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The Effects of Hospital Competition on Inpatient Quality of Care

Existing empirical studies have produced inconclusive, and sometimes contradictory, findings on the effects of hospital competition on inpatient quality of care. These inconsistencies may be due to the use of different methodologies, hospital competition measures, and hospital quality measures. This paper applies the Quality Indicator software from the Agency for Healthcare Research and Quality to the 1997 Healthcare Cost and Utilization Project State Inpatient Databases to create three versions (i.e., observed, risk-adjusted, and "smoothed") of 38 distinct measures of inpatient quality. The relationship between 12 different hospital competition measures and these quality measures are assessed, using ordinary least squares, two-step efficient generalized method of moments, and negative binomial regression techniques. We find that across estimation strategies, hospital competition has an impact on a number of hospital quality measures. However, the effect is not unidirectional: some indicators show improvements in hospital quality with greater levels of competition, some show decreases in hospital quality, and others are unaffected. We provide hypotheses based on emerging areas of research that could explain these findings, but inconsistencies remain.

In recent years, the effects of competition on health care quality have received growing attention in policy discussions. Several reports and articles (e.g., IOM 2003, 2001, 2000; Sage, Hyman, and Greenberg 2003), joint hearings by the Federal Trade Commission (FTC) and Department of Justice (DOJ) (held May 27–30 and June 10–12, 2003), and an invitational conference, "Provider Competition and Quality," co-sponsored by the Agency for Healthcare Research and Quality (AHRQ) and the FTC (held May 28, 2003), exemplify this new policy focus. At the aforementioned conference, FTC Chairman Timothy Muris remarked that "the commission recognizes that quality is a crucial part of the competitive mix when purchasing health care," that "sensible competition policy must include issues of quality," and that "we (the FTC) expect to confront more arrangements involving challenging issues of quality and non-price competition" (For the Record, Inc. 2003, pp. 13–15).[1]

This new policy focus has important economic implications because changes in health care quality, as a result of changes in competition, may lead to different social welfare outcomes. Under reasonable assump-

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tions of provider and consumer behavior, economic theory suggests that any outcome is possible—quality may improve, deteriorate, or remain unchanged with changes in competition. Existing empirical studies typically focus on the effects of hospital competition on inpatient quality of care (e.g., Gowrisankaran and Town 2003; Sari 2002; Mukamel, Zwanziger, and Bamezai 2002; Mukamel, Zwanziger, and Tomaszewski 2001; Ho and Hamilton 2000; Kessler and McClellan 2000; and Shortell and Hughes 1988). Taken together, the findings from these studies appear inconclusive, providing limited evidence in support of any of the implications from the conceptual models. The lack of consensus may be due to differences in the time periods investigated, groups of patients examined (e.g., Medicare patients), geographic regions explored, quality and competition measures utilized, and/or empirical models employed. Alternatively, conflicting findings may highlight the complexity of the relationship between hospital competition and inpatient quality of care or suggest other factors in need of further exploration.

The aim of this paper is to assess the relationship between hospital competition and inpatient quality of care, while addressing issues concerning the ability to generalize findings and the robustness of the results. Our study contributes to this goal and the existing literature in the following important ways. First, our study uses data for all hospital inpatient discharges for all patients in 22 states and up to 2,595 hospitals. Most existing studies focus on a single population (e.g., Medicare patients) and/or a single geographic area (e.g., one or two states, such as California). By using data from nearly half of the states in the country, our study has broader geographic and population representations, making our findings more generalizable.

Second, we use multiple sets of quality measures to serve as proxy measures for hospital quality. The proxy measures of inpatient quality in existing studies typically include mortality rates for selected medical conditions, such as acute myocardial infarction (AMI), pneumonia, congestive heart failure (CHF), and stroke.[2] While mortality measures are included in our analyses, we also include a set of measures that capture complicating factors that should not occur with good medical care, do not necessarily lead to death (e.g., infections typically caused by the lack of good hygiene), and address the overall experience of an inpatient stay. The different measures allow us to capture the various dimensions of quality. Hospitals may respond to competitive pressures differently and the resulting changes in quality may manifest themselves in various ways. In total, 38 quality measures were included in our analyses.

Third, we use a broad set of hospital competition measures based on different methods to define the hospital market area and assess the intensity of competition. We employed 12 hospital competition measures, giving us the ability to assess the robustness of our findings.

The paper is organized as follows. The next section provides a brief literature review. The third section describes the empirical methods and data, and the fourth section presents the results. The last two sections provide a discussion and concluding thoughts about hospital competition and quality of care.

Literature Review

Several empirical studies have contributed to the discussion about how hospital competition affects inpatient quality of care. However, the findings are inconclusive. In this section, we briefly review the relevant literature to provide a better context for our study.

Hospital Competition Improves Inpatient Quality

Several studies support the finding that hospital competition improves inpatient quality. Perhaps the first empirical study to examine the effects of hospital competition on inpatient quality since the recent emergence of health care quality concerns is by Kessler and McClellan (2000). Recognizing the social welfare implications, these researchers studied the effects of hospital competition on the mortality and subsequent readmissions of all nonrural, elderly Medicare beneficiaries hospitalized between 1985 and 1994 for AMI. To circumvent the loss of information that occurs in studies that examine only in-hospital mortality,[3] they used a one-year time frame in assessing mortality[4] and readmission. An important contribution was the creation and use of a metric for hospital competition that circumvents the problems of endogeneity bias prevalent in some existing methods (i.e., the tendency of high-quality hospitals to draw patients from a wider geographic area, making it appear as though they face greater competition). In general, this new approach is an extension of the patient flow method, which employs a multi-step process where patient-level hospital choice models are estimated in the initial phase. In subsequent phases, competition measures are created using predicted measures of patient flow from the initial step, rather than from actual patient flows.[5] Another noteworthy contribution of their empirical analysis is the inclusion of a managed care penetration measure to mediate the impact of hospital competition on quality.[6] Kessler and McClellan found that hospital competition reduces mortality and readmission rates, thereby improving quality.

