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Information Systems and Healthcare XXIX: Information Technology Investments and Returns – Uniqueness in the Healthcare Industry

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Abstract

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KEYWORDS: healthcare industry, productivity, IT management, empirical, economic theory, management theory, archival data

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I. INTRODUCTION

The transformation of the healthcare industry using information technology (IT) is imminent. The healthcare sector's investment in IT has lagged that of other sectors for at least a decade [Menachemi et al. 2006, Weill and Broadbent, 1998], and this sector has historically been a late adopter of information technologies [Khoumbati et al., 2006]. However, as the rising costs of healthcare threaten the competitive advantage of developed nations [Prahalad, 1999], ways to use IT to control costs are being identified. Medical diagnostic outsourcing [Friedman, 2005], supply chain innovations [Porter and Teisberg 2004], and efficiency and quality initiatives [Anderson et al., 2006] are changing the industry. Furthermore, major government projects aim to utilize IT to improve care and reduce costs while protecting patient privacy [BBC, 2006, McGee, 2004]. With these impending changes, the need for researchers to help practitioners understand how IT can improve hospitals' productivity is apparent.

Drawing upon existing research into IT business value [Brynjolfsson and Hitt, 1996, Dehning and Richardson, 2002, Devaraj and Kohli, 2000, Devaraj and Kohli, 2003, Dewan and Min, 1997, Hitt and Brynjolfsson, 1996, Melville et al., 2004, Menon et al., 2000], and a theory base in production economics, we investigate (1) how assets such as IT hardware, IT systems, and IT personnel are related to one another and, (2) how these assets are related to hospitals' productivity. We develop hypotheses and then analyze panel data using a simultaneous equations model to test our hypotheses.

This paper contributes to literature in three ways. First, we refine existing arguments that IT spending improves organizational performance and productivity [Aral et al., 2006, Weill, 1992] by presenting evidence that IT spending impacts hospital performance indirectly, through the various types of IT assets that can be purchased. Second, we examine the interrelationships between different IT assets and the impact of those assets on productivity. Within the healthcare context, the ways in which IT assets impact hospitals' productivity are only beginning to be identified by researchers [Devaraj and Kohli, 2000]. Third, since a unique set of managerial values, incentives, and constraints operates in the healthcare industry [Fottler, 1981, Gouldner, 1957, Newman and Wallender, 1978, Raelin, 1991], we emphasize the particular importance of IT personnel, an organizational asset that has the potential to contribute to maximizing organizational payoff from IT spending [Straub, 2004]. This emphasis on personnel is also an answer to the call that has been issued for increased examination of the human component of the IT resource in IT business value research [Melville et al., 2004].

The paper will proceed as follows. Section II describes the IT business value literature that forms the framework of this study, including the early "productivity paradox" research, subsequent work that resolved the apparent paradox, and more recent developments. Our literature review also includes a discussion of the uniqueness of the healthcare industry and presents reasons why IT payoff is believed to operate differently in this industry. In Section III, we develop 10 hypotheses. These hypotheses will explain how IT investment is related to IT hardware, systems, and personnel; how IT hardware, systems, and personnel are related to one another; and also how IT hardware, systems, and personnel impact hospitals' productivity. Before testing these hypotheses, we explain the specific variables of interest in our study and the proxies for those variables that we have identified in our archival dataset. We also explain the simultaneous equations model that we have developed to investigate our hypotheses, and the econometric techniques that we employ to estimate our model. These explanations appear in Section IV. The statistical results of our study will be presented in Section V and the implications of our study will then be discussed in Section VI, where we highlight the role of IT personnel in improving hospitals' productivity. In our conclusion in Section VII, we describe the limitations of our research and highlight a number of areas of potentially fruitful future inquiry.

II. RESEARCH FRAMEWORK

IT and Productivity

Many early studies of IT business value described a "productivity paradox," where investments in IT failed to deliver the expected improvements in organizational performance [Brynjolfsson, 1993, Strassman, 1990, Strassman, 1997, Weill, 1992]. As investigation into this apparent paradox continued, methodological flaws were shown to be one reason why IT appeared to have little impact on organizational performance [Brynjolfsson, 1993, Robey and Boudreau, 1999]. In addition, the failure to incorporate time lags into research models [Devaraj and Kohli, 2000] and the existence of intermediate variables [Barua and Mukhopadhyay, 2000, Barua et al., 1996] were highlighted as reasons for the apparent paradox. Still others argued that mismanagement of IT was one possible explanation for the paradox [Brynjolfsson, 1993]. A final explanation was that IT was being successfully used by some firms and unsuccessfully by others. Those that were using IT successfully were capturing profit from the unsuccessful users. This reallocation of profits among firms within an industry would thus have only firm-level impacts, but not industry, sector, or national productivity impacts [Brynjolfsson, 1993].

After these explanations were advanced, researchers began to find clear evidence of the proposed beneficial effects of IT. While mismanagement of IT and reallocation of profits likely occurred in some firms, advances in measurement and modeling were the primary ways in which researchers were able to lay the "productivity paradox" to rest [Brynjolfsson and Hitt, 1996, Brynjolfsson and Hitt, 2000, Dewan and Min, 1997, Stratopoulos and Dehning, 2000]. Key findings from this phase of research were summarized and synthesized to provide a basis for future work [Brynjolffson and Yang, 1996, Mahmood et al., 1999, Sircar et al., 1998].

Since the resolution of the productivity paradox, two distinct but largely complementary theoretical approaches to the study of IT business value at the firm level have emerged: the theory of production and the resource-based view of the firm (RBV). The theory of production, borrowed from economics, explains that units of input such as capital, labor, and technology are used to create units of output. In IT business value studies, inputs often include IT hardware, IT systems, and IT personnel [e.g. [Brynjolfsson, 1993, Brynjolfsson and Hitt, 1996, Hitt and Brynjolfsson, 1996, Menon et al., 2000, Mukhopadhyay et al., 1997]]. The alternative theoretical approach in IT business value studies, the RBV, postulates that competing firms possess heterogeneous sets of resources [Wernerfelt, 1984, Wernerfelt, 1995]; those that are valuable, rare, and difficult to imitate are a potential source of sustained competitive advantage [Barney, 1991]. The RBV has been used in studies of IT business value because a firm's resources include the ability "to conceive, implement, and exploit valuable IT applications." [Mata et al., 1995]. While the details of the theory of production and the RBV differ somewhat, both agree that the type and amount of firms' IT assets impacts firms' performance and productivity.

