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Natural Disaster Management
Earthquake Risk and Hospitals' Provision of Essential Services in California

Tom Chang and Mireille Jacobson

11.1 Introduction

Regulation and litigation are two different, although often complementary approaches, to dealing with externalities. Where regulation takes an ex ante approach, establishing rules that force parties to internalize externalities, litigation relies on ex post deterrence. Litigation can be thought of as a form of ex post regulation administered by the courts. However, as discussed by Posner in this volume, if ex post damages are large, "the injurer may not have sufficient resources to pay the penalty." In such cases, the presence of an "ex post enforcement problem"[1] suggests courts are likely to fail, and ex ante regulation is the more effective policy tool.

In this work, we study a particular policy problem—California's efforts to ensure the earthquake safety of its hospital infrastructure that is subject to an ex post enforcement problem. The state first established hospital seismic safety requirements in 1973, following the 1971 Sylmar earthquake, which killed forty-eight people at a Veterans Administration hospital. These requirements applied only to the construction of new hospital buildings; existing hospital buildings were indefinitely exempt. As suggested by a wrongful death case after the 2003 San Simeon earthquake (discussed in more detail later), older hospital buildings were, at least in principle, subject to the threat of ex post litigation. The ineffectiveness of ex post litigation in this context is highlighted, however, by the fact that many hospitals responded to the

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1. Shleifer used this term at the 2009 NBER Regulation and Litigation Conference proceedings.

legislation by deferring new construction in favor of extending the life span of their existing buildings. As such, the 1973 law had the perverse effect of increasing the susceptibility of California's hospitals to seismic damage. This failure had real consequences in 1994 when twenty-three hospitals had to suspend some or all services due to structural damage sustained during the Northridge earthquake.[2]

In many respects reliance on ex post litigation to ensure disaster preparedness seems foolhardy. The potential losses and liabilities from a major earthquake are so large as to strain the limited solvency of hospitals. The limited liability of hospitals creates significant problems for ex post regulation since the expected private costs for any given hospital are likely to be far below the expected social cost. As a result, California responded to the 1994 Northridge earthquake by enacting an extensive regulatory scheme to ensure hospital seismic safety.

While ex ante regulation may be an obvious choice for disaster preparedness efforts, the specific form of regulation adopted is critically important. Traditional regulatory approaches can be both needlessly costly, and generate significant unintended negative consequences. In the context of California's recent earthquake safety mandate for hospitals, the state adopted a traditional command and control type regulatory approach, mandating a timeline by which all general acute care (GAC) hospitals must retrofit or rebuild to remain (a) standing and (b) operational following a major seismic event. The latter goal—ensuring that all hospitals can maintain operations—was tantamount, as the Northridge earthquake caused disruption in services at twenty-three hospitals but little hospital-related injury or death. While hospitals can apply for low-interest loans and bonds from several state and federal sources, they are given no direct financial assistance.[3] Estimates of the direct costs of compliance with the mandate vary, but all put the price tag in the tens of billions of dollars.[4]

The sheer magnitude of these direct compliance costs has lead to significant, unintended distortions on whether and how hospitals provide care. By requiring all hospitals to reach the same earthquake standard, many of those in the highest risk areas are closing or merging, effectively eroding access in the very areas the state seeks to protect. We argue that "market-based" regulatory approaches, specifically the cap-and-trade type mechanisms that have grown in popularity in the context of environmental policy, hold specific promise for disaster management.

We proceed by first describing the evolution of California's approach to

2. See § 130000.8 of the Alfred E. Alquist Hospital Facilities Seismic Safety Act, available at: http://www.oshpd.ca.gov/FDD/seismic_compliance/SB1953/SeismicRegs/hssa.pdf.

3. These sources, which are general in nature, include the CalMortgage and HUD 242 insurance programs.

4. Mead and Hillestand (2007) provide the most recent and most comprehensive estimate—$45 to $110 billion.

ensuring the seismic safety of its hospital infrastructure, from an implicit reliance on ex post litigation to the current very detailed regulatory approach. We trace out some unintended consequences of the current regulation for the availability of hospital services. We provide a back-of-the-envelope estimate of the trade-off the state has made to ensure hospital operations after a seismic event. Finally, we discuss a market-based trading system for earthquake-safe bed obligations that could achieve the same functional goal as the mandate—to ensure that hospitals can sustain and, most importantly, remain operational following a major seismic event—but at a lower cost in terms of money, time, and the long-term availability of services. This approach could be adapted to other mandates that take a one-size-fits-all approach to compliance such as the uniform energy efficiency requirements for new building construction included as part of the American Clean Energy and Security Act of 2009.[5]

11.2 Background: California's Seismic Retrofit Requirements

Until quite recently, the state of California relied heavily on the threat of ex post lawsuits to ensure the safety of private buildings and spaces. Regulation, where passed, has often been weak. For example, a law requiring unreinforced masonry buildings to post "earthquake warning" signs stating a building may be unsafe in the event of an earthquake had no penalty for noncompliance. This law was so lax that full compliace did not ensure protection from liability. For example, in a wrongful death lawsuit brought by the families of two women who died in the 2003 San Simeon earthquake, the building's owners, despite being in compliance with all state and local seismic safety requirements, and being on track to comply with a 2018 deadline for seismic reinforcement, were required to pay $2 million in damages because they knew about "the danger and ignored it for years."[6]

California's original hospital earthquake code, the Alquist Hospital Facilities Seismic Safety Act, dates back to 1973. Prompted by the 1971 San Fernando Valley earthquake, it required all *newly* constructed hospital buildings to follow stringent codes. Consequently, according to experts, the pace of new hospital construction was relatively slow in California and in 1990 over 83 percent of hospital beds were in buildings that did not comply with the act (Meade and Hillestand 2007).

