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Hospital Competition, Quality, and Expenditures in the US Medicare Population

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Abstract

Theoretical models of competition with fixed prices suggest that hospitals should compete by increasing quality of care for diseases with the greatest profitability and demand elasticity. Most empirical evidence regarding hospital competition is limited to heart attacks, which in the US generate positive profit margins but exhibit very low demand elasticity—ambulances usually take patients to the closest (or affiliated) hospital. In this paper, we derive a theoretically appropriate measure of market concentration in a fixed-price model, and use differential travel-time to hospitals in each of the 306 US regional hospital markets to instrument for market concentration. We then estimate the model using risk-adjusted Medicare data for several different population cohorts: heart attacks (low demand elasticity), hip and knee replacements (high demand elasticity) and dementia patients (low demand elasticity, low or negative profitability). First, we find little correlation within hospitals across quality measures. And second, while we replicate the standard result that greater competition leads to higher quality in some (but not all) measures of heart attack quality, we find essentially no association between competition and quality for what should be the most competitive markets—elective hip and knee replacements. Consistent with the model, competition is associated with lower quality care

among dementia patients, suggesting that competition could induce hospitals to discourage unprofitable patients.[1]

Introduction

The question of how competition affects quality of health care is a topic that has received considerable attention in recent years. Theoretical models imply that when price exceeds marginal cost in a fixed-price regime, hospitals respond by competing for more patients by improving quality (Gaynor and Town, 2012; Gaynor *et al*., 2015). In general, the empirical evidence is mixed on the association between competition and quality, with evidence of positive, negative, and zero associations.[2]

Most studies of competition have used acute myocardial infarction (AMI), or heart attacks, as the representative patient population in measuring hospital quality, but heart attack patients typically exhibit a very low elasticity of demand for hospital treatment—ambulance drivers are usually instructed to bring heart attack patients to the nearest emergency room, or to their affiliated hospital (Doyle *et al*., 2015), since damage to the heart muscle worsens for every minute untreated. Therefore, we would

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2. For excellent discussions of the literature see Gaynor and Town (2012), Gaynor *et al*. (2015), and Brekke *et al*. (2014); Gravelle *et al*. (2012) consider the special case of fixed-price competition which we focus on here. Also see Gravelle *et al*. (2014), Kessler and McClellan (2000), Gowrisankaran and Town (2003), Cooper *et al*., (2011, 2013), Pan *et al*. (2015), Bloom *et al*. (2015), Propper *et al*., (2008), Escarce *et al*., (2006), Rogowski *et al*., (2007), Gaynor *et al*. (2013), Santos *et al*. (2016), Gobillon and Milcent (2016), and Moscelli *et al*. (2016).

not expect improved quality of AMI care to increase demand by much for a given hospital. While quality for one treatment could provide a proxy for quality for other conditions—hospitals with better treatments for AMI may have better hip replacement outcomes—this assumption has been questioned by others (e.g., Skellern, 2015; Bevan and Skellern, 2011). One English study, for example, found little correlation among treatment quality for AMI, stroke, and hip fracture patients (Gravelle *et al*., 2014).

In this chapter, we reconsider the association between competition and outcomes using the entire population of fee-for-service patients in the US Medicare claims data for the years 2010-2011. We first derive a theoretically consistent estimating equation for the relevant case in which hospitals are competing on the basis of quality in a fixed-price regime, such as the US. Medicare program. We find the key summary competition measure in this model is the LOCI (the Logit Competition Index), originally developed by Antwi *et al*. (2013) in a different context for hospitals that compete on prices. We argue that this LOCI approach provides a better characterization of competition compared to the conventional Herfindahl-Hirschman Index (HHI), because it captures the influence of hospital size on competition—that a smaller hospital has proportionately more untapped patients in its spatial market than does a larger or dominant hospital. To adjust for potential endogeneity, we instrument both the LOCI, and hospital volume—a key component of quality—using the Kessler and McClellan (2000) differential distance approach in a multinomial logit choice model for each of 306 US hospital market areas.

We test the standard model by considering a wider range of diseases with either greater demand elasticity or with lower profit (or contribution) margins (Eappen *et al*., 2013). We hypothesize that elective high-margin treatments planned weeks in advance and often sought by otherwise healthy people, such as reproductive technologies (as in Bundorf *et al*., 2009), or in our case, hip and knee replacements (as in Moscelli *et al*., 2016), would exhibit much greater underlying demand elasticity for quality of care, and hence lead to a much sharper quality gradient in competitive markets. Concerns with patient selection issues are addressed by comprehensive risk adjusters, and by the clinical reality that hospitals should not perform elective joint replacements for any patient with a high risk of complications.

We also hypothesize that the association between quality and competition would be different for diseases with lower or even negative profitability, such as advanced dementia requiring extensive nursing and physician inputs. In this case, the theoretical model implies *poorer* quality care for treatments with negative margins in competitive markets, as hospitals have greater incentives to avoid such patients.[1]

Briefly, we find that the association between competition and quality for AMI patients is weakly consistent with the model; more competition is predictive of greater use of appropriate medications (beta blockers and statins) after discharge and, in the least-squares regression, lower 30-day risk-adjusted mortality. As well, risk—and price—adjusted spending is slightly higher in more concentrated markets. However, we find that the association between quality of hip and knee replacements and concentration is minimal. This is inconsistent with the theoretical model of competition, which would predict the strongest association between competition and quality for these procedures.

As in Gravelle *et al*. (2014) and Skellern (2015), we do not find that AMI quality is a good summary "marker" for hospital quality; the correlation coefficient between risk-adjusted AMI mortality and risk-adjusted hip or knee complications is essentially zero. This by itself is not inconsistent with the economic model, since hospitals should compete on quality very differently across clinical departments depending on demand elasticities and profit margins, but it does highlight the limitations of using AMI as a paradigm for hospital competition and quality.

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1. Although Brekke *et al*. (2011) discusses the important philanthropic motives of hospital administration and staff that would work against such behavior.

We also consider the likelihood of poor quality in the treatment of dementia patients. Our measure of poor quality is the placement of a feeding tube in the terminal phase of dementia when patients have lost their ability to eat. Feeding tubes for patients with advanced dementia are viewed as a burdensome procedure for the patient, leading to complications and lower quality of life, and thus a marker for poor-quality care (American Geriatrics Society, 2013). For hospitals in the most concentrated markets, poor quality is more pervasive among dementia patients. This result is consistent with the theoretical model in which hospitals pay little attention to quality for treatments with low or even negative margins (e.g., Gaynor and Town, 2012).

In sum, our evidence provides little support for the view that competition *per se* raises quality of care. The weak links in this causal pathway —from measured market concentration to clinical quality—may arise at a variety of points. For example, Bynum *et al*. (2014) suggests that standard models of competition may not be suited to the more complex world of physician referrals, where primary care physicians play a dominant role in referring patients to a specific hospital (Barnett *et al*., 2012). Nor do physicians and patients always have a good idea of which hospitals provide high quality (Schneider and Lieberman, 2001; Goldman and Romley, 2008; Whaley *et al*., 2014; Desai *et al*., 2016, although see Chandra *et al*., 2016, and Santos *et al*., 2016). Finally, the findings based on European data that often support a positive association between competition and quality (e.g., Gaynor *et al*., 2013, Gobillon and Milcent, 2016) could arise because single-payer systems there provides more incentives to compete on quality in a fixed price setting, while Medicare is just one of many insurance providers.

The Model

We begin with the standard model of competition as derived in Gaynor and Town (2012) augmented to include the assumption of fixed prices, as in the Medicare program. We assume the cost function of hospital j

for a specific procedure or treatment, $C_j(x_j,z_j)$ is increasing with respect to both the quantity of services provided, xj (i.e., the number of procedures or admissions), and the average level of quality zj provided for patients at that hospital, given the fixed price for Medicare services, $\bar{p}$. Note that $xj = D(zj,z\text{-}j)$ so that demand at hospital j depends on quality at hospital j relative to quality at all other hospitals in the market except j, z_{-j}. This demand function could include both competition among hospitals for a given group of patients, as well as reflecting overall demand for the procedure.[1] However, in our estimation below, we assume a fixed number of total hospital admissions in each ZIP code.

