The Effect of Hospital Closure on Markets

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Abstract: We measure the effect of hospital closure on the operating efficiency of the remaining hospitals in the local market. Closure of a hospital other than the least efficient can be of detriment to social welfare because treatment costs will be higher at the surviving hospitals. The results show that hospital closure has led to an evolutionary increase in efficiency. The hospitals that closed were less efficient at baseline, and after closure their competitors realized lower costs per adjusted admission through an increase in inpatient admissions and emergency room visits. Overall, we estimate costs per adjusted admission declined by 2-4% for all patients and about 7-9% for patients who would have been treated at the closed hospital.

Keywords: Hospital Closure; Exit; Hospital Competition

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1. Introduction

In the last two decades, the hospital industry has experienced large reductions in the demand for inpatient care due to a variety of factors, including advances in outpatient treatment, utilization management activities of managed care organizations that favor less expensive outpatient care, and changes in the ways that health providers are reimbursed. This has resulted in a nationwide decline in inpatient capacity, namely a 12% decline in the number of short-term hospital beds between 1988 and 1998. A large portion of this decline was the result of hospital closure rather than marginal adjustments to hospital bed capacity. Between 1989 and 1998, a total of 496 short-term general hospitals closed, and these actions represented approximately 40% of total bed closures during this period. We measure the effects of hospital closure by estimating the relative efficiency of hospitals that close and how closure affects the operations and costs of hospitals that remain operational in a market.

If inefficient institutions close first, patients will be treated at the remaining efficient institutions and social welfare can be improved. Closure of a hospital other than the least efficient however can be detrimental to social welfare because treatment costs will be higher at the less efficient surviving hospitals. It is not necessarily true that the least efficient hospital will close first. A hospital may close and exit the market if it feels it is unable to maintain sufficient profitability or it is unable to secure funding to meet its short-term obligations. In addition, inefficient hospitals may adopt other strategies that may reduce costs or improve their ability to attract patients or raise payments, such as aligning themselves with other health providers in the market (Bazzoli, et al., 2000). Hospitals choose a strategy based on their own financial condition, the opportunity cost of beds, the financial status of their competitors, market conditions, and the objectives of ownership. The strategy taken by one hospital affects all other hospitals in the market.

Hospital closure has been studied extensively. From these studies, several consistent empirical results have emerged: smaller hospitals are more likely to close (e.g. Lillie-Blanton, et al. 1992, Succi, Lee, and Alexander, 1997, or Lindrooth and Ciliberto, 2001); hospitals with fewer services are more likely to close (e.g. Williams, Hadley, and Pettengill, 1992); for-profit facilities are more likely to close (e.g. Lindrooth and Ciliberto, 2001; Succi, Lee, and Alexander 1997, Wedig, Hassan, and Sloan, 1989, Williams, Hadley, and Pettengill, 1992); and hospitals with a higher proportion of Medicaid patients are more likely to close (Lindrooth and Ciliberto, 2001). A paper by Deily, McKay and Dorner (2000) used a measure of efficiency derived from a frontier cost function and found that less efficient hospitals had a higher probability of exit. This result is consistent with the first part of our analysis. Frech and Mobley (2000) found that efficient hospitals grew more rapidly than inefficient hospitals, though they did not specifically address closure. These papers only indirectly imply that less efficient hospitals are more likely to experience closure, but they do not directly assess whether the surviving hospitals are indeed more efficient in the aftermath of closure. Pauly and Wilson (1986) did not specifically measure relative efficiency, but did measure the change in average costs that would result from closing hospital beds. Pauly and Wilson focused on the cost of an empty bed and concluded that the cost was relatively small. The cost of an empty hospital bed has been revisited more recently in papers by Keeler and Ying (1996) and Gaynor and Anderson (1995). Both of these papers include simulations of the effect of retiring excess capacity on total costs.

We are aware of only one study that examined subsequent hospital care after closure. McNamara (1999) used administrative claims data to examine the effect hospital closure in rural markets on patient's utility, focusing on the change in access to care resulting from closure. McNamara looked at strictly rural markets where access may override efficiency issues. In our paper, potential access issues are minimized because we examine the effect of closure of urban hospitals with neighboring hospitals within 5 miles. As such, for the majority of patients in the markets we study, access will only minimally be affected by these closures.

Unlike previous work, which can only indirectly assess the effects of closure on surviving hospitals, we directly measure the effect of closure on efficiency of the remaining hospitals within the market by first estimating differences in costs at hospitals that eventually close and their nearby competitors. Next, we examine how competitors are affected (or react) to closure by estimating changes in admissions, case-mix, input levels and market concentration related to closure of a competitor. Finally, we estimate the effect of these changes on hospital cost. We find that on average, hospitals that close had higher cost, two years prior to closure. Furthermore, costs per adjusted admissions fell at nearby hospitals after closure. The latter effect is primarily due to filling previously empty beds. Overall, costs per adjusted admission fall between 2.3% and 4.2% after a hospital closes.

2. Conceptual framework

As noted above, there has been increasing pressure on all hospitals to reduce excess capacity. In this situation, if one hospital exits the market, the pressure to reduce capacity at other hospitals in its market is reduced. Thus, the remaining hospitals may benefit from exit of another hospital. The public good aspect of closure adds a strategic element into the decision making process because each hospital prefers that its competitors reduce capacity first (e.g. Bliss and Nalebuff, 1984). In fact, survival strategies in terms of capacity reduction may be represented as a war of attrition (Ghemawat and Nalebuff, 1990).

The strategic element behind the exit decision implies that a hospital that is not financially distressed may choose to leave the market. For example, a for-profit hospital considers the opportunity cost of capital in their exit decision and may not wait until it is financially distressed. Its owners compare alternative uses of capital, geographically and across industries (Wedig, Hassan and Sloan, 1989). Non-profit hospitals may have a mission tied to inpatient hospital care and will be less willing to close in favor of more profitable uses of capital. Indeed, research suggests that non-profit distressed hospitals are more likely to continue operation and not close (Bazzoli and Andes, 1995; Duffy and Friedman, 1993). This may be due to access to donations or bequests which are not commonly offered to for-profit entities. Alternatively, a hospital may realize early on that it will be unable to outlast its competitors and concedes the war of attrition while it is still profitable and has the funds to convert to other uses.

Due to the strategic nature of the decisions, hospitals predict what other hospitals will do and factor the predictions into their decisions. A firm that appears best able to survive (for whatever reason) may induce competitors to exit first. The characteristics of surviving hospitals have important implications for the long-run efficiency of the industry, which in turn has important implications for policy. If more efficient hospitals survive, it will lead to an evolutionary improvement in the market as in Jovanovic (1982). If, on the other hand, distortions due to ownership objectives or access to operating capital in the hospital market are large enough, exit can reduce efficiency in the market.