After the 1994 Northridge earthquake—a 6.7M earthquake that hit twenty miles northwest of Los Angeles, caused billions of dollars in damage, and left several area hospitals unusable—California amended the Alquist

5. Ironically the heart of the American Clean Energy and Security Act, a.k.a. the "Carbon Cap-and-Trade Bill," is to reduce carbon emissions through a strategy of cap-and-trade.

6. Press release from Friedman | Rubin Trial Lawyers (http://www.frwlaw.us/news.htm).

Act to establish deadlines by which all GAC hospitals had to meet certain seismic safety requirements.[7] The goal of the amendment, SB 1953, was to ensure not only the structural survival of the State's hospitals but also their continued operation after an earthquake (Meade, Kulick, and Hillestand 2002). Table 11.1 describes some of the key provisions of the mandate, which were finalized in March of 1998.[8] By January 2001, all hospitals were to submit a survey of the seismic vulnerability of its building and a compliance plan. Over 90 percent met this requirement (Alesch and Petak 2004). About 70 percent of hospital buildings were deemed to have major nonstructural elements that were not adequately braced to withstand a large earthquake.[9] Hospitals faced a January 1, 2002 deadline for bracing these systems. While we know of no estimates of compliance, this requirement was viewed as a relatively minor aspect of the law. Nonetheless, some (though relatively few) hospitals have requested extensions to comply with this aspect of the mandate.

The first major deadline was January 2008 (or January 2013 with an extension).[10] By this date, all hospitals were to have retrofitted collapse-hazard buildings or taken them out of operation. About 40 percent of hospital buildings were deemed collapse hazards; only 99 or about 20 percent of all hospitals had no such buildings and were thereby in compliance with the 2008 requirements (Meade, Kulick, and Hillestand 2002; Meade and Hillestand 2007). By January 1, 2030, the final SB 1953 deadline, all GAC buildings must be usable following a strong quake. While the legislature thought that hospitals would retrofit collapse-hazard buildings by 2008/2013 and then replace them completely by 2030, most hospitals have chosen to rebuild from the outset due to the high cost of retrofitting. This has effectively moved the final deadline up from 2030 to 2008/2013 and caused an unprecedented growth in hospital construction.

Recognizing that most hospitals would not meet the 2008/2013 deadlines and that initial building assessments were crude, the Office of Statewide Health Planning and Development (OSHPD) authorized on November 14, 2007 a voluntary program allowing hospitals with collapse-hazard buildings to use a "state-of-the-art" technology called HAZUS (Hazards U.S. Multi-Hazard) to reevaluate their seismic risk. Interested hospitals must submit a written request, their seismic evaluation report, and a supplemental report identifying how the original assessment was inaccurate. As of August 2008,

7. Six facilities had to evacuate within hours of the earthquake and twenty-three had to suspend some or all services. See Schultz, Koenig, and Lewis (2003) and http://www.oshpd.ca.gov/FDD/seismic_compliance/SB1953/SeismicRegs/hssa.pdf for details.

8. See http://www.oshpd.state.ca.us/FDD/SB1953/index.htm.

9. For details of how buildings were categorized, see Office of Statewide Health Planning and Development, *Summary of Hospital Seismic Performance Ratings,* April 2001. Available at: http://www.oshpd.ca.gov/FDD/SB1953/sb1953rating.pdf.

10. About 88 percent of hospitals in operation in 2005 applied for an extension to the 2008 deadline and 85 percent (or 96 percent of applicants) received them.

Table 11.1 Key provisions of SB 1953

Date	Requirement
Jan. 2001	Submit risk assessment with NPC and SPC ratings for all buildings and a compliance report plan.
Jan. 2002	Retrofit nonstructural elements (e.g., power generators) and submit a plan for complying with structural safety requirements.
Jan. 2008–Jan. 2013	Collapse hazard buildings should be retrofitted or closed. Extensions available through 2013.
Jan. 2030	Retrofit to remain operational following a major seismic event.

Notes: SPC stands for "Structural Performance Category"; NPC stands for "Nonstructural Performance Category." See http://www.oshpd.ca.gov/fdd/sb1953/FinalJan2008Bul.PDF for extension information.

over 37 percent of GAC hospitals had submitted a HAZUS request.[11] Participation moves the compliance deadline to 2013, if any buildings are still deemed collapse-hazards, or to 2030, if all buildings are reclassified as able to withstand a major earthquake.

Despite the extensions and reclassifications, many hospitals are already engaging in major capital investment projects. Figure 11.1 shows the mean and median value of hospital construction in progress since 1996. After 2001, the year hospitals submitted their building surveys, the mean value of construction in progress rose sharply, from $5.5 to almost $14 million (in 2006 terms). Construction costs increases drive some of this (Davis Langdon, LLP, 2006). While median construction increased as well, this trend started as early as 1996, two years before the details of SB 1953 were finalized. That the median is well below the mean value of construction in progress implies that a few hospitals are spending a lot on construction while the typical hospital is spending much less. Thus, the increase in construction is likely driven by hospitals disproportionately affected by the seismic retrofit mandate and is not simply a general trend.

11.3 Data and Methods

To estimate the effect of SB 1953 on hospital operations, we need to measure exposure to the mandate. Exposure is determined by two factors: (a) a hospital's location, specifically the inherent seismic risk associated with it; and (b) the quality of its buildings. Because building quality may be correlated with hospital operations even absent SB 1953 (e.g., hospitals with more decrepit buildings may be in worse financial condition), we rely on underlying seismic risk to measure exposure. Seismic risk is measured by the

11. Based on author's calculations from data available here: http://www.oshpd.ca.gov/FDD/Regulations/Triennial_Code_Adoption_Cycle/HAZUS_Summary_Report.pdf.

