Entry and Competition in Local Hospital Markets*

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We extend the entry model developed by Bresnahan and Reiss to make use of quantity information, and apply it to data on the U.S. hospital industry. The Bresnahan and Reiss model infers changes in the toughness of competition from entry threshold ratios. Entry threshold ratios, however, identify the product of changes in the toughness of competition and changes in fixed costs. By using quantity data, we are able to separately identify changes in the toughness of competition from changes in fixed costs. This model is generally applicable to industries where there are good data on market structure and quantity, but not on prices, as for example in the quinquennial U.S. Economic Census. In the hospital markets we examine, entry leads to a quick convergence to competitive conduct. Entry reduces variable profits and increases quantity. Most of the effects of entry come from having a second and a third firm enter the market.

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I Introduction

During the second half of the 1990s, a wave of hospital consolidation occurred in the United States. One source puts the total number of hospital mergers from 1994-2000 at over 900 deals [Jaklevic, 2002, and www.levinassociates.com], on a base of approximately 6,100 hospitals. Many of these mergers have occurred in small markets, thereby resulting in merger to monopoly. Some large urban markets such as Boston, Minneapolis, and San Francisco are now dominated by two to three large hospital systems. Not surprisingly, health plans have complained about rising prices as a result of this consolidation [Lesser and Ginsburg, 2001].

A number of "Structure-Conduct-Performance" (SCP) studies find that concentration raises hospital prices, while a parallel literature finds no consistent concentration-quality relationship [for reviews, see Gaynor and Vogt, 2000; Vogt and Town, 2006; Gaynor, 2006]. While these studies have proved valuable in uncovering patterns in the data, they are subject to the usual criticism that it is very hard to know if SCP studies identify competitive effects [Schmalensee, 1989; Bresnahan, 1989; Gaynor and Vogt, 2000].

Bresnahan and Reiss [1991] present a method for examining the effect of market structure on competition that is not subject to the problems associated with the SCP approach. The Bresnahan and Reiss (BR) method uses a simple, general entry condition to model market structure. The intuition is that if the population (per-firm) required to support a given number of firms in a market grows with the number of firms then competition must be getting tougher. The tougher competition shrinks profit margins and therefore requires a larger population to generate the variable profits necessary to cover entry costs. Thus, the key data required for this method are commonly available: market structure and population.

In the BR approach, the threshold population required to support entry is estimated for each successive entrant. These thresholds are determined by the change in fixed costs due to entry combined with the change in the toughness of competition due to entry. As a consequence, the toughness of price competition is not identified separately from fixed costs in the BR approach. This means that any pattern of entry thresholds is compatible with any pattern of changes in competition, including no change. The only way to identify changes in the toughness of price competition in the BR approach is by assuming that fixed costs do not change with entry.

We augment the BR approach by incorporating the use of quantity data. If price competition gets tougher with entry, price will fall. This leads to higher quantity demanded, *ceteris paribus*. Our technique, using this intuition, allows us to separate changes in fixed cost associated with entry from changes in the toughness of competition. Thus the use of quantity data allows us to identify the effect of entry on competition without making the strong assumptions required by the BR approach. Our approach also allows for a limited kind of welfare analysis: if quantity rises, *ceteris paribus*, then consumer welfare must also have risen. If the entry of an additional firm is not accompanied by any increase in quantity, however, then it cannot enhance social welfare, since it carries with it additional fixed costs [Berry and Waldfogel, 1999; Mankiw and Whinston, 1986]. Our approach thus allows us to test for whether entry benefits consumers or is purely wasteful.[1]

This approach extends the empirical literature in industrial organization on evaluating the determinants and effects of entry[2] by adding to the relatively scarce empirical evidence and proposing a simple extension of the BR method for industries that possess good quantity data. This is true, for example, of the U.S. Economic Census industry data.[3]

We apply this new approach to local markets for hospital services in the U.S. The hospital industry is well suited to this method. Hospital markets are local because consumers are not generally willing to travel far to obtain care. We therefore have many local markets, which gives us the variation we need to estimate the model. There are also good data on market structure and quantity for the hospital industry, but not on price. A great deal of information is collected on hospital list prices (called "charges"), but these bear little relation to actual transactions prices. Health plans negotiate with hospitals and pay varying fractions of the listed price. These transactions prices are not generally reported.

In the hospital markets we examine, entry toughens competition quickly. Most of the effects of entry come from having a second and a third firm enter the market. The entry of a fourth has little additional effect. Further, quantity is increasing in the number of firms, implying that entry is beneficial to consumers.

Two recent papers are related to ours. In modelling entry into U.S. broadcast radio markets, Berry and Waldfogel [1999] also extend the BR approach. In addition to data on market structure, Berry and Waldfogel employ data on market shares and prices. This allows them to make inferences about the efficiency of entry in the radio broadcasting industry. We also use quantity data to augment the BR approach; however, we do not have transactions prices for our hospital markets. Genesove [2004] provides another recent variant on the BR framework. Genesove examines possible explanations for the reduction in the number of U.S. cities with at least two daily newspapers. He looks at quantity in some of his analyses but does not estimate a joint model of market structure and quantity.

Like Berry and Waldfogel [1999] and Genesove [2004] we analyze an industry in which the product market is local and the product is differentiated. Like those authors, we assume that firms are symmetric, so that post-entry profits depend only on the number of firms in the market and on market level characteristics. While it is possible in principle to use the method pioneered by Mazzeo [2002] to model entry into differentiated products markets, this method requires a single discrete measure of vertical differentiation (e.g. discretely measured motel quality), which does not lend itself to the hospital industry.

II Model and Econometrics

Our model is based on the entry model of Bresnahan and Reiss [1991]. Their model uses the concept of entry thresholds — the market sizes necessary to support successive entrants to a market — to infer how the toughness of competition varies with market structure. We integrate an analysis of the quantity transacted in the market with their framework, permitting a sharper inference of the effects of structure on competition.

II-i Model

For this analysis we take the output of hospital production to be a single product which is the composite of the set of all hospital services. Since most hospitals sell a common bundle of services (e.g., most hospitals offer obstetrics, surgery, emergency care, etc.), this assumption captures an important aspect of institutional reality.[4]

Let market demand for hospital services be:

$$Q = d(P, X) \cdot S(Y). \tag{1}$$

Market demand is the product of per capita demand (the demand of a representative consumer, $d(\cdot)$) and the total market size, $S(Y)$. Per capita demand is affected by price, P, and exogenous demand shifters such as demographic factors and health insurance coverage, X. We presume that consumers, or health insurers acting as their agents, care about the price of hospital services. There is ample evidence on this point [Manning et al., 1987; Feldman and Dowd, 1986]. The market size, S, is an increasing function of population and other variables, Y.

Hospital costs are characterized by a constant average variable cost, $AVC(W)$, and a fixed (or sunk) cost, $F(W)$, both of which depend upon cost-shifters, W.[5] Following BR, we assume a symmetric equilibrium in price is reached in each market. For a market with N

firms, denote the equilibrium value as P_N. Price depends upon demand and cost conditions as well as the toughness of competition, represented here by θ_N:[6]

$$P_N = P(X, W, \theta_N) \tag{2}$$

The equilibrium value of P determines the equilibrium values of quantity, fixed costs, and variable profits (price minus average variable costs): $d_N = d(P_N, X), F_N = F(W), V_N = V(P_N, W)$.

