The Economics of IT & Hospital Performance*

A Population Study Reveals
Challenges and Opportunities

*connectedthinking

PRICEWATERHOUSECOOPERS

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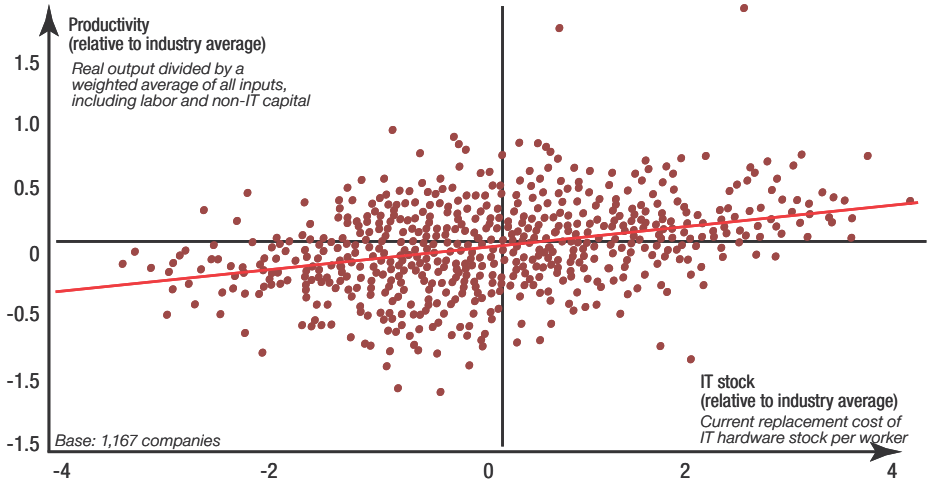
Introduction

The business case for healthcare IT is often stated as a foregone conclusion: improved healthcare quality, reduced costs, and enhanced productivity. By now, this list of perceived benefits is a well-known mantra among policy makers, technology vendors, hospital executives, and even consumers. Outside healthcare, the relationship between IT investment and increased productivity has been documented in macroeconomic and microeconomic studies, including seminal studies at the Massachusetts Institute of Technology. (See Figure 1.)

Figure 1: Relationship of IT Investment to Productivity in the US Economy, Not Including Healthcare



Source: Erik Brynjolfsson and Lorin Hitt, Optimize, July 2003

There has been considerable research on healthcare IT benefits during the past decade, yet the results do not always add up to a compelling business case. Even the most notable studies on the topic—including a broad review of the literature by the Agency for Healthcare Research and Quality (AHRQ)—have been unable to definitively establish a strong relationship between IT investment and operational performance.

Hospital executives are left to wonder: Will an investment in healthcare IT really pay off? How sizable an investment is required and how long will it take to realize a return? To explore these questions, PricewaterhouseCoopers studied US hospitals by using econometric techniques to investigate the relationship between IT adoption and organizational performance in hospitals.

When studies that link healthcare IT and hospital performance are based on an economic model, they have a greater impact because they help disentangle the many intertwined factors of hospital performance.

Study Design

We began our study by combining data from several sources, which we linked by hospital identifier data. The study required three types of data: hospital services and facilities utilization data, healthcare IT investment data, and hospital cost data. Data sources included the Solucient ProviderView database and the American Hospital Association's *Annual Survey* Database. Healthcare IT adoption data was drawn from the HIMSS Analytics™ database (derived from the Dorenfest IHDS+ Database™), which contains annual hospital-level information on healthcare IT adoption for US hospitals. The study explored data from 1999 to 2004.

Merging the data reduced the sample size from the more than 6,000 hospitals in the full census of US hospitals to the final sample of approximately 2,000 US hospitals. Hospitals excluded from the final sample included psychiatric and government hospitals, hospices, and rehabilitation facilities. We also excluded outliers such as very small hospitals. Kaiser Permanente facilities were also excluded, because the business model for Kaiser makes it potentially nonrepresentative of most US acute hospitals. The resulting sample generally represents the acute hospitals in the United States.

Determining the level of IT investment is difficult, and its appropriate economic treatment requires careful study design. In fact, an October 2006 study published by the Robert Wood Johnson Foundation (*Health Information Technology in the United States: The Information Base for Progress*) explores the difficulties of precise determination of the current levels of US adoption of healthcare IT.

