Closing the Loop:
An Empirical Investigation of Causality in IT Business Value

Abstract

Researchers have established that information technology (IT) can improve firms' productivity. Whether improved productivity leads to additional investment in IT, however, remains largely uninvestigated. In this paper, we consider whether the relationship between productivity and subsequent IT investment might be positive, negative, or ad hoc, and hypothesize that this relationship is positive. We analyze seven years of panel data from 1,223 healthcare firms and present empirical evidence supporting our hypothesis. When our finding is combined with extant research, it becomes reasonable to propose that unidirectional causality does not fully describe the process of IT business value creation. Instead, we argue that existing static models of IT business value with unidirectional causality can be recast as dynamic models that explicitly incorporate multiple time periods and a positive feedback relationship to more accurately capture the complexity of this process. The creation of IT business value can thus be understood as a positive feedback model where productivity in a given time period leads to IT investment in a future time period, where IT investment builds the stock of IT inputs, and where those IT inputs then impact productivity, beginning the cycle anew.

Keywords: business value of IT, productivity, causality, longitudinal, healthcare, panel data

INTRODUCTION

What is the relationship between IT investment and an organization's productivity? The importance of this question is illustrated by the fact that approximately $3.7 trillion was spent worldwide on IT in 2013, with continued growth averaging 3% per year expected through 2018 (Gartner, 2014). Given these levels of investment and expenditure, IT leaders need to understand the relationship between IT investment and productivity, and be able to articulate to senior management the ways in which these variables impact the firm over time. The relationship between IT and productivity has been an important research agenda for over two decades (Bender, 1986; Cron and Sobol, 1983). Numerous review articles (Brynjolffson and Yang, 1996; Dehning and Richardson, 2002; Kohli and Devaraj, 2003; Kohli and Grover, 2008; Melville et al., 2004), and special issues of academic journals indicate that this topic continues to draw considerable interest (Clemons et al., 2004; Fichman et al., 2008; Fichman et al., 2011; Mahmood et al., 2004; Mahmood and Mann, 2000).

In spite of the work that has been done, questions about the process of IT business value creation still remain (Brynjolfsson and Hitt, 2000; Chang and Gurbaxani, 2012; Devaraj and Kohli, 2000b; Tambe and Hitt, 2012, 2014). One of the most important of these questions is the question of causality. By now it is well established that investments in IT can lead to improvements in productivity (Brynjolfsson and Hitt, 1996; Kohli and Devaraj, 2003). But what is the influence of improved productivity on subsequent IT investment? It may be the case that IT investment drives productivity *and* that productive firms are then able to invest more in IT. To investigate this issue of causality, we consider rationales for three possible scenarios: that productivity *positively* influences subsequent investment in IT, that productivity *negatively* influences investment in IT, or that investment in IT is *ad hoc* rather than related to prior productivity levels. Drawing upon economic theory, we hypothesize the positive causal relationship, namely that increases in productivity in a given time period lead to increases in IT investment in future time periods.

By coupling our arguments and our empirical findings with extant research into IT business value, we are able to make two contributions to IS literature. First, we help bring clarity to the equivocal results

provided by existing examinations of causality in IT business value. As we investigate a large, longitudinal dataset, we perform statistical tests explicitly designed to determine causality, and find support for positive feedback from productivity in one time period to IT investment in the next. Second, we integrate our results with prior research findings as we propose and describe a comprehensive, dynamic model of IT business value creation.

The paper proceeds as follows. We begin by reviewing IT business value literature and note that the influence of productivity on subsequent IT investment is largely unresearched. In the Hypothesis Development section, we consider the question of causality and argue for a positive relationship, one where productivity gains in a given time period influence a firm to increase investment in IT in future time periods. The Methods section describes our seven-year panel of data from 1,223 firms in the healthcare industry, our variables, and the measurement of those variables. There, we also describe the econometric techniques that we use to test our hypothesis. In the Results section, we note strong support for our hypothesis. Our hypothesis is supported by analysis of our entire dataset as well as when different subsets of organizations are examined. In the Discussion section, we highlight that our empirical results can be combined with foregoing research to re-cast existing static models of IT business value as dynamic models that explicitly incorporate multiple time periods and a feedback relationship. The limitations of our study and potential directions for future research appear in the discussion section as well.

BACKGROUND AND THEORY

The Influence of IT on Firm Performance and Productivity

The investigation of how IT impacts firm performance and productivity has been and continues to be a topic of interest to researchers. Early studies in the 1980s and 1990s identified the "productivity paradox," a phenomenon where investments in IT failed to produce expected benefits in terms of increased productivity or performance (Brynjolfsson, 1993; Strassman, 1997; Weill, 1992). The remediation of measurement and modeling issues during the late 1990s, however, allowed researchers to start observing the positive impact of IT on productivity and performance. A series of papers found clear evidence of the

beneficial effects of IT for organizations and laid the "productivity paradox" to rest (Brynjolffson and Yang, 1996; Brynjolfsson and Hitt, 2000; Dewan and Min, 1997). Several reviews of this phase of research summarize the key findings and methodological advances that enabled researchers to identify the productivity and performance gains attributable to IT (Brynjolffson and Yang, 1996; Mahmood et al., 1999; Sircar et al., 1998).

This research stream has continued to evolve. Some researchers have begun to study the impact of specific types of information systems on performance and productivity (Aral et al., 2006b; Hendricks et al., 2007; Hitt et al., 2002b; Lee and Choi, 2003b). Other researchers have proposed a number of models and frameworks to investigate the impact of IT on performance and productivity (Kumar, 2004; Santhanam and Hartono, 2003; Thatcher and Oliver, 2001; Thatcher and Pingry, 2004). Still others have focused on factors that may catalyze IT investment, such as business process re-engineering (Devaraj and Kohli, 2000b), corporate diversification (Chari et al., 2008), organizational transformation (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000; Milgrom and Roberts, 1990), and organizational learning (Tippins and Sohi, 2003). Researchers have also emphasized several aspects of contract design to capture the business value of IT investments (Wu et al., 2013). Each of these studies has shown similar results: the impact of IT on performance and productivity may be affected by contextual factors beyond merely the information system or technology that is being purchased, implemented, or utilized.

More recent work has questioned whether rapid technological progress has altered the nature of IT as a production factor (Chwelos et al., 2010) and whether returns to IT are diminishing because of common standards for IT infrastructure (Bardhan et al., 2013; Bhatt and Grover, 2005; DosSantos et al., 2012). Researchers have also examined the impact of IT investments on intangible outputs such as innovation and knowledge creation (Kleis et al., 2012). Still others have examined the presence and effects of IT spillovers (Chang and Gurbaxani, 2012), as well as their associated measurement issues (Tambe and Hitt, 2014). Within this research, the question of causality has been raised (Tambe and Hitt, 2014), with particular attention paid to whether IT investments lead to improved productivity, or if the reverse is true. It is to this specific issue of causality that we now turn.

