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# Do Different Measures of Hospital Competition Matter in Empirical Investigations of Hospital Behavior?\*

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**Abstract.** Considerable controversy exists about the appropriate way hospital competition should be measured and whether findings are accurate if certain methods are employed. Data from the Healthcare Cost and Utilization Project (HCUP), the American Hospital Association (AHA), and other supplemental data sources are used to create and evaluate hospital competition measures. Correlation coefficients of these measures are assessed. Moreover, each measure is independently included as an explanatory variable in otherwise identical hospital cost function regressions. Their corresponding parameter estimates are then compared. Most measures are highly correlated. Inferences about the effect of competition on hospital cost remain the same when alternative hospital competition measures are employed. We caution researchers against using this finding to arbitrarily select a competition measure when the magnitude of the estimates is important.

**Key words:** hospital competition measures, hospital markets.

**JEL Classifications:** I11, L19.

## I. Introduction

An extensive empirical literature exists that examines the effects of hospital competition on the cost, access, and quality of hospital services. While these studies typically find statistically significant effects, there is considerable controversy about the appropriate way hospital competition should be measured (Dranove and White, 1994) and whether findings are accurate if certain methods are employed. Differences in the measurement of hospital

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competition arise from two sources. First, researchers disagree on how hospital markets should be defined (Gaynor and Vogt, 2000).<sup>1</sup> Second, the literature lacks consensus on how to measure the intensity of hospital competition once a hospital market has been defined (Gift et al., 2002).

Assessing the performance of hospital competition measures and evaluating the differences between these measures are difficult because of the lack of comparability across studies. Each study is unique, using different databases, employing different methods and approaches, and specifying different explanatory variables in empirical analyses. Because there is a continuing need for such measures in empirical work, this controversy needs to be addressed.

This study reviews the literature on hospital competition measures, recreates versions of these measures, evaluates these measures, and assesses whether different measures of hospital competition matter in empirical investigations of hospital behavior. Using 1997 data from the Healthcare Cost and Utilization Project (HCUP), State Inpatient Databases (SID), the American Hospital Association (AHA) Annual Survey of Hospitals, the U.S. Census Bureau, and the Area Resource File (ARF), hospital competition measures are created. These measures are based on the four most common ways of defining hospital market areas (i.e., geopolitical boundaries, fixed radius, variable radius, and patient flow) and the two most frequently used methods of capturing hospital competition intensity within a market area (i.e., number of hospitals and the Herfindahl–Hirschman Index, HHI). Differences between these measures are then assessed and evaluated by examining correlation coefficients. In addition, each measure is independently included as an explanatory variable in otherwise identical hospital cost function regressions. Their corresponding parameter estimates are then compared.

While this study is not the first to compare different measures of hospital competition, it contributes to and improves upon the existing empirical literature in the following important ways. First, the study is the most comprehensive evaluation to date, creating and assessing a greater number of hospital competition measures than do other studies. Second, the study uses more recent data and includes hospitals in more states, improving the ability to generalize findings. Third, we use a standard empirical hospital cost equation, making direct comparisons of our competition measures possible. Fourth, this study provides a reference guide for empirical researchers seeking to employ existing methods of measuring hospital competition. Novel approaches continue to evolve and may eventually set a new standard for defining markets and measuring hospital competition.

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<sup>1</sup> We recognize that some approaches do not use the structure–conduct–performance framework and, therefore, the market is undefined.

However, until such methods are well-established and widely used, our study provides an important benchmark and a retrospective assessment of past literature, highlighting strengths and limitations, for analysts currently engaged in empirical analyses. And fifth, as new measures evolve and are adopted, this study provides a baseline to assess their relative contribution.

Our paper is organized in the following way. Sections 2 and 3 review the literature and summarize the existing methods used in creating hospital competition measures. Section 4 summarizes the new and evolving approaches to measure hospital competition. Section 5 describes the different databases used, the analytic approach for calculating the different versions of these measures, and the evaluation methodology. Section 6 reports our results and Section 7 concludes.

## II. Defining Hospital Markets

### 1. CROSS ELASTICITY OF DEMAND

In many cases, economic theory posits that firms are in the same market if the pricing and production decisions of one firm affect the demand for goods and services of other firms. Some researchers have suggested that cross elasticities of demand with respect to price (or nonprice variables of interest) can be used to determine market areas (Luft et al., 1989).<sup>2</sup> Under this approach, products or services that have a high degree of substitutability would indicate that they are in the same market.

However, determining hospital markets using this approach has not been embraced by researchers because the data necessary to calculate cross elasticities for hospitals (i.e., hospital prices) are generally unavailable.<sup>3</sup> Consequently, researchers have turned to other strategies for defining hospital market areas (Zwanziger et al., 1994).<sup>4</sup>

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<sup>2</sup> Cross price elasticity measures the substitutability between products. A cross price elasticity between two products, X and Y, is defined as the percentage change in the amount of product Y consumers demand in response to a 1 percent change in the price of product X. If the cross price elasticity is positive, then the products are considered substitutes. The higher the value, the greater the substitutability, and consequently, the greater the likelihood that the products are in the same market.

<sup>3</sup> Gaynor and Vogt (2003) calculate cross price elasticities for 374 California hospitals. Tay (2003) calculates demand elasticities with respect to quality for hospitals in California, Oregon, and Washington.

<sup>4</sup> The lack of appropriate data and the heterogeneous nature of hospital products contribute to the difficulty of using other price-based approaches, such as that proposed by Stigler and Sherwin (1985), to define hospital markets. Stigler and Sherwin argued that firms are in the same market when the correlation of prices, or the first differences of prices, for their products is of a sufficiently high value.

## 2. ELZINGA-HOGARTY

A well-known approach for defining markets among federal antitrust authorities is one proposed by Elzinga and Hogarty (1973). Under the Elzinga-Hogarty approach, a market area is determined by the product flows to (i.e., import ratio) and from (i.e., export ratio) a market. Elzinga and Hogarty proposed that markets be defined as the smallest geographic areas where no more than 10% of the product or service consumed within an area comes from outside of the area and no more than 10% of the product or service made within the area is consumed outside of the area. In other versions of the Elzinga-Hogarty approach, a 25% cut-off level has been used. In the context of the hospital service industry, Elzinga-Hogarty markets are based on patient flows to and from hospital areas (Gaynor and Vogt, 2000).

The Elzinga-Hogarty approach is conceptually appealing. By definition, only a small share of patients cross the boundaries of Elzinga-Hogarty markets, so the demand for the services of the hospitals within the market will be unaffected by the behavior of firms outside of the market. However, a key shortcoming of Elzinga-Hogarty markets is their tendency to be excessively large in urban areas. This is because the import and export ratios that determine the boundaries of the market frequently get small when the denominator (i.e., the total number of patients treated within the boundaries) becomes large rather than when the numerator (i.e., the number of patients crossing into or out of the boundaries) becomes small (Zwanziger et al., 1994).<sup>5</sup> In practice, the Elzinga-Hogarty approach has been limited to antitrust cases and has not been widely used in empirical studies of aggregate hospital behavior.<sup>6</sup> Werden (1989) and Gaynor and Vogt (2000) provide more detailed discussions of the Elzinga-Hogarty approach.

