Refining the IT Business Value Model: Evidence From a Longitudinal Investigation of Healthcare Firms

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REFINING THE IT BUSINESS VALUE MODEL: EVIDENCE FROM A LONGITUDINAL INVESTIGATION OF HEALTHCARE FIRMS

Préciser le modèle de valeur économique des TI : résultats d’une investigation longitudinale des firmes du secteur médical

Completed Research Paper

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Abstract

Extant research into the business value of Information Technology (IT) explains that IT resources and complementary organizational resources impact organizational performance. This paper refines this explanation in three ways. We present theoretical arguments that (1) the direction of causality in the creation of IT business value may not be unidirectional, but that a positive feedback loop exists where IT investment in one time period improves organizational performance, which in turn enables additional IT investment in future time periods, (2) organizational resources may be more than merely complements of organizational performance, but may instead be determinants of organizational performance, and (3) the impact of IT capital resources on organizational performance is mediated by IT human resources. We support our arguments with empirical evidence built upon analysis of seven years of panel data gathered from healthcare firms. We find support for each of our eight hypotheses and present this research as a refinement and extension of existing models of IT business value.

Keywords: Business value of IT, IT payoff, healthcare industry, longitudinal analysis

Résumé

Ce papier argumente que (1) la relation entre investissements en TI et création de valeur est bi-directionnelle, (2) les ressources organisationnelles sont des déterminants de la performance organisationnelle et (3) les ressources humaines en TI sont médiatrices de la relation entre capital en TI et performance. Les huit hypothèses posées sont validées sur la base d’un panel de firmes médicales analysées sur une durée de sept ans.

Introduction

Understanding how IT provides value to businesses has been an important research agenda for over two decades (Bender 1986; Cron et al. 1983; Strassman 1985) and continues to draw considerable interest. In spite of the work that has been done, questions about the process of IT business value creation still remain (Devaraj et al. 2000; Melville et al. 2004; Piccoli et al. 2005). Three of these unanswered questions will be the focus of this study. First, we ask, “Does a positive feedback loop exist where IT investment improves organizational performance, which in turn enables further IT investment?” It has long been asserted that IT investment improves firms’ performance. Instead of investment driving performance, however, it may be the case that better-performing firms spend more on IT. Moreover, causality could be bidirectional, where a positive feedback loop exists between IT investment and firm performance (Aral et al. 2006). To continue the investigation into this issue of causality, we examine whether
evidence exists for the inclusion of a positive feedback relationship in models of IT business value. Second, we ask, “Are organizational resources complements to or determinants of IT resources?” When examining how IT affects organizational performance, it has been noted that a catalytic or synergistic effect may exist between a firm’s IT resources and its’ other non-IT resources (Melville et al. 2004). We argue here that non-IT resources exert a more direct influence upon IT resources than this prior research proposes; we then provide evidence to support our assertion. Third and finally, we ask, “Is the impact of IT capital resources on organizational performance mediated by IT human resources?” We argue that the productive potential of IT capital resources cannot be fully realized without an appropriate amount of IT human resources.

The answers to our research questions suggest refinements of and extensions to existing models of IT business value. Thus, our first contribution is to provide a greater level of detail to the explanation of how IT resources and organizational resources influence firm performance. The comprehensive nature of the model presented here makes it potentially valuable both to researchers and practitioners. The context for this study is the healthcare industry, an industry that has historically been a late adopter of information technologies (Khoumbati et al. 2006; Weill et al. 1998) and one where a knowledge gap exists regarding the creation of IT business value (Devaraj et al. 2000). Because of this knowledge gap and because large investments in IT are now being made in healthcare (McGee 2004; Menachemi et al. 2006), the need for research in this context is apparent. Our second contribution is to provide an empirically-supported explanation of how IT business value is created within the key context of the healthcare industry.

The paper will proceed as follows. In the next section, we develop hypotheses as we provide a review of relevant literature. We explain that we develop our refined model of IT business value based on earlier models (e.g. Dehning and Richardson 2002, Melville et al. 2004). Our data, our variables, and the measurements of those variables are explained in the Methods section. There, we also describe the techniques that we use to analyze our dataset. To investigate our research questions, we model the IT business value generation process as a four-equation simultaneous-equations model and analyze seven years of panel data drawn from firms in the healthcare industry. In the Results and Discussion section, we note our findings and their implications.

Hypothesis Development

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 1997; Weill 1992). As investigation into this apparent paradox continued, methodological flaws (Brynjolfsson 1993; Robey et al. 1999), the failure to incorporate time lags into research models (Devaraj et al. 2000), and the existence of intermediate variables (Barua et al. 2000; Barua et al. 1996) were highlighted as possible explanations for the apparent paradox. After these interpretations emerged, researchers began to find clear evidence of the proposed beneficial effects of IT and laid the “productivity paradox” to rest (Brynjolfsson et al. 1996; Brynjolfsson et al. 2000; Dewan et al. 1997). Key findings from this phase of research were summarized and synthesized to provide a basis for future work (Brynjolfsson et al. 1996; Mahmood et al. 1999; Sircar et al. 1998). Among the studies that have built upon this early work about the “productivity paradox” are those that have proposed models of how businesses gain value from IT. It is to these models that we now turn.

