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Financial Leverage and Hospital Technology Adoption

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Abstract:

I examine the impacts of financial leverage on hospitals' technology adoption of capital-intensive diagnostic and therapeutic radiology services. I use the California Seismic Retrofit Mandate as an exogenous financial shock and interact it with the predetermined financial leverage level to account for the endogeneity problem between financing and operating decisions. Surprisingly, I find that financial leverage does not have significant effects on technology adoption. I do find technology adoption is positively related to hospital size and operating margin, and negatively correlated with system affiliation. Due to a small sample size, it will be worthwhile to include more hospitals in multiple states in an extended study.

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The Detroit Medical Center (DMC) says that while it has made money for seven years, it can't attract donor or investment money for key projects it needs to renovate its aging facilities or to build new ones, such as Cardiovascular Institute or expansion of Children's Hospital of Michigan. As a result, 40% of the people who live near the DMC campus or near its Sinai-Grace Hospital in northwest Detroit leave for care in the suburbs - even though the DMC has some of the state's top ranked physicians.

-- Detroit Free Press, March 20th 2010

I. INTRODUCTION

This paper investigates the effects of financial leverage on hospitals' production decisions, particularly on the adoption of capital-intensive technology. One consequence of using high financial leverage is that it may deplete borrowing capacity and face the difficulty of raising additional funds. In addition, high interest expenses can also crowd out the funds for other operating activities. For example, Matsa (2011) finds that high leverage undermines supermarket firms' product quality. In the hospital industry, high financial leverage can also hinder hospitals' ability to replace their aging facilities and outdated technology. A 2010 merger between Detroit Medical Center (DMC) and Vanguard Healthcare System demonstrated that in extreme cases the consequences are so severe that they lead to an ownership transaction[2].

While extensive studies have discussed the association between financial performance and undesired consequences, most focus on hospitals' profitability. Several studies have examined the effects of profitability on hospital performance and found weak or mild relationships. For example, Bazzoli et al. (2008) find a weak relationship between profitability and quality of patient care and Shen (2002) reports that hospitals with higher financial pressures have adverse health outcomes in the short run but not over the long term. Overall, in contrast to general perceptions, previous studies have concluded that profitability has only limited impacts on the delivery of health services.

Furthermore, it is not clear whether poor financial decisions lead to undesired health consequences or whether the causality actually goes in the opposite direction (i.e., the poor hospital operational performance leads to financial distress). This paper differs from the literature by investigating the casualty of financial leverage on hospital operations. In particularly, I focus on the impacts of financial leverage on adoption of capital-intensive technology.

To facilitate the empirical analysis, I obtain key financial information from a California hospital dataset and technology adoption variables from the American Hospital Association (AHA) Annual Survey. To establish a causal relationship between financial leverage and technology adoption, I also interact financial leverage with hospitals' exposure to the California Seismic Retrofit Mandate. This approach is similar to Zingales's (1998) paper in which he uses

[2] *Vanguard Healthcare System agrees to retire $368.1 million of DMC bonds and other long-term debt and invest up to $850 million for capital projects.*

Carter administration's deregulation to examine whether highly leveraged truck firms are more likely to be financially constrained. The retrofit mandate requires hospitals to replace or improve buildings that are exposed to significant seismic risks. Because most hospitals were built before the mandate was enforced, the exposure to seismic risks serves as an exogenous financial shock that crowds out the financial resources available for operating activities and clinical investments. The interaction term between the predetermined financial leverage and exposure to seismic risks provides the information about whether the retrofit mandate has differential impacts for highly leveraged hospitals than for less leveraged hospitals.

Overall, I find no significant relationship between the level of financial leverage and adoption of radiology technology. The insignificant results are consistent for both the probit model and the exogenous financial shock model. However, the results should be interpreted with caution. Only about 200 hospitals are available in this analysis. Therefore, it is possible that the insignificant results coming from the small sample size. Incorporating more hospitals in other states will be an important extension.

II. CONCEPTUAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

This paper focuses on one of the negative consequences of debt financing: High financial leverage can lead to financial constraints. Tirole (2006) provides the theoretical perspective in which he incorporates moral hazard and agency cost to explain that high-debt firms will be more likely to be credit constrained because over-leverage may distort the incentives of entrepreneurs to misbehave at the cost of lenders. If over-leverage does lead to financial constraints, a highly leveraged organization will have limited access to external capital to finance an investment project that would otherwise generate positive returns. Dranove et al. (2013) finds that hospitals are likely to postpone technology improvements when they face a lump-sum financial shock. Therefore, one may expect highly leveraged hospitals to be less likely to adopt capital-intensive technology because they are more likely to be financially constrained and because interest expense can crowd out funds available for technology investments. This leads to the first hypothesis:

H1a: Hospitals with high existing financial leverage are less likely to adopt capital-intensive technology.

However, on the other hand, a highly leveraged hospital can be more aggressive in adopting technology to generate cash flows from the more profitable services. Because hospitals often have objectives beyond profit maximization, they provide both profitable and unprofitable services. Horwitz and Nichols (2009) identify relatively profitable and unprofitable hospital services. The more profitable services include computed-assisted tomography (CT) scans, diagnostic radioisotope facilities and the radiation therapy, positron emission tomography, and ultrasound. Most of these services require significant investments in medical technology. The relatively unprofitable services include the emergency department, hospice, and psychiatric services. Therefore, because of the difficulty of raising external capital, a highly leveraged hospital may actually be more likely to adopt medical technology to provide more profitable services and forgo less profitable services. This leads to a competing hypothesis as follows:

H1b: Hospitals with high existing financial leverage are more likely to adopt capital-intensive technology that can be used for more profitable services.