In addition to focusing on the relative efficiency of closed hospitals and their competitors we measure the consequences of closure on hospital markets in terms of changes in occupancy rates, economies of scale, case-mix and competition. By looking at relative efficiency before closure and the effect of closure on nearby hospitals, we can make inferences about whether or not closure has led to an increase in efficiency. The effect of changes in occupancy rates at surviving hospitals is particularly important because occupancy rates have been at relatively low levels throughout the 1990s. Keeler and Ying (1996) estimated the cost of excess bed capacity in the United States to be over $24 billion in 1993. This estimate is based on an optimal occupancy rate of 74%, much higher than the 60-65% rates that persisted throughout the 1990's. Gaynor and Anderson (1995) found that an increase in occupancy rates from 65% to 76% would reduce total costs by 9.5% at the average hospital.

The earliest studies of Francisco (1970) and Carr and Feldstein (1967) suggested that economies of scale were exhausted at hospital size of 200 beds or 190 average daily census. More recently, Fournier and Mitchell (1992) and Grannemann et al., (1986) confirmed that economies of scale in inpatient care were exhausted at low levels of hospital output. Dranove (1998) found that economies of scale are exhausted at about 10,000 discharges per year in a study of non-revenue producing cost centers. If additional discharges owing to the exit of a competitor push the hospitals beyond the minimum efficient scale, efficiency can be reduced. Likewise, if the additional admissions occur when economies still exist, efficiency will be improved.

The effect of case-mix must also be considered. If a competitor exits because it treated a disproportionate share of high-cost (and often less profitable) patients, one or several of the surviving hospitals may find that changes in case-mix after exit lead to higher costs. Competition in a market is also affected by exit and thus needs to be measured. Several authors have noted that discounts granted to managed care organizations can induce hospitals to reduce costs (see Robinson, 1991; Zwanziger *et al.*, 1994a and 1994b). These discounts are less likely in markets that are highly concentrated. However, the length of time of our follow-up does not permit us to fully measure the longer run effects of competition on costs.

Consider the following short-run behavioral cost function:

C_i=$f(N_i, I_i, CaseMix_i, Comp_i; Hospital_i, Market_i) - Efficiency_i$, (1)

where C_i is total operating cost, N_i is a vector of all hospital outputs (e.g. inpatient admissions, long-term care admissions, emergency room visits, and outpatient visits), I_i is a vector of quasi-fixed hospital inputs (e.g. hospital beds and long-term care beds), $Casemix_i$ reflects the case-mix of the hospital, $Comp_i$ is the measure of competition, $Efficiency_i$ is a measure short-run hospital cost efficiency, *Hospital* and *Market* reflect other exogenous (in the short-run) hospital and market characteristics that shift the cost function and *i* indexes the hospitals. We assume efficiency is additively separable, for ease of exposition. Additive separability is consistent with a trans-log cost function (See Section 4). The total market cost ($TMC_{t=0}$) prior to closure of a hospital is:

$$TMC_{t=0} = \frac{\left\{\sum_{i=1}^{H-1}\left[N_i^a * f(N_i, \bullet; \bullet) - N_i^a * Efficiency_i\right] + N_c^a * f(N_c, \bullet; \bullet) - N_c^a * Efficiency_c\right\}}{\left(\sum_{i=1}^{H-1} N_i^a + N_c^a\right)} \quad (2)$$

where N_i^a is the number of adjusted admissions at hospital *i; H* is the total number of hospitals in the market (including the hospital that closes); the subscript *c* represents the hospital that will eventually close in the market; and N_c^a represents the increase in adjusted admissions at surviving hospitals that are a result of closure of a competitor. We weight the costs of competitors and closures by there number of adjusted admissions when calculating total market costs.

If we assume for now that only N_i is affected by closure, the market costs after closure ($TMC_{t=1}$) will be:

$$TMC_{t=1} = \frac{\sum_{i=1}^{H-1} \left[\left(N_i^a + N_{ci}^a\right) * f(N_i + N_{ci}, \bullet; \bullet) - \left(N_i^a + N_{ci}^a\right) * Efficiency_i \right]}{\sum_{i=1}^{H-1} \left(N_i^a + N_{ci}^a\right)} \tag{3}$$

where N_{ci}^a represents the increase in of adjusted admissions at hospital *i* that are a result of closure. Similarly, N_{ci} is the increase in output (i.e. inpatient admissions, long-term care admissions, emergency room visits, and outpatient visits) at surviving hospital *i*. Using the fact that $\sum_{i=1}^{H-1} N_{ci}^a = N_c^a$, the change in cost due to closure can be written as:

$$\begin{aligned} TMC_{t=1} - TMC_{t=0} = \Bigg\{ & \sum_{i=1}^{H-1} \left[\left(N_i^a + N_{ci}^a\right) * f(N_i + N_{ci}, \bullet; \bullet) - N_i^a * f(N_i, \bullet\ ; \bullet) \right] - N_c^a * f(N_c, \ \bullet; \bullet) - \\ & N_c^a * \left(\sum_i^{H-1} Efficiency_i - Efficiency_c\right) \Bigg\} \Big/ \left(\sum_{i=1}^{H-1} N_i^a + N_c^a \right) \end{aligned} \tag{4}$$

The first part of the right hand side reflects the change in costs due to economies (or diseconomies) of scale. The scale effect reflects movement along the cost function due to changes in the level of output at all hospitals that remain operational. The second part reflects the difference in efficiency between the closed hospitals and its competitors. The efficiency effect reflects a shift in the cost function due to time-invariant differences in efficiency. Note that each effect is weighted by the number of patients because scale effects are realized by all patients ($N_i^a + N_c^a$) whereas differences in efficiency only affect the market cost for those patients who would have chosen the closed hospital had it remained open (N_c^a).

Equation 4 only considers the case where outputs change due to closure. However, in the empirical analysis below we identify changes in *I* (Inputs), *Casemix*, and *Comp*, that are a result of hospital closure. These changes are included in the model in the same manner as changes in outputs:

$$TMC_{t=1} - TMC_{t=0} = \left\{ \sum_{i=1}^{H-1} \left[\left(N_i^a + N_{ci}^a \right) * f(N_i + N_{ci}, \bullet + \Delta I, \bullet + \Delta CaseMix, \bullet + \Delta Comp; \bullet) - N_i^a * f(N_i; \bullet) \right] - N_c^a * f(N_c; \bullet) - N_c^a * \left(\sum_i^{H-1} Efficiency_i - Efficiency_c \right) \right\} \Big/ \sum_{i=1}^{H-1} \left(N_i^a + N_c^a \right) \quad (5)$$

where Δ reflects the change in *I, CaseMix*, or *Comp* due to closure. Equation 5 measures the change in total market cost. In order to assess whether average costs declined or increased as a results of closure we measure cost per adjusted admission and calculate the percentage change:

$$\left(\frac{TMC_{t=1}}{N^a_{t=1}} - \frac{TMC_{t=0}}{N^a_{t=0}} \right) \Big/ \frac{TMC_{t=0}}{N^a_{t=0}} \quad (6)$$

N^a is the total number of adjusted admissions in the market.