A hospital will enter a local market if it can earn non-negative profits. The N^{th} firm in a market earns profits equal to:

$$\Pi_N = V_N \frac{S}{N} d_N - F_N \tag{3}$$

The minimum market size necessary to support N firms in the market, S_N, is derived by solving the zero-profit condition. This is the population entry threshold. Let s_N be the minimum market size per-firm for N firms. Then the ratios of per-firm minimum market sizes, the entry threshold ratios, are:

$$\frac{s_{N+1}}{s_N} = \frac{F_{N+1}}{F_N} \frac{V_N \cdot d_N}{V_{N+1} \cdot d_{N+1}} \tag{4}$$

The entry threshold ratio contains the product of the change in fixed costs as N increases and the change in per-capita variable profits as N increases (i.e. the change in the toughness of competition).

If we assume that fixed costs do not change with entry, then the value of the threshold ratio provides us with a straightforward inference about the toughness of competition. A threshold ratio of one represents an unchanging level of competition, while a threshold ratio greater than one represents an increase in the toughness of competition. Bresnahan and Reiss [1991] interpret the threshold ratio falling to one as N increases as likely reflecting a convergence of the market to competition with entry.

However, as equation (4) makes clear, the entry threshold ratios alone cannot identify separately the effect of entry on the toughness of price competition and the effect of entry on fixed costs. Our addition to the Bresnahan and Reiss [1991] framework is the use of information on quantity to identify separately the quantity effect, d_{N+1}/d_N. Doing this allows us to distinguish between changes in the threshold ratios due to changes in competition versus changes in fixed costs.

For example, suppose that we observe threshold ratios that decline from 2 to 1.5 to 1 as we move from 1 to 2 firms, then 2 to 3 firms, then 3 to 4 firms, respectively. This pattern is consistent with variable profits falling by 50% with the entry of the 2nd firm, 25% with the entry of the 3rd firm, and then not changing with the entry of the 4th firm, i.e., tougher competition with entry. However, an alternative, equally consistent interpretation is that fixed costs are rising by 100% with the entry of the 2nd firm, 50% with the entry of the 3rd firm, and not changing with the entry of the 4th firm, implying no change in competition. This fixed cost explanation implies that market quantity is unchanging with entry. Now if we can observe market quantity and it is changing with entry, we can rule out the fixed costs as the sole source of the change in the threshold ratios and infer that competition is indeed changing with entry.

The model we use to structure our analysis makes several strong assumptions about the nature of competition in the markets we analyze. It assumes that we have properly defined the geographic market, that the firms play a game resulting in a symmetric equilibrium, and that goods are homogeneous. In the presence of product differentiation, entry threshold ratios are not necessarily informative about the toughness of price competition [Bresnahan and Reiss, 1991]. Since a long line of literature demonstrates the importance of geographical product differentiation in the hospital industry [see Capps et al., 2003; Gaynor and Vogt, 2003, 2000, and references therein], we devote considerable effort through our market definition procedure (described below) to minimize this dimension of product differentiation.

II-ii Econometrics

We observe the number of firms (N) and quantity (Q) for each market, so we seek equations for both N and Q from our theory. The model thus consists of the following two equations:

$$\Pi_N = \frac{1}{N} S d_N V_N - F_N \tag{5}$$

$$Q_N = S d_N \tag{6}$$

We specify market size, S, per-capita quantity, d_N, average variable profit, V_N, and fixed costs of entry, F_N, as:

$$S = \exp\left(Y\lambda + \epsilon_S\right) \tag{7}$$

$$d_N = \exp\left(X\delta_X + W\delta_W + \delta_N + \epsilon_d\right) \tag{8}$$

$$V_N = \exp\left(X\alpha_X + W\alpha_W - \alpha_N + \epsilon_V\right) \tag{9}$$

$$F_N = \exp\left(W\gamma_W + \gamma_N + \epsilon_F\right) \tag{10}$$

The parameters δ_N, α_N, and γ_N are coefficients on dummy variables for market structure. They capture differences in per-capita quantity, average variable profit, and fixed costs between markets with one firm and markets with N firms. For example, consider fixed costs. A positive value for γ_2 indicates that the fixed cost of entry for the second firm is greater than the fixed cost of entry for the first. A value of $\gamma_3 > \gamma_2$ similarly indicates that the fixed cost of entry for the third firm is greater than the fixed cost of entry for the second, and so on. The interpretation is the same for the per-capita quantity and variable profit parameters.[7]

By substituting equations (7) through (10) into equation (5) and noting that the N^{th} firm enters if $\Pi_N > 0$, it follows that the N^{th} firm enters when:

$$\begin{aligned} &Y\lambda + X(\delta_X + \alpha_X) + W(\delta_W + \alpha_W - \gamma_W) \\ &+ \delta_N - \alpha_N - \gamma_N - \ln N + \epsilon_S + \epsilon_d + \epsilon_V - \epsilon_F > 0 \end{aligned} \tag{11}$$

Denote $\mu_N = \alpha_N + \gamma_N + \ln N - \delta_N$ and $\mu_X = \delta_X + \alpha_X$, with μ_W similarly defined and also denoting ϵ_Π as the sum of the error terms above. Employing the fact that the number of firms in the market will be $\max\{N : \Pi_N > 0\}$, we see that:

$$N = \begin{cases} 0 & \text{if} \quad Y\lambda + X\mu_X + W\mu_W + \epsilon_\Pi < \mu_1 \\ 1 & \text{if} \quad \mu_1 < Y\lambda + X\mu_X + W\mu_W + \epsilon_\Pi < \mu_2 \\ 2 & \text{if} \quad \mu_2 < Y\lambda + X\mu_X + W\mu_W + \epsilon_\Pi < \mu_3 \\ 3 & \text{if} \quad \mu_3 < Y\lambda + X\mu_X + W\mu_W + \epsilon_\Pi < \mu_4 \\ 4+ & \text{if} \quad \mu_4 < Y\lambda + X\mu_X + W\mu_W + \epsilon_\Pi \end{cases} \tag{12}$$

If ϵ_Π has a normal distribution, then the entry model is simply a standard ordered probit with threshold values given by the μ_N.

We now obtain the quantity equation by substituting (7) and (8) into (6):

$$\ln Q_N = Y\lambda + X\delta_X + W\delta_W + \delta_N + \epsilon_Q \tag{13}$$

Where $\epsilon_Q = \epsilon_S + \epsilon_d + \epsilon$, and ϵ represents measurement error.[8]

II-ii-a Identification

Observe that from the entry equation alone, (11), it is possible to identify only $(\delta_X + \alpha_X)$, $(\delta_W + \alpha_W - \gamma_W)$, and $(\delta_N - \alpha_N - \gamma_N)$. The parameters $(\delta_N - \alpha_N - \gamma_N)$ take on different values for every value of N, and this controls the behavior of the population threshold ratios as N increases.

