case mix index (CMI) was the hospital's average CMI for all acute-care patients. Teaching status was a dichotomous variable of whether the hospital is a member of the Council of Teaching Hospitals (COTH) or not. 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. Regional location divides the U.S. into nine areas, such as New England, Mid Atlantic, etc. These last two measures were transformed into dichotomous variables for each category.

Market factors included the Herfindahl Hershman 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 the ratio of each hospital's adjusted patient days to total hospital adjusted patient days. The range is from 0 to 1, with 0 indicating a high degree of competition and 1 indicating 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 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' Medicare Cost Report (MCR). Data for the quality and safety indicators were posted publicly on the CMS website in 2010 (CMS, 2010). The 30-day mortality and readmission measures came from the CMS' Acute Myocardial Infarction Heart Failure file (AMIHF) file. The PSI and IQIs came from the CMS' Reporting Hospital Quality Data for Annual Payment Update (RHQDAPU) files. Data for the predictor variables came from the AHA, CMS, and the Area Resource Files (ARF). The gap variables were derived from the SFA.

The most up-to-date data that could be matched for the same year in all data sets was 2007. The number of complete observations in the final data set depended upon the hospitals that matched across all data sets given the particular dependent variable being analyzed. That number is reported in Table 3.

Procedures

Descriptive statistics were performed on input, observed quality and safety, and predictor variables. Next, the SFA estimated the value of the unobserved best possible (i.e., frontier) value for each outcome in each hospital. The extent of "inefficiency" (i.e., the gap) in quality was the actual amount minus frontier amount in each hospital.

The SFA was modeled as:

$$y_i = \beta x_i + v_i + u_i$$

βx_i is the deterministic part of the analysis; v_i is the stochastic (or random) part; and u_i is the inefficiency (or gap) amount. The observed amount is $y_i = \beta x_i + v_i + u_i$. The frontier amount is noted as $y^*_i = \beta x + v$. When the SFA models the minimization of something, as in our analysis, y^* is < y, and $y = y^* + u$ (or $y^* = y - u$).

The SFA used the seven quality outcomes measures listed in Table 1 as *Y* variables and the "inputs into quality" measures listed in Table 1 as X variables. One model was estimated for each of the seven *Y* measures. Truncated normal SFAs with bootstrapping for heteroskedasticity were conducted.

For descriptive purposes, after estimating the gaps, we transformed them into percentage gaps, defined as the gap amount divided by the best possible score. Gap amounts (not the percentage gaps) were regressed on explanatory variables hypothesized to be related to these gaps, as in the following functional model.

Gap = f(financial indicators, organizational indicators, market indicators), where

Financial indicators = total profit ratio, payer mix

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 non-linear relationships with the dependent variable, we squared three of the predictor variables in the model: RN/AAPD, size, and HHI. Prior research with RN/AAPD has indicated that negative patient outcomes are reduced at an decreasing rate as RN/AAPD increases (Mark, et al., 2004). We predicted size and HHI to have an increasingly negative relationship with quality and safety gaps.

The analysis of the predictors of gaps used a Poisson regression with robust standard errors, because the distributions of the gaps were skewed due to a large number of zeros. Such skewness often leads researchers to log-transform the dependent variable. However, Poisson regression with robust standard errors is a better alternative to log-linear regression in this case (Gould, 2011). Both the SFA the Poisson regressions used *Stata* version 12.1.

RESULTS

Descriptive statistics for all variables in the study are presented in Table 2. With regard to inputs into quality, average hospital net revenue was $112 per patient day. RNs represented 71% of the nursing workforce on average. Of 12 technologies, hospitals had 6.3 on average. Total personnel expenses per patient admission were $8,222. Close to 60% of hospitals were part of a system.

