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High-Tech Services And Hospital Performance In The United States

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HIGH-TECH SERVICES AND HOSPITAL PERFORMANCE IN THE UNITED STATES

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ABSTRACT

This dissertation examined the relationship between high-technology medical services and hospital performance by focusing on financial and quality performance dimensions. An initial systematic review disclosed the paucity of research and mixed findings about the technology-performance relationship. The review indicated the need for further analyses by emphasizing some limitations of existing studies.

The resource-based view (RBV) of a firm was used as a conceptual framework in examining the relationship between high-tech medical services and hospital financial performance. It was hypothesized that large breadth (number) of high-tech services and the use of rare high-tech services would be positively associated with hospitals' financial performance. It was further hypothesized that both registered nurse (RN) staffing mix and competition would positively moderate the relationships between high-tech medical services and financial performance. A longitudinal panel design with 6 years of data for the period of 2005-2010 was analyzed by using within-group fixed effects models. The findings supported the breadth hypotheses for four of the five financial performance measures. The rareness hypotheses were supported but only for operating margin (positive) and operating expenses (negative). There was no support for the moderation effects of both RN staffing mix and competition.

A combination of RBV and Donabedian's structure-process-outcome (SPO) model was used to explore the relationship between high-tech medical services and quality performance. It was hypothesized that high-tech medical services with certain attributes (i.e., large breadth, rare, and relevant) would be positively associated with quality performance, measured by 30-day mortality rates for heart attacks, heart failure, and pneumonia. The findings partially supported the hypothesized relationships between rare high-tech services and 30-day mortality rates for pneumonia. The significant finding for the relationship between condition-specific high-tech services and 30 day mortality rates for heart failure was opposite to the predicted direction. There were no other significant finding to support the rest of the hypothesized relationships between high-tech services and quality performance. Condition-specific volume was the only measure that exhibited consistently significant (negative) association with 30-day mortality rates.

DEDICATION

This dissertation is dedicated to all my family and friends including my wife, children, parents, and grandparents. I am grateful for all their support.

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LIST OF ABBREVIATIONS

AHA	American Hospital Association
ARF	Area Resource File
CMI	Case Mix Index
CMS	Center for Medicare & Medicaid Services
FTE	Full Time Equivalent
HHI	Herfindahl-Hirschman Index
LOS	Length of Stay
MCR	Medicare Cost Reports
OLS	Ordinary Least Squares
PPS	Prospective Payment System
RBV	Resource Based View
SPO	Structure Process Outcome

INTRODUCTION

Performance is a matter of survival, because it indicates how well an organization is functioning within its environment. Likewise, performance, with its particular focus on clinical, operational and financial dimensions (Counte, Glandon, Oleske, & Hill, 1995) in healthcare industry, is one of the most critical areas of concern for hospitals. Performance is even more critical given the current trend of increasing public disclosure of quality, patient safety and patient satisfaction scores of hospitals, and linking reimbursement to these scores. To improve their performance, hospitals have been competing with each other to attain larger market share. As a result, hospitals are not only challenged to develop strategies to improve their performance by enhancing quality, reducing costs, and improving efficiency but also heighten their competitive edge to ensure sustainability of these efforts.

To reinforce their competitiveness, hospitals use capital investments on high technology medical services, facilities, information technology (IT), service lines, and physician networks (Levy, Lawrence, & Shiple, 2009). Among these capital investments, the combination of high technology (high-tech) medical services and IT is estimated to be the largest representing approximately 50% of capital investments (Callahan, 2009). High-tech medical services are defined as those equipment or services that are designed to diagnose or improve health conditions of patients such as endoscopic ultrasound, proton beam therapy, and cardiac intensive care. Given the magnitude of these capital investments on high-tech medical services, some scholars suggested they are the major driver of rising health care costs in the United States (Callahan, 2009; Newhouse, 1992; Peden & Freeland, 1995; Reynolds, 1989; Scitovsky, 1985). Hospital administrators usually make such large capital investment decisions on high-technology medical services with the goal of improving their performance, and protecting and enhancing their present and future competitiveness (Trinh, Begun, & Luke, 2008). Despite their potential role in hospital performance, research focused on high-tech medical services has been limited.

Historically, researchers have focused on competition when examining high-technology medical services. For instance, large amounts of literature developed around the so-called '*medical arms race*' era, or the non-price competition period before the hospital prospective payment system (PPS) of 1983 (Devers, Brewster, & Casalino, 2003). During the *medical arms race* era, since price was not an issue due to indemnity insurance and non-capitated retrospective cost-based reimbursements, competition among hospitals was based mostly upon non-price strategies such as offering hotel-like services or cutting edge technologies (Spetz & Maiuro, 2004). Therefore, during this time, high-tech medical services were explored as a dimension of a large span of services that were utilized for 'non-price competition' (see, Robinson & Luft, 1985, 1987)

With the advent of Medicare PPS in 1983 and managed care controls of the 1990s, research focus on high-tech services shifted as competition among hospitals changed from non-price to price-related strategies (Devers et al., 2003; Trinh et al., 2008). During this time, some researchers explored the influence of managed care on the adoption of high-tech medical services. For instance, some studies explored the effects of higher managed care competition on the availability of particular technologies such as MRI (Baker & Wheeler, 1998), neonatal intensive care units (Baker & Phibbs, 2002), angioplasty (Cutler & McClellen, 1996), coronary arterial bypass graft (Grossman & Banks, 1998) and laparoscopic cholecystectomy (Chernew, Fendrick, & Hirth, 1997). Other studies explored the managed care's effects on technology diffusion by taking into account several technologies, various organizational and market characteristics (Bryce & Cline, 1998; Cutler & Sheiner, 1998; Hill & Wolfe, 1997; J. Spetz & Baker, 1999; Teplensky, Pauly, Kimberly, Hillman, & Schwartz, 1995; Zhang, Kohn, McGarrah, & Anderson, 1999). Finally, other studies explored the prevalence of certain technologies in particular settings, such as mobile CT scanner in rural hospitals (Hartley, Moscovice, & Christianson, 1996). Overall, during this time frame, there were substantial amount of studies generated about adoption of various technologies and how these adoption decisions were influenced by certain environmental factors such as managed care.

To date, few studies have attempted to investigate the relationship between high-tech medical services and organizational (financial and quality) performance (Bazzoli, Chen, Zhao, & Lindrooth, 2008; Irwin, Hoffman, & Lamont, 1998; Li & Benton, 2003; Trinh et al., 2008; Trinh, Begun, & Luke, 2010). Most of the studies that used some type of technology measure, emphasized the influence of some other organizational factors (i.e., staffing) on performance (Blegen, Goode, Spetz, Vaughn, & Park, 2011; Mark, Harless, & McCue, 2005; Mark, Harless, McCue, & Xu, 2004; McCue, Mark, & Harless, 2003) as opposed to the effects of high-tech services on performance. Moreover, as a measure of technology, these studies employed inconsistent measures such as one or two technologies, index of three or more technologies, or weighted sums of some technological services.

It still remains unclear whether high-tech medical services influence hospital performance. Moreover, the magnitude and direction of the relationship between high-tech medical services and financial/clinical performance is not well-defined.

The aim of this present study is to explore the relationship between high-technology medical services and hospital performance by examining both the financial and clinical dimensions of performance. This study is timely since the recent revival of the “medical arms race” phenomenon (Devers et al., 2003) might push hospitals into another fast and uncontrolled technology adoption era. Such fast technology adoption decisions may not generate either the desired financial performance or the aspired quality outcomes. The overall goal of such a study is to inform the stakeholders of hospital industry about the potential influence of high-tech services on hospitals’ financial and quality performance.

The aim of this study was achieved in the following three papers: (a) A literature review paper titled “A Systematic Review of Technology and Performance in U.S. Hospitals”; (b) A paper with financial performance focus titled “A Longitudinal Analysis of High Technology Medical Services and Hospital Performance”; and (c) A paper with quality performance focus titled “High Technology Medical Services and Quality of Care at U.S. Hospitals”.

Paper 1: Literature Review

The purpose of this literature review was to account for the findings and methods of existing studies that have explored the relationship between hospital technologies and performance (financial and clinical). A systematic comprehensive literature review of empirical studies was performed by focusing on medical technologies under the large domain of hospital performance. Studies were organized according to the following four research questions:

1) What are the major findings in regards to the relationship between hospital technology and financial/quality performance?
2) How studies are designed and what type of analytical processes are used?
3) What types of hospital technology measures are used in these studies?
4) What types of hospital financial/quality performance measures are used?

The findings of this study were used to develop two subsequent studies, focusing on financial and quality performance.

Paper 2: Financial Performance Focus

The purpose of this empirical study was to examine the relationship between high-tech medical services and hospital financial performance. Several hypotheses were developed by using the resource-based view of a firm. The final longitudinal panel design included 4,262 medical-surgical hospitals for 6 years (2005-2010) from the following data sources: Area Resource Files (ARF), American Hospital Association (AHA) annual survey, CMS Medicare cost reports (MCR), and CMS Case mix index (CMI). For analysis within-group fixed effects with time fixed effects models were used.

Paper 3: Quality Performance Focus

The purpose of this empirical study was to examine the relationship between high-tech medical services and quality performance of hospitals, as measured by 30-day mortality rates for heart attack, heart failure and pneumonia. A combination of RBV and Donabedian's SPO framework was used to develop several hypotheses, focusing on the breadth, rareness, and relevancy of high-tech services. Several data-sets were merged including the Center for Medicare and Medicaid Services (CMS) Hospital Compare Database, the American Hospital Association (AHA) annual survey data, and the Area Resource File (ARF).The final 4 years of (2006-2009) longitudinal unbalanced panels included hospitals, ranging from 2,672 for hearth attacks to 3,950 for pneumonia.

A SYSTEMATIC REVIEW OF TECHNOLOGY PERFORMANCE RELATIONSHIP IN U.S. HOSPITALS

by

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Format adapted for dissertation

ABSTRACT

Recent developments have brought more attention to clinical and financial performance of U.S. hospitals. Hospitals have been adopting various technologies to improve their clinical quality and financial performance. However, the research examining the relationship between hospital technology and performance (clinical and financial) is limited in numbers. This systematic literature review attempts to account for the technology-performance link in U.S. hospitals by focusing on clinical technologies and services. The review confirms the paucity of research on this topic and reveals mixed findings in existing research. It also provides directions and recommendations for future research by identifying major gaps in the existing literature.

INTRODUCTION

U.S. hospitals have been facing increasing challenges to improve their clinical and financial performance. Some of these challenges arise from efforts to control increasing hospital costs. As a result of legislative pressures, pay for performance initiatives, quality enhancement measures, and various other environmental pressures, hospitals are searching for ways to improve their performance. Because it represents a high proportion of hospital capital investments, hospital technology has long been identified as a major contributor to both the clinical and the financial performance of U.S. hospitals. Hospital technology is defined as high technology (high-tech) clinical equipment and services (e.g., medical/surgical intensive care, electron beam computed tomography) that are designed to solve certain human health problems or to improve their health conditions (Spetz & Maiuro, 2004). It is estimated that approximately 50% of hospital capital investment is spent on technology improvement initiatives (Callahan, 2009). Moreover, it is estimated that the adoption of new technologies, including both big and small ticket items, and the increased use of existing technologies are responsible for approximately 30% to 75% of the healthcare costs in the United States (Callahan, 2009; Newhouse, 1992, 1993; Peden & Freeland, 1995; Reynolds, 1989; Scitovsky, 1985). Technological advancements are also identified as a major contributor to better clinical performance in hospitals. Hospital technologies such as minimally invasive surgeries and cardiac catheterization have improved quality of care by reducing both the recovery time and rate of hospital acquired infections.

Today, some researchers argue that the benefits of technology and its adoption by healthcare organizations outweigh the cost (D. Cutler & McClellen, 1996; D. M. Cutler & McClellan, 2001; McClellan, 1996). Although there are many studies that investigate cost-benefit implications of individual technologies, organizational level research on the net benefits of high-tech services over their costs is greatly limited. Therefore, the limited numbers of studies do not provide enough information to rationalize organizational/ national level cost implications of hospital technologies.

Apart from the cost-benefit controversy of hospital technology, there are also challenges for researchers who want to investigate the links between hospital technology and performance. Because of the complex interactions of environmental, governmental, regulatory, sociological, and demographical forces, it is a challenge to trace relationships between technology and performance in the hospital sector. For instance, while investigating some possible links between a specific hospital's technological sophistication and its performance (clinical and financial), researchers need to consider the socioeconomic, demographic patient factors along with reimbursement, and regulatory policies. Therefore, even a single hospital's performance is determined by the interactions of various possible factors. The complexity of these interactions would multiply while studying multiple hospitals. Moreover, the impact of technology is considered within the structure dimension of Donabedian's Structure-Process-Outcome (SPO) (Donabedian, 1966, 1980, 1981) framework. The struggle to find reliable and consistent links between process and outcome measures has long been a source of debate among researchers (Mant, 2001; Werner & Bradlow, 2006). This difficulty becomes even more challenging while searching for links between a structure indicator (i.e., technology) and hospital performance or outcome indicators (i.e., readmission rates, mortality, financial performance).

Overall, the complexity of the healthcare environment and the intricacy of relationships between technology and performance necessitate more well-designed research on the relationship between hospital technology and performance. Besides the need to increase the knowledge-base, there is also the need for critical evaluation of existing research in order to account for the relationships that will improve the level of understanding for future research. This article will attempt to address this second need through a systematic review of existing literature on the relationship between hospital technology and performance. In this study, 'hospital performance' refers to both quality and financial performance dimensions. Because this review focuses on clinical technologies and services, health information technology is outside the scope of this review. Two important rationales for hospital decision makers in adopting new clinical technologies are the expected improvement in clinical performance and positive impacts on the financial bottom-line. Therefore, this literature review provides useful and systematically aggregated information for decision-makers by focusing on clinical technologies and attempting to account for their clinical and financial implications on the performance of hospitals.

Rather than departmental or unit level performances, this study focuses on organizational level performance. There are legitimate concerns that individual performance implications of high-tech services might be attenuated when they are aggregated to organizational levels. We still opted to focus on organizational level studies due to several reasons. 1) There are already a large number of studies that focus on individual clinical technologies and their implications on departmental level performances (i.e., cost-benefit analyses of individual technologies). However, these studies do not provide enough information about overall organizational level implications of high-tech services. 2) Organizational performance does not only depend upon the unit/departmental performances, but also on other factors (i.e., environmental, legislative). In other words, organizational performance cannot be only defined as the aggregate of departmental performances, but also the overall performance that is achieved through the interaction of individuals, departments, other organizations, and various environmental forces. 3) Exploring methodologies and findings of hospital performance studies with high technology focus would not only address a gap in the literature but also might provide some avenues for future research. Overall, there is a need to capture a broad perspective about the implications of high-tech medical services on hospital performance and this review addresses this need.

New Contribution

This article is a technology-focused, systematic review that can be categorized under the broad theme of ‘hospital performance.’ However, this review is not seeking to account for research areas such as the antecedents of technology adoption, diffusion of innovation, or cost-benefit analysis of individual technologies in which many studies/reviews exist. On the contrary, this review is seeking to account for the empirical studies that are investigating the organizational level implications of hospital technologies on performance. Therefore, there are several reasons this review differs from all previous reviews that can be categorized under the similar broad theme of 'hospital performance.' First, it particularly focuses on high-tech clinical services and attempts to account for the relationship between these services and hospital performance. Within this relationship, hospital performance is considered as a dependent variable and technology as an independent variable. Considering that large numbers of studies (i.e., diffusion of innovation or technology adoption studies) have been using technology as the dependent variable, by focusing on technology as an independent variable, this review attempts to bring academic focus to this less explored area of study. Second, it addresses a need to account for organizational level implications of high-tech services by focusing on organizational level performance rather than unit or departmental level performance. Even though this review partially builds upon Spetz and Maurio's (2004) review, it differs substantially due to several reasons: (a) This study focuses on the relationship between hospital technology and performance whereas Spetz and Maurio (2004) focuses on hospital technology measures and methodologies of measurements. (b) This systematic review process was integrated with tools of traditional literature reviews (i.e., manual searches of bibliographies) to improve comprehensiveness of this review. To the best of our knowledge, there are no other reviews available with all of the aforementioned characteristics.

Analytical Framework

As seen in Figure 1, the main objective of this review is to account for and to discuss the relationship that has been revealed in existing literature between hospital technology and performance (clinical/financial). The details of this analytical framework are based upon the following four main research questions:

1) What are the major findings in regards to the relationship between hospital technology and financial/quality performance?
2) How studies are designed and what type of analytical processes are used?
3) What types of hospital technology measures are used in these studies?
4) What types of hospital financial/quality performance measures are used?

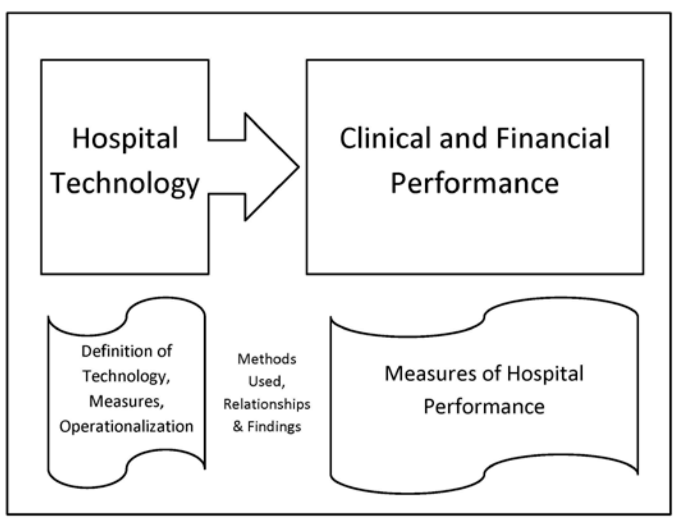


Figure 1. Analytical framework for the relationship between hospital technology and performance

Revealing the relationship between hospital technology and performance requires both sides of this relationship to be defined. At first glance, some might think that it would be easy to measure hospital technology because it is not difficult to gather information about the availability of highly visible new equipment or services. However, depending on the inclusiveness of the definition, a broad range of equipment or services can be easily categorized as hospital technology. For example, even occupational therapy can be counted as a technology (Spetz & Maiuro, 2004). Therefore, similar to Spetz and Maiuro's (2004) methods/review article, this review will also account for various definitions of hospital technology that are used by researchers within the context of the technology-performance relationship. Overall, focusing on high-tech equipment and services allows this review to limit the number of studies to those that include some cutting edge and highly visible equipment and services in their analysis.

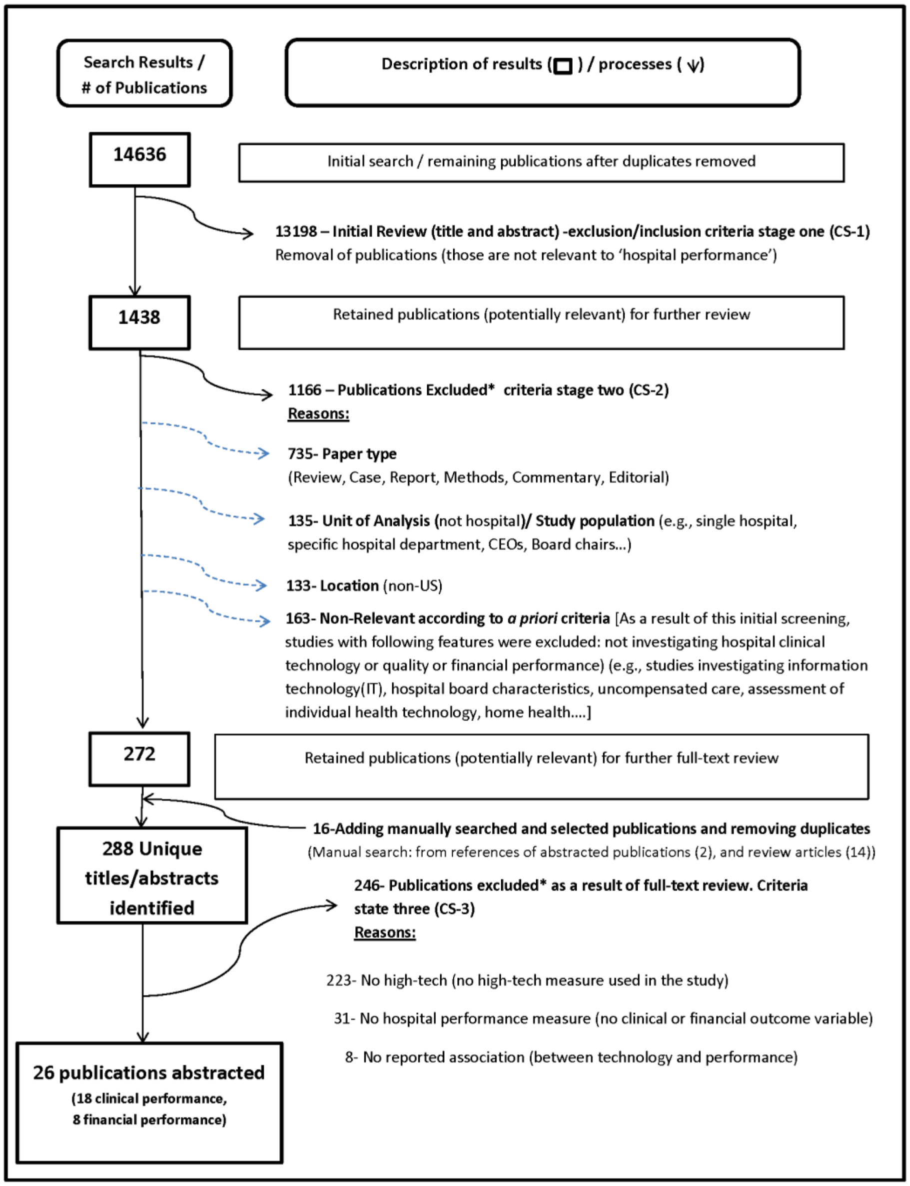
METHODS

Two major strategies were followed in this systematic literature review. First, a systematic and encompassing search process maximized the number of potential studies captured. Second, *a priori* inclusion/exclusion criteria were used to review the studies and select those relevant to the focus of the review.

The search process included several steps. *A priori* search criteria identified relevant papers as those that were (a) U.S.-based, and (b) empirical, peer-reviewed studies that investigated the relationship between high-tech clinical services (equipment) and hospital performance, particularly quality and financial performance. Non-U.S. publications were excluded because of differing regulatory restrictions on high-tech clinical services in different countries. Single hospital studies were also excluded because of substantial constraints on the generalizability of their findings. Second, the search terms were determined by using the authors' own expertise, two books on medical technology (Callahan, 2009; Cohen & Hanft, 2004), several seminal articles with discussions on healthcare technology (Acemoglu & Finkelstein, 2008; Chernew, Hirth, Sonnad, Ermann, & Fendrick, 1998; Morrisey, 2001; Spetz & Maiuro, 2004), and several seminal articles on quality and financial performance (Donabedian, 1980, 1986; Hearld, Alexander, Fraser, & Jiang, 2008; Pink et al., 2006). After running a pilot search in PubMed and searching the PubMed MeSH terms, the following keywords and phrases were determined to be used in this review: (a) For the technology dimension: hospital, technology, high-tech, equipment, service line, service mix, service offering, full service, hospital service; and (b) for the performance dimension: quality, mortality, readmission, outcome, hospital performance, performance, financial performance, and financial. The search result generated limited number of studies for the financial performance dimension. As a result we added "cost" as another search term.

Multiple searches were performed by using the keyword combinations in PubMed, Web of Science, Business Source Premier, and Cumulative Index to Nursing and Allied Health (CINAHL). In this review, Thomson Reuters' EndNote was used to aggregate the search results and to screen for duplicates. After eliminating the duplicates, initial results returned 14,636 articles.

Figure 2 summarizes the selection process of the publications that investigate the relationship between hospital technology and performance. To improve the search/selection/retention process and achieve the ultimate focus of this review, *a priori* determined exclusion/inclusion criteria were applied at three stages by focusing on three dimensions: (a) criteria stage one (CS-1) removes the publications that are not relevant to hospital performance (i.e., financial or clinical performance); (b) criteria stage two (CS-2) screens features of publications according to a priori criteria (i.e., paper type, unit of analysis, location and relevancy); and (c) criteria stage three (CS-3) confirms the presence of technology, hospital performance measures, and the relationship between these two. As a result of applying this three staged inclusion/exclusion criteria and adding manually searched articles, the number of articles for full-text review reduced from 14,636 to 288. After a full text review, 26 publications were abstracted. During the review process, to strengthen the review search process, the reference section of each abstracted publication was also screened for the inclusion of any potentially relevant publication that might have been missed during earlier steps. Two articles were included among abstracted ones as a result of this process.



