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The Northridge Earthquake: A Natural Experiment in Market Structure

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Key words: capacity, identification, hospitals

Abstract

This paper focuses on structural damage from the Northridge earthquake of 1994 as an exogenous shock to hospital capacity in the Los Angeles area. The exogenous shock allows us to identify the effect of reduced capacity on prices by avoiding the standard problem that market variables, such as prices and capacity, are typically determined endogenously. Hospitals in areas unaffected by the earthquake serve as a control group to establish expected prices in the absence of capacity changes. The findings are consistent with a significant positive price effect from the reduced capacity.

JEL Classification: I11, L11

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I. INTRODUCTION

A fundamental question in industrial organization is how excess capacity in a given market affects price competition in that market.[1] Theoretical results suggest conflicting answers to this question. On the one hand, Osborne and Pitchik (1986) show that in a one-period price-setting game, greater excess capacity will yield lower average prices. On the other hand, Davidson and Deneckere (1990) consider a repeated price-setting game with excess capacity and find that greater excess capacity allows higher collusive prices, because the threat point with greater capacity is a worse outcome. Particularly because of these distinct theoretical predictions, it is important to gain some empirical understanding of the effect of excess capacity on price competition. Knowledge of this effect is crucial for determining appropriate regulatory responses to changes in market structure, such as mergers.

In order to identify the effect of capacity on price, this paper concentrates on an exogenous shock to hospital capacity arising from the 1994 Northridge earthquake in Southern California. The earthquake destroyed a large portion of hospital capacity in Santa Monica but not elsewhere in Southern California. By regressing prices at Santa Monica Hospital on prices at similar hospitals and by including a dummy variable for post-earthquake observations, we can test for structural change in prices at Santa Monica Hospital. The dummy variable from this

[1] This question is most relevant for industries such as the automobile industry, the steel industry, the hotel industry, the airline industry, and, as discussed here, the hospital industry.

test has a positive and significant coefficient, suggesting that the capacity reduction due to the earthquake may have had a positive effect on prices.

This natural disaster approach to estimating the effect of capacity on price is distinct from previous empirical approaches that have generally relied on cross-sectional analysis, either at an inter-industry level or at an intra-industry level.[2] These previous approaches are widely accepted, not because they are ideal, but because alternatives are difficult to find. One notable and well-recognized fault with these approaches arises from the simultaneity problem, since both market structure and price are presumably determined within a general system of market equations, leading to a lack of identification of the parameters of interest.[3,4] The usual techniques of dealing with endogenous explanatory variables -- two-stage least squares, three-stage least squares, or full-information maximum likelihood methods -- require instrumental variables, which are not only notoriously difficult to find for studies of markets (see Bresnahan, 1989), but which may, in practice, provide biased estimates when the instruments are weakly correlated with the endogenous explanatory variables (see Nelson and Startz (1990), as well as Bound, Jaeger, and Baker (1993)).

[2] See Bresnahan (1989) and Schmalansee (1989) for reviews of intra-industry and inter-industry studies, respectively. For a study of the effect of capacity constraints on prices in a cross-section of hospitals, see Melnick et al. (1992), or for an inter-industry study, see, for instance, Haskel and Martin (1994).

[3] "Market structure" refers both to the number of firms in a market and to the firms' capacities.

[4] For a recent exposition of the identification problem, see Manksi (1995).

Instead of relying on cross-sectional studies, we might instead concentrate on sudden changes, or "shocks," to market structure, and their subsequent effect on price. An example in this vein is Barton and Sherman's study of two mergers in the microfiche industry (1984). Their analysis suffers from a major problem: no reasonable control group is developed to compare with the merged firms, so we lack a reliable estimate of what would have happened had no merger taken place.[5]

This paper deals with the simultaneity problem by focusing on an exogenous, natural shock to market capacity and its effect on prices. The natural shock consists of the Northridge earthquake of January 17, 1994, which significantly damaged 18 hospitals in the Los Angeles region of California. Most damage was repaired quickly, requiring neither the demolition of existing facilities nor the construction of new facilities. However, the earthquake caused severe structural damage at both hospitals in Santa Monica. Even after the completion of major repair work, St. John's Hospital was operating at roughly two thirds its original capacity of 501 beds. Only four blocks away, Santa Monica Hospital also suffered serious structural damage, its capacity falling from 367 beds to 144 beds. These changes in capacity not surprisingly led to changes in the occupancy rates at these hospitals, most noticeably at Santa Monica Hospital. Prior to the earthquake, occupancy rates were 38% at the Santa

[5] Generally, control groups are difficult to develop for any industry that is based on a national or international market. One advantage of the hospital industry is that markets are generally local, so control groups are likely to exist.

Monica Hospital and 49% at St. John's Hospital. After normal operations resumed in the area, the occupancy rates rose to 71% at Santa Monica hospital and remained 49% at St. John's Hospital.[6]

The change in capacity in Santa Monica can be thought of as a true natural experiment in market structure.[7] For a situation to qualify as a natural experiment, two basic conditions must be satisfied: first, exogenous change of a variable of interest must take place; and second, control groups must exist for purposes of comparison. The situation we are studying satisfies both conditions.

With respect to the exogeneity condition, earthquakes are clearly exogenous events. Moreover, they can change market structure, particularly when markets are local and rely on assets, such as buildings, which are large, complex, and not immediately replaceable. Hospital markets will frequently meet these criteria, because after experiencing structural damage, hospitals face a time-consuming process of re-designing, obtaining permits, and re-building. As a result, the damage caused by earthquakes may well lead to an exogenous change in market structure, particularly with respect to capacity. In this case, the damage also led to the renegotiation of contracts

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[6] The absence of a rise at St. John's, despite the reduction in capacity, seems odd at first. Note, though, that while St. John's was closed for repair, it lost many referrals that may have required continued care. Given the tendency of the sick to remain sick, we might expect a lag between reopening and achieving pre-closing levels of patient admissions.

[7] This paper follows the majority of the economics literature in labeling analysis arising from an exogenous shocks as a "natural experiment," though the term "quasi-experiment" may be more appropriate. See Meyer (1995).

between insurers and hospitals.[8] So prices were relatively free to adjust to the new capacity conditions. The exogenous change in capacity arising from the Northridge earthquake offers an unusual opportunity to analyze market structure in a way that is largely free of the endogeneity problems mentioned earlier.

With respect to the control group condition, the hospital market is particularly attractive. Since hospital markets are generally local in nature, various control groups can be constructed that contain hospitals which were unaffected by the earthquake but which face similar market and regulatory conditions. The Northridge earthquake will then allow us to estimate the influence of capacity on prices by comparing pre- and post-earthquake pricing for inpatient care in Santa Monica to that for otherwise similar markets that did not experience a reduction in capacity.

The rest of this paper is organized as follows: section II discusses the Northridge earthquake; section III examines the geographic markets served by the Santa Monica hospitals; section IV details a model for analyzing changes in one group when control groups exist; section V discusses the data and contains empirical analysis; and section VI concludes.

II. THE NORTHRIDGE EARTHQUAKE

The Northridge earthquake struck Los Angeles County in the early morning of January 17, 1994, registering 6.7 on the Richter scale, equivalent in force to the 1971 San Fernando earthquake in

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[8] See de Laufente (1994).

the Los Angeles area (Wald and Heaton, 1994). The earthquake damaged buildings throughout the Los Angeles area in a geographically uneven pattern.

The epicenter of the earthquake was in northwest Los Angeles, as can be seen on the map in Figure 1. Located on the coast of the Pacific Ocean 23 km south of the epicenter, Santa Monica suffered more severe damage than many closer areas.

The most severe hospital damage in Santa Monica occurred at St. John's Hospital, forcing St. John's to close all its inpatient facilities a few days after the earthquake. 1750 employees were furloughed, while 300 stayed on to provide outpatient care. The north wing of the hospital, built in 1951, was deemed unsalvageable and was demolished. The north wing had included obstetrics, the nursery, and the chemical-dependency unit. An intense effort to reinforce the hospital's main wing and south wing with steel bracing allowed the hospital to reopen for inpatient care on October 3, 1994 with 262 beds, down from its pre-earthquake level of 501 beds.