Theoretical work in IT business value has evolved to the point where conceptual models have been developed in an attempt to provide a comprehensive explanation of the process of business value creation. Building upon earlier work, literature reviews have proposed models that share several similar constructs (Dehning et al. 2002; Melville et al. 2004). One model explains that IT resources have an effect upon business processes; these business processes, in turn, affect the overall performance of the firm (Dehning et al. 2002). In a more specific model, termed the “IT Business Value Model” (ITBVM), IT resources coupled with other complementary organizational resources positively impact business processes. The effectiveness and efficiency of these business processes ultimately determines organizational performance (Melville et al. 2004). Within this model, IT resources are defined to include both IT capital resources (such as PCs, servers, and handheld devices) and human IT resources (such as the technical and managerial knowledge of the firm). Complementary organizational resources include both non-IT capital resources and non-IT human resources.
Determinants of IT Investment

In spite of the vast amount of work that has been done on the business value of IT, the fundamental question of causality has received scant treatment. It is widely believed that organizations that invest in IT see gains in performance. An alternative perspective, however, is that organizations with superior performance simply spend more on IT (Brynjolfsson et al. 2000). The importance of this research issue cannot be overstated. The veracity of the entire IT business value research stream, and the merit of the implications that have been drawn from it, hang on this question of causality. The question of causality has been identified as one of the primary remaining issues in IT business value research (Aral et al. 2006b; Brynjolfsson et al. 2000) and has not, to our knowledge, been conclusively answered in any journal article. It is to this question that we now turn as we develop our first hypothesis.

Early work in the study of IT business value (Cron et al. 1983) led to the development of a model that proposed a positive feedback loop where IT investment improved organizational performance, which in turn enabled additional investment in IT during future time periods (Weill 1992). Empirical tests failed to fully support this model. A later study described how knowledge management systems (KMS) produce an organizational performance payoff that stimulates positive feedback to initial enablers, processes, and intermediate outcomes (Lee et al. 2003). This feedback relationship was not, however, part of that study’s research model and was not empirically tested. A third study examined a positive feedback loop in the context of enterprise software systems and found that Enterprise Resource Planning (ERP) usage improved organizational performance, which enabled the subsequent adoption and use of Supply Chain Management (SCM) and Customer Relationship Management (CRM) systems, which further improved performance (Aral et al. 2006). A fourth study found mixed results for positive feedback to IT investments at a national level, noting that positive feedback may occur in developed nations and newly industrialized economies, but not in developing nations (Lee et al. 2005). Thus, while causality has been discussed and investigated, the inconclusive and incomplete results of this extant work are evident. Furthermore, much of the existing work that investigated positive feedback did so only in investigations of information systems resources (Aral et al. 2006; Lee et al. 2003; Weill 1992), not examining IT capital or personnel resources.

We argue that a positive feedback loop exists in broader contexts than simply enterprise software systems and KMS. Investment in IT capital resources such as hardware and shared systems increase organizations’ abilities to store, analyze, and manage data. As these activities become more efficient and effective, organizational performance improves (Brynjolfsson et al. 1996; Mahmood et al. 1999; Sircar et al. 1998). Similarly, investments in IT human resources allow firms to hire additional personnel or add to the skill sets of existing personnel. The cumulative knowledge and skills of IT personnel then positively influence the performance of firms (Byrd et al. 2004; Tippins et al. 2003). When organizational performance improves, the amount of funds available to invest in IT in future time periods increases. Furthermore, when organizations observe that improvements in performance result from investment in IT, they can choose additional IT investments that will build upon the capabilities delivered by the earlier IT investment (Aral et al. 2006; Weill 1992). We posit that

HYPOTHESIS 1: Organizational Performance in a given time period will be positively associated with IT Investment in later time periods.

The existing ITBVM explains that “synergies” exist between IT resources and other non-IT resources that make the non-IT resources “complementary.” (Melville et al. 2004, p. 294). The ITBVM does not, however, indicate whether complementary organizational resources determine the amount of IT resources a firm possesses. We will continue the process of refining the ITBVM by arguing that a direct positive relationship exists between non-IT organizational resources and IT resources.

It has been noted that organizations of greater size are more likely to adopt innovations, including technological innovations (Kimberly et al. 1981). Greater size can facilitate innovation because the increased economies of scale enable the cost of innovations to be spread over more units. Greater size can also necessitate innovation in order to formalize and coordinate activities, which are more numerous and potentially more complex in large organizations. For instance, a healthcare organization with a relatively large amount of non-IT physical assets (such as a large number of beds), may find a greater economic benefit to investing in an asset management software application than a similar, smaller organization that has a smaller number of beds. In this case, the organizational resource (beds) is a direct determinant of the IT investment that must necessarily precede technological innovation (adoption and use of asset management software). Similarly, if a healthcare system builds a large, new facility that will double the number of staffed beds in the upcoming fiscal year, the healthcare system will need to increase IT investment in the
upcoming fiscal year. This increase in IT investment will enable the purchase of PCs for the new rooms, handheld devices to be used, and servers to manage the expected increase in patient data.