Assuming profit maximization on the part of the provider, where quantity is a function of own-hospital quality z_j and other hospital quality z_{-j}, cost is a function of own-hospital quality and volume x_j, where prices are fixed ($\bar{p}$):

$$\pi_{tj} = \bar{p}D\left(z_j, z_{-j}\right) - C(z_j, x_j) \tag{1}$$

If providers choose their level of quality to maximize profit and there are zero profits in equilibrium (for derivation see the Appendix),

$$\left[\bar{p} - MCx_j\right]\frac{dx_j}{dz_j} = MCz_j \tag{2}$$

The left-hand side of (2) is the incremental profitability from an additional admission to the hospital, times the number of new admissions (x) that would occur if the hospital improved quality (z) by one unit. The right-hand side of (2) is simply the marginal cost of increasing quality by one unit; thus hospitals in this simplified world increase quality to the point where the marginal net revenue is equal to the marginal cost. Note that

1. For example, people in an area with high-quality academic centers could be more likely to undergo a hip replacement (rather than put up with the pain) because their chance of a successful complication-free procedure is greater.

when the contribution margin, or price minus the marginal cost of an extra patient, is small or even negative, hospitals will have a greater incentive to shed patients when demand responds more readily to changes in quality (dx_j/dz_j), as one might expect to observe in more competitive markets.[1] We next turn to a more formal model that characterizes the link between this derivative and the competitive structure of the market.

As in previous studies, we assume a multinomial logit model of patient choice. Let total admissions to all hospitals in ZIP code $t = 1,\ldots,T$ be N_t. In the logistic model, the predicted number of admissions to hospital j, $\hat{x}_j$, is a function also of a hospital zip-code fixed effect (a_{tj}) reflecting the convenience and perceived desirability of hospital j for residents of zip-code t, as well as the clinical quality of the hospital (z_j):

$$\hat{x}_j = \sum_{t=1}^{T} N_t \frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)} \tag{3}$$

To uncover the elasticity of demand with respect to quality, we can write the derivative of hospital j's demand with respect to its own quality under the assumption of a fixed-price model. As we demonstrate in the Appendix, with fixed prices the summary measure of competition ends up looking much like the Antwi *et al*. (2013) derivation of what they call the Logit Competition Index, or the LOCI:

$$\frac{d\hat{x}_j \,/\, \hat{x}_j}{dz_j} = \alpha\, \widehat{LOCI}_j \tag{4}$$

1. This equation implies that hospitals will discourage patients for as long as marginal cost exceeds price, regardless of the elasticity of admissions with respect to quality. The marginal costs may also include the high degrees of stress imposed on nurses and physicians because patients with advanced dementia can be so difficult to treat, thus requiring additional staffing, greater employee turnover, or higher wages. A more general model of hospital behavior that includes eleemosynary motives towards patients, however, would attenuate these purely profit-driven incentives to minimize quality (e.g., Gaynor and Town, 2012).

where

$$\widehat{LOCI}_j = \sum_{t=1}^{T} \left(\frac{\hat{x}_{tj}}{\hat{x}_j} \right) \left[1 - \hat{x}_{tj} \,/\, N_t \right].$$

Thus the proportional responsiveness of admissions to improving quality depends both on the elasticity of demand with respect to quality, summarized by α, and the LOCI or our measure of competition that holds even when prices are fixed.[1] In practice, we calculate the LOCI that is defined on actual admissions x_{jt}, written as $LOCI_j$ (without a caret). In this case, we'd replace actual admissions to hospital j in ZIP t, x_{tj}, for $\hat{x}_{tj}$, and n_{tj}, the share of hospital j's admissions coming from ZIP code t, for the first term in parentheses. Note that for perfect competition, the LOCI converges to 1, and for a monopoly, it is 0.

For the intuition behind the LOCI, it is useful to compare it with the commonly used Herfindahl-Hirschman Index (HHI). Recall that in our setting using actual rather than estimated values, the HHI would be

$$HHI_j = \sum_{t=1}^{T} n_{tj} \left[\sum_{k=1}^{J} x_{kt}^2 \,/\, N_t^2 \right] \tag{5}$$

The HHI is normalized to 1 for a monopoly, and approaching zero for a perfectly competitive market, the opposite of the LOCI.[2] Note that the LOCI captures the fraction of patients in a given hospital's market that are *not* being admitted to the hospital, or the market share that the hospital has to gain. Consider for example a scenario in which a small hospital competes with the larger hospital across the street, and that each hospital drew the same *proportional* number of patients from each zip code (n_{tj}). The HHIs for each hospital would therefore be identical, since the weights

1. While in theory, α varies across regions, for simplicity we adopt a single elasticity.
2. For comparability with the LOCI, we report the HHI as ranging from 0 to 1, rather than from 0 to 10,000 as is often done.

would match up, and the zip code HHI is the same regardless of which hospital is being considered. By contrast, the LOCI would suggest that the smaller hospital is more competitive, in the sense that it is easier for it to increase proportional capacity when its initial share is so modest. Because it is easier for the small hospital to increase its share, the LOCI theoretically better reflects its incentive to improve quality.

Using equation (2) above, we can write the first-order condition for hospitals competing on quality as:

$$\bar{p} - MCx_j = \frac{MCz_j}{\hat{x}_j LOCI_j} . \tag{6}$$

To estimate the association between quality and competition (as proxied by LOCI_j), we consider a Taylor-series approximation of the marginal cost of increasing quality per patient admission:

$$MCz_j / \hat{x}_j \cong \mu_j + az_j + bx_j \tag{7}$$

This approximation captures both a rising marginal cost of improving quality ($a > 0$) as well as the degree of proportionality with respect to output. For example, if the hospital provides better quality by hiring more experienced and skilled nursing staff, the marginal cost of that increment will be roughly proportional to the number of admissions (or bed-days); thus $b \sim 0$. If instead quality was more easily attained with greater volume, for example in surgical quality (Birkmeyer *et al*., 2002, 2003; Ho, 2002; Gaynor *et al*., 2005), then it could be that $b < 0$. It's also possible that $b > 0$; the marginal cost of improving quality for dementia patients (for example) may be higher in bigger hospitals because of challenges in coordinating care across a much larger number of employees and post-hospital settings.

By rearranging, we can write

$$z_j = \frac{\left(\bar{p} - MCx_j\right)LOCI_j - bx_j - \mu_j}{a} \tag{8}$$

Thus quality is dependent on three basic characteristics. First, it is predicted to be higher the greater is the marginal profitability, $\bar{p} - MCx_j$, as noted above.[1] Second, when the marginal profitability is positive, the nearer is the LOCI to perfect competition, the higher is predicted quality of care. Competition also influences hospital behavior by giving a stronger incentive to hospitals with small market share (and thus a larger LOCI) to capture more business from other hospitals in the market. But smaller hospitals may also experience diseconomies in providing high-quality care, for example when $b < 0$, as noted above (or if the coefficient a is higher for smaller hospitals). Finally, Equation (8) implies that volume (x) should be included on the right-hand side of the equation in determining quality. The challenge for estimation is that instruments are required for both volume and for the LOCI (Gaynor, 2006; Gowrisankarajn *et al*., 2008); we address this in p. ** below.

Clinical Considerations

As noted above, the standard economic model posits that hospitals will compete more vigorously by improving quality in more competitive markets and when the profit margins are greater. We consider next three distinct types of treatments that we know, from prior clinical research, differ substantially along these two dimensions.

First we consider acute myocardial infarction (AMI), which is the most common clinical condition considered in previous studies, beginning with Kessler and McClellan (2000). The onset of an AMI is sudden and patients and ambulances are instructed to go to the nearest hospital (or to their affiliated hospital, as in Doyle *et al*., 2015), because treatment is best if delivered within 90 minutes of symptom onset and requires on-site capabilities

1. Of course, MCx_j is itself endogenous, but we assume that changes in z_j have second-order effects on $\bar{p} - MCx_j$ (and more importantly, that changes in quality do not cause its sign to flip).

that are not present at all hospitals. While previous studies have argued that studying AMI allows researchers to worry less about selection bias (that is, healthier patients may seek out one hospital over another), and that AMI quality signals for other types of hospital quality—a conjecture we test below—the poor opportunity for choice makes the clinical case of AMI less than ideal for studying the relationship between competition and quality.