In summary, closure of a hospital affects cost in two ways. First, there is movement along the cost function due to changes in the level of admissions, inputs, case-mix and competition at all hospitals that continue operation. These changes affect all patients in the market. Second, there is a difference in efficiency between closed hospitals and their competitors. This difference only affects those patients who would have been treated at the closed hospital, but are instead treated at a nearby competitor. In the next section we describe the data and the econometric methods follow in Section 4.

3. Data

The primary dataset is drawn from a panel of all short-term urban general hospitals in the American Hospital Association's *Annual Survey of Hospitals* operating between 1989 and 1998.

We identified closures using 'Conlink', a file created by Professor Robert Connor of the University of Minnesota. Conlink is based on data from American Hospital Association, Medicare Cost Report, and the trade magazine *Modern Healthcare* to document hospital closure, mergers, and entry. For the closures, we use data on the last three complete years the hospital was in operation.

Market definition is an important element of determining the demand for goods and services and the number of operating hospitals in a market. Unfortunately there is no generally accepted method for defining markets (Dranove and White, 1990). Our goal is to identify hospitals that would benefit from the closure of a competitor. Ideally, we would use patient flow data to identify competitors. However, there is no complete, nationwide claims dataset for private patients. Medicare claims data could be used, but doing so would require additional assumptions about care patterns between Medicare and private payer patients. Instead of measuring patient flows, we defined a competitor as any hospital within 5 miles of the closed hospital. We also present results with all competitors within 10 and 20 miles from the closed hospital to assess how are results change when we expand the definition of a competitor. We use data on the competitors of the closed hospital three years prior to closure and three years after closure.

The vector *N* (Outputs) includes hospital inpatient admissions, long-term care admissions, emergency room visits, and outpatient visits from the AHA *Annual Survey of Hospitals* (AHA). We also use adjusted admissions from the AHA data set. Adjusted admissions are the sum of inpatient and outpatient admissions weighted by the proportion of revenue generated from each type of admission. The vector *Inputs* includes total staffed beds (1000s) from the AHA data set. The vector *Case-mix* includes the following ratios: inpatient surgery/inpatient admissions; outpatient surgery/outpatient visits; Medicaid discharges/inpatient admissions; and Medicare discharges/inpatient admissions all calculated from the AHA data set. In addition we use the Medicare case-mix index computed by the Health Care Financing Administration.

The market-level variables are population density and per capita income calculated each year and for each MSA from the Area Resource File. If one of these variables in any given year is missing in the Area Resource File we imputed the missing values by computing the mean of the year before and the year after to impute the missing value. HMO penetration rates are from Interstudy and were calculated based on allocating managed care enrollment to counties based on the managed care service area, using approaches developed by Wholey et al., (1997). HMO market penetration rate is calculated as the number of HMO enrollees divided by the resident population in the market. The market concentration measure (*HHI*) is the sum of the squared (adjusted admission) market shares for all hospitals that compete in the same market. We also created dummy variables for teaching status, for-profit ownership, non-federal government ownership, system membership, and whether a competitor merged during the time period.

We did not impute missing data in the AHA data because the common variables with missing data (e.g. total operating expenses) are also dependent variables in our analysis. Thus our panel is unbalanced. We identified 120 closures of urban general short-term hospitals between 1991 and 1996 with complete data. We have 246 complete observations for these hospitals either one, two or three years prior to closure. We have 1686, 1902, 3377 complete observations for competitors within 5, 5-10, and 10-20 miles; respectively (see Table 1).

The summary statistics for the closures and competitors within five miles for the three years prior to closing are presented in Table 1. The hospitals that closed tended to be much smaller than their competitors (Table 1). The adjusted admissions at closed hospitals averaged 5,165, whereas adjusted admissions at competitors ranged from about 14,000 to 17,000 on average. Similar patterns are seen in the remaining input and output measures. In addition, hospitals that closed are more frequently for-profit and less likely to be a teaching hospital.

Table 2 displays the summary statistics for the competitors of closed hospitals and matched comparison groups (defined below) for three years pre and three years post closure. Overall, the competitors within 5 miles are slightly larger than the matched comparison group, with adjusted admissions at competitors averaging about 18,000 over the six-year period whereas competitors averaged about 11,000 adjusted admissions per year. At the market level, the size difference is much less pronounced. Competitors 5-10 miles away and 10-20 miles away are more similar to the hospitals in the comparison group. This trend is repeated for all input and output variables. The case-mix variables are quite similar across all hospital with the exception of the ratio outpatient surgeries to outpatient admissions.

4. Econometric approach

4.1 Comparison group

In order to measure how closures affect admissions, input levels and competition at the competitors we need a comparison group. We use two different types of comparison groups: one based on matching and the other based on distance from the closed hospital. We defined the comparison group based on matching as follows. First, we constructed a propensity score for all hospitals by estimating the probability of closing as in Lindrooth and Ciliberto (2001). The specification models closure as a function of hospital ownership, teaching status, the case-mix variables described above, logged inpatient and outpatient admissions, logged total beds, operating margins (from the Medicare cost report), the number of local hospitals in the system, and the number of high tech inpatient and outpatient services. Next, we matched hospitals that closed to those that were at least twenty miles from a closed hospital and in urban area using nearest-neighbor matching based on the propensity score. The nearest-neighbor is defined as the hospital with the closest propensity score. The comparison group is comprised of those hospitals within 5 miles of the matched hospital in the primary analysis. We include hospitals and the comparison groups between 5-10 and 10-20 miles in the sensitivity analyses.

Figure 1 summarizes the treatment and comparison groups used in the analysis. When we estimate the relative efficiency of closed hospitals we compare the hospitals that actually close to their competitors, 5, 5-10 or 10-20 miles as represented by the arrows in the upper left side of Figure 1. When we estimate the effect of closure on production/costs of competitors we compare either: competitors within 5, 5-10, or 10-20 miles of the closed hospital to competitors within 5, 5-10, or 10-20 miles of the matched hospitals; respectively. The arrows in the middle of Figure 1 represent these samples.

The use of propensity scores in the matching technique is designed to control for the non-random selection of hospital closure based on observables. However, because the closure decision is based, in part, on unobservable expectations about the future the technique is an imperfect control for selection. Thus, we also use hospitals in the same market where the closure occurred but were further than five miles to control for selection based on all market specific criteria. In this specification, the treatment group is defined as those hospitals within five miles of the closed hospital and the comparison group is comprised of those hospitals either within 5-10 miles or 10-20 miles of the closure. This specification is represent by the arrows in the lower left side of Figure 1. Note that this approach will also underestimate the full effect because hospitals beyond five miles may also be affected by closure.