Theoretical work in IT business value has evolved to the point where conceptual models have been developed in an attempt to explain the process of IT business value creation. Building upon earlier work [Barua et al., 1995, Bharadwaj, 2000, Clemons and Row, 1991, Francalanci and Galal, 1998, Mata et al., 1995, Soh and Markus, 1995, Weill, 1992], literature reviews have proposed models that share several similar constructs. These models explain that IT assets have an effect upon business processes which, in turn, affect the overall performance of the firm [Dehning and Richardson, 2002, Melville et al., 2004]. Within the recently-proposed "IT Business Value Model," IT assets are defined to include technological assets (including IT hardware and IT systems) as well as IT personnel assets. This division is similar to the classification of IT resources as including hardware, software, and human resources found in studies built on production economics [Brynjolfsson and Hitt, 1996, Devaraj and Kohli, 2000, Dewan and Min, 1997, Hitt and Brynjolfsson, 1996, Menon et al., 2000]. In spite of the large amount of previous work focusing on IT business value, the human component of IT assets has been understudied and a call for investigating the synergies between human IT expertise and technological IT assets has been issued [Melville et al., 2004]. Therefore, we highlight the role of IT personnel in creating IT business value.

A final development in the discussion of IT business value is the publication of papers and the broad discussion that has taken place in response to Nicholas Carr's article "IT Doesn't Matter" [2003]. Carr opines that IT is no longer a strategic resource or a source of competitive advantage because it is a ubiquitous, commoditized resource rather than a unique, proprietary one. Carr has been criticized for defining IT as simply networks and computer hardware; ignoring software, human knowledge, and the value of information [O'Brien and Marakas, 2007, Piccoli and Ives, 2005, Tallon and Scannell, 2007]. Others have similarly noted that while networks and hardware are becoming increasingly commoditized, the combination of networks and hardware with personnel and systems still offers the opportunity to create competitive advantage [Melville et al., 2004]. Similarly, innovation with IT [Bhatt and Grover, 2005], the strategic management of IT [Ravinchandran and Lertwongsatien, 2005], alignment between business and IT strategy [Tallon, 2007], and shared IT-business understanding [Ray et al., 2007] are all avenues for improving organizational performance and productivity with non-commoditized IT.

Not only can Carr be criticized on the grounds that IT is not always commoditized, but even commoditized IT inputs have been shown to impact performance and productivity. From the perspective of production economics, IT has long been and continues to be viewed as a commodity input to production in analytical models of IT business value [Thatcher and Oliver, 2001, Thatcher and Pingry, 2004a, Thatcher and Pingry, 2004b, Thatcher and Pingry, 2007]. Even as a commodity input, empirical examinations of IT business value at the firm level have revealed that investment in IT impacts firm performance and productivity [Aral et al., 2006, Devaraj and Kohli, 2003, Hendricks et al., forthcoming, Menachemi et al., 2006]. In sum, relatively little empirical support exists for Carr's contention that IT doesn't matter.

IT Business Value in the Healthcare Industry

Professionals are a class of employees that possess advanced training and specialized knowledge. Management of professionals, a group that includes physicians, requires that special considerations be made [Gouldner, 1957, Newman and Wallender, 1978, Raelin, 1991]. Professionals have narrow areas of specialization and firm ideas about what activities lay inside or outside the scope of their job. It has been stated that in settings where professionals have dominant roles, such as physicians do in hospitals, professional traditions prevent behavior patterns from changing [Newman and Wallender, 1978]. Thus, factors exist in industries such as healthcare that dictate a unique set of managerial values, incentives, and constraints [Fottler, 1981].

These explanations point to the reality that the organizational performance benefits of IT may be realized in a different manner in the healthcare industry than in other industries. The unique managerial environment indicates that a unique combination of IT assets could be employed to improve the productivity benefits of IT. We will explore the implications of managing professionals further in the development of hypotheses 9 and 10, where we will explain how the management environment at a hospital necessitates high levels of IT personnel to realize the potential impacts of IT on hospital productivity.

III. HYPOTHESIS DEVELOPMENT

While it has been commonly stated that IT spending impacts organizational performance and productivity, this statement is imprecise at best. To clarify the assertion that IT spending impacts performance and productivity, we argue that IT spending does not have a direct impact, but instead that IT spending impacts firm performance and productivity through the assets that an organization can purchase. Put another way, IT spending allows firms to acquire IT assets and IT assets bring about IT impacts on firms' performance and productivity [Soh and Markus, 1995]. Thus, IT spending may be understood to be the vehicle that allows IT hardware, systems, or personnel to be acquired.

Early studies of IT business value did propose a direct link from IT spending to firms' performance. Rather than finding broad support for this relationship, however, several forms of this hypothesis were unsupported [Weill, 1992]. Subsequently, researchers began to instead investigate a link from IT assets to performance and productivity in order to achieve greater precision in measurement and to more clearly specify the causal chain in the creation of IT business value [Brynjolfsson and Hitt, 1996, Devaraj and Kohli, 2000, Dewan and Min, 1997]. Instead of stating that IT spending impacts organizational performance and productivity, it is more precisely argued that IT spending allows firms to acquire IT assets and IT assets bring about IT impacts on firms' performance [Soh and Markus, 1995]. Indeed, the separation of IT spending from the use of IT hardware, systems and personnel assets has been highlighted as a way to isolate the impact of specific types of technology on performance [Devaraj and Kohli, 2003]. These explanations helped solidify the shift to a model that linked IT spending to IT assets and then those assets to performance and productivity.

Following these theoretical arguments, empirical approaches to the study of IT business value should ideally separate IT investment from the use of IT inputs [Aral et al., 2006]. Spending is not synonymous with the assets that spending can acquire and should be measured separately when feasible. In fact, it has been noted that IT spending is often on hardware and systems [Aral et al., 2006, Dewan and Min, 1997]. The failure to measure IT assets as an intermediate variable between IT spending and firm performance prevents a full, accurate, and clear explanation from being developed. In sum, the separation of IT spending from the use of IT hardware, systems, and personnel provides both a theoretical and empirical benefit by clearly identifying each variable in the process of IT business value creation.