To summarize, greater amounts of non-IT organizational resources create the condition (economies of scale) and the necessity (added complexity) that encourage a higher level of investment in IT. Thus, a greater amount of non-IT organizational resources directly determines the level of IT investment. Therefore, we hypothesize:

**Hypothesis 2:** Organizational Resources will be positively associated with IT Investment.

**Determinants of IT Resources**

A direct link from IT investment to organizational performance has long been asserted in IS literature. 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 resources to organizational performance in order to achieve greater precision in measurement and to more clearly specify the causal chain in the creation of IT business value (Brynjolfsson et al. 1996; Devaraj et al. 2000; Dewan et al. 1997). Instead of stating that IT investment impacts organizational performance, it is more precisely argued that IT investment allows organizations to acquire IT resources and IT resources bring about IT impacts on organizations’ performance (Soh et al. 1995). Indeed, the separation of IT investment from the use of IT capital resources and IT human resources has been highlighted as a way to isolate the impact of specific types of technology on performance (Devaraj et al. 2003). The failure to measure IT assets as an intermediate variable between IT investment and organizational performance prevents a full, accurate, and clear explanation from being developed.

An additional reason to investigate IT investment as distinct from IT resources is related to the aforementioned positive feedback relationship. Improved organizational performance should not directly result in increased amounts of IT capital resources or IT human resources. Rather, improved organizational performance allows additional money to be budgeted for and invested in IT in the following time period. This investment then allows resources to be acquired, resources that will impact performance and begin the IT business value creation cycle anew. Furthermore, it has been argued that empirical approaches to the study of IT business value should ideally separate IT investment from the use of IT inputs (Aral et al. 2006). In sum, the separation of IT investment from IT capital resources and IT human resources provides both a theoretical and empirical benefit by clearly identifying each variable in the process of IT business value creation.

Following Melville, et al. (2004), we define IT resources to include both IT capital resources and IT human resources. IT capital resources include infrastructure such as IT hardware and IT applications/software that are shared across the firm (Chang et al. 2005; Melville et al. 2004; Weill et al. 2000). IT human resources include both IT managerial skills and IT technical skills. If IT investment is defined as the amount of money spent on IT (Ray et al. 2005), it is logical to understand IT investment as a precondition to the acquisition of resources. That is, the expenditure of money enables the acquisition of IT capital resources such as PCs, servers, and handheld devices, as well as IT human resources such as managers, programmers, and help desk personnel. We propose that IT investment is a necessary precursor to IT capital resources or IT human resources and that the existing ITBVM can be refined by its’ inclusion. Based on these arguments, we hypothesize:

**Hypothesis 3:** IT Investment will be positively associated with IT Capital Resources.

**Hypothesis 4:** IT Investment will be positively associated with IT Human Resources.

How are IT capital resources and IT human resources related? We argue that the level of IT capital resources determines the level of IT human resources that an organization possesses. When an organization acquires increasing amounts of IT capital resources, such as PCs, servers, or handheld devices, the need for skilled, qualified people to install hardware, train users, and support systems will also increase. For instance, if a healthcare system plans to invest in the upcoming fiscal year in PCs to place in physicians’ exam rooms, handheld devices for nurses to use, and servers to manage patient data, that investment will need to be accompanied by a corresponding investment in IT human resources during that upcoming fiscal year. Managers understand that a planned investment in IT capital resources also necessitates planning for installation, training, and support of those systems, each of which are accomplished by IT human resources. Our argument aligns with a similar argument at the macroeconomic level that increases in IT will increase the need for skilled IT labor (Bresnahan et al. 2002). For these reasons, we hypothesize:
HYPOTHESIS 5: IT Capital Resources will be positively associated with IT Human Resources.

Determinants of Organizational Performance

IT personnel embody the technical and managerial IT skills an organization possesses and have been identified as a key to improved organizational performance (Bharadwaj 2000; Mata et al. 1995). Successful implementation of information systems and coordination of the IS function are distinguishing factors of high-performing firms (Sambamurthy et al. 1997). Furthermore, when the same ITs are used at different firms, performance advantages at some firms have been explained by noting the influence of human resources (Powell et al. 1997). Elsewhere, it has been noted that the knowledge and skills of IT human resources influence the performance of firms (Tippins et al. 2003) and contribute to competitive advantage (Byrd et al. 2004). For these reasons, we expect that firms with greater levels of IT human resources will display better organizational performance than firms with lesser levels of human IT resources. We seek to confirm that:

HYPOTHESIS 6: IT Human Resources will be positively associated with Organizational Performance.

IT capital resources such as PCs, servers, and handheld devices compose a major portion of IT infrastructure, which is the basis of IT capability (Weill et al. 1998). Such resources have been long-recognized as a significant business resource from which competitive advantage can be built (Chatterjee et al. 2001; Keen 1991; McKenney 1995). Furthermore, it has been shown that investment in IT capital increases the productivity of the firm (Aral et al. 2006). IT capital has been identified as a contributor to positive financial performance in hospitals, which are the context for this study (Menachemi et al. 2006). Similarly, IT capital influences both hospital revenue and patient satisfaction (Devaraj et al. 2000). We therefore hypothesize:

HYPOTHESIS 7: IT Capital Resources will be positively associated with Organizational Performance.