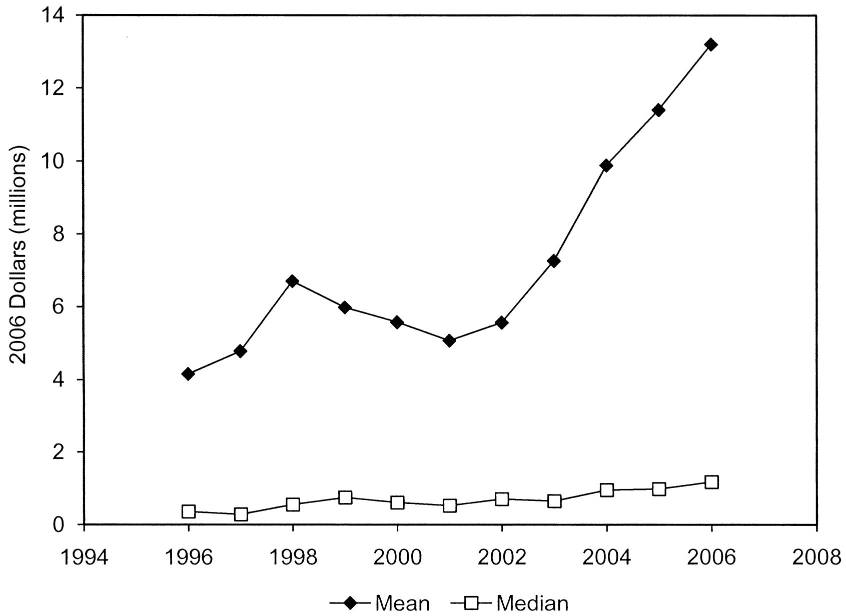

Fig. 11.1 Trends in the mean and median value of construction in progress by California hospitals: Fiscal Years 1996–2006

Source: OSHPD's Annual Hospital Disclosure Reports, 1996–2006.

peak ground acceleration factor (pga), or the maximum expected ground acceleration that will occur with a 10 percent probability within the next fifty years normalized to Earth's gravity.[12] This measure is from the California Geological Survey (CGS) and is matched to every GAC hospital in the state based on exact location.

We assess the relationship between a hospital's seismic risk and several measures of hospital operations—closures, consolidations, and changes in the provision of uncompensated care. Closures are based on OSHPD's Annual Utilization Reports and the California Hospital Association's records for 1996 to 2006.[13] Consolidation data was obtained through a request to OSHPD. Uncompensated care is identified from the 2002 and 2005 Annual Hospital Disclosure Reports (AHDR) as indigent care GAC days, emergency department visits, and clinic visits and is distinct from days/visits reimbursed by county indigent programs. We do not use earlier ADHR data because of changes in the reporting of service provision.[14]

12. This is a standard measure of seismic risk. See http://www.consrv.ca.gov/cgs/rghm/psha/ofr9608/Pages/index.aspx.

13. See http://www.calhealth.org/public/press/Article%5C107%5CClosedHospitals-10-30-08.pdf.

14. Based on discussions with OSHPD, we were advised to not use the data prior to 2001. Results using 2002 to 2006 are quite similar but somewhat less precisely estimated.

Our basic regression specification is:

$$(1) \qquad Y_h = \text{pga}_h + \beta X_h + \gamma_c + \varepsilon_{h,c},$$

where Y_h is our outcome of interest—separate indicators for whether hospital (h) shutdown or merged during the study period or the change in the number of days of care provided to indigent patients; pga_h is a hospital's inherent seismic risk, as measured by its predicted peak ground acceleration factor; X_h is a hospital's observable characteristics, and c is a county fixed effect.

County fixed effects allow us to control for persistent differences in outcomes that are correlated with broad geographic seismic risk patterns. This is important because coastal areas in California are generally wealthier and higher seismic risk than inland areas. In all regressions, we also control for the following basic set of hospital characteristics as of 1992—indicators for whether the hospital was public, for-profit, or not-for-profit (the omitted category); the total number of licensed beds; the license age as of 1992 and its square; and whether the hospital is in a rural area. We also control for the hospital's teaching status—whether it had an accredited residency program—and whether it is part of a multisystem chain. Due to data limitations, teaching and multisystem status are measured as of 1996, two years before the details of SB1953 were finalized.

We analyze closures and mergers, which are both dichotomous outcomes, using both linear probability and probit models. We assess changes in uncompensated care using linear regressions. To allow for spatial correlation in seismic risk and hospital operations, we cluster all standard errors by city.

Our identification strategy, which isolates the mandate's effect on hospital operations so long as underlying seismic risk is as good as randomly assigned within counties, is plausible for several reasons. First, most hospitals in the state were built between 1940 and 1970, at a very early stage in our understanding of seismic risk and well before the development of modern seismic safety standards. Second, new construction has been slow relative to estimates of a reasonable building life span (Meade, Kulick, and Hillestand 2002). And, although many hospitals have built new additions, most are in their original location (Jones 2004). And, many of the new additions have been so well-integrated into the original hospital structure that they will need to be replaced along with the older buildings (Jones 2004). Combined with high seismic variability at relatively small distances (e.g., see appendix figure 11A.1), the result is that well-performing hospitals are unlikely to have selected into "better" locations (along seismic risk dimensions), at least within a locality. Finally, this assumption is consistent with discussions between the authors and seismologists, who lament the fact that seismic risk is factored into building construction on only a very gross, highly-aggregated level (e.g., by county), and is further corroborated by empirical tests (shown following) of the distribution of observables.