If market population is an element of Y, and it is entered in logs with a coefficient of λ_{pop}, then it is easy to see that the per-firm population threshold ratio is:

$$\frac{s_{N+1}}{s_N} = \exp\left(\frac{\gamma_{N+1} - \gamma_N}{\lambda_{\text{pop}}}\right) \exp\left(\frac{\alpha_{N+1} - \alpha_N}{\lambda_{\text{pop}}}\right) \exp\left(\frac{\delta_N - \delta_{N+1}}{\lambda_{\text{pop}}}\right) \tag{14}$$

Equation (14) echos the expression in equation (4), showing that changes in fixed costs, variable profits, and per-capita demand are not identified separately in the entry equation alone.[9]

The additional identification achieved by including a quantity equation is revealed by examining equations (11) and (13). From the quantity equation we are able to identify δ_N, δ_X, and δ_W. Therefore, from the quantity and entry equations, we are able to separately identify δ_N, δ_X, δ_W, $(\alpha_N + \gamma_N)$, $(\alpha_W - \gamma_W)$, and α_X. We can thus identify all the parameters of market quantity, the combined effect of the number of firms on variable profit and fixed costs, the combined effects of cost shifters on variable profits and fixed costs, and the effects of demand shifters on per-capita demand. As we say in the preceding section, the fact that we can identify the effect of quantity on entry allows us to identify whether entry has an effect on the toughness of competition, specifically distinct from the changes in fixed costs.

II-ii-b Distributional Assumptions and Likelihood

We wish to estimate equation (11), an ordered-probit entry equation, and equation (13), a linked demand equation. The error terms in these two equations are sure to be correlated because they have in common the terms ϵ_S and ϵ_d. They are not perfectly correlated, however, because ϵ_Q contains the measurement error term ϵ which is absent from ϵ_Π, and because ϵ_Π contains the cost and average variable profit error terms, ϵ_F and ϵ_V, which do not appear in the demand equation.

In equation (13), the market structure dummies are endogenous. In markets that have high demand unobservables, ϵ_S and ϵ_d, observed quantity is higher than it would otherwise be, and the number of firms is also higher than it would otherwise be, via the effect of the demand errors on the entry equation. This correlation leads to a biased estimate of δ_N, making the effect of competition on quantity look larger than it is in fact. Conversely, the endogeneity coming from variations in θ_N will tend to understate the competitive effects. High quantity will correlate with low N because markets with tough competition will have fewer firms and lower prices. Which of these effects dominates is an empirical matter.

This leads to a selection model. The entry equation is the selection equation. It selects whether or not we see Q (we do not see Q if $N = 0$). It then selects which number of firms we will see in each market and therefore which δ_N we will be estimating in the quantity equation for each market. The model is estimated via maximum likelihood as described below.

Like any selection model, this one may be identified either by an exclusion restriction, or by functional form assumptions.[10] Our model is identified by two exclusion restrictions: state certificate of need laws and a construction cost index are assumed to directly affect fixed costs but not variable profits or demand. State certificate of need laws regulate entry. This affects fixed costs, but it is hard to see how it would affect either variable profits or demand. Similarly, construction costs affect fixed costs, but seem unlikely to affect variable profits or demand. By way of comparison, Berry and Waldfogel [1999] in their similar framework, use an exclusion restriction on population. They assume that their equivalent of our coefficient on population, λ_{pop}, is one: that the population elasticity of demand is one. Thus population appears in their entry equation, but not in their market share equation.

To reflect the correlation between the error terms in the two equations, we use a variance components model:

$$\epsilon_\Pi = \nu_\Pi + r\eta \tag{15}$$

$$\epsilon_Q = \nu_Q + \eta \tag{16}$$

We assume that ν_Π and ν_Q are independent and normally distributed with means of zero and variances of $\sigma^2_{\nu_\Pi}$ and $\sigma^2_{\nu_Q}$, respectively.[11] We also assume that the random variable η is independent of ν_Π and ν_Q and that it has a mean of zero. The dependence of the errors between the two equations is modeled via the common random variable η and the parameter r. If $r > 0$, then the entry equation and quantity equation errors are positively correlated and if $r < 0$, then they are negatively correlated. The common random component, η, is modelled as a discrete factor approximation [Heckman and Singer, 1984; Mroz and Guilkey, 1992]. That is, it is modelled as having a multinomial distribution with points of support β_i having respective probabilities p_i, where i runs from 1 to K.[12]

There are both principled and pragmatic reasons to use the discrete factor approximation as a way of introducing correlation between two equations in an econometric model. Because the discrete factor's distribution is parameterized in a way which is essentially non-parametric, it can reduce the bias which would otherwise result from assuming normal errors where the errors are not in fact normal. Monte Carlo simulations using discrete factor approximations in selection models and simultaneous equations models have shown that discrete factor approximations perform approximately as well as normal maximum likelihood when the equation errors are truly normal, and that discrete factor approximations provide good estimators of underlying structural parameters in the presence of non-normality in the error terms [Mroz and Guilkey, 1992; Mroz, 1999].

Pragmatically, the distributions of the error terms of each equation of the model conditional upon the discrete factor, η, are normal and independent of each other. This makes both the analytical derivation of the likelihood function and the programming of the likelihood function straightforward. The model is estimated via maximum likelihood, and the derivation of the likelihood function is relegated to an appendix provided on this journal's web site.

III Data

The unit of analysis is a market for hospital services. Markets for hospital services are local, owing to the nature of the service [Frech, 1987]. There is no single, agreed upon method for empirical market definition, although it is clear that the markets should be "self-contained" in the sense that there is not relevant competition from outside the market. We thus follow Bresnahan and Reiss by focusing on geographically isolated markets as a way of minimizing the possibility of competition coming from outside the defined market.

III-i Market Definition

We identified all cities and census designated places (CDPs) in the United States with populations of at least 5,000, using the 1990 Census. Each of these we designate a potential market. Second, to reduce the possibility of market overlap, we eliminate potential markets that are within 50 miles of a city with a population of at least 100,000, or within 15 miles of another potential market. Third, we eliminate all potential markets in which a hospital was located outside of the city but within 15 miles. Finally, markets that were on Indian reservations or located in Alaska or Hawaii were excluded from the analysis. Applying these criteria, we identify 613 markets with 490 hospitals.

These markets contain 12.3 million people collectively, about 4.4 percent of the U.S. population. The 490 hospitals represent about 9.1 percent of U.S. hospitals. In Table 1, we compare the size distribution of the hospitals in our sample to the overall distribution of U.S. hospitals. As one might expect,

[Place Table 1 Approximately Here]

given that our sample selection criteria exclude big cities, we under-sample large hospitals. Furthermore, given that we ignore places with population smaller than 5,000, we also under-sample the very smallest hospitals. However, markets like ours have been disproportionately represented in antitrust cases. Three out of the 11 hospital merger cases brought by the U.S. antitrust enforcement agencies from 1985-2004 were against hospitals located in markets contained in our sample. A number of the other 11 cases were also in similar markets, although they were not in our analysis sample. Figure 1 contains a map illustrating the locations of our markets.

[Place Figure 1 Approximately Here]

As a check of the market definition, we include in our regressions the natural log of the distance from a hospital market to the nearest city with a population of at least 100,000, the natural log of the distance from a hospital market to the nearest city with a population of at least 5,000, and the proportion of commuters traveling at least 45 minutes to work. These variables should pick up "leakages" to or from nearby locations.

We also note that geographic differentiation is one of the most important aspects of product differentiation in this industry. A large literature [see Capps et al., 2003; Gaynor and Vogt, 2003, 2000, and references therein] finds that geographic differentiation is extremely important in hospital demand, and that consumers strongly prefer hospitals close to their homes. Our method of market definition results in very small markets, thereby minimizing the extent of geographic differentiation in the markets we analyze. The hospitals in a market are all within five miles of each other and are separated from other hospitals by at least 15 miles.

III-ii Measures

We use data from a variety of sources, including the American Hospital Association [American Hospital Association, 1990], the 1990 U.S. Census, the Area Resource File [Bureau of Health Professions, 1996], the InterStudy National HMO Census [InterStudy, 1990], and the Missouri Certificate of Need Program [Piper, 1998].