When the hospital reopened, it remained a similar institution in the sense that its pay scale was the same, it maintained almost all the same operating units -- such as intensive care and chemotherapy -- and maintained the same referral network of physicians.[9] Upon reopening its inpatient

[9] One operating unit that formerly existed was not replaced -- the neonatal intensive care unit. Financially, this unit was not a particularly important part of the hospital, as evidenced by the fact that in the most recent financial year before the earthquake, the neonatal intensive care unit accounted for about 1/3 of 1% of the hospital's net revenues of $153 million.

services, St. John's hired about 1,000 employees, of whom roughly 90% were formerly employed at the hospital. These former employees maintained their previous seniority and pay levels. Most of the 1200 physicians with admitting privileges at the hospital maintained them after the hospital reopened. To a large degree, St. John's operated after October 3, 1994 much as it had before January 17, 1994, with the primary difference being that it now had less capacity.

The damage to Santa Monica Hospital, just five blocks away from St. John's, was less severe, so that Santa Monica Hospital continued serving patients throughout the period during which St. John's was closed -- though initially with only 144 beds compared to its pre-quake level of 371. Since the earthquake, employees have been laid off gradually in a manner similar to that of other hospitals in California. Santa Monica Hospital's wage structure and its physician referral network suffered no shock from the earthquake.

During St. John's closure, patient overflow from the Santa Monica area was handled by nearby hospitals, including Century City Hospital, Brotman Medical Center in Culver City, UCLA Hospital in Westwood, and Daniel Freeman Marina Hospital in Marina Del Ray. A map that includes these hospitals, as well as other West Los Angeles hospitals, can be seen in Figure 2. As we would expect, after St. John's Hospital resumed normal services, the number of patients declined at these overflow hospitals.

There are two basic points in this section. First, the hospitals in Santa Monica suffered unusually severe damage compared to other hospitals in the region. Second, when they returned to normal operation, their wage structures and referral patterns were similar to before the earthquake, but their capacities were considerably lower.

In the next section, we look at the geographic nature of patient demand to determine the extent to which the Santa Monica hospital market is distinct from other hospital markets in West Los Angeles. Market definition is important, because if the Santa Monica market is indeed distinct, the change in capacity provides a concentrated change in market structure, and therefore a significant impact on prices is plausible.

III. MARKET DEFINITION

The nature of hospital competition is inherently complex in a large metropolitan region such as Los Angeles County, where there are more than 100 acute-care hospitals; much of the complexity arises from the overlapping nature of markets. It seems clear that each hospital in Los Angeles will not view all the other hospitals as equal competitors. A given hospital will most likely view hospitals that are geographically closer as, in some sense, stronger competitors. The reason that these are stronger competitors is not that they are close per se, but that they may be competing for the same patients. Since patients generally prefer a closer hospital to one that is further away, a specific patient will typically consider a stay in only several nearby hospitals.[10] These patient preferences are important, because they prevent insurance companies from dropping coverage for one hospital and substituting a hospital ten miles away.

How can we measure the intensity with which a hospital is competing against other hospitals? One broad measure is the modified Herfindahl index of Zwanziger and Melnick (1987). Under this measure, each hospital in a region receives a rating based on the competitiveness of various sub-markets and on the importance of those markets to a hospital. For the task at hand, this measure is not wholly satisfactory, because it does not indicate the intensity with which two specific hospitals might be competing.

To better understand this intensity, it is worth dividing patient discharges by zip code and hospital for the main zip codes served by Santa Monica Hospital and by St. John's Hospital, and for other nearby hospitals that compete with them. Table 1 provides this breakdown based on 1993 discharge data for the two hospitals in Santa Monica and the thirteen hospitals that appear to be drawing patients from similar areas. The fifteen zip codes included in Table 1 are those which provided 2% or more of the patients for either St. John's Hospital or Santa Monica Hospital during 1993. (See Figure 3 for a map of zip code boundaries, in which the fifteen zip codes are shaded.) Given these zip codes, it is possible to find the hospitals which are significant

[10] An alternate view might be that hospitals are competing for referrals from local specialists. These specialists, in turn, are typically chosen largely as a result of their proximity to a patient's residence.

competitors in each zip code. Any hospital that accounts for 2% or more of the patient discharges from any of these fifteen zip codes is included in the table. Zip codes are ranked so that the most important zip codes to both Santa Monica Hospital and St. John's Hospital, based on the sum of their patient counts, appear first. Hospitals are ranked in the table so that those hospitals with the larger ratio of their actual patients coming from these fifteen zip codes (discharge ratio) are above those with a smaller percentage coming from these zip codes. For instance, 0.36 of Daniel Freeman Marina Hospital's patients come from these zip codes, while only 0.25 of UCLA Medical Center's patients come from these zip codes. So Daniel Freeman Marina Hospital is ranked above UCLA Medical Center. Not surprisingly, based on the way in which these zip codes were selected, Santa Monica Hospital (with 0.82) and St. John's Hospital (with 0.64) are ranked at the top of the table.[11]

The bottom row in the table calculates a zip-code-based Herfindahl index for each zip code, which takes into account all hospitals' market shares in a zip code (including hospitals not shown in the table).

The final columns in the table indicate the correlations between Santa Monica Hospital and other hospitals (r_m) and the correlations between Saint John's Hospital and other hospitals (r_j) over all zip codes served by at least one of the fifteen hospitals. These correlations provide the simplest way of seeing

[11] St. John's relatively low number compared to Santa Monica Hospital's suggests that St. John's attracts patients from a broader swathe of zip codes than Santa Monica Hospital.

how much the other thirteen hospitals are competing with Santa Monica Hospital and St. John's Hospital.

The correlation between Santa Monica Hospital and St. John's Hospital is 0.91, which suggests that the two hospitals are, indeed, competing in roughly the same geographic market. Because 0.91 is higher than any of the other correlations in the table, it also appears that St. John's and Santa Monica Hospital are competing more against each other than against any other hospital. Other hospitals that operate in a similar geographic market include Washington Hospital in Culver City, Daniel Freeman Marina Hospital, UCLA Medical Center, and Brotman Medical Center. Based on the geographic proximity of these hospitals to Santa Monica, as seen in Figure 2, these correlations are not surprising.

Overall, the two Santa Monica hospitals compete for patients most intensely with each other, compete less intensely with other nearby hospitals, and hardly at all with several more distant hospitals, even though the more distant hospitals share at least one zip-code market in common. While the Santa Monica hospitals do not form a duopoly, their market is somewhat distinct from other hospital markets in West Los Angeles. This distinctness is important, because insurance companies may be reluctant to drop both hospitals in Santa Monica from their network of hospitals, since patients from Santa Monica might then switch insurance companies to maintain the option to stay at a local hospital. The reduced capacity could then have a concentrated local effect that could in turn lead to a pronounced price effect. We now turn to the question of how to test for such a price effect.

IV. MODEL AND DATA

Before we discuss the specific attributes of the model below, it is valuable to re-state our question. Broadly, the question is, how does excess capacity influence price competition? Narrowly, the question is, how did the change in capacity in Santa Monica after the Northridge earthquake influence price competition within that area? We might expect the strongest effects in Santa Monica and considerably weaker effects, if any, in the nearby hospitals.

This paper takes advantage of the potential covariance of prices across hospitals. The starting point of the analysis is the model of prices at an individual hospital i. It is assumed that hospital i's price in period t is a linear function of a constant, a local market effect, and an error term. The local market effect may arise in hospitals that face specific demographic or market features. Hospitals facing similar demographic and market features may experience similar local market effects. The price for hospital i in period t can be written as:

$$p_{it} = c_i + L_{it} + \varepsilon_{it}. \qquad (1)$$

c_i is the constant fixed effect which is specific to firm i. L_{it} is the local market effect, and ε_{it} is a stationary Gaussian term for hospital i in period t, independent of the Gaussian terms for all other hospitals.