To assess how much IT an organization had, we established our IT Capital Index, in which the score attributed to each application is weighted according to its price. Using the HIMSS Analytics database to determine the application mix at each hospital, we assigned points to each application at the hospital and generated a hospital-specific score. The number of points was proportional to the typical price for that application. This measure of IT investment reflects the actual capital value of the applications, enabling the potentially different performance contributions of each application to be detected. Moreover, two hospitals of different sizes may have achieved the same level of IT investment, while not necessarily having spent the same amount of money. However, the amount spent for a given level of IT investment will generally be size-appropriate, in accordance with normal market-pricing behavior. We recognize that these assumptions about pricing are imprecise, as smaller hospitals generally are not able to benefit from the same economies of scale that larger hospitals may. However, we sought to minimize this effect by excluding very small hospitals. Additionally, we may further

explore the impact of system membership in the future, as this model may provide access to economies of scale without the hospital actually being a large facility.

Throughout our discussions, we have presented key data distributions and our results in a way that shows the differences between for-profit and not-for-profit institutions. Prior economic research has indicated that there may be important differences in how these groups of hospitals behave economically and in their management of information systems projects. In future research, we may deepen our exploration of this distinction and also examine other potentially important distinctions (such as between urban and rural facilities, academic institutions, and others). The distinctions we have drawn should not be seen as judgmental, but merely descriptive of the basic data and findings.

Tables 1 and 2 and Figure 2 provide statistics that characterize the IT Capital Index. The tables illustrate the distribution of hospitals along the IT Capital Index by breaking the sample into quintiles: five groups each representing 20 percent of the sample.

Table 1: Number and Type of Hospitals in Each IT Capital Index Quintile, 2004

IT Capital Index	Not-for-profit institutions	For-profit institutions
First	147	21
Second	202	40
Third	311	48
Fourth	346	107
Fifth	489	73
Total	1,495	289

Table 2: Average Number of Beds per IT Capital Index Quintile, 2004

IT Capital Index	Not-for-profit institutions	For-profit institutions
First	217	198
Second	263	193
Third	299	210
Fourth	297	217
Fifth	332	237
Total	282	211

The distribution in Figure 2 is highly skewed, indicating that few hospitals are at the lower end of the IT Capital Index scale. The higher average IT Capital Index scores for for-profit hospitals (compared with not-for-profit hospitals) may be somewhat surprising, and we believe that two factors provide the explanation. First, for-profit hospitals have a somewhat higher level of investment in administrative and financial applications. Second, the greater maturity of the financial and administrative systems markets may have produced a higher degree of disaggregation of these applications, leading to higher apparent scores on our index. This is an area of potential continuing research.

Figure 2: Distribution of For-Profit and Not-for-Profit Institutions in IT Capital Index