Sari (2002) extended the work of Kessler and McClellan (2000) by examining the effects of hospital competition on all patients (i.e., not just Medicare patients) and by using a broader array of inpatient quality measures—the Healthcare Cost and Utilization Project (HCUP) Quality Indicators (QIs). One limitation of the HCUP QIs is the fact that they are not risk-adjusted and have since been replaced by the Agency for Healthcare Research and Quality (AHRQ) QIs. The AHRQ QIs are risk-adjusted, exhibit more year-to-year stability, and focus more on nonsurgical aspects of care. Sari applied the HCUP QIs to hospital inpatient data from the HCUP Nationwide Inpatient Sample (NIS) for the period 1992–1997, which includes a sample of hospitals in up to 16 states. In total, Sari's proxies for inpatient quality included six in-hospital mortality rates, seven surgical complication rates, three nonsurgical complication rates, two utilization rates of obstetric procedures, and seven utilization rates of surgical procedures. His hospital competition measure was the county-level Herfindahl-Hirschman Index (HHI). Sari found that hospital competition leads to an improvement in two inpatient quality measures (adverse/iatrogenic complications and inappropriate surgical operations).

Gowrisankaran and Town (2003) contributed to the literature by suggesting that hospitals may have some explicit behavioral responses to hospital competition. They posited that hospitals prefer health maintenance organization (HMO) patients to Medicare patients for conditions for which HMOs pay higher margins. Therefore, hospitals in more competitive markets may lower quality for Medicare patients and raise quality for HMO patients in an effort to change their patient mix. Using a hospital competition measure based on methods developed by Kessler and McClellan (2000) but aggregated to the hospital level, Gowrisankaran and Town explored the impact of hospital competition on risk-adjusted 30-day AMI rates and 10-day pneumonia mortality rates for HMO and Medicare patients in Southern California from 1989 to 1993. They found greater hospital competition to be associated with higher pneumonia and AMI mortality rates for Medicare patients, but lower AMI mortality rates for HMO patients.

Hospital Competition Reduces Inpatient Quality

In contrast to the studies cited in the previous section, there is research consistent with the finding that hospital competition reduces inpatient quality. Mukamel, Zwanziger, and Bamezai (2002) suggested that in markets characterized by price competition, hospitals compete for patients along dimensions that patients can easily evaluate (e.g., "hotel services"[7]) as opposed to dimensions that patients find difficult to appraise (e.g., clinical services). As the intensity of competition within a market increases, hospitals will shift more of their resources away from clinical services and into hotel services, which will lead to poorer patient outcomes. Using California data, they found that greater competition, as measured by patient flow HHI, was associated with a shift of resources from clinical to hotel services during the years

1982 to 1989.[8] In the second step of their analysis, Mukamel, Zwanziger, and Bamezai examined the impact of the resource shift on patient outcomes. They found a statistically significant, inverse relationship between hospitals' expenditures for clinical services per adjusted discharge and 30-day excess mortality rates[9] for several different groups of patients: all causes, AMI, CHF, pneumonia, and stroke. Taken together, these results suggest that hospitals in more competitive markets, characterized by price competition, are associated with poorer patient outcomes.

Hospital Competition Has No Effect on Inpatient Quality

Theory does not mandate that hospital competition must improve or reduce inpatient quality, and there is empirical evidence that it has no effect on quality. Conducted as part of a broader analysis of the effects of hospital institutional and market characteristics on mortality, the study by Shortell and Hughes (1988) was perhaps the earliest empirical study to provide insight into the effect of hospital competition on inpatient quality. Their analysis used Medicare data from the early 1980s and included a group quality measure based on mortality rates from 16 conditions, procedures, and complications.[10] To measure hospital competition, a binary variable based on a modified fixed radius HHI[11] was used. They found that the coefficient on this variable was insignificant.

More recently, Mukamel, Zwanziger, and Tomaszewski (2001) found no association between hospital competition (measured as patient flow HHI) and inpatient quality (measured as 30-day risk-adjusted mortality rates for several different groups of patients: all causes, AMI, CHF, pneumonia, stroke, coronary artery bypass grafting [CABG], and hip replacement surgery). Their analysis was based on hospitals in 134 Metropolitan Statistical Areas (MSAs) and was part of a larger study of the effects of HMOs on inpatient quality.

Hospital Consolidations Reduce Inpatient Quality

In a related literature, an analysis by Ho and Hamilton (2000) was the first and only published study that explicitly examined the effects of hospital consolidations on quality. They identified all California hospitals that consolidated between 1992 and 1995 and assessed whether these consolidations had any effect on inpatient mortality for AMI, 90-day readmission for AMI, inpatient mortality for stroke, and discharge of newborn babies within 48 hours of delivery. Their results showed that consolidations, and hence less competition, had no impact on mortality; however, all three types of consolidation they considered[12] increased the probability of 90-day readmission for AMI patients. Only one type of consolidation—purchase of a system hospital by another system—led to an increase in the early discharge of healthy newborns. Ho and Hamilton (2000) found little evidence that consolidations have differing effects on Medicare and private insurance patients.

Methods and Data

Basic Empirical Model

Based on the existing empirical literature, our empirical model takes the following general form:

$$Q^k = \alpha + \beta COMP^n + \sum_{a=1}^{o} \chi_a HOSP_a + \sum_{b=1}^{p} \delta_b MKT_b + \varepsilon$$

where Q^k is a set of k quality measures[13] applied individually in our regressions. That is, for each quality measure, separate regressions are estimated. $COMP^n$ is a set of n hospital competition measures. Similarly, a single competition measure is used for each regression. Thus, we run $k \times n$ regressions. $HOSP_a$ denotes a vector of hospital-level variables where a represents a specific hospital characteristic. Similarly, MKT_b denotes a vector of market-level variables where b represents a specific market characteristic. $HOSP_a$ and MKT_b are applied to all of the regressions. α, β, χ_a, and δ_b are parameters to be estimated and ε is the error term. Table 1 provides descriptive statistics for the independent variables used in our regression analysis.

Table 1. Descriptive statistics of independent variables in the hospital quality model

Variable	Mean	Standard deviation
Hospital characteristics		
Total beds	192.12	186.01
Surgical discharge rate[a]	.27	.29
For-profit ownership	.15	.36
Nonprofit ownership	.64	.48
Teaching	.24	.43
Urban	.66	.47
Case-mix index	1.30	.25
Medicare discharge rate[b]	.45	.14
Market characteristics		
County physicians per 1,000[c]	2.34	1.97
County unemployment rate, age 16+	.05	.03
County income per capita	$24,584	$7,523
Total county ambulatory surgery centers	12.06	27.55
County HMO penetration rate	.28	.19
Competition measures		
County, *N*	12.71	23.74
MSA, *N*	33.16	32.46
HSA, *N*	24.58	33.94
Fixed radius, *N*	12.79	18.62
Variable radius, *N*	11.78	23.83
Patient flow, *N*	7.04	4.43
County, HHI	.46	.36
MSA, HHI	.15	.17
HSA, HHI	.22	.20
Fixed radius, HHI	.45	.37
Variable radius, HHI	.51	.37
Patient flow, HHI	.32	.13

[a] (Number of inpatient surgeries)/(total discharges).
[b] (Number of Medicare discharges)/(total discharges).
[c] (Total active, non-federal physicians)/(county population estimate)*1,000.