The Effect of Productivity on Subsequent IT Investment

Early work in the study of IT business value (Cron and Sobol, 1983; Gold, 1964; Kriebel and Raviv, 1980; Lucas, 1975a, b; Roach, 1989) led to a preliminary exploration of the question of reinvestment. An early model proposes a circular relationship in the form of a positive feedback loop where IT investment improves firm performance, which in turn enables additional IT investment in future time periods (Weill, 1992). Empirical evidence, however, only partially supports a positive association between performance in a given year and IT investment in the subsequent year. Three types of IT investments are examined in the testing of this early model, with "transactional IT" significantly associated with the previous year's performance, but neither "strategic IT" nor "informational IT" displaying any relationship (Weill, 1992). Elsewhere, a study of knowledge management (KM) systems presents a conceptual model that describes how KM systems produce an organizational performance payoff that, in turn, stimulates positive feedback to initial enablers, processes, and intermediate outcomes (Lee and Choi, 2003b). This feedback relationship is not, however, part of that study's research model and not empirically tested.

An additional study examining the direction of causality in IT business value creation has been conducted in the context of enterprise software systems. These researchers find that ERP usage improves organizational performance and productivity, which enables the subsequent adoption and use of SCM and CRM systems, which further improve performance and productivity (Aral et al., 2006a). The study found that ERP purchase events are not correlated with improved performance, but that go-live events are. This indicates that ERP usage, rather than simply purchase, contributes to improved performance. Further, the study found that both purchase and go-live events for CRM and SCM systems are positively correlated with performance and productivity. This finding implies that firms that experience improved performance from ERP systems make follow-on investments in these additional systems, creating a "virtuous cycle" of IT investment in enterprise systems. While this third study comes closest to empirically addressing the issue of causality, it is limited in that it only examines enterprise systems. It is difficult to generalize from this study as ERP, SCM, and CRM systems are often viewed as components of enterprise software suites, and are planned for sequential implementation from the outset.

The investigation of causality has since become more direct, with researchers expressing a concern that the rate of return for IT investments in extant work may distorted due to reverse causality (Tambe and Hitt, 2012). One approach to this has been to develop new datasets and employ generalized method-of-moments (GMM) estimators in data analysis. This approach, nevertheless, is primarily a refinement of the traditional production function approach and seeks to eliminate the influence of reverse causality in productivity estimates rather than establish its role and incorporate it into a theoretical model.

In sum, causality has been explored, but equivocal or inconclusive results have been found. In one study, a given year's performance was associated with only certain types of subsequent IT investment (Weill, 1992). In another study, positive feedback from productivity gains to initial conditions was proposed, but not tested (Lee and Choi, 2003a). And while performance and productivity benefits arising from enterprise systems led to follow-on investments in other enterprise modules (Aral et al., 2006a), this study contradicts an earlier one that fails to find support for the idea that strategic IT systems such as CRM systems improve productivity (Weill, 1992). Ultimately, foregoing studies fail to conclusively answer the questions of reinvestment and causality. Additional work is needed to clarify causality in theoretical explanations of IT business value creation.

HYPOTHESIS DEVELOPMENT

To address the issue of causality, we consider three possible scenarios: that productivity positively influences subsequent investment in IT, that productivity negatively influences investment in IT, and that the decision to invest in IT is ad hoc and not systematically related to prior productivity. We will argue that the rationale for productivity's positive influence on subsequent investment is more consistent than the other two rationales, and therefore the positive rationale generally outweighs the others, if they occur at all.

Positive Relationship between Productivity and Subsequent IT Investment

We argue that IT investment is a function of productivity in the previous time period. The outline of our argument is (1) improved productivity in one time period increases a firm's financial resources, thus enabling greater investment in subsequent periods, (2) firms decide on the level of investment in the various

inputs to production based on the observed contribution of those inputs in previous time periods, (3) IT is consistently an attractive investment alternative, and (4) increases in resources from IT-related productivity gains flow to subsequent investments in IT. We elaborate on these points in the following paragraphs.

First, improved productivity in one period is an enabler of greater investment in subsequent periods, including investment in IT. When organizational productivity improves, by definition a firm is producing more output per unit(s) of input(s). The result is either that financial resources are conserved because fewer inputs are being purchased or that the additional output can be sold to generate additional financial resources. In either case, after production ceases in that time period, the firm has increased financial resources that can be invested in factors of production for the next time period. In the context of IT, when productivity improves as a result of the application of IT factors of production such as IT labor, IT capital, or IT systems, the financial resources available to potentially invest in IT in future time periods increase.

Second, firms must routinely decide on the level of investment in the various inputs to production. Indeed, every period of time presents a firm with three decisions: (1) whether to exit or continue operation, and if the firm chooses to continue, (2) what factors of production should be invested in, and (3) at what level should the factors of production be invested in (Olley and Pakes, 1996). Firms make the latter decision based on expectations about productivity at the conclusion of the present time period (Olley and Pakes, 1996). They also make this decision based on observed productivity in previous time periods, an idea we introduce here. After a firm decides about the level of investment in inputs to production for a given time period, those investments are made and the inputs are actually purchased. The level of inputs to production is thus determined based on both previously-existing inputs as well as inputs that have been purchased through new investment (Hulten, 1992; Jorgenson, 1966; Olley and Pakes, 1996; Solow, 1962).

Third, IT is consistently an attractive investment alternative. IT that helps the firm execute its business transactions provides a way for firms to substitute capital for labor. Investments in labor-saving IT are positively and significantly associated with the previous year's performance (Weill, 1992). Thus, the substitution of IT capital for labor (Dewan and Min, 1997) is one of the forces that favors the positive

feedback loop. Realized returns on IT capital in the form of reduced labor costs provide a clear and consistent rationale for reinvestment.

Another rationale for investment in IT is that information itself provides value to the organization in several ways that enable increased productivity (Bulkley and Van Alsytne, 2005). One way in which information enables increased productivity is that information reduces uncertainty. This reduction in uncertainty improves resource allocation, improves decision-making, and reduces delay costs (Cyert and March, 1963; Galbraith, 1973). Information, and particularly the analysis of that information, has the effect of reducing risk, enabling firms to quickly make suitable, well-timed decisions (Arrow, 1962; Stiglitz, 2000). IT can also improve productivity by enabling the sharing of procedural knowledge, which improves efficiency (Szulanski, 1996). Knowledge management systems represent one specific application of this theoretical assertion, the use of which has been proposed to stimulate positive feedback in IT business value (Lee and Choi, 2003a). Thus, substituting IT capital for labor, reducing uncertainty, and gaining efficiency through sharing knowledge are the reasons that entice firms to reinvest returns to IT.