III-ii-a Dependent Variables

The number of firms, N, is defined as the total number of short-term general hospitals with 50 or more beds in a local market. We eliminate any hospitals with fewer than 50 beds on the grounds that they are effectively not full service hospitals. Military hospitals are also excluded, since they do not serve the general public. Table 2 contains the distribution of hospital market structures and their average populations in our sample.

[Place Table 2 Approximately Here]

Quantity, Q, is total adjusted admissions in the market. Adjusted admissions allow for the fact that hospitals provide both inpatient and outpatient care by creating a weighted average of the two. There are other commonly used measures of hospital quantity, such as inpatient admissions alone, inpatient hospital days, or hospital beds. We examined the correlations between all pairs of these measures. Each correlation was greater than 0.9.

III-ii-b Independent Variables

Population is the key determinant of market size, S. We use data from the 1990 Census on the population of the places that are markets in our sample. The mean population size for the entire sample is 19,102. Using population of the place may not accurately represent the total population of the market if individuals living outside the place travel there to obtain hospital services. To control for potential inflows, we include a measure of the market fringe population, defined as the population located outside the place, but within 15 miles.

We also include an indicator variable for whether the market has a military base. Since military personnel may obtain health care from military facilities, demand may be lower in an area with a military base than in an otherwise similar area without one.

Referring back to equations (8) and (9), per capita demand, d_N, and variable profits, V_N, are determined in part by exogenous demand shifters, X, such as demographic factors, income, and insurance. The major demographic factor is age. The proportion of the population 65 years of age and older in the market should be positively associated with demand for hospital services. The measure of income we use is per capita income for the place's population. This may not only capture the direct effects of income on demand, but also the extent of health insurance coverage in the population.

We also include the number of health maintenance organizations (HMOs) as a factor affecting demand. HMOs have two effects on demand. First, HMOs attempt to directly control the amount and type of health care used. Specifically, HMOs focus on keeping patients out of the hospital, thereby directly reducing demand for hospital services. Second, HMOs often contract with a subset of hospitals in a market to provide services for their enrolled population, making choices based in large part on price. This leads hospitals to face more elastic demand for their services. We use the number of HMOs operating in the county of the market in 1990 [InterStudy, 1990].[13] The number of HMOs operating in a market is arguably endogenous, but in our application this variable is never significant, and excluding it does not affect our results.

Both variable profits (9) and fixed costs (10) are affected by exogenous cost shifters, W. Hospitals use various labor inputs, and we use the Centers for Medicare and Medicaid Services' (CMS) hospital wage index as a measure of hospitals' labor costs.[14] We also include median gross rent, defined to be the median rent paid by renter-occupied housing units in the market, to control for differences across markets in facility costs.

Fixed costs are affected by building costs and regulatory costs. CMS's area construction cost index controls for differences across areas in building costs. Hospitals may also incur costs associated with regulatory compliance. Some states have "certificate of need" (CON) programs that require hospitals and other health care providers to obtain formal approval before making large capital investments, including the construction of new hospitals.

Table 3 contains variable definitions and descriptive statistics.

[Place Table 3 Approximately Here]

IV Results

Table 4 (1st column of estimates) contains the estimates from the single equation entry model, corresponding to the entry model of Bresnahan and Reiss [1991]. To generate these estimates, we regress the number of firms in a market on all of our market size, demand, and cost shifters using ordered probit. This technique produces consistent estimators of $\frac{\delta+\alpha-\gamma}{\sigma_\Pi}$ and the threshold ratios as long as ϵ_Π is normal, since the entry equation (12) describes an ordered probit model under that condition. This ordered probit model differs from Bresnahan and Reiss [1991] only in that we use a log-log rather than linear functional form for the components of the profit function. As is readily apparent, almost all of the coefficients in this table have the "right" sign. The demand and market size shifters raise the expected number of firms in the market, and the cost shifters reduce it. The coefficients on construction cost index and distance to a big city have statistically insignificant coefficients of the "wrong" sign, and the coefficient on military base has a large, significant coefficient of the wrong sign. We discuss the threshold ratios for this model below in Section IV-iv.

[Place Table 4 Approximately Here]

IV-i Single-equation Quantity Estimates

Table 4 contains (second column of estimates) OLS estimates of the quantity equation parameters obtained by estimating equation (13) using only the markets in which at least one hospital is present. These estimates were generated by regressing the natural log of quantity in each market on the market size shifters, demand shifters, and variable cost shifters, along with a set of market structure dummies. Again, these estimators are inconsistent both because there is selection bias caused by the unobservability of $\ln Q$ when no hospitals are present and because of the endogeneity of the market structure dummies. We can correct the first of these problems by estimating a Heckman sample selection model. Maximum likelihood estimates from such a model are reported in the last column of the table. The first stage regression of the sample selection model included all the variables in the table plus the certificate of need variable and the construction cost index.

For both of these models, many of the point estimates are again reasonable. The market size and demand shifters largely increase the market quantity transacted and the cost shifters largely reduce it. The market structure dummies also have the expected pattern. As more hospitals enter, the quantity transacted in the market rises. Furthermore, the incremental increase in demand with entry declines as more firms enter, consistent with competition becoming tougher but approaching the competitive level as N increases. By the fourth firm, demand is no longer rising appreciably in entry, and in the OLS estimation it even seems to decline slightly (from 0.688 to 0.661). However, in both models the market structure dummies have an implausibly large effect on the quantity transacted. In the selection model, for example, a market with four firms has an expected demand $e^{0.661} = 1.94$ times as large as the same market would have with a single firm. This is consistent with the market structure dummies being endogenous — markets with high unobserved demand will also have many firms because the high demand causes entry.

IV-ii Two-equation model

Table 5 contains the parameter estimates from the maximum likelihood estimation of equations (11) and (13) with the discrete factor approximation.[15] The parameter estimates are organized according to whether the variables enter the market size, per-capita demand, variable profits, or fixed cost branch of the entry model.[16]

[Place Table 5 Approximately Here]

The parameter estimates are largely reasonable. The coefficient on population in the market size branch of the model says that a 1% increase in market population raises the market quantity by 0.83%. Similarly, an increase in fringe population of 1% raises quantity by 0.21%. Thus, the effect of fringe population on demand is about 26% as large as is the effect of market population on demand. Military bases appear to have a small and insignificant effect in this model.

The cost shifters, wages and rent, have the expected negative sign in the per-capita quantity branch, although the parameters are imprecisely estimated. Similarly, the demand shifters, income, commuters, and percentage elderly affect per-capita quantity in the expected direction. The distance variables show some evidence that our market definition procedure was not completely successful in isolating self-contained geographical markets. The coefficient on distance to a big city is very small. With respect to large cities, our markets seem far enough away that leakage is not an empirically important phenomenon.

For small cities, this is less true. The coefficient on distance to a small city shows that a 1% decrease in the distance to a small city decreases local quantity by 0.22%. Markets with small cities closer to them have lower demand.

Recall that the coefficients in the average variable profits branch of the model, α, are not separately identified from the coefficients in the fixed cost branch of the model, γ. Only $\alpha - \gamma$ is identified. However, for many of the variables we are interested in, identification can be achieved via parameter restrictions. The α_X section of Table 5 contains variables which are in X but not W: variables we are willing to assume shift demand but not cost. None of these coefficients are significant at conventional levels, but the point estimates are mostly consistent with the expected effects.