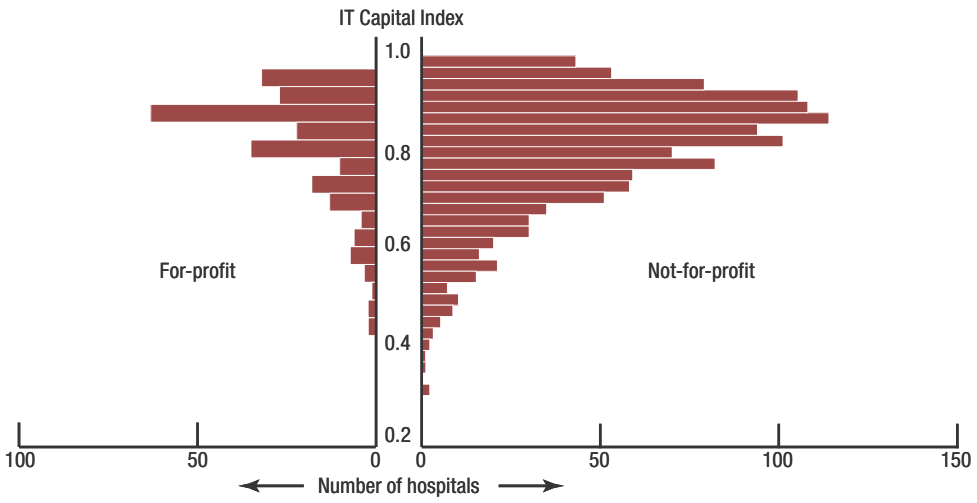


Table 3: Healthcare IT Applications Breakdown

Administrative applications	Clinical applications
Base administrative and financial	**Ancillary department**
Accounts payable	Laboratory
Benefits administration	Picture archiving and communications system (PACS)
Credit/collections	
Electronic claims	Radiology
Eligibility	
Enterprise resource planning	**Clinical department**
General ledger	Cardiology
Healthcare information system	Emergency department
Managed care contract management	Intensive care
Materials management	Obstetrical systems
Nurse staffing	Pharmacy
Patient billing	Surgery
Patient registration	
Patient scheduling	**Enterprise clinical**
Payroll	Clinical data repository
Personnel administration	Clinical documentation
Personnel scheduling	Computerized physician order entry (CPOE)
Premium billing	
Time and attendance	Electronic medication administration record (eMAR)
Financial decision support	Order communication/results
Case mix analysis	Point of care (med/surg bedside)
Clinical decision support (retrospective)	
Cost accounting	
Executive information system	
Flexible budgeting	
Outcomes and quality management	
Medical records	
Abstracting	
Chart deficiency	
Chart tracking/locator	
Encoder	
Master patient index	
Medical records imaging	
Transcription	

Source: HIMSS Analytics Database (derived from Dorenfest IHDS+ Database™), 2004

In addition to assessing the approximate cost of the software applications, we also grouped the applications into broad categories that would permit us to break down aggregate IT expenditures into subcomponents and determine whether any specific type of application (such as administrative or clinical) yielded greater efficiency gains than any other. These categories are shown in Table 3.

Economic Modeling

When studies that link healthcare IT and hospital performance are based on an economic model, they have a greater impact because they help disentangle the many intertwined factors of hospital performance. This study used an economic model of hospital operations, expressed as:

Costs = f(labor costs, material costs, capital, inputs, outputs, IT capital)

The model interrelates labor costs, material costs, hospital capital infrastructure costs, inputs (other inputs to the hospital's activities), outputs (what the hospital produces, such as number of patients admitted or number of emergency room visits), and IT investments (IT capital). The calculations also accounted for variation in case mix, severity (where mortality was included), rural status, teaching status, and disproportionate share status. Because larger hospitals inevitably have higher expenses, we used operating expenses divided by number of beds as an approximately normalized measure of operating expenses, instead of using total operating expenses.

This model is based on well-accepted economic theory that academic institutions and leading economic theoreticians have used for modeling economic activity. In addition, the model (in the form in which it may be used to calculate hospital costs—or operating expenses—from other variables) accurately predicts actual hospital costs. The model we developed accounted for more than 90 percent of the variation in costs (operating expenses) per bed when tested against the actual hospital data.

We used several statistical techniques to estimate the model described in this study. The research described in this paper relies primarily on a technique known as Seemingly Unrelated Regression, which is a commonly used method in econometric work of this nature. The basic pattern of the results was not sensitive to the statistical methods used.

At higher levels of existing IT capital, adding more IT capital may be associated with reduced costs per bed even in same-year analyses, especially in for-profit hospitals.

Results

The results of our analysis reveal interesting patterns in the relationship between IT investment and hospital operating expenses. Table 4 shows average expenditures (per bed) for the hospital industry overall and then shows how the expenditures change across increasing levels of the IT Capital Index. The table includes results for the overall sample and separate results according to for-profit and not-for-profit status.

Table 4: Comparison of Hospital Industry Expenditures per Bed, Study Sample 1999–2004