On the basis of the foregoing discussion, we argue that hospital productivity will improve only as IT spending increases the amount of IT hardware, IT systems, and IT personnel that the hospital has available. Expenditures on IT hardware are necessary so that information systems have servers, PCs, and handheld devices on which to run. Similarly, IT spending enables the acquisition of IT systems. Those systems then deliver gains in productivity and performance as routine, well-defined, repetitive work is automated [Bresnahan et al., 2002]. Finally, IT personnel are charged with the tasks of designing and implementing systems, training users, supporting existing hardware and systems, and making strategic decisions about future IT spending. Expenditures on IT personnel enable these tasks to be completed.

The aforementioned IT assets are not, however, the only IT inputs to a firm. Much IT work is outsourced to vendors who perform IT functions such as the implementation of electronic medical record systems, the remote hosting of data, or PC support. External vendors are yet another resource that hospitals can utilize. Just as IT spending enables the acquisition of IT hardware, systems, and personnel that are internal to the hospital, IT spending also enables the acquisition of IT outsourcing.

Based on these arguments, and in order to more clearly explain the relationship between IT spending and organizational productivity, we therefore hypothesize:

Hypothesis 1: IT Spending will be positively associated with IT Hardware.
Hypothesis 2: IT Spending will be positively associated with IT Systems.
Hypothesis 3: IT Spending will be positively associated with IT Personnel.
Hypothesis 4: IT Spending will be positively associated with IT Outsourcing.

As IT spending enables hospitals to acquire IT hardware and IT systems assets, the need for personnel to train users and support information systems will also increase. This explanation that increasing levels of IT hardware and systems assets will necessitate an increase in IT personnel at the organizational level aligns with the argument that increases in IT investment at the macroeconomic level will increase the need for IT labor at the macroeconomic level [Bresnahan et al., 2002]. Without personnel to install, maintain, and utilize IT hardware and systems, IT spending may not have the anticipated impact on organizational performance. IT systems that are purchased and implemented without adequate user training and support from IT personnel may likewise fail to have the expected beneficial impacts on organizational performance. Thus, we hypothesize that:

Hypothesis 5: IT Hardware will be positively associated with IT Personnel.
Hypothesis 6: IT Systems will be positively associated with IT Personnel.

IT hardware assets impact hospitals' productivity both indirectly, through IT personnel (as hypothesized above in H5) as well as directly. IT hardware assets such as desktops, laptops, and dumb terminals compose a major portion of IT infrastructure, which is the basis of IT capability [Weill and Broadbent, 1998]. Such assets have been long-recognized as a significant business asset from which competitive advantage can be built [Chatterjee et al., 2001, Keen, 1991, McKenney, 1995, Melville et al., 2004]. These explanations align with the production theory explanation that firms' inputs, including labor, capital, and technology, influence organizational performance in terms of production and productivity [Bresnahan et al., 2002, Brynjolfsson and Hitt, 1996, Devaraj and Kohli, 2000, Dewan and Min, 1997, Menon et al., 2000]. Furthermore, IT hardware has been identified as a contributor to positive financial performance in hospitals [Menachemi et al., 2006], where it has been shown to influence hospital revenue [Devaraj and Kohli, 2000]. Therefore, we hypothesize that:

Hypothesis 7: IT Hardware will be positively associated with Productivity.

As with IT hardware, we hypothesize both an indirect effect of IT systems on hospital productivity via IT personnel (H6) as well as a direct effect, which we now explain. Spending on IT systems has been shown to improve organizational performance [Aral et al., 2006]. Additionally, it has been observed that services shared throughout the firm are one of the bases of IT capability [Weill and Broadbent, 1998]. We define IT systems to include the software applications used to automate or computerize business processes. In a healthcare context, IT systems may include financial management applications such as accounts payable and general ledger, electronic medical records (EMR) systems such as clinical decision support or order entry systems, or supply chain management applications such as RFID or ERP systems. We hypothesize:

Hypothesis 8: IT Systems will be positively associated with Productivity.

Now that we have discussed the impact of IT hardware and IT systems assets on hospital performance, we turn to the impact of IT personnel on hospital performance. As has been previously mentioned, a unique set of managerial values, incentives, and constraints exists in non-profit industries such as healthcare [Fottler, 1981]. Management of professionals requires that special considerations be made [Gouldner, 1957, Newman and Wallender, 1978, Raelin, 1991] because professionals have narrow areas of specialization and firm ideas about what activities lie inside and outside the scope of their job. Physicians may be reluctant to embrace new technologies such as physician prescription entry, computerized patient charts, or clinical decision support systems because they feel that interacting with these systems is outside the proper scope of their job.

Because physicians have extensive training and are valued for their medical expertise, they have reason to resist the expansion of their professional role to include new tasks. Physicians view their primary duty as the diagnosis of patients and the administration of medical treatment. Given this understanding of their professional role, physicians could view the introduction of new technologies as unwelcome expansions of their job scope. For instance, a physician could choose not to use a physician prescription entry system because they feel that they should not be forced to learn how to use a new computer or computer system. The physician could argue, "I'm a doctor and I get paid to make medical decisions, not enter data." If prescriptions need to be entered into an information system, the physician can continue to write them on paper and have a nurse or other staffer enter them. This scenario aligns with the explanation that professional traditions may prevent behavior patterns from changing in settings where professionals have dominant roles [Newman and Wallender, 1978]. While physician prescription entry systems or computerized patient charts might be positive changes to business processes within a healthcare setting, resistance from physicians can easily emerge.

Because of these factors, we argue that considerable numbers of IT personnel to help train and support users, including physicians, may reduce the reluctance of hospital users to embrace new technologies. Indeed, when the same ITs are used at different firms, performance advantages at some firms have been explained by noting the influence of personnel [Powell and Dent-Micallef, 1997]. For these reasons, we expect that hospitals with greater personnel-based assets will display superior organizational performance.