Similarly, our exclusion restrictions allow us to identify the effects of certificate of need regulation and construction costs on fixed costs. We excluded these variables from α by assuming that they affect neither demand nor variable costs. As in the variable profits branch of the model, these variables' coefficients are imprecisely estimated.

Two of our cost variables, wages and rent, plausibly affect both fixed and variable costs; thus, we are able to identify only $\gamma - \alpha$. Since we expect increases in these variables to raise fixed costs and to lower variable profits (because they raise variable costs), we expect $\gamma - \alpha$ to be positive for both. As the results in the variable profits and fixed cost section of Table 5 show, these expectations are borne out. Wages have an almost unit elasticity on the ratio of variable profits to fixed costs and rent also has a positive if smaller and statistically insignificant estimated effect.

The market structure dummies show that quantity increases substantially with the entry of the second firm, more modestly with the entry of the third firm and that it drops with the entry of the fourth firm. Expected demand with two firms is $e^{0.254} = 1.29$ times as large as it is with one firm. Expected demand with three firms is $e^{0.415-0.254} = 1.17$ times as large as with two firms, and quantity is $e^{0.297-0.415} = 0.89$ times as large with four or more firms as with three. However, because we have only five markets with four or more firms and eight markets with three firms, the coefficients on the three and four firm market structures are imprecisely estimated. For example, δ_3 and δ_4 are not significantly different from one another at conventional significance levels (t-stat=0.64), nor are δ_2 and δ_3 significantly different from one another at conventional significance levels (t-stat=1.25).

The effects of market structure on variable profits and fixed costs are not identified separately. We can see only $\gamma_N - \alpha_N$, the percent increase in fixed costs plus the percent decline in variable profit relative to monopoly for each market structure. The results in the entry effects subsection of Table 5 show that the entry of the second firm has a strong negative effect on average variable profits net of fixed costs. The effects of subsequent entrants are smaller, and, again, the point estimates indicate that the entry of the fourth firm actually decreases fixed costs net of average variable profits. However, as in the per-capita quantity branch of the model, the difference in the effects of the third and fourth firms is neither large nor significant at conventional levels (t=0.51). Here, however, the t-statistic for the effect of the third firm is significant at conventional levels (t=3.14).

Since the simple ordered probit entry model of Table 4 generates consistent estimators of $(\delta + \alpha - \gamma)/\sigma_\Pi$ under normal errors and since the full model generates consistent estimators of σ_Π, δ, and $\alpha - \gamma$ under its slightly different assumptions, the estimates are directly comparable. Recall from equation (16) that $\epsilon_\Pi = \nu_\Pi + r\eta$. Table 5 reports the estimates $\widehat{\sigma}_{\nu_\Pi}$ and $\widehat{V(r\eta)}$, which are 0.372 and 0.013 respectively. We therefore obtain $\widehat{\sigma}_\Pi$ by squaring $\widehat{\sigma}_{\nu_\Pi}$, adding it to $\widehat{V(r\eta)}$, and taking the square root of the sum. This is 0.389. We can now compare the estimates from the two tables.

For example, the coefficient on population from the single equation model in Table 4, 2.24, should be similar to the coefficient on population from Table 5 divided by $\widehat{\sigma}_\Pi$. Performing this operation we obtain $\frac{0.831}{0.389} = 2.14$, which is very close to the estimate from the full model. Similarly, the coefficients on fringe population are very close: $0.46 \approx \frac{0.212}{0.389} = 0.545$. The coefficient on wage in Table 4, -3.22, should be approximately equal to the corresponding sum, $\frac{\delta_W + \alpha_W - \gamma_W}{\sigma_\Pi} = \frac{-0.241-0.977}{0.389} = -3.13$. For the proportion 65 or older, the two tables give similar values as well: $0.90 \approx \frac{0.189+0.134}{0.389} = 0.830$. The only covariate from Table 4 which is both significant at conventional levels and whose coefficient fails to compare reasonably well with the respective value from Table 5 is the dummy for the presence of a military base: $0.77 \neq \frac{0.046}{0.389} = 0.118$. As we discuss below in section IV-iv and Table 7, the pattern of threshold ratios generated by the simple ordered probit and the full model are also very similar.

IV-iii Discrete Factor Approximation

Since our discrete factor approximation had seven points of support, we have fourteen parameters: the seven values η can take on, the βs, and the seven probabilities associated with these seven values, the ps. The fourteen parameter estimates along with their associated standard errors are presented in the section of Table 5 entitled "Error distributions." The distribution of η is non-normal. There is a large probability mass near zero. The fifth and sixth points of support account for about 98% of the probability mass, and they are relatively close to zero, at -0.093 and 0.336. In addition to this, η has a very long left tail, with its lowest point at -4.845 and its highest at 1.563 and with a (highly significant) skewness of -6.43.

In addition to being non-normal, η has a substantial effect. Consider that the error term in the quantity equation is $\nu_Q + \eta$. The variance of ν_Q is estimated to be $(0.236)^2 = 0.055$ while the variance of η is estimated to be 0.241. Thus, η accounts for about four fifths of the variance in the quantity equation (recall that we assume that ν_Q and η are independent). The error term in the entry equation is $\nu_\Pi + r\eta$. The variance of ν_Π is estimated at $(0.372)^2 = 0.138$ while the variance of $r\eta$ is estimated at 0.013, so that η accounts for 8.6% of the error variance in the entry equation, not as large as in the quantity equation, but still nontrivial.

The discrete factor approximation is also of substantial econometric significance. By adding the discrete factor approximation the log likelihood in the model improves from -589 to -467. Furthermore, when we account for endogenous entry via the discrete factor approximation, the estimate of the effect of entry on quantity falls — compare the δ estimates in the two columns of Table 5, for example. Ignoring the endogeneity of entry in the quantity equation leads to an overestimate of the demand-enhancing effects of entry by the second firm of about 100%.

IV-iv Entry Threshold Ratios and Competition

Table 6 contains the estimated per-firm population thresholds for a hypothetical market with all covariates

[Place Table 6 Approximately Here]

at their mean values. We report per-firm entry threshold ratios in Table 7, along with their standard errors.[17] The first two columns of Table 7 display the threshold ratios for the simple ordered probit model presented in Table 4. The third and fourth columns contain the threshold ratios from the full model of Table 5.

[Place Table 7 Approximately Here]

Since both the ordered probit and the full model provide consistent estimators of $\delta_N - \alpha_N - \gamma_N$, which are the entry equation parameters that determine how the threshold ratios change with N, the threshold ratios implied by these two models should be nearly identical, and they are. Recall that the simple ordered probit model (the BR analogue here) is an estimate of equation 11, the first equation of the model. The disadvantage of the simple ordered probit is that it is not able to distinguish between demand, variable profit, and fixed costs (the δ, α, and γ parameters). But for purposes of calculating threshold ratios there is no need to distinguish among these parameters.

The estimates in Table 7 show that the second firm requires about twice the per-firm population as does the first firm. The third firm requires about 40% more per-firm population than does the second, and the fourth firm requires about the same per-firm population as does the third. The differences between the threshold ratios for the 2/1 entry and the 2/3 entry are statistically significant at 5%, as are the differences between the 2/1 and 3/4 ratios. The differences between the 2/3 and 3/4 ratios are not significant, and the 3/4 ratio is not significantly different from 1.