Table 2. Descriptive Statistics for Gaps in Quality and Safety and Their Predictors

Inputs into Quality	Mean	SD
Net revenue/adjusted patient day	$112	$1,153
% RNs in nursing workforce	71	12
Technology index (count of 12 technologies)	6.30	3.45
Total personnel expenses/admission	$8,222.	$14,795
	Frequency	Percent
System membership, yes	1,809	59.62

Predictors of the Gaps in Quality and Safety

Financial Status		
	Mean	SD
Percentage of Medicare patients	27	10
Profit margin	-0.06	4.03
Organizational Characteristics		
	Mean	SD
CMI	1.37	0.26
RN/adjusted patient days	0.003	0.001
Size (beds, total)	221.11	199.44
	Frequency	Percent
Accreditation	2648	87.22
Ownership, for-profit	600	19.76
Ownership, non-profit government	528	17.39
Ownership, non-profit private	1908	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	1180	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		
	Mean	SD
HHI	0.46	0.35
Percent of for-profit hospitals in the region	25.00	28.99

Observed, Best Possible, Gap, and Percentage Gap in Quality and Safety Scores

	Observed (Y)		Best (Y*)		Gap (Y –Y*)		% Gap*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
30-day mortality								
Heart failure mortality	11.06	1.61	9.7	0.52	1.38	1.20	14	12
Pneumonia mortality	11.52	1.92	9.73	0.55	1.78	1.51	18	15
30-day readmission								
Heart failure readmission	24.59	2.20	22.78	0.94	1.77	1.47	8	6
Pneumonia readmission	18.29	1.78	16.52	0.53	1.75	1.37	10	8
Inpatient Quality Indicator Comp.								
Mortality d/t surgical proced.	0.73	0.08	0.56	0.03	0.18	0.08	32	16
Mortality for sel. medical cond.	0.64	0.10	0.56	0.05	0.08	0.07	13	11
Patient Safety Indicator Composite								
Patient complications	1.11	0.21	0.86	0.06	0.25	0.18	29	21

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

Variables representing predictors of the gaps in quality and safety are described next. The average percentage of Medicare patients per hospital was 27%. Profit margin was slightly below 0 on average, with a standard deviation of 4. Hospitals had 221 beds on average and an average CMI of 1.37, with a standard deviation of 0.26. The ratio of RNs to adjusted patient days was 0.003. Eighty-seven percent of hospitals were accredited, but only 8% were members of COTH. Ownership was distributed as 20% for-profit, 17% non-profit government, and 63% non-profit private. Six of the nine regions had 10% or more of hospitals each. The highest percentage of hospitals was in a metropolitan area of one million or more, and the percentage of hospitals in each continuum category decreased when going from urban to more rural categories. HHI was 0.46, indicating a moderate amount of market concentration on average. Finally, the percent of for-profit hospitals in the county averaged 25.

Next, Table 2 shows the means for the observed quality and safety scores that were used in the SFA, the best possible quality and safety scores, the gaps, and the percentage gaps. Most hospitals have a greater than 10% gap on most of seven Hospital Compare quality and safety indicators. Mortality due to surgical procedures had the highest percentage gap, followed by patient complications (PSI). Thirty-day mortalities due to heart failure and pneumonia and mortality for selected medical conditions were in the middle range of gaps. Gaps were lowest for heart failure and pneumonia readmissions.

Based on the percentage gaps among hospitals, Table 3 presents the distribution of hospitals for each decile of gaps. Depending upon the outcome, 6-68% of hospitals had a less than 10% gap. Thirty-two percent to 94% had greater than 10% quality gaps, and 0-15% of hospitals had greater than 50% quality gaps. Heart failure and pneumonia readmission had the most hospitals with lower gaps, but mortality due to selected surgical procedures and the patient safety indicator had the most hospitals with higher gaps. For example, 68% and 53% of hospitals had a less than 10% gap in heart failure and pneumonia readmissions respectively, whereas only 6% and 19% of hospitals had less than 10% mortality due to surgical procedures and patient safety, respectively. Ninety-four percent and 81% had gaps *greater than* 10% in these indicators.