A host of studies argue theoretically and demonstrate empirically that the type and amount of organizations’ non-IT resources impact those organizations’ performance (e.g. Barney 1991; Dewan et al. 1997; Mata et al. 1995; Melville et al. 2004; Menon et al. 2000; Ray et al. 2005). We seek to confirm these relationships in the context of the healthcare industry at the healthcare system level. In doing so, we test the portion of the ITBVM that explains that non-IT organizational resources influence organizational performance (Sircar et al. 2000):

HYPOTHESIS 8: Organizational Resources will be positively associated with Organizational Performance.

Methods

Data Source

The context for our study is the healthcare industry; we have selected this industry because the industry is presently using IT to transform itself. New strategies and tactics to increase efficiency and quality through the use of IT are being developed and implemented (Anderson et al. 2006). Healthcare purchasers are striving to impose greater cost control through the use of supply chain management techniques (Porter et al. 2004). Even broader changes in the healthcare industry seem imminent, as both the U.S. government and the UK move toward the development of distributed networks of applications and patient records (BBC 2006; McGee 2004). As these changes take place, the beneficial effects of IT investment on healthcare system financial performance are only beginning to be identified by researchers (Devaraj et al. 2000). The need to understand ways to improve organizational performance in healthcare seems apparent when it has been observed that the healthcare costs in developed countries have begun to threaten those countries’ competitive advantage in the global marketplace (Prahalad 1999).

Data were taken from the HIMSS Analytics Database for the years 1998 through 2004 (HIMSSAnalyticsTM 2004). 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. The database is comprehensive and updated annually. It provides annual information on healthcare systems, which are business entities that may be composed of acute care facilities, sub-acute care facilities, ambulatory care facilities, home health care/hospice agencies, affiliated physician organizations, owned payor components, and other owned businesses. Our unit of analysis is the healthcare system. While profitable research has been done at the hospital level, we have chosen the healthcare system level to reflect...
the reality that hospitals, ambulatory care facilities, physicians’ clinics, and other healthcare entities are increasingly merging to form multi-facility healthcare systems in order to gain economies of scale and scope. The number of healthcare systems included in each year’s edition of the database ranges from 1,467 to 1,391, with an average value of 1,435. Of these healthcare systems, 1,266 (88%) provided information on all measured variables in two or more consecutive years and were included in our sample. With each of the 1,266 healthcare systems reporting data in multiple years, our panel includes a total of 4,114 firm-year observations from the 1998 – 2004 period.

**Measurement of Variables**

The proxies for our variables were either taken directly from the database or calculated from query results. The primary dependent variable in our study is organizational performance\(^1\). There are different measures of a firm’s financial performance 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) (Santhanam et al. 2003; Tanriverdi 2006). Nonetheless, revenue-based (rather than profit-based) dependent variables are commonly used in healthcare research because most healthcare systems operate on a nonprofit basis (Devaraj et al. 2000; Devaraj et al. 2003; Menachemi et al. 2006; Menon et al. 2000; Post et al. 1998). Using these precedents as a guide, we will construct our proxy for organizational performance from the basis of revenue.

Here, we note the importance of controlling for the effect of organizational size when selecting proxies for this and other variables (Kimberly et al. 1981). Because size has been recognized as being potentially influential in similar studies, size-independent measures of performance, such as revenue per day or revenue per admission (Devaraj et al. 2000) 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. On the basis of these precedents, several measures of size may be chosen by which revenue could be divided to create a size-controlled proxy for organizational performance. The number of physicians, the number of employees, or the number of beds might be used (Kimberly et al. 1981; Post et al. 1998). We have chosen to use the number of physicians to control for the potential effects of organizational size. Healthcare systems generate revenue by treating patients, performing medical procedures, and prescribing medicines; the presence of physicians is essential for these revenue-generating functions to occur. It is because physicians are at the center of the revenue-generation process in a healthcare system that we have chosen to use the number of physicians to control for size. The number of physicians is the sum of the full-time salaried physicians employed by the healthcare system, the number of on-staff physicians with practicing privileges, and any other physicians (such as those in consulting, contracted, courtesy, or visiting roles). Thus, the proxy we construct to measure organizational performance is revenue per physician.

The IT resources that we have measured include IT investment, IT capital resources, and IT human resources. Our proxy for IT investment is constructed from the dollar amount of the total operating budget that is devoted to IT. The monetary value of inputs has been used in a host of studies of IT business value, both within the healthcare sector as well as in cross-sector studies (Bresnahan et al. 2002; Brynjolfsson et al. 1996; Devaraj et al. 2000; Dewan et al. 1997; Menon et al. 2000; Ray et al. 2005). Again, we recognize that the total operating budget for the IT department is likely to be correlated with organizational size, so we have divided this measure by the number of physicians as we have with our proxy for organizational performance. Thus, our proxy for IT investment is the dollar amount of total operating budget devoted to IT divided by the total number of physicians.