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<sup>5</sup> For other reasons, the Elzinga-Hogarty approach may overstate the size of a hospital's market. For example, if two hospitals are providing very different types of care (e.g., primary and tertiary care) considerable patient flow between the areas may be observed. The flow is occurring because they are providing two different types of services, not because they are competitors. The Elzinga-Hogarty approach would put them in the same market, thereby overstating the true size of the market (Gaynor and Vogt, 2000). On the other hand, the Elzinga-Hogarty approach can also understate the size of a hospital's market by excluding potential competitors (Dranove and White, 1994).

<sup>6</sup> One exception is a study by Manheim et al. (1994). In their study, they examine the impact of hospital competition on hospital cost per admission for Medicare patients. Hospital markets for the 44 largest MSAs were created using an approach based on the concepts of relevance and commitment developed by Griffith (1972) and the flows of patients into and out of hospital service areas, which are based on the Elzinga-Hogarty concept.

### 3. GEOPOLITICAL BOUNDARIES

Because hospital market definitions based on theory are not easily applied in empirical studies of hospital behavior, researchers have used more expedient definitions of hospital markets. In general, researchers use four broad approaches to define hospital markets: geopolitical boundaries, fixed radius, variable radius, and patient flow.

Of these four methodological approaches, definitions based on geopolitical boundaries, such as counties, Metropolitan Statistical Areas (MSAs), and Health Service Areas (HSAs), are the most frequently employed (Gaynor and Vogt, 2000). Computational ease is the primary advantage of using definitions based on geopolitical boundaries. Geopolitical boundaries also have the advantages of capturing potential competitors and of being compatible with socioeconomic data that are frequently made available at the county, MSA, or HSA levels (Garnick et al., 1987).

A disadvantage of using counties to define hospital market areas is that they are arbitrarily defined from the perspective of hospital competition.<sup>7</sup> The use of MSAs, which are designed to enclose an area with a high degree of economic and social cohesion, might be more defensible theoretically.<sup>8</sup> However, biased measures of the amount of competition facing hospitals can result from using either approach to define hospital markets. Overestimates of the amount of competition facing a hospital result when a hospital in a relatively large county or MSA competes with only a few neighboring hospitals in close proximity. However, hospitals within the county or MSA are counted as the hospital's competitors. Underestimates of the amount of competition facing a hospital result when a hospital inside of a geopolitical boundary competes with a hospital located just outside of the boundary (Zwanziger et al., 1994).

HSAs consist of counties grouped together using cluster analysis based on the travel patterns of Medicare beneficiaries seeking routine hospital care (Makuc et al., 1991).<sup>9</sup> The use of patient flow information in the

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<sup>7</sup> Interestingly, the courts have used single counties to define hospital market areas in hospital merger cases. See Gaynor and Vogt (2000) for a discussion and Vistnes (1995) for some examples. In addition, MSAs have also been used to define hospital markets in antitrust cases.

<sup>8</sup> A disadvantage of MSAs is that they are only defined for areas where there is "a large population nucleus" (BEA, 2002).

<sup>9</sup> Makuc et al. (1991) actually generated four HSA solutions. The solutions either have 800 clusters or 1400 clusters and are either linked to MSAs or not linked to MSAs. Makuc et al. (1991) regard the 800-area, non-linked solution as "preferable" to the other three.

creation of HSAs makes them theoretically appealing.<sup>10</sup> However, like county and MSA hospital market definitions, HSA hospital market definitions generate measures of the intensity of competition that are identical for all of the hospitals in a market. Hospitals, however, frequently face competition at different levels of intensity (Zwanziger et al., 1990).

#### 4. FIXED RADIUS

Luft and Maerki (1984–1985) proposed an alternative definition of hospital market, the fixed radius approach, that avoids some of the drawbacks of definitions based on geopolitical boundaries. Under the fixed radius approach, every hospital is assigned a unique market area, which is the region enclosed by a circle centered on the hospital and defined by a fixed radius. The fixed radius approach has the advantage of including a hospital's nearby competitors located on the other side of a geopolitical boundary.

Luft and Maerki (1984–1985) emphasized the role of physicians in determining the hospital to which patients are admitted.<sup>11</sup> They assumed that physicians would be willing to travel no more than 15 miles between hospitals. Therefore, they recommended fixing the radius at 15 miles.<sup>12</sup> Luft et al. (1989) found that a 13.5 mile fixed radius is the median distance, and a 17.6 mile fixed radius is the mean distance, necessary to capture 90% of a hospital's patients in urban areas of California, thereby lending support to the use of the 15 mile fixed radius definition.<sup>13</sup>

Nevertheless, the fact that the radius is fixed is a limitation of this approach. Hospitals have catchment areas that vary in size, and rural hospitals and hospitals that provide tertiary services typically draw patients from an area greater than that defined by the 15 mile fixed radius definition (Zwanziger et al., 1990).

#### 5. VARIABLE RADIUS

The third approach, proposed by Phibbs and Robinson (1993) and updated by Gresenz et al. (2004), allows the size of a hospital's market area to vary.

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<sup>10</sup> Because HSAs are based on flows of patients, they could be classified as a patient flow or a "mixed" method. However, we follow the practice of Gaynor and Vogt (2000) and Meltzer et al. (2002) and categorize them as a geopolitical boundaries method.

<sup>11</sup> Selective contracting, which began in California in 1982, has increased the role of insurers in determining the hospital in which patients are treated (Zwanziger et al., 1994).

<sup>12</sup> Luft and Maerki also computed hospital market areas using a fixed radius of 5 miles.

<sup>13</sup> This finding suggests that the fixed radius approach is based generally on the flow of patients and, therefore, makes it more appealing.

Like the fixed radius method, the variable radius method defines a hospital's market as the area contained within a circle centered on the hospital. However, instead of using a fixed radius to draw the circle, the third method allows the radius to vary so that it captures 75% (or 90%) of the hospital's discharges.<sup>14</sup> Thus, the variable radius method defines a unique market area of a unique size for every hospital.

## 6. PATIENT FLOW

The fourth method, the patient flow approach, also creates a unique market area of a unique size for every hospital. Like the variable radius definition, the patient flow approach directly uses patient origin data. However, it does not constrain the hospital's market area to be circular. Instead, a hospital's market is defined as the collection of geographic areas (typically zip codes) that send a nontrivial amount of patients to the hospital,<sup>15</sup> and that collectively account for 40–95% of a hospital's discharges.<sup>16</sup>

## 7. LIMITATIONS OF CURRENT APPROACHES

A key shortcoming of many current approaches for measuring hospital markets is that they only include active competitors and ignore potential competitors. Economists have long realized that competitive outcomes may be obtained even when a small number of firms are actively in the market, as long as a credible threat of potential entry into the market exists (Baker, 2001). The number of potential competitors faced by a hospital is regarded as a greater constraint on that hospital's behavior than the number of competitors it actually faces (Garnick et al., 1987). This shortcoming primarily affects the cross elasticity, variable radius, and patient flow approaches.