As Table 4 shows, the top 5% of hospitals had percentage gaps of 0-9% between best possible and actual scores. For all but one outcome (mortality due to selected surgical procedures), the top 5% of hospitals had no gaps between best possible and actual scores. The top 10% of hospitals had gaps of 0-15%, with zero gaps for all but two outcomes (patient safety composite and mortality due to selected surgical procedures).

Table 3. Percentage of U.S. Hospitals Having Gaps in Quality or Safety

% Gap in Quality or Safety	Percentage of Hospitals													
	Heart Failure Mortality		Heart Failure Readmission		Pneumonia Mortality		Pneumonia Readmission		Patient Safety Indicator, Composite		Mortality d/t Selected Surgical Procedures		Mortality d/t Selected Medical Conditions	
	%	Reverse Cum. %	%	Reverse Cum. %	%	Reverse Cum. %	%	Reverse Cum. %	%	Reverse Cum. %	%	Reverse Cum. %	%	Reverse Cum. %
0 -10	43.0	100	68.5	100	35.6	100	52.7	100	18.9	100	5.8	100	47.8	100
11 - 20	29.6	56.8	27.8	31.6	25.9	65.4	35.5	47.4	18.0	81	11.6	94.1	27.4	52.3
21 - 30	17.5	27.2	3.5	3.8	19.6	39.5	10.0	11.9	19.7	63	37.1	82.5	16.3	24.9
31 - 40	6.7	9.7	0.3	0.3	11.4	19.9	1.6	1.9	16.7	43.3	23.7	45.4	6.9	8.6
41 - 50	2.4	3	0	0	5.5	8.5	0.3	0.3	11.8	26.6	10.1	21.7	1.5	1.7
51 - 60	0.6	0.6	0	0	2.4	3	0	0	7.1	14.8	6.2	11.6	0.2	0.2
61 - 70	0	0	0	0	0.5	0.6	0	0	3.7	7.7	3.0	5.4	0	0
71 - 80	0	0	0	0	0.1	0.1	0	0	1.6	4	1.3	2.4	0	0
81 - 90	0	0	0	0	0	0	0	0	1.4	2.4	0.5	1.1	0	0
91 - 100	0	0	0	0	0	0	0	0	0.6	1	0.3	0.6	0	0
101 - 110	0	0	0	0	0	0	0	0	0.4	0.4	0.3	0.3	0	0

Table 4. "Best Practice" Targets Based on Top 5% and 10% of Hospitals

Best Practice Based on:	Best Practice % Gap						
	Heart Failure Mortality	Heart Failure Readmission	Pneumonia Mortality	Pneumonia Readmission	Patient Safety Indicator, Composite	Mortality d/t Selected Surgical Procedures	Mortality d/t Selected Medical Conditions
Top 5% of hospitals	0	0	0	0	0	0 - 8.7	0
Top 10% of hospitals	0	0	0	0	0 - 3.5	0 - 15.2	0