Finally, increases in resources from IT-related productivity gains flow to subsequent investments in IT. While productivity gains arising from IT would have to compete with other (non-IT) investment opportunities, IT developers have, to date, offered advancements at a very rapid rate, ensuring that IT would be a vigorous competitor to other investment opportunities (McAfee and Brynjolfsson, 2008). Furthermore, when organizations observe that improvements in productivity result from investment in IT, they have an incentive to reinvest those returns to IT and follow-on investments are likely. They can choose additional investments that will build upon or complement the capabilities delivered by the earlier IT investment (Aral et al., 2006a; Weill, 1992). More generally, it is rational and logical that when organizations can clearly observe the productivity gains from their IT systems, reinvestment should take place.

Negative Relationship between Productivity and Subsequent IT Investment

Next we consider possible reasons that IT-related improvements in productivity might negatively influence future investment in IT. We will argue that these reasons, if they occur at all, are temporary. For example, it is conceivable that highly productive firms may have developed successful ways to manage IT and thus

may not feel the need for high levels of additional IT investment in the short run. A firm with higher IT-derived productivity measures than are standard in that firm's industry could be tempted to scale back future IT investment. For example, infrastructure that is fully installed and operational can yield quantifiable improvements in productivity over a long time horizon (Weill and Broadbent, 2000). Thus, a large infrastructural investment at a single point in time may yield enough productive benefit that subsequent investments may not seem necessary in the short term. It has been empirically shown that the productivity benefits of investments in IT capital continue to manifest themselves as long as seven years after the initial investment (Brynjolfsson and Hitt, 1998, 2003). Such firms could identify productivity gains from IT investment and opt to reap the return on their investment rather than immediately reinvest those gains.

While such conditions for a negative relationship between productivity and subsequent IT investment might occasionally manifest themselves in an individual firm at a point in time, such conditions do not provide a consistent, long-term motive when compared to the forces that encourage a positive relationship, as presented in the prior sub-section. Moreover, we are unaware of any empirical or conceptual work that suggests possible negative feedback to productivity. Rather, researchers have observed broad and sustained growth in productivity, in IT investment, and in IT stocks over the past two decades (McAfee and Brynjolfsson, 2008).

Ad-hoc Relationship between Productivity and Subsequent IT Investment

There are several possible scenarios that could lead to ad-hoc investment decisions depending on the particularities of the firm. For instance, a firm's IT maturity might impact its future IT investment (Karimi et al., 1996). Firms' IT investments are determined by how mature, prepared, or equipped they are to assimilate and utilize a particular type of IT. Firms that are planning to increase IT investment "tend to have achieved a higher degree of IT integration, organization, and control" (Karimi et al., 1996, p. 73). Thus, IT investment decisions may be driven by the firm's evaluation of its own maturity, and not by economic analysis of a technology and its benefits. Alternatively, IT adoption has been observed to occur in fads, where significant bandwagon effects are observed (Swanson and Ramiller, 2004). Very simply, IT investment decisions may at times be more driven by what is taking place among competitors and peer

firms than by an analysis of the realized benefits of already-implemented IT, or by an organization's ability to derive value from IT. Finally, IT investment may occasionally be influenced by government regulations or strategic initiatives that are unique to a given firm. The United States' Sarbanes-Oxley legislation and the Health Insurance Portability and Accountability Act (HIPAA) have necessitated IT investment quite apart from previous productivity gains. Also, within a particular firm, IT may be the highest investment priority in one period, while another strategic need may take precedence in another period.

In sum, IT investment decisions may not always be based exclusively on evaluations of prior productivity, but may instead be based on an assessment of the firm's IT maturity, or on a variety of unpredictable and idiosyncratic factors such as bandwagon phenomena, government decrees, or firm-specific strategic considerations. We observe, however, that the conditions for these ad hoc investment decisions are neither persistent nor systematic. Furthermore, the existence of such conditions does not in any way invalidate the fact that rational decision-making at firms indicates that the productivity of IT investments will be evaluated when considering future investments. Thus, when compared to the negative or ad hoc relationship, we find the logic of a positive feedback loop more compelling. The forces that favor the positive relationship remain consistent, while the factors leading to the negative or ad hoc relationships are more idiosyncratic and temporary. For these reasons, the following hypothesis is presented.

HYPOTHESIS 1: *Productivity in a given time period positively influences the level of IT investment in the subsequent time period.*

METHODS

Data Source

The context for our study is the healthcare industry. Data were collected from the HIMSS Analytics Database[1] for the years 1998 through 2004. We have chosen the years 1998 – 2004 because this time period

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[1] HIMSS Analytics is an organization that tracks growth and change in the use of information technology in the healthcare industry. The database is comprehensive and updated each year, presenting 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. Healthcare systems are business

was free from major macroeconomic shocks that could lead to idiosyncratic results. Also, this time period represents several years of growth in IT investment (McAfee and Brynjolfsson, 2008; WITSA, 2008) and thus is a reasonable time period in which to study the outcomes of such investment. Our unit of analysis is the healthcare system. The annual number of healthcare systems included in the database ranges from 1,467 to 1,391, with an average value of 1,435. Of these firms, 1,223 (85%) provided information on all measured variables in two or more consecutive years and were included in our sample. With each of the 1,223 firms reporting data in multiple years, our panel contains a total of 3,929 firm-year observations[2].

Measurement of Variables

The primary independent variable in our study is productivity (Q). 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), Return on Sales (ROS), labor productivity, inventory turnover, profit margin, asset utilization, collection efficiency, and value added (Hitt and Brynjolfsson, 1996; Kohli and Devaraj, 2003). Revenue-based measures of productivity (rather than profit-based measures) are more appropriate in healthcare contexts because most healthcare systems operate on a nonprofit basis (Devaraj and Kohli, 2000a, 2003; Menachemi et al., 2006; Menon et al., 2000). Using these precedents as a guide, we will construct our proxy for productivity upon the basis of net revenue.

Here, we note the importance of controlling for the effect of organizational size when selecting proxies for this and other variables (Kimberly and Evanisco, 1981). Without controlling for size, the effect of this potentially confounding variable cannot be ruled out. Because size has been recognized as being potentially influential in similar studies, size-independent measures, such as revenue per day or revenue per admission (Devaraj and Kohli, 2000a, 2003) as well as net inpatient revenue per bed per day and net patient revenue

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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.
[2] Our 3,929 firm-year observations out of a possible 10,045 (seven years * 1,435 firms) represents 39% of the possible firm-year observations. This percentage compares favorably to an earlier study that was able to utilize only 23.3% of its possible firm-year observations (Hitt, Wu, and Zhou 2002).

per bed per day (Menachemi et al., 2006), have been used. On the basis of these precedents, several measures of size may be justifiably chosen as a divisor for revenue, including 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). The result of dividing revenue by some measure of size would be to create a size-controlled proxy for productivity. 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. Thus, the proxy we construct to measure productivity is revenue per physician. Labor productivity measures similar to this one have been used in several other IT business value studies (Aral et al., 2006a; Black and Lynch, 2001; Hitt et al., 2002a; Mukhopadhyay et al., 1997). Healthcare systems that generate more revenue per physician will be understood to be more productive than those that generate less revenue per physician.