That said, there are considerable financial gains, as well as potential reputational gains, that can be derived by delivering advanced cardiac care, and these may make hospitals continue to compete in this clinical domain. For example, Robinson (2011) estimated that the average cost of cardiac valve replacement was $38,667, but the contribution margin (price minus average variable cost) was $21,967. And Chandra *et al*. (2016) found evidence showing that hospitals with above-average AMI performance tended to grow in AMI admissions at the expense of their lower-quality rivals.

As an ancillary hypothesis, we consider the association between market concentration and price—and risk—adjusted Medicare reimbursements during the year post-admission. Because we adjust for differences across regions in prices paid by Medicare (largely to capture cost-of-living differences), this measure is best interpreted as an index of utilization. While the theory does not predict whether utilization will rise or fall in response to improving quality—readmission rates might fall in response to better quality, thus reducing one-year utilization—we hypothesize that market concentration should be associated with greater utilization because of substitution effects: To the extent that competition leads to lower prices in the under-65 privately insured markets, this creates a greater incentive to do more for Medicare patients (Glied, 2014).

By contrast, hip and knee joint replacements are elective and planned well in advance which gives the patient opportunity to make informed decisions about where to have the surgery. This clinical situation would seem to fit most closely with any predictions based on the standard model of hospital competition. Furthermore, the profit margins are quite high; one analysis showed average prices to be above even average total cost (and not just marginal cost); see Healy *et al*. (2011). Yet, even for procedures with demonstrated variations in hospital quality, other amenities such as travel time, as in Ho and Pakes's (2014) study of mothers' choices for the choice of obstetric services, could well offset characteristics of the hospital.

One potential shortcoming with hip and knee replacements is the problem of risk-selection; perhaps those seeking a knee replacement at a hospital in a wealthy section of town will be in better underlying health compared to those in a poorer part of town. We address this issue by using hierarchical clinical conditions (HCC) risk adjustment, which, despite its biases (Song *et al*., 2010), is highly predictive of adverse outcomes.

Clinical cases that are associated with lower margins (or may even represent a loss if beds are at full capacity due to the opportunity cost) may create incentives for hospitals to avoid, rather than compete for, those patients (Anderson *et al*., 2011). People with advanced dementia at the end of life are frequently hospitalized, sometimes repeatedly, in the last months of life. Their hospital stay is not technologically intensive but requires appropriate staffing and can be lengthy, which can present financial problems for hospitals paid a fixed DRG amount. For example, Lyketsos, Sheppard and Rabins (2000) estimate average length of stay equal to 10 days for those with dementia, *versus* 6 days for those without; also see Bynum *et al*. (2004). In addition, these patients may present with symptoms that are difficult to manage (e.g. agitation and confusion), resulting in non-financial costs, such as stress for staff members. Many advanced dementia patients come by ambulance from local nursing homes to the hospital, which attenuates the opportunity for patient or family choice of hospital.

In sum, we hypothesize that the quality of care for these three conditions should exhibit very different patterns of association between quality and market structure. Based on clinical and economic considerations, we would expect a small positive association between quality and competition for AMI patients, a large and positive association for hip and knee replacement patients, and a zero or negative association for dementia patients.

Data

We use the entire fee-for-service Medicare data, centered on 2010-2011, to create five cohorts: one cohort of all-cause hospital admissions (to create concentration indices), and 4 disease cohorts of hospitalized patients: AMI, hip replacements, knee replacements, and dementia patients. The Medicare data files used include MedPAR, Carrier, Outpatient, Hospice, and Home Health.

Medicare Payments System Background

There are two major healthcare models paid for by the Medicare rogram, traditional Medicare and managed care plans operated by commercial payers (Medicare Advantage plans). Traditional Medicare includes Parts A and B and is predominately fee-for-service. Under this plan, doctors and hospitals get paid for each service provided, with little to no oversight on the quantity of services. There are limits on the amounts hospitals and doctors can charge, however. One example is the prospective payment system for inpatient care, where hospitals are paid a relatively fixed amount for each diagnostic related group. In traditional Medicare, Medicare pays a proportion of fees and the beneficiary is responsible for the remainder, called a coinsurance, which is often paid by a supplemental private insurance program (called a "Medigap" plan) or under the Medicaid program for low-income recipients.

The other major healthcare model is managed care; for Medicare this is referred to as Medicare Advantage. Managed care organizations supervise the financing of medical care delivered. Typically, members have limited options for where they can receive their care and there may be capitation, which means doctors are paid per enrollee, regardless of the amount and type of care provided. Owing to this system, individual services provided are not billed separately; thus, we do not have claims pertaining to each service, so we limit our attention to the fee-for-service population only.[1] If individuals with Medicare Advantage exhibit the same admission patterns as those in the fee-for-service population, then our measures of the LOCI will not be affected, although our volume estimates will be systematically too low. Biases in the LOCI will be introduced if those with Medicare Advantage go to systematically different hospitals.[2]

Hospital Admission Cohort and Competition Measures

To measure competition, we require information about the location of where each patient lives and to which hospital they were admitted. We created a cohort of all hospital admissions during 2010-2011 in the fee-for-service Medicare population over age 65, with more than 20 million separate admissions, along with the zip code of residence and the first hospital admission. (Subsequent transfers are ignored.) We removed "tourists" living in one hospital region, but admitted to a distant hospital outside of the region, in this analysis.[3]

To create the concentration measure, we sum across the zip codes from which patients are admitted to a given hospital (N_t is the number of admissions from zip code t) and calculate $S_{t \to j}$ as the share of admissions in zip code t to hospital j. We then calculate a weighted average across zip codes from which the hospital admits patients, where the weights are

1. Medicare tries to collect encounter data for the managed care population, but has not yet issued such data for researchers.

2. In Medicare Advantage, there is also likely less competition by hospitals for patients, but more competition to be included in insurance-based hospital networks.

3. One could argue that disease-specific measures of competition are more appropriate. However, Skellern (2015) found that the disease-specific concentration measures in England were highly correlated with the overall concentration measure.

the percentage of the hospital's all-cause admissions from each zip code. As noted above, the LOCI index depends on the fraction of the zip code market *not* admitted to hospital *j*, and therefore represents the potential market for that hospital.

We also created a zip code level HHI for each hospital *j*. The hospital-specific HHI was created by taking a weighted average of the zip code-level HHI, where the weights were (as above) the fraction of patients admitted to hospital *j* who live in zip code *t*.

Four Disease Cohorts

We created cohorts of fee-for-service Medicare patients at least 66 years of age (to allow for one year of observation prior to admission) with eligibility for Medicare Parts A and B and no HMO coverage in the study window. Patients must be hospitalized for 1) AMI; 2) total hip replacement; 3) total knee knee replacement; and 4) dementia (in the six months before death) in 2010-2011.[1]

For AMI patients, we require the primary diagnosis code to be 410.x1 or 410.x2. The beneficiary is assigned to the admitting hospital, regardless of whether they were later transferred to another hospital.

For total knee replacement patients, we require a hospitalization with the procedure code for total knee replacement 81.54 and any diagnostic codes 715.09, 715.16, 715.26, 715.36, 715.89, 715.96. For total hip replacement, we similarly require a hospitalization with the procedure code for total hip replacement 81.51 and any diagnostic codes 715.09, 715.15, 715.25, 715.35, 715.89, 715.95. For both the hip and knee replacement cohorts we exclude patients with cancer, infections, congenital anomalies,

1. AMI patients are ≥ 66 years of age, hip and knee replacement patients are ≥ 66 years of age to allow for one year of observation for the HCC scores and HMO coverage. AMI patients are excluded if they have HMO coverage within one year of the heart attack.

fractures and dislocations from injuries and accidents, or failure of orthopedic devices.

For dementia patients, we require one claim in Medpar (acute care hospital, critical access hospital, or skilled nursing facility), Hospice, Home Health, or evaluation and management claims in the Carrier file for one of the following diagnostic codes during 2010: 331.0, 331.1, 331.11, 331.19, 331.2, 331.7, 331.82, 290.0, 290.1, 290.10, 290.11, 290.12, 290.13, 290.20, 290.21, or 290.3. To qualify for the dementia decedent cohort, the beneficiary must die in 2011 and be hospitalized in the 6 months prior to death.