Table 5. Predictors of Gaps in Quality and Safety

	Heart Failure Mortality (n = 2,706)	Heart Failure Readmission (n = 2,716)	Pneumonia Mortality (n = 2,718)	Pneumonia Readmission (n = 2,718)	Patient Safety Indicator, Composite (n = 2,784)	Mortality d/t Selected Surgical Procedures (n = 1,823)	Mortality d/t Selected Medical Conditions (n = 2,747)
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Payer (% Medicare pts)	-1.08 ***	0.68 ***	-0.83 ***	0.65 ***	-0.06	-0.77***	-0.15
Profit margin	-0.01	0.34	-0.21	0.26	-0.33	0.17	0.23
CMI	0.41 ***	-0.91 ***	0.23 *	-0.66 ***	-0.11	0.16**	0.20*
Accreditation	0.01	0.20 ***	0.14 **	0.08	-0.06	0.12**	0.19***
Ownership, for profit ξ	0.09	0.10	0.00	0.04	-0.09	-0.09	0.16*
Ownership, non-profit,	0.03	-0.05	-0.06	-0.05	-0.12***	-0.11**	-0.07
privateξ RN/AAPD	81.65 ***	66.65 ***	51.91 **	12.62	6.68	32.43	62.79**
RN/AAPD^2	-4795.00 **	-3306.00 **	-2254.00 *	-1555.00	-82.69	-2664.00	-4558.00***
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)	-0.15 *	0.50 ***	0.16 **	0.41 ***	0.39***	0.14**	0.19**
Regionξ ξ							
1 New England	-0.43 ***	0.04	-0.43 ***	0.30 ***	-0.40***	0.00	-0.10
2 Mid-Atlantic	-0.35 ***	0.29 ***	-0.20 **	0.36 ***	-0.20	-0.13**	0.08
3 South-Atlantic	-0.41 ***	0.01	-0.20 ***	0.19 ***	-0.03	-0.20***	-0.34***
4 East North Central	-0.32 ***	0.09	-0.40 ***	0.20 ***	-0.29***	-0.18***	-0.60***
5 East South Central	-0.28 ***	0.15 *	-0.18 **	0.29 ***	-0.05	-0.13*	-0.07
6 West North Central	-0.30 ***	0.09	-0.38 ***	0.17 **	-0.27***	-0.07	-0.25***
7 West South Central	-0.16 **	0.03	-0.23 ***	-0.09	-0.19***	-0.16***	-0.23***
8 Mountain	-0.23 ***	-0.27 **	-0.27 ***	-0.25 **	-0.01	-0.16***	-0.37***
Urban-rural continuumξ ξ ξ							
1 > 1 million metro area	-0.09	-0.29 *	-0.13	-0.29 *	-0.21	-0.03	-0.42**
2 250,000 – 1 million metro	0.20	-0.58 ***	0.09	-0.45 ***	-0.27	0.02	-0.18
3 < 250,0000 metro	0.26	-0.49 ***	0.01	-0.46 **	-0.46**	0.06	-0.04
4 >= 20,000 adj. metro	0.23	-0.45 ***	0.08	-0.36 **	-0.43**	0.03	0.05
5 >= 20,000 not adj. metro	0.32	-0.35 **	0.27	-0.35 *	-0.40**	0.14	0.31*
6 2,500 – 19,999, adj metro	0.11	-0.32 **	0.00	-0.17	-0.24	0.03	-0.04

ξ reference group = government

ξ ξ reference group = 9, the most rural

ξ ξ ξ reference group = 9, Pacific

*p < =.05; ** p < = .01; *** p < = .001

Table 5 presents the results of the prediction analysis. All predictor variables except for-profit margin and percent of for-profit hospitals in the region were statistically significantly related to at least one quality indicator, but, for several of the variables, relationships were not consistent across quality indicators. Consistent predictors of gaps in quality were Joint Commission accreditation, non-profit private ownership, RN/AAPD, size, and urban-rural continuum. Accreditation was associated with a higher gap for four of the seven outcomes (heart failure readmission, pneumonia mortality, and mortality due to selected surgical procedures and selected medical conditions). Being a non-profit private hospital was associated with lower gaps for two of the outcomes (patient safety indicator and mortality due to selected surgical procedures). Taking into account the non-linear relationship, hospitals with higher RN-to-patient ratios had lower gaps for four of the outcomes (heart failure and pneumonia mortality, heart failure readmission, and mortality due to selected medical procedures). Larger hospitals had higher gap percentages for four of the outcomes (heart failure mortality, heart failure and pneumonia readmission, and patient safety indicator). For three outcomes (heart failure, pneumonia readmission, and patient safety indicator), hospitals in more urban areas had lower gaps compared to the most rural hospitals.