Our proxy for IT Investment (IT-I) 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 (e.g. (Bresnahan et al., 2002; Brynjolfsson and Hitt, 1996; Devaraj and Kohli, 2000a; Dewan and Min, 1997; Menon et al., 2000)). While IT investment has been infrequently examined in studies of IT business value, we include it here as our dependent variable in order to examine the direction of causality in IT business value creation. Again, we recognize that the total operating budget for the IT department is likely to be correlated with organizational size, so we have divided the amount of the operating budget that is devoted to IT by the number of physicians, just as we have done with our proxy for Q. Thus, our size-controlled proxy for IT-I is the dollar amount of the total operating budget devoted to IT, divided by the total number of physicians in the healthcare system.

Several control variables have been included as well. The type of services offered by the healthcare system may play a role in determining the way a healthcare firm chooses to reinvest its productivity gains. The type of services offered may also influence the amount of revenue the healthcare system generates, our primary independent variable. For instance, an acute care facility could generate substantially more revenue per physician than a walk-in clinic or hospice facility. For this reason, we have included the number of services offered (SVCS) as a control variable. We have included the percentage of revenue from Medicaid (MDCD), and the percentage of revenue from Medicare (MDCR). Healthcare systems that primarily serve the elderly, indigent, uninsured, or underinsured populations that benefit from Medicare and Medicaid may earn relatively less in revenue than healthcare systems that do not serve these populations. We have also included the age of the healthcare system (AGE) as a control variable as well. These control variables: SVCS, MDCD, MDCR, and AGE, are often included as controls in studies of healthcare organizations (Devaraj and Kohli, 2000a, 2003; Menachemi et al., 2006). Each of these control variables are size-independent, as are our dependent and independent variables listed earlier. Finally, we have included the number of facilities in each healthcare system (FCLT) as an additional control variable to check for the effect of organizational size on our results. This variable is a count of the number of locations within a given healthcare system where medical treatments and related services are delivered. Each of our variables, the definition of its proxy, and its basis in literature are summarized in Table 1.

Table 1
Variables and Definitions

Variable Name	Proxy Definition	Precedent
Variables		
Q (Productivity)	The healthcare 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	(Devaraj and Kohli, 2000a, 2003; Menachemi et al., 2006; Menon et al., 2000)
IT-I (IT Investment)	The dollar amount of the healthcare system's total operating budget devoted to IT, divided by the total number of physicians in the healthcare system	(Ray et al., 2005)
Control Variables		
AGE (System Age)	The number of years since the healthcare system was founded	(Kimberly and Evanisco, 1981)

SVCS (Services Offered)	The number of services offered by the healthcare system (acute care, sub-acute care, ambulatory care/physician office care/clinical care, home health/hospice care, affiliated physician organization management, other owned businesses management, owned payor component management) - a discrete measure ranging from one to seven where one indicates one service offered, two indicates two services offered, and so forth.	(Devaraj and Kohli, 2000a)
MDCD (Percent of Revenue from Medicaid)	The percentage of patient revenue the healthcare system receives from Medicaid	(Devaraj and Kohli, 2000a; Menachemi et al., 2006)
MDCR (Percent of Revenue from Medicare)	The percentage of patient revenue the healthcare system receives from Medicare	(Devaraj and Kohli, 2000a; Menachemi et al., 2006)
FCLT (Number of Facilities)	The number of facilities [i.e. the number of locations] within a given healthcare system where medical treatments and related services are delivered	

Descriptive Statistics and Diagnostics

To address potential non-normality and heteroscedasticity in the data, the natural logarithm transformation was used on each of our independent variables. Descriptive statistics for both log-transformed as well as raw data appear in Table 2. Correlations appear in Table 3. The vast majority of the correlations are well below the general guideline of 0.30. The exception is the correlation between Log(Q) and Log(IT-I) of 0.79. Correlation between independent and dependent variables does not violate any regression assumption and should not be a reason to question the analysis. To further check whether correlation between any of the independent variables affects the statistical results, variance inflation factors (VIFs) were calculated. The mean VIFs range from 2.52 to 1.05 with a mean of 1.73. This number is well below the value of 10 that is commonly taken as an indicator of excessive multicollinearity.

Autocorrelation potentially exists in any longitudinal dataset and when it is present, it lowers the efficiency of the estimates, but does not affect their consistency (Dewan and Min, 1997; Greene, 2003). One remedy for autocorrelation is to first-difference the data when a variable is autocorrelated at a level of 0.80 or higher (Wooldridge, 2006). Neither of our research variables exceeds this threshold.

Table 2
Descriptive Statistics

Variable	Mean	Std Dev	Minimum	Maximum
IT-I	16,494	292,736	0	22,600,000
Q	655,960	8,534,667	0	694,000,000

SVCS	4.30	1.39	1	7
MDCD	0.14	0.16	0.00	0.99
MDCR	0.30	0.21	0.00	0.95
AGE	51.05	39.15	0	201
FCLT	22.69	58.68	1	1841
Log (IT-I)	8.98	0.97	1.33	16.93
Log (Q)	12.89	0.79	5.34	20.36
Log (SVCS)	1.39	0.39	0.00	1.95
Log (MDCD)	-2.05	0.88	-6.21	1.95
Log (MDCR)	-1.14	0.76	-6.91	3.73
Log (AGE)	3.46	1.17	0.00	5.30
Log (FCLT)	2.46	1.04	0.00	7.52

Table 3
Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) IT-I	1.00													
(2) Q	0.98	1.00												
(3) SVCS	0.00	0.01	1.00											
(4) MDCD	-0.01	0.00	-0.25	1.00										
(5) MDCR	0.00	0.00	0.12	-0.66	1.00									
(6) AGE	-0.02	-0.03	-0.13	0.04	-0.03	1.00								
(7) FCLT	0.02	0.02	0.32	-0.07	-0.06	-0.16	1.00							
(8) Log (IT-I)	0.18	0.19	0.14	0.03	-0.06	-0.03	0.11	1.00						
(9) Log (Q)	0.21	0.25	0.06	0.08	-0.01	-0.02	0.06	0.79	1.00					
(10) Log (SVCS)	0.01	0.01	0.97	-0.24	0.11	-0.11	0.29	0.15	0.07	1.00				
(11) Log (MDCD)	-0.01	0.00	-0.21	0.89	-0.54	0.02	-0.04	0.05	0.12	-0.20	1.00			
(12) Log (MDCR)	0.00	0.00	0.13	-0.64	0.89	-0.05	-0.02	-0.04	0.00	0.12	-0.52	1.00		
(13) Log (AGE)	-0.03	-0.04	-0.17	0.05	-0.01	0.89	-0.22	-0.05	-0.02	-0.13	0.02	-0.04	1.00	
(14) Log (FCLT)	0.03	0.03	0.66	-0.14	-0.08	-0.17	0.69	0.24	0.13	0.66	-0.11	-0.04	-0.25	1.00