Patient Characteristics

Patient demographics for the three disease cohorts include age at time of index hospitalization, sex, race/ethnicity (white, black, Hispanic, other), and Rural Urban Commuting Area Codes (RUCA) category (urban, suburban, large town, rural) from the Medicare Denominator file. We also calculate the Hierarchical Clinical Conditions (HCC) score based on claims in the year before hospitalization (hip and knee replacement cohorts) or death (dementia cohort) and create quintiles of the mean HCC score in the cohort to allow for non-linearities. From the Census and American Community Survey (2010) we measure the percentage in poverty and mean income in each patient's ZIP code.

Quality Outcomes

For AMI patients, we calculate the following outcome measures: 30-day mortality, proportion of patients receiving a beta blocker, proportion of patients receiving a statin, and 30-day spending. We calculate the percent of patients discharged after an AMI that fill a beta-blocker and statin prescription within 6 months (not risk adjusted because all patients should receive these treatments; Munson and Morden, 2013). Finally, we consider risk and price-adjusted total spending in the first year post-admission (Gottlieb *et al*., 2010), which are logged in the regression specification. To risk adjust mortality and spending, we adjust for age and sex of the beneficiary (<69, 70-74,75-79,80-84,85-89,90-99), race/ethnicity of the beneficiary (Black, Native American, Hispanic, Asian, other) along with presence of vascular disease, pulmonary disease, asthma, dementia, diabetes, liver and renal disorders, cancer, and the location of the AMI in the heart (ST-elevated MIs, which correspond to anterolateral, anterior wall, infero-lateral, inferior wall, infero-posterolateral, true posterior, non-ST-elevated MIs, or subendocardial, and not otherwise specified).

For total hip replacement (THR) and total knee replacement (TKR) cohorts, we measure risk-adjusted 30-day readmission to any acute care or critical access hospital after discharge for any reason and any complication (medical or surgical). Surgical complications include postoperative deep venous thrombosis or pulmonary embolism, postoperative hemorrhage, postoperative surgical site infection, surgical site bleeding, or mechanical complications. Medical complications include postoperative pulmonary failure, postoperative pneumonia, postoperative myocardial infarction, postoperative acute renal failure, or postoperative gastrointestinal hemorrhage. We risk adjust the complication and readmission rates using race, sex, and HCCs.

For dementia patients, we measure feeding tube placement in the last 6 months or life and whether the patient had a burdensome transition in the last three months of life. We risk adjust using sex, race, and HCCs. Feeding tube placement is identified by procedure codes in Carrier file claims (43750, 43246, 44372, 44373, 74350, 43832, 43830, 43653, 49440, 49441, or 49446).

Hospital-Level Variables

To calculate the competition measures, we require that each hospital have at least 1000 total admissions during the 2 years of analysis (*N* = 2,638); this rules out smaller hospitals. In the cohort-specific regressions, we also require each hospital to have at least 10 admissions per cohort (AMI, hip, knee, and dementia); this restricts the sample further to 1,376 hospitals. We create measures of the fraction female, the fraction of each race/ethnicity, and the fraction living in poverty at the ZIP code level (weighted as described above).

Volume (for both the hospital and the surgeon performing the procedure) is well understood to be important for quality across many surgical procedures (Ho, 2002; Gaynor *et al*., 2006; Birkmeyer *et al*., 2002, 2003). Because competition measures are often closely associated with volume, as noted above—small hospitals almost by definition have many more potential patients in a given region than larger hospitals—we independently adjust for surgical volume using the (Medicare) number of AMI, total hip replacements, total knee replacements, and dementia patients in our cohort admitted during the study period; these in turn are instrumented using total predicted volume (described below). From the Provider of Service File and the AHA file we obtain hospital teaching status (Council of Teaching Hospitals member or not) and ownership status (not-for-profit, for-profit, government) of the hospital.

Empirical Specification

We use both least squares regressions and a two stage linear instrumental variables model to explore the relationship between competition and risk-adjusted quality at the hospital level.[1] The key explanatory variable in each model is a measure of the competition facing each hospital, as measured by the LOCI. Of course, the obvious endogeneity issues, both with regard to the competition measure and volume—since better quality could lead to both greater market share and volume—require instrumental variables for consistent estimation.

1. We do not weight by patient volume because our unit of analysis is the hospital and its behavior, not patient behavior. However, weighted regressions yield similar results.

Instrumental Variables

We presume that the quality of the hospital could potentially influence the hospital's market share as well as facility-level volume for a given procedure or patient cohort. For this reason, we use the Kessler and McClellan (2000) instrument for hospital admissions that depends *only* on the differential distance—or in our case, travel-time—to the hospital.

$$x_j^* = \sum_{t=1}^{T} N_t \bar{q}_t \frac{exp\left(d_{tj} + \epsilon_{tj}\right)}{\sum_{j=1}^{J} exp\left(d_{tj} + \epsilon_{tj}\right)} \tag{9}$$

where d_{tj} is the travel time from zip code t to hospital j. (This is identical to the specification above in Equation 3, except that the ZIP—and hospital—specific term that depends on quality of care is removed.)[1] Note that this estimation model provides ZIP-level estimates of admissions to hospital j (which can be used to calculate a predicted LOCI), but also provides an estimate of admissions (or volume) at hospital j, x_j^*, that can be used as an instrument for volume. Thus we have two separate instruments (predicted LOCI and predicted volume) for our two separate potentially endogenous variables (actual LOCI and actual total admissions).[2] In practice we use predicted total volume as an instrument for the procedure-specific volume measures in the AMI, hip replacement, knee replacement, and dementia cohorts.

1. One could also include additional variables capturing differential travel effects for specific ages or genders, but this is a fairly homogeneous group; everyone is age 65 or over, and we needed to keep the estimation model simple given the large number of distinct hospitals in many regions.
2. Recall that the predicted LOCI for hospital *j* depends on more than the predicted volume for hospital *j*, but also on predicted volumes for other hospitals in the market. Thus these two measures are quite distinct, although they are based on the same first-stage regression; their correlation coefficient is -0.05.

To capture market structure, we include hospitals with at least 1000 admissions in the fee-for-service Medicare population during 2010-11 (N = 2,638). We consider market structure within each of 305 hospital referral regions (HRRs) defined by the Dartmouth Atlas project, excluding Los Angeles. With more than 80 hospitals, the Los Angeles HRR logistics regression did not convergence, so we used the slightly smaller Los Angeles hospital service area (HSA) instead. Thus we have 306 hospital market regions, covering nearly all of the United States.

We draw on methods described in Bekelis *et al*. (2016) using street-level network data from ESRI's StreetMap North America v10.2 (2009 data) and ArcGIS software with the Network Analyst extension, to estimate optimal driving distance from each ZIP code centroid to each regional hospital.[1] We then estimated, for each of the 305 HRRs (and the Los Angeles HSA), a multinomial logistic regression that expressed the likelihood of admission to hospital j based solely on the differential driving time from ZIP t to hospital j, conditional on driving times to all other hospitals in the market.[2]

We include additional variables in our regression that could affect quality of care, for example whether the hospital is for-profit or government, or the share of patients who are African-American, Hispanic, and the average ZIP code poverty rate of hospital patients. A key concern with measures of market concentration is that they may proxy for population density; urban areas tend to exhibit a greater absolute number of hospitals and so exhibit greater degrees of competition. If patients benefit from being nearer to hospitals, rather than competition per se, then we might falsely conclude that competition improves quality (Gravelle *et al*., 2012). We therefore include as exogenous control variables the fraction of patients from rural,

1. Due to the limited street network data in Alaska and Hawaii, driving times there were based on geodesic distances between the origin and destination centroids.
2. While the multinomial logistic model follows from the theoretical choice model, one could also use conditional logit models by HRR.

small city, suburb, and large city regions using rural-urban commuting area measures (RUCAs).

The instruments are highly predictive in the first stages of the IV estimates; as expected, differential driving times strongly predict hospital choice.[1] The partial F-statistic for predicted LOCI (based only on differential driving time) in the LOCI equation is 2,008, while the corresponding partial F-statistic for predicted total volume in the separate cohort-specific volume first-stage estimates exceeds 350 for all IV regressions.