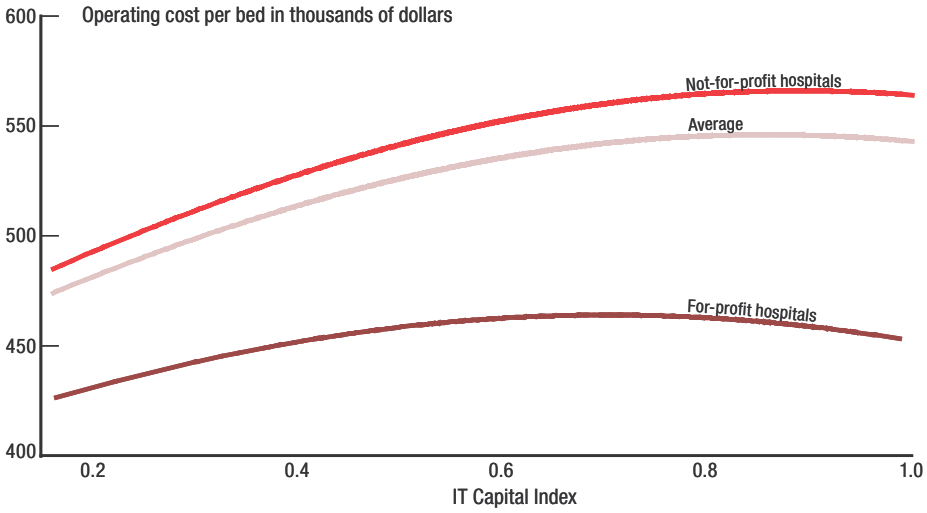
		1999	2000	2001	2002	2003	2004
Total industry average		493	525	549	565	632	716
Not-for-profit industry average		507	538	565	600	654	730
For-profit industry average		434	465	480	414	522	647
Average per bed by IT Capital Index quintiles	First	516	533	552	542	611	740
	Second	478	528	559	581	660	721
	Third	494	533	556	585	634	717
	Fourth	479	522	545	583	644	699
	Fifth	507	499	527	539	617	721

In thousands of dollars

However, this table of data does not necessarily reveal important patterns and relationships that may be apparent if additional parameters are taken into account. To explore the relationship between IT investment and business performance more deeply, the cost model outlined above was used in a more thorough statistical analysis. The results that follow are presented in a sequence that we believe develops the argument in a step-by-step manner. We initially present results for overall IT investment, looking for effects that reflect IT values for the same year as the operating expense (and other business parameter) data.

The analysis of results for all hospitals in the sample demonstrates an effect described by a concave line in Figure 3, suggesting that higher levels of IT investment are initially associated with higher costs per bed. Those costs rise until IT investment reaches a tipping point; that is, until for-profit hospitals exceed 0.7 on our IT Capital Index scale and not-for-profit hospitals exceed 0.88. Once hospitals achieve these levels, then costs per bed trend downward, and that trend is more aggressive in for-profit hospitals. Figure 3 depicts operating costs initially rising with increasing healthcare IT, leveling off at a tipping point, and then gradually decreasing at higher levels of IT capital.

Figure 3: Effect of IT Capital Index on Operating Expenses per Bed by Hospital Type



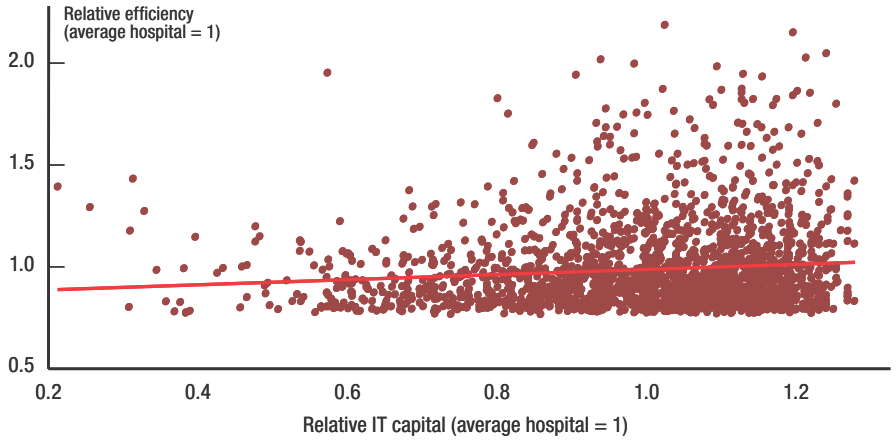
Relationship Between Hospital Performance and IT Capital

This figure illustrates the basic relationship between hospital performance and IT capital across all the hospitals in our sample. Because it is a similar pattern to that captured by Erik Brynjolfsson's analysis of IT's impact on industry-wide productivity (2003), the outcome is encouraging. (See Figure 1 on page 5. For more information on the study, refer to the Bibliography on page 20.)

The figure shows the relationship between IT investment and hospital efficiency (as opposed to cost efficiency, which we use as our principal metric elsewhere in this study). Efficiency—sometimes referred to as productivity—means maximizing output for a fixed input. Cost efficiency means minimizing costs for a given level of output. The two notions can be seen as different facets of the same concept.

The relative efficiency scores were calculated from the individual hospital technical efficiency scores—ranging from 0 to 1—for each of the hospitals in our sample using the productivity form of the model of hospital function used elsewhere in the study.