Predictors that were not consistently related to the gaps were payer mix, case mix index, teaching status, region, and HHI. Hospitals with a higher percentage of Medicare patients had lower gaps in heart failure and pneumonia mortality and in mortality due to selected medical conditions but had higher gaps in heart failure and pneumonia readmissions. Hospitals with a higher case mix index had lower heart failure and pneumonia readmission but higher heart failure and pneumonia mortality as well as mortality due to selected surgical procedures and medical conditions. Being a teaching hospital was associated with higher gaps for all but one outcome, heart failure mortality, which was negatively related to teaching status. Most regions had lower gaps compared to the Pacific for five outcomes, but there were higher gaps for the Mountain and Pacific states for heart failure readmission and higher gaps for six regions for pneumonia readmission. Hospitals in areas with lower competition (higher HHI) had lower gaps in heart failure and pneumonia readmission and patient safety indicator but higher gaps in heart failure and pneumonia mortality and mortality due to selected medical conditions.

Predictors that were not related to any gap were profit margin, and the percentage of for-profit hospitals in the region. For-profit ownership was significantly related to only one outcome: mortality due to selected medical conditions (a positive relationship).

DISCUSSION

Stochastic Frontier Analysis of Hospital Compare data indicates that gaps of 8-23% exist between hospitals' best possible and actual patient outcomes on the average.

Most hospitals had up to a 10% gap between their frontier and actual quality and safety scores. The study found that, based on the top decile of hospitals, “best practice” benchmarks for U.S. hospitals should be gaps between observed and expected outcomes of zero for heart failure and pneumonia mortality and readmission, zero for mortality from selected medical conditions, no greater than 3.5% for patient safety, and15% for mortality due to selected surgical procedures.

Our results indicate that the SFA compares favorably to other quality reporting systems. Whereas other systems compare actual scores, the SFA compares gaps between actual and best possible outcomes. Other systems compare hospitals based on averages or rankings, whereas the SFA compares hospitals based on distributions of “best practice” scores (lowest gaps). Instead of ranking hospitals above, at, or below the average, the SFA allows for a comparison of hospitals across a distribution of gaps. Therefore, the SFA appears to provide a more detailed description of hospital quality and a better comparison of quality between hospitals.

Payer mix, RN staffing, size, case mix index, accreditation, being a teaching hospital, urban location, region, and market competition were significant predictors of gaps, although with some predictors the direction of the association with gaps was not consistent across outcomes and did not go in the expected direction.

Better RN staffing and being in an urban area were associated with lower gaps in quality and safety. These results were expected. Prior research has shown that higher nurse staffing is related to higher quality (Bazzoli, et al., 2007; Unruh, 2003). Though prior research on urban-rural location has not been consistent, the logic is that hospitals in urban settings have better infrastructure to support high-quality care.

Other results were not as expected. That Joint Commission accreditation was associated with higher gaps is surprising, because this accreditation signifies that the hospital has met quality standards. Even though 87% of hospitals have this accreditation, making variation low, one would expect that the association of accreditation with gaps in quality would be weakly negative or, at the most, insignificant. The surprising positive association is accompanied by the result that larger hospitals also had higher gaps. One would expect that larger hospitals would have a stronger infrastructure to support quality of care. Instead, larger hospitals may be more disorganized (due to the difficulty of managing a large organization, perhaps), and these inefficiencies may affect the quality of care.

Alternatively, the impacts of both The Joint Commission and hospital size could be affected by insufficiently controlled patient acuity. Although the outcome variables were risk adjusted and case mix index was included as a predictor variable, it is possible that patient acuity was still not sufficiently captured in the model. In this case, Joint Commission-accredited and larger hospitals may care for patients with higher acuity, which may contribute to the higher gaps in quality. This explanation is weak, however, because other predictors that are likely related to higher patient acuity, such as being an urban hospital, were associated with lower gaps.

Payer mix, case mix index, teaching status, region, and HHI were inconsistently related to gaps in quality and safety. The fact that hospitals with a higher percentage of Medicare patients had low gaps for heart failure and pneumonia *mortality* but high gaps for heart failure and pneumonia *readmission* could be because there is an inverse relationship between mortality and readmission for Medicare patients with heart failure and pneumonia. It could indicate that hospitals are discharging the patients early enough to avoid in-hospital death but not late enough to avoid a readmission.