Our proxy for IT capital resources is constructed from the aggregated the number of servers, PCs, and handheld devices in a given healthcare system. Aggregate variables and counts of resources have been used often in prior research (Bresnahan et al. 2002; Melville et al. 2004). Additionally, the frequently-changing price of hardware may make a count of actual units a better measure of organizational resources than expenditures on hardware, value of hardware, or other similar measures. Again, we have divided this aggregate measure by the number of physicians in the healthcare system. Therefore, this measure of IT technological resources is a measure of the number of servers, PCs, and handheld devices per physician.

We have chosen to quantify IT human resources by measuring the number of employees in the IT department. While some studies (e.g. Devaraj et al. 2000) have used total salary and wage expenses as a proxy for measures of

\(^1\) Our model contains a feedback loop and will be estimated with a simultaneous equations model, where a variable that is dependent in one equation will be independent in another. Nevertheless, we retain the understanding of organizational performance as the primary dependent variable (as is common in IT business value studies).
IT personnel, we deemed this less appropriate for the present study. 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 (as in Devaraj, et al., 2000). 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 for using a count of the number of employees (Bresnahan et al. 2002; Ray et al. 2005). Therefore, we have measured IT human resources by aggregating the number of full-time IT employees (FTEs) in management, operations, PC support, programming, help desk, and additional support roles. We have divided this measure by the number of physicians as well, yielding a proxy for IT human resources of IT employees per physician.

Within healthcare research, the most commonly-used measure of non-IT organizational resources is the number of beds in the healthcare system (Devaraj et al. 2000; Kimberly et al. 1981). This is the measure we have chosen to use to construct our proxy for organizational resources. Here, we measure organizational resources as the number of staffed beds per physician. Healthcare systems that have more staffed beds per physician have a greater capacity and therefore are better-positioned to generate revenue than are healthcare systems that have fewer staffed beds per physician. Thus, our proxy for organizational resources is the number of inpatient beds the integrated healthcare delivery system staffs divided by the total number of physicians in the healthcare system.

Several control variables have been included as well. While we have argued that healthcare systems that have more revenue per physician are performing better than others with less revenue per physician, it seems apparent that the range of services provided by the healthcare system may play a role in determining whether revenue per physician is an appropriate measure for performance. For instance, an acute care facility may generate substantially more revenue per physician than would a walk-in clinic or hospice facility. This is because the types of illnesses being treated at an acute care center are different from the types of illnesses being treated at an ambulatory care facility. For this reason, we have included the range of services offered as a control variable. The range of services offered by the healthcare system, possibly including acute care, sub-acute care, ambulatory care/physician offices/clinics, home health/hospices, affiliated physician organizations, and owned payer components, is a discrete measure ranging from one to seven. The higher this measure is, the wider the range of services rendered.

We have also included the percentage of revenue from Medicaid, and the percentage of revenue from Medicare. It seems apparent that healthcare systems that primarily serve the indigent, uninsured, or underinsured populations that benefit from Medicare and Medicaid would earn relatively less in revenue than healthcare systems that do not serve these populations.

Finally, we have included the age of the healthcare system as a control variable as well. These control variables: the services offered, the percentage of revenue from Medicare and Medicaid, and the age of the healthcare system are often included as controls in studies of healthcare organizations (Devaraj et al. 2000; Menachemi et al. 2006). Table 1 summarizes our variables, the definitions of their proxies, and the basis in literature for that proxy.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Proxy Definition</th>
<th>Precedents in Literature</th>
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<tbody>
<tr>
<td>Organizational Performance</td>
<td>The system’s annual net revenue in numeric form for the most recent fiscal year divided by the total number of physicians in the healthcare system*.</td>
<td>(Devaraj et al. 2000; Devaraj et al. 2003; Menachemi et al. 2006; Menon et al. 2000; Post et al. 1998)</td>
</tr>
<tr>
<td>IT Investment</td>
<td>Dollar amount of total operating budget devoted to IT divided by the total number of physicians in the healthcare system*</td>
<td>(Bresnahan et al. 2002; Brynjolfsson et al. 1996; Devaraj et al. 2000; Dewan et al. 1997; Menon et al. 2000; Ray et al. 2005).</td>
</tr>
<tr>
<td>IT Capital Resources</td>
<td>Sum of “number of handheld units,” “number of nodes that are PCs,” and “number of nodes that are servers” divided by the total number of physicians in the healthcare system*</td>
<td>(Bresnahan et al. 2002; Melville et al. 2004).</td>
</tr>
<tr>
<td>IT Human Resources</td>
<td>Total number of FTEs in the IT department in management, operations, PC support, programming, help desk, and additional IT support roles** divided by the total number of physicians in the healthcare system*</td>
<td>(Bresnahan et al. 2002; Ray et al. 2005)</td>
</tr>
<tr>
<td>Organizational Resources</td>
<td>Number of inpatient beds the integrated healthcare delivery system staffs divided by the total number of physicians in the healthcare system*</td>
<td>(Devaraj et al. 2000; Kimberly et al. 1981)</td>
</tr>
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Control Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
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<tr>
<td>Firm Age</td>
<td>The number of years since the healthcare system was founded</td>
<td>(Kimberly et al. 1981)</td>
</tr>
<tr>
<td>Services Offered</td>
<td>The range of services offered by the healthcare system (acute care, sub-acute care, ambulatory care/physician offices/clinics, home health/hospices, affiliated physician organizations, other owned businesses, owned payor components) [discrete: ranging from 1 – 7; the higher this measure, the wider the range of services rendered by the healthcare system]</td>
<td>(Devaraj et al. 2000)</td>
</tr>
<tr>
<td>Percent Revenue from Medicaid</td>
<td>Percentage of patient revenue the healthcare system receives from Medicaid</td>
<td>(Devaraj et al. 2000; Menachemi et al. 2006)</td>
</tr>
<tr>
<td>Percent Revenue from Medicare</td>
<td>Percentage of patient revenue the healthcare system receives from Medicare</td>
<td>(Devaraj et al. 2000; Menachemi et al. 2006)</td>
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*For each variable that is divided by the number of physicians, the number of physicians is the sum of the full-time salaried physicians employed by the healthcare system, the number of on-staff physicians with practicing privileges, and any other physicians (such as those in consulting, contracted, courtesy, or visiting roles).