Competitive Effects of Financial Leverage

An organization's leverage level does not affect only its own operating activities. Researchers have expressed interests in the implications of financial leverage on product market competition. For example, Chevalier and Scharfstein (1996) find that highly leveraged grocery stories face severe liquidity constraints and are more sensitive to operating cash flows. Compared to unconstrained stores, constrained stores charge higher prices and further soften the price competition in local markets. Furthermore, they find that new entrants also target the constrained incumbents and initiate price competition to force the latter to exit. Khanna and Tice (2004) use a different sample of discount department stores and find similar results. In contrast, Busse (2002) finds that airlines with poor financial condition are more likely to start price wars; Zingales (1998) uses data from the trucking industry and finds that when the market becomes more competitive, highly leveraged firms are associated with less capital expenditure and lower prices, and they are more likely to exit. Overall, the literature has documented that financial leverage interact with product market decisions but the specific impacts depend on the market structure and industry details. Following the literature, one may expect that highly leveraged hospitals are less likely to adopt medical technology and thus have a competitive disadvantage versus hospitals with a lower leverage level. This leads to hypothesis 2, similar to hypothesis 1a:

H2: Hospitals with high existing financial leverage are less likely to adopt capital-intensive technology that is used for profitable services.

For-profit vs. nonprofit ownership

One prominent feature of the hospital industry is the mix between for-profit and not-for-profit ownership. In addition to many researchers who have studied the differences among the objective functions of the two organizational forms, for-profits and not-for-profits also have their advantages and disadvantages in raising capital. Compared to for-profit hospitals, not-for-profits have the advantage of lower costs through tax-exempt debt financing and are mostly constrained for equity financing. Also, it is somewhat easier for not-for-profits to receive donations as an alternative method of financing. For-profit hospitals, like other for-profit corporations, can raise funds through both equity and debt markets. Despite these differences, because not-for-profits have more limited equity-financing channels, with equal financial leverage levels, not-for-profits are more likely to be financially constrained than for-profits. Reiter et al. (2008) finds that when borrowing capacity is binding, highly leveraged not-for-profit hospitals reduce their capital expenditures. Overall, one may expect to see that financial leverage has larger impacts on not-for-profits. Thus, I propose hypothesis 3:

H3: Highly leveraged not-for-profit hospitals are less likely to adopt medical technology than for-profits with an equal leverage level.

Revenue Growth

One way to examine whether financial leverage leads to competitive disadvantages is to compare the revenue growth between the highly leveraged and the less leveraged hospitals (Campello, 2006; Zhu, 2011). Much of the capital-intensive medical equipment is required for the hospitals to provide profitable services. Therefore, if financial leverage does hinder the adoption of medical technology, one should also observe slower revenue growth for highly leveraged hospitals. Thus, I propose hypothesis 4:

H4: The revenue growth of highly leveraged hospitals is slower than that of hospitals with low financial leverage.

III. EMPIRICAL ANALYSIS

Data

As acknowledged in the field of health care finance, reliable and detailed hospital financial statement information has been the major challenge in conducting empirical analysis (Magnus and Smith 2000). Researchers often make the trade-off between the detailed but small state dataset and the large but unaudited national sample. This study focuses on California hospitals because of the availability of reliable hospital financial statement information and a potentially exogenous financial shock from the California Seismic Retrofit Mandate. In addition to financial data, I obtain technology adoption data from the AHA Annual Survey, which provides detailed information on the adoption of major medical technology, particularly on capital-intensive radiology services. I also include the Area Resource File to control for market-level variables such as the county median income. The Healthcare Cost and Utilization Project's State Inpatient Dataset (HCUP-SID) is also used to account for heterogeneous patient mixes among the hospitals.

Hospital Financial Data

California's Office of Statewide Health Planning and Development (OSHPD) has collected audited hospital financial statements annually since 1976 and this dataset has been used extensively in previous studies. I extract both financial and non-financial hospital variables from this dataset. The hospital characteristics include ownership type (e.g. for-profit vs. not-for-profit), number of hospital beds, and teaching or rural status. The system affiliation information is obtained from the California Hospital Project, administrated by Center for Health Financing, Policy, and Management at University of Southern California. For meaningful comparison, I restrict the analysis sample to short-term general acute care hospitals (ST-GACs) because specialty hospitals and long-term GAC hospitals provide significantly different services. About 300 hospitals are in the sample and 67.1% of them are affiliated with healthcare systems. Of the hospitals 24.4% are for-profit and 70.6% are not-for-profit. On average, a hospital has 199.2 available beds. Only 5.9% of the hospitals are teaching hospitals and 18.2% are rural.

Financial Performance

Financial leverage (debt-over-asset ratio) is the primary financial variable that is used in the analysis. Because I focus on financial constraints as the main consequences of financial leverage, I also use other financial measures, including cash flow from operating activities and interest expenses to examine whether the results from leverage analysis are consistent and robust.

Ex-ante financial leverage

The financial leverage ratio is defined as the total liability over the total asset, the broadest definition of financial leverage. Because the exogenous financial shock, the California Seismic Retrofit Mandate, has only been effectively enforced since 2001, I use the financial leverage ratio in 1999 as the proxy for the leverage level prior to the financial shock. California hospitals have financial leverage with a ratio of the mean of 0.63. About 68.6% of hospitals have a debt-to-assets ratio above 50% and 23.4% have negative equity value. California not-for-profit hospitals have slightly higher financial leverage than for-profits (0.64 vs. 0.59). The hospitals with higher financial leverage are generally smaller. Hospitals with negative equity value have 177.4 available beds on average, compared to 199.2 available beds for the entire sample.