11.4 Results

11.4.1 Descriptive Statistics

Table 11.2 provides basic descriptive statistics for nonfederal general acute care hospitals in California during our study period, 1996 to 2006. We show the summary statistics for the full sample and then separately for hospitals that are above and those that are at or below median seismic risk. The first row describes mean seismic risk, as measured by the maximum ground acceleration that is expected with a 10 percent probability over the next fifty years, normalized to Earth's gravity. Overall, the mean seismic risk is just below 0.5 g. It varies from a minimum of 0.05 and maximum of 1.15 g's and follows a rather bell-shaped distribution (see appendix figure 11A.2). The next set of rows show the means of the outcomes studied here. About 13 percent of hospitals closed between 1996 and 2006; closure rates do not vary across high and low seismic risk areas. About 12 percent of hospitals consolidated their licenses (i.e., merged their license with another hospital). Although consolidation rates are higher in high pga areas—13.7 versus 10.7 percent—these differences are not statistically significant. Similarly, hospitals in high g areas provide more total days of indigent care but the difference is not statistically distinguishable from zero.

The next set of rows provides means for the control variables included

Table 11.2 **Summary statistics by seismic risk status**

	Full sample	Above median pga	At or below median pga
Seismic risk, pga	0.480	0.659	0.326
	(0.207)	(0.130)	(0.118)
Closed after 1996	0.134	0.133	0.134
Consolidated after 1996	0.121	0.137	0.107
Indigent care days, 2002	271	296	249
	(901)	(994)	(816)
Public, 1992	0.186	0.171	0.200
For-profit, 1992	0.283	0.294	0.273
Not-for-profit, 1992	0.531	0.535	0.527
Multisystem, 1996	0.364	0.370	0.359
License age, 1992	61.3	60.4	62.0
	(13.7)	(14.2)	(13.2)
Licensed beds, 1992	203	234	177
	(188)	(223)	(147)
Residency program, 1996	0.261	0.309	0.221
Rural	0.090	0.005	0.163
Observations	456	211	245

Notes: Seismic risk is measured by the peak ground acceleration (pga) expected with a 10 percent probability over the next fifty years normalized to the Earth's gravity.

in our main regressions. About 19 percent of hospitals in our sample are government-owned; 28 percent are investor-owned, for-profit institutions. Although investor-owned are slightly more common (29.4 versus 27.3 percent) and government-owned slightly less common (17.5 versus 20.5 percent) in above-median pga areas, these differences are both small in magnitude and statistically insignificant. About 36 percent of hospitals were part of a multisystem chain in 1996, the first year we have such data. This characteristic is relatively invariant across low and high pga areas. Although we do not have building age, we can proxy for this by looking at the age of a hospital's license. We measure age as of 1992, the first year of our annual utilization report data. Consistent with Meade and Hillestand (2007), we find that the average GAC hospital is over sixty years old. Hospitals in above seismic risk areas are slightly newer—60.4 versus 62—although this difference is small and statistically insignificant. Starker differences emerge when we look at bed size and teaching status. The average GAC hospital had 203 beds in 1992. But, in high pga areas the mean is 234 beds and in low pga areas it is only 177. Overall, 26 percent of hospitals have a residency program in place in 1996. In high pga areas, over 30 percent have a program, whereas only 22 percent of hospitals in low pga areas have one. These differences in bed size and teaching status partly reflect the fact that low pga areas are disproportionately rural. About 16 percent of hospitals in low pga areas are rural, in contrast to less than 1 percent in high pga areas. Importantly, our analysis uses within-county comparisons in seismic risk, which eliminates much of the urban-rural differences. As we will show next, most of our baseline characteristics do not differ systematically with seismic risk once we control for county.

In table 11.3, we look at the within-county correlation between characteristics of the hospital itself as well as its neighborhood, defined as the hospital's zip code of operation and all zip codes within a five-mile radius of it. We run regressions, similar to equation (1), of a hospital's 1992 or 1996 characteristics, depending on availability, as well as the 1989 level and the 1989 to 1999 change in a hospital's neighborhood characteristics on seismic risk. In all cases we include an indicator for rural status, based on an OSHPD designation, and county fixed effects, because of systematic differences in seismic risk across larger areas within the state.[15] Except where used as a dependent variable for the purposes of this randomization check, our models control for a hospital's license age and its square, the number of licensed beds in 1992 and dummies for 1992 ownership status. In all models, standard errors are clustered at the city level to allow for spatial correlation in seismic risk.

15. For example, San Francisco County is both high seismic risk and high income relative to Sacramento County. As a result, our identification uses only within-county variation in seismic risk. Within-city variation would be even cleaner but many small to medium cities have only one hospital.

Table 11.3 **Seismic risk and the distribution of hospital observables**

A. 1992 hospital characteristics					
	Share public	Share NFP	License age	Share with ER	Log (Avg. GAC Los)
pga	0.018	0.007	–8.61	–0.034	0.200
	(0.233)	(0.268)	(7.25)	(0.177)	(0.202)
R^2	0.352	0.108	0.100	0.268	0.089
Mean dep. var.	0.213	0.500	61.0	0.703	1.61
Observations	370	370	370	370	370

B. 1996 hospital characteristics					
	Share with detox prog.	Share with NICU	Share with MRI	Share with blood bank	Indigent program
pga	0.166	–0.005	–0.039	–0.129	–0.525
	(0.172)	(0.189)	(0.228)	(0.281)	(0.237)
R^2	0.033	0.106	0.096	0.111	0.423
Mean dep. var.	0.155	0.145	0.456	0.675	0.508
Observations	370	370	370	370	370

C. Neighborhood characteristics, 1989					
	Log pop.	Share below FPL	Share Hispanic	Share 5–17 years old	Log median income
pga	0.347	–0.030	0.026	–0.003	0.130
	(0.698)	(0.028)	(0.078)	(0.014)	(0.130)
R^2	0.745	0.296	0.514	0.454	0.459
Mean dep. var.	292,165	0.130	0.249	0.179	34,924
Observations	369	369	369	369	369