Relationship of Relative Efficiency and IT Adoption



To facilitate interpretation of these and other curves presented later, Table 5 shows illustrative values from specific ranges of IT Capital Index values.

Table 5: Operating Expenses per Bed at Sample Values of IT Capital Index

IT Capital Index sample values	Operating expenses per bed for an average hospital	
	For-profit hospitals	Not-for-profit hospitals
0.200	430.13	492.50
0.400	449.06	502.03
0.600	462.50	552.50
0.800	463.13	565.00
0.825	461.88	565.00
0.850	461.25	566.25
0.875	460.00	566.25
0.900	458.75	566.25
0.925	457.50	565.63
0.950	455.63	565.00
0.975	454.48	564.38
Median IT Capital Index	0.8744	0.8118
Mean IT Capital Index	0.8357	0.7950

1999–2004 average, in thousands of dollars

The table comprises sample hospital operating expenses from selected points across the IT Capital Index scale. It is notable that at the upper and lower ends of the scale, the scope of information systems in place tends to be very similar, reflecting the characteristic implementation paths taken by aggressive adopters of healthcare information technology. At midrange points, there are more variations in the manner in which hospitals may obtain a given score, and as such there is more heterogeneity in IT infrastructures implicitly described by the IT Capital Index.

This concave relationship between IT investment and total operating costs, which is depicted in Figure 4, occurs because initial increases in IT capital may entail significant startup expenses (networking infrastructure, recruitment of IT staff) that increase costs despite any efficiency gains the IT applications might provide. The curve also suggests that eventually, at higher levels of existing IT capital, adding more IT capital may be associated with reduced costs per bed even in same-year analyses, especially in for-profit hospitals.

Prior studies on hospital costs suggested that the effect of IT on cost efficiency was most apparent after a three- to five-year lag period. Additionally, studies outside healthcare have also shown that the benefits of IT may intensify over time, presumably as the organization gains skills in leveraging the technology implemented and as organizational work processes adapt to new ways of doing business afforded by information systems.

We also examined the effect of time lags on the relationship between the IT Capital Index and hospital costs. Our analysis limited the lag period to two years. Introducing the time lag intensified the cost-reduction impact of IT investment and revealed lower estimates for operating cost per bed at every level of IT, implying that the effect of IT increases over time. As Figure 4 shows, the peak of per-bed operating expenses shifted to a lower point on the IT Capital Index scale, implying that after that time, a wider range of IT applications show a positive efficiency effect or a substantially intensified effect for those that do generate effects.

Figure 4: Effect of IT Capital Index Two-Year Lag Model on Operating Expenses per Bed by Hospital Type

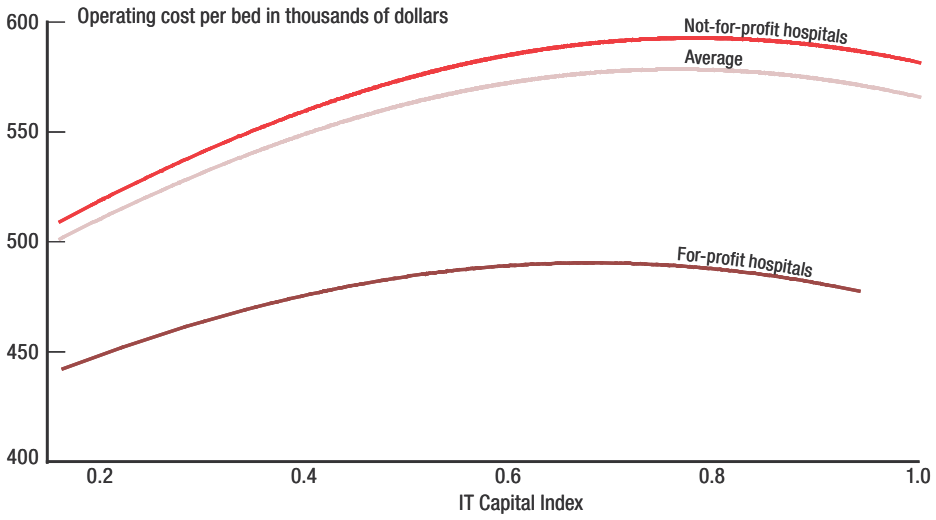


Table 6 shows the results of the analysis for varying time lags.