We assume that the local market effect is either revealed in price indices for other hospitals in the same geographic region (such as a county) or in prices at other hospitals that face similar market conditions.

We can then estimate a relationship between the prices at hospital i and other hospitals by estimating

$$p_{it} = \beta_0 + \beta_1 \mathbf{p}_{-it} \qquad (2)$$

where $\mathbf{p}_{-it}$ is the vector of prices excluding hospital i.

To test for the existence of a structural change in pricing at hospital i after period T, we can construct a dummy d_T that is zero in all periods before T and one otherwise. We can then estimate

$$p_{it} = \beta_0 + \beta_1 \mathbf{p}_{-it} + \beta_2 d_T \qquad (3)$$

If β_2 is significantly different from zero, we do not reject the hypothesis of a structural change.

There are thus two models: one to test for the presence of structural change and another to provide forecasts of prices in the absence of structural change. In the first approach, represented by equation (3), a model is estimated over all periods, including a dummy variable that is one in periods after the earthquake. Then we can test whether hospital i has experienced a structural change based on whether the dummy's coefficient is significantly different from zero.

Under the second approach, represented by equation (2), a model is estimated for the periods prior to the earthquake in order to obtain coefficient estimates for how the prices elsewhere are related to the price in a Santa Monica hospital. Based on these coefficients, we may forecast prices in a Santa Monica Hospital conditioned on observed prices elsewhere.

We next consider the data for these models.

Data

The data for this analysis are from the Hospital Quarterly Data, distributed by the California Office of Statewide Health Planning and Development. Since 1982, all California acute-care hospitals have been required to submit a brief summary of their operating conditions on a quarterly basis. The data include reports on revenues, inpatient visits, operating costs, and fixed assets from the first quarter of 1982 through the first quarter of 1995. The reported data improved significantly in the first quarter of 1986. Since then, changes in reporting format have allowed backward construction of the same variables as were reported in 1986. Consequently, the data with which this work begins are from the first quarter of 1986, yielding 32 quarterly observations of each hospital before the earthquake.

Not all hospitals in California should be or can be included in this analysis. We are interested only in hospitals that compete with each other for privately insured patients. As a result, four categories of hospital are excluded from this analysis. First, government-owned hospitals are excluded because they primarily treat Medicaid or indigent patients. Second, some hospitals are excluded from the sample because they do not bid against other hospitals for patients from insurers, notably the Kaiser HMO hospitals. Third, some are excluded from the sample because they do not operate or report continuously over the period of interest. Fourth, some are excluded because, despite remaining open during the entire period, they changed their primary focus of care. For example, an acute-care hospital might change to a drug-rehabilitation hospital. Out of California's 585 hospitals reporting their operating figures in the first quarter of 1995, about 345 hospitals are excluded for the reasons given above, leaving 238 hospitals for the analysis which follows.

Prices are measured as inpatient revenue per patient day for non-Medicare and non-Medicaid patients. Inpatient revenue per patient day for this category of patients approximates prices for privately insured patients.[12] This approximation to a per diem rate is chosen as the price variable because per diem rates are the primary price negotiated between hospitals and insurers. An approximation is used instead of actual negotiated rates because negotiated rates between insurers and hospitals are proprietary.

Revenues are deflated by the Bureau of Labor Statistics' medical care service price index for the Los Angeles area or the San Francisco area, as is appropriate. For hospitals outside of

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[12] OSHPD quarterly hospital data includes variables for gross inpatient revenue by payor source, gross outpatient revenue by payor source, and net revenue by payor source. Net inpatient revenue is then estimated based on the average discount from all gross revenues for that payor source.

these areas, an average of the two indices is used. Monthly data for the medical care service index are available (see Bureau of Labor Statistics (1995)). These are then averaged to produce a quarterly index for deflating revenues.

V. EMPIRICS

Given the framework outlined above, we can proceed to report the results of the analysis. We first estimate models to test for structural change in prices at Santa Monica Hospital. We then test for structural change in prices at St. John's Hospital.

Table 2 displays the coefficient estimates from the regression of revenue per patient day at Santa Monica Hospital on price indices which covers the period from the first quarter of 1986 through the first quarter of 1995. The regression includes a dummy variable that is one in all the periods following the earthquake and zero otherwise. If this dummy's coefficient is significantly different from zero, we reject the null hypothesis that no structural change occurred.

In the ordinary least squares estimation, the Durbin-Watson statistic is below its critical value of 1.66, which suggests that there is a problem with autocorrelation of the errors. To account for this autocorrelation, we follow the iterative maximum likelihood method of Beach and McKinnon (1978).

In the first regression, prices at Santa Monica Hospital are regressed on only a constant, the earthquake dummy, and a trend. In the second regression, an index of Los Angeles County prices is also included. This index excludes the Santa Monica hospitals and their close competitors. In the third regression, price indices for neighboring counties are also included, because some neighboring counties are demographically more similar to Santa Monica than is Los Angeles County as a whole. In the fourth regression, the price index used is constructed as an average of prices at sixteen hospitals that are deemed similar to Santa Monica Hospital, by a method described below.

In all cases, the earthquake dummy is positive and significantly different from zero at the 0.01 level, allowing us to reject the hypothesis that there was no structural change after the earthquake.

We might imagine that correlations between the local market effect in Santa Monica and those elsewhere will be confused by aggregative county indices. In order to deal with this possibility, we select a group of hospitals that share significant features with Santa Monica Hospital, with the rationale that similar hospitals are more likely to experience a high covariance of their prices with Santa Monica Hospital. Having selected these hospitals, we will regress prices at Santa Monica Hospital on prices at these hospitals, again with an earthquake dummy.

The variables deemed, a priori, most relevant to finding a control group of hospitals similar to Santa Monica Hospital are: the number of patients, the occupancy rate, the percentage of white patients, the percentage of patients who are covered by non-governmental insurance, and the average complexity of cases treated, or case-mix. Hospitals are included with the group when they are within one standard deviation of Santa Monica Hospital's value for each of these variables. The standard deviation is calculated based on the 238 hospitals in the sample. An important property of this process for finding similar hospitals is that the group selected is independent of the order in which variables are considered. After completing this process for an intermediate year in the time series (1991), sixteen hospitals remain. These are listed in Appendix B.

Simple regressions of Santa Monica Hospital's prices on each individual hospital's prices are reported in Table 3. Note that in each case, the earthquake dummy is positive and significantly different from zero at the 0.01 level.

To gain insight into the robustness of these results, further estimates are made with these hospitals, regressing Santa Monica hospital's revenues per patient day on the revenues per patient day of all combinations of five of these sixteen hospitals. We might expect these revenues per patient day to exhibit significant multicollinearity. However, since the earthquake dummy will not be subject to multicollinearity, its estimated standard error will be unaffected by this problem.[13] There are 4,368 distinct combinations of five hospitals out of the group of sixteen. Based on 4,368 regressions that follow the Beach and MacKinnon AR(1) method, the minimum coefficient estimate for the earthquake dummy is 0.2158, the maximum is 0.3236, the mean is 0.2626, and the median is 0.2628. The minimum t-value is 3.4573, the maximum is 5.6374, the mean

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[13] See Conlisk (1971).

t-value is 4.3807, and the median is 4.3769. These results suggest that the positive and significant coefficient estimate for the earthquake dummy variable is fairly robust.

What values of price might we have predicted in absence of any structural change? This question can be answered based on coefficient estimates from before the earthquake. Figure 4 is a chart that displays the values of revenue per patient day at Santa Monica Hospital against the fitted values and the forecast values, based on the coefficients from the five county price indices. The coefficients are calculated based on the 32 quarters prior to the earthquake. Actual values are consistently higher than forecast values, initially more than 25% higher and always at least 13% higher than the forecast prices. It appears that after St. John's hospital reopened in the fourth quarter of 1994, values fell from their peak, but remained above their predicted level.

We turn now to examine revenue per patient day at St. John's Hospital. Table 4 shows regressions parallel to those for Santa Monica Hospital in Table 2. Time trends are not included because, in unreported regressions, their coefficients are insignificant. The results reported below are not sensitive to this exclusion.