Model Estimation

We have hypothesized that $IT\text{-}I_t = f(Q_{t-1})$. To test this hypothesis, we employ a series of econometric

procedures. First, we perform time series regression on the following equation:

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\begin{aligned}
Log(IT\text{-}I)_t = {}& \alpha_0 + \alpha_1 Log(Q)_{t-1} \\
& + \alpha_2\, Y1999 + \alpha_3\, Y2000 + \alpha_4\, Y2001 + \alpha_5\, Y2002 + \alpha_6\, Y2003 + \alpha_7\, Y2004 \\
& + \alpha_8 Log(SVCS)_t + \alpha_9 Log(MDCD)_t + \alpha_{10} Log(MDCR)_t + \alpha_{11} Log(AGE)_t + \alpha_{12} Log(FCLT)_t \\
& + \varepsilon_I
\end{aligned}
\tag{1}
$$

Both random-effects (RE) and fixed-effects (FE) specifications will be presented. RE models estimate

explanatory variables under the assumption that any unobserved effects have a zero mean, are uncorrelated

with the explanatory variables in all time periods, and thus do not influence the estimates. If this assumption does not hold, FE models, which produce unbiased and consistent estimates even when unobserved effects are present, are preferred. It is common to estimate equations with both RE and FE, and then formally test for statistically significant differences in the coefficients (Wooldridge, 2006). We will therefore present both RE and FE models as well as results of the Hausman test to check the assumptions of the RE model. If the Hausman test rejects the null hypothesis that unobserved effects have a zero mean, the FE results will be preferred.

Causality

In addition to the aforementioned estimation methods, we also perform a Granger causality test, an econometric procedure for identifying causal direction (Devaraj and Kohli, 2003; Granger, 1969; Greene, 2003; Marvell and Moody, 1996), to check the specification of our model and clearly identify the direction of causality. Granger causality tests have been developed in an effort to help researchers infer causality from associative relationships in data (Granger, 1969). In time series analysis, variable x can be said to Granger-cause y if past values of x are useful for predicting y. This causal relationship is shown by regressing lagged values of x on y and then performing F-tests on the lagged values of x to see if those lagged x values are jointly significant predictors of y. After performing these tests, the lagged values of y are regressed on x to see if y may also Granger-cause x. It may be the case that x Ganger-causes y and that y Granger-causes x. A clearer story emerges, however, when the researcher can definitively state that x Granger-causes y, but that y does not Granger-cause x (or vice-versa).

It is precisely this type of causality that we propose: that productivity in a given time period (Q_{t-1}) causes IT investment in the next time period (IT-I$_t$) – and not vice-versa. The Granger causality test involves two separate autoregressive analyses. First, we regress IT-I on lags of itself and on lags of Q. If an F test indicates that the lags of Q are jointly significant, then we can state that Q Granger-causes IT-I (which would support our hypothesis). Second, we regress Q on lags of itself and on lags of IT-I. Again, if an F test indicates that the lags of IT-I are jointly significant, then we would state that IT-I Granger-causes Q. Such a result would provide evidence of causality in the opposite direction we have hypothesized.

Granger-causality in both directions would indicate bidirectional causality and provide evidence against our hypothesis. Statistical tests and model estimation are performed with the STATA software package.

RESULTS

Model Estimation

We find strong support for our hypothesis that performance causes subsequent investment in IT, with no support for causation in the opposite direction. As Table 4 shows, Q_{t-1} is positively and significantly related to IT-I_t. This result, which is consistent across both the fixed-effects (FE) and random-effects (RE) models, provides support for the primary argument of this paper, namely that increases in productivity (Q) in a given time period lead to increases in IT investment (IT-I) in future time periods.

There are slight differences between the FE and RE models. First, the χ^2 value given by the Hausman test indicates that the RE model assumption that the unobserved effect has a zero mean is questionable. The correlation between the error term and the fitted values is measured as 0.23. However, even if the assumption of the RE model is questionable, the effect of Q_{t-1} on IT-I_t in the FE model is still positive and very highly significant. Second, the R^2 for the FE model is lower than for the RE model. Nevertheless, both models clearly show significant effects of Q_{t-1} on IT-I_t. Thus, our hypothesis is strongly supported.

Table 4
Model Estimation [a, b] (N = 3,937)

Dependent Variable	Independent Variable or Control Variable	FE[c]	RE[d]	Result
Log (IT-I) $_t$	Log (Q)$_{t-1}$	.101*** (.020)	.257*** (.017)	H1: Supported
	Log (SVCS)$_t$	-.075 (.078)	-.007 (.058)	
	Log (MDCD)$_t$	-.043 (.027)	-.011 (.020)	
	Log (MDCR)$_t$	-.030 (.028)	-.011 (.021)	
	Log (AGE)$_t$	-.001 (.020)	-.001 (.014)	
	Log (FCLT)$_t$	.004 (.041)	.178*** (.024)	
		R^2=.111	R^2=.267	
		$\chi^2_1 = 886.92$***		

* p < . 05; **p < .01; ***p < .001

It is common in management literature to look for size effects by subdividing a sample of firms into several subsets. Therefore, after testing our hypothesis, we also explored whether our hypothesis holds for small, medium, and large healthcare systems (defined in terms of number of employees); healthcare systems with low, moderate, or high levels of IT spending (defined in terms of the percentage of operating budget spent on IT); and healthcare systems with various levels of revenue (healthcare systems from our sample were placed into quartiles and our hypothesis was tested for each quartile). This supplemental analysis provides additional support for our hypothesis, with 16 of 20 additional tests of our hypothesis indicating a positive and significant relationship. Details appear in Appendix A.

Causality

We conducted the initial analysis of whether Q Granger-causes IT-I with three lags for each variable. We then chose to drop the third year lag for Q because it was not significant and because the level of the *F* test did not decline after dropping it. Thus, we tested three lags for IT-I and two for Q. The lags for Q were jointly significant predictors of IT-I ($\chi^2_2 = 32.63$, p < .0001), indicating that Q Granger-causes IT-I. The test of whether IT-I Granger-causes Q also began with three lags for each variable, dropping the third lag for IT-I because it was not significant and because the level of the *F* test did not decline after dropping it. This resulted in three lags for Q and two lags for IT-I. Here, it cannot be stated that IT-I Granger-causes Q ($\chi^2_2 = 4.04$, p = .133). The Granger causality test thus supports our assertion that increases in productivity (Q) in a given time period lead to increases in IT investment (IT-I) in future time periods. In summary, we state that significant results, in the hypothesized direction, are found for all tested relationships and with various lag structures[3].