Operating Cash Flow over Total Asset

I use the ratio of operating cash flow over assets to measure the ability to generate cash flow internally. According to *pecking order theory* (Myers 1984), with the presence of informational asymmetry between managers and investors, internal funds are preferred to external debt and equity financing. If financial leverage leads to financial constraints and cause a slower adoption of medical technology, one should expect to find that technology adoption is also positively related to operating cash flow. I divide net cash flow from operating activities by total assets. In the sample, the average ratio of operating cash flow over total assets is around 5.9%.

Interest Expense over Total Debt

Historical borrowing costs can be measured as the total interest expense over total debt. Because the calculation includes both old and new debt, the ratio does not necessarily reflect the present cost of borrowing. In addition, because the interest expense is a before-tax measure, the calculation does not take the tax-deduction benefits into consideration (for for-profit hospitals). However, all else being equal, the higher ratio may indicate higher financing costs in general for affected hospitals. These higher financing costs may reflect higher relative risk associated with these hospitals or serious imperfect information between these hospitals and lenders. In the sample, the interest rate of an average hospital is about 3.3%.

Measure of Profitability

To demonstrate that financial leverage has effects on technology adoption that are independent of profitability, it is important to control for the heterogeneous profitability among hospitals. I use the operating margin as the measure for hospital profitability. The ratio is defined as operating profits over revenue. It provides a basic understanding of the profitability of each hospital. In the sample, the average operating margin is -1.4%.

Technology Adoption

The main outcome of interest is the adoption of capital-intensive medical technology. In particular, I focus on the technology required for highly profitable services. Information about technology adoption is obtained from the AHA Annual Survey. I select four types of therapeutic and diagnostic technologies, including the shaped beam radiation system, stereotactic radiosurgery, 64 slice CT scan, and positron emission tomography. Such medical technologies can cost from several millions to hundreds of millions of dollars. The prevalence is 22.3%, 21%, 19.7%, and 17.9%, respectively.

Market and Patient Characteristics

Other important control variables include market and patient characteristics. I use the health referral regions (HRRs) as the definition of hospital markets. The HRR data are obtained from the Dartmouth Atlas of Health Care and there are 28 HRRs in California. According to the Dartmouth Atlas, "HRRs represent regional health care markets for tertiary medical care that generally requires the services of a major referral center." Because capital-intensive medical technology is often used in major procedures, HRRs are the preferred definition of hospital markets because the regions are defined as where patients are referred for intensive procedures[3]. Because more than 60% of the hospitals are affiliated with multi-facility systems, I adjust for the system affiliation in calculating the Herfindahl-Hirschman Index (HHI). For example, two hospitals that belong to the same health system are combined as one organization in the calculation. The system-adjusted HHI is 0.35. From the Area Resource Files, I extract the county-level average income. The mean is about $37,309. I also use the HCUP inpatient dataset to control for several patient-level characteristics that are aggregated at the hospital-level. These variables include average patient age, percentage of patients who are female, and percentage of patient who are white. On average, the patients are 48.2 years old, 59.9% of them are female, and 51.4% of them are white.

Exogenous Financial Shock

The endogeneity problem between financial leverage and product market outcomes is well noted in the literature. Financial arrangements and product market decisions can affect each other and these two decisions are often made simultaneously. To account for endogeneity, previous studies have adopted exogenous shocks that affect either financial decisions or production choices, but not both. For example, Chevalier (1995) and Chevalier and Scharfstein (1996) use leveraged buyouts (LBOs) in the supermarket industry to examine the effect of financial leverage on product markups. Zingales (1998) uses the Carter administration's deregulation to examine effects of market competition on highly leveraged and financially constrained trucking firms. Lamont (1997) uses the 1986 oil price decrease to examine the capital expenditure of nonoil subsidiaries of oil companies.

In the hospital context, all else being equal, less leveraged hospitals may have better access to external capital that can be used to renovate buildings and adopt capital-intensive medical technology. Such activities provide the hospitals with product market advantages in competing with hospitals with high existing leverage. On the other hand, unfavorable product market situations can adversely affect the level of financial leverage. For example, chronic operating losses may erode equity and inflate the ratio of financial leverage; a pessimistic product market

[3] http://www.dartmouthatlas.org/data/region/

outlook may discourage equity investors and constrain the financing channels. These two forces can bolster each other and the causal relationship between financial leverage and product market outcomes becomes difficult to disentangle.

To account for the endogeneity problem, I follow Chang and Jacobson (2010), using the California Seismic Retrofit Mandate as the exogenous financial shock that applies to most of California's GACs. Because the financial burdens from this seismic retrofit mandate are independent of hospitals' profitability and clinical performance, it is ideal for studying the effect of financial leverage on hospitals' technology adoption decisions. This mandate requires GAC hospitals to improve building strength to fulfill earthquake safety requirements. Depending on the age and structure of the buildings and their geographic location, the government of California government has classified GAC hospitals into different risk categories. Each category requires different levels of capital expenditures to retrofit or rebuild the buildings to satisfy the safety requirements. Because the average building age can be potentially endogenous to whether the hospitals are financially constrained, I only use the geographic seismic risk factor as the proxy for the exogenous financial shock. As Chang and Jacobson did in their paper, I first use Geographic Information System (GIS) to determine each hospital's coordinates and use the coordinates to locate and calculate each hospital's peak ground acceleration (PGA) factor. Because the PGA factors highly correlate with the earthquake belt, the distribution of high-PGA hospitals is concentrated in certain areas (the Bay Area and Los Angeles). Therefore, most PGA hospitals will probably locate in the same areas and low-PGA hospitals will locate in the same regions. To examine the market competition perspective of the seismic shock, I also calculate the relative risk measures that categorize the hospitals with a higher (lower) risk factor than the average seismic risk of the market in which the hospital resides. Both the absolute and relative values of the seismic risk are included in the analysis.