Inpatient Quality Measures

Our proxy measures for inpatient quality (i.e., our dependent variables) are based on the AHRQ QIs. AHRQ makes the three modules of the QI software available for free on its Web site.[14] We used the two modules that assess the quality of inpatient care given to patients, the Inpatient Quality Indicators (IQIs) and the Patient Safety Indicators (PSIs).[15] Table 2 lists the specific indicators that we used.[16] Following Romano and Mutter (2004), we did not use the IQI's volume of procedure rates as quality measures. We also did not use two of the utilization indicators calculated by the IQI software, Caesarean section (C-section) delivery rate and vaginal birth after C-section (VBAC) delivery rate, because they reflect local practice patterns and because the quality signal they provide is more difficult to interpret.

To create our proxy quality measures, we applied the AHRQ QI software to the 1997 HCUP State Inpatient Databases (SID) for 22 participating states.[17] For each participating state, the SID contain the discharge abstract for every inpatient hospitalization that occurred. We aggregated the patient-level files generated by the software to create hospital-level analytic files.

For each quality measure, three rates were created. The observed rate for each hospital *j*, $Q_j^{k,\,obs}$, consists of the total number of quality events of type *k* that occurred at that hospital divided by the population of cases for which quality event *k* could have occurred.

In addition, the IQI software calculates risk-adjusted rates using controls for age, sex,[18] and severity score calculated by 3M's All Patient Refined Diagnosis Related Groups (APR-DRGs).[19] Analogously, the PSI software uses age, sex, modified diagnosis-related group categories,[20] and a modified version of the AHRQ Comorbidity Software[21] to control for differences in severity of patient illness. Further details of the risk-adjustment methodologies used by the IQIs and PSIs can be found in the AHRQ *Guide to Inpatient Quality Indicators* (2002) and McDonald et al. (2002), respectively.

Finally, the IQI software produces smoothed rates, which aim to remove the random noise in the observed rates due to fluctuations in the number of procedures that hospitals perform each year and other factors unrelated to differences in patient severity or provider quality that can influence in-hospital mortality rates.[22] These smoothed rates were estimated using a multivariate signal extraction (MSX) method, which consists of two steps. First, the software estimates the signal-to-noise ratio for each hospital for each condition (procedure) using a univariate approach based on the number of patients on which the observed rate is based. Hospitals treating relatively fewer patients with a

Table 2. Descriptive statistics of AHRQ QIs in hospital quality models

	Number of hospitals in sample	Observed rate		Risk-adjusted rate		Smoothed rate	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Inpatient Quality Indicators (IQIs)							
In-hospital mortality: Esophageal resection	442	.1467	.3145	.0664	.1063	ND	ND
In-hospital mortality: Pancreatic resection	787	.0984	.2411	.0644	.1288	.0662	.0132
In-hospital mortality: Pediatric heart surgery	212	.0550	.1498	.0162	.0315	.0394	.0127
In-hospital mortality: Abdominal aortic aneurysm (AAA) repair	1,379	.1725	.2343	.0488	.1086	.0963	.0194
In-hospital mortality: Coronary artery bypass grafting (CABG)	544	.0429	.0469	.0256	.0429	.0288	.0094
In-hospital mortality: Craniotomy	1,148	.1043	.1317	.1114	.0940	.0838	.0201
In-hospital mortality: Hip replacement	1,939	.0052	.0385	.0032	.0175	.0023	.0011
In-hospital mortality: Acute myocardial infarction (AMI)	2,442	.1551	.1339	.1325	.0884	.1076	.0187
In-hospital mortality: Congestive heart failure (CHF)	2,541	.0540	.0586	.0575	.0386	.0510	.0096
In-hospital mortality: Stroke	2,532	.1132	.0840	.1305	.0630	.1213	.0199
In-hospital mortality: Gastrointestinal hemorrhage	2,510	.0353	.0519	.0288	.0294	.0329	.0034
In-hospital mortality: Hip fracture	2,246	.0326	.0597	.0083	.0305	.0242	.0052
In-hospital mortality: Pneumonia	2,555	.0838	.0474	.0855	.0416	.0874	.0171
In-hospital mortality: Percutaneous transluminal coronary angioplasty (PTCA)	640	.0284	.0803	.0029	.0165	.0099	.0029
In-hospital mortality: Carotid endarterectomy	1,577	.0114	.0536	.0028	.0212	ND	ND
Laparoscopic cholecystectomy	2,368	.6771	.1990	.6836	.1831	.7049	.1282
Incidental appendectomy in the elderly	2,363	.0293	.0468	.0313	.0391	.0271	.0145
Bilateral cardiac catheterization	1,217	.1563	.1806	.1336	.1494	.1282	.1312
Patient Safety Indicators (PSIs)							
Complications of anesthesia	2,514	.0009	.0070	.0009	.0070	.0006	.0007
Death in low mortality diagnosis-related groups (DRGs)	2,587	.0011	.0111	.0011	.0110	.0007	.0007
Decubitus ulcer	2,586	.0215	.0216	.0181	.0190	.0195	.0142
Failure to rescue	2,546	.1387	.0904	.1353	.0628	.1436	.0159
Foreign body left in during procedure	2,595	.0000	.0001	.0000	.0001	.0000	.0000
Iatrogenic pneumothorax	2,594	.0010	.0022	.0010	.0022	.0009	.0007
Selected infections due to medical care	2,595	.0014	.0018	.0013	.0014	.0016	.0007
Postoperative hip fracture	2,502	.0014	.0059	.0014	.0053	.0009	.0004
Postoperative hemorrhage or hematoma	2,511	.0018	.0031	.0018	.0030	.0017	.0005
Postoperative physiologic and metabolic derangements	2,328	.0011	.0108	.0009	.0033	ND	ND
Postoperative respiratory failure	2,326	.0027	.0054	.0017	.0044	.0026	.0015
Postoperative pulmonary embolism or deep vein thrombosis	2,511	.0073	.0126	.0061	.0108	.0075	.0028
Postoperative sepsis	2,247	.0111	.0423	.0074	.0165	.0087	.0032
Postoperative wound dehiscence in abdominopelvic surgical patients	2,452	.0025	.0085	.0026	.0085	.0020	.0004
Accidental puncture and laceration	2,594	.0024	.0027	.0029	.0020	.0030	.0015
Transfusion reaction	2,595	.0000	.0000	ND	ND	ND	ND
Birth trauma – injury to neonate	1,947	.0094	.0308	.0096	.0311	.0097	.0305
Obstetric trauma – vaginal delivery with instrument	1,860	.2052	.1451	.2077	.1311	.2198	.0835
Obstetric trauma – vaginal delivery without instrument	1,977	.0753	.0572	.0762	.0527	.0783	.0418
Obstetric trauma – C-section delivery	1,927	.0063	.0170	.0063	.0128	.0060	.0030