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[3] This test also provides some insight into the issue of how many lags might be used in a regression model when examining IT business value. The initial tests of our hypothesis used only a one-year lag; these Granger causality tests use two- and three-year

Control Variables

Among the control variables included in our model, only FCLT may play a role in determining the level of IT-I. FCLT is significant in slightly less than half of the analyses we perform (including those in Appendix A). This can be interpreted to mean that, *ceteris paribus*, a healthcare system with more individual facilities (i.e. more locations where medical care is delivered) will invest more money in IT per physician than will a healthcare system with fewer facilities. This result is not surprising when realizing that a healthcare system with a relatively high number of facilities will need to invest in information technology to connect facilities, coordinate operations, and enable collaboration among staff and physicians. Furthermore, larger organizations are more likely to realize economies of scale and scope that result from IT investment across the enterprise. In light of these arguments, we do not believe that the significance of FCLT in some analyses should in any way call our results into question.

DISCUSSION

We have presented robust empirical support for the idea that productivity in a given time period influences the level of IT Investment in the subsequent time period. In further analysis, we have shown that productivity Granger-causes IT investment. As we discuss these results, we will describe the implications of the finding that productivity Granger-causes IT investment; we will also describe the implications of the unsupported relationship, namely that IT investment does not Granger-cause productivity.

Theoretical Implications

As we have noted, the primary empirical finding of this paper is that productivity Granger-causes IT investment. By presenting this empirical evidence, and by demonstrating the direction of causality in this relationship between productivity and IT investment, we go beyond earlier research that fails to find support for positive feedback in the creation of IT business value (Weill, 1992), research that proposes feedback

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lags. No significant relationships were found with lags greater than two years. For additional information on sustained effects of IT investment over time, see Brynjolfsson and Hitt (1998, 2003), Devaraj and Kohli, (2000a), and Santhanam and Hartono (2003).

but does not test for it (Lee and Choi, 2003a), research that examines feedback limited to enterprise systems (Aral et al., 2006a), and research that guards against reverse causality but fails to incorporate it into a theoretical model (Tambe and Hitt, 2012). We test for feedback and find support for it, building on earlier work in IT business value that emphasizes the importance of investigating time lags in data (Devaraj and Kohli, 2000a) and responding to a stated need to directly examine reverse causality (Tambe and Hitt, 2012). This leads us to consider what variables might be included in a model of IT business value and how those variables might be linked.

We have failed to find support for the idea that IT investment Granger-causes productivity. Rather than reviving the productivity paradox, we argue that this result indicates the presence of variables that must mediate the relationship between investment and productivity. In research that formed part of the foundation for the productivity paradox, a direct link from IT investment to organizational performance was proposed and tested, but support for this link was not found (Weill, 1992). This should not be surprising in hindsight, for investment itself does not impact productivity or performance. Instead of IT investment directly affecting productivity, IT investment affects performance and productivity through the IT inputs that an organization can obtain. In fact, researchers have explained that IT investment allows firms to acquire IT inputs; that IT inputs bring about IT impacts; and finally that IT impacts alter the firm's productivity (Soh and Markus, 1995). IT investment may therefore be properly understood to be the vehicle that allows IT inputs such as IT capital and IT labor to be acquired. Indeed, research in economics explains that a firm's capital stock is a function not only of previously accumulated capital, but also, as we have stated here, of investment (Hulten, 1992; Jorgenson, 1966; Olley and Pakes, 1996; Solow, 1962).

Traditional production functions examine the transformation of inputs into outputs, stating that $Q = f(K, L)$, where Q is output, and K and L are capital and labor, respectively. In IT business value research, it is common to disaggregate capital (K) into IT capital (IT-K) and non-IT capital (simply K) (Bresnahan et al., 2002; Brynjolfsson and Hitt, 1996; Dewan and Min, 1997; Hitt and Brynjolfsson, 1996; Menon et al., 2000). The same is often done for labor (IT-L and L) (Brynjolfsson and Hitt, 1996; Menon et al., 2000). Expenditures on technological inputs such as computer hardware, a type of IT capital (IT-K), increase firms'

abilities to store, analyze, and manage data. As these activities become more efficient and effective, productivity improves (Brynjolffson and Yang, 1996; Mahmood et al., 1999; Sircar et al., 1998). Similarly, investments in IT labor allow firms to hire additional personnel or add to the skill sets of existing personnel. The cumulative knowledge and skills of the IT labor input then positively influence the productivity of firms by enabling them to work more effectively and efficiently (Byrd et al., 2004; Tippins and Sohi, 2003). Thus, investments in *IT-K* and *IT-L* increase organizations' ability to compete in the marketplace (Mata et al., 1995). The entire body of post-productivity paradox literature attests to these relationships. Thus, a portion of a dynamic model of IT business value states that $Q_t = f(K_t, L_t, IT\text{-}K_t, IT\text{-}L_t)$.

While the productivity measurement, *Q*, is in some sense a final output of the production process, we have provided evidence in this paper that *Q* can also be understood as a determinant of IT investment in the next time period ($IT\text{-}I_{t+1}$). In light of this finding, another portion of a dynamic model of IT business value states that $IT\text{-}I_{t+1} = f(Q_t)$.

The remaining variables in a dynamic model of IT business value allow us to explicate the conversion of IT investment to IT inputs. Separating IT investment from the use of IT inputs has been highlighted as a way to isolate the impact of specific types of technology on productivity and performance (Devaraj and Kohli, 2003). In addition to the theoretical advantage of identifying each variable in the model in order to clearly specify the relationship between IT and productivity, it has been stated that an "ideal" empirical solution to the question of causality would separate IT investment from the use of IT inputs (Aral et al., 2006a, p. 1820). Thus, we affirm that IT investment affects productivity only through the IT inputs that the firm acquires. The final portions of a dynamic model of IT business value then explain how IT Investment (*IT-I*) is converted to IT capital (*IT-K*) and IT labor (*IT-L*).[4] Mathematically, $IT\text{-}K_t = f(IT\text{-}I_t, IT\text{-}K_{t-1})$ and $IT\text{-}L_t = f(IT\text{-}I_t, IT\text{-}L_{t-1})$.

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[4] Note that both $IT\text{-}K_t$ and $IT\text{-}L_t$ are determined not only by $IT\text{-}I_t$, but also by the stock of *IT-K* and *IT-L* in earlier time periods. The stock of the inputs *IT-K* and *IT-L* at time *t* is built largely upon the stock those same inputs from the previous time period (Hulten 1992, Jorgenson 1966, Menon, Lee, and Eldenberg 2000, Olley and Pakes 1996, Solow 1962).

In sum, a dynamic model of IT business value states that IT inputs to production impact productivity; productivity then impacts IT investment in the next time period; and finally, IT investment enables the acquisition of additional IT inputs that begin the cycle anew[5,6]. Why do these relationships hold? As we have previously noted, in every time period firms decide on factors of production and the levels at which to invest in those factors based on expectations about productivity (Olley and Pakes, 1996). We argued that these expectations are based on previously observed levels of productivity and on the investments' productive potential.