In addition, a disadvantage of the variable radius and patient flow methods is that they have a potential for endogeneity bias when used in studies that investigate the effects of hospital competition on hospital cost and quality. The endogeneity bias arises because the patient flows, which are

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<sup>14</sup> Phibbs and Robinson (1993) use admissions.

<sup>15</sup> The patient flow approach assumes that hospitals do not regard geographic areas that only account for a "small percentage" of their discharges as part of their market (Zwanziger et al., 1990). Although there are different definitions of "small percentage," researchers employing this method typically exclude geographic areas from the market if they account for less than 3% or less than 1% of a hospital's discharges.

<sup>16</sup> The literature contains a number of different rules for defining hospital markets using the patient flow approach. See Garnick et al. (1987), Zwanziger and Melnick (1988), and Zwanziger et al. (1990) for examples. Zwanziger et al. (1990) find that HHIs calculated for hospital markets defined using 14 different patient flow rules are very highly correlated.



used to determine the boundaries of the market, are driven, in part, by differences in the cost and quality of hospitals. Novel approaches, which are discussed in a later section, are emerging to address this concern.

### III. Measuring Hospital Competition Intensity

#### 1. NUMBER OF HOSPITALS

Following the selection of market area definition, researchers must decide how to measure the intensity of competition within the market area. The number of hospitals in the market is a frequently used measure. It has the advantages of being intuitive and easy to implement. It is also an appealing measure in studies where the number of hospitals in a market influences a hospital's behavior more than the relative sizes of the hospitals in the market (Baker, 2001).<sup>17</sup>

A disadvantage of this measure is that it does not reflect differences in market share. For example, a hospital in a market with 5 hospitals, where each hospital has a 20% market share, will behave differently than a hospital in a market with one hospital that has a 80% market share and the remaining 4 hospitals each have a 5% market share.

#### 2. HERFINDAHL-HIRSCHMAN INDEX (HHI)

An alternative measure of the intensity of competition that captures these differences in market share is the HHI. The HHI is the sum of squared market shares for all of the hospitals in the market. In the context of hospital competition, a hospital's market share is frequently calculated as the number of discharges from that hospital divided by the total number of discharges from all hospitals in the market (Zwanziger et al., 1990). The HHI ranges from a minimum of  $1/N$ , where  $N$  is the number of hospitals in the market, to a maximum of 1, with higher values representing increased market concentration.<sup>18</sup>

In an industry producing a homogenous good, a Cournot model of non-cooperative oligopolistic competition yields an HHI that is linearly related to the industry-wide average firm markup weighted by firm market share. However, hospitals are more accurately characterized as a differentiated product oligopoly, differing in the geographic location of the provision of service and in the nature and quality of the services provided. As

<sup>17</sup> For example, the medical arms race hypothesis suggests that the number of competitors who have a new technology will be a more important determinant of a hospital's behavior than the distribution of market shares in the area (Baker, 2001).

<sup>18</sup> In many antitrust applications, the HHI is reported as the sum of squared market shares times 10,000.

a result, the theoretical appropriateness of the HHI as a measure of hospital market competition has been questioned (Gaynor and Vogt, 2003; Tay, 2003). Among the reasons researchers continue to employ the HHI in both empirical studies of aggregate hospital behavior and in antitrust cases are as follows: precedent, computational ease, absence of agreement on a preferred alternative measure, the continual use by the Federal Trade Commission (FTC) in hospital antitrust cases, and the fact that the HHI reflects both the number of hospitals and the market shares across hospitals.

### 3. CONCENTRATION RATIO

Another possible measure of the intensity of competition within a market is the  $m$ -firm concentration ratio, where  $m$  is typically 4 or 8. Although the  $m$ -firm concentration ratio measures the dispersion of market shares in a hospital market area, it only does so for the largest 4 or 8 hospitals. Therefore, it conveys less information than the HHI. Consequently, it is not frequently used in the literature.

## IV. New and Evolving Approaches in Measuring Hospital Competition

In recent years, several studies have introduced new approaches to measure hospital competition that circumvent the problems of endogeneity bias prevalent in some existing methods. In general, these new approaches are extensions of the patient flow method. These methods employ 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 flows from the initial step, rather than from actual measures.

The most notable of these studies is Kessler and McClellan (2000). Using hospital discharge data for the vast majority of nonrural elderly Medicare beneficiaries with a new diagnosis of acute myocardial infarction (AMI) for selected years between 1985 and 1994, the probability of choosing a particular hospital  $j$  in a market<sup>19</sup> by each individual  $i$  (i.e.,  $\hat{p}_{ij}$ ) is estimated from  $i$ 's indirect utility function of hospital choice. The parameter estimates for the probability function are estimated based on exogenous factors such as individual characteristics (e.g., age, gender, race), characteristics of hospital  $j$  (e.g., ownership, teaching status), and the relative distances from individual  $i$ 's zip code of residence (denoted by  $k$ ) to hospital  $j$ , a "good" substitute hospital  $j'$ , and a "poor" substitute hospital  $j^*$ .

<sup>19</sup> Kessler and McClellan define the market based on the distance from the patient's zip code of residence to general medical/surgical and large teaching hospitals. Their methodology permits the geographic area from which patients can choose hospitals to be broad without biasing the patient's predicted hospital selection decision.

The  $\hat{p}_{ij}$  for all  $i$  and  $j$  are then aggregated by zip code and, subsequently, the predicted shares of patients for each hospital in each zip code are created (i.e.,  $\hat{s}_{jk}$ ). Squaring and summing the  $\hat{s}_{jk}$  for all  $j$  in  $k$  gives the predicted HHI for patients in zip code  $k$  (i.e.,  $\text{ZIPCOMP}_k$ ):

$$\text{ZIPCOMP}_k = \sum_{j \in J} \hat{s}_{jk}^2.$$

Hospital-level competition measures,  $\text{HOSPCOMP}_j$ , are created by summing the  $\text{ZIPCOMP}_k$  for all  $k$  that each  $j$  is predicted to serve, weighted by the share of  $j$ 's patients predicted to come from each  $k$ ,  $\hat{w}_{kj}$ .

$$\text{HOSPCOMP}_j = \sum_{k \in K} \hat{w}_{kj} \text{ZIPCOMP}_k.$$

Finally, because Kessler and McClellan employ a patient-level analysis, a hospital competition measure at the zip code level is needed. For zip code  $k$ , this measure is created by summing  $\text{HOSPCOMP}_j$  across all  $j$  in  $k$ , weighted by the  $\hat{s}_{jk}$

$$\text{PATCOMP}_k = \sum_{j \in J} \hat{s}_{jk} \text{HOSPCOMP}_j.$$

Patients in the same zip code share the same  $\text{PATCOMP}$ .