California Seismic Retrofit Mandate

This paragraph provides a description of key time lines and the magnitude of the retrofit mandate. SB 1953 originally passed in 1994 after the Northridge earthquake to regulate the safety of hospital buildings. The most seismic-vulnerable GAC buildings (SPC-1) had to be retrofit, replaced, or removed from GAC services by 2008. In the initial report in 2001, 1,027 hospital buildings fell into SPC-1 categories (total hospital buildings 2,627). In 2002, SB 1801 passed, which permits a five-year extension of the first deadline of 2008. Almost every hospital requested an extension of the deadline from 2008 to 2013. According to the OSHPD report[4], by the end of 2009, 70% of SPC-1 buildings were likely to comply, 13% were possible to comply, and 17% are possibly non-compliant. The non-compliant buildings have to be removed from general acute care services. The estimated total capital expenditures related to the retrofit mandate varies and is as high as $41.7 billion (Meade 2002). Successful compliance with the seismic retrofit mandate not only ensures the continuation of operation, but it can also affect the cost of borrowing and the hospital's competitive advantage. For example, Moody's upgraded the bond rating of Good Samaritan Hospital in September 2011 because Good Samaritan satisfies the seismic safety requirement through 2030. Compliance with the seismic retrofit mandate is one of the important considerations in Moody's several bond rating reports. Furthermore, Sutter, University of California at Los Angeles Medical Center, and University of California at San Francisco Medical Center, which have the financial resources to comply with the retrofit

[4] Seismic Safety Hearing

mandates, have highlighted their successful compliance with the regulations on their web pages and in their annual reports. This might serve as a signal to payers and patients to differentiate between hospitals that have not or are not able to comply with the mandate.

Table 1. Summary Statistics

	Mean	Std	Min	Max	Obs
Technology Adoption					
Shaped Beam Radiation System	0.223	0.417	0	1	229
Stereotactic Radiosurgery	0.210	0.408	0	1	229
64 Slice CT Scan	0.197	0.398	0	1	229
Poistron Emission Tomography	0.179	0.384	0	1	229
Others					
Chg. Market Shr	0.006	0.03	-0.207	0.153	276
Revenue Growth (100%)	1.376	0.819	-0.128	4.721	276
Financial Measures					
Leverage Ratio	0.629	0.384	0.043	2.399	314
Operating Margin	-0.014	0.11	-0.379	0.262	315
Operating Cashflow /Asset	0.059	0.132	-0.468	0.587	315
Interest Expense/ Debt	0.033	0.028	0	0.234	281
Hospital Characteristics					
Absolute Value of Seismic Risk	0.405	0.193	0	0.95	324
Relative Value of Seismic Risk	0.456	0.499	0	1	340
Hospital Beds (in 100)	1.992	1.389	0.1	8.49	340
Public Hospital	0.05	0.218	0	1	340
For-profit Hospital	0.244	0.43	0	1	340
System Affiliation	0.671	0.471	0	1	340
Teaching Hospital	0.059	0.236	0	1	340
Rural Hospital	0.182	0.387	0	1	340
Market Characteristics					
HHI Index	0.349	0.244	0	1.248	340
ln(County Income)	10.527	0.273	10.025	11.363	335
Patient Characteristics					
Avg. Age	48.149	10.979	11.942	76.077	288
Perct. of Female	0.599	0.058	0.272	0.785	288
Perct. of White	0.514	0.232	0.001	0.944	288

Empirical Specification

I use two empirical specifications in the paper – a simple lagged model and a model that interacts with the exogenous financial shock. The basic empirical specification is as follows:

$$Y_{i,t} = \beta \cdot FL_{i,t-7} + \gamma \cdot XH_{i,t-7} + \lambda M_{m,t-7} + \theta \cdot P_{i,t-7} + \epsilon$$

Where $Y_{i,t}$ is the outcome of interest (technology adoption or revenue growth) for hospital i at year t (2006). $FL_{i,t-7}$ is the financial leverage for hospital i at year t-7 (1999). Financial leverage is the primary variable of interest. I also use the operating cash flow over assets ratio and interest expense over debt ratios as robustness checks. In the basic model, I use the financial leverage ratio in 1999, a year prior to the first evaluation of the exposure to seismic retrofit. Because the major construction has taken place since 2000', to some extent, the hospitals' financial leverage should be independent of their seismic risks. For the technology adoption variables, I use the prevalence in 2006 because the hospitals should already have started their seismic retrofit projects and the related financial shock should already be reflected in their decisions, regarding the adoption of medical technology. In addition, using the technology prevalence in 2006 also helps to avoid complications from the 2007 financial crisis. $XH_{i,t-7}$ represents the basic set of hospital characteristics including ownership types (i.e., for-profit versus not-for-profit), the number of hospital beds, system affiliation, and teaching/rural status. These variables are based on the 1999 information because of the concern that hospital-level variables may change when the seismic retrofit construction projects begin. $M_{i,t-7}$ is the hospital market-level characteristics[5], such as the HHI concentration level and median county income. $P_{i,t-7}$ represents patient-level characteristics at 2006 to account for the differential patient case mix among hospitals.