D. Growth in neighborhood characteristics, 1989–1999					
	Pop.	Share below FPL	Share Hispanic	Share 5–17 years old	Median income
pga	0.025	0.287	0.090	0.056	–0.022
	(0.078)	(0.127)	(0.099)	(0.076)	(0.061)
R^2	0.412	0.402	0.351	0.347	0.564
Mean dep. var.	0.105	0.187	0.349	0.079	0.315
Observations	369	369	369	369	369

Notes: Dependent variables are from OSHPD's Hospital Annual Utilization Reports (panel A), OSHPD's Hospital Annual Financial Data (panel B), the 1990 Census (panel C) and the 1990 and 2000 Census (panel D). Dependent variables in panels C and D are based on zip codes within five miles of a hospital. All models include county fixed effects and a rural indicator. Except where used as a dependent variable, models also control for a hospital's license age and its square, the number of licensed beds in 1992 and dummies for 1992 ownership status. Standard errors are clustered at the city level to allow for spatial correlation in seismic risk.

NICU = Neonatal Intensive Care Unit; FPL = federal poverty level; NFP = not-for-profit.

Unlike our main results, we generally find no significant correlation between seismic risk and our hospital or neighborhood characteristics. Panel A presents results for hospital characteristics in 1992. The correlation between seismic risk and the probability that a hospital is government-owned or not-for-profit is small and imprecise. The relationship between seismic risk and a hospital's age, the probability it had an emergency department, or its average length of stay is also insignificant. And the implied effects are small. For example, a 1 standard deviation increase in seismic risk, approximately 0.2 g, is associated with about 1.7 fewer license years off a base of sixty-one years. Moreover, a 1 standard deviation increase in seismic risk implies a 0.7 percentage point lower probability of having an emergency room, off a base of 70 percent, and 4 percent longer average length of stay. In results not shown here, we also tested for differences by ownership status by including interactions between pga and indicators for public and for-profit status (with not-for-profit the omitted category). We do this since we have found some differences by ownership in the way hospitals respond to the mandate (see Chang and Jacobson 2008). However, we find no evidence that baseline hospital characteristics differ significantly by ownership status.

For four of the five 1996 characteristics presented in panel B—the share of hospitals with a drug detoxification program, the share with a Neonatal Intensive Care Unit (NICU), the share with MRIs, and the share with blood banks—the correlation with seismic risk is similarly small and imprecise. The one exception is the probability of participating in a county indigent care program. A 1 standard deviation increase in seismic risk is associated with an 11 percentage point lower probability of participating in the program off a base of about 50 percent. The effects do not differ by ownership status.

Panels C and D provide results for the correlation between seismic risk and the characteristics of the neighborhoods surrounding a hospital. We find no significant relationship between seismic risk and the 1989 characteristics of their neighborhoods—the population, the share living below the federal poverty line, the share Hispanic, the share five to seven years old, and the log median income—regardless of ownership status. When we look at growth in these characteristics between 1989 and 1999, we find no significant relationship in four out of five cases. A 1 standard deviation increase in seismic risk is associated with almost 6 percentage points higher growth in the share living below the federal poverty line in the neighborhoods surrounding hospitals off a base of 19 percent. Estimates by ownership status reveal that the effects are concentrated in the neighborhoods around public and not-for-profit hospital. The effect is indistinguishable from zero in the case of for-profit hospitals.

Nonetheless, in eighteen out of twenty cases seismic risk is largely uncorrelated with hospitals' characteristics, both overall and by ownership status. Thus, we conclude that a hospital's underlying seismic risk is broadly unrelated to a host of pre-SB 1953 hospital characteristics, (such as not-for-profit status), and neighborhood demographics (such as median household income within a five-mile-radius of the hospital). Consequently, seismic risk, a key determinant of the cost of mandate compliance, will enable us to identify the implications of this regulation.

11.4.2 Regression Results

To the extent that SB 1953 increased the cost of capital, as hospitals compete for scarce financing resources, the mandate may have had the unintended consequence of increasing closures. For example, if equity and bond ratings decline for those with higher seismic risk (i.e., hospitals with higher leverage), some hospitals may have more difficulty financing their day-to-day activities and may choose to shut down.[16]

Hospital closures are not new to California and may be an important way for inefficient hospital systems to reduce capacity. For our purposes, the important question is whether SB 1953 had an independent effect on this process. We test this possibility in table 11.4 by modeling the probability that a hospital shuts down after 1996. Over our study period fifty-five hospitals, or almost 12.5 percent, closed. We present both linear probability and probit models overall (columns [1] and [3], respectively) and by ownership status (columns [2] and [4]). A shown in columns (1) and (3), seismic risk has a significant impact on the probability of closure after 1996: a 1 standard deviation increase in the ground acceleration factor increases the likelihood of closure by 6 to 7 percentage points off a base of 14 to 15 percent. This effect does not differ by ownership status.

The results in table 11.4 clearly indicate that seismic risk, an important predictor of the impact of SB 1953, increases the probability of hospital closure. To further test the validity of this conclusion, appendix table 11A.1 tests whether seismic risk is correlated with hospital closures between 1992 and 1996. Of the sixteen hospital closures during this period, six of them occurred in 1992 and 1993, before the Northridge earthquake that prompted the passage of SB 1953, while the rest occurred prior to the finalization of the details of the mandate. If seismic risk predicts these closures this would raise considerable doubt as to the causal effect of the mandate.