These relationships should hold in the vast majority of organizational settings. Nevertheless, when firms do not or cannot accurately monitor their productivity, when macroeconomic shocks prevent the revinvestment of productivity gains, or when non-economic forces dictate levels of investment (such as government regulations), the links described in this model may be weakened. This model will be most likely to be observed in stable firms with moderate rates of productivity change in in developed market economies. As one moves farther from such settings, the usefulness of the model declines. Extremely rapid firm growth, economic instability, labor unrest, centralized economic planning, or open conflict would likely prevent firms from behaving in the manner described herein.

Methodological Implications

The inclusion of IT investment as distinct from IT capital and IT labor has allowed us to test for positive feedback from productivity in one time period to IT investment in the next. It has also allowed us to examine the direction of causality, a concern that has been noted by researchers (Tambe and Hitt, 2012).

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[5] A full test of this model has been conducted by the authors where they have found empirical support for these arguments and this model. Results are available upon request.

[6] This model can be applied by researchers taking an economics-based approach to the study of IT business value such as we present here – as well as by researchers who build on alternate theory bases. For instance, one paper from a non-economic theory base (the RBV) describes the "IT Business Value Model" (ITBVM) (Melville et al. 2004). The ITBVM explains that IT resources and complementary organizational resources impact business processes, which in turn impact business process performance; business process performance then influences organizational performance. The ITBVM does not, however, indicate how organizational performance affects the competitive position of the firm across time. It seems plausible that improved organizational performance would provide more abundant resources for a firm, strengthen the firm's competitive standing, and possibly re-shape industry dynamics if a firm becomes dominant within an industry. Thus, the ITBVM could be extended by making it a dynamic, multi-period conceptual model of IT business value creation.

Indeed, as we noted earlier, it has been stated that an "ideal" empirical solution to the question of causality would separate IT investment from the use of IT inputs (Aral et al., 2006a, p. 1820). The use of IT investment in studies of IT business value thus allows researchers to clearly explain this dynamic process where productivity in one time period impacts IT investment in the next time period which then dictates the level of IT inputs to production, beginning the cycle anew. The inclusion of IT investment in future studies of IT business value will allow for more detailed examinations of the process of IT business value creation in the future.

Managerial Implications

The primary managerial implication of this study is that executives and managers should evaluate their IT investments over the long run and with advanced approaches. The methods most commonly used for evaluating IT investment are still generally limited to techniques such as net present value (NPV), return on investment (ROI), return on equity (ROE), and discounted cash flow (DCF). Although such analyses are useful, reliance upon book values and discounting approaches introduces the possibility of distorting values (Brealey et al., 2005; Luehrman, 1997). Rather than simply conducting discounted cash flow analysis to justify IT investments, managers consider how investments in IT may improve organizational performance, provide gains for reinvestment, create options for future investment (Fichman, 2004), and even change the competitive dynamics of their industry. Similarly, the costs associated with IT investments may also need to be calculated by taking into account the positive externalities or "spillovers" that arise from value chain partners' and even from competitors' IT investments (Chang and Gurbaxani, 2012; Tambe and Hitt, 2014).

The application of our advice may require businesses to implement new methods of tracking the costs and benefits of their IT investments. Nevertheless, we encourage the development of such tools and techniques to analyze the value of IT investments over longer time horizons than firms may ordinarily consider, and by taking novel approaches to valuation.

Limitations and Future Research

The large, comprehensive dataset that we have analyzed for this study is a strength of the study because it allows us to examine firms of varying sizes, and because it is drawn from a period of time free from macroeconomic shocks. Nevertheless, our dataset also presents some limitations. Our analysis would benefit from information on other potential measures of organizational performance such as ROA, ROI, and ROE, which are often seen in studies of IT business value. These measures do not exist in our data. Similarly, other measures of performance that are unique to the healthcare industry such as patient satisfaction and mortality could provide a more complete picture of how IT creates business value. An additional limitation of the dataset is that a change in database administration took place after the 2004 data were collected, resulting in changes to the number and type of variables measured. Comparisons of data collected before and during 2004 with data collected after 2004 are problematic.

Several directions for future work are possible. First, replication of these findings in additional time periods would be beneficial. Our results are most likely to generalize to similar time periods of relative economic stability; however, they might not generalize to time periods where major macroeconomic shocks are observed. For instance, any IT investment research that draws data from the years 2007-2009 would need to address the effects of the global economic downturn on corporate IT budgets. It seems likely that the organizational benefits of IT investment would be difficult to observe when such investment was limited. Furthermore, some researchers have speculated that common standards for IT infrastructure in the 2010s (Bardhan et al., 2013), and rapid technological progress in general (Chwelos et al., 2010) may affect the nature of IT as a factor of production.

Second, a more detailed examination of IT business value creation in the healthcare industry could be undertaken. In this industry, the role of IT labor would likely be of great importance. Management of professionals, a class of employees that possess advanced training and specialized knowledge, 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. In settings where professionals have dominant roles, such as healthcare systems,

professional traditions may prevent behavior patterns from changing (Newman and Wallender, 1978). Because of these factors, physicians may be reluctant to embrace new technologies such as physician prescription entry, computerized patient charts, or clinical decision support. Increasing the number of personnel to help train and support healthcare system users may improve the likelihood that users will embrace new technologies.

Third, as we have implied above, the study that we have conducted here, as well as the proposed future research, could be conducted in different industries and contexts. The evidence presented here is based on analysis of the healthcare industry in the United States. Because of this, the boundary conditions of our claims should be evaluated. Future work could thus focus on different industries, different levels of analysis, or different national and cultural contexts. Such work would provide a reasonable basis for the generalization of our findings to other contexts.

Fourth and finally, the role of an organization's strategy on IT investment could be investigated as well. Researchers have examined how IT strategy and business strategy can be aligned to improve organizational performance. These studies often investigate how alignment can mediate or moderate the relationship between IT inputs and the firm's performance. Strategy could also be examined as a possible variable that may determine the type and level of investment made by firms.

CONCLUSION

In this study, we have sought to complement existing approaches to IT business value by identifying what variables might be included in such studies and by explaining how and why those variables might be related. Our emphasis on separating IT investment from IT labor and IT capital, as well as our empirical approach, have opened the way to develop a multi-time period model that includes a positive feedback relationship. The model proposed here improves on static models with unidirectional causality and challenges those that allow for bidirectional causality. Our endeavor to address one of the remaining open questions in IT business value research, the question of causality, should provide benefits to the community of business researchers and practitioners and stimulate additional research.

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APPENDIX A

Table 5 shows that organizations with less than 200 employees, with 200 to 500 employees, and with more than 500 employees all show a positive and significant relationship between Q_{t-1} and IT-I_t. Table 6, which shows the results of exploratory analysis with organizations categorized by IT budget, also lends support to our hypothesis. It shows that organizations with an IT budget of less than 2% of the overall operating budget, organizations with an IT budget of 2% to 4% of the overall operating budget, and organizations with an IT budget of more than 4% of the overall operating budget also show a positive and significant relationship between Q_{t-1} and IT-I_t. Finally, Table 7 shows that regardless of the revenue the organization brings in, a positive and significant relationship between Q_{t-1} and IT-I_t can be observed.