The alternative specification interacts the seismic risk with the financial leverage before the mandate is effectively enforced. The focus is on the interaction term of the seismic risk and existing financial leverage.

$$Y_{i,t} = \beta \cdot FL_{i,t-7} + \delta \cdot HighRisk + \rho FL_{i,t-7} \cdot HighRisk + \gamma \cdot XH_{i,t-7} + \lambda M_{m,t-7} + \theta \cdot P_{i,t-7} + \epsilon$$

In this equation, *High Risk* represents two variables: the absolute and relative values of seismic risk. The absolute seismic risk is the hospital's PGA factor. For the relative seismic risk, a dummy variable that takes the value of 1 if the hospital has a higher seismic risk relative to the market average (hospital referral regions). The interaction term of financial leverage and seismic risk suggests that seismic risk may have disproportionate impacts on hospitals that use higher financial leverage. Furthermore, because hospitals that face high (low) seismic risk may have very different decision processes, I also run a fully interacted model to examine whether financial leverage has differential effects for hospitals facing high (low) fixed cost shocks. I split the sample into high and low seismic risk categories, in which the hospitals in the high (low) risk category face higher (lower) fixed cost shocks than their competitors within the same HRR. In this fully interacted model, I expect to see that financial leverage has negative consequences on

[5] Hospital market level characteristics are calculated on all short-term GAC hospitals within each health referral region.

technology adoption for hospitals that have relatively high seismic risks. In all regressions, the standard errors are clustered at the HRR level.

IV. RESULTS

Technology Adoption

This paper tries to provide direct evidence of the impact of leverage on technology adoption. Examination of the hospital markets provides a unique opportunity because of the availability of rich and detailed information on the adoption of medical technology at the individual hospital level. The main hypothesis is that a hospital with high leverage is more likely to be financially constrained and will have fewer financial resources for technology investments. Meanwhile, there is an alternative hypothesis that financially constrained hospitals may be more likely to adopt such medical technologies. Capital-intensive medical technologies are also often used to perform lucrative services with higher profit margins. The alternative hypothesis can be that hospitals with higher existing leverage level are faster to adopt medical technology so as to generate additional operating cash flows. The probit regression is used in the analysis and the marginal effects (Ai and Norton, 2003) are reported in the tables. Table 2 shows the results from the basic model. The leverage ratio has a negative relationship with the adoption of shaped beam radiation, 64-slice CT scan, and positron emission tomography. However, surprisingly, the results are not statistically significant. Consistent with previous studies, operating margins and the number of hospital beds are positively correlated with technology adoption. The number of hospital beds is significant at the 1% level for all four types of technology. To ensure that the results are not endogenous and biased, I also run an alternative model with an exogenous seismic shock. The alterative set of results is reported in Table 3. Similarly, leverage has a negative but not statistically significant relationship with adoption. The results on the interaction terms are mixed and insignificant. Table 4 also shows similar results. Among the regressions, operating margin and number of hospital beds are significantly positively correlated with adoption. One interesting result is that hospitals affiliated with hospital systems are less likely to adopt all four types of radiology technology. It would be worth investigating the role of system affiliation in technology adoption.

Revenue Growth

For each hospital, I also compute the revenue growth over the seven-year period from 1999 through 2006. The revenue, on average, increases drastically by about 137.6%. The regressions are reported in Table 5. In column (1), the leverage ratio and absolute value of seismic risk have negative and insignificant relationships with revenue growth. From columns (2) and (4), coefficients of the interaction of leverage and absolute seismic risk are negative and significant. Thus, seismic risks have a large and negative effect on revenue growth for highly leveraged hospitals. Because the results of technology regressions are not significant, I cannot make too many inferences regarding the pathway of lower revenue growth. Prices and patient mix can be one direction for future research.

Ownership Status: for-profit and not-for-profit

To examine whether financial leverage has differential effects on technology adoption for for-profits or not-for-profits, I include the interaction term of financial leverage and the indicator variable of for-profit status. The results are presented in Table 6. The coefficient of the interaction term is negative across all four regressions. This suggests that leverage has larger impacts for for-profit hospitals. However, the result is only statistically significant in the positron emission tomography regression and should be interpreted with caution. In fact, the negative sign on the coefficient of the interaction term is the opposite of what the hypothesis will predict. This result is similar to Magnus et al. (2004a), in which they suggest that the association between debt and capital-investment may be weaker because the creditors' oversight is less tight in the not-for-profit setting and the tax-exempt debt at times is tied to capital-investment legal requirement. One potential explanation is that not-for-profit hospitals balance between profits and community benefits. When not-for-profits do not face immediate financial pressures, they tradeoff some profits for community benefits, to be better quality or more quantity. Thus, when a highly leveraged not-for-profit is affected by the seismic retrofit mandate, it can provide less community to yield sufficient cash flow internally. In fact, Chang and Jacobson (2010) find that not-for-profits are more seriously impacted by the retrofit mandate, increase the utilization of imaging services to finance the retrofit costs. Thus, compared to for-profits, not-for-profits are more able to adjust the mix between profitable and less profitable service when they are liquidity constrained.

Overall Discussion

Based on the results from the basic model and the model using the seismic retrofit mandate, I do not find significant relationship between financial leverage and technology adoption. I also repeat the same analysis using other financial measures, including operating cash flow over total asset and interest expense over total debt. The results are presented in Table 7 and I do not find consistent relationship with these two financial measures and technology adoption. Because the results are statistically insignificant, I cannot disentangle the two competing hypothesis that financial leverage leads to financial constraints or financial leverage distorts hospitals' incentive to adopt technology. Despite the insignificant results, because financial leverage has consistent negative effects on for-profit hospitals, it may be worthy to have policy-makers discuss solutions for already highly leveraged for-profit hospitals or to regulate and prevent the for-profits from being over-leveraged.