We find no evidence to suggest that seismic risk predicts pre-1997 hospital closures. In appendix table 11A.1, the correlation between seismic risk and closure is negative, small in magnitude, and indistinguishable from zero across both the ordinary least squares (OLS) and Probit models. Given the relatively low rate of closure over this period—just under 4 percent—the Probit model may be more appropriate. However, because closures were con-

16. In a 2009 California Hospital Association survey of hospital CFOs, 64 percent of those surveyed said that they were having trouble accessing enough "affordable capital" to comply with SB1953.

Table 11.4 The impact of seismic risk on the probability of hospital closures: 1997–2006

	OLS		Probit	
Seismic risk, pga	0.338	0.326	0.287	0.331
	(0.139)	(0.140)	(0.137)	(0.162)
pga · for-profit		–0.046		–0.093
		(0.268)		(0.199)
pga · government		0.090		0.053
		(0.209)		(0.210)
For-profit	0.118	0.141	0.060	0.071
	(0.053)	(0.150)	(0.051)	(0.053)
Government	0.001	–0.044	–0.027	–0.013
	(0.044)	(0.132)	(0.037)	(0.048)
Probability	0.134	0.134	0.163	0.163
Adj. R^2	0.048	0.043		
Observations	429	429	320	320

Notes: All models include county fixed effects. We also include controls for the number of licensed beds in 1992, the license age in 1992 and its square, 1992 ownership status (government-owned or for-profit, with not-for-profit status excluded), rural status, 1996 teaching status and 1996 multihospital system status. Teaching status and system status are measured as of 1996 because of data limitations. Standard errors are clustered at the city level to allow for spatial correlation in seismic risk.

centrated in a few counties and closures by ownership status varied very little within counties over this period, we are unable to estimate Probit models with interaction effects. Based on a linear probability model, we find no evidence of seismic risk effects, irrespective of ownership status. This suggests that the mandate is not simply exacerbating preexisting trends in hospital closures, which were concentrated in for-profit facilities (see Buchmueller, Jacobson, and Wold 2006). It also implies that local governments are not shielding their hospitals from the financial pressure associated with SB 1953. Finally, our results highlight the importance of weighing the benefit of having "earthquake-proof" hospitals against the cost of fewer hospitals overall. Whether policymakers were aware of this potential cost when they passed SB 1953 is unclear, but seems unlikely as the closures disproportionately affect hospitals with higher levels of seismic risk (i.e., the very hospitals policymakers wanted to be operational in the event of an earthquake).

We next consider the impact of seismic risk on hospital consolidations. We might expect consolidations to increase in response to SB 1953 as hospitals attempt to achieve economies of scale in service provision or other aspects of hospital operations (Cuellar and Gertler 2003). This would give them more financial flexibility to deal with the cost of the mandate. It may also improve their access to "affordable" capital, allowing one or both of the hospitals involved in the merger to more easily obtain financing. The results in table 11.5 suggest that these possibilities may indeed be important.

Table 11.5 The impact of seismic risk on the probability of hospital consolidations: 1997–2006

	OLS		Probits	
Seismic risk, pga	0.252	0.210	0.386	0.302
	(0.136)	(0.123)	(0.197)	(0.201)
pga · for-profit		0.133		0.078
		(0.274)		(0.260)
pga · government		0.102		0.238
		(0.261)		(0.328)
For-profit	0.071	0.064	0.080	0.036
	(0.053)	(0.111)	(0.060)	(0.169)
Government	–0.013	0.005	–0.030	–0128
	(0.048)	(0.150)	(0.060)	(0.105)
Probability	0.121	0.121	0.179	0.179
Adj. R^2	.205	.205		
Observations	429	429	291	291

Notes: All models include county fixed effects. We also include controls for the number of licensed beds in 1992, the license age in 1992, the license age in 1992 and its square, 1992 ownership status (government-owned or for-profit, with not-for-profit status excluded), rural status, 1996 teaching status, and 1996 multihospital system status. Teaching status and system status are measured as of 1996 because of data limitations. Standard errors are clustered at the city level to allow for spatial correlation in seismic risk.

A 1-standard deviation increase in the ground acceleration factor increases the probability of a merger by 5 to 8 percentage points. Estimates with interactions between seismic risk and ownership status are quite imprecise and do not allow us to reject similar effects of the mandate on consolidations across for-profit, public, and not-for-profit hospitals.[17] Assuming the effects are causal and drawing on prior research on hospital mergers, these results point to another potential unintended consequence of SB 1953—an increase in prices.[18] Whether prices actually rose is an area for future research.

In table 11.6, we assess whether hospitals that are financially squeezed by the mandate cut back on indigent care. When not differentiating by ownership type, we find small and imprecise negative effects of seismic risk on indigent care (not shown here). Breaking the effects out by ownership type, however, we find that government-owned hospitals unambiguously respond to seismic risk by changing their provision of uncompensated care. A 1-standard deviation increase in seismic risk is associated with about 330 fewer days of indigent care. This estimate, which is distinguishable from zero at the 10 percent level, is driven largely by GAC days (as opposed, for example, to psychiatric days). A 1-standard deviation increase in seismic risk is

17. We requested but have thus far not received pre-1997 merger data from the state to run a placebo test like the one performed for closures.

18. Dafny (2005) provides a nice review of the hospital merger literature as well as original evidence on the issue of price increases after hospital mergers.