** The documentation for our dataset does not indicate that any healthcare systems distribute their IT employees across the various facilities that compose the healthcare system or across the functional departments of a healthcare system. In spite of the lack of evidence for this distribution, such a possibility exists and thus our count of IT employees should be interpreted as a conservative estimate. Thus, the effects that we report may be underestimated.

**Model Estimation**

Simultaneity presents a potential problem in the estimation of our model. When estimating multiple-equation models, some explanatory variables may be jointly determined with the dependent variables; this is known as simultaneity. Examination of our hypotheses and research model (Figure 3) reveals the presence of simultaneously-determined variables. When simultaneity exists, seemingly unrelated regression (SUR), as well as instrumental variable approaches such as two-stage least squares (2SLS), three-stage least squares (3SLS), and generalized method of moments (GMM) are appropriate methods for estimation (Wooldridge 2002). It has been noted in earlier IT business value research that instrumental variable approaches are often infeasible because of the difficulty in acquiring data on variables that are uncorrelated with performance, but still correlated with IT (Aral et al. 2006). Instruments based on lagged values of variables may have low statistical power (Brynjolfsson et al. 2003). Furthermore, the use of lagged values as instruments reduces the number of observations that can be included in the analysis, effectively removing data from the sample. Because of these issues, we have chosen not to pursue the instrumental variable approaches and have instead opted for SUR, an estimation method that has been used previously in IT business value research (Brynjolfsson et al. 1996). Here, because the equations share independent variables, the errors are likely to be correlated across the equations. SUR accounts for this possible cross-equation correlation in the estimation of coefficients by simultaneously estimating the equations (Wooldridge 2002).

In sum, SUR is an approach that mitigates the potential issues of simultaneity and cross-equation correlation. To address potential non-normality and heteroscedasticity in the data, the natural logarithm transformation was used on each of our independent variables. In addition, we have used the Huber-White sandwich estimator to generate heteroscedasticity-robust standard errors. An alternate approach to estimation that would possibly not require these remedial measures would be the specification of a first-differenced model. Missing values in the dataset make this approach unattractive because missing values would prevent the calculation of first-differences on a large number of observations. In an effort to preserve as many observations as possible, we have avoided this approach. Furthermore, while first-differencing is advised for time-series models when a variable is autocorrelated at a level of 0.90 or 0.80 (Wooldridge 2002), none of the three lagged variables we include in our model approach this threshold. Descriptive statistics for our sample appear in Table 2, and correlations are available from the authors upon request.

Table 2. Descriptive Statistics (n=4,114)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(Organizational Performance)</td>
<td>12.66</td>
<td>1.94</td>
<td>0.00</td>
<td>20.36</td>
<td>3.77</td>
<td>-5.59</td>
<td>33.84</td>
</tr>
<tr>
<td>Log(IT Investment)</td>
<td>8.92</td>
<td>1.16</td>
<td>0.00</td>
<td>16.90</td>
<td>1.35</td>
<td>-3.19</td>
<td>22.87</td>
</tr>
</tbody>
</table>

2 \( \log(x+1) \) was used to avoid indeterminate transformations of zero values. The interpretation of values transformed using the \( \log(x+1) \) transformation is identical to that of those transformed using \( \log(x) \).
Refining the IT Business Value Model  
Baker, Song, and Jones

Each of our equations takes the general form:

\[ Y_t = X_t \beta + \delta_t + \epsilon_t \]  

(1)

where \( Y \) represents the dependent variable, \( X \) represents the independent variables, \( \beta \) represents the coefficients for those independent variables, \( \delta \) represents the coefficients for the year dummy variables, and \( \epsilon \) represents an error term (the intercept term is included in our estimation as well, but is omitted here in the interest of simplicity). In our equations where IT capital resources and IT human resources are the dependent variables, a one-period time lag for the dependent variable is included as well. We have chosen to include this time lag for technological IT resources and human IT resources because these resources are not consumed each year as is the IT department’s budget and the net revenue of the healthcare system, which are our proxies for IT investment and organizational performance, respectively. Instead, the IT capital and IT human resources of a firm are built largely upon the levels of those resources in the previous time period. Thus, the two equations where IT capital resources and IT human resources are dependent variables take the more specific form:

\[ Y_t = Y_{t-1} \alpha + X_t \beta + \delta_t + \epsilon_t \]  

(2)

Where \( Y \) represents the dependent variable, \( \alpha \) represents the coefficient for a one-period time-lagged dependent variable, and the remaining symbols retain the meanings described above. Explicit specification of our system of equations can be found in Appendix A. Estimation of our model was performed with the TSP software package.