*Exclusions are not mutually exclusive

Figure 2. Selection of publications that are investigating the relationship between hospital technology and performance

RESULTS

The results of this literature review, in regards to hospital technology and performance is summarized in Table 1 and Table 2. In sequence, studies in these tables used financial performance and clinical performance as the dependent variables. These two tables show that researchers found mixed results by using a variety of technology and performance measures with an assortment of research goals and analytical methods. Technology was not the main focus of these studies most of the time. Some studies used one or two technologies; others developed various indices of technologies. Most of the time these technology measures were used as a control variable while investigating a main research objective other than technology.

Abstracted studies exhibited mixed results in regards to the relationship between hospital technology and financial performance (Table 1). For example, one study found a positive relationship between a technology index and financial performance (ROA, and Total Margin) (Irwin, Hoffman, & Lamont, 1998), whereas another study found a non-significant relationship by using ROA and Operating Expenses as financial performance measures (McCue, Mark, & Harless, 2003). Both studies developed their indices by using American Hospital Association's (AHA) annual survey. Both studies also used similar profitability measures as dependent variables such as total margin, operating margin, and ROA.

Some of the results also indicate an association between the availability of technologies and higher costs at hospitals. For example, one study that used a cardiac intensive care unit (CICU) and a medical intensive care unit (MICU) as markers of technological sophistication for hospitals found that hospitals in the higher cost quartile for conges-

Table 1
Studies Examining the Relationship between Hospital Technology and Financial Performance

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
1	Chen, Jha, Guterman, Ridgway, Orav, & Epstein (2010)	2006	3146 hospitals for Congestive Heart Failure (CHF), 3152 hospitals for pneumonia	CS	No direct definition however, among IV's presence of cardiac intensive care unit (CICU) and medical ICU (MICU) were included.	Process quality measures, mortality, readmission and hospital structural characteristics	1-Cost of care for pneumonia and CHF	Linear regression & Multivariate models	Hospitals classified in higher cost quartile for CHF were more likely to have CICU. Hospitals in low cost quartile for pneumonie had slightly less presence of MICU
2	Irwin, Howffman, & Lamont (1998)	1990, 1991	222 general, short-term hospitals in FL	CS	A high-tech index developed by using the AHA data and the ratings of health professionals by using likert-type surveys on value, inimitability, rareness, and non-substitutability	Hospital Size (only control variable)	1-Return on Asset(ROA) 2-Total Margin (TM)	OLS, hierachical, multiple regressions	Positive significant relationship (both for ROA and TM) especially for those hospitals with technologies that are valuable, rare, and inimitable

continued

Table 1 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
3	Li, & Collier, (2000)	1994	157 community hospitals with 33% return rate)	CS	Clinical technology measure based upon survey questions on 1) lab equipment , 2)radiology equipment, 3) drug dispensing.	1-clinical outcome 2-physician participation	1-operating profit 2- Return on assets 3-Return on investments	Chi-Square to see responder, non-responder difference. Structural Equation Model (SME)	Positive association between clinical technology and financial performance (ROA, Operating Profit, ROI)
4	Jha, Orav, Dobson, Brook, & Epstein (2009)	FY 2002	Out of 4648 AHA hospitals 3794 were used due to missing data on hospital costs.	CS	No direct definition, however, structural characteristics include presence of ICU or MICU	Risk adjusted quality and mortality measures for AMI, CHF, Pneumonia	1-Risk adjusted costs for AMI, CHF	Chi-square tests, t-tests, multivariable logistic regressions	Hospitals at the lowest quartile of risk-adjusted costs were less likely to have ICU

continued

Table 1 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
5	Jiang, Friedman, & Begun (2006)	1997 and 2001	Final sample: 934 non-federal, general acute hospitals in 10 states	CS	Presence of high-tech & profitable 9 services including CABG, angioplasty, cardiac catheterization, extracorporeal shock-wave lithtripsy, CT, diagnostic radioisotope, MRI, positron emission tomography, and single photon emission CT	Market characteristics , Hospital characteristics, Human resource characteristics	1- CMS cost-to-discharge ratios 2-Operating margin 3-Total Margin	Stratification of cost/mortality quadrants (C/MQ). Logistic regression .	hospitals likelihood of moving from worst to best quadrant were positively associated with number of high-tech services. NS association was found between presence of high-tech and persistenly being in the low C/MQ overtime.
6	McCue, Mark, & Harless (2003)	1990-1995	422 Acute care hospitals	LG	Saidin index (see text)	RN, LPN, Non-nurse staffing (separate); Mortality;	1-Operating Margin 2-Operating Expense	Dynamic model regression with lagged dependent variable	Used as a control variable / Not significant

continued

Table 1 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
7	Trinh, Begun, & Luke (2008)	1998, 2000, 2002	2204 acute care hospitals in US	LG	# of 15 high tech services such as angioplasty, cardiac catheterization lab service, certified trauma service, extracorporeal shock wave lithotripter service, HIV-AIDS service,	Duplication of services for Inpatient and Ancillary services	1- Average cost per patiend day 2-Average cost per discharge 3-Operating margin 4-Return on assets	Structural Equation Modeling with Maximum Likelihood Estimator	High-tech duplication was associated with higher cost and lower operating margin
8	Trinh, Begun, & Luke (2010)	1997, 2000, 2003	1227 urban acute care hospitals belong to multihospital system	Longitudinal structural equation modeling	Number of 15 high-tech services such as MRI, PET, single photon emission computerized tomography, ultrasound, and reproductive health	Duplication of services for Inpatient and Ancillary services	1- Average cost per patiend day 2-Average cost per discharge 3-Operating margin 4-Return on assets	Structural Equation Modeling with Maximum Likelihood Estimator	Receiving high-tech services is financially more beneficial than service sharing for individual hospitals

CS = Cross-Sectional, **LG**=Longitudinal, **NS** = Not-significant; **IV**=Independent Variable tive heart failure (CHF)/pneumonia were more likely to have a CICU/MICU (Chen et al., 2010). Similarly, another study found that hospitals classified at the lowest *risk-adjusted cost quartile* for acute myocardial infraction (AMI), CHF, and pneumonia were less likely to have an intensive care unit (ICU) (Jha, Orav, Dobson, Book, & Epstein, 2009). Studies investigating the technology- performance (financial) link differ from each other in regards to research and analytical design, sample size, and study period. Four out of nine studies were based upon longitudinal data (G. Bazzoli & Andes, 1995; McCue et al., 2003; Trinh, Begun, & Luke, 2008, 2010)

While analyzing the association between hospital technology and clinical performance, researchers found mixed and in some cases contradictory results (Table 2). Mortality rate was one of the most frequently used outcome measures. Some studies found non-significant relationships (G. J. Bazzoli, Chen, Zhao, & Lindrooth, 2008; Blegen, Goode, Spetz, Vaughn, & Park, 2011; Tomal, 1998) for mortality rates. A few studies found significant and negative associations between hospital technology and mortality rates (Hartz et al., 1989; Krakauer et al., 1992), while a longitudinal study found significant and positive association by using ordinary least squares (OLS) (Mark, Harless, McCue, & Xu, 2004). For the technology-mortality link in high managed care penetrated markets, a study found significant and positive association by using OLS, and significant and negative association by using within-group fixed effects statistical model (Mark, Harless, & McCue, 2005). For the relationship between technology and AMI mortality, a study found non-significant association by using bivariate correlations, and significant and negative association by using regression (Schultz, van Servellen, Litwin, McLaughlin, & Uman, 1999). Overall, of the nine studies that used mortality outcome

Table 2
Studies Examining the Relationship between Hospital Technology and Clinical Performance

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
1	Bazzoli, Chen, Zhao, & Lindrooth (2008)	1995-2000	1544 non-federal, general acute care hospitals from 11 states	CS	High-tech services defined as a count of up to 33 services reported in AHA survey including NICU, trauma centers, open-heart surgery etc.	Financial performance (operating margin, cashflow to total revenues)	1- In hosp. mortality in low death DRGs, 2- Nursing & Surgical Patient safety indicators (PSI)s	Generalized Method of Moments (GMM)	Significantly positively associated with surgical-related PSI (p<0.01). No significant relationship with other outcome measures
2	Blegen, Goode, Spetz, Vaughn, & Park (2011)	2005	54 hospitals member of University HealthSystem Consortium(UHC)	CS	Saidin Index (see text)	Safety-net status, RN skill mix, Total hours of nursing care, size, ownership, location, Case mix index	1-CHF mortality, 2-Decubitus Ulcer, 3-Failure-to-rescue (FTR), 4- infection due to medical care, 5-post-operative sepsis,	Robust Regression	NS

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
3	Ghaferi, Osborne, Birkmeyer, & Dimick (2010)	2000-2006	8862 patients in 672 nationwide hospitals	LG	dichotomous (yes/no) variable of presence of organ transplantation or open-heart surgery	Nurse-to-patient ratio, Teaching status, hospitals size, and average daily census	Failure to rescue (FTR)	Multivariate logistic regression models	Significant association with lower FTR (OR 0.65, 95% CI 0.52 to 0.82)
4	Hartz, et al (1989)	1986	3100 hospitals	CS	Number of 5 sevices available: cardicac catheterization lab, extracorporeal lithotripter, MRI, open-heart surgery, and organ transplantation	Financial Status (payroll expenses and occupancy rate), ownershi% board-certified specialists, % of RN)	Predicted Mortality Rates	Weighted Least Squares Regression	Higher technology sophistication significantly associated with lower mortality

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
5	Jha, Orav, & Epstein (2009)	2007	2222 hospitals that reported discharge instructions on HQA and HCAHPS	CS	presence of coronary care unit presented as an indicator of technology	Two discharge measures (chart-based, patient reported) Ratio of nurses to 1000 patient-days,	1- Readmission rate for CHF and Pneumonia	Chi-sq. tests, t-tests to compare hospital characteristics on discharge planning, Mutlivariable linear regression models	There is a positive significant (P<0.05) association between hospitals with coronary care unit and HQA performance on discharge instructions
6	Jha, Orav, Zheng, & Epstein (2008)	2007	2429 hospitals with patients' experience data	CS	Presence of Medical ICU was presented as a marker of technological capability	Nurse-to-1000 patient days ratio, HQA process measures for AMI, CHF, Pneumonia, and surgical care	Patient reported quality of care based upon HCAHPS survey	Chi-sq. tests, t-tests and Mutlivariable linear regression models	Very modest difference found between hospitals with and without Medical ICU in % of patient's global ranking (62.3.3% and 63.9%, respectively; P = 0.001)

continued

Table 2 *Continue*

	Authors	**Study Period**	**Sample**	**Design**	**Hospital Technology (HT)**	**Other major IV's ***	**Variable (OV)**	**Analysis**	**HT relationship with OV**
7	Jha, Stone,Lave, Chen, Klusaritz, & Volpp (2010)	Fys 1996-2002	42 more minority-serving versus 108 disproportinately non-minority serving VA hospitals	LG	Presence of cardiac ICU and availability of key tecnologies (angioplasty, CABG, and MRI)	Concentration of black veterans, hospital characteristics	30-day mortality on AMI, CHF, gatrointestinal hemorrage (GI bleed), and pneumonia	Ordinary Logistic regression for mortality outcome.	Adjusted mortality rates for pneumonia and AMI were significantly higher at minority serving hospitals, which more likely to have cardiac ICU, angioplasty, CABG
8	Jiang, Friedman, & Begun (2006)	1997 and 2001	Final sample: 934 non-federal, general acute hospitals in 10 states	CS	Presence of high-tech & profitable 9 services such as angioplasty, cardiac catheterization, extracorporeal shock-wave lithtripsy, CT, diagnostic radioisotope	Market characteristics , Hospital characteristics, Human resource characteristics	AHRQ Inpatient mortality quality indicators	Stratification of cost/mortality quadrants (C/MQ). Logistic regression	Positive association with the likelihood of moving from worst to best quadrant. NS association was found for persistenly being in the low C/MQ overtime.

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
9	Krakauer et al (1992)	1986	84 hospitals throughout U.S. (42,773 patients)	CS	Index including : cardiac catheterization lab, extracorporeal lithotripter, MRI, open-heart surgery facility, or organ transplantation capability	% of RN, % board-certified specialist physicians, Other structural characteristics	30-day mortality rates	Logistic regression	statistically significant negative relationship both for claims and clinical models
10	Li, & Collier, (2000)	1994	157 community hospitals D68	CS	Clinical technology measure based upon survey questions on 1) lab equipment , 2)radiology equipment, 3) drug dispensing.	SEM based upon three stage links: 1)technology measures 2)two quality measures, 3) hospital financial performance	1-Survey question on clinical quality	Chi-Square to see responder, non-responder difference. Structural Equation Model (SME)	Positive association between clinical technology and clinical quality

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
11	Mark, & Harless, (2010)	1996-2001	283 acute care hospitals in CA	LG	Saidin Index (see text),	RN, LVN, and Aide hours per patient (separate measures), CMI, payer mix, HMO penetration	Post operative ratios for: 1)pneumonia, 2) septicemia, 3)urinary tract infection	Dynamic panel regression model with generalized method of moments (GMM).	NS
12	Mark, Harless, & McCue, (2005)	1990-1995	422 acute care hospitals	LG	Saidin index (see text)	RN, LPN, Non-nurse staffing (separate); Market characteristics, hospital characteristics	Mortality	Ordinary Least Squares (OLS), Within Group, and Dynamic panel model regressions	Only in high HMO penetration markets high-tech was significantly (positive in OLS, negative in Fixed effects) associated with mortality rates (except the Dynamic panel model).

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
13	Mark, Harless, McCue, & Xu (2004)	1990-1995	422 Acute care hospitals	LG	Saidin index (see text)	RN, LPN, Non-nurse staffing (separate); Market characteristics, hospital characteristics	Risk adjusted complication ratios: mortality, pneumonia, decubitius ulcer, and urinary tract infection	Ordinary Least Squares (OLS), Within Group, and Dynamic panel model regressions	HT was significantly (+) associated with mortality (only in OLS model). HT was significantly (-) associated with pneumonia complications ratio (Dynamic panel model)
14	Mukamel, Zwanziger, &Tomoszewski (2001)	1990	1927 hospitals in 134 metropolitan statistical areas (MSA)	CS	Index including: cardicac catheterization lab, extracorporeal lithotripter, MRI, open-heart surgery, and organ transplantation	% of Medicaid days, % of ICU days, Ratio of ER visits to total inpatient days	Risk adjusted mortality rates	Regression models with MSA random effects	hospitals in top technology quartile (having at least 2 high-tech services) had a lower mortality rate compared to hospitals with no high-tech services

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
15	Schultz, Van Servellen, Litwin, McLaughlin, & Umran (1999)	1992	373 medical surgical hospitals in CA	CS	Availability of: CABG, PCI, or both	Teaching status, board-certified physician %, RN hours/inpatient days, profit status, total expenses/patient days	AMI mortality ratio	Bivariate corrolations. Then, linear regression and hierarchical order of entry	NS in bivariate corelations. Significant and inverse in regression results.
16	Person et al (2004)	1994-1995	4401 of 6668 hospitals from Cooperative Cardiovascular Project (CCP)	CS	In 4 categories availability of 3 procedures: 1)Coronary Angiogram, 2)Percutaneous coronary intervention 3)Coronary artery bypass grafting (CABG)	Nurse to patient ratio for RN and LPN (categorized into quartiles)	In-hospital mortality ratio	comparison of RN/LPN staffing quartiles with chi-sq , and t-test Then, multivariable logistic models.	High RN staffed hospitals are more likely to have more techologies and more likely to be teaching hospital. Higher RN staffing associated with lower mortality

continued

Table 2 *Continue*

	Authors	Study Period	Sample	Design	Hospital Technology (HT)	Other major IV's *	Variable (OV)	Analysis	HT relationship with OV
17	Tomal, (1998)	1991	398 general acute care hospitals in CA with at least 50 Medicare cases	LG	Number of three high-tech services: coronary intensive care, organ/tissue transplant, burn unit	Market characteristics Hospital characteristics	Adjusted mortality rate	Ordered probit (compared with OLS)	NS
18	Werner, & Bradlow, (2006)	2004	3657 acute care hospitals reported quality measures to Hospital Compare	CS	Presence of open heart surgery	Process Measures form AMI, CHF, and Pneumonia	Risk Adjusted mortality rate	Regression - Bayesian approach	Significanlty higher number of hospitals with open heart surgery (67%) were categorized under low, and average mortality groups.

CS = Cross-Sectional, **LG**=Longitudinal, **NS** = Not-significant; **IV**=Independent Variable and multivariate regression, 44% (4 studies) found no significant, 44% (4 studies) found significant and negative, 11% (1 study) found significant and positive association between high-tech medical services and mortality rates.

For the link between technology and failure to rescue (FTR), one study found non-significant association by using the Saidin index (Blegen et al., 2011), and another study found significant and negative association by using technology measures based upon organ transplantation and open-heart surgery (Ghaferi, Osborne, Birkmeyer, & Dimick, 2010). The majority (70%) of studies in Appendix C used cross-sectional designs with sample sizes ranging from 54 to 4,401 hospitals.

Measures of hospital technology in the 26 abstracted studies also display a wide range of possibilities (See Table 1 and 2). Fourteen of the 26 publications used an index of three or more technological services. Seven publications used one or two technological services as a marker of hospital technology. Five publications with a nursing focus used the Saidin Index, a special high-tech index that takes into account both breadth and rareness of high-tech services.

DISCUSSION AND FUTURE DIRECTIONS

In this systematic review, we attempted to account for the U.S. based empirical research on the relationship between hospital technology and performance. As a result of systematic processes that include three staged *a priori* exclusion/inclusion criteria, 26 publications were abstracted. Full text review of these 26 publications, according to the analytical framework, revealed several major findings.

First, the results in Table 1 and 2 indicate that the studies exhibited mixed and, in some cases, contradictory results regarding the relationship between hospital technology and performance (clinical and financial). Especially, the contradicting results on certain clinical measures such as mortality and mixed findings on financial performance measures, such as ROA are noteworthy. Therefore it is necessary to reveal the underlying reasons for the variations in studies. However, it is hard to determine the underlying reasons for these mixed findings mainly due to not having sufficient number of studies that used similar research designs and measures. Researchers attained these mixed results by using various research and analytical designs, samples, study periods and hospital technology measures. In other words, the variation in technology measures and study designs limits the comparability across studies. Therefore, based upon this review, there is no clear evidence for either positive or negative relationships between high-tech services and hospital performance.

Second, searching for a relationship between technology and performance within the larger domain of hospital performance and ending up with 26 studies for abstraction (8 for financial, and 18 for clinical performance) is an important finding itself. This indicates that the number of empirical studies investigating the relationship between hospital technology and performance is greatly limited. Moreover, except for two publications (Irwin et al., 1998; Li & Collier, 2000), technology was not the focus of these 26 studies.

Third, generalizability and comparability of these 26 abstracted studies are constrained due to some methodological limitations. For example, the generalizability of the findings of two technology-focused publications are limited due to the following reasons. First, Li & Collier (2000) based their research solely on cross-sectional survey data. Second, Irwin et al (1998) based their research on cross sectional data from only one state (Florida).

In summary, more evidence is needed to clarify the technology-performance link, especially when considering the possibility of hospitals being in (Devers, Brewster, & Casalino, 2003) or moving into another medical arms race era. In the medical arms race era prior to the prospective payment system in 1983, hospitals exhibited uncontrolled and unplanned competitive behaviors by adopting various services and technologies to attract patients and physicians (Trinh et al., 2008). Such competitive behavior may not only have negative effects on healthcare cost but may also substantially reduce financial performance of hospitals. In their study of service duplication, Trinh et al. (2008) found that high-tech service duplication in a hospital market is associated with a higher cost and a lower operating margin. However, the significant and positive association between high-tech service duplication and occupancy rate within the same study (Thrinh et al., 2008) also indicate the legitimacy of strategically using technology to attract patients. Therefore, future research should not only focus on revealing the relationship between hospital technology and performance, but also consider providing administrators some insights into achieving the right balance between costs and benefits of hospital technologies. Besides the aforementioned future directions, we also have several recommendations for future studies.

The first recommendation pertains to the recognition of the intricate relationship between hospital technology and performance, and the development of strategies to overcome this obstacle. As the results (Table 1 and Table 2) indicate, researchers use hospital performance as a dependent variable and use various hospital characteristics including technology as predictors. The difficulty in showing the influence of technology as an independent variable on hospital performance, considering many confounding organizational, operational and market characteristics, makes it very difficult to draw any causal inferences. Moreover, as a structural component, the outcomes of hospital technologies are moderated/mediated by the processes of care. Processes of care and operations are provided by the human capital of the organization. Therefore, for future studies, we recommend more robust research designs that acknowledge both human and operational characteristics of organizations in addition to market and organizational characteristics.

The second recommendation suggests the development of hospital technology measures. The results of this review confirmed Spetz and Maurio's (2004) conclusion about the lack of standardized methods for defining, conceptualizing and measuring hospital technology (See Table 1 and Table 2). Hospital technologies have been defined and conceptualized in various ways that span from one technology as a marker of technology to sophisticated technology indices such as the Saidin index. Spetz and Maurio's (2004) suggestion of choosing or creating technology measures that are customized according to the research purpose might be a reasonable argument for explaining the variety of definitions and measurements in hospital technology. However, not having a reliable, consistent technology measure makes it very difficult to draw inferences, generalize findings and perform comparisons across studies. The inability to compare study findings due to differing technology measures severely limits the development of future research. Therefore, for future studies, we not only recommend development of new technology measures according to the research objective but also endorse testing the reliability, strength and weaknesses of existing technology measures in different settings and study periods.

The third recommendation calls for the examination of organizational and societal implications of hospital technologies. Societal implications of hospital technologies such as welfare benefit or loss, build upon organizational and individual impacts of those technological services. However, these societal implications may not be the simple cumulative forms of organizational/individual impacts. For example in order to understand the societal cost implications of technologies one should consider also the market forces. Joseph P. Newhouse, in his seminal 1992 article, identifies medical technologies as the largest contributor of rising health care cost in the United States after discussing several other plausible options. The author supports his claim by pointing out the fact that the largest portion of rising healthcare cost is attributed to hospital expenditures, and technological change seems to represent the bulk of these hospital expenditures (Newhouse, 1992). Considering the underlined cost impact, there is need for more research on organizational and societal cost-benefit implications of hospital technologies. This need permeates in both realms of thought, whether one finds the societal benefits of hospital technologies over their costs more plausible (Cutler, 2007; Cutler & McClellan, 2001; Newhouse, 1993) or declares medical technologies as a major source of welfare loss for the nation (Callahan, 2009)

The fourth recommendation relates to the health policy implications of hospital technology-performance research. Currently, the United States is lacking a coordinated technology planning and assessment process (Coye & Kell, 2006). Uncoordinated adoption of high-cost medical technologies may be impeding the efficient use of the nation's limited resources. A hospital's adoption decision for a technology independent of another hospital (Coye & Kell, 2006) might cause service duplication in their market, which may translate into underutilization, excess capacity, operational and financial inefficiency. More research on the technology-performance link would not only better inform the decision makers, but also well coordinate the technology adoption decisions among hospitals. Therefore, better availability of useful information about the pros and cons of medical technologies would improve the efficiency of the market.

The fifth recommendation is about the betterment of hospital technology data collection and methods. Development of high quality information requires the availability of high quality data for analysis. Hospital performance researchers build their research according to the research objectives and availability of data. Moreover, the continuously increasing number of technologies and problems with the data collection methods make it difficult to find reliable data, especially on hospital technologies (Spetz & Maurio, 2004). Thus, future policies should also address the generation of reliable data sources to improve knowledge about the relationship between hospital technology and performance.

The major limitation of this review is that the lead author was responsible for the searches and the coding. Having only one person performing searches and applying inclusion/exclusion criteria might have limited the comprehensiveness of this review. However, several strategies were used in this review to reduce the effects of this limitation. First, large numbers of keywords were identified and used in four academic search engines to maximize the number of potentially relevant studies captured. Second, Thomson Reuter's EndNote, a very useful technological tool for organizing, reviewing and citing publications, was used to ease management of the large number of studies and improve the consistency of the inclusion/exclusion criteria application. Third, a three staged *a priori* exclusion/inclusion criteria were used with the full-text review stage (last stage) being the technology focused one. This three staged use of *a priori* criteria reduced the chances of missing any study that might have used technology as a secondary focus or control variable. As the results of the review indicate, most of the time, technology was not the main predictor of interest and may not have been recognized in either the title or the abstract of the publication. Last, the authors claim that any limitations that might have arisen as a result of keyword selection, search engines, or the search process itself, have been substantially diminished by additional review of manually selected publications from the bibliographies of two related books, several review articles, and 26 abstracted articles.