Table 11.6 **The impact of seismic risk on changes in the provision of uncompensated care: 2002–2005**

	Total days	Total GAC days	ER visits	Clinic visits
Seismic risk, pga	408	259	321	691
	(363)	(345)	(542)	(881)
pga * for-profit	–183	–206	–179	–120
	(420)	(391)	(904)	(1,264)
pga * government	–2,069	–1,351	–2,300	–5,426
	(932)	(682)	(1,573)	(2,642)
For-profit	220	180	223	–389
	(212)	(195)	(430)	(770)
Government	1,100	725	1,278	1,938
	(556)	(411)	(894)	(1,150)
Mean days/visits	271	213	302	302
Adj. R^2	.030	.042	.103	.054
Observations	353	353	353	353

Notes: All models include county fixed effects. We also include controls for the number of licensed beds in 1992, the license age in 1992 and its square, 1992 ownership status (government-owned or for-profit, with not-for-profit status excluded), rural status, 1996 teaching status and 1996 multihospital system status. Teaching status and system status are measured as of 1996 because of data limitations. Standard errors are clustered at the city level to allow for spatial correlation in seismic risk.

associated with about 220 fewer indigent GAC days in public hospitals. High seismic risk public hospitals appear to reduce indigent ER visits, although our estimate is not statistically distinguishable from zero. They do, however, clearly cut free/reduced price clinic visits. A 1-standard deviation increase in seismic risk is associated with over 900 fewer visits. How hospitals reduce these visits is unclear from our data. They may, for example, limit operating hours, the number of patients per hour, or both.

That public hospitals with greater exposure to SB 1953 reduce uncompensated care suggests that the mandate has forced public hospitals to cut back on their altruistic goals, at least in the near term. We have found no evidence to suggest that policymakers anticipated this effect as a cost of insuring the earthquake safety of all hospitals in the state.

11.5 Discussion

Seismologists agree that the question of a major earthquake in California is not one of whether but when. Researchers at the Southern California Earthquake Center estimate an 80 to 90 percent chance that a temblor of 7.0 or greater magnitude will hit Southern California before 2024 (Chong and Becerra 2005). And earthquake risk is as high, if not higher, in parts of Northern California. Thus, California's desire to safeguard its health care infrastructure is eminently sensible.

While ex ante regulation is the obvious way to handle the market's failure to ensure access to care in the event of a serious earthquake, our results raise some serious questions about the wisdom of the current approach. Does the value of retrofitting or rebuilding hospitals to remain operational following an earthquake outweigh the cost of fewer hospitals overall? The potential for higher hospital prices raise additional issues.

Even putting these unintended consequences aside, the gain from ensuring every hospital's viability post-earthquake may not be worth the direct cost of retrofitting and rebuilding. The most comprehensive estimates of the construction costs imposed by SB 1953 range from $45 to $110 billion. Assuming a modest value of a statistical life of $2 million (see Viscusi and Aldy 2003), this would imply that 22,000 to 55,000 lives would need to be saved for the mandate to be worth the cost. Officials attribute sixty-one deaths to the Northridge Earthquake and some work suggests that an additional 100 cardiac arrests can be tied to the quake (Leor, Poole, and Kloner 1996).[19] A similar number of deaths have been attributed to the Loma Prieta Earthquake, which occurred five years earlier south of the Bay Area, and the Sylmar Earthquake, which occurred in northern Los Angeles County in 1971.[20] Thus, even assuming (a) the RAND cost estimates are overstated by an order of magnitude, (b) deaths are undercounted by an order of magnitude, and (c) earthquake-proof hospitals could have prevented all deaths, the benefits of the mandate hardly seem worth the cost.[21]

Obviously, this back-of-the-envelope calculation is a gross oversimplification. Injuries may be more common than deaths—the Northridge, Loma Prieta, and Sylmar earthquakes each caused several thousand injuries—and smoothly functioning hospitals may be indispensable for treating the injured and providing ongoing care to existing patients. Nonetheless, our work suggests that the costs of SB 1953 likely swamp the benefits.

11.6 Alternative Approach

Given the high risk of a devastating earthquake in California and evidence that private parties do little to insure against earthquake risk (e.g., see Palm 1981, 1995), the broad goals of SB 1953 and, in particular the move away from an ex post litigation approach, seem sensible. But more cost-efficient regulatory approaches may exist. For example, the state could pass a "functional" requirement that each GAC hospital "provide" a certain number of earthquake-proof beds. A hospital could provide these beds by retrofitting or rebuilding its own infrastructure according to SB 1953 standards. Alter-

19. Estimates of deaths attributable to the Northridge quake vary somewhat, although all are under 100. The number reported here is from the California Geological Survey: http://www.consrv.ca.gov/cgs/geologic_hazards/earthquakes/Pages/northridge.aspx.

20. See Nolte (1999) and http://earthquake.usgs.gov/regional/states/events/1971_02_09.php.

21. Many of the Sylmar deaths were caused by the collapse of a VA hospital. The VA hospitals are not subject to SB 1953.

natively, a hospital could contract with other hospitals within a defined area to provide those beds. In other words, to cover their burden, hospitals that faced a high cost of retrofitting could contract with hospitals that could more cost-effectively provide earthquake-safe beds. In this way, retrofitting would be concentrated among the hospitals in a market that could most cost-effectively do so.

This approach is akin to a carbon-trading system. Instead of permits to pollute, hospitals would have earthquake-proof bed obligations. The OSHPD would determine the number of beds each hospital is required to provide as well as the geographic boundaries of its market. Following the Acid Rain Program, the allocation could be based on the average of beds licensed and staffed by each hospital in a three- or four-year-period prior (e.g., 1993 to 1996) to the mandate. Hospitals could then trade bed obligations with other hospitals in the same market. In this way, hospitals that have a high cost of providing retrofitted beds would pay those with lower costs to provide them. The significant variation in underlying seismic risk (and therefore significant variation in the cost of new seismically safe construction), suggests that even in the absence of any economies of scale, there will be significant variation in the cost of providing seismically safe beds.

In markets with only one hospital, this trading system will not be feasible. For markets with at least two hospitals, however, this system would provide a more cost-effective means to ensure "operational readiness" in the event of a quake. The cost-efficiency should be greatest in markets with the most hospitals. Moreover, this system should prevent many of the closures and possibly mergers caused by SB 1953.