The matched comparison groups contained fewer hospitals than the markets where a closure occurred. This is primarily due to the fact that closures occurred in just practically every major metropolitan area. This difference is controlled for in the regressions below using fixed effects. However, there in the comparison group, there were several years where there were not complete data; even at the market level. While we expect missing data to be equally distributed in the treatment and comparison groups; the frequency of missing data is greater in the comparison group. The specifications using hospitals from 5-10 and 10-20 miles as a comparison group do not suffer from this problem.

The unit of analysis in the regressions below is either the hospital or the average hospital in a market, depending on the specification. We include estimates at the market-level for several reasons. Hospital inputs, output, and case-mix may be endogenous at the hospital level because individual hospitals may manipulate the levels of these variables to their advantage. Finding suitable, valid instruments for this endogeneity in a trans-log framework is extremely difficult. However, as Keeler and Ying (1996) argue, these variables are not endogenous at the market level. Following Keeler and Ying, we use the average values in each market in order to preserve the structure of the cost function.

There are three parts to the econometric analysis. First, we assess whether the total cost is different at eventual closures and their competitors prior to closure. Second, we measure the extent that *I* (inputs), *N* (outputs), *Comp* and *Case-mix* change at competitors after a closure occurs in the market. Finally, we measure the effect of these changes on cost per adjusted admission.

4.2. Baseline difference in efficiency

The specification is based on a short-run trans-log cost function:

$$\ln(TotalCost_{it}) = \alpha + \beta_N \ln(N_{it}) + \beta_{NN} \ln(N_{it})^2 + \beta_b \ln(I_{it}) + \beta_{bb} \ln(I_{it})^2 + \beta_{Nb} \ln(N_{it}) * \ln(I_{it})$$

$$\sum_{j=1}^{J} \beta_j CaseMix_{ijt} + \beta_c HHI_{it} + \beta_M Market_{it} + \beta_H Hospital_{it} - Efficiency_{it} + Time_t + \theta_m + \varepsilon_{ti} \qquad (7)$$

where *Total Cost* is total operating expenditures, θ_m is a market fixed effect and ε_{it} is random error. We treat *I* as a quasi-fixed input. As suggested by Skinner (1994), we have chosen a simple specification of efficiency without parametric assumptions about the nature of the efficiency common in frontier cost function approaches. *Efficiency* is identified using a dummy variable that equals one if the hospital eventually closes and zero otherwise. Thus, it captures the relative efficiency of closed to surviving hospitals holding other factors constant. This simple measure of efficiency captures the effect of all systematic (unmeasured) differences in hospital-level characteristics that are not captured in *N*, *I*, *CaseMix*, *HHI*, *Market*, or *Hospital*. Of particular concern is case-mix. Any difference in case-mix not captured by Medicare case-mix, Medicare share, Medicaid share, percent inpatient surgery, or percent outpatient surgery will be picked up by our efficiency measure.

The sample used to estimate Equation 7 includes all closed hospitals and their competitors one, two, and three years prior to closure. We include dummy variables that indicate whether the observation is one year or three years prior to closure. The estimated difference in efficiency one-year prior to closure may be biased by regression to the mean because hospitals with unusually high costs may be more likely to close. In addition, hospitals may start to scale back operations in the year before closing. Thus, we focus on the estimated difference in efficiency two years prior to closing. If this approach is valid, there should be no significant difference in efficiency two and three years prior to closing. We adjust the estimates for smearing because the dependent variable is logged (Duan, 1983) and calculate the difference between eventual closures and competitors two years prior to closure. The estimates are bootstrapped 1000 times to yield confidence intervals for the smearing adjusted estimates.

4.3 Changes due to closure

In this step, hospitals within 5, 5-10, or 10-20 miles of a closed hospital are included in the treatment group and hospitals within 5, 5-10, or 10-20 miles of non-closing hospitals that were matched to closing hospitals based on the propensity score are in the comparison group. The sample includes observations three years pre- and three years post-closure. We estimate the difference in outputs (inpatient admissions, long-term care admissions, emergency visits and outpatient visits), inputs (hospital beds and long-term care beds), all case-mix variables (Medicare case-mix, Medicare share, Medicaid share, percent inpatient surgery, and percent outpatient surgery), and HHI using the following reduced-form equation:

$$\begin{aligned} X_{it} = {} & \lambda Treatment_i * Post_t + \lambda_1 Treatment_i * OneYearPost_t + \lambda_3 Treatment_i * ThreeYearPost_t + \gamma Post_t + \\ & \beta_M Market_{it} + \beta_H Hospital_{it} + \alpha_i + Time_t + \varepsilon_{it} \end{aligned} \quad (8)$$

where X is either the log of one of the outputs or inputs; case-mix variables; or HHI. *Treatment* is a dummy variable which equals one if the hospital is in the market in which a hospital closed (treatment group); *Post*, *One Year Post* and *Three Years Post* are dummy variables that indicate whether the observation is in the period after closure, one year after closure, and three years after closure, respectively; and α_i is a hospital or market fixed effect; depending on the unit of analysis.

As discussed above, λ is the lower-bound estimate of the effect of closure on inputs, outputs and case-mix because of selection bias. Recall that we selected the comparison group using propensity score matching of the closed hospitals to other hospitals. The comparison group is defined as the competitors of the matched hospitals. However, the closure decision is based, in part, on circumstances that we cannot measure. We expect that these unobservable circumstances will be correlated with subsequent negative market conditions. Thus, selection may bias our estimates downwards since the closure decision is likely to be correlated with poor market conditions. We also estimate Equation 8 using hospitals within 5 miles of the closed hospital as the treatment group and hospitals either 5-10 miles or 10-20 miles away from the closed hospital as the comparison group. This sample controls for unobserved market conditions but is also biased downwards because hospitals beyond 5 miles may also be affected by closure. However, if the results of these two definitions of the comparison group are similar, we have increased confidence that we have identified the lower bound of the effect of closure.

4.4 Changes in cost at competitors

The change in cost per adjusted admission is based on the changes in *X* estimated in Equation 8; namely changes in outputs, inputs, case-mix variables, and *HHI*. We estimate N_i, N_c, N_{ci}, and ΔI_i adjusting for smearing because these measures are based on regressions with a logged dependent variable and use the point estimate (λ from Equation 8) to calculate $\Delta CaseMix_i$, ΔHHI_i. The simulations of the effect of the changes are based on the parameter estimates from the following equation:

$$\begin{aligned} \ln(Total\,Cost_{it}) = {} & \alpha_i + (\beta_N)\ln(N_{it}) + \beta_{NN}\ln(N_{it})^2 + \beta_b \ln(I_{it}) + \beta_{bb}\ln(I_{it})^2 + \beta_{Nb}\ln(N_{it}) * \ln(I_{it}) \\ & \sum_{j=1}^{J}\beta_j Case\,Mix_{ijt} + \beta_c Comp_{it} + \lambda Treatment_i * Post_t + \gamma Post_t + \\ & \beta_M Market_{it} + \beta_H Hospital_{it} + Time_t + \varepsilon_{it} \end{aligned} \tag{9}$$

Fixed effects cause the efficiency measure and the market fixed effect to be differenced out of Equation 9. The estimates of β_N, β_{NN}, β_b, β_{bb}, β_{bb}, $\beta_{Nb,}$ β_J…. , and β_c are used to simulate the effect of closure on the competitor's cost. First, we calculate the fitted value of cost, adjusted for smearing in the post period. Then we recalculate the fitted value after subtracting N_{ci}, $\Delta I_i,$

$\Delta CaseMix_i$, $\Delta Comp_i$ to obtain the pre-period level of cost. The difference between these two estimates reflects the change in cost per adjusted admission attributable to closure.