Results

Measuring Market Structure

We first show the distribution of LOCI and HHI across the 2,638 hospitals in the United States in Figure 3.1. There is a wide range of hospital-level competition, ranging from near-perfect competition (with a value of 1) to a more competitive environment (with a value of 0.2). Smaller hospitals tended to exhibit measures of LOCI closer to 1.0 (as they are better able to proportionately expand capacity), but large New York City hospitals (e.g., New York Presbyterian, Mount Sinai, NYU) range between 0.76 and 0.91 as well, reflecting the highly competitive New York market. At the other end of the spectrum, larger hospitals serving rural areas (e.g., Champlain Valley, Vermont; Lynchburg, Virginia; Western Maryland) tend to exhibit LOCI values between 0.2 and 0.3. Figure 3.1 also demonstrates the association between the LOCI and the HHI. Despite the different construction inherent for each measure, there is a strong (negative) association between the two. (Recall that for the HHI, 1 is perfect monopoly and 0 perfect competition, the opposite of the LOCI.)

1. Of the 2,658 hospitals in this larger sample, 7 exhibited predicted volumes that were less than 100 admissions for a variety of numerical optimizing algorithms. (In one HRR, we switched algorithms to achieve convergence.) However, none of these "outlier" hospitals ended up in the sample of 1,376 ultimately used in the data analysis.

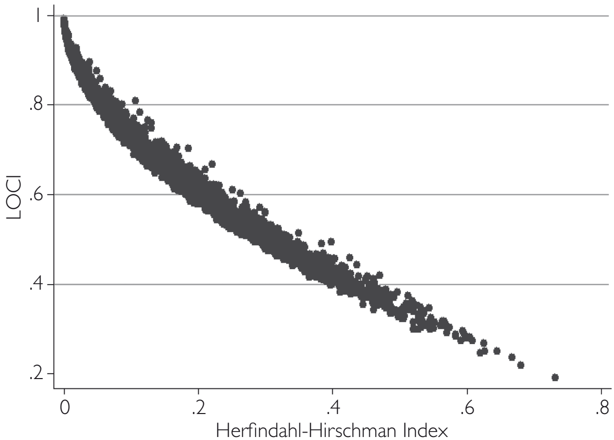

Figure 3.1 – Comparison of LOCI and HHI Measures of Competition, by Hospital ($N = 2{,}638$).

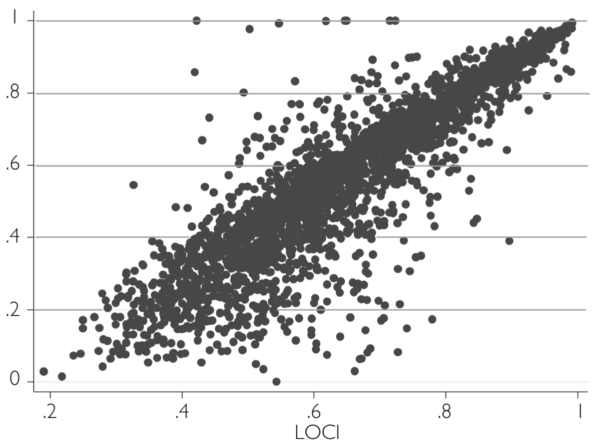

Figure 3.2 – Association between Predicted and Actual Measures of LOCI ($N = 2{,}638$).

We also show the association between predicted and actual LOCI in Figure 3.2. As was mentioned above, predicted LOCI is a very strong predictor of actual LOCI. Figure 3.3 shows predicted and actual volume measures, which again show a very close correlation.

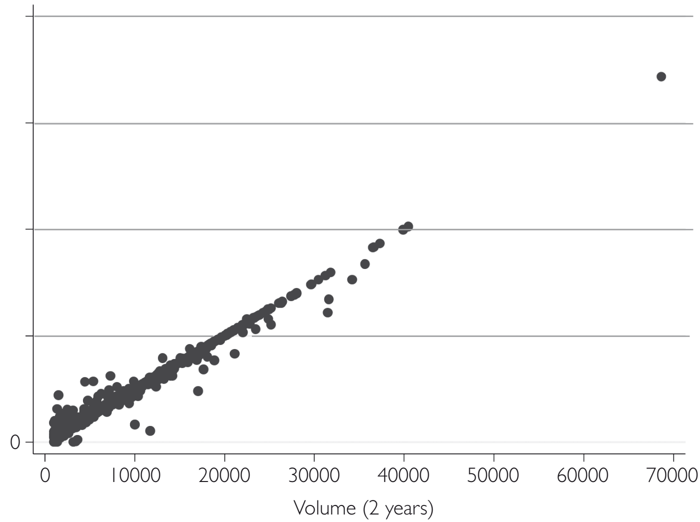

Figure 3.3 – Association between Predicted and Actual Measures of Hospital Volume (any Admission) (*N* = 2,638).

There is a clear outlier hospital in Figure 3.3, with much higher 2-year volumes than the other hospitals. This is the Florida Hospital in Orlando, which (according to *Becker's Hospital Review*) is also the largest hospital in America, with 2,382 beds.[1] That New York Presbyterian hospital, which is second-largest but has nearly identical beds in 2015 (2,373), has far fewer

1. *http://www.beckershospitalreview.com/lists/50-largest-hospitals-in-america-2015.html*

admissions in our data likely reflects Florida Hospital's larger population of over-65 patients, and a smaller share of elderly patients in Medicare Advantage, the managed care option, and thus not present in our sample.

For our regression analysis, we limit the number of hospitals to those with at least 10 admissions for AMI, hip replacement, knee replacement, and dementia during our study period (*N* = 1,376 hospitals). On average, the sample hospitals had 9,959 admissions during 2010-11 (Table 3.1), or a total of 13.7 million admissions underlying the hospital-level sample. The average LOCI competition measure is 0.62 with a standard deviation of 0.16, while the average HHI is 0.22, with a similar standard deviation (0.15).

Table 3.1 – Characteristics of Hospitals (*N* = 1.376)

Hospital characteristics	Mean	Std. Dev.
Number of admissions per hospital	9,959	6,699
Fraction African-American	0.090	0.110
Fraction Hispanic	0.042	0.084
Fraction in poverty	0.098	0.038
Fraction of hospitals with teaching status	0.110	0.311
Logit Competition Index (LOCI)	0.620	0.161
Predicted LOCI based on driving time to hospital	0.522	0.221
Herfindahl-Hirschman Index (HHI)	0.216	0.148
Fraction of patients in urban area	0.622	0.329
Fraction of patients in suburban area	0.113	0.135
Fraction of patients in large town area	0.126	0.231
Fraction of patients in rural area	0.139	0.173

Notes: Unweighted means. Sample comprises all hospitals in the 306 HRRs (except for Los Angeles, which is limited to the the Hospital Service Area) with at least 10 admissions in each of the 4 cohorts: AMI, hip replacements, knee replacements, and dementia.

Turning next to the cohorts, on average, each of the 1,376 hospitals admitted 96.5 patients for AMI during our study period, and provided beta blockers to 83.8 percent, and statins to 75.9 percent of patients in the first 6 months (Table 3.2). The standard deviation for age across hospitals was 2.2; hospitals do not differ substantially with regard to the average age of

Table 3.2 – Characteristics of Hospital-Level Admission Cohorts

Acute Myocardial Infarction Cohort	**Mean**	**Std. Dev.**
Number of AMI patients admitted per hospital	96.5	75.5
Mean age of AMI patients	78.8	2.2
Fraction of AMI patients who are black	0.075	0.111
Fraction of AMI patients who are female	0.500	0.086
Fraction of patients who received a beta blocker within 6 months post-AMI	0.838	0.136
Fraction of patients who received a statin within 6 months post-AMI	0.759	0.164
Risk-adjusted mortality 1 year post-AMI	0.320	0.071
Risk-adjusted mortality 30 days post-AMI	0.148	0.057
Risk- and price-adjusted spending within 1 year post-AMI	$44,083	$7,823
Total Hip Replacement Cohort		
Number of total hip replacement patients admitted per hospital	43.8	39.0
Mean age of admitted total hip replacement patients	75.3	1.4
Fraction African-American	0.051	0.090
Fraction female	0.629	0.095
Fraction with medical complications	0.059	0.053
Fraction with surgical complications	0.047	0.047
Fraction with any complications	0.097	0.066
Mortality 30 days post-total hip replacement	0.003	0.001
Total Knee Replacement Cohort		
Number of total knee replacement patients admitted per hospital	107.32	86.9
Mean age of admitted total knee replacement patients	74.5	1.0
Fraction admitted African-American	0.057	0.092
Fraction admitted female	0.647	0.070
Fraction admitted with medical complications	0.056	0.039
Fraction admitted with surgical complications	0.038	0.032
Fraction admitted with any complications	0.088	0.049
Mortality 30 days post-total knee replacement	0.003	0.007
Deceased Dementia Cohort		
Number of dementia patients admitted per hospital	68.6	48.6
Mean age of admitted sementia patients	85.4	1.4
Fraction admitted dementia patients black	0.094	0.131
Fraction admitted sementia patients female	0.616	0.084
Fraction admitted dementia patients with 1+ burdensome transition	0.210	0.083
Fraction admitted dementia patients with feeding tube placement	0.062	0.056

Notes: Unweighted means by hospital (N = 1,376) their patients. Risk-adjusted mortality rates following admission for AMI were 14.8 percent in the first 30 days and 32.0 percent in the first year after admission, while Medicare price-adjusted spending for these patients totaled $44,083 during the first year post-AMI.