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A LONGITUDINAL ANALYSIS OF HIGH TECHNOLOGY MEDICAL SERVICES AND HOSPITAL FINANCIAL PERFORMANCE

by

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ABSTRACT

This study examined the association between high-tech medical services and financial performance of U.S. hospitals by using the resource-based view of a firm. It was hypothesized that hospitals with a *rare* or *large numbers (breadth) of* high-tech medical services will experience better financial performance. Furthermore, it was hypothesized that *registered nurse (RN) staffing mix* and *market competition* would positively moderate the relationship between high-tech medical services and financial performance. A longitudinal panel sample of 4,362 hospitals from 2005 to 2010 was used to assess the hypothesized relationships. Fixed effects regression models generated results that supported the link between a larger breadth of high tech services and all of the financial performance measures including operating margin, operating expenses per inpatient day, total margin, and return on assets. The same association for the rare high-tech services was supported for only operating margin (positive) and operating expenses (negative) in the same direction that they were predicted. However, significant results for operating revenue (negative) were opposite to the predicted direction. The study did not find evidence for the presence of moderating effects of *RN staffing mix* or *competition*.

INTRODUCTION

The study of hospital financial performance has become an important part of organizational performance research. Considering the current attention on the financial sustainability of U.S. hospitals, understanding the major factors that influence hospital financial performance is imperative for researchers, policy makers, and administrators. Despite a slight dip after the 2008 financial crisis, U.S. hospitals continue their capital investments in plants, facilities, and cutting edge technologies (M. J. McCue, 2011; US Census Bureau, 2012; Zengul & O'Connor, 2012). About 50% of hospital capital investments is attributed to clinical and information technologies (Callahan, 2009). These capital investments are expected to continue considering the legislative, demographical, and environmental forces that are taking place in the U.S. For example, retirement of the baby-boomer generation, and approximately 31 million previously uninsured people becoming insured as a result of the Patient Protection and Affordable Care Act of 2010 (ACA, 2010), would require not only investment in additional hospital space (Basu, 2011) but also additional equipment and services. Among these investments, high technology medical services (e.g., positron emission tomography, organ transplant services) have a prominent place given their high upfront costs. Recouping the initial cost within a certain time frame is important for the financial performance of hospitals. This importance multiplies when one takes into account the suggested link between service duplication in a certain hospital service area and lower patient volume of hospitals in the same area (Bryce & Cline, 1998b). Considering this link, if investments in high technology medical services are not accompanied with enough patient volume, the initial investment cost and excess capacity might cause negative effects on financial performance.

However, little information is known about the implications of high-tech medical services on hospital financial performance. Prior research has tended to focus on the availability (Baker & Phibbs, 2002; Baker & Wheeler, 1998; Bryce & Cline, 1998a; Cutler & McClellan, 1996; Grossman & Banks, 1998; Hill & Wolfe, 1997), antecedents of diffusion (Teplensky, Pauly, Kimberly, Hillman, & Schwartz, 1995; Zhang, Kohn, McGarrah, & Anderson, 1999), or cost implications (Chernew, Fendrick, & Hirth, 1997) of high-tech medical services rather than the influence of these services on hospital financial performance. Moreover, there are only a few studies that have specifically focused on clinical technology and explored the effects of high-tech services on hospital financial performance (Irwin, Hoffman, & Lamont, 1998; Li & Collier, 2000; Trinh, Begun, & Luke, 2008, 2010). However, most of these have methodological limitations, which constraint their generalizability, such as being cross-sectional, using inconsistent measures of high-tech services, and being confined to a geographical location. Therefore, it remains unclear whether there is a relationship between high-tech medical services and hospital financial performance.

The aim of this present paper is to evaluate the implications of availability of high-tech medical services on financial performance of hospitals by using the resource-based view (RBV) of a firm. RBV attributes the better performance of organizations to the unique amalgam of their resources (Barney, 1991). RBV is rarely used in hospital financial performance studies (Irwin et al., 1998; Short, Palmer, & Ketchen, 2002) despite being one of the most frequently used strategic management frameworks for organizational performance. Overall, this study will contribute to the literature through three major ways: 1) by addressing the aforementioned need for research on the ‘technology-financial performance’ link; 2) by addressing the limitations of previous studies, and 3) by expanding the knowledge-base through the addition of one more RBV- based empirical study into its limited applications in hospital financial performance studies.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

Similar to other theoretical frameworks, the emergence of RBV can be attributed to the long-run scholarly endeavors (e.g., Dierickx & Cool, 1989; Lippman & Rumelt, 1982; Pfeffer, 1994; M.E. Porter, 1980; M.E. Porter, 1985; Rumelt, 1984; Rumelt & Wensley, 1981; Wernerfelt, 1984) of understanding the underlying reasons of an existing phenomenon. In the case of RBV, this phenomenon is the outperformance of some organizations relative to their peers. RBV posits that certain organizations exhibit superior performance and achieve sustained competitive advantage (SCA) through some organizational resources with distinctive features. Achieving SCA requires these resources or resource bundles to be valuable, rare, inimitable and non-substitutable (VRIN) (Barney, 1991). Barney (1991) posited that the dimensions of VRIN criteria are related to one another. Value refers the attributed capability of the resource bundle in creating added worth to an organization. Rareness indicates whether this value creating mechanism is uncommon or not. Inimitability refers the difficulty of duplicating this value generating and rare resource bundle. Lastly, non-substitutability refers that there are no alternatives available for this unique organizational resource bundle. A recent meta-analysis of 125 RBV studies found significant support for the link between organizational resources and performance (Crook, Ketchen, Combs, & Todd, 2008).

Figure 1 summarizes the posited relationship between a firm's resources, performance, and sustained competitive advantage. Barney (1991) proposed three dimensions for a firm's capital resources: physical, human, and organizational. In another categorization these were presented as: physical, intangible, and financial (Chaterjee & Wernerfelt, 1991). These classifications are similar considering the intangible dimension of human

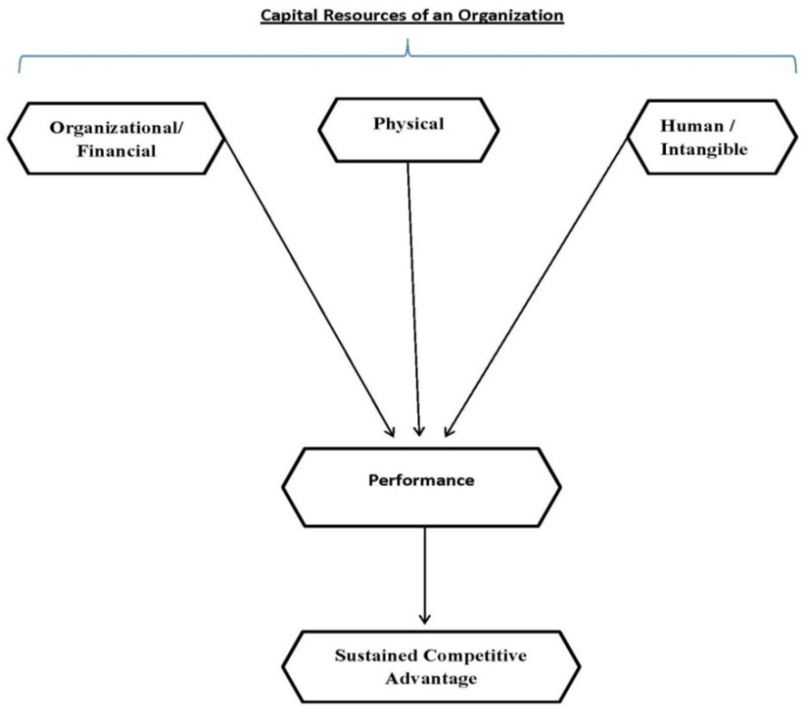

Figure 1. Resource-based View of a Firm

capital resources and the financial aspects of organizational capital resources. The focus of this present study, high-tech services, falls under the physical resources category. However, the labor and operationally intensive nature of healthcare delivery makes it imperative to recognize the human and organizational dimensions as well. Moreover, a physical resource by itself may not satisfy the inimitability and non-substitutability criteria of RBV. Therefore, this paper will use the physical dimensions of hospital resources (i.e., high-tech medical services) and human capital resources.

Investment in physical capital resources is a necessary business practice for hospitals to enhance survival and to protect their competitive edge. Hospitals adopt high-tech medical services with an expectation that the generated revenue from these services will outweigh their costs. In other words, to have positive impact on the financial bottom line, revenue from high-tech services should be higher than their costs. Especially due to the initial large capital investment cost, investing in certain technologies may increase costs in the short-term. However, the benefits (increased revenues and/or lower costs) may outweigh the costs in the long-term.

There are potential direct financial benefits of high-tech medical services: (a) lower costs by increasing efficiency of existing service or processes; and (b) increased revenue by adding service line or substituting for a more lucrative service. There may be also indirect financial benefits through increase in patient volume, which can result in higher revenues for other services and economies of scale.

Regarding the potential direct financial benefits, new technologies may lower costs by improving the efficiency or increase revenue by receiving higher reimbursements. Considering that both government and private payers tend to reimburse high-tech services with relatively higher rates (Coye & Kell, 2006), hospitals tend to adopt a new service line or substitute an existing one with an expectation of higher reimbursements. However, relatively higher reimbursement rates would not occur unless they are accompanied with higher patient volume.

Indirect financial benefits of high-tech services are generated through increases in patient volume. To increase patient volume, hospitals use marketing power and attractiveness of new and cutting edge technologies. Furthermore, hospitals improve their competitiveness, image, and prestige by providing high-tech medical services (Teplensky et al., 1995). In other words, hospitals use high-tech services to attract more patients and physicians (Irwin et al., 1998). Attracting physicians, especially more qualified ones, helps hospitals to attract even more patients (Coye & Kell, 2006). Besides, making more high-tech services available and increasing patient volume may result in economies of scale (Morrisey, 2001). Higher patient volume would reduce hospital costs by reducing per-patient fixed cost allocation. Moreover, being capable of investing in high-tech medical services and offering a large breadth of these services might indicate other organizational capabilities and resources such as proper training and staffing policies that would allow efficient use of these technologies too. Therefore, considering the aforementioned financial benefits of high-tech services, offering a larger breadth of these services is expected to yield better financial performance.

Hypothesis 1a. Overall, there is a positive relationship between the number of high-tech medical services offered (breadth) and hospital financial performance.

Historically, heterogeneity of profit margins in a diagnosis related group (DRG) based reimbursement system not only favored the emergence of single specialty hospitals (SSHs) but also increased the adoption of more lucrative services by general hospitals (Carey, Burgess, & Young, 2009). Some of the inequalities in DRG-based reimbursement were intentionally done by the Center for Medicare & Medicaid Services (CMS) to accelerate the adoption of certain high-tech services (Straube, 2005). However, adoption of these more lucrative services by various hospitals in the same market area created service duplications (Trinh et al., 2008). Even so, organizations with economies of scale may not be able to reap all potential benefits from their valuable resources if their competitors have access to the same resources. As RBV suggests, having rare resources would provide an organization with competitive advantage over its rivals (Barney, 1991). Therefore, not only the number of resources (breadth), but also the rareness of these resources would be an important factor for financial performance. Overall, hospitals offering a larger number of rare high-tech services are expected to exhibit better financial performance.

Hypothesis 1b.There is a positive relationship between the availability of rare high-tech medical services and hospital financial performance.

Among all capital resources of healthcare organizations, human capital resources have a special place. As previously mentioned, any technology can only reach its potential within the hands of skilled and knowledgeable people. RBV also recognizes human capital resources as an important part of unique resource bundle. Human capital resources provide an intangible dimension to organizational resources through their actions, knowledge, culture and habits. This intangible dimension of organizational resources makes it very difficult to imitate an organization. Because hospitals are service intensive environments, human capital resources represent significance both for financial performance and for efficient and proper operation of high-tech medical services. Nurses, also, are an important part of human capital resources for hospital operations. The previous research indicates that an increase in nursing education and RN staffing mix (ratio of RN/All Nurses) are associated with better healthcare outcomes (Aiken et al., 2011; Aiken, Clarke, Cheung, Sloane, & Silber, 2003). Therefore, RNs with their knowledge and with their availability in almost all areas of hospital have capacity to synergize with high-tech services. In other words, being more educated and more prevalently available, RNs would be able to optimize the benefits of high-tech services. Overall, in light of the aforementioned discussions, we expect that the impact of high-tech services on hospital financial performance would be positively moderated by RN staffing mix.

Hypothesis 2a.When the breadth of high-tech services is considered, higher RN staffing mix positively moderates the relationship between high-tech services and financial performance.

Hypothesis 2b.When the rareness of high-tech services is considered, higher RN staffing mix positively moderates the relationship between high-tech services and financial performance.

Hospital competition is considered a major driver of hospital technology adoption (Devers, Brewster, & Casalino, 2003). Hospitals may use high-tech services as a differentiation strategy in more competitive markets to increase market share and ultimately experience better financial performance. As previously mentioned, hospitals utilize prestigious image of high-tech services to attract quality physicians and more patients (Teplensky et al., 1995). Trinh et al. (2008) suggest that hospitals with more and better high-tech services will have better occupancy rate. Therefore, it is expected that increased competition among hospitals would positively moderate the relationship between high-tech medical services and hospital financial performance by increasing demand for those high-tech hospitals and ultimately financial performance.

Hypothesis 3a. When the breadth of high-tech services is considered, competition positively moderates the relationship between high-tech services and financial performance.

Hypothesis 3b. When the rareness of high-tech services is considered, competition positively moderates the relationship between high-tech services and financial performance.

Figure 2 provides the analytical/theoretical framework for this study by summarizing the hypothesized relationships among high-tech services and financial performance by also controlling for organizational, staffing, and environmental factors.

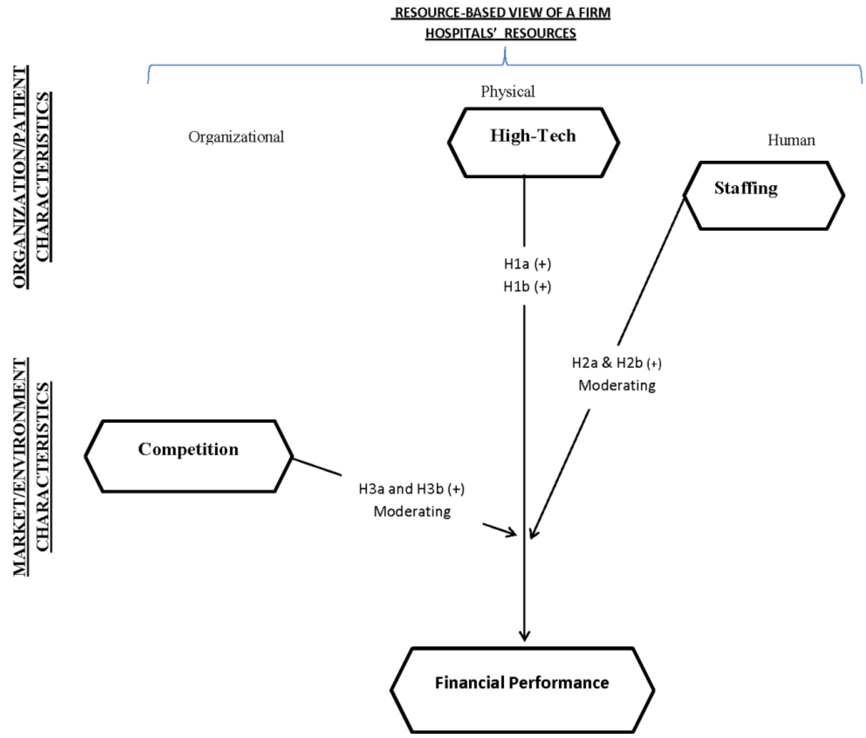

Figure 2. Analytical framework for the examination of relationship between high-tech medical services and financial performance.

METHODS

Data and Sample

This study uses longitudinal panel data covering the period of 2005-2010 from the following sources: Area Resource Files (ARF), American Hospital Association (AHA) annual survey, CMS Medicare cost reports (MCR), and CMS Case mix index (CMI). Because this study merged several data sources, the final sample includes the hospitals that reported data to all of the aforementioned sources except ARF. The AHA survey files consisted of 38,082 observations from an average of 6,347 hospitals per year for 6 years. From the AHA survey files, 8,881 observations for specialty and other service type hospitals were excluded. The study only focused on medical surgical hospitals in the United

States for two reasons: (a) specialty hospitals tend to have relatively narrow technological focus; and (b) focusing on medical surgical hospitals allows better interpretation of results in regards to high-tech services. Moreover, 1,357 hospitals were also excluded because of not having Medicare provider ID to merge with AHA data. Hospitals that reported 6 months or less of Medicare Cost Report data were dropped, and the remaining data with coverage period other than 12 months were annualized. After merging with CMS Medicare Cost Reports, 27,786 observations (4,631 per year) remained. Further merging the data with Area Resource File led to the decision to drop 279 hospitals in Puerto Rico and U.S. Territories because of missing market control variables. To prevent effects of outliers, observations in excess of five standard deviations from the mean for all dependent variables were also excluded from the study. Finally, 1,335 observations were eliminated due to missing financial performance information. This resulted in a final analytic sample of 26,172 observations (an average of 4,362 hospitals per year).

Variables

Dependent, independent, and control variables of this study and their operational definitions are shown in Table 1. The financial performance (dependent variable) variables consisting three commonly used hospital profitability measures including operating margin, total margin, and return on assets (ROA) (Flexmonitoring, 2005). Two complementary dependent variables for operating expenses and operating revenue were also added to these dependent variables. Operating margin takes into account the operating income (net-patient revenue- total gross operating expenses) and excludes non-operating sources of income or expenses such as government appropriations, philanthropy, endowments, grants, investments, gift shops, and all other non-patient related expenses or revenues (McCracken, McIlwain, & Fottler, 2001). Total margin takes into account both operating and non-operating sources of income and expenses. Not-for-profit and government hospitals tend to receive income from non-patient related sources (i.e., gifts, endowments, grants, government transfers) more regularly than for-profit hospitals. Because this study includes some hospitals that experience non-operating revenue and expenses regularly and some non-regularly, it is proper to use both operating margin and total margin as indicators of financial performance. Moreover, it is possible that high-tech services may attract non-operating revenues such as philanthropic contributions due to their relatively prestigious status. For a particular hospital, if non-operating revenue and expenses occur regularly, total margin would be a better financial performance indicator than operating margin. However, for hospitals that do not depend upon (experience) non-operating sources of revenue (expenses) on a regular-basis, operating margin would be a better financial performance indicator.

In this study, despite being part of the formula of operating margin, operating expenses and operating revenues are still used separately to observe the possible effects of major independent variables on the expense and revenue side. In this study, we used the natural log of operating expenses per inpatient day and operating revenue per inpatient day to normalize the values of operating expenses and operating revenues. In the regression interpretation, one unit of change in non-transformed independent variable indicates the percentage change in these log-transformed variables when these coefficients are multiplied by 100.

ROA shows the profitability of a hospital relative to its assets. High-tech medical services/equipment is generally a large part of a hospital's capital assets. Therefore, it is suitable to use ROA because it shows the efficiency of an organization in generating income by using its assets/investments and controlling its expenses (Langland-Orban, Gapenski, & Vogel, 1996).

Two different measures of high-tech services are developed to test our hypotheses. High-tech services are defined as those highly visible equipment or services that diagnose and/or improve various human health conditions. The first measure, High-Tech Breadth, is an index that is based upon simple counts of available high-tech medical services (breadth of high-tech services) (hypothesis 1a). This index is based upon the American Hospital Association's (AHA) Annual Survey data. The high-tech services included in the index is provided in Appendix B. This list was originally developed by Spetz and Baker (1999); however, the list was enriched by adding some more services through a comprehensive literature review and through the new additions of high-tech services in the AHA survey since 1999 (Bazzoli & Andes, 1995; Bernet, Rosko, & Valdmanis, 2008; Chen et al., 2010; Irwin et al., 1998; Jha, Orav, Dobson, Book, & Epstein, 2009; Trinh et al., 2008, 2010). Any hospital service that was used as an indicator of a hospital's technological sophistication in prior studies was included in the high-tech breadth index used in this study (see Appendix B). As a result, the high tech breadth index includes an average of 61 services for each year, starting from 54 in 2005 to 68 in 2010 with the new additions of services.

The second measure, the Saidin index, is a high-technology index that takes into account the breadth and rareness of offered high-tech services (hypothesis 1b); it represents the weighted sum of technologies and services offered in hospitals (Spetz & Baker, 1999). The weights are calculated by finding the proportion of hospitals in the United States that do not own the technology or service (Spetz & Baker, 1999). Appendix B provides the list of the Saidin index weights for each hospital high-tech service from 2005 to 2010. For example, a weight of 0.85 indicates that only 15% of hospitals own that particular service in that particular year. The Saidin index is the sum of the high-tech services weighted by the relative rareness of the particular service. In this study, we used a modified Saidin index which represents the weighted sum of 35 services that had 85% or larger weights in the year 2010. Using 85% weight threshold was more appropriate than choosing a larger threshold such as 90%. If the 90% threshold were utilized, 73% of hospitals would have had zero index value. With the 85% weight threshold, only 44% of hospitals had index value of zero. Therefore, an 85% threshold provided a more balanced approach in regards to the Saidin index.

Hypotheses 2a and 2b are measured with *RN staffing mix moderator* based upon interactions between the aforementioned high-tech indices and RN staffing mix. RN staffing mix is a measure that allows accounting for the proportion of RN staffing among all types of nursing staff. Similarly, hypotheses 3a and 3b are measured with competition as a moderator, which is measured by using Herfindahl-Hirschman Index.

Table 1

Variables and Their Operational Definitions and Data Sources

Variable	***Operational Definition***	***Source***
Financial Performance (DV)		
Operating Margin (OM)	(Operating Revenues- Operating Costs)/ Operating Revenue	MCR
Operating Expenses (OE)	Operating Costs/ Inpatient Days	MCR
Operating Revenues (OR)	Operating Revenues/ Inpatient Days	MCR
Total Margin (TM)	Net income/ Total Revenue	MCR
Return on Assets (ROA)	Net Income/ Total Assets	MCR
Hospital Technology Indices (IV)		
High-Tech Breadth Index	Simple count of high-tech services	AHA
Modified Saidin (Rareness) Index	Weighted sum of high-tech services	AHA
<u>Control Variables</u>		
Organizational/Operational Factors		
Occupancy Rate	Occupied bed days/ Total bed days available	AHA
Length of Stay (LOS)	Total Inpatient Days/Inpatient Days	MCR
Outpatient Mix	(Total Outpatient Visits/3)/Total Facility Equivalent patient Days	AHA
Case Mix Index (CMI)	Case mix index	CMS
Staffing Factors		
RN Staffing Intensity	RN FTEs staffing per 1000 patient day	AHA
RN Staffing Mix	RN FTEs / total Nursing Personnel FTEs	AHA
Non-Nurse Staffing Mix	Non Nurse Staffing / Total Staffing	AHA
Physician Staffing Intensity	Physician and Dentist FTEs staffing per 1000 patient days	AHA
Market/Environmental Factors		
Hospital Market Competition	Health Service Area HHI	AHA
Market Affluence	Per capita income within county	ARF
Medicare Managed Care Penetration	% of county population enrolled in Managed Care	ARF

ARF= Area Resource File; AHA=American Hospital Association;

CMS= Center for Medicare and Medicaid Services; HHI=Herfindahl-Hirschman Index
MCR=Medicare Cost Reports; FTE=Full time equivalent

Among the control variables (Table 1), organizational/operational factors include a hospital's characteristics related to its operations. In a study about hospital financial performance, it is important to recognize factors related to organizational outputs (M. McCue, Mark, & Harless, 2003). Operational characteristics such as Occupancy rate, Average Length of Stay, Percentage of Medicare/Medicaid Discharges, Case Mix Index, and Outpatient Mix are among these factors. *Occupancy rate*, a commonly used measure indicating the utilization of hospital beds, is calculated by dividing *total hospital inpatient days* to *total bed days* available. *The total bed days* variable was calculated by multiplying *number of hospital beds* with *365* (referring 365 days in a year). In this study, variable calculations, where AHA survey data are used, are based upon hospital unit measures that do not include the data for hospital-based nursing homes. AHA survey data allows calculating the hospital unit measures since it separately reports the data for hospital operated nursing home facilities. For example, *hospital unit beds* is calculated by subtracting the nursing home beds from the total beds. Since, Medicare Cost Report file includes audited information; we opted to use this source to calculate the average *Length of Stay* (LOS). LOS may be an important factor for the profitability of hospitals since most reimbursements are not based upon the patient's length of stay in a hospital. Therefore, lower length of stay would reduce costs and improve profitability by lesser utilization of hospital resources.

Another important factor in the reimbursement rates of hospitals is the Case Mix Index (CMI). Higher CMI value indicates not only the higher complexity of inpatient services but also the higher reimbursement rates from Medicare. We decided to include CMI in our final model because of its importance in controlling various levels of both patient case severities and reimbursement rates of hospitals. However, there were approximately 29% missing observations for CMI in our sample. Instead of dropping 29% of our sample because of this missing CMI observations we used two imputation methods: (a) we calculated averages for every individual hospital that had CMI values during 2005-2012 period in historical CMI data and used these averages to replace any missing observation for that particular hospital for that particular year; (b) for hospitals where there were no historical figures available, we replaced the missing observations with yearly CMI means from all hospitals for that year. Hospitals receive relatively lower reimbursement rates for the Medicaid/Medicare patients than the privately insured patients. Therefore, the proportion of Medicaid (or Medicare) inpatient days to total inpatient days is one of the key factors for the financial profitability of hospitals. Even though percent of Medicare/Medicaid variables were included in the original models, these variables were dropped in the final model due to endogeneity concerns. However, CMI already partially controls for the Medicare patients since it takes into account the severity of cases; and, it is highly related to the Medicare reimbursement rates. The last organizational control variable *outpatient mix* takes into account the proportion of one third of *outpatient visits* to *total facility equivalent patient days*. Following a couple of studies (Detsky, O'Rourke, Naylor, Stacey, & Kitchens, 1990; Vujicic, Addai, & Bosomprah, 2009), we also assumed that outpatient visits utilize one third of hospital resources. *Total facility equivalent patient days* is basically the total of one third of *outpatient visits* and *total inpatient days*.