A complicating factor arises for estimating the dummy for post-earthquake observations at St. John's Hospital. Because the hospital was closed between the time of the earthquake and the fourth quarter of 1994, there are three missing observations for price at St. John's Hospital, leaving only two post-earthquake observations. As autoregressive models are extremely sensitive to missing observations, ordinary least squares techniques are used.

Table 4 finds no significant price effect for St. John's Hospital. Moreover, these regressions perform poorly. Their adjusted R-squared values are negative, indicating that variables in addition to the constant have no explanatory power. Table 5 examines the thirteen hospitals deemed most similar to St. John's Hospital, based on the standard deviation reduction technique. These hospitals are listed in Appendix B. Note that these regressions have poor explanatory power. In only three cases is the adjusted R-squared value greater than zero. Nonetheless, in no case is the coefficient for the earthquake dummy significantly different from zero. That is, we cannot conclude from these data that St. John's Hospital experienced a significant change in revenue per patient day after the earthquake.

Figure 5 illustrates the time series of revenues per patient day at St. John's Hospital. No fitted values are included, because the significance of the estimated regressions is low. To provide a reference series, an index of values over the entire period for the thirteen similar hospitals is displayed. This figure suggests that St. John's revenues per patient day have a high variance, much higher than we might expect of actual per diem rates. This variance may arise from accounting practices at

St. John's Hospital.[14] Annual data experience a much lower variance, but adequate data for an annual analysis of post-earthquake pricing at St. John's are currently unavailable.

To conclude, the models estimated suggest that after the Northridge earthquake, revenues per patient day experienced a significant positive increase at Santa Monica Hospital. This may be a result of the reduced capacity at the hospitals in Santa Monica. Because insurers might be reluctant to exclude both hospitals in Santa Monica from their provider networks, the credibility of the insurers' threat to move patients may have fallen due to the lower excess capacity in the area. However, the models estimated suggest that St. John's Hospital did not experience a significant change in revenues per patient day. The absence of a significant price effect for St. John's Hospital suggests caution in the interpretation of the price results for Santa Monica Hospital.

VI. CONCLUSIONS

Before we accept any finding of a positive price effect, we must ask how confident we can be in the finding in this case. Then we can ask whether the finding is consistent with previous empirical work that focuses on hospitals.

There are several reasons we might doubt findings from this data. First, the number of post-earthquake observations is

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[14] For instance, if revenues are booked only when received, rather than when billed, then delays in payment by federal authorities or private insurance companies will lead to a high variance of the estimated per diem rate.

small. As a result, the phenomenon we are most interested may not be precisely what we are measuring: we are interested in a short-run response but possibly measuring an extreme short-run response.

Second, it is possible that there is an omitted variable which may explain the change in prices. The likelihood of this problem is difficult to gauge.[15]

Third, as stated earlier, prices at St. John's Hospital have not increased significantly since the earthquake. Even though revenues per patient day have a high variance at St. John's Hospital, the absence of a significant positive price effect cannot be immediately dismissed.

For these reasons, then, the results must be interpreted with care. Before we can be confident in the results, further research is needed that examines similar sudden shocks to hospital capacity in other places at other times. Nonetheless, the results do buttress those of a recent cross-sectional analysis of hospital capacity and pricing.

In a study of one preferred provider organization's negotiated prices with hospitals in California, Melnick et al. (1992) examine hospitals that both have a greater than 75% occupancy rate and operate in a market with greater than 75% occupancy rates. A dummy variable is set to one for hospitals that satisfy these two conditions, and is zero otherwise. The estimated coefficient for the dummy variable is 0.184, which is

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[15] We might be concerned about a possible change in the case-mix at Santa Monica Hospital. When discharge data for the post-earthquake period becomes available, it will be possible to address this concern.

significant at the 0.01 level. This suggests that hospitals satisfying the high-occupancy conditions have prices 20.2% above those of other hospitals. While a dummy-variable approach to a presumably continuous phenomenon is problematic, the dummy's positive coefficient is consistent with the general nature of the results found in Santa Monica after the Northridge earthquake.

In review, this paper both analyzes a problem and illustrates a method. The problem is to estimate the extent to which lowering capacity might increase prices. The method is to take advantage of natural disasters, such as earthquakes, as generators of exogenous shocks to market variables, such as capacity. The method can be viewed as a true natural experiment approach. The strength of the method is that changes in the variables of interest are well identified. Since identification is crucial for policy purposes, there is potentially high value in pursuing further studies of this nature.

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Appendix A. Details of the Northridge Earthquake

This appendix first discusses the pattern of physical damage arising from the Northridge earthquake and second discusses its general economic effects.

Pattern of Physical Damage

Levels of horizontal ground acceleration are listed in Table A1 for sites less than 30 km from the epicenter. These figures help explain why Santa Monica suffered such extreme damage from the Northridge earthquake: despite its distance from the earthquake's center, Santa Monica experienced the second largest horizontal ground acceleration level of all the sites, at 0.93 g. Given these ground acceleration measurements, it is not surprising that the Office of Statewide Health Planning and Development initially closed (or "red-tagged") seven health-care buildings in Santa Monica, four buildings in Los Angeles (which is a much larger area and includes the epicenter of the earthquake), and one building in San Pedro, after extensive inspections throughout the Los Angeles area. This "red-tag" pattern suggests that Santa Monica's health care-facilities were more severely damaged than health-care facilities elsewhere. (EERI 1994, p. 48)

The red-tag patterns confirm that there was a high variability in the damage from the Northridge earthquake to hospitals in Los Angeles County. This variability helps our study, because hospitals left undamaged by the quake can serve as a control group against which to compare the Santa Monica hospitals.

Economic Effects

While it is natural to concentrate on the earthquake's direct physical effects, it is also important to consider effects the earthquake may have had on employment in general, which might have influenced the number of privately insured patients. For instance, one might imagine that the earthquake caused many layoffs -- some of them at St. John's hospital, but also more generally in retail establishments -- which led to reduced health-insurance coverage and reduced demand for health-care services. These issues are important, because a local change in the nature of demand could confuse the estimates of the role of changed capacity on prices, due to a potential bias from omitted variables.

A precise investigation of the nature of health care demand is beyond the scope of this paper. Nonetheless, it does appear that the earthquake did not fundamentally alter the employment patterns of the region. Net job loss at the time of the earthquake appears slight. In Los Angeles County, non-farm employment rose 1% from 1993 to 1994, an increase of 35,000. About a third of this increase occurred in the quarter after the earthquake. Construction employment rose 4%, a higher percentage than for employment overall, which is not surprising, due to the increased need for construction after the damage caused by the earthquake (Barton, 1995).

If the effects of the Northridge earthquake are similar to those of the 1989 Loma Prieta earthquake in Northern California, retail sales, and presumably retail employment, declined in areas in which stores suffered serious damage, but this decline was offset by increased sales, and presumably employment, in neighboring areas (Federal Reserve, 1994).