Table 6: Predicted Average Operating Expenses per Bed, 2004

	Initial year model		One-year lag model		Two-year lag model	
IT Capital Index quintiles	Not-for-profit	For-profit	Not-for-profit	For-profit	Not-for-profit	For-profit
First	543	458	536	451	524	434
Second	558	464	549	454	538	440
Third	563	463	554	452	542	440
Fourth	566	461	555	448	542	437
Fifth	566	459	554	442	539	431

In thousands of dollars

By examining the effects of a two-year lag model and taking the maximum cost-reduction benefit achievable by a hospital between the cost-per-bed peak and the cost per bed at the maximum possible score on the IT Capital Index, we obtained the results shown in Table 7.

Table 7: Predicted IT Capital Index Results with Time-Lag Effect

	For-profit	Not-for-profit
Average cost per bed at IT Capital Index tipping point	441	547
Average cost per bed at maximum IT Capital Index	425	530
Maximum cost reduction	16	17

In thousands of dollars

In summary, the situation is complex. The question of whether IT generates a return on investment is still not easy to answer. Hospitals that have minimal IT appear to be facing significant cost increases as they contemplate investment in IT, though they represent a very small share of US hospitals. While IT investment may initially appear to have a cost-increasing effect, above a certain level of investment—a tipping point—the impact levels off and is associated with cost reductions. Thus, incremental investments are associated with either no increase in costs

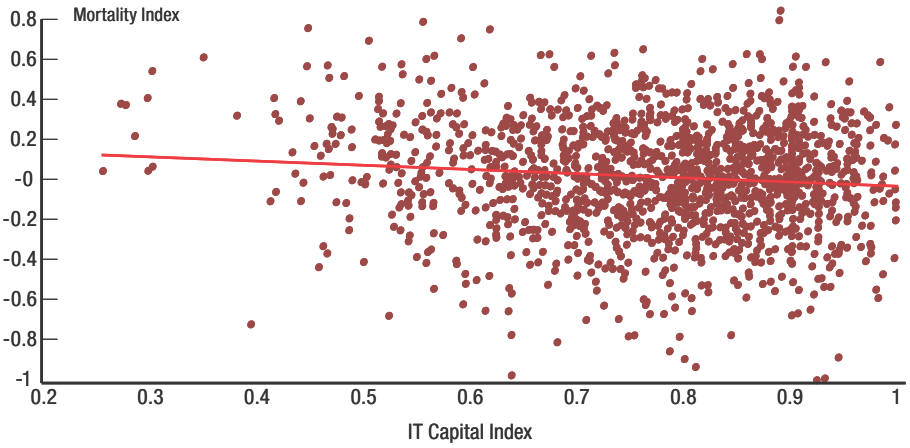
or actual reductions in hospital operating expenses. Moreover, the effects found at higher levels of investment strengthen over time. This is consistent with findings in other industries.

Clinical Quality

Although this paper focuses primarily on cost efficiency, we also applied some of our research techniques to an initial exploration of the effect of IT investment on clinical quality. Data on quality of care is difficult to obtain. No national standard data sets have been collected in a systematic way, covering all patients, for a sufficient period of time, to enable a valid study to be conducted. For these reasons, we chose to explore the relationship between IT capital investment and mortality (as reported in the Medpar data set).

Mortality is not a good measure of quality of care, for many reasons that are well described in the literature. Recognizing that mortality rates do not comprehensively measure quality of care, we used mortality rates adjusted for risk, case mix, and state average to examine if at least a directional impact of IT investment is detectable. Figure 5 uses four years of data to show a simple scatterplot relationship between IT investment and mortality.

Figure 5: Relationship Between IT Investment and Mortality, 2003



We also adjusted our economic model to account for mortality. The rationale for doing so can be understood by considering a similar economic model of a widget factory. Two factories may at first glance appear to have different costs per widget produced, which may be accounted for

if consideration is given to the difference in the quality of the widgets they produce. Thus, quality may be an important factor in understanding costs in hospitals, too. While acknowledging the objections to the use of mortality as a quality metric, our results suggest that an understanding of the relationship between IT investment and operating expenses may be deepened by considering quality of care.

Including a mortality factor in our economic model intensifies the relationship between IT investment and cost, implying that hospitals investing in IT can reduce mortality without increasing costs. This effect is shown in Table 8, where mortality rates are captured in four types of hospitals: those with low and high costs, and those with low and high IT capital. The table shows mortality rates for the top and bottom 20 percent of hospitals (determined by their IT Capital Index score) and also groups hospitals according to whether they fall into the top or bottom half of the cost distribution for the sample.