Under staffing factors, RN staffing (Table 1) variables were included among control variables due to their hypothesized importance in this study and prominent place in financial performance studies. There are various ways to measure staffing, particularly nurse staffing, while there is no uniform standard (Mark, Harless, McCue, & Xu, 2004). These measures can include various staffing types (i.e., RN, LPN, Nursing Aide, non-nurse) in different formulas such as productive staff hours per patient day, nurse-to- patient ratios, or full-time equivalents (FTEs). Among these various alternatives, FTE based formula of RN FTE to inpatient days is used in this study for three reasons: 1) It can be calculated by using AHA survey; 2) One recent study found high correlation between AHA data and California Office of Statewide Health Planning and Development data for full-time-equivalent employment of RNs and LPNs (J. Spetz, Donaldson, Aydin, & Brown, 2008); 3) It would be easier to compare the results of this study with a previous nurse staffing focused longitudinal study that used similar measures (M. McCue et al., 2003).

We included two RN staffing variables in our models at the same time since they are measuring two different dimensions of staffing. RN Staffing Intensity, measured as RN staffing per 1,000 inpatient days, is calculated by dividing RN FTEs to hospital unit inpatient days and multiplying the result with 1,000. RN Staffing Mix is the ratio of RN staffing to total nurse staffing. The former focuses on the intensity whereas the latter focuses on the mix (highly-qualified) of nurse staffing. Because we hypothesized that the benefits of high-tech services can be achieved with appropriate and qualified RN staffing, we also included several other staffing control variables such as non-nurse staffing mix, proportion of non-nurse staffing to total staffing, and physician staffing intensity, physician or dentist staffing per one thousand inpatient days. In the final model, to prevent multicollinearity due to potential high correlation between staffing variables, we confirmed the assumed difference among staffing variables by examining correlations among them. In the final models, no staffing variable with more than 40% correlation was included.

Financial performance of hospitals is influenced by market/environmental factors such as competition, market affluence, managed care penetration and market share. Therefore, it is essential to include market/environmental factors (Table 1) as control variables in this study. Market competition is an important variable due to its influence on hospital costs and its use in developing hypothesis 3 of this study. Studies indicate that prior to the introduction of the prospective payment system in 1983; competition increased both the hospital costs and LOS (Luft et al., 1988; Robinson & Luft, 1985, 1987; Robinson, Luft, McPhee, & Hunt, 1988). Some studies indicate an association between higher competition and lower hospital cost especially in a managed care and prospective payment environment (Gift, Arnould, & DeBrock, 2002; Keeler, Melnick, & Zwanziger, 1999; Melnick & Zwanziger, 1988). However, some other studies have found an association between higher competition and higher hospital costs (Devers et al., 2003; Rivers, Glover, & Munchus, 2000; Trinh et al., 2008). We have attempted to address the aforementioned findings on cost-competition relationship by using both managed care penetration and Herfindahl-Hirschman Index among control variables.

Measuring market competition requires taking into account several conceptual issues such as identification of market areas and products, and considering the forces (including managed care) that might influence the competitive environment (Baker, 2001). In this study, market competition was measured by using the Herfindahl-Hirschman Index (HHI). This index is a popular measure that is calculated by finding the sum of squared market shares of hospitals in a health service area (Mark & Harless, 2010). We decided to use HHI because it takes into account both the number and relative sizes of hospitals in the health service area. Use of HHI is advantageous over other measures that use either relative sizes or numbers of hospitals in health service area (Baker, 2001). Market share measures are based upon the hospital unit inpatient days from the AHA survey. Furthermore, health service area is based upon Dartmouth health service areas that are identified again in AHA survey. For cases where health service area codes were not available (approximately 110 cases), county HHI was substituted. We used FIPS State and County codes to calculate the HHI variable. Larger HHI value indicates smaller competition in a health service area whereas smaller one indicates higher competition.

Analysis

In this paper, we used a within-group hospital and time fixed effect regression model for analysis. Before adding time fixed effects to our regression equation, we compared random effects and fixed effects models with the Hausman test. The significant result of the Hausman test for all of the analytical models for five dependent variables favored the fixed effects models over random effects models. Therefore, we opted to use fixed effects models with clustered-robust standard error.

A fixed effects model has an advantage over traditional multivariate regression models in regards to omitted variable bias given that the model controls for unmeasured time-constant attributes (Allison, 2005). For example, if we compare some hospitals on commonly used and easily measured attributes such as size, system affiliation, teaching status, patient volume, ownership and so on, we would most probably omit some unmeasured attributes such as organizational culture and climate, traditions, and some other unknown and unmeasured time invariant hospital specific attributes. For unmeasured and stable characteristics of hospitals, the fixed effects model uses each hospital as its own control by using *within variation* (Allison, 2005). Therefore, to be able to utilize a fixed effects model, one needs enough *within variation* for the measures of interest. Propitiously in our sample, we had enough within variation for our measures of interest. For example, in our sample of 4,362 hospitals, the three variations for high-tech breadth index were reported as: 1) overall= 12.25, 2) between=11.21, and 3) within=4.96. In these figures, *between variation* indicates the variation across hospitals whereas the *within variation* indicates the variation within individual hospitals across time.

In our fixed effects models, we excluded measures with zero or very low *within variation* such as location, teaching status, size, ownership status. This decision is based upon the fact that each hospitals serves as its own control in the fixed effects model and all stable and time invariant factors are already controlled for. In our sample of 4,362 hospitals across 6 years, we have hospitals with different characteristics in regards to their size, ownership, teaching status, and location. In our fairly large sample, these hospitals with different characteristics also had some significant intraclass correlations between some groups of hospitals such as not-for-profit and for-profit hospitals. To overcome the limitations of excluding these important organizational characteristics in our fixed effects regression and to account for intraclass correlation, we utilized three strategies: 1) using the cluster-robust standard error estimator to tackle possibly underestimated standard error that arises through the assumption of each hospital being independent from other hospitals (Nichols & Schaffer, 2007; Stata Library, 2013); 2) splitting our sample by ownership type (i.e., not-for-profit, for-profit, or government), or by market competition (i.e., no-competition vs. some competition) and analyzing these clusters separately; 3) analyzing the data by using random effects models with state and time fixed effects. In this study, FileMaker Pro was used for data management, while SAS 9.3 and STATA 12 were used for data analysis.

RESULTS

Table 2 presents the descriptive statistics for the variables that were included in the fixed effects model. The descriptive statistics for the other measures and the measures that were used in random effects models are reported in Appendix C. In Appendix D, we also included the results for random effects regression models with time and state fixed effects. Table 2 provides a good example for the previously discussed difference between operating margin and total margin in regards to the non-operating income. The mean value for operating margin is negative 0.02 with standard deviation of 0.14 for hospitals in our sample. On the contrary, the mean value for total margin is positive with standard deviation of (0.10) for hospitals in our sample. Hospitals that receive regular non-operating revenue (i.e., government transfers, philanthropy) may have negative operating margin, however, when the non-operating income added into the formula their total margin may become positive.

Table 3 compiles and displays the fixed effects regression coefficients (and clustered- robust standard errors) for the relationship between high-tech services and five financial performance measures (hypotheses 1a and 1b) including operating margin (OM), natural log of operating expenses per inpatient days (IPD), natural log of operating

Table 2

Descriptive Statistics for Study Variables (Untransformed)

Variables	**Mean**	**(SD)**
	***N* = 26172**	
Operating Margin	-0.02	(0.14)
Operating Expenses	$5,127	(8236)
Operating Revenue	$5,196	(11211)
Total Margin	0.03	(0.10)
Return on Assets	0.04	(0.14)
Hospital Technology Indices (IV)		
Index 1: High-Tech Breadth Index	15.89	(12.25)
Index 2: Saidin Rareness Index	2.38	(3.88)
Control Variables		
Organizational/Operational Factors		
Occupancy Rate	0.52	(0.20)
Length of Stay	6.38	(49.77)
Outpatient Mix	0.57	(0.20)
CMS Case Mix Index (CMI)	1.35	(0.23)
Staffing Factors		
RN Staffing	8.79	(6.72)
RN Staffing Mix	0.85	(0.13)
Non-Nurse Staffing	0.60	(0.35)
Physician Staffing	0.66	(1.68)
Market/Environmental Factors		
Competition (Herfindahl-Hirschman Index)	0.71	(0.35)
Per Capita Income in a County	$34,659	(10317)
Medicare Managed Care Penetration	15.72	(13.55)

revenues per IPD, total margin (TM), and ROA. Coefficients for high-tech breadth index are presented under the *breadth* column. Coefficients for high-tech Saidin index are presented under the *rareness* column. Table 3 displays only the main-effects coefficients. Interaction-effects for the remaining hypotheses are displayed in subsequent tables.

Table 3

Fixed Effects Regression of the Relationship between High-Tech Services and Financial Performance

	OP.MARG		OP.EXPS. PER IPD		OP.REV PER. IPD		TOT.MARG		ROA	
Number of Obs	26071		26052		26057		26172		26017	
	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness
High-Tech Services	0.060 ****	0.113 **	-0.001 ****	-0.002 ****	-4.E-04 ****	-0.001 ****	0.035 ***	0.043	0.035 **	0.008
	(0.01)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.04)	(0.02)	(0.06)
Occupancy Rate	3.066 ****	2.999 ***	-0.034 ***	-0.034 ***	-0.022 **	-0.021 **	1.638 *	1.593 *	1.484	1.424
	(1.06)	(1.06)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.13)	(1.13)
Length of Stay	-0.481	-0.499	0.146	0.146	0.145	0.145	0.165	0.159	-0.477	-0.480
	(0.80)	(0.81)	(0.09)	(0.09)	(0.09)	(0.09)	(0.66)	(0.66)	(0.92)	(0.92)
Outpatient Mix	0.596	0.670	0.044 ****	0.043 ****	0.047 ****	0.046 ****	0.416	0.453	-0.043	-0.022
	(1.16)	(1.17)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.30)	(1.30)
CMI	2.890 **	2.986 **	-0.039 ***	-0.040 ***	-0.028 *	-0.028 *	2.287 **	2.364 **	1.840	1.967
	(1.38)	(1.39)	(0.01)	(0.01)	(0.01)	(0.01)	(1.17)	(1.17)	(1.80)	(1.79)
RN Staffing Intensity	-0.013	-0.009	0.001 ****	0.001 ****	0.001 ****	0.001 ***	-0.030	-0.028	-0.009	-0.007
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.03)
RN Staffing Mix	2.260	1.935	0.021	0.024 *	0.030 **	0.032 **	-0.575	-0.778	1.077	0.855
	(1.55)	(1.55)	(0.01)	(0.01)	(0.01)	(0.01)	(1.27)	(1.27)	(1.98)	(1.97)
Non-Nurse Staffing Mix	-0.093	-0.068	0.018	0.018	0.017	0.017	-0.089	-0.074	-0.083	-0.067
	(0.30)	(0.30)	(0.01)	(0.01)	(0.01)	(0.01)	(0.27)	(0.27)	(0.32)	(0.31)
Physician Staffing Intensity	-0.115 *	-0.114 *	0.003	0.003	0.003	0.003	-0.094 *	-0.094 *	-0.135 *	-0.135 *
	(0.06)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.06)	(0.08)	(0.08)
Market Competition (HHI)	3.387 **	3.291 *	0.011	0.012	0.025	0.025	2.379 *	2.319	3.503 *	3.437 *
	(1.73)	(1.74)	(0.02)	(0.02)	(0.02)	(0.02)	(1.45)	(1.45)	(2.13)	(2.13)
Market Affluence	-4.556	-5.375	0.222 ****	0.229 ****	0.206 ****	0.210 ****	5.012	4.423	-6.847	-7.583
	(6.63)	(6.61)	(0.04)	(0.04)	(0.05)	(0.05)	(4.45)	(4.45)	(5.24)	(5.22)
MC Penetration	0.033	0.033	0.000	0.000	0.000	0.000	-0.009	-0.009	-0.012	-0.012
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Fixed Effects for Years										
R-squared	0.74	0.74	0.94	0.94	0.94	0.94	0.61	0.61	0.62	0.62
Adj. R-Squared	0.69	0.69	0.93	0.93	0.93	0.92	0.52	0.52	0.54	0.54
F-test of Significance	5.71 ****	5.00 ****	395.15 ****	393.38 ****	368.72 ****	348.83 ****	24.77 ****	24.22 ****	15.27 ****	14.80 ****

Significance at *0.1 **0.05 ***0.01 ****0.001 or less ; CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Hypotheses 1a (breadth) predicted positive association between high-tech services and financial performance of a hospital. Hypothesis 1a is supported for four of the five financial performance measures at significance levels ranging from .05 to .001. To ease the display of the coefficients in our tables, the observations for operating margin, total margin and return on assets were transformed by multiplying by one hundred. Therefore, for operating margin, the coefficient of 0.06 under the breadth column indicates that holding all other variables constant, for every 10 unit increase in high-tech services there would be 6% (10x0.06) increase in operating margin at 0.001significance level. Since the *operating expenses per inpatient days* and *operating revenue per inpatient days* were log transformed, coefficients that are multiplied by one hundred would indicate the percent-age change for these variables. For example, for *Operating expenses per inpatient days,* the coefficient of -0.001 under the rareness column indicates that holding all other varia-bles constant, for every 10 unit increase in high tech services there would be 1% (10x0.001x100) decrease in *operating expenses per inpatient days* at 0.001significance level. As a sensitivity analysis, we tested the model separately on not-for-profit and for-profit hospitals. Similar results to that of the full sample were observed for three out of five financial performance measures (See Appendix E). However, for total margin and ROA, only for-profit hospitals exhibited statistically significant results.

Hypothesis 1b predicted positive association between rare high-tech services (Saidin Index) and financial performance of hospitals. The regression results show partial support for hypothesis 1b; only *operating margin* (positive) and *operating expenses per inpatient days* (negative) were associated at 0.05 and 0.001 significance levels, respec-tively. Contrary to our hypothesized relationship, for both breadth and rareness, *high-tech* *services* were negatively related to *operating revenue per inpatient days.* For example, for *operating revenue per inpatient day,* the coefficient of -0.001 under rareness column indicates that holding all other variables constant, for every 10 unit increase in Saidin index (rareness), there would be 2% (10x0.002x100) decrease in *operating revenue per inpatient days* at .001 significance level. Finally, there was no statistically significant difference among *rare high-tech services, total margin* and *return on assets*. As a sensitivity analysis, we tested the model separately on not-for-profit and for-profit hospitals. Similar results to that of the full sample were observed for only *operating expenses per inpatient day* and *operating revenue per inpatient day* (Appendix E).

Besides the coefficients for high-tech services, there are some other noteworthy statistically significant coefficients present in Table 3 for other measures in the models. For example, *occupancy rate* exhibited similar statistically significant patterns under both breadth and rareness columns. Consistent with expectations, *occupancy rate* is positively associated with *operating margin* and *total margin* and negatively associated with *operating expenses per inpatient day*. However, inconsistent with expectations, *occupancy rate* is negatively associated with *operating revenue per inpatient day*. Among organizational control variables, CMI significantly and positively associated with *operating margin* and *total margin*; however, CMI significantly and negatively associated with both *operating expenses* and *operating revenue per inpatient days*. Among staffing control variables, physician staffing intensity is significantly and negatively associated with *operating margin, total margin,* and *return on assets*. *Market affluence* (log of per capita income in a county) is significantly and positively associated both with *operating expenses* and *operating revenue per inpatient days*.

Table 4 and Table 5 present the interaction-effects results for RN staffing mix moderation and competition moderation, respectively. RN staffing moderation is defined as the product of RN staffing mix and high-tech indices. Similarly, competition moderation is defined as the product of competition and high-tech indices. In hypotheses 2a and 3a, both moderation variables predicted to positively moderate the relationship between the number of high-tech services (breadth) and financial performance of hospitals in the United States. Likewise, in hypotheses 2b and 3b, both RN staffing and competition interactions predicted to positively moderate the relationship between the rare high-tech services and financial performance of medical and surgical hospitals in United States.

Even though there are some significant coefficients for *RN staffing mix moderator* in Table 4, hypotheses 2a and 2b are not supported. Moreover, there is no significant coefficient for *competition moderator* in Table 5; therefore, hypotheses 3a and 3b were not supported either. The reasoning behind the no-support for these hypotheses can be summarized with three points: (a) according to hierarchical multiple regression test there is no statistically significant evidence for the presence of bilinear interaction effect, (b) the model fit does not improve through the addition of product term moderating variables, (c) therefore, the interaction-effects models in this study (Table 4 and Table 5) are merely other displays of the main-effects models (Table 3) as the Adjusted R Squared values suggest.

R-squared values in all three tables refer the variation in financial performance variables that are explained by the respective models. In the hierarchical multiple regression test, if adding an interaction (or a predictor) to a model produces a significant difference between the R-squared of extended model and the R-squared of the original model,

Table 4

Fixed Effects Regression of the Relationship between High-Tech Services and Financial Performance with RN Staffing Mix Interaction

	OP.MARG		OP.EXPS. PER IPD		OP.REV PER. IPD		TOT.MARG		ROA	
Number of Obs	26071		26052		26057		26172		26017	
	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness
High-Tech Services	-0.034	-1.158 **	0.004 ***	0.012 ****	0.003 ***	0.007 *	0.007	-0.513	0.207	-0.029
	(0.14)	(0.55)	(0.00)	(0.00)	(0.00)	(0.00)	(0.11)	(0.42)	(0.16)	(0.54)
RN Staffing Mix Moderator	0.103	1.376 **	-0.005 ****	-0.015 ****	-0.004 ****	-0.009 **	0.031	0.602	-0.189	0.039
	(0.15)	(0.59)	(0.00)	(0.00)	(0.00)	(0.00)	(0.12)	(0.45)	(0.17)	(0.59)
Occupancy Rate	3.059 ***	2.979 ***	-0.034 ***	-0.034 ***	-0.021 **	-0.021 **	1.636 *	1.582 *	1.497	1.423
	(1.06)	(1.06)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.13)	(1.13)
Length of Stay	-0.488	-0.508	0.146	0.146	0.145	0.145	0.163	0.155	-0.464	-0.480
	(0.80)	(0.81)	(0.09)	(0.09)	(0.09)	(0.09)	(0.66)	(0.66)	(0.92)	(0.92)
Outpatient Mix	0.608	0.676	0.044 ****	0.043 ****	0.046 ****	0.046 ****	0.419	0.455	-0.065	-0.022
	(1.16)	(1.16)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.30)	(1.30)
CMI	2.835 **	2.832 **	-0.037 ***	-0.038 ***	-0.025 *	-0.027 *	2.271 **	2.298 **	1.945	1.963
	(1.38)	(1.38)	(0.01)	(0.01)	(0.01)	(0.01)	(1.17)	(1.17)	(1.80)	(1.80)
RN Staffing Intensity	-0.013	-0.010	0.001 ****	0.001 ****	0.001 ***	0.001 ****	-0.030	-0.028	-0.009	-0.007
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.03)
RN Staffing Mix	1.214	0.916	0.068 ****	0.035 **	0.072 ****	0.038 ***	-0.887	-1.226	2.989	0.826
	(2.34)	(1.62)	(0.02)	(0.01)	(0.02)	(0.01)	(1.90)	(1.33)	(2.96)	(2.10)
Non-Nurse Staffing Mix	-0.094	-0.066	0.018	0.018	0.017	0.017	-0.089	-0.073	-0.082	-0.067
	(0.30)	(0.30)	(0.01)	(0.01)	(0.01)	(0.01)	(0.27)	(0.27)	(0.32)	(0.31)
Physician Staffing Intensity	-0.114 *	-0.112 *	0.003	0.003	0.003	0.003	-0.094 *	-0.093 *	-0.137 *	-0.135 *
	(0.06)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.06)	(0.08)	(0.08)
Market Competition (HHI)	3.401 **	3.317 *	0.011	0.012	0.024	0.025	2.383 *	2.332	3.477 *	3.438 *
	(1.73)	(1.73)	(0.02)	(0.02)	(0.02)	(0.02)	(1.45)	(1.45)	(2.14)	(2.13)
Market Affluence	-4.230	-4.690	0.208 ****	0.222 ****	0.193 ****	0.205 ****	5.113	4.732	-7.432	-7.564
	(6.71)	(6.66)	(0.04)	(0.04)	(0.05)	(0.05)	(4.44)	(4.47)	(5.25)	(5.24)
MC Penetration	0.034	0.034	0.000	0.000	0.000	0.000	-0.009	-0.009	-0.013	-0.012
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Fixed Effects for Years										
R-squared	0.74	0.74	0.94	0.94	0.94	0.94	0.61	0.61	0.62	0.62
Adj. R-Squared	0.69	0.69	0.93	0.93	0.93	0.92	0.52	0.52	0.54	0.54
F-test of Significance	5.43 ****	5.10 ****	398.87 ****	377.37 ****	356.43 ****	348.83 ****	23.41 ****	23.03 ****	14.50 ****	13.99 ****

Significance at *0.1 **0.05 ***0.01 ****0.001 or less ; CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Table 5

Fixed Effects Regression of the Relationship between High-Tech Services and Financial Performance with competition interaction

	OP.MARG		OP.EXPS. PER IPD		OP.REV PER. IPD		TOT.MARG		ROA	
Number of Obs	26071		26052		26057		26172		26017	
	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness	Breadth	Rareness
High-Tech Services	0.085 ***	0.180 *	-0.001 ****	-0.002 ****	0.000 **	-0.002 **	0.042 *	0.065	0.048	0.027
	(0.03)	(0.11)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.07)	(0.03)	(0.11)
Competition Moderator	-0.043	-0.128	0.000	0.001	0.000	0.000	-0.013	-0.042	-0.023	-0.037
	(0.04)	(0.15)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.10)	(0.04)	(0.15)
Occupancy Rate	3.066 ***	3.000 ***	-0.034 ***	-0.034 ***	-0.022 **	-0.021 **	1.638 *	1.593 *	1.483	1.424
	(1.06)	(1.06)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.13)	(1.13)
Length of Stay	-0.487	-0.497	0.146	0.146	0.145	0.145	0.162	0.159	-0.481	-0.479
	(0.79)	(0.80)	(0.09)	(0.09)	(0.09)	(0.09)	(0.66)	(0.66)	(0.92)	(0.92)
Outpatient Mix	0.644	0.681	0.044 ****	0.043 ****	0.047 ****	0.046 ****	0.430	0.457	-0.017	-0.019
	(1.16)	(1.17)	(0.01)	(0.01)	(0.01)	(0.01)	(0.88)	(0.88)	(1.30)	(1.30)
CMI	2.836 **	2.952 **	-0.039 ***	-0.040 ***	-0.028 *	-0.028 *	2.271 **	2.353 **	1.809	1.957
	(1.39)	(1.39)	(0.01)	(0.01)	(0.01)	(0.01)	(1.17)	(1.17)	(1.80)	(1.79)
RN Staffing Intensity	-0.012	-0.009	0.001 ****	0.001 ****	0.001 ****	0.001 ****	-0.030	-0.028	-0.009	-0.007
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.03)	(0.03)
RN Staffing Mix	2.166	1.932	0.021	0.024 *	0.030 **	0.032 **	-0.602	-0.778	1.027	0.854
	(1.55)	(1.55)	(0.01)	(0.01)	(0.01)	(0.01)	(1.27)	(1.27)	(1.98)	(1.98)
Non-Nurse Staffing Mix	-0.096	-0.070	0.018	0.018	0.017	0.017	-0.090	-0.075	-0.085	-0.067
	(0.30)	(0.30)	(0.01)	(0.01)	(0.01)	(0.01)	(0.27)	(0.27)	(0.32)	(0.31)
Physician Staffing Intensity	-0.114 *	-0.114 *	0.003	0.003	0.003	0.003	-0.094 *	-0.094 *	-0.135 *	-0.135 *
	(0.06)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.06)	(0.08)	(0.08)
Market Competition (HHI)	3.999 **	3.539 **	0.010	0.011	0.025	0.025	2.566 *	2.401 *	3.832 *	3.510 *
	(1.85)	(1.77)	(0.02)	(0.02)	(0.02)	(0.02)	(1.53)	(1.47)	(2.29)	(2.19)
Market Affluence	-4.540	-5.431	0.222 ****	0.230 ****	0.206 ****	0.210 ****	5.019	4.403	-6.834	-7.598
	(6.63)	(6.61)	(0.04)	(0.04)	(0.05)	(0.05)	(4.45)	(4.45)	(5.24)	(5.22)
MC Penetration	0.033	0.033	0.000	0.000	0.000	0.000	-0.009	-0.009	-0.012	-0.012
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Fixed Effects for Years										
R-squared	0.74	0.74	0.94	0.94	0.94	0.94	0.61	0.61	0.62	0.62
Adj. R-Squared	0.69	0.69	0.93	0.93	0.92	0.92	0.52	0.52	0.54	0.54
F-test of Significance	5.39 ****	4.74 ****	373.66 ****	371.85 ****	348.83 ****	351.48 ****	23.40 ****	22.94 ****	14.43 ****	13.97 ****

Significance at *0.1 **0.05 ***0.01 ****0.001 or less ; CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

this indicates an evidence for the presence of interaction effect (Jaccard, Turrisi, & Wan, 1990). The significance of the difference in R-Squared values is tested by using the F test formula. In this formula, the numerator includes the deduction of the R-Squared value of expanded model from the R-Squared value of the original model ($R^2_{Expanded} - R^2_{Original}$). Because the R-Squared values in Table 4 and Table 5 are equal to the corresponding R-Squared values in Table 3, F test would be equal to zero. This indicates that there is no significant difference among the models in Table 4 and Table 5 and their counterpart models in Table 3. Consequently, this finding indicates the absence of bilinear interaction effects in Table 4 and 5.