The estimates of the β*'s* are not biased by selection because the hospital fixed effects control for selection criteria that is fixed over time and the interaction *Treatment*Post* controls for unobserved characteristics that change over time and are correlated with closure in a market.

4.5 Total change in costs

The total change in cost is measured by substituting estimated values from previous equations and simulations into Equation 10:

$$TMC_{t=1} - TMC_{t=0} = \left\{ \sum_{i=1}^{H-1} \left[\left(N_i^a + N_{ci}^a \right) * f(N_i + N_{ci}, \bullet + \Delta I, \bullet + \Delta CaseMix, \bullet + \Delta Comp, \bullet) - N_i^a * f(N_i; \bullet) \right] - N_c^a * f(N_c; \bullet) - N_c^a * \left(\sum_i^{H-1} Efficiency_i - Efficiency_c \right) \right\} \Big/ \sum_{i=1}^{H-1} \left(N_i^a + N_c^a \right) \tag{10}$$

N_i, N_c, N_{ci}, ΔI_i, $\Delta CaseMix_i$, $\Delta Comp_i$ are estimated using Equation 8. *f(.)* is estimated using Equation 9, and $\Sigma Efficiency_i - Efficiency_c$ is estimated using Equation 7. We use adjusted admissions as weights because it is the only measure that captures all of the hospital activities. Equation 10 is identical to Equation 5. We bootstrap the entire system (Equation 7, Equation 8, and Equation 9) 1000 times to obtain confidence intervals. We express the result in percentage change in cost per adjusted admissions as shown in Equation 6 for ease of interpretation.

5. Results

The estimates of the difference in efficiency are in Table 3. The results using competitors within a 5-mile radius are in Column 1. The results using competitors within 5-10 miles and 10-20 miles are in Columns 2 and 3, respectively. The point estimates of the difference between eventual closures and competitors ranges from approximately 4.3% for competitors within 5 miles to 7.5% for competitors within 5-10 miles and are significant at either the 5 or 10% level. These estimates reflect differences in costs 2 years prior to closure, the estimates for one and three years prior to closing are not significantly different from the two-year estimates. We discuss the smearing adjusted estimates below.

Table 4 lists the estimates of the change in outputs, inputs, case-mix and competition. Each row reflects a different dependent variable, each column a different definition of a competitor. In the first column, the unit of observation is the hospital. In the last three columns the unit of observation is the average hospital in the market. In both specifications with the competitors defined as hospitals within 5 miles of the closed hospital, we find significant increases in hospital admissions, emergency room visits, and adjusted admissions. The market level estimates are greater than the hospital level estimates. These estimates reflect the lower range of the effect because it is likely that exit occurred in markets where *future* prospects were bleak. As we extend the definition of the market to 5-10 miles and 10-20 miles the effect of closure on outputs are insignificant and not meaningfully different from the comparison hospitals. However, we did detect a significant decline in the number of hospital beds at hospitals 5-10 miles from the closure.

Among the case-mix measures, Medicare case-mix appears to be affected by closure at the average hospital within 5 miles of the closed hospital. This effect was not detected at the hospital level. Medicare percent of inpatient admissions was, however, affected at the hospital-level. The change in the HHI was significant at the hospital level and at competitors within 10-20 miles. However, the magnitude of the change was large, but insignificant, in the market-level estimates using competitors within 5 miles.

The estimates of total effect of closure are in Table 5. These estimates are based on the changes displayed in Table 4 and the parameter estimates from Equation 9. First, the smearing-adjusted difference in efficiency at eventual closed hospitals and their competitors ranges from 5.1% to 8.1% depending on the definition of competitors. This row is calculated from using the regressions in Table 3. This represents a shift in the cost function and is weighted by the adjusted admissions that would have occurred at the closed hospitals when calculating the total. Next, the simulated change in costs at competitors directly related to closure is about –3.8% at the average hospital within 5 miles using the matched comparison group. This result is significant at the 10% level. When we use hospitals within 5-10 miles as the comparison group, the estimate declines to about –2.1%, also significant at the 10% level. The other estimates are not statistically significant.

The total effect in the bottom row of Table 5 is the weighted average of the difference in efficiency and the total hospital-level change from Equation 10 converted into a percentage change in cost per adjusted admission using Equation 6. The total effect ranges between –4.2% using the matched comparison group and –2.3% using the hospitals between 5-10 miles as a comparison group. The estimates are all significant at the 10% level.

6. Discussion

Hospitals that eventually close are less efficient than their competitors (See column 1 Table 5). This result is consistent whether eventual closures are compared to hospitals within 5 miles, between 5 and 10 miles, or between 10 and 20 miles. We measure relative efficiency two years prior to closure and the results suggest hospitals that closed were in a gradual decline. Namely, hospitals that closed appear to be more efficient three years prior to closure and less efficient one year prior to closure, though the differences are not statistically significant. This pattern is not consistent with a regression to the mean explanation for the differences in relative efficiency.

The difference in efficiency is due to two important differences between eventual closures and their competitors. First, consistent with Lillie-Blanton and colleagues (1992), Succi, Lee, and Alexander (1997) and Lindrooth and Ciliberto (2001), Table 1 reveals that hospitals that closed were about a quarter of the size of their competitors. Ghemawat and Nalebuff (1985) prove that sufficiently strong economies of scale can induce smaller firms to exit first. Also note that the case-mix measures were virtually identical. Thus, closed hospitals were operating on a significantly smaller scale but do not appear to be specialty or niche hospitals. Second, the occupancy rate at eventual closures was about 48% versus over 64% at competitors. This difference is significant at the 1% level. Thus the difference in efficiency may also be due to the cost of an empty bed (Keeler and Ying, 1996 or Gaynor and Anderson, 1995). Indeed, if we include occupancy rate as an independent variable the difference in efficiency becomes smaller and not significantly different from zero.

Closure of a hospital leads to an increase in hospital inpatient admissions and emergency room visits at neighboring hospitals within 5 miles. This result is consistent whether we use the matched comparison group or the comparison group of hospitals 5-10 or 10-20 miles from the closure. Long-term care admissions and outpatient visits at neighboring hospitals are not significantly affected by closure. This result is probably due to the fact that there are alternatives to hospital-based care for long-term care and outpatient visits, including free-standing nursing homes and doctors offices. Furthermore, some of the hospitals studied may have only exited the inpatient market and converted to outpatient or long-term care. Thus, we not expect to see a significant effect where conversions did occur. As expected, the effect of closure attenuates at competitors 5-10 miles and 10-20 miles.