We further emphasize that these personnel should be on-site and should be hospital employees. Personnel that are on-site have the potential to provide immediate and direct assistance to physician users. Personnel that are hospital employees better understand the needs of physicians, the business processes of a hospital, the urgency of issues, and the organizational culture of the hospital. In contrast, an IT vendor to whom services have been outsourced, whether on-site or off-site, will be a less-desirable option for IT services. Physicians, as professionals, expect immediate, thorough, and expert assistance with IT issues. A physician that encounters a problem with an information system is less likely than a non-professional to troubleshoot the issue on their own or to call an off-site helpdesk. Thus, hospitals are one setting where outsourcing arrangements will likely not show the beneficial effects on productivity that have been observed in other industries. Instead, as more of the IT function is moved outside of the hospital, the less well-received technological changes will be. We seek to confirm that:

Hypothesis 9: IT Personnel will be positively associated with Productivity.
Hypothesis 10: IT Outsourcing will not be positively associated with Productivity.

These hypotheses are summarized in Figure 1, our research model.

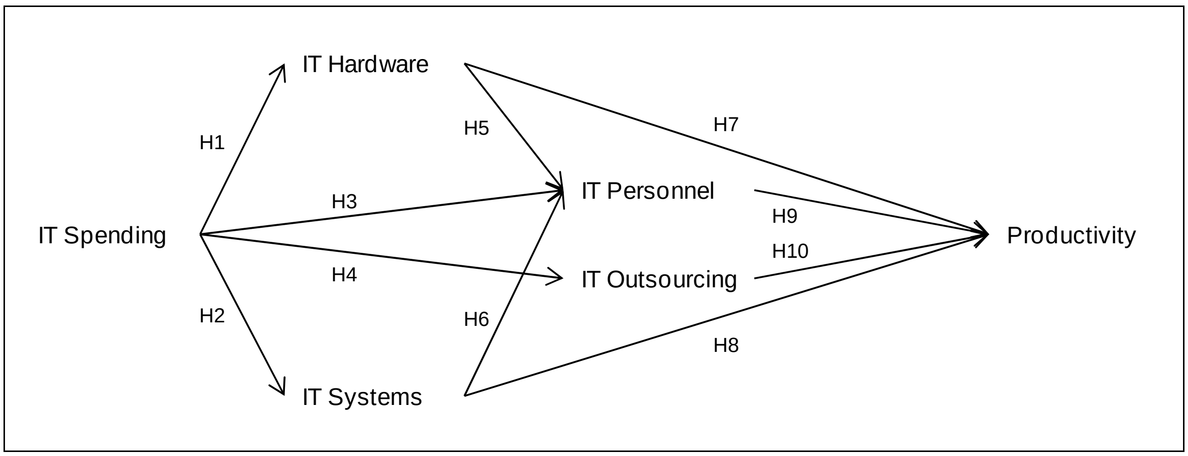

Figure 1: Research Model

IV. METHODS

Data Source

Data were collected from the HIMSS Analytics Database for 2006 and 2007, the most recent years for which data is available. HIMSS Analytics is an organization that tracks growth and change in the healthcare industry [Clark, 2007] by providing annual information on every healthcare system in the United States that owns at least one short-term, acute care, non-federal hospital with at least 100 beds. Our unit of analysis is the acute-care facility (hospital). Each hospital is identified with a Medicare Identification Number that allows us to track the hospital over both 2006 and 2007. The number of acute-care facilities included in the database is 4,144 in 2006 and 5,066 in 2007. Of the acute-care facilities included in the 2006 and 2007 versions of the database, 4,576 reported data on our variables in 2006, 2007, or both.

Variables and Measurement

The proxies for the variables in our research model were either taken directly from the database or calculated from query results. The dependent variable in our study is hospital productivity. There are different measures of a firm's performance and productivity in IS and management literature, including Tobin's q, return on investment (ROI), return on assets (ROA), return on equity (ROE), and return on sales (ROS) [Kohli and Devaraj, 2003, Santhanam and Hartono, 2003, Tanriverdi, 2006]. Revenue-based (rather than profit-based) dependent variables are commonly used in healthcare research, including healthcare IT business value research, because most hospitals operate on a nonprofit basis [Devaraj and Kohli, 2000, Menachemi et al., 2006, Menon et al., 2000, Post and Kagan, 1998]. With these precedents as a guide, we will use revenue as a basis from which to construct our proxy for hospital productivity.

Before proceeding, we pause to highlight the need to control for the effect of organizational size when selecting proxies for our variables. Organizational size represents a potentially-confounding variable [Kimberly and Evanisco, 1981] and must be addressed. In healthcare research, size-independent measures of productivity such as revenue per day or revenue per admission [Devaraj and Kohli, 2000, Devaraj and Kohli, 2003], as well as net inpatient revenue per bed per day and net patient revenue per bed per day [Menachemi et al., 2006], have been used to address the issue of organizational size. On the basis of these precedents, several measures of size may be justifiably chosen as a divisor for revenue to create a size-controlled proxy for productivity. While the number of physicians, the number of employees, or the number of beds [Kimberly and Evanisco, 1981, Post and Kagan, 1998, Zuckerman et al., 1994] have all been used in prior studies, the most frequently used measure of size is the number of beds [Kimberly and Evanisco, 1981]. The number of beds is a measure of a hospital's capacity and thus indicates the potential the hospital has to generate revenue. We have chosen to use the number of staffed beds to control for the potential effects of hospital size. Our proxy for productivity will be revenue per staffed bed. Hospitals that generate more revenue per staffed bed will be understood to be more productive than hospitals that generate less revenue per staffed bed.