Town and Vistnes (2001) employ a similar approach in measuring hospital competition. Like Kessler and McClellan (2000), they estimate the indirect utility of functions of patients by using patient characteristics, hospital characteristics, and patient–hospital distances. However, Town and Vistnes extend the concept by evaluating the different welfare states of potential enrollees in health maintenance organizations (HMOs) under alternative hospital network configurations. More specifically, they estimate and compare the welfare states when a hospital is dropped from the network and when a hospital is dropped from the network and replaced by a close substitute hospital. These welfare estimates provide information on the relative desirability of a hospital and, therefore, are indicators of market bargaining power.

Following Kessler and McClellan (2000) and Town and Vistnes (2001), Gowrisankaran and Town (2003) compute measures of hospital competition based on the results of patient-level hospital choice models, again using patient characteristics, hospital characteristics and patient–hospital distances in the first stage. An important extension of Gowrisankaran and Town is the aggregation of patient-level measures to create hospital-level competition measures by different insurance types (e.g., Medicare, HMO) to address issues about competition, payer type, and quality.

Employing patient flow approaches based on patient-level hospital choice models to measure hospital competition represents a new frontier and a trend is clearly developing in this direction. These approaches have considerable theoretical appeal because they circumvent methodological limitations of existing measures, especially endogeneity issues. However, despite this appeal, these methods have yet to be fully embraced and employed by the majority of empirical researchers who explore a range of health policy issues. These new approaches are significantly complex and few researchers have mastered the necessary skills to understand the subtleties of the technique, and to write and execute the statistical programs that employ a multi-stage process in creating the hospital competition measures. Moreover, while the hospital discharge databases used in these approaches are becoming more widely available, the resources needed to obtain the databases and to process the data into analytic files are not insignificant.<sup>20</sup> Consequently, researchers continued to use more traditional approaches to measure hospital competition.<sup>21</sup> Because these new approaches are not yet been established as the industry standard, we focus our study on the traditional measures of hospital competition.

## V. Data and Methods

### 1. HOSPITAL COMPETITION MEASURES

We create and evaluate hospital competition measures based on the four most common ways of defining hospital markets areas (i.e., geopolitical boundaries, fixed radius, variable radius, and patient flow) and the two most frequently used methods of capturing hospital competition intensity within a market area (i.e., number of hospitals ( $N$ ) and the HHI). For each market definition employed, we create the two aforementioned measures of hospital competition. We limit our study to community hospitals because they are relatively homogeneous.

*Geopolitical boundary.* Our first set of hospital competition measures consisted of three hospital market definitions based on the geopolitical boundary approach. Using the 1997 American Hospital Association (AHA)

<sup>20</sup> Kessler and McClellan (2000) limit their study to Medicare beneficiaries while Town and Vistnes (2001) and Gowrisankaran and Town (2003) limit their studies to Southern California. This may be due, in part, to the complexity of these approaches and the significant resources to obtain and to process the data.

<sup>21</sup> Research continues to be published in renown general economics, health economics, and policy-oriented journals using the traditional approaches: Burdorf et al. (2004), Gresenz et al. (2004), Bamezai et al. (2003), Carey (2003), Cuellar and Gertler (2003), Dranove and Lindrooth (2003), Sloan et al. (2003), Duggan (2002), Gaskin et al. (2002), Gift et al. (2002), Greenberg and Goldberg (2002), Meltzer et al. (2002), Sari (2002), and Santerre and Adams (2002).

Annual Survey, the 5,113 community hospitals in the U.S. were grouped by their county location. For each county, the number of community hospitals and the corresponding HHI were calculated. HHIs were calculated based on the total number of hospital beds, admissions, and discharges.<sup>22</sup> A hospital-level analytic file was created by assigning each hospital the set of hospital competition measures corresponding to the county in which the hospital is located. Hospitals in the same county share the same hospital competition measures.

To create hospital competition measures based on MSA and HSA market definitions, the AHA file was linked to the 2001 Area Resource File (ARF) by county location. Using the MSA and HSA codes on the ARF, community hospitals on the AHA file were grouped by MSA and HSA locations. 2,893 community hospitals were located in MSAs. Because HSAs are not defined for Alaska and Hawaii, we assigned HSAs to the 5,076 community hospitals in the AHA data that were located in the 48 contiguous states.<sup>23</sup> The same hospital competition measures created at the county level were also created at the MSA and HSA levels. As before, these measures were subsequently included in the hospital-level file.

*Fixed radius.* To create hospital market areas using the fixed radius approach, we calculated the distances between each community hospital in the AHA and every other community hospital using the latitude and the longitude of each institution.<sup>24</sup> For each community hospital, we determined the set of community hospitals that are located within a 15 mile radius of it, thereby characterizing a unique market for each hospital. We then calculated the same hospital competition measures and assigned them to the corresponding hospital.

*Variable radius.* To define markets based on the variable radius approach, the resident location of patients are needed. Consequently, the Healthcare Cost and Utilization Project (HCUP), State Inpatient Databases (SID) for 1997 were used. The 1997 SID files contain all of the inpatient discharge

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<sup>22</sup> We follow the practice in the literature of regarding hospitals with separate AHA identification numbers as separate entities, even though some might, in fact, be jointly owned (e.g., Connor et al., 1998). Nauenberg et al. (2001) suggest that this will lead to an overestimation of the amount of competition in certain markets because of the increase in mergers and networking activity among hospitals. See footnote 31 for how we empirically address this issue in our study.

<sup>23</sup> The HSAs in the ARF are the 800-area, non-linked solutions generated by Makuc et al. (1991).

<sup>24</sup> We make the simplifying assumption that the earth is a sphere in our calculations. Since the distances between hospitals are so small in comparison to the size of the earth, the fact that the earth is actually elliptical does not materially affect our results. For cases where the longitude and latitude are not reported on the AHA file, we obtained longitude and latitude information by using the AHA hospital address and the Mapblast website ([www.mapblast.com](http://www.mapblast.com)) query system.

abstracts for all 2,596 community hospitals in 22 states<sup>25</sup> and include zip code information on patient residence. For each hospital, we divided its discharges by patient zip codes. We obtained the latitude and longitude for each hospital from the 1997 AHA Annual file. Correspondingly, the latitude and longitude of the centroid location of each zip code were obtained from the United States Census Bureau. We calculated the distance between every hospital and the zip codes it served and used the distance to rank order the zip codes in ascending order. We sequentially aggregated the discharges in every zip code for the corresponding hospital until 75% of the hospital's discharges were captured. The distance between the hospital and the last zip code to achieve this cutoff is the radius measure of interest. We created an alternative radius measure by employing this same approach but raised the cut off to 90% of the hospital's discharges. We linked the variable radius measures back to the AHA Annual file and calculated the competition measures in the same way as we performed under the fixed radius approach. Under this approach, each hospital has a unique market radius and competition measures.