One can reach the same conclusion by comparing the Adjusted R-Squared values, which refers the R-Squared values that are adjusted for the number of cases and number of variables. The Adjusted R-Squared values for models in Table 4 and 5 are equal to their corresponding models in Table 3. By observing these equal Adjusted R-Squared values, one can say that model-fit does not improve in Table 4 and 5 through the addition of new interaction measures. Therefore, we can conclude that the interaction effect models in this study (Table 4 and Table 5) are merely other displays of the main effects models (Table 3).

CONCLUSIONS AND IMPLICATIONS

This study addressed the association between high-tech services and several hospital financial performance measures by using RBV of a firm as a theoretical framework. To date, the relationship between high-tech services and hospital financial performance has not been explored extensively. However, the methodological limitations of these existing studies confine the generalizability of their findings. Therefore, we attempted to improve the knowledge base about the possible link between high-tech services and financial performance. In line with RBV, we hypothesized that the breadth and the rareness of high-tech services would be positively associated with financial performance of hospitals. We also hypothesized that RN staffing mix and market competition would positively moderate these relationships. To test our hypothesis, we used within-group fixed effects models on a longitudinal panel data of approximately 4,362 hospitals from 2005 through 2010.

Study results support hypothesis 1a, that the number of high-tech services (breadth) and financial performance are positively and significantly associated. Moreover, the study results also partially support hypothesis 1b, that the rare high-tech services (Saidin index) and hospital financial performance are significantly associated for operating margin (positive) and operating expense per inpatient day (negative). However, counter to expectations, rare high-tech services were also significantly but negatively associated with operating revenue per inpatient day. One previous comparable longitudinal study of 422 hospitals (M. McCue et al., 2003) used the Saidin index and failed to find significant association between high-tech services and financial performance (i.e., operating margin and operating expenses). Nevertheless, this might have been caused by the difference between sample size (422 versus 4,362), study period (1990-1995 versus 2005-2010), the statistical models (dynamic panel versus fixed effects) or the Saidin indices (the Saidin index versus modified Saidin index). Interestingly before we made the decision to modify the Saidin index to include only 35 services with 85% or larger rareness weights, we had an original Saidin index that was mirroring the high-tech breadth index. This original Saidin index generated even more significant results. All these findings suggest that the breadth of high tech services and rareness of these services are linked to financial performance. However, if one examines the magnitude of the relationship, one can see that the magnitude is not large. Even though in this study we used 6 years of longitudinal data with larger sample size, there is definitely a need for more future studies to clarify the difference between findings of this study and the previous comparable studies.

In this study, we failed to find any evidence for the presence of bilinear (linear function of two variables) interaction-effects for RN staffing mix (hypotheses 2a and 2b) by using the product of high-tech services and RN staffing. Similarly, we failed to find evidence to support competition moderation (hypotheses 3a and 3b), which was also bilinear and measured by using the product of high-tech services and market competition variables. However, one should not conclude absence of moderation (interaction effect) by looking at these results given that interaction effect might exist in other non-linear forms (e.g., U-shaped, polynomial) (Jaccard et al., 1990). Therefore, future studies may explore this possibility by considering non-linear forms of interaction effect such as polynomial or logarithmic forms. Moreover, future studies may also explore the moderation role of some other staffing measures such as physician staffing, and radiology technician staffing instead of using only RN staffing moderators. Future studies may also focus on more correlated (clustered) technologies and might use staffing moderators that are more directly linked to these technology clusters. For example, for financial performance, the moderating role of radiology technicians on technologies related to the radiology department might be explored.

There are several important managerial implications of this study. First, an increase in the breadth of high-tech services is associated with decrease in operating expenses per inpatient days. This finding suggests that hospitals benefits some cost advantage through economies of scale (i.e., size of their business). However, as the findings indicates that the revenue per inpatient day also reduces (i.e., revenue disadvantage) with an increase in the breadth of high-tech services. Findings on occupancy rates would be useful in explaining this revenue disadvantage. An increase in occupancy rates is associated with a decrease in operating revenue per inpatient days. Even though initially this finding seems to be counter intuitive. However, achieving better revenue per inpatient day does not only depend upon higher occupancy rates but also the payer mix of these occupied beds. In other words, the reimbursements rate for the patients is an important factor in regards to the revenue per inpatient days. A payer mix with relatively greater number high reimbursing insurance policies would be expected to have positive impact on operating revenue per inpatient days. In fact, the results of this study supported this claim by finding a significant and positive association between market affluence (per capita income in county) and operating revenue per inpatient days. However, the results also indicate that hospitals located in more affluent counties are experiencing higher operating expenses per inpatient days too. These findings suggest that there are some cost advantages and revenue disadvantages associated with the breadth of high-tech services at the same time. However, market affluence, and payer mix can be important factors in changing the revenue disadvantage into an advantage. Furthermore, the significant positive association between the breadth of high-tech services offered and three financial indicators (i.e., operating margin, total margin, and return on assets) suggests that enhancing the breadth of high-tech services is a legitimate organizational strategy in improving financial performance. Therefore, hospital administrators who are developing strategies related to the breadth of high tech services should take into account the positive impact of breadth on financial performance along with possible cost and revenue implications.

The second managerial implication is related to the rareness of high-tech services. Findings about rare high-tech services suggest that economies of scope strategy (i.e., focusing on certain services) may also generate cost advantage. However, there may be also some revenue disadvantage given that an increase in rare high-tech services is associated with a decrease in operating revenue per inpatient days. The significant and positive association between rare high-tech services and operating margin also confirms the legitimacy of focusing on certain (i.e., rare) technologies to achieve better financial performance. Therefore, similar to the breadth strategy, hospital administrators may develop strategies not only by focusing on certain high-tech services to achieve cost advantage but also focusing on better payer mix to achieve revenue advantage too.

There are also several theoretical implications of this study. First, RBV's notion of bundling of resources may generate better performance was supported by finding a positive association between the breadth of high-tech services offered and financial performance. Second, rareness criteria of RBV was also partially supported in this study since an increase in the number of rare high-tech services were positively associated with financial performance of hospitals for some of the financial performance indicators (i.e., operating margin, operating expenses per inpatient day). Third, we did not find a clear evidence to support RBV's notion of potential positive impact of human capital resources as part of the unique resource bundle. We did not find evidence for moderating effect for RN staffing mix. Furthermore, both RN staffing intensity (proportion of RN staffing per 1,000 inpatient days) and RN staffing mix (RN staffing/ all nurse staffing) are significantly and positively associated with operating revenue per inpatient day. However, an increase in RN staffing intensity is also associated with increase in operating expenses per inpatient day. As the results indicate there are no significant associations between RN staffing measures and any of overall financial performance indicators such as operating margin or total margin. Therefore, it is not clear that how cost and revenue dimensions of RN staffing influence overall financial performance of hospitals.

This study has several limitations. The first and foremost limitation stems from the use of secondary data. Limitations that are applicable to secondary data sources such as design limitations (i.e., not designed to test particular theoretical framework), and accuracy limitations (i.e., not certain about the correctness or completeness of the data) are all applicable to our study too. Second, potential for endogeneity is a problem even for fixed effects models. Third, the reverse causality might be a potential limitation for our study since one can argue that better financial performance of previous years may be leading to the adoption of more high-tech services.

Despite these limitations, we believe that several strengths of our study provide an important foundation for future research. First, all our data are coming from secondary data sources that are tested and used extensively by researchers. Especially, the financial performance measures, which come from Medicare Cost Reports file where the data is mostly audited. Second, even after merging several data sources, we ended with a fairly large sample, which provided enough statistical power and allowed us to run various subgroup analyses through split samples. Third, for our independent variables (indices of high-tech services), we also developed different versions by using different parameters and tested the sensitivity of our results. These different versions of high-tech indices generated similar results. Fourth, we used a fixed effect statistical model with clustered-robust standard error on 6 years of panel data. This approach reduced the possibility of omitted variable bias and addressed the potential endogeneity issues for unobserved time-constant factors. Fifth, we used time fixed effects to account for the time trend. Because our study period included the worldwide economic downturn, controlling for any time related confounding factors is substantially important. Using time fixed effects allowed us to control for unaccounted time trend factors, which would have affected all hospitals during the underlined study period. Moreover, controlling time trend also controlled for inflation, which might have been a problem especially for our operational expense, and operational revenue dependent variables. Sixth, we used RBV, an extensively used theoretical framework, on longitudinal panel data to address some of the concerns for the reverse causality. Last, analyzing and reporting results for five different models (five dependent variables) in the same study would allow our study to be used as a comprehensive comparison with related previous and future studies.

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HIGH TECHNOLOGY MEDICAL SERVICES AND QUALITY OF CARE AT U.S. HOSPITALS

by

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ABSTRACT

The aim of this study was to examine the relationship between high-tech medical services and quality performance of general medical-surgical acute care hospitals. Quality performance was measured with a 30-day mortality rate for heart attack, heart failure and pneumonia. As conceptual frameworks, the combination of the resource based view of a firm and the structure-process-outcome quality framework were used. It was hypothesized that high-tech services with certain attributes (i.e., large numbers, rare, and condition-specific) would be significantly and negatively associated with 30-day mortality rates. Four years of longitudinal panel data covering 2006-2009 for 2,672 to 3,950 hospitals was analyzed by using random effects and fixed effects models. For analysis and sensitivity tests, 16 different high-tech indices were developed. The findings provided partial support for hypothesized relationships between high-tech services and 30-day mortality rates. The condition-specific patient volume was the only measure that was consistently and significantly (negative) associated with 30-day mortality rates.

INTRODUCTION

One of the most pressing issues facing U.S. hospitals today is improving the quality of patient care. This improvement is vital for a hospital's present success as well as its future survival. State and federal governments, employers, insurance companies, and patients continuously demand that quality of care be improved. Both public and private payers of healthcare increasingly demand better quality by linking their reimbursement schedules to the quality of care provided. Beside these demands, hospitals also must deal with competitive pressures and develop strategies to attract more patients, especially those with relatively better paying insurance policies. As one of these strategies, hospitals have been adopting various high-tech medical services and equipment to improve both their competitive edge and quality of care.

Competitive pressures play an important role in technology adoption decisions. Therefore, historically, much attention focused on high-tech medical services was about their availability and diffusion (Baker, 2001a; Baker & Phibbs, 2002; Baker & Wheeler, 1998; Bryce & Cline, 1998; Chernew, Fendrick, & Hirth, 1997; Cutler & McClellen, 1996; Grossman & Banks, 1998; Hill & Wolfe, 1997; Teplensky, Pauly, Kimberly, Hillman, & Schwartz, 1995; Zhang, Kohn, McGarrah, & Anderson, 1999), rather than the relationship between high-tech medical services and quality performance of hospitals.

To date only a limited number of studies have examined the relationship between high-tech medical services and hospital quality performance. These studies exhibit mixed and contradictory results. For instance, several researchers found availability of high technology medical services to be a significant predictor of better quality, improved patient outcomes (Bazzoli, Chen, Zhao, & Lindrooth, 2008; Ghaferi, Osborne, Birkmeyer, & Dimick, 2010; Kuhn, Hartz, Gottlieb, & Rimm, 1991; Landon et al., 2006), and lower mortality (Hartz et al., 1989; Krakauer et al., 1992; Mukamel, Zwanziger, & Tomaszewski, 2001; R. M. Werner & E. Bradlow, 2006). However, others did not find high-tech medical services to be a significant predictor of quality, patient outcomes (Blegen, Goode, Spetz, Vaughn, & Park, 2011; Mark & Harless, 2010) and mortality (Bazzoli et al., 2008; Tomal, 1998). The mixed findings may be the result of methodological limitations and inconsistencies in the definition of high-tech medical services. For example, three studies used more than one statistical technique within the same study and produced mixed results in regards to the technology-quality relationship (Mark, Harless, & McCue, 2005; Mark, Harless, McCue, & Xu, 2004; Schultz, van Servellen, Chang, McNeese-Smith, & Waxenberg, 1998). In addition, high-tech medical services have been defined and measured in different ways, limiting the comparability across studies. Overall, due to the limited number of studies, the mixed and contradictory findings, and the inconsistent technology measures, it is still not clear whether the availability of high technological medical services makes a significant difference in quality of care.

The aim of this current work is to evaluate the relationship between the availability of high technology services in U.S. hospitals and quality of care, which is measured with a 30-day mortality rate for heart attack (i.e., acute myocardial infarction [AMI]), heart failure, and pneumonia. Examining this relationship is timely and important. Studies, including some recent ones, indicate that hospitals have been intensifying their adoption of high-tech medical services as a result of competitive pressures (Devers, Brewster, & Casalino, 2003; Trinh, Begun, & Luke, 2008). Better knowledge about the association between high-tech medical services and quality performance would not only benefit researchers and policy makers, but also hospital strategists in their technology adoption decisions.

As a conceptual framework, Donabedian's Structure-Process-Outcome (SPO) quality framework (Donabedian, 1980) and the Resource Based View (RBV) of a firm are used. SPO and RBV are useful because performance of a hospital depends upon its ability to optimize the benefits of its physical, human and organizational capital resources (J. Barney, 1991). Moreover, high technology medical services can be both classified within the structure dimension of the SPO quality framework and among physical capital resources of RBV. The overall aim of this paper is achieved by focusing on physical resources (i.e., high-tech medical services) and by controlling for human, organizational and market level factors.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

According to Donabedian (1966, 1980), evaluating quality of care at healthcare facilities can be performed by examining structural characteristics of hospitals, processes and outcomes of care. The structural component of Donabedian's framework includes visible characteristics such as technology, staffing, plant, and facilities. In his framework, process refers to processes of care, whereas outcomes indicate end results, such as better healthcare status, survival, or death (Donabedian, 1981). Structural characteristics are the initial step in evaluating the quality of care in hospitals because of their visible nature and vital role. Not having the necessary staffing, equipment, and facilities may substantially limit the quality of care. However, structural components by themselves are not sufficient for better quality of care unless these components are accompanied with proper processes of care. Moreover, processes of care are valuable according to their relevance to outcomes of care (Donabedian, 1966). Overall, all these components of Donabedian's framework are interconnected, and the value of both structure and process dimensions are determined according to their relationship with outcomes of quality.

RBV (Wernerfelt, 1984) attributes the superior performance of some organizations to the unique combination of their physical, human/intangible, and organizational/financial resources (J. Barney, 1991; Chatterjee & Wernerfelt, 1991). A recent meta-analysis reaffirmed the conceptual value of RBV (Crook, Ketchen, Combs, & Todd, 2008), despite some prior debates regarding pros and cons of RBV (J. B. Barney, 2001a; Newbert, 2007; Priem & Butler, 2001a, 2001b).

RBV literature focuses on finding explanations for heterogeneous organizational performance by concentrating on internal factors of organizations (Amit & Schoemaker, 1993; J. B. Barney, 2001b; Dierickx & Cool, 1989; Lippman & Rumelt, 1982; Peteraf, 1993). Similarly, investigating the technology-quality link requires understanding the organizational factors that differentiate hospitals from each other. Therefore, RBV can be a very useful framework in investigating the relationship between high-tech medical services and hospital quality performance.

Hypotheses

According to Donabedian's SPO framework (1966, 1980), better structural quality and process quality are expected to generate better healthcare outcomes. Even though the literature exhibits mixed results, some previous studies have found a significant relationship between availability of high-tech services (structural quality) and better quality outcomes (Bazzoli et al., 2008; Ghaferi et al., 2010; Mukamel et al., 2001; R. M. Werner & E. T. Bradlow, 2006). One early cross-sectional study of 3,100 U.S. hospitals in 1986 found that higher technological sophistication (index of 5 services) was associated with lower mortality rates (Hartz et al., 1989). Another earlier (1986) study of 84 U.S hospitals found a significant and negative relationship between high-tech services (index of 5 services) and 30-day mortality rates (Krakauer et al., 1992). A later longitudinal study (1990-1995) of 422 U.S. acute care hospitals found a significant positive association between high-tech services (Saidin Index) and mortality, but only in the Ordinary Least Squares (OLS) model (Mark et al., 2004). Another follow up study that used the same sample found significant association in OLS (positive) and within-group fixed-effects statistical model (negative) but for only high managed care penetration markets (Mark et al., 2005).

It is expected that hospitals with sophisticated technologies will also have a more sophisticated and educated work force. Therefore, these high-tech hospitals will have a better capacity of providing not only better quality of healthcare but also better processes of care. Therefore, we expect a negative relationship between the number of high-tech medical services (large breadth) and mortality rates.

> *Hypothesis 1. There is negative relationship between the breadth of high-tech medical services and mortality rates, while controlling for environmental and other organizational factors.*

RBV posits that having resources with certain features (rare, valuable, inimitable and non-substitutable) would allow organizations to achieve better performance (J. Barney, 1991). According to RBV, these features are synergistic and in combination can differentiate organizations in regards to their performance. High-tech services have the potential to create such a synergy since they inherently have some of the aforementioned RBV features. For example, high-tech services tend to be more valuable and rare due to barriers of adoption, such as high investment costs and the requirement for highly qualified staffing (J. Spetz & Maiuro, 2004). Therefore hospitals with rare high-tech services would be expected to exhibit better quality of performance.

> *Hypothesis 2. There is negative relationship between rare high-tech medical services and mortality rates, while controlling for environmental and other organizational factors.*

Up to this point, we have been hypothesizing in broad terms that more high-tech services are associated with better quality. However, quality is a broad construct. As a construct, quality has many dimensions and it can be operationalized and measured in many different ways. In this study, we opted to use specific outcome quality measures to operationalize quality performance. Specifically, we use mortality rates for three specific conditions (heart attack, heart failure, and pneumonia) as quality performance measures. When we explore these specific measures of quality, we expect that there are some technologies that are more relevant than the others in affecting outcomes. Therefore, we posit that hospitals with a higher number of high-tech services that are more specific to the three conditions are expected to have lower mortality rates.

Hypothesis 3. There is negative relationship between condition-specific high-tech services and mortality rates, while controlling for environmental and other organizational factors.

The analytical framework (Figure 1) summarizes the hypothesized relationships in this study. This study integrates both RBV and Donabedian's SPO framework given that both structural quality from SPO and physical capital resource from RBV relate to high-tech services. Figure 1 indicates processes of care as an important dimension of SPO framework. However, direct measures of processes of care are outside the scope of this study given that the main focus of this study is the in-depth exploration of the possible link between a structural component (i.e., technology) and a outcome measure (mortality rates). In other words, to address the limitations of previous studies, we opted to focus on developing various measures of high-tech services instead of including processes of care.

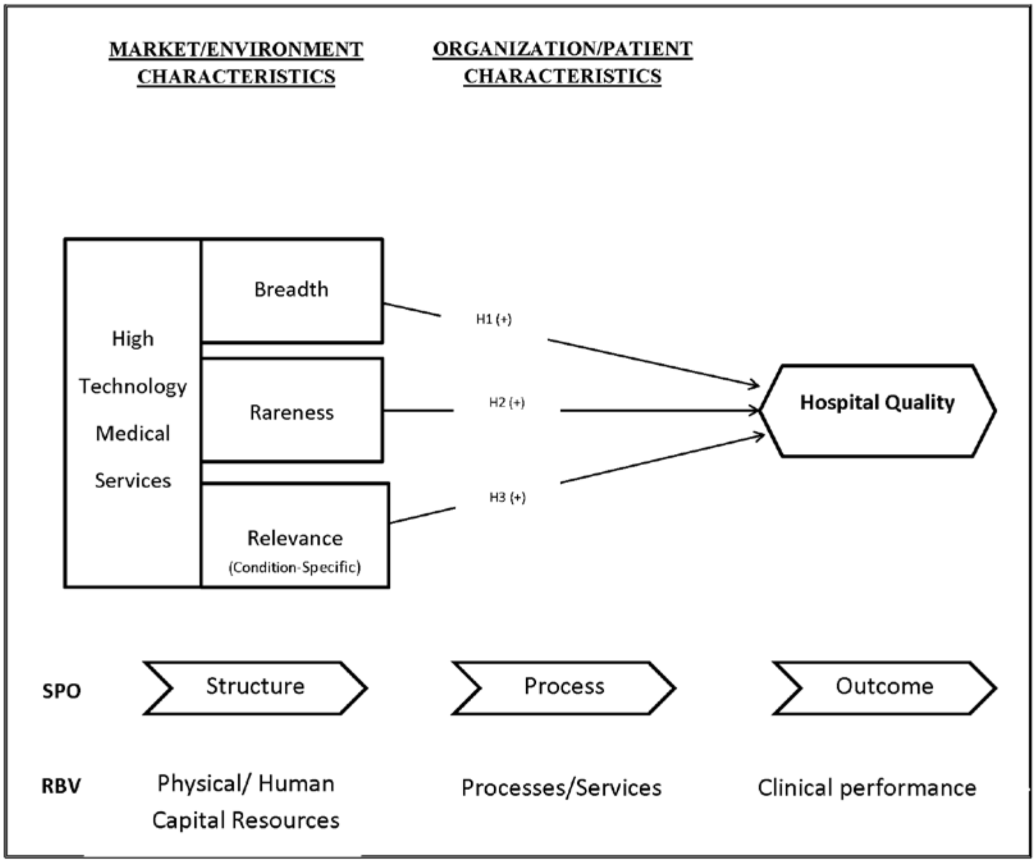

Figure 1. Analytical framework for the relationship between high tech services and quality performance

METHODS

Data and Sample

This study uses longitudinal panel data of medical surgical hospitals covering 2006 through 2009. It excludes specialty hospitals since they tend to focus on certain services and have a limited number of high-tech services. The final sample was generated by merging several datasets: the Center for Medicare and Medicaid Services (CMS) Hospital Compare Database, the American Hospital Association (AHA) Annual Survey Data, and the Area Resource File (ARF). The initial merge of the AHA with the Hospital Compare database resulted in 18,371 observations, with an average of 4,592 hospitals per year for heart attacks, heart failure, and pneumonia. Dropping the specialty hospitals and observations with missing values, resulted in different sample sizes for each condition (Heart Attack = 10,825; Heart Failure = 15,091; and Pneumonia = 15,972). Missing observations in the Hospital Compare may be a result of (a) hospitals not reporting the mortality rates, or (b) the CMS not reporting because of the requirement of having at least 25 cases per hospital for public reporting (QualityNet, 2013). Later, during the merger with the ARF file, hospitals located in Puerto Rico, the U.S. territories and some other hospitals were dropped (average of 150 cases) due to missing market control variables. There was also an average of 65 hospitals with missing observations for per capita income. Because all these hospitals were located in the South, the yearly mean per capita income in the South was calculated and used to replace those missing observations. The aforementioned steps resulted in three different unbalanced panel sample sizes for each condition (Heart Attack = 10,689; Heart Failure = 14,927; and Pneumonia = 15,800). In these final three samples, the annual average number of hospitals was 2,672 for heart attacks, 3,731 for heart failure, and 3,950 for pneumonia.

Even though mortality data is updated annually in Hospital Compare, the data collection period covers 3 previous years (36 months) for each update. For instance, the December 2009 update covers July 2005 through June 2008, whereas the December 2010 update covers July 2006 through June 2009. Therefore, we matched the coverage period that included a full year data in Hospital Compare with a corresponding year of the AHA data. For instance, Hospital Compare data that covers the July 2005-June 2008 period was merged with 2006 AHA data, since year 2006 (as a full year) falls into this period.

Similarly, July 2006-June 2009 was merged with 2007 AHA data, and so forth. As a result, we were able to merge Hospital Compare data with AHA data for 4 years (2006-2009).