Appendix B. Control Group Hospitals

Hospitals similar to Santa Monica Hospital, based on standard deviation reduction technique

No.	Name	City
1	Clovis Community Hospital	Clovis
2	Community Memorial Hospital	Ventura
3	Foothill Presbyterian Hospital	Glendora
4	Inter-Community Medical Center	Covina
5	La Palma Intercommunity Hospital	La Palma
6	Long Beach Community Hospital	Long Beach
7	Los Robles Regional Medical Center	Thousand Oaks
8	Medical Center of North Hollywood	North Hollywood
9	Mills Memorial Hospital	San Mateo
10	Mission Hospital Regional Medical Center	Mission Viejo
11	Redlands Community Hospital	Redlands
12	Santa Barbara Cottage Hospital	Santa Barbara
13	Simi Valley Hospital	Simi Valley
14	Tarzana Encino Regional Medical Center	Tarzana
15	Verdugo Hills Hospital	Verdugo Hills
16	West Hills Regional Medical Center	West Hills

Hospitals similar to St. John's Hospital, based on standard deviation reduction technique

1	Desert Hospital	Palm Springs
2	Inter-Community Medical Center	Covina
3	John Muir Medical Center	Walnut Creek
4	Marin General Hospital	San Rafael
5	Mercy Hospital and Medical Center	San Diego
6	Methodist Hospital of Southern California	Arcadia
7	Northridge Hospital Medical Center	Northridge
8	Roseville Community Hospital	Roseville
9	Saddleback Memorial Medical Center	Laguna Hills
10	St. Joseph Medical Center	Burbank
11	Santa Barbara Cottage Hospital	Santa Barbara
12	Tarzana Encino Regional Medical Center	Tarzana
13	Valley Presbyterian Hospital	Van Nuys

Table 1. Geographic source of patients, by zip code

HOSPITALS	Total discharges for hospital	90066	90405	90403	90404	90049	90272	90025	90291	90064	90034	90402	90230	90024	90045	90401	Discharge Ratio	r_m	r_j
Santa Monica Hospital	10480	1040	970	816	892	470	473	632	794	462	513	338	486	169	286	307	0.82	--	0.91
St. John's Hospital	13954	756	794	900	719	1097	892	707	370	543	391	509	266	434	295	228	0.64	0.91	--
Washington Hospital	1958	310	32	16	20	5	4	36	74	24	80	3	140	4	58	13	0.42	0.66	0.48
Daniel Freeman Marina Hospital	4041	362	53	6	15	19	10	22	279	24	35	8	180	13	419	9	0.36	0.55	0.42
UCLA Medical Center	20482	624	195	130	176	444	173	676	375	320	596	103	401	810	174	43	0.26	0.69	0.71
Century City Hospital	3774	68	36	30	30	64	36	136	40	153	134	16	41	123	36	7	0.25	0.48	0.56
Brotman Medical Center	8642	354	55	32	45	23	6	47	74	105	618	7	620	32	77	9	0.24	0.47	0.34
Kaiser Foundation Hospital	11590	390	98	61	100	72	51	180	133	182	509	26	302	98	242	7	0.21	0.34	0.28
Cedars-Sinai Medical Center	36668	474	225	240	122	708	248	724	212	604	1036	146	359	1019	317	44	0.18	0.30	0.38
Daniel Freeman Memorial Hospital	11784	120	9	3	15	20	6	9	66	17	71	2	138	15	528	1	0.09	0.13	0.08
Centinella Medical Center	13051	33	17	14	11	31	17	12	28	24	52	11	79	21	463	2	0.06	0.10	0.07
LA County Harbor -- UCLA Medical Center	21348	181	45	13	85	11	7	45	145	38	137	17	104	43	116	23	0.05	0.07	0.05
LA County -- USC Medical Center	64684	197	53	21	53	19	16	121	123	81	233	12	111	49	53	26	0.02	0.37	0.03
Torrance Memorial Medical Center	17000	39	11	14	5	6	5	10	9	14	45	0	25	8	100	2	0.02	0.02	0.04
Little Company of Mary Hospital	12945	30	2	1	0	6	6	2	5	5	9	0	5	8	86	0	0.01	0.02	0.04
Discharges in this table		4781	2542	2276	2235	2976	1934	3238	2604	2515	4226	1186	3146	2797	3197	695			
Total discharges for zip code		5566	2861	2500	2462	3353	2118	3838	3020	2905	5330	1308	3750	3178	3845	820			
Zip code-based Herfindahl index		0.092	0.206	0.25	0.228	0.19	0.25	0.133	0.121	0.125	0.093	0.238	0.084	0.193	0.074	0.227			

Source: OSHPD 1993 Discharge Data and OHSPD 1993 Hospital Quarterly Data

Table 2. Santa Monica Hospital index regressions

Dependent variable: revenue per patient day at Santa Monica Hospital

constant	7.258* (0.0379)	8.034* (2.517)	5.911*** (2.973)	7.049* (1.809)
earthquake dummy	0.261* (0.0559)	0.250* (0.0663)	0.278* (0.0758)	0.267* (0.0753)
time	-0.0221* (0.0019)	-0.0226* (0.0026)	-0.0223* (0.0038)	-0.0221* (0.0023)
L.A. County price index	--	-0.111 (0.360)	-0.393 (0.569)	--
Ventura County price index	--	--	0.133 (0.280)	--
Orange County price index	--	--	-0.134 (0.451)	--
Riverside County price index	--	--	0.468 (0.308)	--
San Bernardino County price index	--	--	0.128 (0.236)	--
Sixteen hospital index	--	--	--	0.0305 (0.264)
D-W statistic	1.717	1.690	1.789	1.722
Autocorrelation coefficient	0.377* (0.159)	0.378** (0.162)	0.290*** (0.174)	0.374** (0.162)
Adjusted R-squared	0.892	0.889	0.885	0.889
Observations	37	37	37	37

Calculated with AR(1) Maximum-Likelihood Method of Beach and McKinnon (1978). Program: TSP.
Standard errors in parentheses. All variables are logged values.
*Significant at 0.01 level. **Significant at 0.05 level.
***Significant at 0.10 level.

Table 3. Santa Monica Hospital and regressions on sixteen similar hospitals

Dependent variable: revenue per patient day at Santa Monica Hospital

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
constant	7.014* (0.520)	7.058* (0.434)	6.470* (0.558)	7.368* (0.788)	6.077* (1.034)	7.314* (1.153)	5.811* (0.881)	7.668* (0.399)	6.251* (0.910)	6.672* (0.740)	8.832* (0.728)	7.599* (0.713)	7.126* (0.841)	7.234* (0.822)	7.863* (0.629)	7.625* (0.557)
earthquake dummy	0.271* (0.0596)	0.270* (0.0597)	0.285* (0.0562)	0.258* (0.0603)	0.266* (0.0533)	0.261* (0.0585)	0.299* (0.0593)	0.229* (0.0637)	0.274* (0.0562)	0.277* (0.0593)	0.246* (0.0582)	0.259* (0.0564)	0.265* (0.0620)	0.262* (0.0612)	0.247* (0.0572)	0.243* (0.0622)
time	-0.0229* (0.0026)	-0.0221* (0.0020)	-0.0216* (0.0018)	-0.0222* (0.0020)	-0.0210* (0.0021)	-0.0222* (0.0024)	-0.0217* (0.0019)	-0.0225* (0.0020)	-0.0227* (0.0020)	-0.0223 (0.0019)	-0.0219* (0.0022)	-0.0221* (0.0019)	-0.0220* (0.0021)	-0.0221* (0.0020)	-0.0227 (0.0020)	-0.0225* (0.0020)
revenue per patient day at similar hospital	0.0412 (0.0876)	0.0308 (0.0666)	0.112 (0.0793)	-0.0158 (0.113)	0.173 (0.151)	-0.0081 (0.168)	0.203*** (0.120)	-0.0610 (0.0588)	0.155 (0.139)	0.0817 (0.103)	-0.0504 (0.105)	0.0571 (0.0713)	0.0191 (0.121)	0.0033 (0.114)	-0.0855 (0.0889)	-0.0506 (0.0765)
D-W statistic	1.719	1.691	1.782	1.704	1.787	1.714	1.744	1.691	1.744	1.759	1.711	1.797	1.711	1.717	1.718	1.739
rho	0.366** (0.161)	0.380** (0.162)	0.345** (0.163)	0.383** (0.161)	0.320*** (0.166)	0.380** (0.161)	0.377** (0.161)	0.382** (0.161)	0.364* (0.161)	0.370** (0.161)	0.372** (0.162)	0.505* (0.146)	0.384** (0.161)	0.377** (0.162)	0.357** (0.163)	0.368** (0.162)
adjusted R-squared	0.889	0.889	0.895	0.889	0.893	0.889	0.897	0.892	0.893	0.891	0.889	0.743	0.889	0.889	0.892	0.891
observations	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37

AR(1) maximum-likelihood method of Beach and MacKinnon (1978). Program: TSP.
Standard errors in parentheses. All prices are logged values. *Significant at 0.01 level. ** Significant at 0.050 level. ***Significant at 0.10 level.