The hip and knee replacement cohorts were 75.3 and 74.5 years old, respectively, on average, and had very low 30-day mortality rates (0.3 percent for both knee and hip replacement). Volume (averaged over the 1,376 hospitals) was 43.8 patients for hip replacements, and 107.3 knee replacements. On average, 9.7 percent of hip replacement patients, and 8.8 percent of knee replacement patients, experienced either medical or surgical complications following the procedure.[1]

Our sample of hospitals had 68.6 admissions during our study period on average for dementia patients in the last six months of life. The mean age of these patients was older than the other cohorts (85.4 years), 61.4 percent were women, and 9.4 percent were African-American. During this period, 6.2 percent had a feeding tube, but with considerable variability across hospitals; the standard deviation was 5.6 percent.

Correlation of quality measures across study cohorts

As shown in Table 3.3, there is a surprisingly modest correlation in quality measures across clinical departments in hospitals—cardiology (for AMI), orthopedic (for hips and knees), and hospitalist/general internal medicine, or geriatrics (for feeding tube placement), a result others have found (e.g., Bevan and Skellern, 2011; Skellern, 2015; Gravelle *et al*., 2014).

Within clinical departments, the correlations are higher; the correlation between knee and hip replacement complication rates, for example, is 0.285 ($p < .001$), while for beta blockers and statins, it is 0.210 ($p < .001$).

1. The surgical complication rate, and the medical complication rate, do not add up to the "medical or surgical complication" rate because a few patients experienced both kinds of complications.

Table 3.3 – Correlation of Quality Measures Across Study Cohorts

		AMI			Hip Replacement	Knee Replacement
		Risk-adjusted Mortality	Beta blockers	Statins	Risk-adjusted Any complications	Risk-adjusted Any complications
AMI						
Beta blockers	Corr coeff	−0.0064				
	P-value	0.81				
Statins	Corr coeff	−0.1151	0.2101			
	P-value	<0.001	<0.001			
Hip Replacement						
Any complications	Corr coeff	−0.0010	0.0211	−0.0482		
	P-value	0.97	0.43	0.07		
Knee Replacement						
Any complications	Corr coeff	−0.0542	0.0343	0.0070	0.2851	
	P-value	0.04	0.18	0.80	<0.001	
Dementia						
Feeding tube placement	Corr coeff	−0.0001	−0.0477	−0.0094	0.1169	0.1626
	P-value	0.99	0.08	0.73	<0.001	<0.001

Association of AMI Quality with Market Power

In accordance with previous studies (e.g. Kessler and McClellan, 2000), greater competition is, in some equations, associated with better outcomes in the AMI cohort (Table 3.4a). The coefficient on LOCI in the simple bivariate regression is -0.021 (t-statistic 2.21), implying that a two-standard-deviation shift in the LOCI would reduce mortality by 0.67 percentage points (on an average of 14.8 percent). Model 2 replaces LOCI with the HHI, and suggests the same beneficial effects of competition, but the estimate is not statistically significant. Results for Models 3 and the fully specified 30-day mortality regression in Table 3.4a (Model 4) are similar, with a coefficient on the LOCI of -0.026 (t-statistic of 2.40). The beneficial effects of competition, however, are not found in the IV model; the fully specified equation yields a coefficient of -0.009, with a t-statistic of 0.67. In both the OLS and IV specifications, log volume is estimated to be strongly associated with lower mortality.

Table 3.4a – Relationship between Competition Measures and Risk-Adjusted 30 Day Mortality Following Acute Myocardial Infarction

	Model 1 OLS	**Model 2** OLS	**Model 3** OLS	**Model 4** OLS	**Model 5** IV	**Model 6** IV	**Model 7** IV
LOCI	−0.021		−0.018	−0.026	0.016	−0.002	−0.009
	(2.21)		(1.78)	(2.40)	(1.37)	(0.16)	(0.67)
HHI		0.015					
		(1.55)					
Fraction suburban			0.004	0.002	0.016	0.008	0.005
			(0.26)	(0.12)	(1.15)	(0.55)	(0.35)
Fraction large town			0.022	0.017	0.040	0.028	0.022
			(2.17)	(1.57)	(3.60)	(2.59)	(1.97)
Rural			−0.003	−0.008	0.009	0.001	−0.005
			(0.22)	(0.61)	(0.75)	(0.04)	(0.39)
Log AMI volume			−0.014	−0.015		−0.012	−0.013
			(5.44)	(5.46)		(4.23)	(3.93)
Fraction Black				0.021			0.018
				(1.32)			(1.13)
Fraction Hispanic				−0.022			−0.023
				(1.04)			(1.10)
Fraction poverty				0.101			0.097
				(1.94)			(1.87)
Teaching hospital				0.001			−0.003
				(0.15)			(0.65)
Not-for-profit hospital				−0.009			−0.008
				(1.88)			(1.78)
Government hospital				0.001			0.002
				(0.12)			(0.34)
Constant	0.161	0.145	0.218	0.223	0.130	0.198	0.201
	(27.39)	(52.71)	(15.04)	(13.71)	(15.59)	(11.56)	(10.29)

Table 3.4b – Relationship between Competition and AMI Cohort Quality and Spending Measures

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dep. Var	Beta blocker		Statins		1-year spending	
	OLS	IV	OLS	IV	OLS	IV
LOCI	0.024	0.087	0.073	0.131	0.089	0.102
	(0.88)	(2.39)	(2.26)	(3.03)	(2.75)	(2.39)
Fraction suburban	0.058	0.073	0.018	0.032	0.007	0.018
	(2.02)	(2.51)	(0.52)	(0.94)	(0.21)	(0.51)
Fraction large town	−0.001	0.025	−0.026	0.0004	−0.091	−0.064
	(0.06)	(1.18)	(1.14)	(0.02)	(3.99)	(2.59)
Rural	−0.013	0.006	−0.104	−0.084	−0.133	−0.104
	(0.51)	(0.25)	(3.51)	(2.76)	(4.52)	(3.48)
Fraction Black	−0.008	−0.016	−0.033	−0.039	0.341	0.351
	(0.19)	(0.38)	(0.66)	(0.78)	(6.85)	(7.17)
Fraction Hispanic	−0.067	−0.065	0.010	0.014	0.359	0.382
	(1.32)	(1.28)	(0.15)	(0.22)	(5.92)	(6.43)
Fraction poverty	−0.024	−0.075	−0.077	−0.138	0.335	0.212
	(0.18)	(0.57)	(0.50)	(0.89)	(2.16)	(1.38)
Teaching hospital	0.028	0.010	0.054	0.035	0.027	0.005
	(2.24)	(0.70)	(3.60)	(2.10)	(1.81)	(0.32)
Not-for-profit hospital	0.007	0.006	0.014	0.011	-0.018	−0.027
	(0.68)	(0.59)	(1.05)	(0.89)	(1.39)	(2.17)
Government hospital	−0.005	−0.001	0.014	0.016	−0.031	−0.035
	(0.31)	(0.09)	(0.77)	(0.91)	(1.73)	(1.97)
Log AMI volume		0.021		0.024		0.041
		(3.00)		(2.86)		(4.83)
Constant	0.817	0.686	0.722	0.584	10.587	10.417
	−33.26	−13.76	−24.69	−9.86	−362.55	−178.51

We consider additional measures for AMI quality, and costs, in Table 3.4b. More competitive markets were associated with greater use of beta blockers in both the OLS and IV specification, as were statins; indeed, the coefficients were larger in magnitude for the IV specification. For example, a two-standard-deviation increase in the LOCI is predicted to improve statin adherence by 4.2 percentage points (on an average of 75.9 percent). Log one-year Medicare expenditures are also predicted to rise in more competitive markets, but not by much. A two-standard-deviation increase in the LOCI is predicted to increase spending by a modest 2.8 percent (in the OLS) or 3.3 percent (in the IV). This holds even after adjusting for the fraction African-American and Hispanic in hospitals.