VARIABLES

Table 1 shows the summary for the variables used in this study by providing variable names, operational definitions, and data sources. In this study, quality outcomes (dependent variables) consist of risk adjusted 30-day mortality rates for heart attack, heart failure and pneumonia. The 30-day mortality indicates the estimate of deaths from any cause within 30 days of admission to a hospital for the aforementioned three conditions (HospitalCompare, 2012). In the Hospital Compare files, 30-day mortality measures are risk adjusted according to patient characteristics (age, gender, past medical conditions, other comorbidities) (HospitalCompare, 2012). The data file only includes Medicare beneficiary patients (65 years and older).

The main predictor of interest, high-tech services, is defined as those services and equipment that are designed to diagnose or improve health conditions of patients. High-tech services are measured by using three different indices. The first one, the high-tech breadth index, is an index measuring the breadth of high-tech services by having the simple count of available high-tech services. This index is used to test hypothesis 1. Services that were included in this index are listed in Appendix F. There was an average of 61 services included in the index, starting from 54 in 2006 and ending with 68 in 2009. This index includes the services that were originally included in the Spetz (1999) index along with some other high-tech services that were used by some other studies (Bazzoli et al.,

Table 1
Variables, Operational Definitions and Data Sources

Variable	*Operational Definition*	*Source*
Quality Performance (DV)		
30-day Mortality	Risk adjusted mortality within 30 day of admission to a hospital for three health conditions (Heart Attack, Heart Failure, and Pneumonia)	HC
Hospital Technology Indices (IV)		
High-Tech Breadth Index	Simple count of high-tech services	AHA
Saidin Index	Weighted sum of high-tech services	AHA
Condition-Specific high-tech Indices	indices including services that are related to three health conditions(heart attack, heart failure, and pneumonia)	AHA
<u>Control Variables</u>		
Staffing		
RN Staffing Intensity	RN FTE staffing per 1000 patient day	AHA
RN Staffing Mix	RN FTEs / Total Nursing Personnel FTEs	AHA
Non-Nurse Staffing Mix	Non Nurse Staffing / Total Staffing	AHA
Physician Staffing Intensity	Physician and Dentist FTEs staffing per 1000 patient days	AHA
Organizational/Operational Factors		
Condition-Specific Volume	# of Patients that 30-day Mortality based upon	HC
Occupancy Rate	Occupied bed days/ total bed days available	AHA
Length of Stay	Total Inpatient days/ Admissions	AHA
% of Medicare Inpatient Days	Medicare Inpatient Days/Total Inpatient Days	AHA
% of Medicaid Inpatient Days	Medicaid Inpatient Days/Total Inpatient Days	AHA
Outpatient Mix	(Total Outpatient Visits/3)/Total Facility Equivalent Inpatient Days	AHA
System Affiliation	Binary: No=0, Yes=1	AHA
Teaching Status	Either Medical School Affiliated, or Member of COTH or Residency Training Approval by ACGME; Binary Yes:1; No:0	AHA
Urban Status	Location of Hospital in Metropolitan area: yes=1	ARF
Bed Size Categorical	Small (5-149), Medium (150-399), Large(400+)	AHA
Ownership Categories	Government (Federal or Non-Federal), Not-For-Profit, For Profit	AHA
Market/Environmental Factors		
Hospital Market Competition	Health Service Area Herfindahl-Hirschman Index	AHA
Market Affluence	Per capita income within county	ARF
Medicare Managed Care Penetration	% of county population enrolled in Managed Care	ARF
Census Region	Northeast, Midwest, South, West	ARF

ACHME=Accreditation Council for Graduate Medical Education; ARF= Area Resource File; AHA=American Hospital Association; CMS= Center for Medicare and Medicaid Services; HC=CMS Hospital Compare; FTE=Full time equivalent COTH=Council of Teaching Hospitals

2008; Ghaferi et al., 2010; Hartz et al., 1989; Jha et al., 2010; Jiang, Friedman, & Begun, 2006; Mark et al., 2005; Mukamel et al., 2001; Schultz, van Servellen, Litwin, McLaughlin, & Uman, 1999). The breadth index also included some additional services that were added to the AHA survey in recent years.

The second index, the rareness index, is based upon the Saidin Index (Spetz, 1999), the weighted sums of available high-tech services (Spetz & Baker, 1999). This index is testing the rareness of high-tech services of hypothesis 2. The weights in the Saidin index are calculated by finding the proportion of hospitals that do not possess a particular service to all hospitals in that particular year (Mark et al., 2004). In our rareness index, we only included services that had 85% or higher weights in 2009. The weights were also used in the calculation of the index. Since the weights account for the rareness of the particular service, 85% refers that, on that particular year, 85% of the hospitals did not possess that particular service.

Last, by using the services listed in Appendix F, several additional health condition-specific indices were developed to test the hypothesis 3. In these last indices, only those high-tech services that are more related to heart attack, heart failure and pneumonia outcomes were included. These condition-specific indices included the simple count of 6, 13, and 8 high-tech services for heart attack, heart failure, and pneumonia, respectively (Appendix F). For these three conditions, to account for the rareness dimension, condition specific Saidin indices were also calculated by using the Saidin index weights reported in Appendix F. In all, total of 6 indices were created: 3 based upon simple counts and other 3 based upon the Saidin index weights.

To test the sensitivity of high-tech indices developed in this study, there were several more high techs services developed: (a) 6 additional indices were created by adding some more services to condition-specific indices; and (b) 2 additional indices were created by separating high-tech services into type of their use (intervention, diagnostic, or both intervention and diagnostic) .

Due to their importance in processes of care, four different staffing measures are used as control variables, RN staffing intensity, RN staffing mix, Non-Nurse staffing mix, and Physician staffing intensity. Among these four measures, two different measures of RN staffing were calculated. *RN staffing intensity* measures the concentration of RN staffing per 1,000 inpatient days, whereas *RN staffing mix* measures the proportion of RN staffing relative to other nurse staffing. Both higher RN staffing and RN staffing mix have been identified as important contributors of better quality care in literature (Lang, Hodge, Olson, Romano, & Kravitz, 2004; Lankshear, Sheldon, & Maynard, 2005; Stone, Pogorzelska, Kunches, & Hirschhorn, 2008). Additionally, a recent meta-analytic review shows a consistent association between higher RN staffing and lower hospital mortality rates (Kane, Shamliyan, Mueller, Duval, & Wilt, 2007). In addition, physician staffing per 1,000 patient days, along with non-nurse staffing mix were included among control variables. The issue of multi-collinearity was explored by comparing correlations between staffing measures. There was low correlation among the staffing variables: the largest correlation was 0.28 between *Physician staffing intensity* and *RN staffing intensity*.

Previous studies found some supporting evidence for the relationship between higher hospital patient volume and better mortality rates (Hillner, Smith, & Desch, 2000;

Luft, Hunt, & Maerki, 1987). One recent cross sectional study found significant association between higher volume hospitals and lower mortality rates for heart attack, heart failure, and pneumonia (Ross et al., 2010). CMS reports the condition-specific volume (number of patients) in Hospital Compare if a hospital has 25 or more cases (QualityNet, 2013). Therefore, we included condition-specific volume among control variables.

Table 1 shows the remaining control variables that are included in the analytical models. The *Occupancy rate* measures hospital inpatient days in proportion to hospital beds whereas the average *length of stay* measures hospital inpatient days as a fraction of hospital admissions. The former indicates the utilization of beds, whereas the latter indicates the efficiency of provided care during this utilization. From the quality perspective, both utilization and efficiency of care are important factors. Since the condition-specific mortality rates in the Hospital Compare data file are based upon Medicare patients (QualityNet, 2013), we also controlled for the *percentage of Medicare patients.* The *Outpatient mix* shows a hospital's outpatient utilization as a percentage of total facility equivalent patient utilization. In the calculation of this measure, it is assumed that outpatient services utilize one third of hospitals' resources, relative to inpatient services (Detsky, O'Rourke, Naylor, Stacey, & Kitchens, 1990; Vujicic, Addai, & Bosomprah, 2009). As previously mentioned, competition has been identified as one of the major drivers for technology adoption decisions by hospitals. Hospital competition is measured with the *Herfindahl-Hirschman index* (HHI), the sum of squared *market shares* of hospitals (Baker, 2001b). Hospital *market share* measures hospital inpatient days as a percentage of total inpatient days in the health service area. In the AHA survey data, there were some missing Dartmouth health service area codes for some hospitals. For these hospitals, county-based HHIs were calculated and used. *Market affluence,* the natural logarithm of per capita income in a county, is another market level measure. It is widely used by hospital performance researchers to control for confounding factors that might be associated with the affluence levels of the county population where the hospital is located. Due to cost-containment nature of managed care contracts, *managed care penetration* is another market level factor that would be critical to recognize in a quality performance study. The remaining organizational and market factors in Table 1, such as bed size, system affiliation, and census region are widely used by researchers to account for differences that might emerge as a result of some structural, organizational, or locational characteristics of hospitals.

ANALYSIS

In this paper, a longitudinal panel design with two types of models is used: 1) the random effects model with state and time fixed effects, and 2) within-group fixed effects models with year dummies. In both models, robust standard errors estimator was used to control for heteroskedasticity. For the fixed effects model, an additional cluster standard error estimator is used to account for intraclass correlation among different clusters (Nichols & Schaffer, 2007) such as hospital types (i.e., for-profit and not-for-profit hospitals).

There were several reasons for choosing two different statistical models to test our hypotheses. First, one of the major goals of this study is to provide some results which can shed some light on the mixed or contradictory findings of previous studies in regards to the technology-quality link. Using both random effects and fixed effects models would allow accounting for possible different results of prior studies that used different statistical models. Second, despite the possible introduction of some bias in random effects models, the random effects model might be preferable over the fixed effects model in some sluggish cases (Clark & Linzer, 2012). The sluggish case refers to a sample where between-variations are larger than within-variations for variables of interest. Within-variation indicates the variation of a measure (i.e., quality) within a particular hospital across time (i.e., years). In contrast, between-variation denotes the variation in a measure (i.e., quality) between this particular hospital and other hospitals. For a sluggish case, when one has large numbers of units (i.e., more than 50) and few observations per unit (less than 6), the random effects model can be preferred over the fixed effects model if the correlation between regressors and unit effects is moderate to low (i.e., less than 0.5) (Clark & Linzer, 2012). In our samples, despite having sufficient within-variations to be able to use the fixed effects model, between-variations were consistently higher for dependent and major independent variables. In our study, we had more than 2,500 hospital units with 4 or less observations per unit. Furthermore, we had low correlation (approximately 0.4) between regressors and unit effects. As a result, we decided to include the random effects model with state and time fixed effects among our analytical models. In this study, FileMaker Pro was used for data management, while SAS 9.3 and STATA 12 were used for data analysis.

RESULTS

Table 2 displays the descriptive statistics for measures included in this study under separate columns for three conditions (heart attack, heart failure, and pneumonia). It

Table 2
Descriptive Statistics for Independent and Control Variables for 30-Day Mortality Rates for Heart Attack(HA), Heart Failure(HF), and Pneumonia (PN)

	N=10689		N=14927		N=15800	
	HA MORT (DV)		**HF MORT (DV)**		**PN MORT (DV)**	
	15.99	(1.69)	11.39	(1.54)	11.83	(1.84)
Variable	Mean	(SD)	Mean	(SD)	Mean	(SD)
High-Tech Indices(IVs)						
Breath Index (simple count)	20.32	(11.66)	17.15	(11.48)	16.54	(11.49)
Rareness (Saidin)	2.92	(3.70)	2.24	(3.36)	2.13	(3.31)
Condition-Specific (simple count)	2.68	(1.57)	3.03	(2.27)	2.70	(1.45)
Condition-Specific (Saidin)	1.62	(1.10)	1.89	(1.65)	1.33	(0.82)
Sensitivity- (simple count)	7.17	(4.69)	6.33	(4.69)	8.56	(5.42)
Sensitivity-(Saidin)	4.93	(3.65)	4.15	(3.54)	5.03	(3.83)
Sensitivity- Intervention	11.58	(7.30)	9.62	(7.12)	9.26	(7.10)
Sensitivity-Diagnostic	9.71	(5.48)	8.35	(5.39)	8.08	(5.39)
Staffing Variables (control)						
RN Staffing Intensity	7.37	(2.93)	8.05	(3.93)	8.29	(4.46)
RN Staffing Mix	0.90	(0.09)	0.87	(0.12)	0.86	(0.12)
Non-Nurse Staffing Mix	0.52	(0.29)	0.52	(0.32)	0.52	(0.37)
Physician Staffing Intensity	0.47	(0.98)	0.59	(1.18)	0.66	(1.77)
Organizational/Operational Factors						
Condition-Specific Volume	191.59	(187.28)	291.89	(297.62)	268.66	(225.08)
Occupancy Rate	0.61	(0.15)	0.56	(0.18)	0.55	(0.19)
Length of Stay (LOS)	4.65	(1.79)	4.67	(2.83)	4.83	(3.89)
% of Medicare Inpatient Days	0.17	(0.10)	0.16	(0.10)	0.15	(0.10)
% of Medicaid Inpatient Days	0.52	(0.12)	0.54	(0.14)	0.55	(0.15)
Outpatient Mix	0.53	(0.17)	0.56	(0.19)	0.57	(0.19)
System Affiliated %	62.12		57.21		55.91	
Teaching Hospital %	33.58		26.16		24.95	
Urban %	93.26		85.84		83.42	
Bed Size Categorical						
Small (5-149) %	43.47		58.55		60.77	
Medium (150-399) %	41.59		30.68		29.07	
Large (400+) %	14.93		10.77		10.16	
Ownership Categories						
For Profit %	16.76		15.39		14.78	
Not-For-Profit %	68.67		63.94		62.62	
Government (Federal)%	0		0.17		0.42	
Government (Non-Federal) %	14.58		20.51		22.18	
Market/Environmental Factors						
Hospital Market Competition (HHI)	0.64	(0.35)	0.70	(0.35)	0.71	(0.35)
Market Affluence (Per-capita Inc.)	$37,176	(11199)	$35,433	(10642)	$35,241	(10559)
Managed Care Penetration	18.61	(13.89)	16.94	(13.58)	16.62	(13.54)
Census Region						
Northeast %	19.02		14.58		13.91	
Midwest %	24.88		29.32		30.13	
South %	39.12		39.14		38.3	
West %	16.98		16.96		17.66	

DV=Dependent Variable, IV=Independent Variable is proper to report the descriptive statistics in this way, since we had different sample sizes for each condition. Majority of hospitals in our samples were located in urban areas (83-93%), not-for-profit (62-68%), and system affiliated (55-62%). In our samples only 10% to 15% of hospitals were large with more than 400 beds.

Tables 3, 4 and 5 display the results for 30-day mortality rates for heart attack, heart failure and pneumonia, respectively. In these tables, the results for the random effects models were reported under the *random* column, whereas fixed effects were reported under the *fixed* column. The results under *breadth* column show the findings of study for 30-day mortality rates by using the breadth of high-tech services. The results under *rareness* column show the findings of study for 30-day mortality rates by using the modified Saidin Index. Similarly, condition-*specific* column displays the findings for condition-specific indices.

Table 3 displays the random and fixed effects regression results for 30-day mortality rates for heart attack. All models in Table 3 generated no statistically significant results to support the association between high-tech services and 30-day mortality rates for heart attack. Therefore, for 30-day mortality rates, none of our hypotheses were supported. Condition-specific volume is the only measure that consistently exhibited significant and negative association with 30-day mortality rates for heart attack. Some other measures exhibited consistent associations in the random effects models too. For example, RN staffing mix, physician staffing intensity, market affluence and managed care penetration were among these measures that consistently exhibited significant and negative association with 30-day mortality rates for heart attack in random effects models. To illustrate, in the random effects model, the coefficient of -2.082 under the breath column

Table 3

Random And Fixed Effects Regression Results For 30-Day Mortality Rates For Heart Attack

	Breadth				Rareness				Condition-Specific			
	Random		Fixed		Random		Fixed		Random		Fixed	
Obs.	10689		10689		10689		10689		10689		10689	
	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)
High-Tech Services	5.E-04	(0.00)	0.001	(0.00)	-0.012	(0.01)	-0.008	(0.01)	0.011	(0.01)	0.017	(0.02)
Condition-Specific Volume	-0.002 ****	(0.00)	-0.003 ****	(0.00)	-0.002 ****	(0.00)	-0.003 ****	(0.00)	-0.002 ****	(0.00)	-0.003 ****	(0.00)
Occupancy Rate	0.096	(0.15)	0.204	(0.24)	0.126	(0.15)	0.203	(0.24)	0.093	(0.15)	0.208	(0.24)
Length of Stay	0.002	(0.01)	-0.001	(0.01)	0.002	(0.01)	-0.002	(0.01)	0.002	(0.01)	-0.001	(0.01)
Outpatient Mix	0.165	(0.16)	-0.094	(0.30)	0.181	(0.16)	-0.102	(0.30)	0.166	(0.16)	-0.091	(0.30)
RN Staffing Intensity	-1.E-04	(0.01)	0.002	(0.01)	0.001	(0.01)	0.003	(0.01)	0.000	(0.01)	0.002	(0.01)
RN Staffing Mix	-0.470 *	(0.27)	-0.306	(0.46)	-0.463 *	(0.27)	-0.328	(0.46)	-0.474 *	(0.27)	-0.309	(0.46)
Non-Nurse Staffing Mix	0.026	(0.20)	0.104	(0.27)	0.045	(0.20)	0.102	(0.27)	0.020	(0.20)	0.098	(0.27)
Physician Staffing Intensity	-0.053 *	(0.03)	-0.044	(0.04)	-0.053 *	(0.03)	-0.045	(0.04)	-0.052 *	(0.03)	-0.044	(0.04)
% of Medicare Inpatient Days	-0.173	(0.17)	-0.066	(0.24)	-0.172	(0.17)	-0.041	(0.24)	-0.182	(0.17)	-0.075	(0.24)
% of Medicaid Inpatient Days	-0.010	(0.19)	-0.293	(0.28)	-0.029	(0.19)	-0.314	(0.28)	0.001	(0.19)	-0.282	(0.27)
Hospital Market Competition (HHI)	-0.011	(0.08)	-0.556	(0.38)	-0.027	(0.08)	-0.565	(0.38)	-0.009	(0.08)	-0.554	(0.38)
Market Affluence	-2.082 ****	(0.28)	0.418	(1.25)	-2.052 ****	(0.27)	0.351	(1.24)	-2.083 ****	(0.28)	0.425	(1.25)
Managed Care Penetration	-0.008 ****	(0.00)	-0.005	(0.01)	-0.008 ****	(0.00)	-0.005	(0.01)	-0.008 ****	(0.00)	-0.005	(0.01)
Medium	0.145 **	(0.06)			0.157 ***	(0.06)			0.141 **	(0.06)		
Large	0.289 ***	(0.11)			0.331 ***	(0.11)			0.284 ***	(0.10)		
Not-For-Profit	-0.162 **	(0.07)			-0.157 **	(0.07)			-0.162 **	(0.07)		
Government	-0.054	(0.09)			-0.043	(0.09)			-0.056	(0.09)		
Teaching Hospital	-0.103 *	(0.05)			-0.089 *	(0.05)			-0.105 **	(0.05)		
Urban	0.015	(0.10)			0.019	(0.10)			0.014	(0.10)		
Northeast	-0.316	(0.60)			-0.330	(0.60)			-0.313	(0.60)		
Midwest	0.142	(0.62)			0.165	(0.61)			0.137	(0.62)		
South	-0.105	(0.61)			-0.105	(0.61)			-0.109	(0.62)		
Time Fixed Effects	✔ ****		✔ ****		✔ ****		✔ ****		✔ ****		✔ ****	
State Fixed Effects	✔				✔				✔			
sigma_u	1.154				1.154				1.154			
sigma_e/Root MSE	0.958		0.96		0.958		0.96		0.957		0.96	
rho/ R-Squared	0.592		0.77		0.592		0.77		0.592		0.77	

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; HHI=Herfindahl-Hirschman Index; Reference hospitals: Small (5-149 beds), For-Profit (ownership), West (location)

indicates that holding all other variables constant, for a 10% increase in market affluence, there would be a 21% (10x2.082) decrease in 30-day mortality rates for heart failure.

Table 4 displays the random and fixed effects regression results for 30-day mortality rates for heart failure. Except for the condition-specific index, all models in Table 4 generated no statistically significant results to support the association between high-tech services and 30-day mortality rates for heart attack. Even though the association between condition-specific high-tech services and 30-day mortality rates for heart failure was significant in random effects model, the direction was not in line with our hypothesis 3. In hypothesis 3, we predicted significant and negative association between condition-specific high-tech services and 30-day mortality rates. Contrary to our prediction, the association was significant but positive. Therefore, for heart failure 30-day mortality rates, none of our hypotheses were supported. Similar to the results for heart attack, the condition-specific volume is the only measure that consistently exhibited significant and negative association with 30-day mortality rates for heart failure too. In Table 4, the random effects estimates suggests that outpatient mix, hospital market competition, market affluence, managed care penetration affect the 30-day mortality rates for heart failure.

Table 5 displays the random and fixed effects regression results for 30-day mortality rates for pneumonia. Except for the Saidin index (rareness), all models in Table 5 generated no statistically significant results to support the association between high-tech services and 30-day mortality rates for pneumonia. Hypothesis 2 predicted significant and negative association between rare high-tech services and 30-day mortality rates for each of the three conditions including pneumonia. In Table 5, the random effects estimates under *rareness* column suggest that hypothesis 2 is partially supported. To illustrate, in the

Table 4

Random And Fixed Effects Regression Results For 30-Day Mortality Rates For Heart Failure

	Breadth				Rareness				Condition-Specific			
	Random		Fixed		Random		Fixed		Random		Fixed	
Obs.	14927		14927		14927		14927		14927		14927	
	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)
High-Tech Services	0.002	(0.00)	2.E-04	(0.00)	-0.006	(0.01)	-0.001	(0.01)	0.016 **	(0.01)	-0.001	(0.01)
Condition-Specific Volume	-0.001 ****	(0.00)	-0.001 **	(0.00)	-0.001 ****	(0.00)	-0.001 **	(0.00)	-0.001 ****	(0.00)	-0.001 **	(0.00)
Occupancy Rate	0.149	(0.11)	0.038	(0.16)	0.170	(0.11)	0.038	(0.16)	0.152	(0.11)	0.037	(0.16)
Length of Stay	0.008	(0.01)	0.006	(0.01)	0.008	(0.01)	0.006	(0.01)	0.009	(0.01)	0.006	(0.01)
Outpatient Mix	0.450 ****	(0.11)	0.008	(0.19)	0.456 ****	(0.11)	0.007	(0.19)	0.456 ****	(0.11)	0.007	(0.19)
RN Staffing Intensity	0.003	(0.00)	0.002	(0.00)	0.003	(0.00)	0.002	(0.00)	0.003	(0.00)	0.002	(0.00)
RN Staffing Mix	0.038	(0.17)	-0.222	(0.28)	0.044	(0.17)	-0.223	(0.28)	0.033	(0.17)	-0.223	(0.28)
Non-Nurse Staffing Mix	0.028	(0.07)	0.143	(0.12)	0.031	(0.07)	0.143	(0.12)	0.027	(0.07)	0.143	(0.12)
Physician Staffing Intensity	-0.013	(0.02)	-0.005	(0.02)	-0.013	(0.02)	-0.005	(0.02)	-0.013	(0.02)	-0.005	(0.02)
% of Medicare Inpatient Days	-0.044	(0.10)	0.032	(0.14)	-0.039	(0.10)	0.034	(0.14)	-0.049	(0.10)	0.034	(0.14)
% of Medicaid Inpatient Days	0.008	(0.14)	0.148	(0.19)	-0.004	(0.14)	0.146	(0.19)	0.017	(0.14)	0.146	(0.19)
Hospital Market Competition (HHI)	0.420 ****	(0.07)	-0.111	(0.33)	0.407 ****	(0.07)	-0.112	(0.33)	0.423 ****	(0.07)	-0.112	(0.33)
Market Affluence	-1.367 ****	(0.22)	-0.816	(0.77)	-1.351 ****	(0.22)	-0.826	(0.77)	-1.368 ****	(0.22)	-0.823	(0.77)
Managed Care Penetration	-0.004 **	(0.00)	-0.001	(0.00)	-0.004 **	(0.00)	-0.001	(0.00)	-0.004 **	(0.00)	-0.001	(0.00)
Medium	0.011	(0.05)			0.024	(0.05)			0.003	(0.05)		
Large	-0.063	(0.09)			-0.030	(0.09)			-0.068	(0.09)		
Not-For-Profit	0.067	(0.06)			0.072	(0.06)			0.068	(0.06)		
Government	-0.010	(0.07)			-0.001	(0.07)			-0.008	(0.07)		
Teaching Hospital	0.046	(0.05)			0.059	(0.05)			0.044	(0.05)		
Urban	0.159 ***	(0.06)			0.165 ***	(0.06)			0.159 ***	(0.06)		
Northeast	-0.949 ****	(0.29)			-0.975 ****	(0.29)			-0.944 ****	(0.29)		
Midwest	-0.609 **	(0.29)			-0.607 **	(0.29)			-0.613 **	(0.29)		
South	-1.079 ****	(0.31)			-1.086 ****	(0.31)			-1.084 ****	(0.31)		
Time Fixed Effects	✔ ****		✔ ****		✔ ****		✔ ****		✔ ****		✔ ****	
State Fixed Effects	✔				✔				✔			
sigma_u	1.121				1.121				1.119			
sigma_e/Root MSE	0.849		0.85		0.849		0.85		0.849		0.85	
rho/ R-Squared	0.635		0.78		0.635		0.78		0.635		0.78	