Table 4. Saint John's Hospital index regressions

Dependent variable: revenue per patient day at Saint John's Hospital

constant	6.947* (0.0192)	8.792* (2.386)	7.497*** (3.753)	8.165* (2.681)
earthquake dummy	-0.0095 (0.0795)	-0.0665 (0.108)	-0.278 (0.0758)	-0.0322 (0.0947)
L.A. County price index	--	-0.267 (0.345)	-0.717 (0.691)	--
Ventura County price index	--	--	-0.0222 (0.391)	--
Orange County price index	--	--	0.424 (0.450)	--
Riverside County price index	--	--	0.421 (0.587)	--
San Bernardino County price index	--	--	-0.192 (0.385)	--
Sixteen hospital index	--	--	--	0.0305 (0.264)
D-W statistic	1.349	1.375	1.405	1.364
Adjusted R-squared	-0.030	-0.0438	-0.136	-0.0569
Observations	37	37	37	37

Standard errors in parentheses. All variables are logged values.
*Significant at 0.01 level. **Significant at 0.05 level.
***Significant at 0.10 level.
Calculated by OLS. Note that the first, second, and third quarters of 1994 are excluded since St. John's was closed to inpatient care during these times. Program: TSP.

Table 5. Saint John's Hospital and regressions on thirteen similar hospitals

Dependent variable: revenue per patient day at Saint John's Hospital

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
constant	7.920* (0.835)	7.819* (1.195)	6.039* (1.533)	6.106* (0.798)	5.569* (1.454)	9.187* (1.391)	4.049** (1.508)	6.558* (0.747)	6.871* (0.873)	7.652* (1.151)	7.813* (1.501)	9.412* (1.152)	7.812* (0.952)
earthquake dummy	-0.0005 (0.0794)	-0.0487 (0.0964)	-0.0141 (0.0806)	-0.0131 (0.0794)	0.0541 (0.104)	-0.0597 (0.0836)	0.0449 (0.0593)	-0.0166 (0.0815)	-0.0046 (0.0984)	-0.0109 (0.0803)	-0.0291 (0.0872)	-0.105 (0.0877)	-0.0245 (0.0814)
revenue per patient day at similar hospital	-0.141 (0.120)	-0.125 (0.171)	0.112 (0.210)	0.118 (0.112)	0.197 (0.208)	-0.330 (0.205)	0.425*** (0.221)	0.0557 (0.107)	0.0106 (0.121)	-0.103 (0.169)	-0.127 (0.221)	-0.344** (0.161)	-0.127 (0.139)
D-W statistic	1.332	1.344	1.335	1.395	1.312	1.439	1.272	1.366	1.344	1.408	1.336	1.646	1.375
adjusted R-squared	-0.019	-0.046	-0.052	-0.027	-0.034	0.018	0.049	-0.055	-0.063	-0.051	-0.052	0.073	-0.036
observations	37	37	37	37	37	37	37	37	37	37	37	37	37

Standard errors in parentheses. All prices are logged values. *Significant at 0.01 level. ** Significant at 0.050 level. ***Significant at 0.10 level.
Calculated by OLS. Note that the first, second, and third quarters of 1994 are excluded since St. John's was closed to inpatient care during these times. Program: TSP.

Table A1. Horizontal ground acceleration from Northridge Earthquake

Location	**Distance from epicenter**	**Maximum horizontal ground acceleration**
Tarzana, Cedar Hill Nursery A	5 km	1.93g
Van Nuys, hotel	7 km	.41g
Sherman Oaks, 13-story commercial building	9 km	.24g
Arleta, fire station	10 km	.35g
Sylmar, County Hospital Parking Lot	16 km	.91g
Pacoima, Kagel Canyon	18 km	.30g
UCLA, Grounds	18 km	.32g
North Hollywood, hotel	19 km	.13g
Century City, LACC	20 km	.27g
Newhall, LA County fire station	20 km	.63g
Los Angeles, office building	20 km	.20g
Burbank, 10-story residential building	21 km	.35g
Santa Monica, City Hall grounds	23 km	.93g
Los Angeles, Hollywood storage building	23 km	.24g
Los Angeles, Baldwin Hills	28 km	.24g

Source: California Strong-Motion Instrumentation Program data, Northridge earthquake, California Division of Mines and Geology, as reported in Earthquake Spectra, "Recorded Ground and Structure Motions" (April, 1995)