Table 2. Leverage on Technology Adoption – Marginal Effects of Probit Model

	Shaped Beam Radiation System	Stereotactic Radiosurgery	64-Slice CT Scan	Poistron Emission Tomography
Leverage Ratio	-0.087	0.039	-0.014	0.004
	[0.095]	[0.051]	[0.091]	[0.074]
Operating Margin	0.675**	0.309	-0.215	0.218
	[0.292]	[0.401]	[0.264]	[0.247]
# of Hospital Beds (100)	0.106***	0.103***	0.043***	0.069***
	[0.019]	[0.018]	[0.017]	[0.022]
For-profit Hospital	-0.108*	-0.009	-0.130*	-0.149
	[0.063]	[0.077]	[0.071]	[0.101]
Public Hospital	0	-0.296*	-0.115	-0.151
	[.]	[0.153]	[0.120]	[0.105]
System Affiliation	-0.105**	-0.131**	-0.092*	-0.014
	[0.047]	[0.064]	[0.051]	[0.050]
Teaching Hospital	-0.044	-0.025	0.033	-0.098
	[0.109]	[0.103]	[0.115]	[0.127]
Rural Hospital	-0.162	-0.009	-0.148**	0.047
	[0.128]	[0.077]	[0.074]	[0.092]
HHI Index	-0.032	0.04	0.162*	0.054
	[0.095]	[0.097]	[0.083]	[0.125]
ln(County Income)	0.033	-0.097	0.099	0.074
	[0.117]	[0.124]	[0.091]	[0.094]
Avg. Age	-0.002	-0.006	-0.011***	-0.002
	[0.004]	[0.004]	[0.003]	[0.002]
Perct of Female	-0.009	-0.638	-0.875*	-0.11
	[0.522]	[0.780]	[0.519]	[0.426]
Perct of White	0.204*	0.243**	0.411***	-0.039
	[0.108]	[0.108]	[0.127]	[0.082]
N	193	203	203	203

Footnote: (1) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(2) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

Table 3. Leverage on Technology Adoption – Marginal Effects of Probit Model

	Shaped Beam Radiation System		Stereotactic Radiosurgery		64-Slice CT Scan		Poistron Emission Tomography	
Leverage Ratio	-0.138	-0.145	0.02	0.069	-0.276	-0.217	-0.1	-0.099
	[0.364]	[0.349]	[0.099]	[0.089]	[0.252]	[0.260]	[0.156]	[0.131]
Absolute Seismic Risk	-0.031	0.014	-0.075	-0.091	-0.435	-0.537	-0.076	-0.174
	[0.416]	[0.398]	[0.313]	[0.323]	[0.323]	[0.338]	[0.336]	[0.316]
Relative Seismic Risk	0.017	-0.04	0.06	0.133	0.048	0.224**	-0.098*	0.103
	[0.063]	[0.089]	[0.046]	[0.095]	[0.066]	[0.110]	[0.058]	[0.116]
Absolute Seismic Risk	*0.113*	*0.002*	*0*	*0.043*	*0.585*	*0.797*	*0.214*	*0.462*
X Leverage Ratio	*[0.735]*	*[0.707]*	*[0.237]*	*[0.249]*	*[0.443]*	*[0.516]*	*[0.366]*	*[0.344]*
Relative Seismic Risk		*0.12*		*-0.135*		*-0.315**		*-0.389**
X Leverage Ratio		*[0.179]*		*[0.111]*		*[0.164]*		*[0.210]*
Operating Margin	0.681**	0.705**	0.214	0.202	-0.391	-0.454	0.041	-0.033
	[0.286]	[0.289]	[0.419]	[0.426]	[0.322]	[0.299]	[0.271]	[0.261]
Hospital Beds (in 100)	0.104***	0.103***	0.105***	0.105***	0.043***	0.043***	0.073***	0.074***
	[0.019]	[0.019]	[0.017]	[0.017]	[0.014]	[0.013]	[0.025]	[0.025]
For-profit Hospital	-0.11	-0.106	0.001	-0.004	-0.135*	-0.164**	-0.149	-0.179*
	[0.068]	[0.067]	[0.080]	[0.082]	[0.074]	[0.064]	[0.103]	[0.105]
System Affiliation	-0.102*	-0.105*	-0.131**	-0.130**	-0.091*	-0.074	-0.011	0.003
	[0.056]	[0.054]	[0.067]	[0.065]	[0.054]	[0.050]	[0.055]	[0.053]
Teaching Hospital	-0.037	-0.035	-0.027	-0.034	-0.018	-0.017	-0.147	-0.152
	[0.103]	[0.103]	[0.106]	[0.107]	[0.112]	[0.103]	[0.138]	[0.135]
Rural Hospital	-0.162	-0.167	-0.005	0	-0.136*	-0.137*	0.051	0.051
	[0.127]	[0.131]	[0.077]	[0.077]	[0.078]	[0.079]	[0.094]	[0.096]
HHI Index	-0.024	-0.027	0.017	0.017	0.176**	0.180**	0.094	0.083
	[0.105]	[0.105]	[0.122]	[0.119]	[0.089]	[0.082]	[0.139]	[0.138]
N	193	193	193	193	193	193	193	193