Results

We find strong support for each of our eight hypotheses, supporting our proposed theoretical refinements to the ITBVM (Table 3). We now turn to a discussion of the theoretical, managerial, and methodological implications of our research. We note the results of each hypothesis as it applies to a particular implication of our findings.

Table 3. Results of Seemingly Unrelated Regressions (n=4,114)*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable</th>
<th>Coefficient</th>
<th>Std. Err.</th>
<th>P-value</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(IT Investment)</td>
<td>Log(Organizational Performance),1</td>
<td>0.08</td>
<td>0.01</td>
<td>[.000]</td>
<td>H1: Supported</td>
</tr>
<tr>
<td>R² = .12</td>
<td>Log(Organizational Resources)</td>
<td>0.56</td>
<td>0.05</td>
<td>[.000]</td>
<td>H2: Supported</td>
</tr>
<tr>
<td></td>
<td>Log(Firm Age)</td>
<td>0.05</td>
<td>0.02</td>
<td>[.037]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Services Offered)</td>
<td>0.65</td>
<td>0.07</td>
<td>[.000]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Percent Medicaid)</td>
<td>-0.08</td>
<td>0.19</td>
<td>[.660]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Percent Medicare)</td>
<td>0.05</td>
<td>0.19</td>
<td>[.801]</td>
<td></td>
</tr>
<tr>
<td>Log(IT Capital Resources)</td>
<td>Log (IT Capital Resources),1</td>
<td>0.49</td>
<td>0.02</td>
<td>[.000]</td>
<td>H3: Supported</td>
</tr>
<tr>
<td>R² = .39</td>
<td>Log(IT Investment)</td>
<td>0.14</td>
<td>0.01</td>
<td>[.000]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Firm Age)</td>
<td>-0.01</td>
<td>0.01</td>
<td>[.195]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Services Offered)</td>
<td>0.05</td>
<td>0.03</td>
<td>[.161]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(Percent Medicaid)</td>
<td>0.10</td>
<td>0.09</td>
<td>[.268]</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Theoretical Implications

In this paper, we have proposed three theoretical refinements to the ITBVM. The first contribution of this paper is that it provides evidence that a positive feedback loop exists in IT business value creation. This is the clear implication of the causal chain linking our supported hypotheses H1, H3, H4, H6, and H7. We go beyond earlier research that fails to find support for positive feedback (Weill 1992), research that proposes feedback but does not test for it (Lee et al. 2003), and research that examines feedback to enterprise systems (Aral et al. 2006). We test for feedback, find support for it, and find that IT capital resources and IT human resources, in addition to the previously-examined IT systems, provide improvements in organizational productivity. Our results build on earlier work on IT business value that emphasizes the importance of investigating time lags in data (Devaraj et al. 2000). Based on our results, we suggest that the ITBVM, a static model with unidirectional causality, can be re-cast as a dynamic model that explicitly incorporates a positive feedback relationship.

Second, we have found evidence to support H2, which states that organizational resources will be positively associated with IT investment. The existing ITBVM argues that organizational resources are complements of IT resources, while we provide evidence that they are determinants of those IT resources. The explanation of a direct relationship rather than a synergistic or catalytic effect more clearly specifies the relationship of these two types of firm resources to one another. Our analysis provides initial evidence of these relationships, thus suggesting a refinement of the ITBVM and providing a second theoretical contribution.

Third, we have argued for a specific causal chain among IT investment, IT capital resources, and IT human resources. IT investment is a key organizational resource and one of the drivers of organizational performance in many IT business value studies, but it is not noted in the ITBVM. The inclusion of IT investment as an IT resource enables a more refined explanation of the IT business value creation process. In addition to the inclusion of IT investment in the ITBVM, we argue that the knowledge that IT investment impacts firm performance through the resources an organization can obtain should be fused with the ITBVM. Researchers have argued that IT investment allows firms to acquire IT resources; IT resources bring about IT impacts; and finally that IT impacts alter the firm’s performance (Soh et al. 1995). These (as yet to our knowledge untested) assertions about the relationships of IT resources to one another are tested in H3 (IT investment will be positively associated with IT capital resources), H4 (IT investment will be positively associated with IT human resources), and H5 (IT capital resources will be positively associated with IT human resources). Each of these hypotheses are supported (p < 0.000 for all). Thus, IT investment may be most properly understood as a determinant of IT resources, which may in turn influence organizational performance. This is in contrast to the slightly less-specific assertion that IT investment itself improves organizational performance.
Managerial Implications