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; HHI=Herfindahl-Hirschman Index; Reference hospitals: Small (5-149 beds), For-Profit (ownership), West (location)

Table 5

Random And Fixed Effects Regression Results For 30-Day Mortality Rates For Pneumonia

	Breadth				Rareness				Condition-Specific			
	Random		Fixed		Random		Fixed		Random		Fixed	
Obs.	15800		15800		15800		15800		15800		15800	
	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)
High-Tech Services	0.001	(0.00)	0.002	(0.00)	-0.012 *	(0.01)	-0.001	(0.01)	0.011	(0.01)	0.013	(0.02)
Condition-Specific Volume	-3.E-04 **	(0.00)	2.E-04	(0.00)	-3.E-04 **	(0.00)	1.E-04	(0.00)	-3.E-04 **	(0.00)	1.E-04	(0.00)
Occupancy Rate	-0.014	(0.12)	-0.089	(0.17)	0.008	(0.12)	-0.092	(0.17)	-0.015	(0.12)	-0.086	(0.17)
Length of Stay	-0.006	(0.00)	-0.008	(0.01)	-0.007 *	(0.00)	-0.008	(0.01)	-0.006 *	(0.00)	-0.008	(0.01)
Outpatient Mix	0.217 *	(0.13)	-0.107	(0.20)	0.221 *	(0.13)	-0.113	(0.20)	0.218 *	(0.13)	-0.108	(0.20)
RN Staffing Intensity	0.000	(0.00)	0.002	(0.01)	0.001	(0.00)	0.002	(0.01)	0.000	(0.00)	0.002	(0.01)
RN Staffing Mix	-0.045	(0.18)	0.012	(0.27)	-0.037	(0.18)	-0.002	(0.27)	-0.044	(0.18)	0.016	(0.27)
Non-Nurse Staffing Mix	-0.005	(0.03)	0.019	(0.02)	-0.004	(0.02)	0.019	(0.02)	-0.006	(0.03)	0.018	(0.02)
Physician Staffing Intensity	-0.014	(0.02)	-0.002	(0.02)	-0.013	(0.02)	-0.002	(0.02)	-0.013	(0.02)	-0.001	(0.02)
% of Medicare Inpatient Days	-0.054	(0.11)	-0.029	(0.14)	-0.052	(0.11)	-0.017	(0.14)	-0.060	(0.11)	-0.029	(0.14)
% of Medicaid Inpatient Days	0.243	(0.15)	-0.059	(0.21)	0.234	(0.15)	-0.070	(0.21)	0.245	(0.15)	-0.061	(0.21)
Hospital Market Competition (HHI)	0.400 ****	(0.09)	-0.493	(0.38)	0.384 ****	(0.09)	-0.499	(0.38)	0.401 ****	(0.09)	-0.494	(0.38)
Market Affluence	-1.526 ****	(0.27)	-0.021	(0.81)	-1.508 ****	(0.27)	-0.085	(0.81)	-1.527 ****	(0.27)	-0.043	(0.81)
Managed Care Penetration	-0.003	(0.00)	0.003	(0.00)	-0.003	(0.00)	0.003	(0.00)	-0.003	(0.00)	0.003	(0.00)
Medium	-0.069	(0.06)			-0.055	(0.06)			-0.070	(0.06)		
Large	-0.133	(0.10)			-0.086	(0.10)			-0.133	(0.10)		
Not-For-Profit	-0.183 **	(0.07)			-0.178 **	(0.07)			-0.184 ***	(0.07)		
Government	0.023	(0.08)			0.031	(0.08)			0.022	(0.08)		
Teaching Hospital	0.022	(0.06)			0.039	(0.06)			0.020	(0.06)		
Urban	0.180 **	(0.08)			0.184 **	(0.08)			0.177 **	(0.08)		
Northeast	0.215	(0.30)			0.195	(0.30)			0.220	(0.30)		
Midwest	0.116	(0.30)			0.132	(0.30)			0.116	(0.30)		
South	0.526	(0.33)			0.520	(0.33)			0.525	(0.33)		
Time Fixed Effects	✔ ****		✔ ****		✔ ****		✔ ****		✔ ****		✔ ****	
State Fixed Effects	✔				✔				✔			
sigma_u	1.424				1.423				1.424			
sigma_e/Root MSE	1.004		1.00		1.004		1.00		1.004		1.00	
rho/ R-Squared	0.668		0.78		0.668		0.78		0.668		0.78	

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; HHI=Herfindahl-Hirschman Index; Reference hospitals: Small (5-149 beds), For-Profit (ownership), West (location)

random effects model, the coefficient of -0.012 under the *rareness* column indicates that holding all other variables constant, for a 10 unit increase in rare high-tech services, there would be a 12% (10x0.012x100) decrease in 30-day mortality rates for pneumonia. In Table 5, the random effects estimates suggest that hospital market competition, and market affluence affect the 30-day mortality rates for heart failure. Hypothesis 1 predicted significant and negative association between the number of high-tech services (breadth) and 30-day mortality rates heart attack. Hypothesis 1 was not supported. Hypothesis 2 predicted significant and negative association between rare high-tech services and 30-day mortality rates for each of the three conditions. This hypothesis was also not supported. Last, hypothesis 3 predicted significant and negative association between condition-specific high-tech services and 30-day mortality rates. There was no statistically significant result to support this hypothesis either.

Overall, in fixed effects models (Table 3, 4, and 5), all analyses (including the sensitivity tests) generated no statistically significant results to support the association between high-tech services and quality performance. However, in the random effects models, there was some partial support for hypotheses 2. Hypothesis 1 predicted significant and negative association between the number of high-tech services (breadth) and 30-day mortality rates for each of the three conditions (heart attack, heart failure, and pneumonia). Hypothesis 1 was not supported. Hypothesis 2 predicted significant and negative association between rare high-tech services and 30-day mortality rates for each of the three conditions. This hypothesis was only supported for pneumonia in random effects estimators. Last, hypothesis 3 predicted significant and negative association between condition-specific high-tech services and 30-day mortality rates. This hypothesis was not supported either. Contrary to our prediction, the significant result in random effects estimators for condition-specific high-tech services was positive. This indicates that an increase in condition-specific high-tech services was associated with an increase with 30-day mortality rates for heart failure.

CONCLUSIONS AND IMPLICATIONS

This study explored the association between high-tech medical services and quality performance of medical-surgical hospitals in the United States by using 4 year longitudinal data for the period of 2006-2009. The quality performance was measured with 30-day mortality rates for three conditions including heart attack, heart failure and pneumonia. The study had three major hypotheses: 1) negative association between number of the high-tech services (breadth) and 30-day mortality rates; 2) negative association between rare high-tech services and 30-day mortality rates; and 3) negative association between condition-specific high-tech services and 30-day mortality rates. To test these hypotheses, a breadth index, a rareness index (the Saidin index), and six condition-specific indices were developed. Eight additional indices were developed to test the sensitivity of condition-specific indices. For analyses, both random effects and fixed effects methods were utilized.

To address the limitations of previous studies, we used the following strategies: (a) we used a conceptual framework and tested our hypotheses by using large samples of longitudinal data that covers a 4 year period; (b) we utilized fixed effects model in addition to random effects model; and (c) we employed an extensive amount of sensitivity tests on additional high-tech indices.

Overall, we failed to find evidence to support the relationship between high-tech medical services and hospital quality performance by using fixed effects models. In the random effects models, we found some partial support for hypothesis 2 that predicted negative association between availability of rare high-tech services and 30-day mortality rates for only one (pneumonia) out of three conditions. Contrary to our expectations we found positive association between condition-specific high-tech index and 30-day mortality rate for heart failure.

One prior comparable longitudinal study of 422 hospitals for the period of 1990-1995 (Mark et al., 2004) also found no statistically significant result for the relationship between high-tech services (the Saidin Index) and hospital mortality rates by using the fixed effects and dynamic panel models. The only statistically significant and positive result was found by using pooled OLS. In another follow up study with the same data set Mark et al., (2005) found significant results only in high-managed care penetrated markets (positive with OLS, negative with fixed effects). However, since the OLS tend to introduce more bias than the random effects (Clark & Linzer, 2012) we suggest caution in interpreting these results that were generated from OLS models.

Despite finding no support for most of the hypothesized relationships, this study still makes an important contribution to the existing knowledge-base on the relationship between high-tech services and quality outcomes. The longitudinal panel design and fixed effects model that we used in our study controls for omitted variable bias especially for the time-invariant factors. Therefore, in regards to study design and omitted variable bias, findings of this study is more reliable than some previous studies that used cross-sectional data or some other multivariate models such as OLS. However, despite their advantage, findings of fixed effects models are limited by the samples and open to the sampling error. Further research that uses different data sets for different time periods are needed to verify the findings of this study.

An immediate managerial implication of this study would be to caution against basing the decision of adoption of high-tech services solely on their potential positive impact on quality outcomes. There should be more consideration given to technology adoption decisions by comparing the pros and cons for individual technologies.

Special consideration should be given to patient volume since condition-specific patient volume was found consistently as the most significant predictor of mortality rates for heart attack, heart failure, and pneumonia (only in random effects model). High volume hospitals may exhibit better results because staff skills improve substantially by practicing with higher number of patients, or certain hospitals attract more patients and become high-volume because of exhibiting better patient outcomes (Luft et al., 1987). The managerial implications of this study would be the development of strategies to increase patient volume. For example, while adopting high-tech services, hospital managers should also develop some strategies to attract larger volumes to accompany these newly adopted high-tech services. Sometimes, prestigious status of some high-tech services might be used as an attraction for patients.

There are also several limitations of this study. First, it is based upon secondary data sources. The study is limited by the sources of measurement error associated with secondary data. Second, combining several hospital services in an index might conceal the individual relationships between high-tech services and outcomes by zeroing out the positive and negative relationships. Third, the condition-specific indices are not based upon empirical data (on the relationship between these technologies and the particular outcome). Future research is needed using empirical data such as an expert survey that not only identifies the relevant high-tech services but also the degree of influence of these services on particular outcomes. Another limitation is the use of hospital level staffing data instead of unit level. Future studies are necessary to address this limitation by using unit level staffing data for the investigated quality outcomes.

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SUMMARY

The study explored the relationship between high-tech medical services and hospital performance. It particularly focused on the implications of high-tech medical services on financial and quality performance of medical surgical hospitals in the United States. The study sought to answer the following three major research questions:

1) What does existing research show about the relationship between high-tech medical services and hospital performance (clinical and financial)?
2) Does the availability of high-tech medical services influence financial performance of hospitals?
3) Does the availability of high-tech medical services have an impact on quality performance of hospitals?

In a healthcare environment where hospitals are continuously adopting new technologies, answering these research questions is critical. Furthermore, there is a need for expanding the knowledge-base about the relationship between high-tech medical services and hospital performance. Researchers as well as hospital administrators and policy makers can benefit from this expanded knowledge-base.

The findings of this study were presented in details in respective papers: A Systematic Review of Technology and Performance in U.S. Hospitals; A Longitudinal Analysis of High Technology Medical Services and Hospital Performance; High Technology Medical Services and Quality of Care at U.S. Hospitals. The synthesis of these chapters can be organized around the three research questions of this study.

Exploring answers for the first research question revealed several major findings. First, there is a limited number of studies examining the relationship between high-tech medical services and hospital performance. Second, this research has generated mixed and oftentimes contradictory findings. Third, prior studies used various research designs, samples, and study periods. Finally, medical technologies are defined and measured in inconsistent ways, which limits the comparability across studies.

Examining the second research question on the association between high-tech services and hospital financial performance has shown that (a) there is a positive relationship between the number of high-tech services (breadth) and hospital financial performance and (b) there is partial support for the positive relationship between rare high-tech services and hospital financial performance.

For the third research question, we did not find evidence of an association between high-tech medical services and hospital quality performance, as measured by 30-day mortality rates for heart attack, heart failure, and pneumonia.

This study has several theoretical implications. The RBV of a firm suggests that a unique combination of internal resources of an organization can lead to better organizational performance (Barney, 1991). This study found some consistent results with RVB's predictions, but only for financial performance. RBV's notion is not supported in regards to quality performance; high-tech-services do not necessarily impact quality performance. Moreover, Donabedian's SPO framework suggests that better structural quality (i.e., more/condition-specific high-tech services) can lead to better outcome quality (i.e., lower 30-day mortality rates)(Donabedian, 1966, 1981, 1986). However, our results suggest that neither high-tech services breadth, nor condition-specific high-tech services are associated with better quality outcomes.

There are some managerial and policy implications of this study. First, the empirical findings of this study suggest that investing in high-tech services to improve hospital financial performance is a reasonable organizational strategy. Therefore, hospital administrators may investigate the financial benefits of certain high-technology services and develop strategies accordingly. Second, quality performance is not as sensitive as financial performance to high-tech services. Therefore, adoption decisions of high-tech services in regards to their quality impact should be determined case by case. For instance, during the adoption process of a certain technology, predicted quality impact of a technology can be compared with the quality impact of another substitutable technology. Third, hospital administrators should balance environmental or competitive pressures while adopting high-technology services. For example, an intensified competition among hospitals may result in the adoption of high-tech medical services without giving enough consideration to their financial and quality implications.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

DATE: October 29, 2012

MEMORANDUM

TO: Ferhat Zengul
Principal Investigator

FROM: Cari Oliver, CIP
Assistant Director

RE: Request for Determination—Human Subjects Research
IRB Protocol #N121017002– High-Tech Services and Hospital Performance in the United States

A member of the Office of the IRB has reviewed your application for Designation of Not Human Subjects Research for above referenced proposal.

The reviewer has determined that this proposal is **not** subject to FDA regulations and is **not** Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

470 Administration Building
701 20th Street South
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Fax 205.934.1301
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Mailing Address:
AB 470
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BIRMINGHAM AL 35294-0104

APPENDIX B

HIGH-TECH SERVICES AND THE SAIDIN INDEX WEIGHTS

High-Tech Services and Saidin Index Weights

High-Tech Services	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	2010 90% +	2010 85% +
Medical/surgical intensive care	0.52	0.51	0.51	0.52	0.53	0.53		
Cardiac intensive care	0.76	0.77	0.76	0.77	0.78	0.79		
Neonatal intensive care	0.85	0.85	0.85	0.85	0.85	0.85		+
Neonatal intermediate care	0.89	0.89	0.88	0.88	0.88	0.89		+
Pediatric intensive care	0.92	0.93	0.92	0.93	0.93	0.93	+	+
Burn care	0.97	0.97	0.96	0.97	0.97	0.97	+	+
Other special care	0.89	0.88	0.89	0.88	0.88	0.89		+
Other intensive care	0.92	0.92	0.91	0.92	0.92	0.92	+	+
Airborne infection isolation room	0.51	0.47	0.46	0.46	0.45	0.45		
Ambulatory surgery center	0.87	0.83	0.83	0.83	0.82	0.81		
Blood Donor Center	0.94	0.94	0.94	0.95	0.95	0.95	+	+
Breast cancer screening/mammograms	0.47	0.47	0.46	0.47	0.48	0.48		
Adult diagnostic catheterization	0.73	0.73	0.72	0.72	0.72	0.72		
Pediatric diagnostic catheterization	0.96	0.96	0.97	0.97	0.97	0.97	+	+
Adult interventional cardiac catheterization	0.79	0.79	0.78	0.77	0.77	0.77		
Adult cardiac surgery	0.83	0.83	0.83	0.82	0.82	0.82		
Pediatric cardiac surgery	0.97	0.97	0.97	0.97	0.97	0.97	+	+
Cardiac Rehabilitation	0.63	0.62	0.63	0.62	0.62	0.62		
Chemotherapy	0.62	0.61	0.61	0.61	0.62	0.62		
Computer assisted orthopedic surgery	0.94	0.93	0.92	0.91	0.90	0.90		+
Emergency Department	0.36	0.36	0.35	0.36	0.37	0.37		
Freestanding/Satellite Emergency Department	0.98	0.97	0.97	0.97	0.96	0.95		+
Certified trauma center	0.77	0.77	0.76	0.76	0.76	0.75		
Extracorporeal shock waved lithotripter (ESWL)	0.83	0.83	0.82	0.81	0.81	0.80		
Hemodialysis	0.78	0.78	0.78	0.78	0.78	0.77		
HIV-AIDS services	0.81	0.81	0.81	0.82	0.82	0.82		
Neurological services	0.67	0.66	0.65	0.65	0.65	0.64		
Outpatient surgery	0.38	0.38	0.37	0.38	0.39	0.39		
Image-guided radiation therapy	0.94	0.92	0.90	0.89	0.87	0.86		+
Intensity-Modulated Radiation Therapy (IMRT)	0.87	0.85	0.85	0.84	0.84	0.83		
Shaped beam Radiation System	0.89	0.88	0.87	0.87	0.87	0.87		+

Continue

Continued

High-Tech Services	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	2010 90% +	2010 85% +
Stereotactic radiosurgery	0.90	0.90	0.89	0.88	0.88	0.87		+
Computed-tomography (CT) scanner	0.39	0.38	0.36	0.37	0.38	0.38		
Diagnostic radioisotope facility	0.58	0.58	0.58	0.59	0.59	0.59		
Electron Beam Computed Tomography (EBCT)	0.95	0.95	0.95	0.95	0.95	0.95	+	+
Full-field digital mammography	0.90	0.87	0.83	0.77	0.72	0.67		
Magnetic resonance imaging (MRI)	0.57	0.55	0.54	0.53	0.53	0.52		
Multislice spiral computed tomography < 64 slice	0.64	0.60	0.58	0.57	0.57	0.57		
Positron emission tomography (PET)	0.89	0.89	0.89	0.89	0.89	0.89		+
Positron emission tomography/CT (PET/CT)	0.92	0.90	0.88	0.87	0.87	0.86		+
Single photon emission computerized Tomog. (SPECT)	0.73	0.72	0.72	0.72	0.72	0.72		
Ultrasound	0.39	0.39	0.38	0.39	0.40	0.39		
Fertility Clinic	0.95	0.95	0.95	0.96	0.96	0.96	+	+
Genetic testing/counseling	0.93	0.92	0.92	0.92	0.91	0.90		+
Robotic surgery	0.96	0.95	0.93	0.91	0.89	0.87		+
Bone Marrow transplant services	0.97	0.97	0.97	0.97	0.97	0.97	+	+
Heart transplant	0.98	0.98	0.98	0.98	0.98	0.98	+	+
Kidney transplant	0.97	0.96	0.96	0.96	0.96	0.96	+	+
Liver transplant	0.98	0.98	0.98	0.98	0.98	0.98	+	+
Lung transplant	0.99	0.99	0.99	0.99	0.99	0.99	+	+
Tissue transplant	0.97	0.96	0.96	0.96	0.95	0.95	+	+
Other Transplant	0.97	0.97	0.97	0.97	0.96	0.96	+	+
Virtual colonoscopy	0.92	0.90	0.89	0.89	0.89	0.88		+
Endoscopic ultrasound			0.80	0.80	0.79	0.78		
Ablation of Barrett's esophagus			0.90	0.88	0.87	0.85		+
Esophageal impedance study			0.75	0.88	0.87	0.86		+

Continue

Continued

High-Tech Services	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	2010 90% +	2010 85% +
Endoscopic retrograde cholangiopancreatography (ERCP)			0.90	0.73	0.71	0.71		
Proton beam therapy			0.99	0.99	0.98	0.98	+	+
Intraoperative magnetic resonance imaging			0.97	0.97	0.97	0.97	+	+
Adult cardiac electrophysiology				0.83	0.81	0.81		
Pediatric cardiac electrophysiology				0.97	0.97	0.97	+	+
Optical Colonoscopy				0.67	0.62	0.58		
Robot-assisted walking therapy				0.98	0.98	0.97	+	+
Simulated rehabilitation environment				0.87	0.84	0.83		
Adult cardiology services					0.69	0.66		
Assistive technology center					0.89	0.88		+
Electrodiagnostic services					0.86	0.84		
NUMBER OF HIGH-TECH SERVICES	**54**	**54**	60	65	68	**68**	21	35
Number of Hospitals that the weights based upon	6349	6346	6312	6407	6334	6334		

+ indicates the services included in two different Saidin index calculations: 1) based upon 2010 weights 90% or more, 2) based upon 2010 weights 85% or more

APPENDIX C

DESCRIPTIVE STATISTICS FOR THE FINAL SAMPLE AND RANDOM EFFECTS MODELS

Variables	Mean	(SD)
	N=26172	
Operating Margin	-0.02	(0.14)
Operating Expenses	5127	(8236)
Operating Revenue	5196	(11211)
Total Margin	0.03	(0.10)
Return on Assets	0.04	(0.14)
Hospital Technology Indices (IV)		
Index 1: High-Tech Breath Index	15.89	(12.25)
Index 2: Saidin Rareness Index	2.38	(3.88)
Control Variables		
Organizational/Operational Factors		
Occupancy Rate	0.52	(0.20)
Length of Stay	6.38	(49.77)
System Affiliated %	53.82	
Number of Beds	156.06	(183.32)
Bed Size Categorical		
Small (5-149) %	64.28	
Medium (150-399) %	26.63	
Large (400+) %	9.09	
Ownership Type		
Profit %	12.89	
Not-for-Profit %	47.85	
Government (Non-Federal) %	19.07	
Government (Federal) %	0.01	
Teaching Hospital %	22.99	
% of Medicare Inpatient Days	0.12	(0.10)
% of Medicaid Inpatient Days	0.50	(0.18)
Urban Hospital	80.96	
Outpatient Mix	0.57	(0.20)
CMS Case Mix Index (CMI)	1.35	(0.23)

continue

Continued

Variables	**Mean N=26172**	**(SD)**
Staffing Factors		
RN Staffing	8.79	(6.72)
RN Staffing Mix	0.85	(0.13)
Non-Nurse Staffing	0.60	(0.35)
Physician Staffing	0.66	(1.68)
Market/Environmental Factors		
Competition (Herfindahl-Hirschman Index)	0.71	(0.35)
Market Affluence	4.52	(0.11)
Per Capita Income in a County	34659	(10317)
Census Region		
Northeast %	13.18	
Midwest %	30.34	
South %	38.10	
West %	18.36	
Medicare Managed Care Penetration	15.72	(13.55)

APPENDIX D

RANDOM EFFECTS REGRESSION MODELS FOR THE RELATIONSHIP BETWEEN HIGH-TECH SERIVCES AND HOSPITAL FINANCIAL PERFORMANCE

Random Effects Regression Models for the Relationship between High-Tech Services and Hospital Financial Performance