Footnote: (1) Patient characteristics are also included in the regressions and are omitted in the table for brevity.
(2) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(3) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

Table 4. Marginal Effects of Financial Leverage and Seismic Risk – Results from Fully Interacted Model

	Shaped Beam Radiation System		Stereotactic Radiosurgery		64-Slice CT Scan		Poistron Emission Tomography	
Leverage Ratio	-0.306	-0.871	-0.284	0.313	-0.465	0.786	-1.814	0.364
	[0.709]	[0.679]	[0.558]	[0.330]	[0.501]	[0.710]	[1.131]	[0.416]
Absolute Seismic Risk	1.055	-1.406*	0.414	-2.446	-0.707	0.426	0.421	-0.307
	[1.412]	[0.743]	[1.041]	[1.544]	[1.003]	[1.053]	[1.064]	[1.488]
Operating Margin	6.737**	2.448	0.485	1.855	-0.308	-0.796	-0.846	2.136
	[2.680]	[1.981]	[3.571]	[3.072]	[1.737]	[1.786]	[3.941]	[1.429]
Hospital Beds (in 100)	0.703***	0.424**	0.566***	0.558***	0.302**	0.256	0.365	0.449***
	[0.177]	[0.166]	[0.187]	[0.151]	[0.130]	[0.203]	[0.332]	[0.114]
Public Hospital	NA	NA	NA	-1.231	0.039	-1.17	NA	-0.982
				[0.836]	[0.820]	[0.990]		[0.604]
For-profit Hospital	-1.761***	0.018	-0.983	0.412	-0.804***	-1.043*	NA	-0.676
	[0.576]	[0.277]	[0.893]	[0.545]	[0.310]	[0.549]		[0.572]
System Affiliation	-1.046**	-0.123	-0.794*	-0.573	-0.365	-0.472	0.007	-0.069
	[0.446]	[0.604]	[0.432]	[0.498]	[0.345]	[0.568]	[0.486]	[0.300]
Teaching Hospital	0.081	-0.022	-0.733*	0.261	0.634	-0.061	-0.762	-1.05
	[0.666]	[0.722]	[0.402]	[0.906]	[0.939]	[0.856]	[0.971]	[0.807]
Rural Hospital	NA	-0.533	-0.784	0.436	-0.18	NA	NA	0.773
		[0.640]	[0.872]	[0.499]	[0.486]			[0.557]
HHI Index	0.469	0.021	-0.043	-0.872	1.214	0.275	-0.061	0.508
	[0.911]	[0.958]	[0.816]	[1.248]	[0.809]	[0.886]	[1.092]	[0.999]
	[0.979]	[0.832]	[1.040]	[0.788]	[0.886]	[1.069]	[1.117]	[0.468]
N	71	106	87	113	90	91	57	113

Footnote: (1) Patient characteristics are also included in the regressions and are omitted in the table for brevity.
(2) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(3) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

Table 5. Financial Leverage and Seismic Risk on Revenue Growth

	(1)	(2)	(3)	(4)
Leverage Ratio	-0.047	0.255	-0.042	0.224
	[0.141]	[0.167]	[0.142]	[0.162]
Absolute Value of Seismic Risk	-0.039	0.559	-0.221	0.426
	[0.210]	[0.373]	[0.225]	[0.361]
Relative Value of Seismic Risk			0.126*	0.034
			[0.071]	[0.109]
Absolute Value of Seismic Risk		-0.898**		-0.968**
X Leverage Ratio		[0.431]		[0.434]
Relative Value of Seismic Risk				0.147
X Leverage Ratio				[0.169]
Operating Margin	-1.685**	-1.660**	-1.647**	-1.612**
	[0.676]	[0.669]	[0.664]	[0.663]
Hospital Beds (in 100)	-0.056	-0.055	-0.053	-0.051
	[0.035]	[0.036]	[0.034]	[0.036]
Public Hospital	-0.23	-0.211	-0.221	-0.189
	[0.160]	[0.170]	[0.160]	[0.175]
For-profit Hospital	-0.239**	-0.246**	-0.236**	-0.237**
	[0.087]	[0.091]	[0.088]	[0.092]
System Affiliation	0.343**	0.345**	0.335**	0.333**
	[0.139]	[0.141]	[0.142]	[0.146]
Teaching Hospital	-0.047	-0.034	-0.046	-0.028
	[0.142]	[0.150]	[0.140]	[0.147]
Rural Hospital	-0.417***	-0.413***	-0.413***	-0.406***
	[0.136]	[0.128]	[0.134]	[0.124]
HHI Index	-0.09	-0.09	-0.136	-0.132
	[0.229]	[0.234]	[0.218]	[0.222]
ln (County Income)	-0.242	-0.239	-0.196	-0.195
	[0.142]	[0.142]	[0.140]	[0.141]
Avg. Age	-0.011**	-0.011**	-0.010*	-0.010*
	[0.005]	[0.005]	[0.005]	[0.005]
Perct. of Female	-0.541	-0.477	-0.452	-0.311
	[1.000]	[1.019]	[1.026]	[1.072]
Perct. of White	0.23	0.249	0.205	0.244
	[0.230]	[0.219]	[0.240]	[0.237]
N	256	256	256	256

Footnote: (1) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(2) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

Table 6. Marginal Effects of Financial Leverage and Nonprofit on Technology Adoption