Case mix index was positively associated with all the mortality gaps but was negatively associated with readmission gaps. One would expect that hospitals with higher case mix would have higher quality and safety gaps, which would include readmissions. Perhaps hospitals with higher case mix had longer lengths of stay for patients with higher acuity, which could contribute to lower readmission gaps.

Teaching hospitals had higher gaps for all outcomes except for heart failure mortality, in which they had lower gaps. These results were unexpected. Conceptually, teaching hospitals should be able to provide higher quality, and for the most part prior research has shown teaching hospitals to have higher quality or to not have a significant effect on quality (Carretta, et al., 2013; Harrison, Lambiase and Zhao, 2010; Maeng and Martsolf 2011). As with accreditation and size, our results for teaching hospitals may be explained by inadequately controlled patient acuity.

Results for region show that the amount of gap varies by region and that, like payer mix and case mix, the direction of the gaps in mortality were the opposite of the gaps in readmissions. Gaps related to market competition also varied depending upon whether the gap was in mortality (higher) or readmissions (lower).

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. As mentioned earlier, it is possible that there is a connection between low mortality and readmission gaps. Hospitals that discharge patients sooner may have lower in-patient mortality rates but higher readmission rates as patients get sick at home and need to be readmitted.

We also want to note where there were *not* significant relationships between predictors and outcomes. Profit margin, for-profit ownership, and the percentage of for-profit hospitals in the county were not related to any gap, and non-profit private ownership was related to only two types of gap. These results would seem to indicate that profitability is not significantly related to gaps in quality and safety. Also, there were no urban-rural differences in heart failure and pneumonia mortality and very little urban-rural difference in mortality due to selected procedures and conditions. This is an interesting result; one would expect lower gaps in these outcomes among urban hospitals because they have the expertise and infrastructure to handle these conditions.

Limitations of the study

A limitation of this study relates to the conceptual framework and validity of both the gap and predictor models. The SFA models used to estimate the gaps contained a parsimonious number of inputs. It is possible that the best possible (frontier) values, and therefore the gap amounts, would have been better predicted if more inputs and covariates had been included in the SFA models. To test model performance, validity checks of the models were conducted. It was found that confidence intervals for *y* and *y** do not overlap, but *t* tests indicate that the two are not independent. These tests indicate that *y* and *y** are distinct from each other yet related to each other, which indicates that the model performed well technically. However, the R^2s of the models were low (0.02-0.65), indicating that the inputs did not explain much of the variation in y, weakening the validity of the gap.

To correct for this problem in the future, some of the explanatory variables used in the predictor analysis might be important to include in the gap model. Even though the measures were chosen based on a conceptual framework and prior studies of predictors of quality, there is no prior study that has used SFA in this manner. Further work on finding better models for estimating the gaps is certainly called for. This could encompass both adding more explanatory variables and experimenting with different functional forms.

Policy and research implications

The SFA found significant gaps between hospital's best possible and observed quality and safety indicators. This indicates that, based on their existing capital, labor, and technology, hospitals have room for improving the quality of care, especially with regard to mortality due to surgical procedures and patient complications. Financial, organizational, and market characteristics were predictors of those gaps, but because the direction of relationships was not uniform across several of the gaps, policy prescriptions should be made with caution at this time. As far as predictors amenable to policy, there seems to be some indication that some gaps could be lowered with higher RN staffing, higher Medicaid and private insurance payments, and assistance to rural hospitals and hospitals in certain regions.

The predictor part of the study is part of the ongoing research regarding the relationship between financial, organizational, and market characteristics of hospitals and quality. This research has been going on for a number of years and has not resolved questions regarding which financial, organizational, and market factors affect hospital quality and how they affect it. The current study adds another layer to the discussion but does not resolve the issues. It will be important to conduct more research on quality using SFA to estimate gaps in quality and safety. Different quality indicators, as well as predictors, could be explored in future studies. In future research, we also plan to take the methodology a step further by introducing the Count Data Stochastic Frontier Analysis (CDSFA), which is capable of utilizing count data. The CDSFA approach will make use of a new technique for Stochastic Frontier Analysis developed by Fe and Hofler (2013) that uses count data and thus provides a better estimate of the best practice values for such discrete variables.