While previous studies have quantified IT personnel assets by measuring total salary and wage expenses [Devaraj and Kohli, 2000], we choose to measure the actual number of employees as a proxy for this variable. Labor costs are an appropriate measure with a relatively homogeneous sample of sites, such as hospitals within a single healthcare system or within a given geographical area; however, the variability in pay rate from one region of the United States to another as well as from one healthcare system to another makes salary or wage expenses a poor choice with a large, heterogeneous sample such as ours. Furthermore, a precedent exists in the literature for using a count of the number of employees [Bresnahan et al., 2002, Ray et al., 2005]. Therefore, we have quantified IT personnel by aggregating the number of full-time employees (FTEs) in IT in management, programming, operations, network administration, help desk, PC support, security, and other support roles. While greater detail might be gained by exploring what type of IT personnel most influence organizational performance, severe multicollinearity among the various types of IT personnel makes meaningful analysis and interpretation problematic. As with our proxy for productivity, organizational size is a concern for this variable as well. Therefore, we have divided the number of IT FTEs by the number of staffed beds to create a size-controlled proxy for IT personnel.

Our next variable is IT hardware. Our proxy for IT hardware is the number of computers (desktops, laptops, dumb terminals, and blade PCs) in use in a given hospital divided by the number of staffed beds. The frequently-changing price of IT hardware makes a count of actual units a better measure of IT hardware assets than expenditures on hardware, the value of hardware, or other similar measures. Aggregate variables and counts of assets have been used often in prior research [Bresnahan et al., 2002, Melville et al., 2004].

Our proxy for IT spending is the percentage of the total hospital operating budget that is devoted to IT. Hospitals that place a greater emphasis on IT should perform better than those that have a reduced IT emphasis. This proxy quantifies how highly a hospital has prioritized IT by measuring its' expenditure there. This proxy is similar to one that was used in an earlier seminal study that examined the size of IT investment relative to the size of the firm [Weill, 1992]. Because this proxy is a percentage, it is size-independent and does not need to be divided by the number of staffed beds as our other proxies have.

Our proxy for IT systems is the percentage of business processes that are executed with the help of software applications. Our database identifies 99 business processes that each hospital may execute with such applications. These applications include human resources, supply chain management, general financial, and other applications. A full list can be found in Appendix A. We coded this data to indicate which processes were transacted manually and which are transacted using IT systems. The percentage of IT-enabled business processes at each hospital gives an average measure of business process automation. This proxy is similar to the "number of software capabilities" measure [Cron and Sobol, 1983] and the measure for the range of technologies used to support business processes [Ray et al., 2005]. Furthermore, a study of ERP implementation examined the number of modules of a given ERP system that were implemented and how this degree of implementation impacted performance and productivity [Hitt et al., 2002]. As with IT spending, IT systems is a count (essentially a percentage value) and therefore size-independent. It does not need to be divided by the number of staffed beds as several of our other variables have.

Finally, our proxy for IT outsourcing is the number of services the hospital has outsourced. The HIMSS Analytics database tracks 42 services that may be outsourced by a hospital (see Appendix B). Thus, this measure indicates how much of the work at a hospital is performed by external vendors. It is virtually identical to a measure used in a previous study in a top-tier healthcare journal [Thouin et al., 2008] and it is a size-independent measure that does not need to be divided by the number of staffed beds. Our proxies and their precedents in literature are summarized in Table 1.

Table 1. Variables and Definitions

Variable Name	Proxy Definition	Precedent
IT Spending	This variable gives the percentage of the operating budget devoted to IS/IT. It is defined in the database as "the total amount budgeted by the IS department at the Acute-Care Hospital for the current fiscal year end. This amount includes all operating and capital expenses."[a]	[Weill, 1992]
IT Hardware	A count of the "number of units in use" divided by the "number of beds that can be operated at present staffing levels." These units include various models of desktops, laptops, dumb terminals, and blade PCs.	[Bresnahan et al., 2002, Kimberly and Evanisco, 1981, Melville et al., 2004]
IT Systems	The percentage of business processes that are executed with the help of software applications. Of the 99 business processes tracked by the HIMSS database that can be transacted with the help of software systems (see Appendix A), this proxy is the ratio how many such systems are "live and operational" to those that are not at a given hospital.	[Cron and Sobol, 1983, Hitt et al., 2002, Ray et al., 2005]
IT Personnel	The "total number of IS full-time equivalents (FTEs)" in management, programming, operations, network administration, help desk, PC support, security, and other IT roles in the hospital, divided by the "number of beds that can be operated at present staffing levels."	[Bresnahan et al., 2002, Kimberly and Evanisco, 1981, Ray et al., 2005]
IT Outsourcing	The number of services the hospital has outsourced (see Appendix B for a list).	[Thouin et al., 2008]
Productivity	The "revenues associated with the main operations of the hospital (net inpatient + net outpatient revenue)[b]" divided by the "number of beds that can be operated at present staffing levels."	[Devaraj and Kohli, 2000, Devaraj and Kohli, 2003, Kimberly and Evanisco, 1981, Menachemi et al., 2006, Menon et al., 2000]

[a] phrases in quotation marks are taken directly from HIMSS Analytics Database documentation.
[b] This measure of revenue does not include dividends, interest income or non-operating income.

Due to relatively large values for productivity, the linearity assumption between independent variables and the dependent variable is violated. A common remedial measure to address skewness is to take the natural logarithm, which we have done here for each of our variables. Descriptive statistics for both raw and log-transformed variables are reported in Table 2 and correlations appear in Table 3.

Upon first glance, some of the correlations in the lower right quadrant of the table, where the correlations between the transformed values of our research variables appear, may be potentially problematic. Before assessing this potential issue, it is important to note that our research model will necessitate the construction of a five-equation simultaneous-equations model (described in detail in the next subsection, "Research Design"). Upon realizing that a five-equation model means that five of our research variables will be dependent variables, a different picture of the correlation table emerges.