Note: S.D.= standard deviation; ND = not defined.

particular condition (using that procedure) are regarded as having lower signal-to-noise ratios. Second, the hospital's observed rate for a condition (procedure) is shifted closer to the rate calculated for all of the hospitals in the HCUP states for that condition (procedure) over multiple years. The extent of the shift is determined by the signal-to-noise ratio: observed rates associated with lower signal-to-noise ratios are shifted more than hospitals with higher signal-to-noise ratios. The PSI software produces smoothed rates using a similar methodology. Further details can be found in the AHRQ *Guide to Inpatient Quality Indicators* (2002) and McDonald et al. (2002).

In total, 38 AHRQ QI measures, each with three versions, were used in our investigation for a total of 114 proxies for inpatient quality.

Hospital Competition Measures

The main independent variable of interest is the hospital competition measure. We used 12 measures of hospital competition based on six definitions of hospital market area (county, MSA, Health Service Area [HSA], 15-mile fixed radius, 75% variable radius, and patient flow) and two metrics for the intensity of competition within a market (the number of hospitals, *N*, and HHI). The data and methods used to create these measures are described in Wong, Zhan, and Mutter (2005). We review them briefly here.

We used the 1997 American Hospital Association (AHA) Annual Survey of Hospitals to link hospitals to counties and MSAs. We also assigned hospitals to the 800-area, nonlinked HSA solutions generated by Makuc et al. (1991) using the Area Resource File (ARF).

To create hospital market areas using the fixed-radius approach, we calculated the distances between each community hospital in the 1997 AHA and every other community hospital using the latitude and longitude of each institution. For each hospital, we created unique market areas, which consisted of the target hospital and all other hospitals within 15 miles.

We created variable-radius market areas by linking the 1997 SID to the 1997 AHA to obtain the latitude and longitude coordinates of each hospital, and by linking the 1997 SID to data from the U.S. Census Bureau to determine the latitude and longitude coordinates of the centroid location of each patient ZIP code in the SID. We measured the distance between every hospital and the within-state ZIP codes it serves and rank ordered the ZIP codes by distances from the hospital. We then calculated a radius for each hospital that captured 75% of the hospital's discharges.[23]

We created patient flow market areas using the 1997 SID. The market areas consisted of all the ZIP codes that the hospital served and which were in the same state.

The calculation of *N* was straightforward for the hospital market areas defined by geopolitical boundaries, the fixed-radius approach, and the variable-radius approach. To calculate HHIs for the hospital market areas defined by these approaches, we used hospital discharge data. To calculate *N* and the HHI for the markets defined by the patient-flow approach, we first calculated *N* and the HHI for each of the ZIP codes in the SID. For each hospital, we then weighted the ZIP codes by the proportion of the hospital's discharges that came from that ZIP code. We calculated *N* and the HHI for each hospital's market area by summing the weighted *N*s and HHIs of the ZIP codes that sent patients to the hospital.

The patient-flow approach assumes that ZIP codes that send a trivial number of patients to a hospital are unlikely to affect the hospital's behavior. Therefore, we employed a rule to exclude hospitals receiving a small percentage of patients from a ZIP code from the calculation of *N* for that ZIP code. The rule counted the number of hospitals that made up 90% of the ZIP code's discharges and excluded the rest. There was no need to make a similar adjustment for the HHI because the impact of even a monopolized ZIP code that sends a trivial number of patients to a hospital will have a negligible effect on the hospital market's HHI.

Hospital and Market Characteristics

To control for hospital characteristics, we used the 1997 AHA Annual Survey of Hospitals to create the following variables:

the number of beds, the percentage of discharges paid for by Medicare, the percentage of discharges that are surgical, and teaching status.[24] We defined a hospital as being urban or rural depending on whether it was located in a MSA, using the 1997 Area Resource File's MSA designation. Finally, to control for hospital case mix, we used the 1997 case-mix index from the Centers for Medicare and Medicaid Services (CMS).

To account for other market conditions, we also included the following variables in our analyses: the number of physicians per capita, unemployment rate, income per capita, and number of ambulatory surgical centers (as a control for substitute sources of care [Luke, Begun, and Walston 2000]) from the 1997 ARF.[25] We included InterStudy's 1998 county HMO penetration rate (as reported in the 1997 ARF), as well as the interaction between HMO penetration and hospital competition.[26]

Estimating the Total Effect of Hospital Competition on Inpatient Quality

For all observed, risk-adjusted, and smoothed quality measures, we estimated the total effect of hospital competition on inpatient quality as follows:

$$\frac{\partial QI^k}{\partial COMP^n} = \hat{\beta} + \hat{\delta}_{(HMO*COMP^n)}\left(\overline{HMO^{k,n}}\right)$$

where $\hat{\delta}_{(HMO*COMP^n)}$ is the estimated coefficient on the interaction term between managed care penetration and hospital competition measure n and $\overline{HMO^{k,n}}$ is the sample mean HMO penetration rate for the hospitals for which quality indicator k and competition measure n are defined. We calculated the standard error as follows (Greene 2000):

$$S.E.\left(\frac{\partial QI^k}{\partial COMP^n}\right) = \sqrt{Var\left(\hat{\beta}\right) + \left(\overline{HMO^{k,n}}\right)^2 Var\left(\hat{\delta}_{(HMO*COMP^n)}\right) + 2\left(\overline{HMO^{k,n}}\right) Cov\left(\hat{\beta},\hat{\delta}_{(HMO*COMP^n)}\right)}$$

For the smoothed quality measures, we also calculated the effect of hospital competition on quality at the mean ± one standard deviation of the HMO penetration rate where quality indicator q and competition measure n are defined.[27]