Association of Hip and Knee Replacement Quality with Competition

In contrast with the AMI cohort, there does not appear to be a consistent association between LOCI and rates of complications among hip and knee replacements. For hip replacements, there is essentially no association between our LOCI competition measure and rates of complications after hip replacements (Table 3.4c). The greater preponderance of negative coefficients for knee replacements (Table 3.4d) is consistent with theory, but only the fully specified IV regression (Model 6) exhibits a marginally significant estimate (coefficient -2.45, p-value, 0.044). Procedure volume is strongly predictive of better quality in the least-squares regressions in Tables 3.4c and 3.4d, but these results do not persist when procedure-specific volume is instrumented by total hospital volume.[1]

1. These coefficient patterns are consistent with a model in which some hospitals specialize in hip and knee replacements (reflected in their high volume), but this specialization would not be captured by the instrument—overall predicted hospital admissions. See Chandra *et al*. (2016).

Table 3.4c – Relationship between Competition and any Complication after Hip Replacement

	Model 1 OLS	Model 2 OLS	Model 3 OLS	Model 4 OLS	Model 5 IV	Model 6 IV
LOCI	1.867	1.533	0.344	2.113	2.301	1.114
	(1.52)	(1.26)	(0.27)	(1.49)	(1.57)	(0.72)
Fraction suburban	1.896	1.239	1.470	1.950	2.227	2.473
	(1.09)	(0.71)	(0.83)	(1.12)	(1.28)	(1.36)
Fraction large town	−1.207	−1.900	−1.650	−1.141	−0.794	−0.646
	(1.27)	(1.96)	(1.59)	(1.18)	(0.76)	(0.59)
Rural	−1.628	−2.084	−1.304	−1.593	−1.366	−0.578
	(1.35)	(1.73)	(0.97)	(1.31)	(1.10)	(0.42)
Log hip repl. volume		−1.025	−0.912		0.503	0.609
		(4.14)	(3.44)		(1.02)	(1.15)
Fraction Black			4.077			4.747
			(1.99)			(2.31)
Fraction Hispanic			2.570			3.824
			(0.94)			(1.35)
Fraction poverty			−3.507			−1.270
			(0.52)			(0.19)
Teaching hospital			0.499			−0.273
			(0.93)			(0.47)
Not-for-profit hospital			−1.120			−1.494
			(1.91)			(2.46)
Government hospital			−0.847			−0.944
			(1.10)			(1.20)
Constant	8.73	12.74	13.654	8.558	6.575	7.568
	(9.63)	(9.62)	(8.89)	(8.31)	(2.84)	(2.95)

Table 3.4d – Relationship between competition and any complication after Knee Replacement

	Model 1 OLS	Model 2 OLS	Model 3 OLS	Model 4 OLS	Model 5 IV	Model 6 IV
LOCI	0.584	−0.070	−1.255	−0.867	−0.817	−2.45
	(0.64)	(0.08)	(1.31)	(0.83)	(0.76)	(2.02)
Fraction suburban	−0.119	−0.490	−0.210	−0.437	−0.400	−0.246
	(0.12)	(0.49)	(0.21)	(0.43)	(0.39)	(0.23)
Fraction large town	−1.610	−2.238	−2.213	−2.006	−1.941	−2.124
	(2.45)	(3.45)	(3.27)	(2.99)	(2.77)	(2.89)
Rural	−2.626	−3.002	−2.945	−2.831	−2.791	−2.730
	(3.29)	(3.82)	(3.40)	(3.53)	(3.43)	(2.88)
Log knee repl. volume		−1.338	−1.413		0.146	−0.363
		(7.40)	(7.75)		(0.40)	(0.98)
Fraction Black			3.666			4.263
			(2.50)			(2.84)
Fraction Hispanic			−1.535			−0.790
			(0.86)			(0.33)
Fraction poverty			2.398			2.049
			(0.52)			(0.43)
Teaching hospital			1.247			1.194
			(2.81)			(2.65)
Not-for-profit hospital			0.138			−0.194
			(0.36)			(0.49)
Government hospital			−0.348			−0.572
			(0.65)			(1.03)
Constant	9.017	15.500	15.819	10.035	9.338	12.116
	(13.40)	(14.13)	(13.01)	(13.20)	(4.67)	(5.69)

Association of Dementia Patient Quality with Competition

For dementia, the likelihood of both feeding tube placement and burdensome transitions in patients with severe dementia are substantially greater in more competitive markets (Table 3.4e). The coefficient for the fully specified OLS model, which implies a two-standard-deviation increase in the LOCI leading to a 1.4 percentage point increase in feeding tube placement (on an average of 6.2 percent), with a similar estimate in the IV specification without the full set of covariates (Table 3.4e, Model 6). However, the fully specified IV estimate is smaller in magnitude, with a coefficient of 2.12 and only marginal significance (t-statistic of 1.83). As well, volume is positively associated with the use of feeding tubes, suggesting poor coordination of care in larger hospitals. Finally, the regression coefficients on the proportion of Hispanic and African-American patients in the hospital, and poverty in the region are large and significant. Recall that our estimates of feeding-tube use already control at the individual level for patient race and ethnicity, so these coefficients more likely reflect factors such as financial stress arising from high rates of Medicaid and uncompensated care patients served by these hospitals.

Table 3.4e – Relationship between Competition and Quality of End of Life Care for Dementia Patients (Feeding Tube Placement)

	Model 1 OLS	Model 2 OLS	Model 3 OLS	Model 4 OLS	Model 5 IV	Model 6 IV
LOCI	5.461	7.698	4.393	4.893	6.159	2.115
	(5.44)	(7.57)	(4.58)	(4.26)	(5.05)	(1.78)
Fraction suburban	−4.598	−3.515	−1.979	−4.721	−4.082	−2.444
	(4.11)	(3.20)	(2.06)	(4.21)	(3.65)	(2.65)
Fraction large town	−1.361	0.731	0.021	−1.515	−0.266	−0.859
	(1.89)	(0.98)	(0.03)	(2.06)	(0.33)	(1.13)
Rural	−3.986	−1.509	−1.676	−4.066	−2.569	−2.425
	(4.54)	(1.66)	(1.96)	(4.62)	(2.66)	(2.59)
Log dementia volume		1.992	1.432		1.215	0.847
		(8.25)	(6.54)		(3.61)	(2.54)
Fraction Black			15.200			16.266
			(10.71)			(8.47)
Fraction Hispanic			12.435			12.869
			(7.35)			(8.48)
Fraction poverty			29.999			29.419
			(6.91)			(5.83)
Teaching hospital			−2.121			−1.729
			(4.97)			(4.44)
Not-for-profit hospital			−1.323			−1.374
			(3.68)			(3.30)
Government hospital			−1.492			−1.638
			(2.96)			(3.03)
Constant	4.061	−6.045	−5.258	4.457	−1.635	−1.282
	(5.49)	(4.25)	(3.82)	(5.34)	(0.83)	(0.66)

Discussion

Does competition in health care lead to better outcomes and lower costs? There is little agreement in this controversy, with papers finding positive, negative or zero associations. In this paper, we revisit this question by deriving a model that expresses in a fixed-price regime the association between competition and quality. We estimated the model with a national sample of Medicare fee-for-service patients during 2010-11, aggregated up to the hospital level. Our primary focus was to test the standard model of competition as to whether diseases or procedures with either greater demand elasticity or higher profit margins exhibited greater effects of competition on quality. Generally, we found the answer to be no. While the use of high-value beta blockers following AMI was greater in more competitive regions, the association between competition and 30-day AMI mortality was sensitive to model specification. Hip and knee replacements, arguably the cleanest cohort with high theoretical elasticity of demand and a reputation for sizable financial margins, showed little consistent association between competition and quality. For dementia patients, which are likely to exhibit low elasticity of demand with respect to quality and zero or negative financial margins, poor clinical care was positively associated with competition—a result arguably consistent with the theoretical model when financial margins are negative.