If one makes the assumption that fixed costs are constant in N, then these point estimates can be interpreted as showing that the toughness of competition is no longer changing with entry after the third firm enters. If we interpret unchanging toughness of competition as the achievement of competitive results, then we conclude that (at point estimates) three firms is enough to achieve a competitive market.

Without using the quantity part of our model, we would be compelled to assume that fixed costs are unchanging in N in order to make inferences about competition from the entry threshold ratios. As we have previously made clear, absent this assumption, the results in Table 7 by themselves could result from fixed costs rising with N at a decreasing rate without any change in competitive conditions.

However, our quantity results dispel this possibility. We decompose the threshold ratios into a per-capita demand effect and a variable profits and fixed cost effect in Table 8. The per-capita demand

[Place Table 8 Approximately Here]

contribution to the 2/1 threshold is 0.77. This means that, were variable profits and fixed costs to remain the same when the second firm enters, so that only per-capita demand changes with entry, the second firm would require a per-firm market size only 77% as large as the first firm did. This is another way of saying that per-capita demand rises by about

23% with the entry of the second firm. Similarly, the ratio of fixed costs to variable profits rises by a factor of 2.54 with the entry of the second firm. The product of the per-capita demand and fixed cost and variable profit numbers yields the overall 2/1 threshold ratio from Table 7 of 1.95.

Taken together, the entry and quantity results indicate that entry by the second firm both increases market quantity and decreases average variable profits as a fraction of fixed costs. A reduction in price would do this. Similarly, the entry of the third firm increases quantity and reduces the ratio of average variable profits to fixed costs, which would also happen if a price decrease occurred. Both of these effects are statistically significant at conventional levels (see Table 5). The entry of the fourth firm, however, leads to a non-significant decline in demand and a non-significant increase in the ratio of average variable profits to fixed costs. The quantity results thus allow us to infer that competition is increasing with entry up until the fourth firm, and that this entry increases consumer welfare. We can therefore conclude that market structure affects the toughness of competition in the hospital markets we examine, and that increasing competition is beneficial for consumers.

V Summary and Conclusions

The relationship between market structure and competition is central to industrial organization. In this paper we augment the parsimonious empirical approach developed by Bresnahan and Reiss. By adding a quantity equation, it is possible to solve a fundamental identification problem in the BR framework. Estimates from the quantity equation can rule out a fixed-cost-only explanation for the pattern of entry threshold ratios. This approach can be implemented for industries where there are good data available on quantity in addition to market structure. Such data are commonly available.

We use this approach to examine the relationship between market structure and competition in hospital markets. In the hospital markets we examine we find evidence that entry leads to a significant increase in competition and benefits consumers. Entry raises quantity transacted in the market and reduces the ratio of variable profits to fixed costs. Most of the effect on competition comes from the entry of a second and third hospital. Subsequent entry has a much smaller estimated effect on competition.

Courts in recent years have reject the U.S. antitrust authorities' efforts to block hospital mergers. Our work indicates that, on average, mergers which take local hospital markets to duopoly or monopoly likely cause significant harm to competition and consumers.

Three out of the 11 hospital merger cases that the U.S. antitrust enforcement agencies prosecuted from 1985-2004 were in markets in our sample.[18] The mergers in each of these cases reduced the number of hospitals from 3 to 2. Our estimates imply substantial reductions in competition from these mergers, and a reduction in consumer welfare. Our estimates of the entry threshold ratios indicate that the third firm in a market requires a 41% larger population per-firm to support it than does the second firm (Table 6), implying a substantial increase in competition due to the entry of a third firm. Furthermore, per-capita demand increases by about 15% due to the entry of a third firm (Table 7), implying an increase in consumer welfare. Some of the other cases have involved merger to monopoly.[19] The anticompetitive effects of such mergers are even greater. This calls for careful antitrust scrutiny of hospital mergers in isolated, concentrated markets such as these.

Notes

[1]We cannot test for socially inefficient entry in general. That requires evaluating the benefits of increased quantity from entry against the fixed costs. To do so would require the use of price data – precisely what we are trying to avoid.

[2]See, for example, Bresnahan and Reiss [1991]; Berry [1992]; Berry and Waldfogel [1999]; Scott Morton [1999]; Davis [2002].

[3]These data have good information on the number of firms and on quantity (measured as sales or employment), but information on relatively little else (`http://www.census.gov/econ/census02`).

[4]The majority of buyers of hospital services are managed care insurance plans, which purchase the rights to a bundle of hospital services for their enrollees *ex ante*. This assumption is nearly universally used in economic and antitrust analyses of the hospital industry [see Dranove and White, 1994; Dranove and Satterthwaite, 2000; Gaynor and Vogt, 2000].

[5]The assumption of constant average variable costs is not restrictive. Inferences from this model regarding conduct are unchanged even with U-shaped average costs [see Bresnahan and Reiss, 1991, 1988].

[6]Tougher competition with more competitors is a robust prediction of theoretical oligopoly models [Sutton, 1991; Bresnahan and Reiss, 1991].

[7]Bresnahan and Reiss [1991] use a different specification for S, d, and V. They specify S and $d \cdot V$ as linear functions of covariates, $S = Y\lambda$ and $d \cdot V = X\alpha_X + W\alpha_W$. We favor our logarithmic specification since it facilitates a clear discussion of identification (see the next section, II-ii-a). As a check we also estimated a linear version of the model. The results were

very similar.

[8]This measurement error arises from using quantity observed at a point in time as a measure of long-run equilibrium quantity.

[9]In Bresnahan and Reiss [1991], γ_N and $\delta_N - \alpha_N$ are separately identified only because of the imposition of the linear functional form.We claim no originality for this insight, as a close reading of Bresnahan and Reiss [1991] reveals that they are aware of this.

[10]As we describe later, we use a discrete factor approximation in order to avoid strong functional form assumptions.

[11]Since the entry equation is an ordered probit, one might think that the variance of ν_Π is not identified. In our model, however, it is because λ is identified from equation (13), so that no normalization is necessary in equation (11).

[12]K is chosen large enough that the likelihood function ceases to rise in K. In our application, raising K from six to seven resulted in the likelihood function rising by 0.05, so we set K equal to seven.

[13]We thank Doug Wholey for providing us with these data.

[14]This wage index was developed for the purposes of Medicare hospital payment. CMS is the U.S. government agency which runs Medicare.

[15]We also estimated the model suppressing the discrete factor approximation. Those estimates are reported in the column labeled “No DFA.” We discuss those estimates later.

[16]In performing this estimation, we expressed all of the right-hand-side variables in deviations from their means. This affects only the estimates of the intercept parameters in each equation.

[17]Here and elsewhere, standard errors for non-linear transformations of the parameters are calculated via the delta method.

[18]Poplar Bluff, Missouri (*FTC et al* v. *Tenet Healthcare Corporation, et al*, 186 F.3d 1045 (8th Cir, 1999)), Ukiah, California (*Adventist Health System/West* (117 FTC 23, 1994)), Dubuque, Iowa (*U.S.* v. *Mercy Health Services and Finley Tri-States Health Group, Inc.* (902 F. Supp. 968, N.D. IO, 1995)). See Gaynor and Vogt [2000] for more details.

[19]For example, Grand Rapids, Michigan (FTC vs. Butterworth Health Corporation and Blodgett Memorial Medical Center (1996, 947 F. Supp. 1285)).

References

American Hospital Association (1990). American Hospital Association Guide to the Health Care Field. American Hospital Association, Chicago, IL.