Table 2. Descriptive Statistics				
Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
IT Spending	2.61	2.77	0.00	38.00
IT Hardware	5.46	17.53	0.01	560.00
IT Systems	51.59	17.02	1.92	93.75
IT Personnel	0.15	0.54	0.00	19.00
IT Outsourcing	2.72	2.70	1	29
Productivity	$ 835,357.40	$ 485,616.40	$ 125.89	$ 4,467,484.00
Log(IT Spending)	0.80	0.60	0.00	3.64
Log(IT Hardware)	1.17	1.01	-5.07	6.33
Log(IT Systems)	3.87	0.43	0.65	4.54
Log(IT Personnel)	-2.46	0.98	-5.86	2.94
Log(IT Outsourcing)	0.70	0.73	0	3.37
Log(Productivity)	13.47	0.64	4.84	15.31

Table 3. Correlation Table												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) IT Spending	1.00											
(2) IT Hardware	0.18	1.00										
(3) IT Systems	0.12	0.07	1.00									
(4) IT Personnel	0.56	0.79	0.11	1.00								
(5) IT Outsourcing	0.07	0.05	0.13	0.12	1.00							
(6) Productivity	0.04	0.19	0.28	0.12	0.13	1.00						
(7) Log(IT Spending)	0.81	0.22	0.15	0.55	0.11	0.13	1.00					
(8) Log(IT Hardware)	0.14	0.40	0.24	0.26	0.13	0.44	0.15	1.00				
(9) Log(IT Systems)	0.11	0.07	0.94	0.10	0.12	0.27	0.13	0.23	1.00			
(10) Log(IT Personnel)	0.40	0.32	0.32	0.46	0.23	0.46	0.48	0.48	0.25	1.00		
(11) Log(IT Outsourcing)	0.07	0.06	0.11	0.11	0.89	0.11	0.09	0.15	0.11	0.22	1.00	
(12) Log(Productivity)	0.03	0.16	0.33	0.10	0.12	0.84	0.14	0.47	0.33	0.46	0.11	1.00

Many of the potentially-troubling correlations are between independent and dependent variables; such correlations violate no assumptions of the regression model. The only correlation between two independent variables that may be problematic is the correlation between IT hardware and IT personnel, which both appear as independent variables in equation 5 (correlation of 0.48). To investigate whether this correlation affects the statistical results, we conducted supplemental analysis by performing a pooled OLS regression on equation 5 and calculating the variance inflation factors (VIFs). The VIFs for these independent variables appear below, in Table 4. None approach the value of 10 that is commonly taken as an indicator of excessive multicollinearity [Kutner et al., 2004]. On the basis of these results, we are confident that multicollinearity is not a problem in our analysis.

Table 4. Variance Inflation Factors	
Variable	**VIF**
Log(IT Hardware)	1.32
Log(IT Systems)	1.30
Log(IT Personnel)	1.09
Log(IT Outsourcing)	1.03
Mean VIF	1.15

Research Design

The hypotheses in our model can be stated as a system of five equations. When estimating multiple-equation models, it is possible to either estimate each equation individually or to simultaneously estimate the equations. Equations can be estimated individually if the errors are not correlated across the equations, but because several of our equations share independent variables, cross-equation correlation may exist [Pindyck and Rubinfeld, 1997]. If cross-equation correlation exists, equations must be estimated simultaneously using a method that accounts for cross-equation correlation. Simultaneous estimation procedures (in the presence of cross-equation correlation) produce estimates that are less biased than when equations are estimated independently. Cross-equation correlation can be checked using a Breusch-Pagan test. If cross-equation correlation exists, seemingly unrelated regressions (SUR), three-stage least squares (3SLS), multivariate regression (MVREG), full-information maximum likelihood (FIML), or generalized method of moments (GMM) are appropriate methods of estimation [Greene, 2003, Wooldridge, 2002]. If, on the other hand, no cross-equation correlation exists, individual estimates of each equation are appropriate and will be preferred [Greene, 2003, Wooldridge, 2002].

We employ the following equations to estimate the effect of (1) IT spending on IT hardware, (2) the effect of IT spending on IT systems, (3) the effect of IT spending, IT hardware, and IT systems on IT personnel, and (4) the effect of IT spending on IT outsourcing, and (5) the effect of IT hardware, IT systems, IT personnel, and IT outsourcing on hospital productivity.

$$IT\ Hardware_{it} = \alpha_0 + \alpha_1\ IT\ Spending_{it} + \alpha_2\ y2007 + v_{it} \quad (1)$$

$$IT\ Systems_{it} = \beta_0 + \beta_1\ IT\ Spending_{it} + \beta_2\ y2007 + v_{it} \quad (2)$$

$$IT\ Personnel_{it} = \gamma_0 + \gamma_1\ IT\ Spending_{it} + \gamma_2\ IT\ Hardware_{it} + \gamma_3\ IT\ Systems_{it} + \gamma_4\ y2007 + v_{it} \quad (3)$$

$$IT\ Outsourcing_{it} = \delta_0 + \delta_1\ IT\ Spending_{it} + \delta_2\ y2007 + v_{it} \quad (4)$$

$$Productivity_{it} = \phi_0 + \phi_1 IT\ Hardware_{it} + \phi_2\ IT\ Systems_{it} + \phi_3\ IT\ Personnel_{it} + \phi_4\ IT\ Outsourcing_{it} + \phi_5 y2007 + v_{it} \quad (5)$$

In these equations, the α, β, γ, δ, and ϕ characters represent the coefficients for the constants, independent variables, and year dummy variables. The subscript *i* denotes the cross-sectional unit (hospital) and the subscript *t* denotes the time period (year). The error term is v_{it} . This notation follows that of Wooldridge [2002].

V. RESULTS

Simultaneous estimation of the equations was first conducted in Stata using SUR. After estimation, we performed the Breusch-Pagan test of independence to ascertain if the residuals of the equations were indeed correlated. The results of the Bresuch-Pagan test revealed that the equations are independent (χ^2_{10} = 15.376, *p* = 0.1190). Thus, a simultaneous-equations approach to estimation is not needed.

Instead of a simultaneous-equations estimation technique, we performed a time-series regression on each of the five equations. We found support for each of our hypotheses (Table 5). As we have noted above, the results presented in Table 5 are based on the annual data from the years 2006 and 2007, the most recent years for which data is available. We now turn to a discussion of the implications of our findings.

VI. DISCUSSION

Theoretical Implications

This study contributes to literature in three ways. First, support for H1, H2, H3, and H4, which state that IT spending will be associated with IT hardware, systems, personnel, and outsourcing, respectively, refines earlier work on the relationships between IT spending, IT assets, and productivity. An earlier paper has proposed, but not tested, the assertion that IT spending enables the acquisition of IT assets, that in turn, improve performance [Soh and Markus, 1995]. Yet another study found mixed results for the hypothesis that IT spending improves performance [Weill, 1992]. We bring clarity to these results by finding strong statistical support for the assertion that spending enables the acquisition of IT assets. Evidence for this relationship provides a theoretical benefit by encouraging researchers to clearly specify the causal chain of IT business value creation. A simple statement that IT spending improves organizational performance or productivity misses the crucial intermediate variables of IT assets.