We estimated the elasticity of the smoothed rates with respect to competition using ordinary least squares (OLS) or the two-step efficient generalized method of moments (GMM) as subsequently described. The large number of zero values in the risk-adjusted series meant that we could not use logs of the values; therefore, we approximated the logarithmic distribution by taking square roots of the dependent variable, and then estimated the model using either OLS or GMM. We estimated the effect of competition on unadjusted quality events using negative binomial regression with the numerator of the observed rate as the dependent variable and the denominator as the exposure.[28]

We calculated robust standard errors using HC0, the sandwich estimator proposed by Huber (1967) and White (1980) for all regressions for which there were at least 275 observations. We calculated robust standard errors using HC3, the jackknife estimator of Efron (1982, per the citation of MacKinnon and White 1985) for the remaining regressions.[29]

There is reason to believe that hospital quality will affect the flow of patients to hospitals, thereby causing the variable-radius and patient-flow measures of hospital competition to be endogenous with respect to quality. In addition, because they rely on the market shares of competing hospitals, the geopolitical boundary and fixed-radius measures of the hospital HHI also may be endogenous. Accordingly, we used the Durban-Wu-Hausman test proposed by Davidson and MacKinnon (1993) to test whether our competition measures were endogenously determined with the quality measures.

We used OLS for the measures that were not endogenous. We used a two-step efficient GMM estimator[30] for the measures that were endogenous. We used a combination of the number of large firms (i.e., with 100 or more workers) from the U.S. Census Bureau's County Business Patterns file, population, and the number of dentists from the ARF as instruments since they proxy demand for hospital services and are unrelated to hospital quality.[31] We followed a strategy recommended by Wooldridge (2000) and instrumented for the interaction of hospital competition and HMO penetration using predicted hospital competition from a reduced form estimation multiplied by HMO penetration. We use a *J*-statistic to test the validity of the instruments. The *J*-statistic in all of the GMM regressions was at least .10.

We ran a total of 2,280 regressions. We estimated the effect of each of the 12 competition measures on each observed, risk-adjusted, and smoothed QI, correcting for heteroskedasticity and endogeneity (where appropriate), and evaluated at the mean HMO penetration rate. We also estimated the effect of each of the 12 competition measures on each of the smoothed QIs, correcting for heteroskedasticity and endogeneity (where appropriate), and evaluated at the mean ± one standard deviation of the HMO penetration rate.

Results

Table 3 presents the estimated total effects of hospital competition on our inpatient quality measures for our "baseline" regression model. Our baseline model employed the commonly used patient-level HHI as our hospital competition measure and the smoothed version of the AHRQ QIs with endogeneity correction as appropriate. The total effect was evaluated at the mean HMO penetration rate.[32] Table 3 is meant to be illustrative of our "typical" regression and should not be considered our "best" model. Because each AHRQ QI has its own unique characteristics, it is impossible to have a single best model that can be applied to all of the AHRQ QIs.

Consequently, we summarize the findings of all our regression models—60 regressions for each of 38 QIs—in Table 4. Column 2 reports the mode results of the effect of hospital competition on the corresponding AHRQ QI (i.e., insignificant, is associated with increased quality or reduced quality, or not defined) from our 60 regressions, using a 10% level of significance.[33] Columns 3 to 5 report the number of regression models that showed an association of improvement, reduction, or no effect of hospital competition on the corresponding inpatient quality measure.[34] Column 6 indicates the number of regression models that could not be defined because the QI version did not exist.

The majority of the AHRQ QIs exhibit infrequent sign shifts across model specifications. Based on the mode results, hospital competition was associated with improved inpatient quality as measured by six AHRQ QIs, a reduction in inpatient quality as measured by six AHRQ QIs, and no effect (or undefined) on inpatient quality as measured by the remaining AHRQ QIs. In sum, hospital competition was associated with an improvement in inpatient quality for the following AHRQ QIs: in-hospital mortality for CHF, complications of anesthesia, iatrogenic pneumothorax, accidental puncture and laceration, obstetric trauma with instrument, and obstetric trauma without instrument. In contrast, hospital competition was associated with a reduction in inpatient quality for the following AHRQ QIs: in-hospital mortality for abdominal aortic aneurysm (AAA) repair, in-hospital mortality for AMI, bilateral cardiac catheterization, decubitus ulcer, postoperative respiratory failure, and postoperative pulmonary embolism or deep vein thrombosis.

In general, our results at the high and low ends of HMO penetration were consistent with each other and with the findings at the mean level of HMO penetration. The one exception was iatrogenic pneumothorax. More incidences of that adverse event were associated with greater competition in markets with high managed care penetration; yet in markets with low managed care penetration, the opposite was true. Iatrogenic pneumothorax is associated with care provided by residents instead of physicians (McDonald et al. 2002). Therefore, our finding may reflect a preference by HMOs for the substitution of care by residents for care by more experienced doctors; however, further research would be required to explore this conjecture.

Discussion

If one were to view all of the AHRQ QIs as equal proxies for overall inpatient quality, the evidence would appear to be inconclusive as

Table 3. Total effect of hospital competition on inpatient quality: benchmark results

QI, Smoothed rate	Total effect, $\frac{\partial QI^k}{\partial COMP}$	*t-stat*	Interpretation of $\frac{\partial QI^k}{\partial COMP}$
In-hospital mortality: Esophageal resection	ND	ND	ND
In-hospital mortality: Pancreatic resection	−.0196	−.74	
In-hospital mortality: Pediatric heart surgery	−.0573	−.88	
In-hospital mortality: AAA repair	.0723	3.28**	Reduces quality
In-hospital mortality: CABG	−.0070	−.19	
In-hospital mortality: Craniotomy	.0034	.20	
In-hospital mortality: Hip replacement	.0426	.82	
In-hospital mortality: AMI	.0581	2.18*	Reduces quality
In-hospital mortality: CHF	−.1323	−3.93**	Improves quality
In-hospital mortality: Stroke	−.0154	−.63	
In-hospital mortality: Gastrointestinal hemorrhage	.0003	.06	
In-hospital mortality: Hip fracture	.0477	1.96*	Reduces quality
In-hospital mortality: Pneumonia	−.0186	−.53	
In-hospital mortality: PTCA	.0291	1.27	
In-hospital mortality: Carotid endarterectomy	ND	ND	ND
Laparoscopic cholecystectomy	−.0025	−.23	
Incidental appendectomy in the elderly	−.0963	−1.28	
Bilateral cardiac catheterization	.5906	3.99**	Reduces quality
Complications of anesthesia	−.2503	−2.45*	Improves quality
Death in low mortality DRGs	−.0934	−.73	
Decubitus ulcer	.2594	2.15*	Reduces quality
Failure to rescue	−.0261	−1.52	
Foreign body left in during procedure	−.0021	−.21	
Iatrogenic pneumothorax	−.0809	−1.49	
Selected infections due to medical care	.1456	2.27*	Reduces quality
Postoperative hip fracture	−.0026	−.08	
Postoperative hemorrhage or hematoma	−.0558	−1.53	
Postoperative physiologic and metabolic derangements	ND	ND	ND
Postoperative respiratory failure	.2643	3.74**	Reduces quality
Postoperative pulmonary embolism or deep vein thrombosis	.0597	1.20	
Postoperative sepsis	.0620	1.34	
Postoperative wound dehiscence in abdominopelvic surgical patients	−.0412	−1.34	
Accidental puncture and laceration	−.5138	−4.51**	Improves quality
Transfusion reaction	ND	ND	ND
Birth trauma - injury to neonate	−.3573	−1.27	
Obstetric trauma - vaginal delivery with instrument	−.2741	−3.53**	Improves quality
Obstetric trauma - vaginal delivery without instrument	−.4522	−3.75**	Improves quality
Obstetric trauma – C-section delivery	−.1316	−1.93†	Improves quality