Berry, S. T. (1992). Estimation of a model of entry in the airline industry. *Econometrica*, 60:889–917.

Berry, S. T. and Waldfogel, J. (1999). Free entry and social inefficiency in radio broadcasting. *Rand Journal of Economics*, 30:397–420.

Bresnahan, T. (1989). Empirical studies of industries with market power. In Schmalensee, R. and Willig, R. D., editors, *Handbook of industrial organization*, volume 2, pages 1011–1057. Elsevier Science, New York.

Bresnahan, T. and Reiss, P. (1988). Do entry conditions vary across markets? *Brookings Papers on Economic Activity*, 3:833–882.

Bresnahan, T. and Reiss, P. (1991). Entry and competition in concentrated markets. *Journal of Political Economy*, 99:977–1009.

Bureau of Health Professions (1996). Area Resource File. prepared for the Bureau of Health Professions by Applied Management Sciences. available through the National Technical Information Service.

Capps, C., Dranove, D., and Satterthwaite, M. (2003). Competition and market power in option demand markets. *Rand Journal of Economics*, 34(4):737–63.

Davis, P. J. (2002). Entry, cannibalization and bankruptcy in the U.S. motion picture exhibition market. unpublished paper, Sloan School, MIT.

Dranove, D. D. and Satterthwaite, M. A. (2000). The industrial organization of health care markets. In Culyer, A. and Newhouse, J., editors, *Handbook of Health Economics*, chapter 20, pages 1094–1139. Elsevier Science, B.V., Amsterdam.

Dranove, D. D. and White, W. D. (1994). Recent theory and evidence on competition in hospital markets. *Journal of Economics and Management Strategy*, 3:169–209.

Feldman, R. and Dowd, B. (1986). Is there a competitive market for hospital services? *Journal of Health Economics*, 5(3):277–92.

Frech, III, H. E. (1987). Comments on (hospital) antitrust issues. *Advances in Health Economics and Health Services Research*, 7:853–872.

Gaynor, M. (2006). What do we know about competition and quality in health care markets? unpublished paper, Carnegie Mellon University.

Gaynor, M. and Vogt, W. B. (2000). Antitrust and competition in health care markets. In Culyer, A. J. and Newhouse, J. P., editors, *Handbook of Health Economics*, volume 1B, chapter 27, pages 1405–1487. Elsevier Science B.V., Amsterdam.

Gaynor, M. and Vogt, W. B. (2003). Competition among hospitals. *Rand Journal of Economics*, 34(4):764–85.

Genesove, D. (2004). Why are there so few (and fewer and fewer) two-newspaper towns? unpublished paper, Hebrew University of Jerusalem.

Heckman, J. and Singer, B. (1984). A method for minimizing the impact of distributional assumptions in econometric models for duration data. *Econometrica*, 52:271–320.

InterStudy (1990). InterStudy National HMO Census. InterStudy, Excelsior, MN.

Jaklevic, M. C. (2002). Tired trend. *Modern Healthcare*, 32(26):10.

Lesser, C. S. and Ginsburg, P. B. (2001). Back to the future? new cost and access challenges emerge: initial findings from HSC's recent site visits, Issue Brief #35. Center for Studying Health Systems Change, Washington, DC.

Mankiw, N. G. and Whinston, M. D. (1986). Free entry and social inefficiency. *Rand Journal of Economics*, 17:48–58.

Manning, W. G., Newhouse, J. P., Duan, N., Keeler, E. B., and Leibowitz, A. (1987). Health insurance and the demand for medical care: evidence from a randomized experiment. *American Economic Review*, 77(3):251–77.

Mazzeo, M. J. (2002). Product choice and oligopoly market structure. *Rand Journal of Economics*, 33(2):221–242.

Mroz, T. (1999). Discrete factor approximations in simultaneous equations models: estimating the impact of a dummy endogenous variable on a continuous outcome. *Journal of Econometrics*, 92(2):233–74.

Mroz, T. and Guilkey, D. (1992). Discrete factor approximations for use in simultaneous equation models with both continuous and discrete endogenous variables. unpublished paper, Department of Economics, University of North Carolina, Chapel Hill.

Piper, T. (1998). Documentation on Certificate of Need Programs in United States for 1990. tabulated by State of Missouri Certificate of Need Program.

Schmalensee, R. (1989). Inter-industry studies of structure and performance. In Schmalensee, R. and Willig, R. D., editors, *Handbook of industrial organization*, volume 2, pages 951–1009. Elsevier Science, New York.

Scott Morton, F. M. (1999). Entry decisions in the generic pharmaceutical industry. *Rand Journal of Economics*, 30:421–440.

Sutton, J. (1991). *Sunk Costs and Market Structure*. MIT Press.

Vogt, W. B. and Town, R. (2006). How has hospital consolidation affected the price and quality of hospital care? Research Synthesis Report No. 9, Robert Wood Johnson Foundation, Princeton, NJ. Downloadable at `http://www.rwjf.org/publications/synthesis`.

Table 1: Sample Hospitals

	Sample Hospitals		U.S. Hospitals	
Beds	Count	Percent	Count	Percent
< 10	0	0.0	13	0.2
10- 25	1	0.2	307	5.6
26- 50	5	1.0	986	17.8
51-100	176	35.9	1213	21.9
101-200	195	39.8	1269	22.9
201-300	63	12.9	744	13.5
301-400	30	6.1	425	7.7
> 400	20	4.1	574	10.4

Table 2: Market Structure and Population

Hospitals in Market	Number of Markets	Average Population
0	205	9,562
1	346	19,004
2	49	51,930
3	8	70,379
4+	5	114,087

Table 3: Variable Definitions and Descriptive Statistics

Variable Name	Definition	Mean	Std Dev
Quantity	Adjusted admissions, market (1000s)	5.50	7.82
Market population	City population (100,000s)	0.20	0.20
Fringe population	Non-city population within 15 miles (100,000s)	0.16	0.13
Commuters	Proportion commuting 45+ min to work	0.06	0.03
Proportion 65+	Proportion of city population age 65+	0.17	0.05
# HMOs	# HMOs in county	0.96	1.56
Per-capita income	City per-capita income ($1000s)	10.77	2.21
CON	Dummy for state certificate of need law	0.56	
Wage index	CMS wage index (base=1)	0.80	0.08
Rent	City median gross rent ($1000s)	0.31	0.07
Construction cost	Adjusted CMS construction cost index (base=1)	0.88	0.10
Distance→big	Distance to place with pop. $>$ 100K (100s miles)	1.02	0.15
Distance→small	Distance to place with pop. $>$ 5K (100s miles)	0.29	0.15
Military base	Dummy for military base $>$ 500 employees	0.04	

Table 4: Single equation estimates

Variable	N ordered probit	$\ln Q$ OLS	$\ln Q$ Selection
	$(\delta+\alpha-\gamma)/\sigma_\Pi$	δ	δ
constant	0.92	8.38	8.55
	(0.08)	(0.03)	(0.03)
Market Population	2.24	0.68	0.46
	(0.16)	(0.06)	(0.06)
Fringe Population	0.46	0.21	0.13
	(0.09)	(0.04)	(0.04)
Military Base	0.77	-0.10	-0.17
	(0.29)	(0.11)	(0.11)
Wage index	-3.22	-0.17	0.17
	(0.99)	(0.33)	(0.33)
Rent	-0.81	-0.24	-0.15
	(0.50)	(0.20)	(0.20)
Income per capita	0.32	0.37	0.37
	(0.46)	(0.18)	(0.18)
Number of HMOs	-0.05	-0.02	-0.01
	(0.04)	(0.02)	(0.02)
Proportion 65+	0.90	0.11	0.01
	(0.24)	(0.10)	(0.10)
Distance $\rightarrow$ big	-0.07	-0.05	-0.03
	(0.16)	(0.07)	(0.07)
Distance $\rightarrow$ small	-0.03	0.14	0.06
	(0.13)	(0.08)	(0.08)