Table 5. Model Estimation[a, b]				
Equation Number and Dependent Variable	**N R^2**	**Independent Variable**	**Coefficient (Std. Error)**	**Result**
(1) Log(IT Hardware)	*N = 485,* R^2*=0.037*	Log(IT Spending)	0.168** (0.061)	H1: Supported
(2) Log(IT Systems)	*N = 575,* R^2*=0.024*	Log(IT Spending)	0.081** (0.027)	H2: Supported
(3) Log(IT Personnel)	*N = 467,* R^2*=0.364*	Log(IT Spending)	0.449*** (0.053)	H3: Supported
		Log(IT Hardware)	0.338*** (0.036)	H5: Supported
		Log(IT Systems)	0.203* (0.081)	H6: Supported
(4) Log(IT Outsourcing)	*N = 431,* R^2*=0.007*	Log(IT Spending)	0.139* (0.068)	H4: Supported
(5) Log(Productivity)	*N = 1139,* R^2*=0.333*	Log(IT Hardware)	0.092*** (0.013)	H7: Supported
		Log(IT Systems)	0.189*** (0.032)	H8: Supported
		Log(IT Personnel)	0.170*** (0.016)	H9: Supported
		Log(IT Outsourcing)	0.006 (0.015)	H10: Supported

[a] coefficients for constant terms and for year dummies omitted in the interest of space
[b] Missing values for some variables yielded slightly different numbers of observations for each regression equation. Because of these missing values, we performed our analysis two different ways, first, retaining only hospitals with complete data on all variables, and second, using hospitals that provided complete data as well as hospitals that had incomplete data. This table shows the results from the second analysis. These results are presented because they retain more data points and provide a more comprehensive examination of the phenomena of interest, and also because these estimates are more conservative (i.e. the coefficients are "lower") than the first analysis.
*p< 0.05, ** p< 0.01, ***p < 0.001

Second, while previous studies have examined the effects of various IT assets on firm performance, this study is among the first to examine the interrelationships among these assets. Support for H5 and H6 indicates that increases in the amount of IT hardware and IT systems will necessitate increases in the number of IT personnel needed to install, maintain, and manage that hardware. These observations about the contingencies and interrelationships among IT assets are one of the primary contributions of this paper. A host of IT business value studies have built upon production economics and assume that inputs to production such as IT hardware, software, systems, and outsourcing are commodities with rates of substitution, but do not examine whether there are functional dependencies among these inputs [e.g. [Aral et al., 2006, Bresnahan et al., 2002, Brynjolfsson and Hitt, 1996, Dewan and Min, 1997, Hitt et al., 2002, Hitt and Brynjolfsson, 1996, Menon et al., 2000, Soh and Markus, 1995]]. We argue that future work should continue to investigate functional dependencies among the inputs to production. Furthermore, research based on the RBV, such as the IT Business Value Model of Melville et al. [2004], does not mention how IT resources may be related to one another. In addition to investigating the propositions put forward in Melville et al., [2004], it would be beneficial to open what is simply a "black box" in Melville's model and continue to investigate how different IT resources are functionally related to one another.

Third, and perhaps most interestingly, we have found indications that IT personnel play a key role in improving hospital productivity. The insignificant relationship shown in H10 (which was hypothesized in the null form) may signify that IT outsourcing does not provide the beneficial effects in healthcare settings that it does in others. We argue that (in-house, on-site) IT personnel are preferable to outsourcing relationships. The dominance of professionals in leadership positions at hospitals necessitates a different type of relationship between the IT function of the organization and IT management. Given that professionals have strong ideas about what tasks lie inside and outside the scope of their job, and given that they may be resistant to changing their patterns of behavior [Newman and Wallender, 1978] , additional numbers of IT personnel may be needed to ease the transition to a new IS or a re-engineered business process. This preliminary finding may identify a boundary condition to theoretical explanations about the value of outsourcing in organizations.

Managerial Implications

A long-held assumption of many managers is that IT enables a firm to increase productivity using the same number of employees, or would even allow the firm to maintain the same level of productivity with fewer employees. Thus, it will seem counterintuitive to many that firm productivity is tied to an increase in the number of employees in IT. The primary managerial implication of this research is that simply investing in IT hardware and system assets may not bear the fruit that managers anticipate. These investments alone may not influence firm productivity to the degree desired. This study demonstrates that IT investments should also include appropriate (on-site, in-house) staffing to maximize the return on investment in these IT hardware and IT systems assets. While this study was not able to disaggregate the separate effects of IT labor components such as management, operations, PC support, etc., the clear implications of this study are that more IT personnel are better than less at hospitals[1].

We also suggest that healthcare firms can benefit from taking a systems approach to the analysis, design, and implementation of healthcare IT, with the view of system components including hardware, systems, outsourcing, and organizational culture. The delivery of health care has inherent interactions among these components, and we highlight the idea that IT managers in hospitals should be attuned to the reality of working with professionals. What works in other industries may not work in hospitals (as we have shown in the case of outsourcing). Our results are consistent with the view that the best firms are capitalizing on the system approach [Schwalbe, 2007].

Limitations and Future Research

A more complete picture of how IT creates business value in the healthcare industry could be developed through future research. Other studies may explicitly compare the role of outsourcing in healthcare with its role in other industries. The results presented here provide a point from which to investigate what type of outsourcing relationships, what length of contracts, what types of services can be effectively outsourced in healthcare and in other industries. The discovery of boundary conditions and the identification of contingencies in the creation of value through outsourcing would be valuable to both researchers and practitioners.