*Patient flow.* Similar to the variable radius approach, the patient flow approach requires information on the patient residence location. Consequently, we used the 1997 HCUP SID files because they provide zip code information on patient residence. We grouped all discharges for a given state by zip code and created our hospital competition measures at the zip code level.

For each zip code, the number of unique hospitals that served that zip code was obtained. To avoid over-estimation of the number of hospitals serving a zip code, we employed three different rules to exclude hospitals that accounted for a small percentage of patients from that zip code. For each zip code, we ranked in descending order of discharges, the hospitals serving the respective zip code. For each zip code, we sequentially aggregated the discharges of the hospitals until 75% of the zip code's discharges were captured. The corresponding number of hospitals needed to achieve this level was our competition measure for the zip code. We repeated this approach and created competition measures that capture 90% and 95% of each zip code's discharges.

No adjustments for creating the HHI were necessary. The share of hospitals with trivial amounts of patients for a zip code is so small that the zip code HHI did not change noticeably. For each hospital, we calculated the proportion of the hospital's discharges that came from each zip code.

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<sup>25</sup> The 22 states are Arizona, California, Colorado, Connecticut, Florida, Georgia, Hawaii, Iowa, Illinois, Kansas, Massachusetts, Maryland, Missouri, New Jersey, New York, Oregon, Pennsylvania, South Carolina, Tennessee, Utah, Washington, and Wisconsin.

Table I. Descriptive statistics of competition measures

Variable	Obs	Mean	S.D.
<i>HHI</i>			
County	5,110	0.54453	0.36184
MSA	2,893	0.17779	0.18263
HSA	5,076	0.27367	0.21239
Fix Rad	5,113	0.52381	0.36600
Var Rad 75%	2,569	0.50870	0.37394
Var Rad 90%	2,562	0.33898	0.31745
Pat Flow	2,596	0.32332	0.13382
<i>N</i>			
County	5,112	8.91510	18.27552
MSA	2,893	27.18458	27.97158
HSA	5,076	18.18006	26.62338
Fix Rad	5,113	9.18932	14.79902
Var Rad 75%	2,569	11.78241	23.83230
Var Rad 90%	2,562	24.04489	65.08242
Pat Flow 75%	2,596	3.66254	1.89841
Pat Flow 90%	2,596	7.04483	4.42869

Finally, for each hospital, hospital competition measures were calculated by weighting the zip-code level competition measures by the proportion of the hospital's discharges to that zip code and summing the weighted measures across all zip codes served. Table I presents the descriptive statistics of the hospital competition measures used in this study.

## 2. CORRELATION AND HOSPITAL COST FUNCTION ANALYSES

Differences between our hospital competition measures are assessed by examining correlation coefficients. In addition, each measure is independently included as an explanatory variable in otherwise identical hospital cost function regressions.<sup>26</sup> Their corresponding parameter estimates are then compared. We chose to evaluate the impact of the different measures of hospital competition using hospital cost functions because the

<sup>26</sup> Kwoka (1981) demonstrates that using correlation coefficients alone to evaluate competition measures may lead to false inferences. Consequently, alternative techniques, such as regression analysis, need to be considered as well.

relationship between hospital competition and hospital cost<sup>27</sup> is the most frequently studied relationship in the empirical literature on hospital competition.<sup>28</sup> Moreover, by standardizing our cost function specification, with the exception of the hospital competition measures investigated, we circumvent the heterogeneity issues of independent studies that make comparisons difficult.

We specified a hospital cost function with the intention of evaluating the different measures of hospital competition and not with the intention of making a contribution to the literature on the specification or econometric estimation of hospital cost functions. Therefore, we followed the literature in our selection of functional form, variables, and estimation techniques.<sup>29</sup>

We employ a hospital cost function that is a hybrid of ad hoc specifications and the flexible functional forms approach. Our model takes the following form:

$$\ln \text{COST} = \alpha + \beta \ln \text{OUTPUT} + \delta \ln \text{PRICE} + \gamma \ln \text{HOSP} + \lambda \ln \text{MKT} + \epsilon,$$

where  $\alpha, \beta, \delta, \gamma$ , and  $\lambda$  are parameters to be estimated and  $\epsilon$  is the error term. Following recent contributions (e.g., Zwanziger et al., 2000; Rosko, 2001), we employ a translog specification with interaction terms between hospital outputs and input prices.

Our dependent variable, COST, is hospital total operating expenses and comes from the 1997 AHA Annual Survey. Our vector of hospital output variables, OUTPUT, also comes from 1997 AHA Annual Survey and consists of inpatient discharges, outpatient visits, and surgical discharges as a percentage of total discharges.

We follow Zwanziger et al. (2000) and control for hospitals' relative cost of labor with a wage index from the Centers for Medicare & Medicaid Services (CMS). PRICE is the 1997 hospital wage index. We recognize that our study would benefit from a fuller specification of hospital input prices, but we are constrained by the data available to us.

HOSP is a vector of hospital characteristics. We used 1997 AHA data to create hospital ownership variables, to control for the number of beds

<sup>27</sup> Although the industrial organization literature typically examines price-cost margins in competition studies, the hospital competition literature frequently assesses hospital costs because of data limitations.

<sup>28</sup> We do not aim to evaluate the relative merits of existing studies in this literature. Instead, we evaluate the effects of hospital competition on cost to help inform the researcher's selection of a hospital competition measure, regardless of the dependent variable.

<sup>29</sup> We recognize that there are important supply and demand variables that affect cost and are omitted from our model. However, our main focus is to conform to a standard set of explanatory variables that have been employed in the existing literature on hospital competition.



and the percentage of discharges paid for by Medicare, and to construct a teaching status variable.<sup>30</sup> We defined a hospital as urban or rural depending on whether or not it was located in an MSA, using the ARF's MSA designation. To control for hospital case mix, we used the 2000 case mix index from CMS.