A major advantage of the SFA is that the technique can be applied to any continuous measure that is used to indicate quality and safety.

Moreover, the technique works well with large data sets and administrative data, just the type of data in use by both public and private agencies to benchmark, compare, and pay for quality. The importance of this study goes beyond our findings regarding a specific sample of hospitals and specific quality and safety measures and applies to any benchmarking of quality and safety by public and private agencies in all provider settings. There is much work to be done in the future on establishing meaningful quality and safety indicators, including measures that are good composites of quality and safety in healthcare institutions. Future research, therefore, should apply the SFA to other quality and safety measures, both those currently in use by other agencies and those not in use but for which data are available (such as PSIs or IQIs). For example, "death in low mortality DRGs" and "failure to rescue" are two PSIs that are also on the National Quality Forum (NQF) measures list. The measures are more general indicators of safety than many of the Hospital Compare measures and may be excellent safety indicators in hospitals. As quality and safety measures improve over time, the SFA can continue to be used for benchmarking the improved measures.

An SFA approach to quality and safety has the potential to be the method adopted by public and private payers to establish best practice levels of quality and safety and to ascertain the gaps between actual and best practices. It can also assist hospital administrators to direct resources toward the factors best suited to making improvements in performance. An SFA approach, therefore, can serve as a basis for quality reporting, cross-hospital comparisons, trend analysis, pay-for-performance, and quality and safety improvement. The method works with any continuous quality measure, so it could be utilized with measures other than those in this analysis. Altogether, this proposed usage of SFA will provide policymakers and hospital administrators with the techniques and knowledge to assess how well best practices are being met and how to improve existing practices. This has the potential be enormously beneficial to every hospital patient.

REFERENCES

Bazzoli GB, Clement JP, Lindrooth RC, et al. Hospital financial condition and operational decisions related to the quality of hospital care. *Med Care Res Rev* 2007 64(2): 148-168.

Bazzoli GJ, Chen HF, Zhao M, et al. Hospital financial condition and the quality of patient care, *Health Econ* 2008 *17*: 977–995.

Carretta H, Chukmaitov A, Tang A, et al. Examination of hospital characteristics and patient quality outcomes using four inpatient quality indicators and 30-day all-cause mortality. *Am J Med Qual* 2013 *28*(1): 46-55.

Cho S, Yun S. Bed-to-nurse ratios, provision of basic nursing care, and in-hospital and 30-day mortality among acute stroke patients admitted to an intensive care unit: Cross-sectional analysis of survey and administrative data. *Int J Nurs Stud* 2009 *46*: 1092-1101.

CMS. *Outcomes Measures*. 2010. Department of Health and Human Services. Available from http://www.cms.gov/HospitalQualityInits/20_OutcomeMeasures.asp#TopOfPage.

CMS. Hospital Compare. 2013. Department of Health and Human Services. Available from: http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/HospitalCompare.html

Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *JAMA* 2013 *309* (15): 1599 – 1606.

Elixhauser A, Pancholi M, Clancy CM. Using the AHRQ quality indicators to improve health care quality. *Jt Comm J Qual Patient Saf* 2005 *31*(9): 533-538.

Fe, E, Hofler, RA. Count data stochastic frontier models, with an application to the patents-R&D relationship. *J Prod Anal* 2013 *39*(3): 271-284.

Gould, W. *Use poisson rather than regress; tell a friend. The Stata Blog.* 2011. http://blog.stata.com/2011/08/22/use-poisson-rather-than-regress-tell-a-friend/

Gowrisankaran G, Town R. Competition, payers, and hospital quality. *Health Serv Res* 2003 *38*(6 Pt 1): 1403-1421.

Harrison JP, Lambiase LR, Zhao M. Organizational factors associated with quality of care in US teaching hospitals. *J Health Care Finance* 2010 *36*(3): 1-12.