Notes: Using patient flow, *N*; endogeneity correction employed as appropriate.
ND = not defined.
** Significant at 1% level.
* Significant at 5% level.
† Significant at 10% level.

Table 4. Total effect of competition on inpatient quality: summary of all regressions

QI	Mode[a] (number)	Number improves quality	Number reduces quality	Number insignificant effect on quality	Number ND[b]
In-hospital mortality: Esophageal resection	Insignificant (24)	0	0	24	36
In-hospital mortality: Pancreatic resection	Insignificant (44)	16	0	44	0
In-hospital mortality: Pediatric heart surgery	Insignificant (57)	3	0	57	0
In-hospital mortality: AAA repair	Reduces (41)	0	41	19	0
In-hospital mortality: CABG	Insignificant (58)	0	2	58	0
In-hospital mortality: Craniotomy	Insignificant (47)	12	1	47	0
In-hospital mortality: Hip replacement	Insignificant (57)	1	2	57	0
In-hospital mortality: AMI	Reduces (32)	2	32	26	0
In-hospital mortality: CHF	Improves (32)	32	0	28	0
In-hospital mortality: Stroke	Insignificant (40)	20	0	40	0
In-hospital mortality: Gastrointestinal hemorrhage	Insignificant (55)	3	2	55	0
In-hospital mortality: Hip fracture	Insignificant (31)	0	29	31	0
In-hospital mortality: Pneumonia	Insignificant (46)	6	8	46	0
In-hospital mortality: PTCA	Insignificant (53)	2	5	53	0
In-hospital mortality: Carotid endarterectomy	Insignificant (24)	0	0	24	36
Laparoscopic cholecystectomy	Insignificant (42)	12	6	42	0
Incidental appendectomy in the elderly	Insignificant (42)	14	4	42	0
Bilateral cardiac catheterization	Reduces (39)	0	39	21	0
Complications of anesthesia	Improves (41)	41	1	18	0
Death in low mortality DRGs	Insignificant (49)	9	2	49	0
Decubitus ulcer	Reduces (45)	0	45	15	0
Failure to rescue	Insignificant (33)	19	8	33	0
Foreign body left in during procedure	Insignificant (49)	10	1	49	0
Iatrogenic pneumothorax	Improves (31)	31	17	12	0
Selected infections due to medical care	Insignificant (39)	1	20	39	0
Postoperative hip fracture	Insignificant (51)	5	4	51	0
Postoperative hemorrhage or hematoma	Insignificant (45)	7	8	45	0
Postoperative physiologic and metabolic derangements	Insignificant (15)	9	0	15	36
Postoperative respiratory failure	Reduces (51)	0	51	9	0
Postoperative pulmonary embolism or deep vein thrombosis	Reduces (30)	3	30	27	0
Postoperative sepsis	Insignificant (37)	0	23	37	0
Postoperative wound dehiscence in abdominopelvic surgical patients	Insignificant (41)	19	0	41	0
Accidental puncture and laceration	Improves (55)	55	1	4	0
Transfusion reaction	Insignificant (12)	0	0	12	48
Birth trauma - injury to neonate	Insignificant (35)	25	0	35	0
Obstetric trauma – vaginal delivery with instrument	Improves (45)	45	0	15	0
Obstetric trauma - vaginal delivery without instrument	Improves (31)	31	0	29	0
Obstetric trauma – C-section delivery	Insignificant (40)	20	0	40	0

Note: There are 60 regressions per QI.
[a] Based on a statistical significance of $p \leq .10$.
[b] ND = not defined.

to the effects of hospital competition on inpatient quality. This is consistent with the existing literature. However, because of the diversity of our measures, upon further examination, we offer the following hypothesis-generating suggestion: there appear to be important distinctions between AHRQ QIs associated with an improvement and those associated with a reduction in inpatient quality. The AHRQ QIs that show an improvement of inpatient quality with hospital competition seem to be highly visible and generally understood by the typical patient consumer. To illustrate, in-hospital mortality for CHF and stroke are likely to be based on physician skill, expertise, and decision-making. Complications of anesthesia, iatrogenic pneumothorax, accidental puncture and laceration, obstetric trauma with instrument, and obstetric trauma without instrument are largely attributable to the physician or surgeon (McDonald et al. 2002). Moreover, these events are particularly visible and understood by the patients.