Other types of studies would be beneficial as well. We have focused on the hospital level, rather than the departmental or business process level. We have reserved for future work an examination of what non-IT organizational assets impact hospital performance. Additionally, the inclusion of other dependent variables that are not available to us in our dataset, such as mortality or patient satisfaction, would also be of interest. Other work could examine the roles of IT strategy and business strategy as contingency factors enabling or hindering the creation of IT business value. Levels of information system usage may be another such factor that mediates or moderates the impact of IT assets on productivity. Furthermore, the hypotheses investigated here in a healthcare context would also bear investigation in other industries. While the measures of IT spending, personnel, hardware, and systems assets may vary somewhat from industry to industry, the knowledge that IT personnel are a catalyst for IT-enabled organizational performance would be of broad importance.

Finally, the large, comprehensive, secondary dataset is both a strength of this study as well as a limitation. A nationwide sample of hospitals is a strong basis from which to investigate IT business value in the healthcare industry. In spite of this strength, the fact that the researchers must rely on previously defined data values means they lose a degree of control over the process of defining and capturing information. Furthermore, missing values and the absence of other potentially interesting variables such as the level of skill of IT employees limits the scope of our research.

VII. CONCLUSION

The growing importance of the healthcare industry and the expenditure of increasingly large sums of money on healthcare IT beg for theoretically-grounded, empirically tested explanations of how to generate value for these organizations. Simultaneously improving patient care, reducing the cost of care and ensuring patient privacy is a difficult goal for healthcare organizations to achieve. Modern IT systems, however, have been identified as a powerful tool with the potential ability to meet this goal. As a more complete understanding of the benefits of IT assets emerges from research, healthcare organizations will be poised to meet the challenging objectives of managers and policymakers.

[1] Of course, this relationship may be curvilinear rather than linear and at some point, continuing to add IT personnel will retard rather than improve performance. The point at which marginal gains to productivity cease remains to be discovered. This is clearly a potentially fruitful area for future research.

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APPENDIX A – BUSINESS PROCESSES IDENTIFIED IN THE HIMSS ANALYTICS DATABASE

Ambulatory
- Ambulatory EMR
- Ambulatory Laboratory
- Ambulatory PACS
- Ambulatory Pharmacy
- Ambulatory Radiology
- Practice Management

Business Office
- Document Management - Business Office
- Electronic Forms - Business Office

Cardiology and PACS
- Cardiology - Cath Lab
- Cardiology - CT (Computerized Tomography)
- Cardiology - Echocardiology
- Cardiology - Intravascular Ultrasound
- Cardiology - Nuclear Cardiology
- Cardiology Information System

ED/Operating Room/Respiratory
- Emergency Department Information System (EDIS)
- Operating Room (Surgery) - Peri-Operative
- Operating Room (Surgery) - Post-Operative
- Operating Room (Surgery) - Pre-Operative
- OR Scheduling
- Respiratory Care Information System

Electronic Medical Record
- Clinical Data Repository
- Clinical Decision Support
- Computerized Practitioner Order Entry (CPOE)
- Enterprise EMR
- Order Entry (Includes Order Communications)
- Physician Documentation

Financial Decision Support
- Budgeting

Human Resources
- Benefits Administration
- Document Management - Human Resources
- Electronic Forms - Human Resources
- Payroll
- Personnel Management
- Time and Attendance

Information Sharing
- Browser
- DBMS
- Email
- Interface Engines
- Single Sign-On
- Turnkey Portal
- Web Development Tool

Laboratory
- Anatomical Pathology
- Blood Bank
- Laboratory Information System
- Microbiology

Nursing
- Electronic Medication Administration Record (EMAR)
- Intensive Care/ Medical Surgical
- Intensive Care/Critical Care (ICU)
- Nurse Acuity
- Nurse Staffing/Scheduling
- Nursing Documentation
- Obstetrical Systems (Labor and Delivery)
- RFID - Patient Tracking
- Staff Scheduling

Pharmacy
- Pharmacy Management System

Radiology and PACS

- Business Intelligence
- Contract Management
- Cost Accounting
- Data Warehousing/Mining - Financial
- Executive Information System
- Financial Modeling

General Financials
- Accounts Payable
- General Ledger

Health Information Management (HIM)
- Abstracting
- Chart Deficiency
- Chart Tracking/Locator
- Dictation
- Dictation with Speech Recognition
- Document Management - HIM
- Electronic Forms - HIM
- Encoder
- In-House Transcription
- Outsourced Transcription

Home Health
- Home Health Administrative
- Home Health Clinical

- Radiology - Angiography
- Radiology - CR (Computed Radiography)
- Radiology - CT (Computerized Tomography)
- Radiology - DF (Digital Fluoroscopy)
- Radiology - Digital Mammography
- Radiology - DR (Digital Radiography)
- Radiology - MRI (Magnetic Resonance Imaging)
- Radiology - Nuclear Medicine
- Radiology - Orthopedic
- Radiology - US (Ultrasound)
- Radiology Information System

Revenue Cycle Management
- ADT/Registration
- Bed Management
- Credit/Collections
- Electronic Data Interchange (EDI) - Clearing House Vendor
- Eligibility
- Enterprise Master Person Index (EMPI)
- Patient Billing
- Patient Scheduling

Supply Chain Management
- Enterprise Resource Planning
- Materials Management
- RFID - Supply Tracking

Utilization Review/Risk Management
- Case Mix Management
- Data Warehousing/Mining - Clinical
- Outcomes and Quality Management

APPENDIX B – OUTSOURCED SERVICES IDENTIFIED AND TRACKED IN THE HIMSS ANALYTICS DATABASE

ADT/Registration
Cardiology
Coding
Credit Collection
Electronic Data Interchange - Clearing House Vendor
Electronic Medical Record
Eligibility
EMPI Enterprise Master Person Index
Enterprise Resource Planning
Home Health Care
Knowledge Management
Laboratory
Master Person Index
Materials Management
Medical Staff Credentialing
Other (specify)
Patient Billing
Patient Scheduling
Pharmacy
Practice Management
Radiology
Respiratory Therapy
Disaster Recovery Planning
Application Development
Application Implementation
Disaster Recovery Planning
Implementation or Project Management
IT Plans or Strategies
Network Administration
Other (specify)
Supplemental IS Staffing (help desk, IS department specific personnel)
System Selection
Web Development
Workstation/PC Support
Entire IS Function
Help Desk
Network Administration
Other (specify)
Remote Hosting
Transcription
Web Development
Workstation/PC Support

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