MKT is a vector of market variables. It includes our set of hospital competition measures (individually applied) and InterStudy's 1998 county HMO penetration rate (as reported in the ARF). We followed Bamezai et al. (1999) and Kessler and McClellan (2000) and included the interaction between managed care penetration and hospital competition as a regressor in our models.<sup>31</sup>

A Breusch and Pagan (1979) test indicated the presence of heteroskedastic disturbances. Subsequently, Goldfeld–Quandt tests suggested that the error variances were related to the number of discharges and the number of available beds. We calculated robust standard errors using HC0, the sandwich estimator proposed by Huber (1967) and White (1980). Following the recommendation of Long and Ervin (2000), we also calculated robust standard errors using HC3, the jackknife estimator of Efron (1982, per the citation of MacKinnon and White, 1985). We used feasible generalized least squares (FGLS) under a variety of assumptions about the functional relationship between the independent variables and the disturbances, and we found that the estimators yielded similar results. We report the results from a flexible specification where we assume that the heteroskedasticity arose from the number of discharges and the number of beds and had an unknown functional form (FGLS 1). We also report the results from regressions where we divided both sides of the equation by the log of beds (FGLS 2). This correction, based on Connor et al. (1998), makes stronger assumptions about the source and functional form of the heteroskedasticity.<sup>32</sup>

We tested for the endogeneity of our competition measures (i.e.,  $N$  and the HHI) using the Durban–Wu–Hausman test proposed by Davidson and MacKinnon (1993). This test indicated that  $N$  and HHI were endogenous. Therefore, in separate analyses, we used instrumental variables (IV)

<sup>30</sup> 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 0.25.

<sup>31</sup> Although it is uncommon for studies in this literature to include, in their empirical specifications, a variable to indicate that a hospital is a member of a multiple hospital system, we do so to assess robustness of our findings. Inclusion of this variable does not materially affect our general results. However, some of the parameter estimates for our 90% variable radius measures were no longer statistically significant at standard levels.

<sup>32</sup> Connor et al. (1998) divide through by admissions.

Table II. Descriptive statistics of hospital cost function model

Variable	Mean	S.D.
Total Operating Expenses	\$60,000,000	\$89,900,000
Total Discharges	6,192.267	7,455.027
Total Outpatient Visits	88,246.25	123,873.60
Surgical Discharge Rate <sup>a</sup>	0.25633	0.23681
Hospital Wage Index	0.92356	0.17263
Non-profit Ownership	0.58909	0.49205
For-profit Ownership	0.16233	0.36879
Teaching	0.32544	0.46859
Urban	0.57168	0.49488
Case Mix Index	1.24714	0.26054
Total Beds	167.6642	172.3576
Medicare Discharge Rate <sup>b</sup>	0.46584	0.14164
County HMO Penetration Rate	0.20984	0.17945

<sup>a</sup>(number of inpatient surgeries)/(total discharges).

<sup>b</sup>(number of Medicare discharges)/(total discharges).

estimation with robust standard errors. We used three county-based variables from the ARF (i.e., 1997 per capita income, number of persons in poverty in 1997, and the 1997 ratio of physicians to patients) as instruments. Following Wooldridge (2000), we instrumented for the interaction of hospital competition and HMO penetration using predicted hospital competition from a reduced form equation and multiplying it by HMO penetration. Table II presents the descriptive statistics of the variables used in our regression analyses.

For all our models, we estimated the total effect of hospital competition on cost as follows:

$$\frac{\partial \ln \text{COST}}{\partial \ln \text{COMP}^n} = \hat{\lambda}_{\text{COMP}^n} + \hat{\lambda}_{(\text{HMO} * \text{COMP}^n)} (\overline{\text{HMO}^n}),$$

where  $\text{COMP}^n$  denotes the hospital competition measure (e.g.,  $N$  or  $\text{HHI}$ ),  $\hat{\lambda}_{\text{COMP}^n}$  is the estimated coefficient on hospital competition measure  $n$ ,  $\hat{\lambda}_{(\text{HMO} * \text{COMP}^n)}$  is the estimated coefficient on the HMO penetration and the hospital competition measure  $n$ , and  $(\overline{\text{HMO}^n})$  is the sample mean HMO penetration rate for the markets for which measure  $n$  is defined. Correspondingly, we calculate the standard error as follows (Greene, 2000):

$$\begin{aligned} \text{S.E.} \left( \frac{\partial \ln \text{COST}}{\partial \ln \text{COMP}^n} \right) &= \sqrt{\text{Var}(\hat{\lambda}_{\text{COMP}^n}) + (\overline{\text{HMO}^n})^2 \text{Var}(\hat{\lambda}_{(\text{HMO} * \text{COMP}^n)}) + 2(\overline{\text{HMO}^n}) \text{Cov}(\hat{\lambda}_{\text{COMP}^n}, \hat{\lambda}_{(\text{HMO} * \text{COMP}^n)})}. \end{aligned}$$

## VI. Results

### 1. CORRELATION COEFFICIENTS

Table III presents the correlation coefficients for our hospital competition measures (i.e.,  $N$  and HHI) across the different market area definitions. The correlation coefficients for the group of HHI measures range from 0.4177 to 0.7857. The correlation coefficients for the group of  $N$  measures range from 0.2398 to 0.9576. In general, competition measures based on the variable radius market definitions yielded the lowest correlations with other measures (particularly for the variable radius 90%  $N$  measure). In contrast, competition measures based on the geopolitical boundary definitions and the patient flow definitions yielded the highest correlations with other measures. The correlation coefficients between the  $N$  and HHI measures across the different market definitions range from  $-0.3136$  to  $-0.7237$  and show a negative relationship between these two groups of measures. (A concentrated market is indicated by a low  $N$  and a high HHI.) As with our earlier comparisons, competition measures based on the variable radius market definitions yielded the lowest correlations with other measures. Overall, the correlation coefficients between measures are relatively high, but there is significant variation between some measures.

### 2. HOSPITAL COST FUNCTION

Table IV presents our results from including different measures of hospital competition in otherwise identical hospital cost function regressions. A variety of econometric estimation techniques were employed. Only the total effect estimates of hospital competition on cost are reported.<sup>33</sup> The parameter estimates on the other variables in the model were generally consistent with results found in the literature and were robust to estimation technique.<sup>34</sup>

We make a number of observations about the results presented in Table IV. First, the total effect estimates from the models were remarkably similar in sign and level of significance, and hence, in the overall inferences they yielded. All the estimates for HHI measures were negative, and most were significant at the 1% level. Similarly, the estimates for the  $N$  measures were all positive, and most were significant at the 1% level. In general,

<sup>33</sup> We report the total effect estimated at the mean HMO penetration rate. We also calculated the total effect at the mean HMO penetration rate  $\pm$  one standard deviation to see if the sign of the effect changed. We found that it did not, and we do not report the results here.

<sup>34</sup> Tables V and VI present estimates for the effect of hospital teaching status and number of beds by competition measure and method.