Figure 1

Earthquake Epicenter

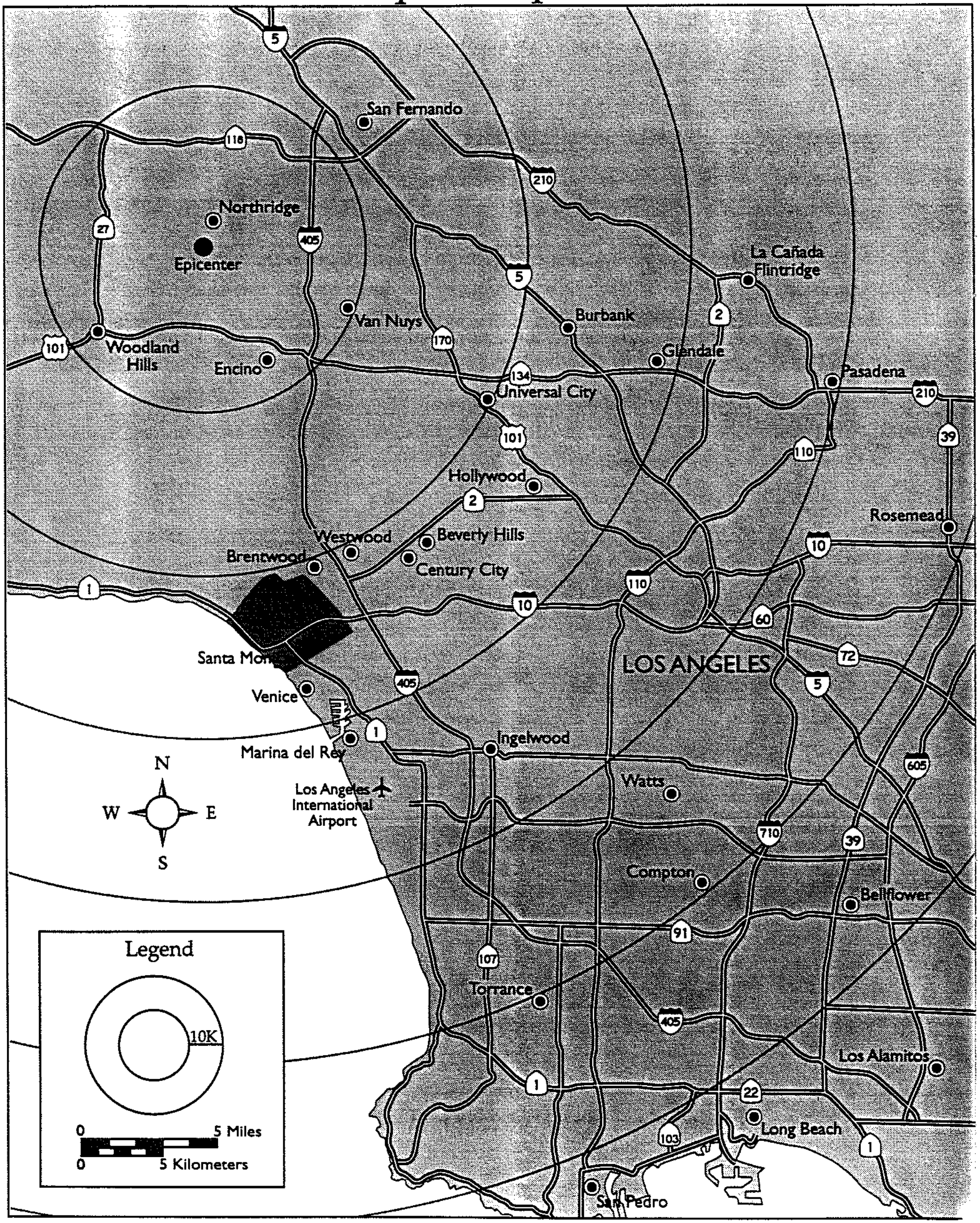


Figure 2

West Los Angeles Hospitals

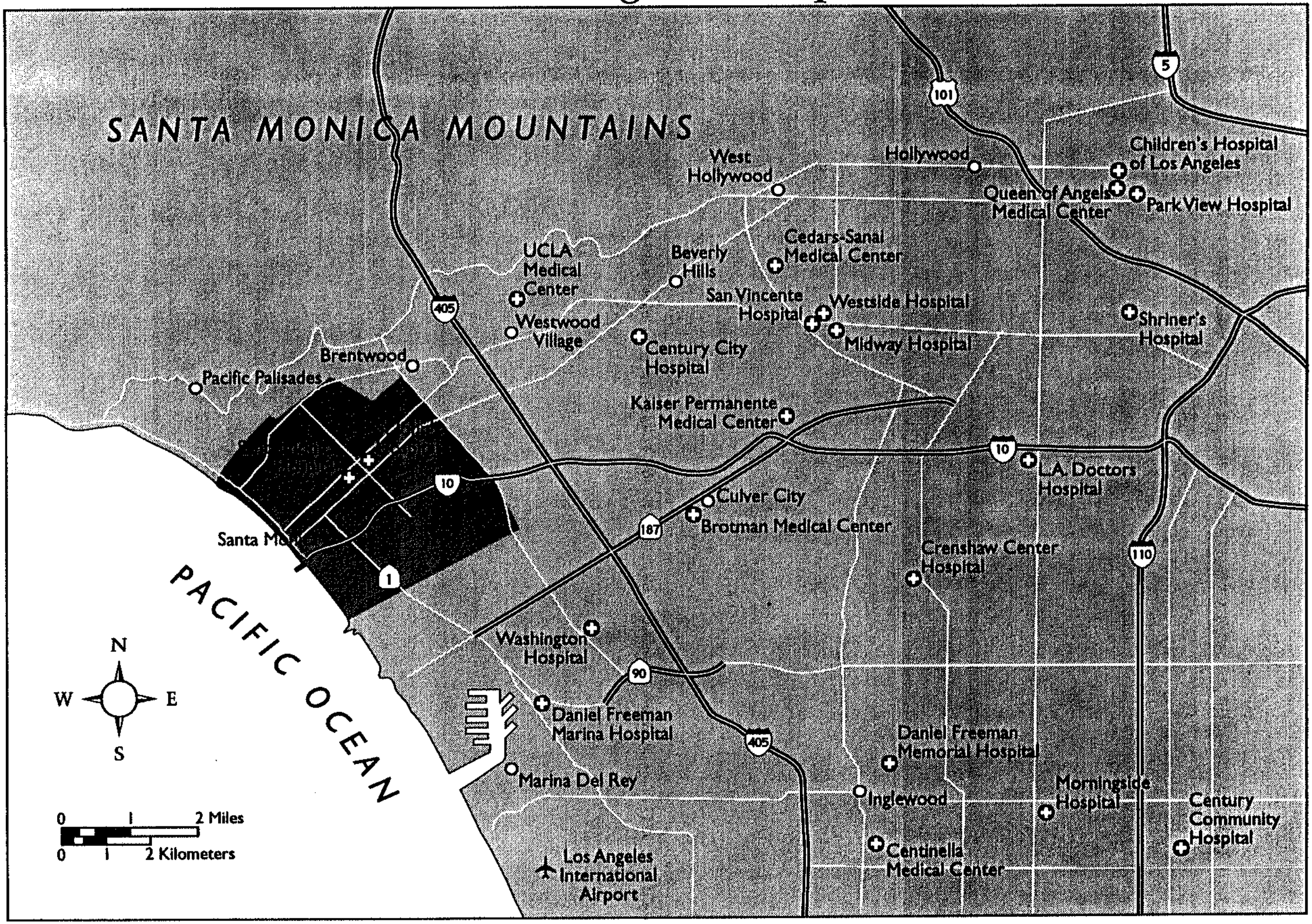


Figure 3

Primary Zip Codes for Santa Monica Hospitals

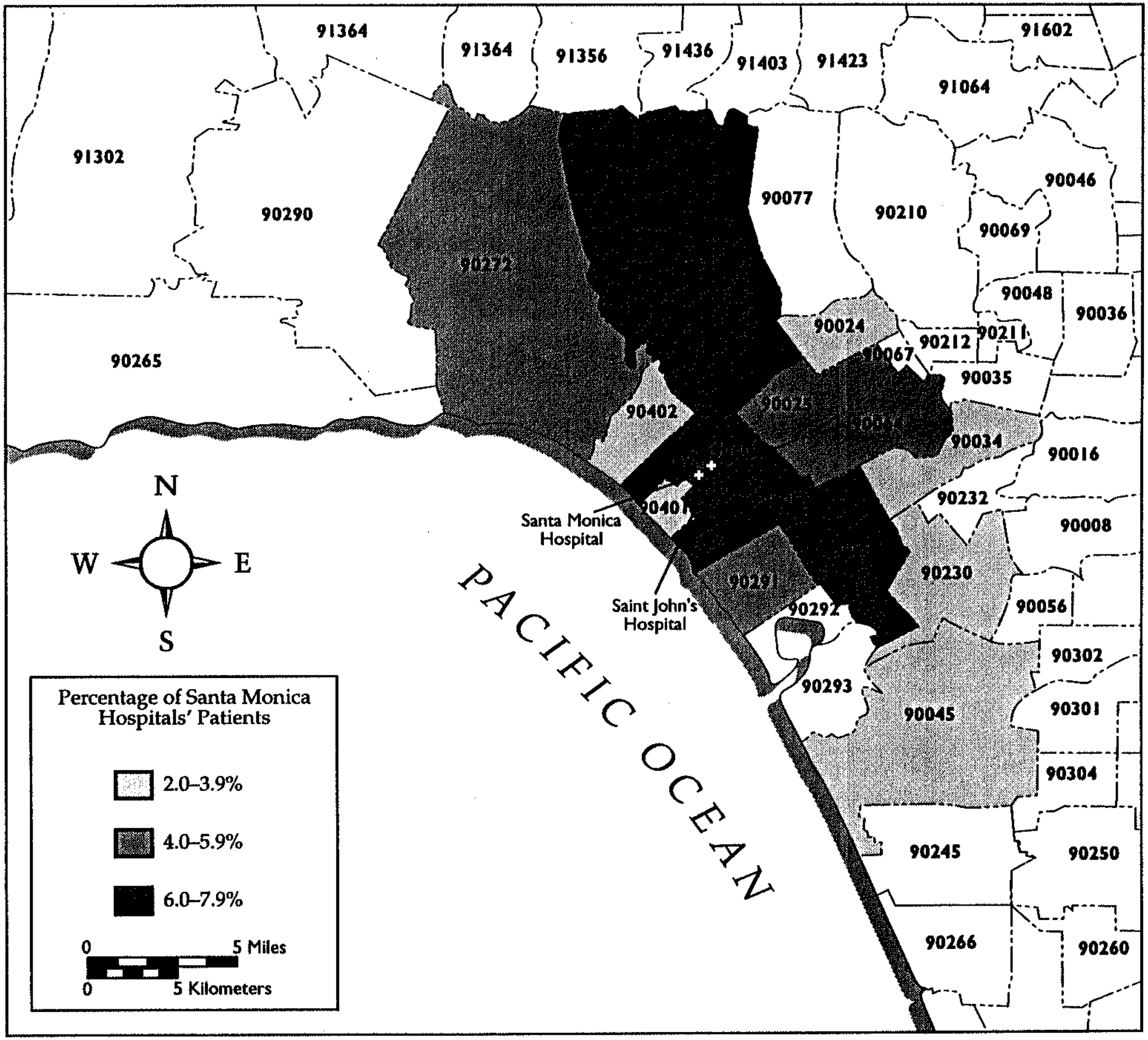


Figure 4

Revenue per patient day at Santa Monica Hospital