Table 5
Exploratory Analysis – Health Care Systems Categorized by Number of Employees [a, b]

Dependent Variable	Independent Variable or Control Variable	Small Organizations (< 200 employees).		Medium-Sized Organizations (200 - 500 employees)		Large Organizations (> 500 employees)	
		N = 168		N = 473		N = 650	
		FE[c]	RE[d]	FE[c]	RE[d]	FE[c]	RE[d]
Log (IT-I) $_t$	Log (Q)$_{t-1}$	.319** (.113)	.440*** (.079)	.071 (.077)	.429*** (.055)	.207*** (.059)	.442*** (.044)
	Log (SVCS)$_t$	-.185 (.711)	-.096 (.438)	-.430 (.295)	-.223 (.192)	-.436 (.267)	-.198 (.178)
	Log (MDCD)$_t$	-.310 (.214)	-.038 (.132)	-.182 (.099)	-.102 (.063)	-.239** (.088)	-.076 (.057)
	Log (MDCR)$_t$	-.355 (.223)	-.061 (.156)	-.094 (.116)	-.016 (.088)	-.214* (.099)	-.046 (.075)
	Log (AGE)$_t$	-.225 (.383)	-.037 (.104)	.353 (.130)	.066 (.064)	.147 (.124)	.031 (.053)
	Log (FCLT)$_t$	.577 (.444)	.495 (.282)	.347* (.188)	.236* (.117)	.427* (.167)	.339** (.109)
		R^2=.190	R^2=.329	R^2=.038	R^2=.262	R^2=.126	R^2=.290
		$\chi^2_1 = 65.80$***		$\chi^2_1 = 90.59$***		$\chi^2_1 = 198.08$***	

* $p < .05$; **$p < .01$; ***$p < .001$
[a] Constant terms and coefficients for year dummies are omitted in the interest of space,
[b] Coefficients presented with standard errors in parentheses, [c] Fixed-Effects Model, [d] Random-Effects Model

Table 6
Exploratory Analysis – Health Care Systems Categorized by IT Budget [a, b]

Dependent Variable	Independent Variable or Control Variable	Low IT Spending (< 2% of budget).		Medium IT Spending (between 2% and 4% of budget)		High IT Spending (> 4% of budget)	
		N = 1711		N = 1937		N = 289	
		FE[c]	RE[d]	FE[c]	RE[d]	FE[c]	RE[d]
Log (IT-I)$_t$	Log (Q)$_{t-1}$	.164***	.437***	-.062*	.157***	.170*	.393***
		(.030)	(.022)	(.027)	(.021)	(.077)	(.045)
	Log (SVCS)$_t$	-.067	.072	-.036	-.015	-.476	.150
		(.115)	(.071)	(.103)	(.069)	(.322)	(.129)
	Log (MDCD)$_t$	-.094	-.039	-.001	.068**	.089	.110**
		(.046)	(.027)	(.031)	(.022)	(.100)	(.042)
	Log (MDCR)$_t$	-.085	-.036	.036	.087***	.050	.081
		(.048)	(.031)	(.033)	(.023)	(.099)	(.041)
	Log (AGE)$_t$	-.004	.024	-.019	-.022	-.001	-.011
		(.033)	(.019)	(.024)	(.016)	(.059)	(.030)
	Log (FCLT)$_t$	.000	.136***	-.015	.087**	.164	.011
		(.065)	(.032)	(.050)	(.026)	(.167)	(.054)
		R^2=.256	R^2=.405	R^2=.002	R^2=.242	R^2=.185	R^2=.423
		χ^2_1 = 288.61***		χ^2_1 = 69.00***		χ^2_1 = 6.35**	

* $p < .05$; **$p < .01$; ***$p < .001$
[a] Constant terms and coefficients for year dummies are omitted in the interest of space,
[b] Coefficients presented with standard errors in parentheses, [c] Fixed-Effects Model, [d] Random-Effects Model

Table 7
Exploratory Analysis – Health Care Systems Categorized by Revenue [a, b]

Dep. Var.	Independent Variable or Control Variable	First Quartile (< $47.6 million)		Second Quartile (>$47.6 million & < $104 million)		Third Quartile (> $104 million & > $252 million)		Fourth Quartile (< $252 million)	
		N = 855		N = 1129		N = 1061		N = 884	
		FE[c]	RE[d]	FE[c]	RE[d]	FE[c]	RE[d]	FE[c]	RE[d]
Log (IT-I)$_t$	Log(Q)$_{t-1}$	.190*** (.053)	.433*** (.040)	.080 (.046)	.334*** (.035)	.109*** (.027)	.245*** (.025)	.028 (.027)	.067** (.024)
	Log(SVCS)$_t$	-.139 (.232)	.376* (.164)	-.084 (.119)	.111 (.092)	.004 (.102)	.103 (.079)	-.136 (.158)	-.033 (.116)
	Log(MDCD)$_t$	-.246** (.080)	-.021 (.057)	.005 (.050)	.021 (.034)	-.011 (.042)	.041 (.028)	.020 (.036)	.040 (.031)
	Log(MDCR)$_t$	-.184* (.090)	.062 (.072)	.035 (.055)	.048 (.042)	-.014 (.042)	.033 (.027)	-.017 (.037)	.026 (.031)
	Log(AGE)$_t$	-.100 (.075)	.080 (.047)	.019 (.035)	.029 (.025)	-.015 (.028)	-.006 (.020)	-.026 (.031)	-.018 (.023)
	Log(FCLT)$_t$	.245 (.144)	-.272** (.089)	-.013 (.066)	.029 (.049)	-.023 (.053)	-.011 (.038)	-.044 (.075)	.010 (.045)
		R^2=.038	R^2=.273	R^2=.074	R^2=.273	R^2=.247	R^2=.304	R^2=.016	R^2=.072
		$\chi^2_1 = 161.47$***		$\chi^2_1 = 410.47$***		$\chi^2_1 = 288.30$***		$\chi^2_1 = 124.51$***	

* $p < .05$; **$p < .01$; ***$p < .001$
[a] Constant terms and coefficients for year dummies are omitted in the interest of space,
[b] Coefficients presented with standard errors in parentheses, [c] Fixed-Effects Model, [d] Random-Effects Model

Only 4 of the 20 tests of our hypothesis in this exploratory analysis presented in Tables 5, 6, and 7 fail to achieve significance in the hypothesized direction. We consider the high number of significant results unsurprising. We are unaware of a theoretical rationale that would explain why organizational size would impact a firm's reinvestment of returns to IT. Furthermore, because these exploratory analyses are not tests of any specific theory, the few nonsignificant results do not cast doubt on any prevailing theory of productivity reinvestment. Rather, this exploratory analysis provides further broad support for the central argument of our paper, namely that increases in productivity (Q) in a given time period lead to increases in IT investment (IT-I) in future time periods.