The effect of closure on competitors makes up a large proportion of the total effect of closure (last row Table 5) mainly because the closed hospitals are so small. The reduction in average cost at competitors is realized over all adjusted admissions whereas the difference in efficiency is only realized by patients who would have visited the closed hospital. The results, at the market level, are consistent whether the sample includes the matched comparison group or a comparison group consisting of hospitals between 5-10 miles or 10-20 miles from the competitor. Overall, average costs declined between 2 and 4 percent after closure. Pauly and Wilson (1986) estimated that moving a hypothetical patient from a small hospital to a larger hospital could save 11% of the initial cost of treating the patient. Our results imply that the savings for the patients that would have been treated at the closed hospitals is between 7-9%. This result is comparable to Pauly and Wilson, despite a different time period, sample and approach.

7. Conclusions

The results suggest that hospital closure has led to a small but significant evolutionary improvement in efficiency. The hospitals that closed were less efficient at baseline, and after closure their competitors realized lower costs per adjusted admission. Both of these results are linked to the cost of an empty bed and the efficiencies that can be gained by closing beds. Thus, though there has been concern that the more common exit of for-profit hospitals might be leaving less efficient hospitals to operate in the market, this concern is not supported by our analysis. Hospital closure in urban markets is welfare improving as long as access is not severely restricted. Since we have focused on hospitals within five miles of the closed hospitals access should not be a problem for the vast majority of patients. We measure the effect of selfselected closures, and our results do not necessarily imply that efficiencies can be gained through a policy that encourages closure. Instead, in urban markets where access is not an important issue, closure of a hospital should not be prevented.

References

Bazzoli, G. J. and Andes, S., 1995. Consequences of hospital financial distress. Hospital and Health Services Administration 40, 472--495.

Bazzoli, GJ, Chan, B., Shortell, S.M., and D'Aunno, T., 2000. The financial performance of hospitals belonging to health networks and systems. Inquiry 37, 234--252.

Bliss, C. and B. Nalebuff., 1984. Dragon-slaying and ballroom dancing: The private supply of a public good. Journal of Public Economics 25, 1--12.

Carr, WJ; Feldstein, PJ, 1967. The relationship of cost to hospital size. Inquiry 4: 45-65.

Deily, M.E., McKay, N.L., and Dorner, F.H., 2000. Exit and inefficiency. Journal of Human Resources 35, 734-747.

Dranove, D., 1988. Economies of scale in non-revenue producing cost centers: Implications for hospital mergers. Journal of Health Economics 17, 69-83.

Dranove, D. and White, W., 1994. Recent theory and evidence on competition in hospital markets. Journal of Economics and Management Strategy 4, 169-209.

Duan, N., 1983. Smearing estimate: A nonparametric transformation method. Journal of the American Statistical Association 78, 605-610.

Duffy, S. and Friedman, B., 1993. "Hospitals with chronic financial losses: What came next. Health Affairs 12, 151-63.

Fournier, GM and Mitchell, J.M., 1992. Hospital costs and competition for services: A multiproduct analysis. Review in Economics and Statistics 72, 627-34.

Francisco, EW, 1970. Analysis of cost variation among short-term general hospitals, in: H.E. Klarman (ed.), Empirical Studies in Health Economics. The Johns Hopkins University Press, Baltimore, MD.

Frech, H.E. and Mobley, L.R., 2000. Efficiency, growth, and concentration: An empirical analysis of hospital markets. Economic Inquiry 38, 369-384.

Gaynor, M. and Anderson, G. 1995. Uncertain demand, the structure of hospital costs, and the cost of empty hospital beds. Journal of Health Economics 14, 291-317.

Ghemawat, P. and Nalebuff, B., 1985. Exit. RAND Journal of Economics 16,184-194.

Ghemawat, P. and Nalebuff, B., 1990. The devolution of declining industries. Quarterly Journal of Economics 105, 167-186.

Grannemann, T. W., Brown, R. S. and Pauly, M.V., 1986. Estimating hospital costs: A multiple-output analysis. Journal of Health Economics 5, 107-127.

Javanovic, B. 1982. Selection and the evolution of industry. Econometrica 50, 649-70.

Keeler, T.E. and Ying, J.S., 1996. Hospital costs and excess bed capacity: A statistical analysis. Review of Economics and Statistics 78, 470-481.

Lillie-Blanton, M., Felt, S., Redmon, P.,Renn, S., Machlin, S., and Wennar, S., 1992. Rural and urban hospital closures, 1985-1988: Operating and environmental characteristics that affect risk. Inquiry 29,332-344.

Lindrooth, R.C. and Ciliberto, F., 2001. Exit from the hospital industry. Working Paper.

McNamara, P.E., 1999. Welfare effects of rural hospital closures: A nested logit analysis of the demand for rural hospital services. American Journal of Agricultural Economics 81, 686-691.

Pauly, M and Wilson, P. 1986. Hospital output forecasts and the cost of empty hospital beds. Health Services Research 21, 403-428.

Robinson, J.C. 1991. HMO market penetration and hospital cost inflation in California. Journal of the American Medical Association 266, 2719-2723.

Skinner, J. 1994. What do stochastic frontier cost functions tell us about inefficiency? Journal of Health Economics 13, 323-28.

Succi, M.J., Lee, S.D., and Alexander, J.A. 1997. Effects of market position and competition on rural hospital closures. Health Services Research 31, 679-699.

Wedig, G. J., Hassan, M. and Sloan, F.A. 1989. Hospital investment decisions and the cost of capital. Journal of Business 62, 517-37.

Wholey, D. R., Christianson, J. B., Engberg, J., and Bryce, C., 1997. HMO market structure and performance: 1985 – 1995. Health Affairs 16, 75-84.

Williams, D.J., Hadley, J., and Pettengill, J., 1992. Profits, community role, and hospital closure: An urban and rural analysis. Medical Care 30, 174-187.

Zwanziger, J., Melnick, G.A., and Bamezai, A., 1994a. Costs and price competition in California hospitals, 1980-1990. Health Affairs 13, 118-126.

Zwanziger, J., G.A. Melnick, J. Mann, and L. Simonson. 1994b. How hospitals practice cost containment with selective contracting and the Medicare prospective payment system. Medical Care 32, 1153-1162.