In contrast, the AHRQ QIs that show a reduction of inpatient quality with hospital competition seem to share one or both of the following features: 1) the outcome or measure relies on the hospital's infrastructure, processes, and/or skill mix of key support staff such as nurses, and 2) the outcome or measure is difficult for the patient to assess and he may not know whether a preventable adverse medical event has even occurred. To illustrate, decubitus ulcer, postoperative respiratory failure, and postoperative pulmonary embolism or deep vein thrombosis are situations that largely depend on the infrastructure and support staff established by the hospital to deliver physician services (e.g., number of nurses and nursing mix).[35]

Based on this broad initial observation, we offer the following hypothesis to explain our findings. A hospital facing increased competition is forced to make a decision about how to allocate its resources. One strategy may be to spend more resources on attaining well-trained and highly skilled physicians. Under this view, a hospital values a dimension of quality that appears to be highly visible and understood by its patients. Patients can readily understand that death, lacerations, and other such events should not occur for some conditions or procedures. Therefore, a hospital will ensure that the right resources, such as skilled physician services, are in place to reduce these adverse outcomes. However, because price still may be a key factor and thus to keep costs down, hospitals may reduce nonphysician resources such as those that affect the hospitals' infrastructure and support physicians in delivering services. For example, hospitals may reduce the nursing work force or use a less-skilled nursing mix. This may lead to an increase in infection rates and other postoperative problems not directly related to physician skill and expertise. Moreover, problems influenced by these resources may be more difficult for patients to understand and to assign responsibility to the hospital. For example, patients may not understand that a postoperative infection is due to carelessness with hygiene as opposed to the natural risk of undergoing surgery. They simply may view such events as inevitable consequences of hospitalization for the patient's medical condition. The consequence to the hospital for these types of problems is less dramatic than a death.

Several of our results are inconsistent with this hypothesis. In particular, our equations for failure to rescue (i.e., mortality often due to complications unrecognized by the hospital), AAA repair, bilateral cardiac catheterization, and AMI mortality all generate results that are contradictory. In addition, some may argue that highly skilled physicians would not tolerate hospitals skimping on necessary infrastructure and support staffing, especially in a litigious health system. Finally, our study assesses the correlations between measures of quality and measures of competition. Consequently, no causal inferences can be drawn.

We recognize these inconsistencies, counter arguments, and limitations of our hypothesis and our analysis. Our intent here is not to develop a definitive hypothesis, but rather to suggest a possible explanation for our results and to stimulate further research in this area. Accordingly, readers should view this hypothesis with caution and consider how well real world observations and evidence fit with the hypothesis. Clearly, additional research in this area is needed.

Concluding Comments about Hospital Competition and Quality of Care

Our study contributes to the existing literature on the effects of hospital competition on inpatient quality of care by using the most comprehensive array of inpatient quality measures to date,[36] and providing a more complete view of the association between the two factors. Our broad finding is that hospital competition does not have a unidirectional effect on quality. Hospital competition improved inpatient quality as measured by six inpatient quality measures, but also reduced inpatient quality in six other inpatient quality measures. This observation leads us to conclude that focusing on a single measure or a group of related measures may lead to erroneous inferences, especially if the measures are meant to make a statement about overall hospital quality.

While our findings may first appear inconclusive, they illustrate that hospital competition may affect quality dimensions differently. As noted by Romano and Mutter (2004), hospitals that have strengths in certain quality dimensions tend to have weaknesses in others. Our findings support this view, and we offer the following hypothesis-generating suggestion based on our findings. Hospital competition appears to improve quality in the dimensions that are associated with physician skill, expertise, and decision-making, and/or are highly visible to patients and their families. In a more competitive environment, hospitals seeking to attract patients may want to signal that they provide high quality of care. They could do this by ensuring high quality in dimensions that patients understand. Hospitals may seek to draw the best physicians in the market because physicians play a major role in directing flows of patients.

However, hospital competition appears to reduce quality in the dimensions that are associated with hospital infrastructure, hospital staff, and nursing mix. As hospitals face greater competition and with resource constraints, they may respond by shifting resources to augment quality in one dimension at the expense of another quality dimension. As resources for the dimensions of quality associated with physician expertise increase, resources for the dimensions of quality associated with infrastructure and support staff are reduced. The latter dimensions of quality may be less visible to patients.

We wish to emphasize, however, that research is only beginning on the determinants of the quality indicators used in this research. Therefore, our suggestion about the interpretation of our findings should be regarded as nothing more than conjecture that is intended to promote further research in what could be a very fruitful field of endeavor.

Notes

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expressed herein are those of the authors and no official endorsement by AHRQ or DHHS is intended or should be inferred.

1 Papers from a related conference, "Health Care Markets: Concepts, Data, Measures, and Current Research Challenges," sponsored by AHRQ, were published in the spring 2008 issue of *Inquiry*.

2 The one exception is Sari (2002), who uses a broader set of measures. These measures have several limitations and are discussed in the "Literature Review" section.

3 It is possible that hospitals confronted with certain market structures will, as a result of financial pressures or other reasons, systematically discharge patients early. Consequently, their inpatient mortality rates will be lower; however, the lower rates will not be due to higher quality care. To prevent this problem from biasing their results, Kessler and McClellan (2000) extended to one year the time frame over which they observed patients; it is the longest observation time in any of the studies in this literature. A disadvantage of their approach is that it permits factors over which hospitals have no control—such as the quality of post-discharge outpatient care patients receive and patient compliance with post-discharge medical advice—to affect hospital quality measures (Ho and Hamilton 2000).

4 See Romano and Mutter (2004) for a discussion of the risk-adjustment strategies used in the papers reviewed in this section.

5 For a more detailed description of the various methods to create hospital competition measures, see, for example, Wong, Zhan, and Mutter (2005).

6 Kessler and McClellan (2000) captured variation in managed care penetration across communities by a set of dummy variables that indicate whether managed care penetration for the state is above or below the median value for all states.

7 Hotel services consist of characteristics such as the quality of the food and the appearance of the facilities.

8 There is some evidence that California hospitals transitioned to price-based competition during this period as a result of the introduction of selective contracting. Mukamel, Zwanziger, and Bamezai (2002) also favored this time period for analysis because there were fewer hospital consolidations in California in the 1980s than in the 1990s, thereby leading to more stability in the levels of competition faced by hospitals.

9 The difference between a hospital's observed mortality rate and its predicted, risk-adjusted rate is the excess mortality rate.

10 Here are the 16 conditions, procedures, and complications. Conditions: 1) AMI, 2) acute tubular necrosis, 3) CHF, 4) cholecystitis and cholangitis, without mention of calculus, 5) pulmonary embolism. Procedures: 6) primary lens procedure, 7) cholecystectomy, 8) transurethral resection of prostate, 9) repair of inguinal hernia, 10) mastectomy, 11) excision or destruction of local lesion of bladder, 12) coronary artery bypass grafting (CABG), 13) laminectomy, 14) total hip replacement, 15) total knee replacement. Complications: 16) preventable complications and other misadventures in medical care and other complications (ICD-9 codes 995.2–995.4, 997.0, 998.0–998.6, 998.9, 990.0).