One of the primary managerial implications of this study is that IT human resources can play a significant role in influencing organizational performance. This may be particularly true in the healthcare industry, due to its remaining potential for IT investment and the nature of healthcare as a knowledge-intensive activity. Furthermore, management of professionals, a class of employees that possess advanced training and specialized knowledge, requires that special considerations be made (Gouldner 1957; Kohli et al. 2004; Newman et al. 1978; Raelin 1991). It has been noted that in settings where professionals have dominant roles, such as healthcare systems, professional traditions may prevent behavior patterns from changing (Newman et al. 1978). Professionals have narrow areas of specialization and firm ideas about what activities lay inside or outside the scope of their job. Because of these factors, physicians may be reluctant to embrace new technologies such as physician prescription entry, computerized patient charts, or clinical decision support. In light of these arguments, and in light of the empirical results here, we note that increased levels of IT human resources may improve the payoff of IT investments in the healthcare industry. Increasing the number of personnel to help train and support users may reduce the reluctance of healthcare system users to embrace new technologies.

Limitations and Future Research

This study is limited slightly by the absence of information about the software systems used within each healthcare system, and by lack of additional dependent variables such as mortality or patient satisfaction. Additionally, our dataset does not provide direct information about the medical specialties of particular healthcare facilities (e.g. cardiac care, oncology, geriatrics) or the severity of illnesses that are treated. Some of this information about medical specialties and illness severity is captured in our “Services Offered” control variable, but more direct measures would be beneficial. Future research, particularly research conducted at the hospital level of analysis rather than the healthcare system level of analysis, could consider these additional variables.

An additional area for research has to do with the identification of returns to IT. It has been shown here that IT does improve organizational performance, but the method by which those organizations identify successful IT investments remains unexplained. A logical question to ask is, “How do firms recognize successful investments in IT?” Are financial measures used? Are productivity measures instead used? Is executive judgment more common? Does the process of identifying these successful investments vary from industry to industry? Future research will be needed to identify the workings of this process.

Yet another potential area for research is the examination of other variables that impact organizational performance. For instance, alignment between organizational strategy and IT strategy has been shown to influence performance (Sabherwal et al. 2001). Future research that integrates the findings and theoretical underpinnings of strategic alignment studies with IT business value research may provide additional valuable insights not only for researchers, but for practitioners as well.

Finally, the hypotheses investigated here in a healthcare context would also bear investigation in other industries. It seems probable that the IT resources and organizational resources that are valuable to an organization may differ from industry to industry. Defining valuable resources for differing contexts will yield actionable insights for practitioners.

Conclusion

The growing importance of the healthcare industry in both the developed and the developing worlds 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. This study proposes refinements to and extensions of existing models of IT business value. More specifically, this study has endeavored to address one of the remaining open questions in IT business value research: the question of causality. We suggest that models of IT business value should not be static models with unidirectional or even bidirectional causality. Instead, we advocate a novel approach, a dynamic model that includes a positive feedback.

Simultaneously improving patient care, reducing the cost of care and ensuring patient privacy is a considerably difficult goal for healthcare organizations to achieve. Modern IT, however, has been identified as a powerful tool with the potential ability to meet this goal. As a more complete understanding IT business value creation emerges
from research, healthcare organizations will be poised to meet the challenging objectives of managers and policymakers.

Appendix A

Table A.1. Explicit Specification of System of Simultaneous Equations

\[ \text{Log}(\text{IT Investment})_t = \alpha_0 + \alpha_1 \text{Log}(\text{Organizational Performance})_{t-1} + \alpha_2 \text{Log}(\text{Organizational Resources})_t + \alpha_3 \text{Log}(\text{Firm Age})_t + \alpha_4 \text{Log}(\text{Services Offered})_t + \alpha_5 \text{Log}(\text{Percent Medicaid})_t + \epsilon_1 \]

\[ \text{Log}(\text{Technological IT Resources})_t = \beta_0 + \beta_1 \text{Log}(\text{IT Investment})_t + \beta_2 \text{Log}(\text{Organizational Performance})_t + \beta_3 \text{Log}(\text{Firm Age})_t + \beta_4 \text{Log}(\text{Services Offered})_t + \beta_5 \text{Log}(\text{Percent Medicaid})_t + \epsilon_2 \]

\[ \text{Log}(\text{Human IT Resources})_t = \gamma_0 + \gamma_1 \text{Log}(\text{Human IT Resources})_{t-1} + \gamma_2 \text{Log}(\text{IT Investment})_t + \gamma_3 \text{Log}(\text{Firm Age})_t + \gamma_4 \text{Log}(\text{Services Offered})_t + \gamma_5 \text{Log}(\text{Percent Medicaid})_t + \epsilon_3 \]

\[ \text{Log}(\text{Organizational Performance})_t = \zeta_0 + \zeta_1 \text{Log}(\text{Human IT Resources})_t + \zeta_2 \text{Log}(\text{Technological IT Resources})_t + \zeta_3 \text{Log}(\text{Organizational Resources})_t + \zeta_4 \text{Log}(\text{Firm Age})_t + \zeta_5 \text{Log}(\text{Services Offered})_t + \zeta_6 \text{Log}(\text{Percent Medicaid})_t + \epsilon_4 \]

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