Hofler RA, Folland S. How reliable are hospital efficiency estimates? Exploiting the dual to homothetic production. *Health Econ* 2001 *10*(8):683-698.

Inpatient Quality Indicators. *Inpatient Quality Indicators (IQI) Composite Measure Workgroup Final Report.* 2008. Agency for Healthcare Research and Quality. Available from: http://www.qualityindicators.ahrq.gov

Jiang H, Friedman B, Jiang S. Hospital cost and quality performance in relation to market forces: An examination of U.S. community hospitals in the "post-managed care era". *International Journal of Health Care Finance and Economics* 2013 *13*(1): 53-71.

Keenan P, Normand S, Lin Z, et al. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. *Circ Cardiovasc Qual Outcomes* 2008 *1*(1): 29-37.

Krumholz H, Wang Y, Mattera J, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with heart failure. *Circulation* 2006 *113*(13): 1693-1701.

Laditka, J.N., Laditka, S.B., and Cornman, C.B. (2005). Evaluating hospital care for individuals with Alzheimer's disease using inpatient quality indicators. *Am J Alzheimers Dis Other Demen 20*(1): 27-36.

Lindenauer PK, Remus D, Roman S, et al. Public reporting and pay for performance in hospital quality improvement. *N Engl J Med 2007 36*(5): 486–496.

Maeng DD, Martsolf GR. Comparing patient outcomes across payer types: Implications for using hospital discharge records to assess quality. *Health Serv Res* 2011 *46*(6 Pt1): 1720-1740.

Mark BA, Harless DW, McCue M, Xu Y. A longitudinal examination of hospital registered nurse staffing and quality of care. *Health Serv Res 2004 39*(2): 279-299.

Meddings JA, McMahon LF. Measuring quality in Pay-for-Performance programs: From 'One-Size-Fits-All' measures to individual patient risk-reduction scores. *Dis Manag Health Out* 2008 16(4): 205-216.

Mutter R, Rosko M, Wong H. Measuring hospital inefficiency: The effects of controlling for quality and patient burden of illness. *Health Serv Res* 2008 *43*(6): 1992-2013.

Mutter R, Valdmanis V, Rosko M. High versus lower quality hospitals: A comparison of environmental characteristics and technical efficiency. *Health Serv Outcomes Res Methodology* 2010 *10*(3/4): 134-153.

Patient Safety Indicators. *AHRQ Quality Indicators: Composite Measures User Guide for the Patient Safety Indicators (PSI).* 2010. Agency for Healthcare Research and Quality Available from: http://www.qualityindicators.ahrq.gov

Rogowski J, Jain AK, Escarce JJ. Hospital competition, managed care, and mortality after hospitalization for medical conditions in California. *Health Serv Res 2007 42*(2): 682-705.

Rosko M, Mutter R. Stochastic frontier analysis of hospital inefficiency: A review of empirical issues and an assessment of robustness. *Med Care Res Rev 2008 65*(2): 131-166.

Rosenthal MB, Frank RG. What is the empirical basis for paying for quality in health care? *Med Care Res Rev* 2006 *63*(2): 135-157.

Ryan A. Effects of the Premier Hospital Quality Incentive Demonstration on Medicare patient mortality and cost. *Health Serv Res* 2009 *44*(3): 821-842.

Stone PW, Mooney-Kane C, Larson EL, Horan T, Glance LG, Zwanziger J, Dick AW. Nurse working conditions and patient safety outcomes. *Med Care 2007* 45(6): 571-578.

Unruh L. Licensed nurse staffing and adverse events in hospitals. *Med Care* 2003 *41*(1): 142-152.

LIST OF PUBLICATIONS AND PRODUCTS:

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Unruh, L. & Hofler, R. “Benchmarking Patient Safety and Quality: The Stochastic Frontier Approach,” Oral presentation at the International Health Economic Association meeting, Sydney Australia, July 7-10, 2013.

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Papers under Review:

Unruh, L, Hofler, R. Benchmarking patient safety and quality: The stochastic frontier approach. *Int J Qual Health C.*

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