Table 8: Mortality Rates by Hospital Cost and IT Investment

	Low IT Capital Index score (bottom 20%)	High IT Capital Index score (top 20%)
High costs (top 50%)	40.18	39.24
Low costs (bottom 50%)	44.49	44.12

Deaths per thousand admissions
National average rate for population of hospitals in our study: 41/1000

The differences in mortality between the low and high IT Capital Index groups that have above-average hospital costs is statistically significant. For a 300-bed hospital experiencing 20,000 admissions per year, the impact of the IT-related investment can be quite notable. This relationship suggests a positive association between IT investment and quality of care, and it warrants deeper investigation using more precise and accepted definitions of quality.

Characteristics of Results

Initial reactions to our study's results may be a degree of disappointment that the evidence is not more conclusive in its assertion of an economic benefit to IT investment. Why might the impact of IT be so modest? Several possible explanations follow:

- Data variance—Hospitals may vary in how they submit data, and the methods of collecting additional data may alter the data on which we rely, introducing random error that reduces the apparent effects of IT.
- Data bias—If the data has a bias not detectable by our statistical methods, that bias could obscure a stronger relationship between IT and cost. For example, one such factor, the impact of scope of services, is not included in the analysis presented here.
- Conservative economic model—The approach to economic modeling we used is deliberately conservative in its derivation of the impact IT has on cost and quality. Thus, this approach underestimates the significance of effects that may actually be present.
- Incomplete IT installation or underutilization—Some hospitals have reported acquiring systems but have not yet truly begun installation, or they have implemented systems that are not fully being used.
- Lack of process redesign—Hospitals may not have made the investments in process redesign that are necessary to ensure the realization of potential benefits.
- Different targeted goals—Hospitals may have in fact achieved the goals they targeted with IT capital investments, but the outcomes we measured were not part of their targets. For example, they may have targeted convenience or customer experience factors that do not reduce costs.
- Reinvestment of savings—Hospitals may have achieved the targeted levels of cost savings in process areas they targeted, but they chose to reinvest those savings in other hospital operations and therefore did not reduce their total costs.
- Benefits accrue to others—Benefits may have been realized that do not appear in the factors included in our economic model because they accrue to others, such as hospital payers.

The data available for the study did not enable us to distinguish between these hypotheses. However, professional opinion would support the contention that hospitals are likely to overstate the level of automation reported to the HIMSS Analytics survey, and that hospitals have frequently not undertaken the significant process redesign efforts needed to realize the benefits that they theoretically could achieve.

Conclusion

These results illuminate the link between IT investment and organizational performance in US hospitals, overcoming several of the shortcomings of previous work in this field. The results, however, while stable across a number of statistical treatments, are complex. The following highlight the main takeaways:

- Higher investment in IT improves hospital business performance—This analysis, which incorporates real performance data from almost 2,000 US hospitals and a more precise measure of IT investment, can be considered as close a measure of IT's real-world impact on hospital performance as has yet been published. Although modest, there is strong and conclusive evidence that higher levels of IT create more business benefit. Given the representative nature of the sample and the rigor of the analysis, we believe we can retire the question of whether IT has a positive impact on hospital business performance. However, the degree of the effect, while statistically significant, is modest. It can nevertheless rise to the level of millions of dollars per year for a large hospital. Additionally, apparent quality effects, although not fully explored in this study, appear to be detectable.
- Until IT investment reaches a threshold, total operating expenses increase in hospitals that have little IT—The study clearly indicates that those few hospitals that are uncharacteristically low on the IT Capital Index scale will experience increases in total operating expenses as they bring more IT online, at least until they reach an overall threshold. Although these greater costs have reasonable explanations, hospitals in this situation face a daunting prospect if they must justify IT investments on the basis of near-term payback.
- For-profit and not-for-profit hospitals show consistent differences in costs—The study demonstrates a consistent difference in costs between for-profit and not-for-profit hospitals. Our model may fail to account for cost or output categories that differ between the two types of hospitals. This finding may imply a focus on efficiency that goes beyond any baseline causes of cost differences, such as more limited service offerings, different case mixes, or more morbidity in patients entering the facility. One hypothesis is that for-profit hospitals tend to be more likely to be part of a large system that has centralized IT acquisition and thus greater capacity for standardized approaches to application deployment. Further research is clearly warranted to confirm this effect and to explore it in more detail.
- IT capital investment has the potential to pay for itself—As hospitals move up the IT Capital Index scale, they all show at least a leveling off of costs. It is important to note that this leveling off occurs despite the added costs of more IT capital; that is, IT capital at some point pays for itself by displacing costs elsewhere in the hospital. Given the suggestive results about quality (as

measured by mortality rates), the fact that new IT capital investments may be cost neutral could be a more-than-sufficient justification for making the investments: improved quality at constant cost per bed.