	OP.MARGIN				OP.EXPS.PER.IPD				OP.REV.PER.IPD			
Number of Obs	26071				26052				26057			
	Breadth		Rareness		Breadth		Rareness		Breadth		Rareness	
High-Tech Services	0.080 ****	(0.01)	0.111 ***	(0.04)	-0.001 ****	(0.00)	-0.001 ****	(0.00)	-0.001 ****	(0.00)	-0.001 ***	(0.00)
Occupancy Rate	4.014 ****	(0.85)	4.251 ****	(0.85)	-0.032 ****	(0.01)	-0.033 ****	(0.01)	-0.017 *	(0.01)	-0.018 *	(0.01)
Length of Stay	-0.002	(0.00)	-0.002	(0.00)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)
Medium	0.589	(0.40)	0.834 **	(0.40)	-0.027 ****	(0.00)	-0.027 ****	(0.00)	-0.024 ****	(0.00)	-0.024 ****	(0.00)
Large	-0.341	(0.64)	0.013	(0.64)	-0.030 ****	(0.01)	-0.031 ****	(0.01)	-0.030 ****	(0.01)	-0.030 ****	(0.01)
Not-For-Profit	-4.044 ****	(0.56)	-3.890 ****	(0.56)	0.021 ****	(0.01)	0.020 ****	(0.01)	0.006	(0.01)	0.006	(0.01)
Government	-7.595 ****	(0.71)	-7.503 ****	(0.72)	0.018 **	(0.01)	0.018 **	(0.01)	-0.001	(0.01)	-0.002	(0.01)
Teaching Hospital	-1.364 ****	(0.40)	-1.216 ***	(0.41)	0.004	(0.00)	0.003	(0.00)	0.002	(0.00)	0.002	(0.00)
Urban	3.422 ****	(0.50)	3.643 ****	(0.51)	0.010	(0.01)	0.008	(0.01)	0.028 ***	(0.01)	0.026 ***	(0.01)
Outpatient Mix	0.756	(0.86)	1.083	(0.86)	0.096 ****	(0.01)	0.094 ****	(0.01)	0.101 ****	(0.01)	0.100 ****	(0.01)
CMI	4.791 ****	(0.85)	5.182 ****	(0.85)	0.022 **	(0.01)	0.019 *	(0.01)	0.040 ****	(0.01)	0.038 ****	(0.01)
RN Staffing Intensity	0.001	(0.02)	0.004	(0.02)	0.002 ****	(0.00)	0.002 ****	(0.00)	0.002 ****	(0.00)	0.002 ****	(0.00)
RN Staffing Mix	6.563 ****	(1.21)	6.489 ****	(1.22)	0.042 ****	(0.01)	0.044 ****	(0.01)	0.060 ****	(0.01)	0.061 ****	(0.01)
Non-Nurse Staffing Mix	-0.421	(0.33)	-0.384	(0.32)	0.018	(0.01)	0.018	(0.01)	0.017	(0.01)	0.017	(0.01)
Physician Staffing Intensity	-0.180 ***	(0.06)	-0.178 ***	(0.06)	0.003	(0.00)	0.003	(0.00)	0.003	(0.00)	0.003	(0.00)
Market Competition (HHI)	3.544 ****	(0.65)	3.464 ****	(0.66)	0.016	(0.01)	0.017 *	(0.01)	0.028 ***	(0.01)	0.028 ***	(0.01)
Market Affluence	-3.025	(2.36)	-2.981	(2.37)	0.156 ****	(0.03)	0.159 ****	(0.03)	0.145 ****	(0.03)	0.147 ****	(0.03)
MC Penetration	0.003	(0.01)	0.003	(0.01)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)
Northeast	-9.560 ****	(2.21)	-9.970 ****	(2.23)	-0.178 ****	(0.04)	-0.175 ****	(0.04)	-0.218 ****	(0.04)	-0.216 ****	(0.04)
Midwest	-1.291	(2.36)	-1.547	(2.39)	0.048	(0.04)	0.051	(0.04)	0.060	(0.05)	0.061	(0.05)
South	-3.106	(2.51)	-3.165	(2.53)	-0.129 ***	(0.04)	-0.129 ***	(0.04)	-0.144 ***	(0.05)	-0.144 ***	(0.05)
State Fixed Effects												
Time Fixed Effects												
sigma_u	11.190		11.237		0.156		0.156		0.159		0.159	
sigma_e	8.025		8.030		0.063		0.063		0.066		0.066	
rho	0.660		0.662		0.858		0.858		0.853		0.853	

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; CMI= Case Mix Index; HHI= Herfindahl-Hirschman Index; MC= Managed Care *Continue*

Reference hospitals: Small (5-149 beds) , For-Profit (ownership), West (location)

Continued

	TOT.MARGIN				ROA			
Number of Obs	26172				26017			
	Breadth		Rareness		Breadth		Rareness	
High-Tech Services	0.049 ****	(0.01)	0.114 ****	(0.03)	0.045 ****	(0.01)	0.073 *	(0.04)
Occupancy Rate	3.111 ****	(0.65)	3.247 ****	(0.65)	3.498 ****	(0.88)	3.650 ****	(0.88)
Length of Stay	0.004	(0.00)	0.004	(0.00)	0.006	(0.01)	0.006	(0.01)
Medium	0.391	(0.31)	0.517 **	(0.30)	0.347	(0.44)	0.489	(0.44)
Large	-0.123	(0.46)	-0.060	(0.47)	-0.241	(0.73)	-0.069	(0.75)
Not-For-Profit	-0.944 **	(0.44)	-0.869 **	(0.44)	-3.185 ****	(0.69)	-3.103 ****	(0.69)
Government	-0.878 *	(0.47)	-0.863 *	(0.47)	-3.633 ****	(0.77)	-3.603 ****	(0.77)
Teaching Hospital	-0.325	(0.26)	-0.291	(0.26)	-0.476	(0.38)	-0.404	(0.38)
Urban	1.169 ****	(0.33)	1.270 ****	(0.33)	1.275 ***	(0.49)	1.384 ***	(0.49)
Outpatient Mix	2.548 ****	(0.59)	2.745 ****	(0.59)	2.195 **	(0.92)	2.395 ***	(0.92)
CMI	3.902 ****	(0.66)	3.996 ****	(0.67)	5.182 ****	(1.05)	5.376 ****	(1.05)
RN Staffing Intensity	-0.003	(0.02)	-0.001	(0.02)	0.018	(0.02)	0.020	(0.02)
RN Staffing Mix	1.384	(0.90)	1.399	(0.90)	2.258	(1.43)	2.265	(1.43)
Non-Nurse Staffing Mix	-0.346	(0.32)	-0.332	(0.31)	-0.313	(0.35)	-0.296	(0.34)
Physician Staffing Intensity	-0.129 **	(0.05)	-0.128 **	(0.05)	-0.168 **	(0.08)	-0.168 **	(0.08)
Market Competition (HHI)	1.448 ****	(0.45)	1.460 ****	(0.45)	1.279 **	(0.66)	1.260 **	(0.66)
Market Affluence	1.532	(1.37)	1.555	(1.37)	-2.697	(1.91)	-2.652	(1.91)
MC Penetration	-0.039 ****	(0.01)	-0.039 ****	(0.01)	-0.023	(0.01)	-0.023	(0.01)
Northeast	-8.336 ****	(1.48)	-8.571 ****	(1.48)	-10.424 ****	(2.15)	-10.660 ****	(2.15)
Midwest	-2.145	(1.62)	-2.363	(1.62)	-4.966 **	(2.18)	-5.131 **	(2.19)
South	-6.657 ****	(1.76)	-6.676 ****	(1.75)	-9.035 ****	(2.78)	-9.061 ****	(2.78)
State Fixed Effects								
Time Fixed Effects								
sigma_u	7.195		7.201		11.173		11.175	
sigma_e	6.752		6.754		9.539		9.540	
rho	0.532		0.532		0.578		0.578	

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; CMI= Case Mix Index; HHI= Herfindahl-Hirschman Index; MC= Managed Care
Reference hospitals: Small (5-149 beds) , For-Profit (ownership), West (location)

APPENDIX E

FIXED EFFECTS REGRESSION FOR THE RELATINSHIP BETWEEN HIGH-TECH SERVICES AND HOSPITAL FINANCIAL PERFORMANCE (FOR-PROFIT VERSUS NOT-FOR-PROFIT HOSPTIALS)

Fixed Effects Regressions for the Relationship between High-Tech (Breadth) Services and Hospital Financial Performance

	OPERATING MARGIN						OP. EXPENSES PER IPD					
Number of Obs	15667			4213			15663			4203		
Sample	Not-For-Profit Only			For-Profit Only			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Breadth)	0.039	**	(0.02)	0.082	**	(0.04)	-0.001	****	(0.00)	-0.001	****	(0.00)
Occupancy Rate	2.607	**	(1.31)	10.103	***	(3.28)	-0.025	*	(0.02)	-0.079	***	(0.03)
Length of Stay	-1.200		(2.12)	0.357		(0.72)	0.324	***	(0.10)	0.037		(0.02)
Outpatient Mix	0.483		(1.56)	2.872		(4.28)	0.025	*	(0.02)	0.122	***	(0.04)
Case Mix Index (CMI)	2.050		(1.75)	-0.392		(2.73)	-0.002		(0.02)	-0.071	***	(0.02)
RN Staffing Intensity	-0.014		(0.03)	0.029		(0.05)	0.003	****	(0.00)	0.000		(0.00)
RN Staffing Mix	2.514		(1.76)	0.235		(5.26)	-0.011		(0.02)	0.058		(0.04)
Non-Nurse Staffing Mix	-0.658		(0.48)	5.129		(8.23)	0.034		(0.02)	-0.011		(0.04)
Physician Staffing Intensity	-0.099	**	(0.05)	0.484		(0.87)	0.001		(0.00)	0.008		(0.01)
Market Competition	3.159		(2.20)	5.974		(4.03)	0.017		(0.03)	-0.019		(0.03)
Market Affluance	-8.928		(10.63)	4.069		(13.61)	0.175	****	(0.05)	0.179		(0.16)
MC Penetration	-0.002		(0.02)	0.064		(0.07)	0.000	**	(0.00)	0.000		(0.00)
Fixed Effects for Years												
R-squared	0.70			0.76			0.94			0.95		
Adj. R-Squared	0.64			0.69			0.93			0.94		
Root MSE	6.98			9.44			0.06			0.06		
F-test of Significance	4.54	****		1.56	****		306.37	****		46.50	****	
Degrees of Freedom	(17, 2907)			(17, 4213)			(17, 2906)			(17, 966)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses) next to the coefficients *Continue*

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Continued

Fixed Effects Regressions for the Relationship between High-Tech (Breadth) Services and Hospital Financial Performance

	OPERATING REVENUE PER INPATIENT DAY						TOTAL MARGIN					
Number of Obs	15666			4203			15650			4201		
Sample	Not-For-Profit Only			For-Profit Only			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Breadth)	-5.E-04	****	(0.00)	-4.E-04	*	(0.00)	0.016		(0.01)	0.078	***	(0.03)
Occupancy Rate	-0.015		(0.01)	-0.039		(0.03)	2.247	**	(1.05)	9.559	****	(2.64)
Length of Stay	0.321	***	(0.10)	0.039		(0.03)	-0.128		(2.01)	0.370		(0.60)
Outpatient Mix	0.030	**	(0.02)	0.128	***	(0.05)	1.356		(1.22)	0.218		(3.47)
Case Mix Index (CMI)	0.001		(0.02)	-0.065	**	(0.03)	2.960	**	(1.42)	0.382		(2.42)
RN Staffing Intensity	0.002	****	(0.00)	0.000		(0.00)	-0.012		(0.02)	0.034		(0.05)
RN Staffing Mix	0.001		(0.02)	0.053		(0.04)	1.201		(1.49)	-4.730		(3.97)
Non-Nurse Staffing Mix	0.032		(0.02)	0.006		(0.02)	-0.890	**	(0.43)	2.962		(4.02)
Physician Staffing Intensity	0.001		(0.00)	0.011		(0.01)	-0.076	*	(0.04)	-0.766		(0.77)
Market Competition	0.029		(0.03)	0.005		(0.03)	0.667		(1.95)	7.121	**	(3.07)
Market Affluance	0.133	**	(0.06)	0.210		(0.17)	6.401		(5.01)	4.893		(10.27)
MC Penetration	0.001	**	(0.00)	0.000		(0.00)	-0.025		(0.02)	0.043		(0.06)
Fixed Effects for Years												
R-squared	0.94			0.95			0.58			0.78		
Adj. R-Squared	0.93			0.94			0.49			0.72		
Root MSE	0.06			0.07			6.13			7.50		
F-test of Significance	288.88	****		48.38	****		31.83	****		3.61	****	
Degrees of Freedom	(17, 2907)			(17, 966)			(17, 2907)			(17, 967)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses) next to the coefficients *Continue*

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Continued

Fixed Effects Regressions for the Relationship between High-Tech (Breadth) Services and ROA

	RETURN on ASSETS								
Number of Obs	26017			15603			4102		
Sample	Full Sample			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Breadth)	0.035	**	(0.02)	0.006		(0.02)	0.092	**	(0.05)
Occupancy Rate	1.484		(1.13)	1.467		(1.30)	11.490	***	(3.99)
Length of Stay	-0.477		(0.92)	-1.234		(2.74)	-0.246		(0.94)
Outpatient Mix	-0.043		(1.30)	1.396		(1.64)	-3.099		(4.92)
Case Mix Index (CMI)	1.840		(1.80)	2.727		(2.19)	-1.425		(4.03)
RN Staffing Intensity	-0.009		(0.03)	-0.006		(0.04)	0.094		(0.07)
RN Staffing Mix	1.077		(1.98)	3.898	*	(2.21)	-5.798		(7.06)
Non-Nurse Staffing Mix	-0.083		(0.32)	-1.170	**	(0.49)	1.238		(3.81)
Physician Staffing Intensity	-0.135	*	(0.08)	-0.074	*	(0.05)	-0.342		(1.00)
Market Competition	3.503	*	(2.13)	0.227		(2.14)	13.554	**	(5.66)
Market Affluance	-6.847		(5.24)	-7.526		(8.23)	0.774		(14.92)
MC Penetration	-0.012		(0.02)	-0.026		(0.02)	0.016		(0.11)
Fixed Effects for Years									
R-squared	0.62			0.57			0.77		
Adj. R-Squared	0.54			0.47			0.69		
Root MSE	9.55			8.08			12.99		
F-test of Significance	15.27	****		23.04	****		4.00	****	
Degrees of Freedom	(17, 4749)			(17, 2904)			(17, 957)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses)

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Fixed Effects Regressions for the Relationship between High-Tech (Saidin) Services and Hospital Financial Performance

	OPERATING MARGIN						OP. EXPENSES PER IPD					
Number of Obs	15667			4213			15663			4203		
Sample	Not-For-Profit Only			For-Profit Only			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Saidin)	0.075		(0.06)	0.196		(0.14)	-0.002	****	(0.00)	-0.004	****	(0.00)
Occupancy Rate	2.583	**	(1.31)	9.824	***	(3.31)	-0.025	*	(0.02)	-0.077	***	(0.03)
Length of Stay	-1.238		(2.13)	0.365		(0.71)	0.325	***	(0.10)	0.037		(0.02)
Outpatient Mix	0.544		(1.56)	2.845		(4.29)	0.024		(0.02)	0.121	***	(0.04)
Case Mix Index (CMI)	2.159		(1.75)	-0.521		(2.72)	-0.003		(0.02)	-0.069	***	(0.02)
RN Staffing Intensity	-0.010		(0.03)	0.027		(0.05)	0.002	****	(0.00)	0.000		(0.00)
RN Staffing Mix	2.192		(1.75)	0.380		(5.30)	-0.006		(0.02)	0.058		(0.04)
Non-Nurse Staffing Mix	-0.638		(0.48)	5.400		(8.22)	0.034		(0.02)	-0.013		(0.04)
Physician Staffing Intensity	-0.100	**	(0.05)	0.529		(0.88)	0.001		(0.00)	0.008		(0.01)
Market Competition	3.117		(2.20)	5.717		(4.03)	0.018		(0.03)	-0.017		(0.03)
Market Affluance	-9.670		(10.53)	3.773		(13.82)	0.184	****	(0.05)	0.190		(0.15)
MC Penetration	-0.003		(0.02)	0.066		(0.07)	0.001	**	(0.00)	0.000		(0.00)
Fixed Effects for Years												
R-squared	0.71			0.76			0.94			0.95		
Adj. R-Squared	0.64			0.69			0.93			0.94		
Root MSE	6.99			9.45			0.06			0.06		
F-test of Significance	4.20	****		1.32	****		303.59	****		47.02	****	
Degrees of Freedom	(17, 2907)			(17, 4213)			(17, 2906)			(17, 966)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses) next to the coefficients *Continue*

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Continued

Fixed Effects Regressions for the Relationship between High-Tech (Saidin) Services and Hospital Financial Performance

	OP. REVENUE PER IPD						TOTAL MARGIN					
Number of Obs	15666			4203			15650			4201		
Sample	Not-For-Profit Only			For-Profit Only			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Saidin)	-0.001	***	(0.00)	-0.003	***	(0.00)	0.029		(0.04)	0.174		(0.10)
Occupancy Rate	-0.014		(0.01)	-0.038		(0.03)	2.238	**	(1.05)	9.325	****	(2.64)
Length of Stay	0.321	***	(0.10)	0.039		(0.03)	-0.145		(2.01)	0.380		(0.60)
Outpatient Mix	0.029	*	(0.02)	0.127	***	(0.04)	1.381		(1.22)	0.206		(3.48)
Case Mix Index (CMI)	0.000		(0.02)	-0.064	**	(0.03)	3.004	**	(1.42)	0.254		(2.41)
RN Staffing Intensity	0.002	****	(0.00)	0.000		(0.00)	-0.011		(0.02)	0.033		(0.05)
RN Staffing Mix	0.005		(0.02)	0.054		(0.04)	1.071		(1.48)	-4.608		(4.00)
Non-Nurse Staffing Mix	0.032		(0.02)	0.005		(0.02)	-0.882	**	(0.43)	3.219		(4.02)
Physician Staffing Intensity	0.001		(0.00)	0.011		(0.01)	-0.076	*	(0.04)	-0.723		(0.78)
Market Competition	0.030		(0.03)	0.005		(0.03)	0.649		(1.95)	6.882	**	(3.06)
Market Affluance	0.139	**	(0.06)	0.219		(0.16)	6.077		(4.99)	4.666		(10.43)
MC Penetration	0.001	**	(0.00)	0.000		(0.00)	-0.025		(0.02)	0.044		(0.06)
Fixed Effects for Years												
R-squared	0.94			0.95			0.58			0.79		
Adj. R-Squared	0.93			0.94			0.49			0.72		
Root MSE	0.06			0.07			6.13			7.51		
F-test of Significance	285.47	****		48.88	****		31.61	****		3.25	****	
Degrees of Freedom	(17, 2907)			(17, 966)			(17, 2907)			(17, 967)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses) next to the coefficients *Continue*

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

Continued

Fixed Effects Regressions for the Relationship between High-Tech (Saidin) Services and ROA

	RETURN on ASSETS								
Number of Obs	26017			15603			4102		
Sample	Full Sample			Not-For-Profit Only			For-Profit Only		
High-Tech Services (Saidin)	0.008		(0.06)	-0.030		(0.07)	0.167		(0.22)
Occupancy Rate	1.424		(1.13)	1.443		(1.30)	11.204	***	(3.98)
Length of Stay	-0.480		(0.92)	-1.244		(2.74)	-0.231		(0.94)
Outpatient Mix	-0.022		(1.30)	1.384		(1.64)	-3.155		(4.93)
Case Mix Index (CMI)	1.967		(1.79)	2.808		(2.18)	-1.550		(4.02)
RN Staffing Intensity	-0.007		(0.03)	-0.005		(0.04)	0.093		(0.07)
RN Staffing Mix	0.855		(1.97)	3.811	*	(2.20)	-5.650		(7.07)
Non-Nurse Staffing Mix	-0.067		(0.31)	-1.165	**	(0.49)	1.545		(3.80)
Physician Staffing Intensity	-0.135	*	(0.08)	-0.074		(0.05)	-0.288		(1.00)
Market Competition	3.437	*	(2.13)	0.209		(2.14)	13.277	**	(5.61)
Market Affluance	-7.583		(5.22)	-7.978		(8.18)	0.584		(15.07)
MC Penetration	-0.012		(0.02)	-0.026		(0.02)	0.017		(0.11)
Fixed Effects for Years									
R-squared	0.62			0.57			0.77		
Adj. R-Squared	0.54			0.47			0.69		
Root MSE	9.55			8.08			13.00		
F-test of Significance	14.80	****		23.07	****		3.76	****	
Degrees of Freedom	(17, 4749)			(17, 2904)			(17, 957)		

Significance at *0.1 **0.05 ***0.01 ****0.001 or less; Standard Errors (in parentheses)

CMI=Case Mix Index; HHI=Herfindahl-Hirschman Index; MC= Managed Care

APPENDIX F

HIGH-TECH SERVICES, THE SAIDIN INDEX WEIGHTS, AND CONTITION-SPECIFIC HIGH-TECH SERVICES

High-Tech Services, Saidin Index Weights, and Condition-Specific High-Tech Services

High-Tech Services	***2006***	***2007***	***2008***	***2009***		HA	HF	PN
Medical/surgical intensive care	0.51	0.51	0.52	0.53	I	*	*	**
Cardiac intensive care	0.77	0.76	0.77	0.78	I	**	**	**
Burn care	0.97	0.96	0.97	**0.97**	I		*	*
Other special care	0.88	0.89	0.88	**0.88**	I	*	*	*
Other intensive care	0.92	0.91	0.92	**0.92**	I	*	*	*
Airborne infection isolation room	0.47	0.46	0.46	0.45	I			**
Ambulatory surgery center	0.83	0.83	0.83	0.82	I			
Blood Donor Center	0.94	0.94	0.95	**0.95**	I			
Breast cancer screening/mammograms	0.47	0.46	0.47	0.48	D			
Adult diagnostic catheterization	0.73	0.72	0.72	0.72	D	*	**	*
Adult interventional cardiac catheterization	0.79	0.78	0.77	0.77	I	**	**	*
Adult cardiac surgery	0.83	0.83	0.82	0.82	I	*	**	*
Cardiac Rehabilitation	0.62	0.63	0.62	0.62	I	**	**	*
Chemotherapy	0.61	0.61	0.61	0.62	I			
Computer assisted orthopedic surgery	0.93	0.92	0.91	**0.90**	I			*
Emergency Department	0.36	0.35	0.36	0.37	B	**	**	**
Freestanding/Satellite Emergency Department	0.97	0.97	0.97	**0.96**	B	**	**	*
Certified trauma center	0.77	0.76	0.76	0.76	I	*	*	*
Extracorporeal shock waved lithotripter (ESWL)	0.83	0.82	0.81	0.81	I			
Hemodialysis	0.78	0.78	0.78	0.78	I	*	*	
HIV-AIDS services	0.81	0.81	0.82	0.82	B	*		*
Neurological services	0.66	0.65	0.65	0.65	I	*	*	*
Outpatient surgery	0.38	0.37	0.38	0.39	I			*
Image-guided radiation therapy	0.92	0.90	0.89	**0.87**	I			
Intensity-Modulated Radiation Therapy (IMRT)	0.85	0.85	0.84	0.84	I			
Shaped beam Radiation System	0.88	0.87	0.87	**0.87**	D			

continue

Continued

High-Tech Services	***2006***	***2007***	***2008***	***2009***		HA	HF	PN
Stereotactic radiosurgery - hospital	0.90	0.89	0.88	**0.88**	I			
Computed-tomography (CT) scanner	0.38	0.36	0.37	0.38	D			*
Diagnostic radioisotope facility	0.58	0.58	0.59	0.59	D			
Electron Beam Computed Tomography (EBCT)	0.95	0.95	0.95	**0.95**	D			
Full-field digital mammography	0.87	0.83	0.77	0.72	D			
Magnetic resonance imaging (MRI)	0.55	0.54	0.53	0.53	D		*	*
Multislice spiral computed tomography < 64 slice	0.60	0.58	0.57	0.57	D			
Positron emission tomography (PET)	0.89	0.89	0.89	**0.89**	D			*
Positron emission tomography/CT (PET/CT)	0.90	0.88	0.87	**0.87**	D			
Single photon emission computerized Tomog. (SPECT)	0.72	0.72	0.72	0.72	D			
Ultrasound	0.39	0.38	0.39	0.40	D			
Fertility Clinic	0.95	0.95	0.96	**0.96**	B			
Genetic testing/counseling	0.92	0.92	0.92	**0.91**	D			
Robotic surgery	0.95	0.93	0.91	**0.89**	I			
Bone Marrow transplant services	0.97	0.97	0.97	**0.97**	I	*	*	*
Heart transplant	0.98	0.98	0.98	**0.98**	I	**	**	*
Kidney transplant	0.96	0.96	0.96	**0.96**	I	*	*	*
Liver transplant	0.98	0.98	0.98	**0.98**	I	*	*	*
Lung transplant	0.99	0.99	0.99	**0.99**	I	*	*	**
Tissue transplant	0.96	0.96	0.96	**0.95**	I	*	*	*
Other Transplant	0.97	0.97	0.97	**0.96**	I	*	*	*
Virtual colonoscopy	0.90	0.89	0.89	**0.89**	D			
Endoscopic ultrasound		0.80	0.80	0.79	D			
Ablation of Barrett's esophagus		0.90	0.88	**0.87**	I			
Esophageal impedance study		0.75	0.88	**0.87**	I			

continue

Continued

High-Tech Services	***2006***	***2007***	***2008***	***2009***		HA	HF	PN
Endoscopic retrograde cholangiopancreatography (ERCP)		0.90	0.73	0.71	I			
Proton beam therapy		0.99	0.99	**0.98**	I			
Intraoperative magnetic resonance imaging		0.97	0.97	**0.97**	D			
Adult cardiac electrophysiology			0.83	0.81	D	*	*	
Optical Colonoscopy			0.67	0.62	D			
Robot-assisted walking therapy			0.98	**0.98**	I			
Simulated rehabilitation environment			0.87	**0.84**	I			
Adult cardiology services				0.69	I		**	**
Assistive technology center				**0.89**	D			
Electrodiagnostic services				**0.86**	D	*	*	
NUMBER OF HIGH-TECH SERVICES	49	55	59	62		**6 *17	**9 *16	**6 *22
Number of Hospitals that the weights based upon	6346	6312	6407	6334				

Condition-Specific High-Tech Index= includes services that are marked **
Sensitivity Test Indices = includes services that are marked ** and *
HA=Heart Attack , HF= Heart Failure, PN=Pneumonia
Bold services were included in the rareness (a modified Saidin) Index
I= Intervention, D=Diagnostic, B=both (Intervention and Diagnostic)