	(1)	(2)	(3)	(4)
Leverage Ratio	-0.121	-0.021	-0.065	-0.143*
	[0.120]	[0.082]	[0.111]	[0.077]
For-profit Hospital	-0.158	-0.088	-0.136	-0.616***
	[0.108]	[0.118]	[0.093]	[0.212]
For-profit hospital	*0.104*	*0.151*	*0.016*	*0.613****
X Leverage Ratio	*[0.175]*	*[0.169]*	*[0.156]*	*[0.179]*
Operating Margin	0.701**	0.267	-0.384	0.247
	[0.308]	[0.447]	[0.303]	[0.307]
Hospital Beds (in 100)	0.106***	0.106***	0.048***	0.072***
	[0.018]	[0.016]	[0.017]	[0.023]
System Affiliation	-0.100**	-0.125**	-0.08	0.006
	[0.048]	[0.062]	[0.051]	[0.049]
Teaching Hospital	-0.045	-0.049	-0.04	-0.144
	[0.109]	[0.107]	[0.120]	[0.128]
Rural Hospital	-0.165	0.003	-0.124*	0.069
	[0.128]	[0.074]	[0.075]	[0.093]
HHI Index	-0.032	0.049	0.189**	0.061
	[0.094]	[0.096]	[0.078]	[0.133]
ln (County Income)	0.025	-0.121	0.116	0.004
	[0.113]	[0.128]	[0.099]	[0.085]
Avg. Age	-0.001	-0.006	-0.011***	-0.001
	[0.003]	[0.004]	[0.003]	[0.002]
Perct. of Female	0.025	-0.874	-1.199**	-0.366
	[0.512]	[0.815]	[0.472]	[0.595]
Perct. of White	0.199*	0.231**	0.387***	-0.093
	[0.105]	[0.113]	[0.135]	[0.084]
N	193	193	193	193

Footnote: (1) Patient characteristics are also included in the regressions and are omitted in the table for brevity.
(2) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(3) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

Table 7. Marginal Effects of Financial Measures on Technology Adoption

	Shaped Beam Radiation System			Stereotactic Radiosurgery		
	(1)	(2)	(3)	(1)	(2)	(3)
Leverage Ratio	-0.121			-0.021		
	[0.120]			[0.082]		
Operating Cashflow/Asset		-0.182			-0.202	
		[0.182]			[0.132]	
Interest Expense/ Debt			-0.667			-2.342*
			[0.848]			[1.381]
N	193	193	173	193	193	173

	Multi-Slice CT Scan (64+)			Poistron Emission Tomography		
	(1)	(2)	(3)	(1)	(2)	(3)
Leverage Ratio	-0.065			-0.143*		
	[0.111]			[0.077]		
Operating Cashflow/Asset		0.091			-0.256	
		[0.305]			[0.196]	
Interest Expense/ Debt			0.538			-1.596
			[1.123]			[1.655]
N	193	193	173	193	193	173

Footnote: (1) All regressions include the same independent variables as in the Table 2 and are omitted in the table for brevity.
(2) ***,**, and * represent significance at 1%, 5%, and 10% levels.
(3) All standard errors are clustered at the health referral regional level to account for the within market heterogeneity.

V. LIMITATIONS AND FUTURE WORK

Empirical Analysis

There are two major limitations of this paper: the small sample size and compliance with the seismic retrofit mandate. Because this study only uses California data and the unit of analysis focuses on the hospital level (short-term general acute hospital), the analysis sample at most consists of 250 hospitals. Furthermore, because the variations in the financial leverage are small between years, the dataset is not ideal for constructing panel data for a hospital fixed-effect analysis. Such a small sample limits the possibility of using different econometric techniques and running different robust analyses. Second, although the California Seismic Retrofit Mandate seems to be an exogenous financial shock, there are concerns that the hospitals are not bound by the mandate. In particular, the initial mandate requires enormous financial resources that are beyond many hospitals' financial capabilities. The mandate's compliance deadline has been extended several times and there have also been several special arrangements between the government of California and hospitals to finance the construction projects. This concern may explain the insignificant results of the model that uses the seismic retrofit mandate. In future studies, one might want to consider using a national sample that comprises more hospitals or changing the unit of analysis from the California hospital level to the patient level.

Welfare Implications

This paper has not discussed the potential impacts of financial leverage on quality of care and the provision of uncompensated care (Magnus et al., 2004b), two dimensions with strong welfare implications. It will be a natural extension to examine the long-term impacts of financial leverage on the quality of care at the individual patient level.

VI. CONCLUSION

This paper explores the effects of financial leverage on technology adoption. Although I am not able to identify a solid causal relationship between financial leverage and the probability of adopting radiology technology, I do find the adoption is significantly correlated with the hospital size and operating margin. More interestingly, I also find a consistent and negative relationship between system affiliations and technology adoption. This inverse relationship may provide evidence of the centralization of capital-intensive technology within health systems. It will be worth to pursue a further study of evaluating the efficiency gains through the centralization of medical technology.

Another interesting finding is that financial leverage has more significant impacts on for-profit hospitals than not-for-profits. While not-for-profits rely more on debt financing (Reiter et al., 2008), they also have the flexibility to adjust the service mix between highly profitable and less profitable service during the financial hardship. Thus, financial leverage may not have significant impacts on technology adoption of not-for-profits, but it can still lead to undesired consequences in quality and quantity. Because of the small sample size of this study, it is difficult to conclude that financial leverage does not have impacts on technology adoption, or the lack of statistical power leads to the insignificant results. In the sample, about 23.4% of the hospitals have negative equity, which means that the book value of debts exceeds the book value of total assets. It will be interesting to examine whether hospitals with negative equity are also prevalent in other states. To sum up, this paper calls for more attention to reviewing the role of financial leverage in the hospital industry.

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