- The effect of IT capital investment has been proven in other industries—The studies of other industries using similar economic modeling and econometric techniques demonstrated far more powerful effects of IT. Brynjolfsson and Hitt estimate a productivity advantage of IT investment that is five times the cost of the IT investment itself. Overall, then, these results for hospitals are rather disappointing. A likely culprit—that hospitals have failed to take advantage of IT by making more significant process changes in business and clinical activities—cannot be verified by this study and requires future research.
- Higher levels of IT investment create a cost-reducing effect—As hospitals move into "high adopter" categories—especially those in the for-profit sector—there is very strong evidence that they enter a cost-reducing relationship with IT investments. As suggested in our previous research on digitally advanced hospitals (*Reactive to Adaptive: Transforming Hospitals with Digital Technology,* March 2005), this finding is consistent with the idea of network effects—that is, incremental additions of IT contribute directly to the clinical/business processes they are targeting and at the same time make pre-existing IT at the hospital more valuable. We hypothesize that this is caused by the increasingly interconnected nature of processes made possible by a hospital on the road to complete digitization, or the full automation of clinical care.

Hospitals are gaining significant value from their IT investments, and this study suggests that investments may result in demonstrable cost-reduction and quality-improvement benefits. However, a number of hospitals considering new IT investments will be at a point on the IT Capital Index scale that precedes the point where operating expenses begin to fall in response to additional investment. Moreover, our results also demonstrate that real performance benefits may take at least two years to become fully apparent. There are also quality improvements to consider—but evidence of that is still in a formative stage. Hospital management should not justify expensive new IT investments purely on the assumption that these investments will create huge and rapid paybacks for the organization. If anything, management should use these results to justify moving along the IT investment axis to a position where future IT investments at least pay for themselves.

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Acknowledgments

Principal Authors
Nick Beard, M.D., Kinga Z. Elo, Ph.D.

Research Associates
Lorin M. Hitt, Ph.D., Michael G. Housman; University of Pennsylvania, Wharton School

Advisory Review Board
Neal Bowlen, David Chin, M.D., Jim Fisher, David Levy, M.D., Sandy Lutz, Kevin Malley, Bo Parker, Jack Rodgers, Hindy Shaman, Rita Zielstorff

Project Team
Kelly Conley, Todd Hall, Amos Klausner, Bruce Leininger, Susan Mills, Saba Mirza, Matthew Wakeman, Christine Wendin

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PricewaterhouseCoopers Contacts

Jim Henry
Partner, Health Industries Leader
jim.henry@us.pwc.com
(678) 419-2328

David Chin, M.D.
Partner, Health Research Institute Leader
david.chin@us.pwc.com
(617) 530-4381

David Levy, M.D.
Partner
david.l.levy@us.pwc.com
(201) 486-5487

Bo Parker
Managing Director
bo.parker@us.pwc.com
(408) 817-5733

Jack Rodgers
Managing Director
jack.rodgers@us.pwc.com
(202) 414-1646

Nick Beard, M.D.
Director
nicolas.beard@us.pwc.com
(206) 398-3293

Neal Bowlen
Director
neal.bowlen@us.pwc.com
(801) 534-3888

Jim Fisher
Director
james.e.fisher@us.pwc.com
(317) 435-5712

Sandy Lutz
Director
Health Research Institute
sandy.lutz@us.pwc.com
(214) 754-5434

Hindy Shaman
Director
Health Research Institute
hindy.shaman@us.pwc.com
(703) 453-6161

Kinga Z. Elo, Ph.D.
Research Analyst
kinga.z.elo@us.pwc.com
(646) 471-0591

Todd W. Hall
Director
Global Healthcare Marketing
todd.w.hall@us.pwc.com
(617) 530-4185