Lessons from the U.S. experience with environmental policy regulation suggest that this type of market-based policy instrument could be well-suited to ensuring hospital seismic safety (see Stavins 1998; Schmalensee et al. 1998; Ellerman et al. 2003). As in the case of pollution abatement, hospitals likely face very different costs of compliance, even within the same region. Some hospitals may have buildings that are close to the end of their life span and thus nearing a point to retrofit or rebuild even in the absence of the mandate; others may be in relatively new but still noncompliant buildings. Similarly, some hospital buildings may be on lots that—because they sit on the side of a hill or on relatively porous soil—are fundamentally costlier to retrofit. Allowing hospitals to contract amongst themselves would ensure the availability of earthquake-proof beds at the lowest cost.

California has built a large infrastructure to enforce SB 1953. We do not anticipate that the state will reverse course. The proposed system, however, can provide lessons for policymakers considering one-size-fits all regulation. In the most direct sense, this proposal could prove useful in Seattle, where the City Council is currently considering citywide seismic safety measures.[22]

22. See "New Seattle earthquake study targets up to 1,000 buildings," *Seattle Post Intelligencer,* May 14, 2008.

But areas prone to hurricanes, tornados, or other disaster scenarios may benefit from similar approaches to cost-effectively improve the performance of critical facilities in the event of catastrophe. More generally, using a cap-and-trade type system may be more efficient than a one-size-fits-all mandate in changing standards for an entire class of goods or services when there is heterogeneity in production. Thus, even where ex ante regulation clearly dominates ex post litigation, the specific form of regulation chosen can offer important efficiency gains.

Appendix

Table 11A.1 The impact of seismic risk on the probability of hospital closures: 1992–1996

	OLS		Probit
Seismic risk, pga	–0.013	–0.010	–0.004
	(0.080)	(0.071)	(0.005)
pga · For-profit		–0.056	
		(0.103)	
pga · Government		–0.056	
		(0.176)	
For-profit	0.064	0.036	0.060
	(0.026)	(0.095)	(0.051)
Government	0.033	0.061	0.010
	(0.026)	(0.072)	(0.008)
Probability	0.036	0.036	0.069
Adj. R^3	0.121	0.121	
Observations	443	443	231

Notes: All models include county fixed effects. We also include controls for the number of licensed beds in 1992, the license age in 1992 and its square, 1992 ownership status (government-owned or for-profit, with not-for-profit status excluded), and rural status. Standard errors are clustered at the city level to allow for spatial correlation in seismic risk. OLS = ordinary least squares.

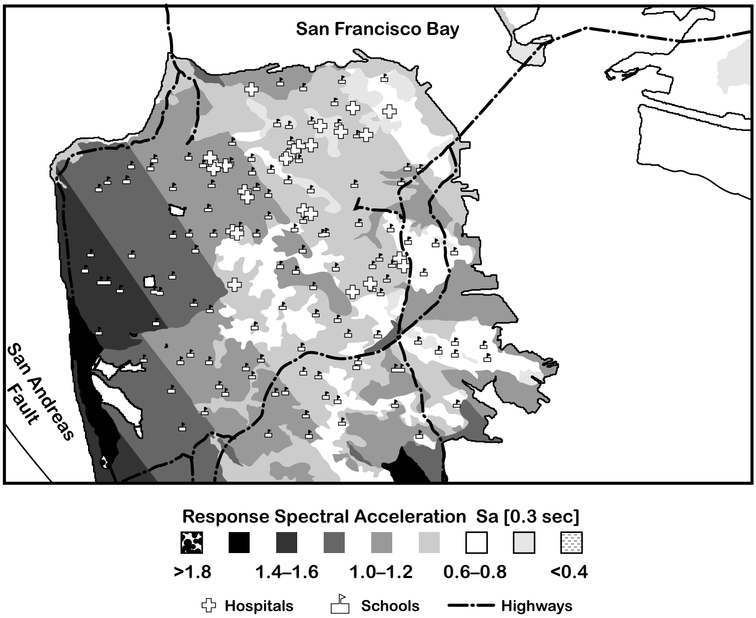

Fig. 11A.1 A map of expected ground acceleration in the event of an earthquake similar to the great quake of 1906

Source: U.S. Geological Survey.

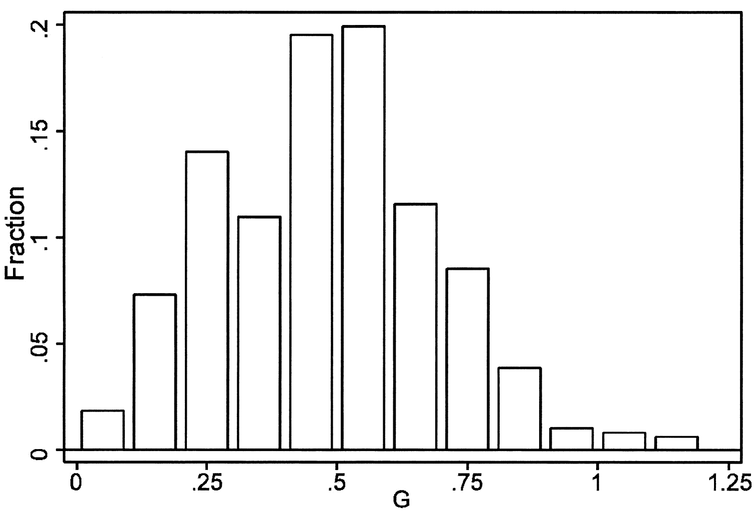

Fig. 11A.2 Frequency distribution of seismic risk among California hospitals

Sources: U.S. Geological Survey; OSHPD.

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