Table 1 Summary Statistics for Closed Hospitals and Competitors

	Closed Hospitals	Competitors within: 5 Miles	5-10 Miles	10-20 Miles
Cost				
Total Expenditures ($100,000s)	303.446	1217.424	982.840	930.068
	(308.809)	(1124.507)	(969.552)	(1053.442)
Output				
Adjusted Admissions (1000s)	5.165	17.050	15.196	14.288
	(5.327)	(12.365)	(10.941)	(11.379)
Hospital Admissions	3586.142	13060.660	11350.760	10641.040
	(3813.096)	(9608.300)	(8418.301)	(8931.643)
LTC Admissions	57.037	72.546	77.736	89.450
	(148.135)	(178.119)	(198.441)	(213.249)
Outpatient Admissions (1000s)	25.221	120.490	88.339	83.910
	(35.440)	(200.241)	(113.517)	(121.647)
ER Admissions (1000s)	10.783	32.068	30.112	28.963
	(9.811)	(31.186)	(24.034)	(25.567)
Inputs				
Hospital Beds, Set up and Staffed	125.370	348.994	296.303	283.114
	(94.369)	(231.352)	(198.300)	(222.531)
LTC Beds, Set up and Staffed	9.980	9.436	11.737	12.198
	(32.467)	(31.617)	(44.868)	(40.446)
Case-mix				
Medicare Case-mix	1.219	1.419	1.364	1.353
	(0.189)	(0.215)	(0.195)	(0.196)
Ratio of:				
Medicare to inpatient admissions	0.392	0.348	0.356	0.344
	(0.167)	(0.140)	(0.148)	(0.129)
Medicaid to inpatient admissions	0.158	0.178	0.174	0.157
	(0.146)	(0.159)	(0.169)	(0.163)
Inpatient surgeries to inpatient admissions	0.307	0.352	0.320	0.318
	(0.173)	(0.136)	(0.122)	(0.118)
Outpatient surgeries to outpatient visits	0.074	0.055	1.918	2.290
	(0.095)	(0.064)	(81.169)	(91.683)
Hospital and Market				
For-profit	0.362	0.160	0.193	0.229
	(0.481)	(0.366)	(0.395)	(0.420)
Non-federal government	0.081	0.116	0.100	0.107
	(0.274)	(0.320)	(0.301)	(0.309)
Teaching	0.126	0.541	0.399	0.309
	(0.333)	(0.498)	(0.490)	(0.462)
System Ownership	0.565	0.487	0.536	0.511
	(0.497)	(0.500)	(0.499)	(0.500)
Merged	0.037	0.038	0.033	0.047
	(0.188)	(0.191)	(0.179)	(0.212)
HMO Penetration	0.172	0.198	0.210	0.211
	(0.111)	(0.104)	(0.098)	(0.101)
Per capita income ($s)	21244.940	21541.540	22317.810	22451.720
	(4126.558)	(3544.430)	(3354.416)	(3525.261)
Population Density	857.9178	1129.547	1375.667	1617.851
	(1057.681)	(1403.582)	(1540.193)	(1837.750)
Number of Observations	246	1686	1902	3377

Notes: Standard Deviation in Parentheses. Sample includes observations one, two, and three years prior to closure.

Table 2. Summary Statistics for Competitors and Comparison Group

Hospital within:	5 miles				5-10 miles	10-20 miles
Unit of Observation:	Hospital Level		Market Level		Market Level	
	Competitors	Comparison	Competitors	Comparison	Competitors	
Cost						
Total Expenditures ($100,000s)	1364.992 (1303.528)	734.096 (891.892)	1128.902 (718.853)	909.913 (564.810)	874.217 (520.034)	769.146 (544.422)
Output						
Adj. Admissions (1000s)	18.053 (12.962)	11.160 (10.098)	16.486 (7.010)	14.305 (6.449)	14.070 (6.457)	12.842 (6.332)
Hospital Admissions	13424.610 (9814.630)	7830.406 (7570.514)	12396.410 (5323.096)	10345.320 (5345.736)	10256.920 (4873.798)	9160.145 (4812.149)
LTC Admissions	102.735 (233.282)	88.406 (233.067)	107.835 (161.122)	82.681 (150.244)	100.666 (164.358)	108.961 (196.103)
Outpatient Admissions (1000s)	132.118 (193.924)	73.131 (105.399)	123.002 (108.619)	85.995 (67.870)	86.970 (78.678)	79.205 (75.255)
ER Admissions (1000s)	33.206 (30.743)	22.280 (18.845)	33.617 (15.038)	28.470 (12.605)	28.943 (13.486)	27.710 (12.298)
Inputs						
Hospital Beds, Set up and Staffed	347.188 (233.001)	205.207 (175.541)	312.562 (125.983)	268.207 (142.323)	255.286 (119.593)	229.723 (128.164)
LTC Beds, Set up and Staffed	11.827 (39.874)	13.317 (34.258)	10.902 (20.317)	12.797 (33.159)	10.678 (20.718)	11.546 (19.159)
Case-mix						
Medicare Case-mix	1.447 (0.229)	1.341 (0.245)	1.432 (0.246)	1.398 (0.179)	1.374 (0.125)	1.346 (0.125)
Ratio of:						
Medicare to inpatient Admissions	0.354 (0.144)	0.399 (0.140)	0.367 (0.091)	0.375 (0.083)	0.373 (0.100)	0.367 (0.087)
Medicaid to inpatient Admissions	0.187 (0.159)	0.159 (0.134)	0.177 (0.094)	0.161 (0.097)	0.156 (0.099)	0.144 (0.092)
Inpatient surgeries to inpatient Admissions	0.343 (0.159)	0.301 (0.141)	0.338 (0.094)	0.338 (0.104)	0.341 (0.617)	0.314 (0.073)
Outpatient surgeries to outpatient visits	0.055 (0.084)	0.056 (0.142)	0.104 (1.014)	0.056 (0.047)	0.334 (7.329)	0.485 (8.721)
Number of Observations	3212	1153	802	304	720	846

Notes: Standard Deviation in Parentheses. Sample includes observations one, two, and three years before and after closure.

Table 3. Regression Analysis of Differences in Cost at Closed Hospitals and Competitors

Dependent Variable:	Competitors within:		
Ln(Expenditures)	5 Miles	5-10 Miles	10-20 Miles
Closure indicators			
Closure (any year)	0.043*	0.075***	0.059**
	(0.024)	(0.024)	(0.025)
One year prior to closure	0.026	0.009	0.010
	(0.032)	(0.031)	(0.035)
Three years prior to closure	–0.038	–0.023	–0.047
	(0.028)	(0.028)	(0.032)
Output			
Ln(Hospital Admissions)	0.365**	0.353**	0.088
	(0.162)	(0.171)	(0.108)
Ln(Hospital Admissions), Squared	–0.067**	–0.005	–0.002
	(0.026)	(0.029)	(0.019)
Ln(LTC Admissions)	–0.037	0.135*	–0.131*
	(0.126)	(0.081)	(0.068)
Ln(LTC Admissions), Squared	–0.001	–0.003	–0.019***
	(0.010)	(0.008)	(0.007)
Ln(Outpatient Visits)	0.140***	–0.050	0.114***
	(0.052)	(0.037)	(0.031)
Ln(Outpatient Visits), Squared	0.005***	0.008***	0.006***
	(0.001)	(0.001)	(0.001)
Ln(ER Visits)	–0.062*	0.019	–0.010
	(0.033)	(0.026)	(0.025)
Ln(ER Visits), Squared	0.010***	0.006***	0.001
	(0.001)	(0.001)	(0.001)
Ln(Hospital Admissions) *Ln(LTC Admissions)	0.030	–0.001	0.061***
	(0.031)	(0.022)	(0.021)
Ln(Hospital Admissions) *Ln(Outaptient Visits)	–0.009	0.031**	–0.022**
	(0.015)	(0.013)	(0.010)
Ln(Hospital Admissions) *Ln(ER Visits)	0.045***	0.040***	0.015**
	(0.008)	(0.009)	(0.006)
Ln(LTC Admissions) *Ln(Outaptient Visits)	–0.009	–0.010	–0.028***
	(0.011)	(0.008)	(0.008)
Ln(LTC Admissions) *Ln(ER Visits)	–0.023	–0.028***	0.008
	(0.015)	(0.009)	(0.005)
Ln(Outpatient Visits) *Ln(ER Visits)	–0.015***	–0.014***	0.000
	(0.003)	(0.003)	(0.002)
Competition			
HHI	0.010	–0.005	0.250
	(0.019)	(0.461)	(0.310)