11 For their analysis, Shortell and Hughes (1988) measured the competition faced by each hospital in their analysis as the number of hospitals within 15 miles of the target hospital. If a hospital was in a "large metropolitan statistical area," the chief executive officer of the hospital was asked to identify the neighboring hospitals he regarded as competitors. Shortell and Hughes used a binary variable to indicate whether a hospital was in a competitive market (which they defined as a market with three or more competitors), or a noncompetitive market.

12 The three transaction types are mergers among hospitals, acquisitions of independent hospitals by systems, and acquisitions of system hospitals by another system.

13 We calculate observed, risk-adjusted, and smoothed rates for each of the 38 QIs for which they exist. Smoothed rates cannot be calculated for four of the QIs and a risk-adjusted rate cannot be calculated for one. We report "not defined" (ND) as the result for these regressions.

14 See http://www.qualityindicators.ahrq.gov

15 The third module, the Prevention Quality Indicators (PQIs), is a measure of the quality of outpatient care received by patients.

16 Dimick, Welch, and Birkmeyer (2004) identify the drawbacks in using the AHRQ IQIs to evaluate individual hospital performance when the hospitals have small caseloads. However, since we are not assessing the performance of hospitals individually, we do not require a certain number of observations in the denominator.

17 HCUP is a family of health care databases and related software tools developed through a federal-state-industry partnership to build a multistate health data system for health care research and decision-making. For more information, visit http://www.hcup-us.ahrq.gov/home.jsp. The 22 states are: Arizona, California, Colorado, Connecticut, Florida, Georgia, Hawaii, Illinois, Iowa, Kansas, Maryland, Massachusetts, Missouri, New Jersey, New York, Oregon, Pennsylvania, South Carolina, Tennessee, Utah, Washington, and

Wisconsin. In 1997, these states accounted for 53% of all hospitals, 60% of all hospital beds, and 61% of all hospital discharges in the United States.

18 Laparoscopic cholecystectomy is only risk-adjusted using sex.

19 The APR-DRG software categorizes patients into 382 DRGs and assigns them a severity score from 1 to 4 based on the severity of their case. Higher scores imply more complex cases. Iezzoni (1997) evaluates the APR-DRG software and other severity scoring systems.

20 The obstetric PSI indicators are not risk-adjusted using modified DRGs since they are associated with so few DRGs.

21 The AHRQ Comorbidity Software is described in Elixhauser et al. (1998). The modifications made so that the software better identifies patient safety events are described in McDonald et al. (2002).

22 For example, a hospital may have an unusually high pneumonia mortality rate because the area it serves had a particularly severe winter (AHRQ 2002).

23 Wong, Zhan, and Mutter (2005) concluded that out-of-state ZIP codes could be excluded without materially affecting the measurement of hospital competition.

24 We identified a hospital as a teaching institution if: 1) it had a residency program that was approved by the AHA, 2) it was a member of the Council of Teaching Hospitals and Health Systems (COTH), or 3) it had a ratio of full-time equivalent interns and residents to beds that was at least .25.

25 An anonymous referee noted that the nature of competition in Maryland may be different than in other states because Maryland has rate regulation. While only about 2% of all hospital observations in our analysis are from Maryland (i.e., 51 of 2,545 hospitals), we assess whether the inclusion of a Maryland state dummy variable in a sample of our models would affect our findings. While the Maryland state dummy variable was statistically significant in some models, the parameter estimates associated with the other variables did not change materially. In addition, the parameter estimates that were originally statistically significant continue to be statistically significant with the same sign. In this sensitivity analysis, our initial findings did not change.

26 Data constraints dictated the use of 1998 data. A 1997 county HMO penetration rate from InterStudy was not available to us.

27 Some researchers recognize advantages of the smoothed rates over the observed and risk-adjusted rates. See, for example, Miller et al. (2005). Our decision to use the smoothed rates here should not be taken as an endorsement of them over the other rates by either us or AHRQ, however. Since the basic results were relatively consistent across the smoothed, risk-adjusted, and observed quality rates, choosing one to illustrate how competition relates to HMO penetration seemed appropriate.

28 We do not correct for endogeneity in the observed rates because of the conceptual and operational difficulties in correcting for endogeneity in a negative binomial regression. However, inclusion of results from the negative binomial regressions does not affect the overall findings of the paper.

29 We use HC0 in all of the negative binomial regressions.

30 The presence of heteroskedasticity yields inconsistent standard errors when standard instrumental variables (IV) estimation is used. GMM is a commonly used alternative approach that allows for efficient estimation when the form of the heteroskedasticity is unknown (Baum, Schaffer, and Stillman 2003).

31 We hypothesize that communities with high overall demand for medical services will also have high demand for hospital services. The number of dentists in the community serves as a proxy for the overall demand for medical services. While the number of physicians in the community would be a better candidate for an instrument, this variable is already included in our empirical equations to capture market-level characteristics. Alternatively, we use the number of dentists. In addition, the difficulty in controlling for endogeneity in these types of empirical equations is well documented in the literature. See, for instance, Kessler and McClellan (2000), Gowrisankaran and Town (2003), and Wong, Zhan, and Mutter (2005).

32 Because of space constraints, we do not report the parameter estimates for all of the variables, but only the ones that are of primary interest. However, the other independent variables follow patterns typically reported in the literature.

33 We follow the general practice of the economics and health services research literatures and report results at the 1%, 5%, and 10% levels of significance. See, for example, Gowrisankaran and Town (2003). Although we recognize that the 5% level of significance (and lower) is regarded as a "gold standard" in these literatures, reporting results over a large number of regressions makes it necessary to use the 10% level of significance to avoid making the difference between, say, the observed and risk-adjusted rates appear overly dramatic when the level of statistical significance changes from, say, 4.8% to 5.2%. Ninety-three percent of significant results are significant at the 5% level (and below) rather than at the 10% level. When the 5% threshold is used, all mode results remain the same

except for in-hospital mortality for CHF, which changed from "improves" to "insignificant."

34 Hospital sample sizes vary across the quality-competition equations because of the variability of the number of hospitals providing specific services. For relatively small sample sizes, the "true" effects of competition on the quality measure may be more difficult to detect, producing an insignificant finding. However, the majority of the equations (about 63%) have samples sizes of 2,000 or more and only a handful (about 7%) had fewer than 1,000 observations. Our findings, however, are not influenced by this limitation because they are drawn from our broad observations of subsets of the models that include both small and large sample sizes.

35 See Haberfelde, Bedecarré, and Buffum (2005) for a review of the literature on nurse-sensitive patient outcomes.

36 See Romano and Mutter (2004) for a review.

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