Hospital care is far from a homogeneous product and the difficulty of observing quality is a well-known problem. We have attempted to include a broad array of available technical quality measures in our analyses, and have been able to include outcome measures of importance to patients, rather than solely process measures. There are publically available data for AMI mortality but not for complication rates after joint replacement or rate of feeding tube placement among advanced dementia patients. Under these circumstances, competition may mean recruiting the best physicians, reaching out to primary care doctors, or more traditional interpretations of market power. Hospitals may choose to invest in amenities rather than quality if they think the elasticity with respect to quality to be low. Indeed, in more complex models, Katz (2013) has suggested that in a fixed-price regime, greater competition may *reduce* the quality equilibrium in health-care markets under certain circumstances.

One of the key questions is whether it's worthwhile for hospitals to compete on quality if neither patients nor referring physicians can distinguish between high—and low—quality hospitals, either because they do not have sufficient information, or because they simply don't pay attention? For example, it may be difficult for patients to observe technical hospital quality; quality measures may ignore commonly available objective measures such as hospital infection rates (Emanuel and Steinmetz, 2013), and quality measures for hip and knee replacements are often limited to just readmission rates (Chandra *et al*., 2016). Also, patients may not be familiar with public reports on quality (Schneider and Lieberman, 2001; Schneider and Epstein, 1998) and could choose a hospital based on distance or amenities (Goldman and Romley, 2008; Luft *et al*. 1990). Newer initiatives seek to inform consumers on public reporting of quality, and employer-sponsored, crowd-sourced, and mandated price reporting.[1] Research shows that use of these tools is low (Whaley *et al*., 2014; Desai *et al*., 2016), with a variety of explanations for their low use. Examples include (a) not knowing about their existence, (b) lack of health insurance literacy, (c) absence of consistency across different rankings, and (d) few incentives to choose a lower-cost provider.

A further complexity of the competition story arises from the intermediate role of physicians in directing patients toward or away from a particular hospital, as in preliminary work by Bynum *et al*. (2014). When choosing where to have one's knee replaced, for example, a patient may ask their primary care doctor for advice and a referral. Those physicians

1. For example, see *www.castlighthealth.com, www.clearhealthcosts.com, and https://nhhealthcost.nh.gov.*

may recommend based on the perceived quality of the hospital, but other evidence suggests that physicians are more likely to refer to their own affiliated hospital, even when it is low-quality (Baker *et al*., 2015).

Despite this concern that health care markets are uniquely inefficient, several recent studies provide evidence that patients do make their way to higher quality providers. Chandra *et al*. (2016) finds that higher-quality hospitals experience more rapid growth in volume of patients over time, with roughly one-quarter of the secular gain in AMI survival attributed to reallocation from lower to higher quality hospitals, with smaller effects for pneumonia and heart failure. Less clear is whether regions with higher concentration experience more rapid or slower reallocation of patients to higher-quality hospitals.[1] Similarly, Santos *et al*. (2016) have shown that in England, high-quality physicians (as measured by public ratings) are more likely to attract patients. Clearly, there must be some information about quality getting through to patients, although the mechanism is not always clear.

We acknowledge the limitations of this analysis. Previous studies have used changes over time in competition to study changes over time in quality of care (e.g., Kessler and McClellan, 2000), or plausible natural experiments in political alignment or health care reforms to predict competition (e.g., Gaynor *et al*., 2013; Cooper *et al*., 2011, 2013). Our cross-sectional analysis allows us to test longer-term equilibrium outcomes, but also risks biases arising from hospital fixed effects that are correlated with competition measures. We do not measure patient-reported quality measures, such as patient satisfaction, where arguably hospitals may find it most valuable to compete.[2]

1. They do find that transfer patients are more likely to seek out higher-quality hospitals; presumably these patients, who have been stabilized, are better able to choose from among the universe of nearby hospitals.
2. Although see Chandra *et al*., 2016, who find no evidence that patient satisfaction is associated with growth in patient volume.

We also recognize the limitations of Medicare fee-for-service claims data, which is only a fraction of the hospital's total market, and does not capture the hospital's Medicare managed care population. Additionally, in Europe, waiting times are an important component of quality—one that we do not account for in our theoretical model or empirical work. Finally, we have followed the conventional literature in measuring "competition" by whether one's neighbors seek care at many different hospitals, but these may or may not translate into the motivations and actions of hospitals in implementing quality improvement initiatives, nor do our measures reflect that in some areas, patients may be more skilled at searching than others.

What do our results mean for the current US debate about competition *versus* coordination in health care? Regulators balance allowing mergers based on potential benefits from clinical integration while trying to promote price and quality competition in commercial markets and quality competition with fixed-price payers. Our paper (and others) suggests that consolidation *per se* is modestly associated with a decline in quality for cardiac care, but that clinical integration could also lead to higher volumes of patients treated at higher-quality, or at least higher-volume hospitals. Preliminary evidence is also beginning to emerge that under payment models incentivizing care coordination and accountability, formal financial integration is not necessary to achieve clinical integration. Therefore, potential effects of mergers on commercial prices could still be the most important consideration for regulators.

In sum, we did not find strong evidence in support of the standard models of competition on quality. This may mean that the information available to consumers is fragmented and incomplete, or that potential patients are not very skilled in looking outside of their local neighborhoods for higher quality facilities (Ho and Pakes, 2014), rather than an indictment of competition *per se*. Further validation of quality measures and consumer (or physician) knowledge about these measures would be of great value, and have implications for the consolidation currently accelerating under risk-based payment models.

APPENDIX – MATHEMATICAL DERIVATIONS

Derivation of equation (2'): the derivation of cost if providers choose their level of quality to maximize profit and there are zero profits in equilibrium

$$\frac{d\pi_{tj}}{dz_j} = \overline{p}\frac{dx_i}{dz_j} - \frac{dC}{dx_j}\frac{dx_j}{dz_j} - \frac{dC}{dz_j} \tag{2a}$$

$$\frac{d\pi_{tj}}{dz_j} = \left(\overline{p} - MCx_j\right)\frac{dx_j}{dz_j} - \frac{dC}{dz_j} = 0 \tag{2b}$$

$$\left[\overline{p} - MCx_j\right]\frac{dx_j}{dz_j} = MCz_j \tag{2c}$$

Derivation of equation (4): the derivative of hospital j's demand with respect to its own quality

$$\frac{d\widehat{x_j}}{dz_j} = \sum_{t=1}^{T} N_t \left[\frac{d}{dz_j}\frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)}\right]$$

$$= \sum_{t=1}^{T} N_t \left[\alpha\, exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)\left(\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)\right)^{-1}\right.$$

$$\left. + \alpha\, exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)^2 (-1)\left(\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)\right)^{-2}\right]$$

$$= \alpha \sum_{t=1}^{T} N_t \frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)}\left[1 - \frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)}\right]$$

$$= \alpha \sum_{t=1}^{T}\left(N_t \frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)}\right)\left(\frac{N_t}{N_t}\left[1 - \frac{exp\left(\alpha z_j + a_{tj} + \epsilon_{tj}\right)}{\sum_{t'=1}^{T} exp\left(\alpha z_j + a_{t'j} + \epsilon_{t'j}\right)}\right]\right)$$

$$= \alpha \sum_{t=1}^{T} (\hat{x}_{tj})\left(1 - \frac{\hat{x}_{tj}}{N_t}\right)$$

Thus

$$\frac{d\hat{x}_j}{\hat{x}_j dz_j} = \alpha \sum_{t=1}^{T} \frac{\hat{x}_{tj}}{\hat{x}_j}\left(1 - \frac{\hat{x}_{tj}}{N_t}\right) = \alpha \ LOCI_j$$

So the elasticity of demand with respect to a change in quality is equal to α times the LOCI measure.

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