(continued)	Competitors within: 5 Miles	5-10 Miles	10-20 Miles
Inputs			
Ln(Hospital Beds)	–0.170	0.177	0.256**
	(0.156)	(0.169)	(0.114)
Ln(Hospital Beds), squared	–0.060	0.166***	–0.045
	(0.037)	(0.031)	(0.031)
Ln(LTC Beds)	0.166	–0.058	0.402***
	(0.201)	(0.111)	(0.100)
Ln(LTC Beds), squared	0.070***	0.014*	–0.013
	(0.019)	(0.008)	(0.013)
Ln(Hospital Beds) *Ln(LTC Beds)	–0.054	–0.068**	0.024
	(0.050)	(0.031)	(0.033)
Ln(Hospital Beds) *Ln(Hospital Admissions)	0.179***	–0.083	0.095**
	(0.054)	(0.055)	(0.045)
Ln(Hospital Beds) *Ln(LTC Admissions)	0.046	0.053**	–0.020
	(0.034)	(0.023)	(0.022)
Ln(Hospital Beds) *Ln(Outpatient Visits)	0.008	–0.031*	0.008
	(0.018)	(0.016)	(0.012)
Ln(Hospital Beds) *Ln(ER Visits)	–0.052***	–0.054***	–0.025***
	(0.010)	(0.011)	(0.007)
Ln(LTC Beds) *Ln(Hospital Admissions)	–0.095**	–0.037	–0.117***
	(0.045)	(0.030)	(0.030)
Ln(LTC Beds) *Ln(LTC Admissions)	–0.026	0.017	0.046***
	(0.019)	(0.012)	(0.014)
Ln(LTC Beds) *Ln(Outpatient Visits)	0.012	0.007	0.050***
	(0.019)	(0.013)	(0.012)
Ln(LTC Beds) *Ln(ER Visits)	0.054**	0.053***	–0.015**
	(0.025)	(0.017)	(0.007)
Case-mix			
Medicare Case-mix	0.803***	0.587***	0.472***
	(0.033)	(0.030)	(0.030)
Medicare / inpatient adm.	–0.044	0.071	–0.027
	(0.050)	(0.045)	(0.041)
Medicaid / inpatient adm.	–0.027	0.030	0.078**
	(0.044)	(0.040)	(0.034)
Inpatient surgeries / inpatient adm.	0.067	0.163***	0.434***
	(0.041)	(0.040)	(0.037)
Outpatient surgeries / outpatient visits	0.806***	0.000***	0.000***
	(0.102)	(0.000)	(0.000)
Constant	11.385***	11.124***	11.348***
	(0.813)	(0.804)	(0.792)

Notes: All rows correspond to different dependent variables; all columns correspond to different definitions of competitors. Standard Error in Parentheses. Sample includes observations one, two, and three years prior to closure. Regressions control for the hospital and market characteristics listed in Table 1, year dummies and market fixed effects. *, **, and *** represents 90%, 95%, and 99% Confidence Levels. N=1932 (5 miles), 2148 (5-10 miles), and 2623 (10-20 miles).

Table 4. Estimates of the Change in Inputs, Outputs, Case-mix and Competition Due to Closure of a Competitor; 2 Years after Closure

	Competitors within:			
	5 Miles		5-10 Miles	10-20 Miles
Dependent Variable:	Hospital Level	Market Level	Market Level	Market Level
Output				
Ln(Hospital Admissions)^s	0.046***	0.111***	–0.007	0.007
Ln(LTC Admissions)^s	0.137	0.217	–0.007	–0.005
Ln(Outpatient Visits)^s	0.252	0.130	–0.008	–0.014
Ln(ER Visits)^s	0.055***	0.137***	–0.034	0.009
Ln(Adjusted Admissions)^s	0.037***	0.067***	–0.007	–0.005
Inputs				
Ln(Hospital Beds)^s	0.021	0.029	–0.032**	–0.009
Ln(LTC Beds)^s	0.077	0.029	–0.206	0.027
Case-mix				
Medicare Case-mix	0.003	0.079***	–0.015	0.001
Medicare / inpatient adm.	–0.009**	–0.010	0.002	0.006
Medicaid / inpatient adm.	0.003	–0.006	0.003	–0.005
Inpatient surgeries / inpatient adm.	–0.006	0.008	0.050	–0.003
Outpatient surgeries / outpatient visits	0.003	–0.027	–0.637	–0.149
Competition				
HHI	0.091*	0.092	–0.008	0.011*
Number of Observations	3811	1106	975	1402

Notes: All rows correspond to different dependent variables; all columns correspond to different definitions of competitors. All regressions control for hospital and market characteristics and hospital fixed effects (See Equation 7). Significance level based on an empirical bootstrap with 1000 iterations. *, **, and *** represent 90%, 95%, and 99% confidence levels, respectively. Sample includes observations one, two, and three years before and after closure. Superscript s indicates smearing-adjusted estimates.

Table 5. Estimates of the percent change in cost per adjusted admission due to closure.

Competitors within:	**5 Miles versus matched comparison group**		**5-10 Miles versus matched comparison group**	**10-20 Miles versus matched comparison group**	**5 miles versus 5-10 Miles**	**5 miles versus 10-20 Miles**
Unit of Observation:	Hospital	Market	Market	Market	Market	Market
Difference in Efficiency (Equation 7)	–0.051**	–0.051**	–0.081***	–0.069**	–0.051**	–0.051**
Total Change per adjusted admission (Equations 8 & 9)	0.001	–0.038*	–0.001	0.004	–0.021*	–0.019
Total (Equation 5)	–0.0001	–0.042*	–0.015	–0.005	–0.023*	–0.024*

Notes: All estimates are adjusted for smearing. Significance level is based on an empirical bootstrap (1000 iterations).

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