Table III. Correlation coefficients of competition measures

HHI		N																		
County	MSA	HSA	Fix	Var	Var	Pat	County	MSA	HSA	Fix	Var	Var	Pat	County	MSA	HSA	Fix	Var	Var	Pat
			Rad	Rad	Rad	Flow				Rad	Rad	Rad	Flow				Rad	Rad	Rad	Flow
				75%	90%							90%						75%	90%	
HHI																				
County	1.0000																			
MSA	0.5438	1.0000																		
HSA	0.6689	0.6850	1.0000																	
Fix Rad	0.6960	0.5803	0.5860	1.0000																
Var Rad 75%	0.6126	0.4446	0.4828	0.6951	1.0000															
Var Rad 90%	0.5603	0.4313	0.4434	0.7082	0.7857	1.0000														
Pat Flow	0.6254	0.6566	0.6474	0.6126	0.5084	0.4177	1.0000													
N																				
County	-0.5066	-0.3800	-0.4538	-0.3851	-0.4101	-0.3416	-0.4946	1.0000												
MSA	-0.4514	-0.6096	-0.5244	-0.4599	-0.3888	-0.3619	-0.5399	0.7748	1.0000											
HSA	-0.4973	-0.4380	-0.5630	-0.4091	-0.4034	-0.3431	-0.5261	0.8942	0.7699	1.0000										
Fix Rad	-0.5082	-0.4654	-0.4948	-0.6133	-0.4639	-0.4305	-0.5619	0.5157	0.6688	0.5228	1.0000									
Var Rad 75%	-0.3735	-0.3126	-0.3442	-0.3322	-0.4960	-0.3971	-0.3425	0.5868	0.5045	0.5589	0.3865	1.0000								
Var Rad 90%	-0.2149	-0.1844	-0.2345	-0.1939	-0.3162	-0.3431	-0.1756	0.2917	0.2808	0.3011	0.2398	0.5438	1.0000							
Pat Flow 75%	-0.5771	-0.5687	-0.5445	-0.5544	-0.4826	-0.4081	-0.8076	0.7482	0.7604	0.7662	0.7326	0.4723	0.2464	1.0000						
Pat Flow 90%	-0.5512	-0.5603	-0.5906	-0.5124	-0.4288	-0.3830	-0.7237	0.7895	0.8235	0.8171	0.7281	0.5131	0.2705	0.9576	1.0000					

Table IV. Total effect estimates of competition measures in hospital cost function analysis by method

Market Definition	HC0		HC3		FGLS 1		FGLS 2		IV with HC0	
	Effect	t-stat	Effect	t-stat	Effect	t-stat	Effect	t-stat	Effect	t-stat
<i>HHI</i>										
County	-0.02461**	-4.12	-0.02461**	-4.09	-0.02725**	-5.03	-0.01938**	-2.85	-0.07176**	-6.11
MSA	-0.01208*	-2.16	-0.01208*	-2.13	-0.00940†	-1.79	-0.01423*	-2.43	-0.03836**	-2.76
HSA	-0.02825**	-5.14	-0.02825**	-5.06	-0.02345**	-4.73	-0.03239**	-5.61	-0.08325**	-5.58
Fix Rad	-0.03556**	-6.22	-0.03556**	-6.17	-0.03432**	-6.75	-0.03474**	-5.41	-0.12718**	-7.74
Var Rad 75%	-0.03837**	-5.03	-0.03837**	-4.84	-0.03811**	-6.02	-0.03052**	-4.20	-0.10191**	-5.92
Var Rad 90%	-0.03659**	-5.52	-0.03659**	-5.21	-0.03999**	-7.64	-0.03306**	-6.07	-0.11559**	-6.70
Pat Flow	-0.03950**	-2.70	-0.03950**	-2.65	-0.03751**	-2.71	-0.03601*	-2.32	-0.17042**	-3.69
<i>N</i>										
County	0.02424**	4.79	0.02424**	4.75	0.02763**	6.06	0.01949**	3.46	0.06360**	6.30
MSA	0.01220*	2.28	0.01220*	2.24	0.01015*	2.07	0.01464**	2.65	0.03496**	2.74
HSA	0.02345**	4.67	0.02345**	4.62	0.02342**	5.26	0.02490**	4.92	0.07854**	5.59
Fix Rad	0.03169**	6.60	0.03169**	6.54	0.03142**	7.37	0.03183**	6.05	0.10981**	7.95
Var Rad 75%	0.03076**	4.86	0.03076**	4.68	0.03215**	6.09	0.02369**	4.01	0.08789**	5.96
Var Rad 90%	0.03047**	5.33	0.03047**	5.04	0.03494**	7.68	0.02647**	5.65	0.10378**	6.71
Pat Flow 75%	0.04741**	3.59	0.04741**	3.53	0.04518**	3.63	0.04414**	3.13	0.14571**	3.99
Pat Flow 90%	0.03875**	3.39	0.03875**	3.34	0.03262**	3.07	0.04181**	3.46	0.11656**	3.91

\*\*Significant at 1% level.

\*Significant at 5% level.

†Significant at 10% level.

Table V. Effect estimates of teaching in hospital cost function analysis by method

Market Definition	HC0		HC3		FGLS 1		FGLS 2		IV with HC0	
	coef	t-stat	coef	t-stat	coef	t-stat	coef	t-stat	coef	t-stat
<i>HHI</i>										
County	0.06018**	6.51	0.06018**	6.40	0.05171**	6.43	0.06586**	6.30	0.05665**	6.02
MSA	0.08320**	7.34	0.08320**	7.24	0.07634**	7.48	0.09369**	7.78	0.08308**	7.25
HSA	0.05885**	6.42	0.05885**	6.31	0.05176**	6.46	0.06462**	6.22	0.05749**	6.13
Fix Rad	0.05515**	6.04	0.05515**	5.94	0.04751**	5.90	0.05965**	5.69	0.04230**	4.27
Var Rad 75%	0.05351**	4.37	0.05351**	4.32	0.04488**	4.13	0.05930**	4.48	0.04411**	3.41
Var Rad 90%	0.05207**	4.29	0.05207**	4.24	0.04360**	4.03	0.05614**	4.26	0.04163**	3.14
Pat Flow	0.06745**	5.33	0.06745**	5.26	0.05598**	5.08	0.07935**	6.02	0.05546**	4.12
<i>N</i>										
County	0.05937**	6.43	0.05937**	6.32	0.05069**	6.31	0.06550**	6.22	0.05557**	5.92
MSA	0.08311**	7.33	0.08311**	7.23	0.07624**	7.47	0.09349**	7.77	0.08304**	7.25
HSA	0.05789**	6.32	0.05789**	6.20	0.05085**	6.35	0.06316**	6.07	0.05511**	5.87
Fix Rad	0.05480**	5.99	0.05480**	5.89	0.04680**	5.82	0.05926**	5.66	0.04281**	4.35
Var Rad 75%	0.05320**	4.33	0.05320**	4.28	0.04415**	4.06	0.05922**	4.48	0.04232**	3.25
Var Rad 90%	0.05177**	4.26	0.05177**	4.21	0.04289**	3.97	0.05646**	4.28	0.03918**	2.94
Pat Flow 75%	0.06629**	5.24	0.06629**	5.18	0.05496**	5.00	0.07772**	5.90	0.05763**	4.37
Pat Flow 90%	0.06791**	5.38	0.06791**	5.31	0.05693**	5.19	0.07868**	6.00	0.06328**	4.91

\*\*Significant at 1% level.