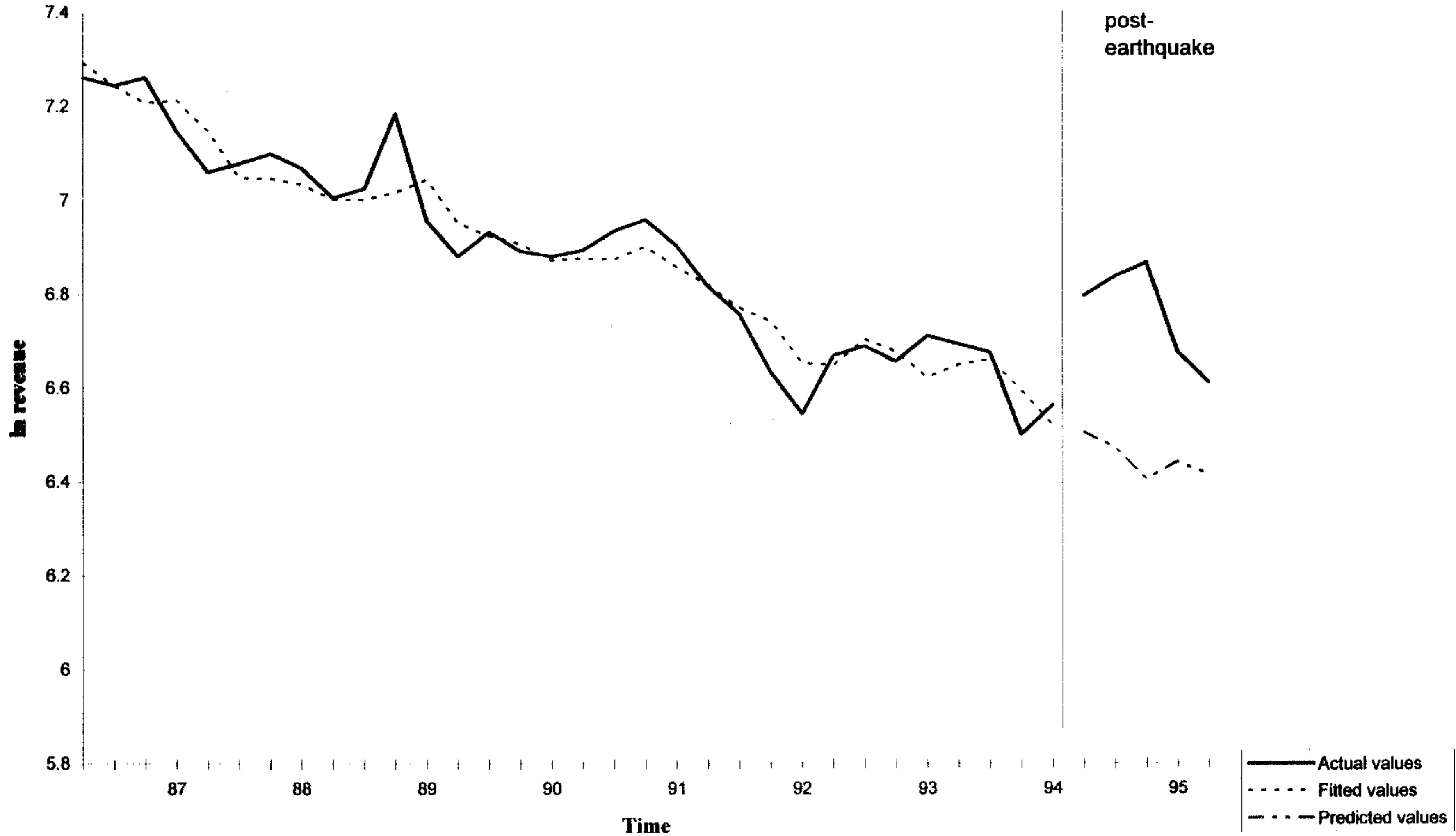
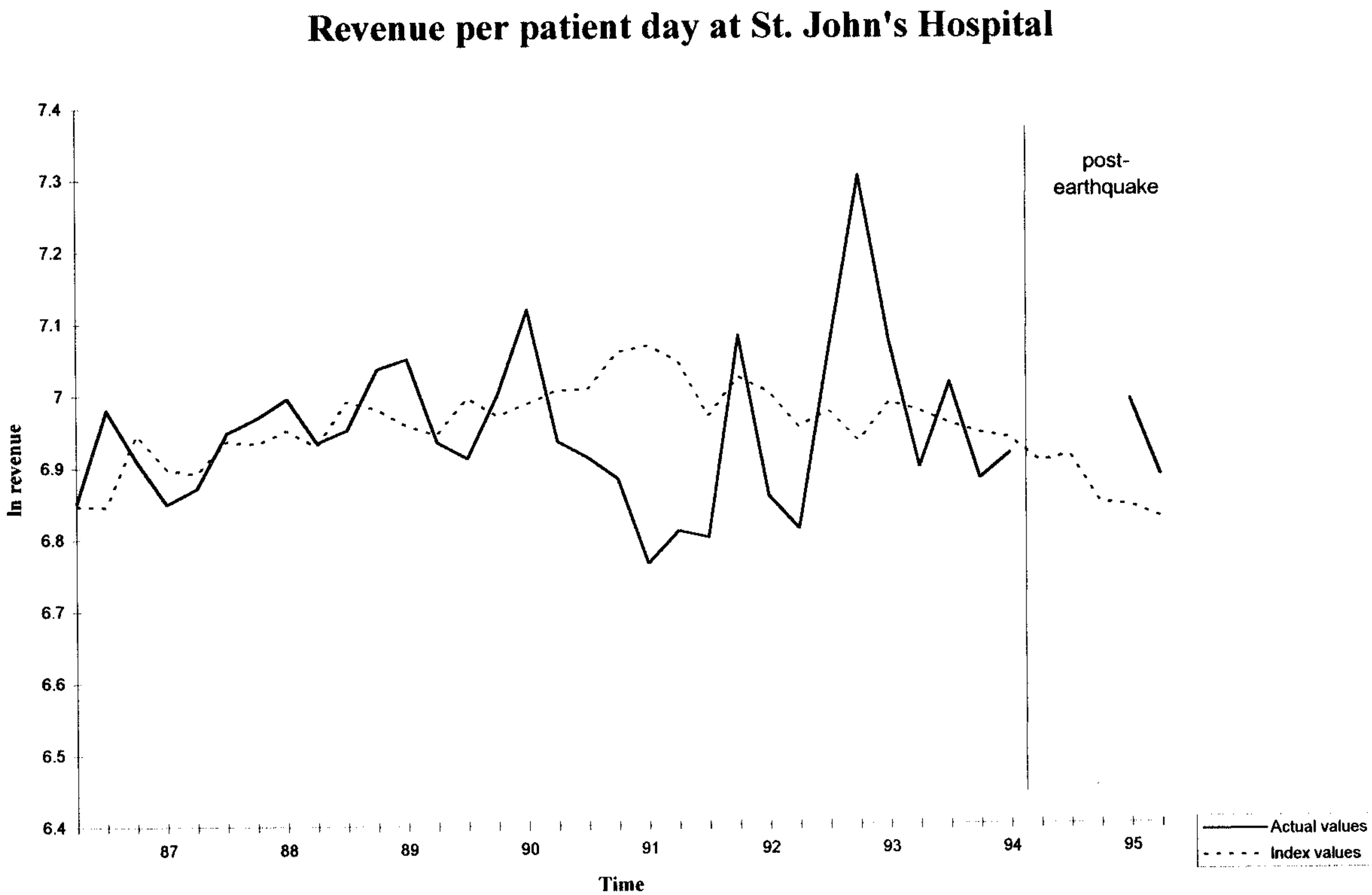


Figure 5


Revenue per patient day at St. John's Hospital
ln revenue
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
87
88
89
90
91
92
93
94
95
Time
post-
earthquake
Actual values
Index values

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