Table 4: Single equation estimates

Variable	N ordered probit	$\ln Q$ OLS	$\ln Q$ Selection
	$(\delta+\alpha-\gamma)/\sigma_{\Pi}$	δ	δ
Commuters	-0.24	-0.05	-0.00
	(0.12)	(0.05)	(0.05)
Construction Cost	0.96		
	(0.71)		
CON	-0.03		
	(0.13)		
2 firms	2.53	0.48	0.62
	(0.15)	(0.08)	(0.09)
3 firms	4.48	0.69	0.90
	(0.29)	(0.18)	(0.19)
4+ firms	5.36	0.66	1.07
	(0.38)	(0.23)	(0.25)

Table 5: Maximum Likelihood Parameter Estimates

	Full Model		No DFA	
Parameter	Estimate	Std Error	Estimate	Std Error
Market Size, λ				
Market population	0.831	0.039	0.710	0.051
Fringe population	0.212	0.021	0.173	0.025
Military base	0.046	0.062	0.093	0.070
Per Capita Quantity, δ				
constant	8.342	0.035	8.380	2.735
Wage index	-0.241	0.235	-0.086	0.329
Rent	-0.161	0.137	-0.275	0.199
Income per capita	0.376	0.118	0.379	0.181
Number of HMOs	-0.012	0.013	-0.019	0.017
Proportion 65+	0.189	0.070	0.140	0.097
Commuters	-0.041	0.032	-0.043	0.050
Distance $\rightarrow$ big	-0.002	0.047	-0.071	0.068
Distance $\rightarrow$ small	0.215	0.051	0.108	0.074
δ_2	0.254	0.059	0.463	0.083
δ_3	0.415	0.130	0.201	0.176
δ_4	0.297	0.152	-0.110	0.264

Table 5: Maximum Likelihood Parameter Estimates

	Full Model		No DFA	
Parameter	Estimate	Std Error	Estimate	Std Error
Variable Profits: demand shifters, α_X				
Income per capita	-0.254	0.209	-0.271	0.236
Number of HMOs	-0.006	0.020	0.024	0.021
Proportion 65+	0.134	0.103	0.140	0.116
Commuters	-0.054	0.055	-0.038	0.064
Distance $\rightarrow$ big	-0.005	0.074	0.056	0.084
Distance $\rightarrow$ small	0.053	0.075	0.103	0.087
Fixed Costs: γ_W				
Construction cost	-0.315	0.270	-0.278	0.229
CON	0.027	0.047	0.017	0.041
Variable Profits & Fixed costs:				
Cost shifters, $\gamma_W - \alpha_W$				
constant	7.997	0.046	8.084	0.044
Wage index	0.977	0.438	0.947	0.466
Rent	0.110	0.227	-0.024	0.254
Entry effects: $\gamma_N - \alpha_N$				
$\gamma_2 - \alpha_2$	0.871	0.077	0.885	0.093
$\gamma_3 - \alpha_3$	1.344	0.156	1.296	0.195
$\gamma_4 - \alpha_4$	1.251	0.186	1.171	0.239

Table 5: Maximum Likelihood Parameter Estimates

	Full Model		No DFA	
Parameter	Estimate	Std Error	Estimate	Std Error
Error distributions				
p_1	0.005	0.005		
p_2	0.004	0.004		
p_3	0.003	0.005		
p_4	0.007	0.006		
p_5	0.644	0.079		
p_6	0.336	0.079		
p_7	0.002	0.002		
β_1	-4.845	0.243		
β_2	-3.513	0.242		
β_3	-1.918	0.362		
β_4	-1.476	0.249		
β_5	-0.093	0.045		
β_6	0.336	0.061		
β_7	1.563	0.252		
σ_{ν_Π}	0.372	0.027	0.325	0.030
σ_{ν_Q}	0.236	0.017	0.455	0.016
r	0.230	0.073		
$V(\eta)$	0.241	0.125		
$V(r\eta)$	0.013	0.011		
Number of Observations		613	613	
Log-Likelihood		-467.29	-588.84	

Table 6: Per-Firm Population Thresholds

Number of Hospitals	Threshold	Std Error
1	6,988	203
2	12,616	682
3	19,145	1,688
4+	19,861	2,449

Table 7: Threshold Ratios

	Ordered Probit		Full Model	
Ratio	Estimate	Std Error	Estimate	Std Error
s_2/s_1	1.97	0.12	1.95	0.12
s_3/s_2	1.44	0.13	1.41	0.12
s_4/s_3	1.06	0.12	1.04	0.11

Table 8: Threshold Ratios' Decomposition

Component		2/1	3/2	4+/3
Per-Capita Q	d_{N+1}/d_N	0.77	0.85	1.13
Fixed Cost & Profit	$\frac{V_N}{V_{N+1}}\frac{F_{N+1}}{F_N}$	2.54	1.66	0.92
Overall	s_{N+1}/s_N	1.95	1.41	1.04

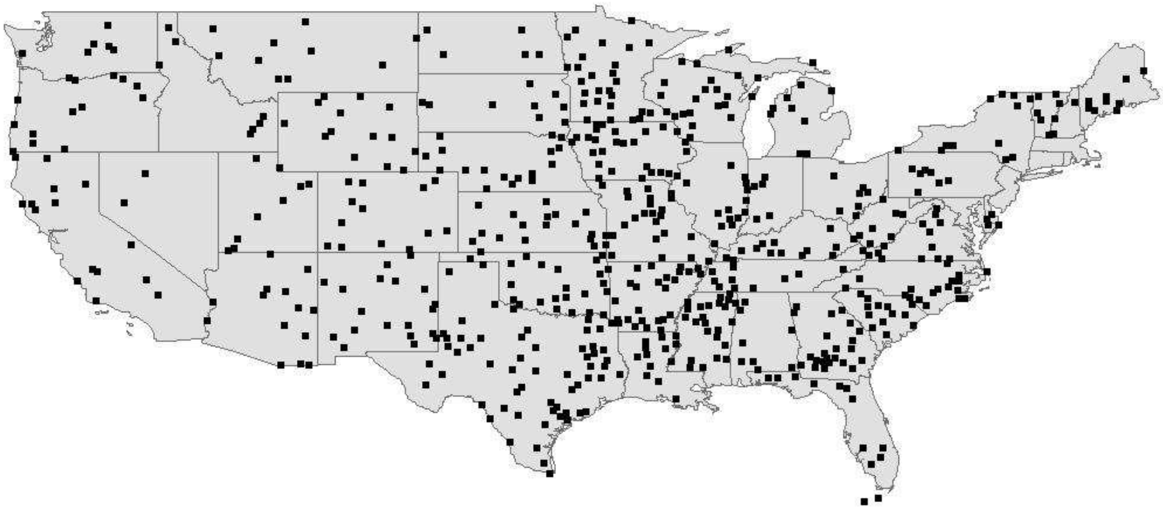

Figure 1: Geographical Distribution of Hospital Markets