Table VI. Effect estimates of number of beds in hospital cost function analysis by method

Market Definition	HC0		HC3		FGLS 1		FGLS 2		IV with HC0	
	coef	t-stat	coef	t-stat	coef	t-stat	coef	t-stat	coef	t-stat
<i>HHI</i>										
County	0.22075**	19.16	0.22075**	18.22	0.20314**	19.21	0.21142**	25.13	0.21881**	18.99
MSA	0.24659**	13.11	0.24659**	12.45	0.23550**	13.81	0.22836**	16.58	0.24355**	12.95
HSA	0.22045**	19.16	0.22045**	18.20	0.20563**	19.52	0.21007**	25.05	0.22203**	19.39
Fix Rad	0.21682**	18.86	0.21682**	17.92	0.19811**	18.76	0.20829**	24.83	0.20663**	17.56
Var Rad 75%	0.19411**	12.78	0.19411**	12.46	0.18460**	12.20	0.16995**	14.32	0.18911**	12.50
Var Rad 90%	0.19410**	12.93	0.19410**	12.60	0.18484**	12.32	0.17078**	14.44	0.19195**	12.63
Pat Flow	0.19170**	12.44	0.19170**	12.19	0.18538**	12.08	0.16635**	13.80	0.18266**	11.81
<i>N</i>										
County	0.22023**	19.12	0.22023**	18.17	0.20219**	19.17	0.21111**	25.11	0.21819	18.93
MSA	0.24626**	13.07	0.24626**	12.41	0.23479**	13.77	0.22794**	16.55	0.24374	12.97
HSA	0.21979**	19.10	0.21979**	18.13	0.20509**	19.49	0.20910**	24.91	0.22108	19.15
Fix Rad	0.21658**	18.80	0.21658**	17.86	0.19732**	18.71	0.20800**	24.81	0.20656	17.53
Var Rad 75%	0.19432**	12.76	0.19432**	12.44	0.18441**	12.19	0.17001**	14.33	0.18945	12.43
Var Rad 90%	0.19421**	12.91	0.19421**	12.59	0.18483**	12.32	0.16997**	14.41	0.19236	12.50
Pat Flow 75%	0.19506**	12.40	0.19506**	12.14	0.18338**	11.97	0.16555**	13.74	0.18360	11.93
Pat Flow 90%	0.19201**	12.51	0.19201**	12.25	0.18542**	12.11	0.16735**	13.94	0.18855	12.30

\*\*Significant at 1% level.

the  $t$ -statistics for the coefficient estimates on the MSA measures were lower than for the other measures, although they usually were still significant at the 5% level (and once at the 10% level). This may be due to the fact that there is relatively little variation among MSAs. Indeed, there are only 323 unique MSAs in our analysis.

Second, within broad methods of defining hospital market areas (e.g., geopolitical boundaries and radius approaches), the magnitudes of the estimated total effects were similar. We observed the closest similarities between the county and HSA measures in the geopolitical boundary approach and the fixed radius, variable radius, and patient flow measures under the radius/patient flow approaches. The estimated total effects on the MSA measures were consistently lower in absolute value than on the other measures. In absolute value, the county and HSA measures were consistently higher than the MSA measures and lower than the fixed radius, variable radius, and patient flow measures. To illustrate the similarities and differences, the estimated total effects of HHI on cost (with robust standard errors calculated using HC0) is  $-0.01208$  for our MSA approach, ranged from  $-0.02461$  to  $-0.02825$  for the county and HSA approaches, and ranged from  $-0.03556$  to  $-0.03950$  for radius and patient flow approaches.

Third, the inferences about the broad impact of hospital competition on hospital costs are not sensitive to whether we use  $N$  or HHI to measure the intensity of competition in the market. Both the  $N$  and HHI measures suggest that greater hospital competition is associated with higher costs.

Our finding that greater hospital competition is associated with greater costs is supported by Rosko (2001).<sup>35</sup> This does not necessarily contradict the findings of other recent studies that concluded that greater hospital competition is associated with lower costs. Indeed, the coefficients on the interaction between hospital competition and managed care penetration suggest that greater hospital competition is associated with lower costs in the presence of greater managed care penetration.

## VII. Conclusions

There has been considerable controversy about the appropriate measurement of hospital competition in the literature. This paper evaluates the four most common definitions of hospital market area and the two most common methods of measuring the intensity of competition within an area. Correlation coefficient analysis indicates that most measures are highly correlated. Including the measures in otherwise identical hospital cost function

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<sup>35</sup> The negative coefficient on the HHI that Rosko (2001) estimated with a stochastic frontier regression became positive when estimated with fixed effects.



regressions reveals that the estimated total effects of hospital competition on costs are similar in sign and level of significance. In addition, parameter estimates are similar, with stronger similarities within broad methodological approaches.

In most empirical research applications, the primary objective is to determine the direction of the effect of hospital competition on a dependent variable (Rosko, 2001; Zwanziger et al., 2001) or to use the hospital competition measure as a secondary control variable. Although there may be theoretical reasons to prefer one method of measuring hospital competition to another, this paper suggests that such empirical studies are insensitive to the choice of hospital competition measure employed. Researchers should be able to choose the method of measuring hospital competition that is most convenient and/or theoretically appealing to them without being overly concerned that it will dramatically affect their empirical results.

However, when point estimates are desired or when the magnitude of the estimated effects are important in empirical studies of aggregate hospital behavior, researchers might wish to use several measures as robustness checks. In estimating the impact of hospital competition on cost, we found that estimates from MSA based measures were consistently smaller in absolute value than county and HSA based measures, which in turn were smaller in absolute value than fix radius, variable radius, and patient flow based measures. MSA and county based measures are relatively easy for researchers to obtain, and updated variable radius measures are available to researchers from Gresenz et al. (2004). Using these three measures would give researchers a sense of the range into which the point estimates they wish to obtain would fall.

The implications of our findings for studies wishing to include hospital competition as a control variable mirror those for studies where hospital competition is the main independent variable of interest.

Researchers may wish to calculate hospital competition measures for specific hospital product lines, and the measures we evaluate can be generalized for such applications. For example, Brooks et al. (1997) calculate a county-based HHI that measures the intensity of hospital competition for appendectomy patients.

Our results may not generalize to individual markets. Particularly when evaluating individual mergers, the idiosyncracies of specific markets must be taken into account. There is a considerable literature devoted to selecting metrics of hospital competition in analyses of individual markets, and new methods are emerging.

New methods for measuring hospital competition in empirical studies of aggregate hospital behavior also have emerged. We are not being dismissive of these measures in choosing not to evaluate them in this paper. Rather,

we evaluate those measures frequently used in the literature thus far and that will likely continue to be used in the next few years. We acknowledge the recently proposed measures as new frontiers and leave their evaluation to future work. As new measures evolve and are adopted, this study provides a baseline to assess their relative contribution.

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