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Doctors' orders––If they're electronic, do they improve patient satisfaction? A complements/substitutes perspective

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ABSTRACT

Doctors' orders entered with Computerized Physician Order Entry (CPOE) systems are designed to enhance patient care by standardizing routines that are intended to improve quality of healthcare. As with other health information technology (IT) performance studies, literature shows conflicting results regarding the CPOE–performance relationship. By adopting a more nuanced perspective and employing not just adoption but extent of use of CPOE, we first examine whether or not CPOE *use* improves patient satisfaction. Next, given that CPOEs are implemented in the backdrop of other hospital IT infrastructure, we examine how IT infrastructure impacts the relationship between CPOE use and satisfaction, testing both a complementary and substitution perspective. Finally, we examine the differential impact of CPOE use between academic and non-academic hospitals. Using data from 806 hospitals nationwide, we find a positive relationship between extent of CPOE use and patient satisfaction. Contrary to extant research, our results suggest this relationship is stronger in non-academic hospitals. We also find evidence that a hospital's IT infrastructure substitutes for CPOE use in its effect on patient satisfaction.

1. Introduction

In 1999, the United States' Institute of Medicine released a report titled "To Err Is Human," which estimated that between 48,000 and 98,000 deaths occur each year due to medical errors (Kohn et al., 1999). The stark results of this report prompted an increased focus on medical safety and error prevention, and a drive to improve processes to enhance safety (Han et al., 2005). Operations management has a long history of providing insights into process improvement, including building quality into processes (Samson and Terziovski, 1999; Anderson et al., 1994; Flynn et al., 1994). Therefore, it is not surprising that the process of providing care to patients can be improved through embedded error prevention and appraisal tasks, enabled by information technology (IT) systems.

One specific health IT used to improve process quality is a Computerized Physician Order Entry (CPOE) system that enables clinicians to enter orders electronically and alerts them to possible drug interactions or overdoses. Through single-site studies, some researchers have demonstrated that CPOE adoption improves various aspects of hospital quality and/or performance, but other studies found mixed results or unintended negative consequences (for a review see Chaudhry et al., 2006). From an error reduction standpoint, research largely supports the notion that CPOE provides benefits, which is one reason the U.S. Government is encouraging adoption: through the American Recovery and Reinvestment Act Congress set aside $19.2 billion to reimburse healthcare providers who install specific ITs, including CPOE systems. Recognizing the difference between adoption and use, these funds are only available to providers who exhibit "meaningful use" of IT (see www.healthhit.hhs.gov). Because of both the legislative emphasis on "meaningful use" and the scholarly support for measuring system use rather than simply adoption (Devaraj and Kohli, 2003), we include "CPOE use" as a key variable within our study. We will discuss this in greater detail in the hypothesis section.

With few exceptions, prior large-scale studies have simply looked at the presence of CPOE (adoption) as the correlate of quality (McCullough et al., 2010; Yu et al., 2009). In this study we examine the extent of CPOE integration and its impact on one important measure of quality: patient satisfaction. Drawing from prior literature, we acknowledge the importance of complementary technologies and processes in new technology integration. Therefore, our study investigates the role that other health ITs play relative to the link between CPOE use and patient

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satisfaction. Although multiple medical studies have examined how CPOE impacts specific clinical quality measurements, to our knowledge this is the first study that examines how CPOE directly impacts patient satisfaction. We argue that patient satisfaction is part of quality and that it offers a new lens to the discussion of the value of CPOE.

Our study is motivated by the following research objectives. First, building on the nascent research of large-sample-size studies, we empirically examine how CPOE use impacts patient satisfaction across a set of 806 hospitals. Second, we examine the effectiveness of CPOE systems in the context of other IT infrastructure in the hospital. To do this, we adopt a "complements versus substitutes" perspective to test the role that IT infrastructure plays relative to CPOE use in hospitals. Third, from previous operations management research we know that technology investment payoffs vary widely across firms (Hendricks et al., 2007). There is evidence in healthcare research that the academic status of hospitals significantly relates to performance (Ayanian and Weissman, 2002). Therefore, we test for systematic differences between academic and non-academic hospitals in the effectiveness of utilizing CPOE relative to patient satisfaction. Lastly, we introduce a measure of technology infrastructure that is weighted by the innovativeness of the IT adopted (the Saidin index), to the operations management field.

2. Conceptual development and hypotheses

We ground our hypotheses using three complementary perspectives: (1) routines, (2) an IT value model, and (3) the cost of quality. We will argue first that CPOE allows for routinization of care and that routines provide value within organizations. Next, we argue that possession of IT assets does not necessarily translate to positive organizational outcomes; instead, IT assets must be used in a suitable environment in order to positively impact organizational performance. Finally, we assert that investment in CPOE will ultimately reduce a hospital's failure costs, as predicted in the cost of quality literature (Harrington, 1987; Crosby, 1979; Feigenbaum, 1956).

Kuperman and Gibson (2003) describe CPOE as a system that not only allows electronic orders, but also can address quality issues. For example, CPOE allows providers to "standardize practice; incorporate clinical decision support into daily practice; improve interdepartmental communication; facilitate patient transfers; and capture data for management, research, and quality monitoring" (Kuperman and Gibson, 2003, p. 31). We posit hospital processes can be improved through investment in IT and its proper implementation and effective use, which in turn positively improves patient satisfaction. We contend that these process improvements can result from the use of CPOEs and health IT in general because they provide the means to codify routines within hospitals. Routines have been defined as "regular and predictable patterns of activities which are made up of a sequence of coordinated actions by individuals" (Grant, 1991, p. 122). Researchers have long recognized the value routines provide to organizations for improving operations (Peng et al., 2008; Grant, 1991; Nelson and Winter, 1982). CPOEs require users to explicitly follow routines that result from standardized processes and decision support (Davidson and Chismar, 2007; Kaushal et al., 2001; Shojania et al., 2001). Furthermore, because CPOEs provide instructions across organizational boundaries (e.g., an order for transport may be placed by an interventional radiologist but executed by a staff member), they reduce confusion and ambiguity. Prior work shows that communication mistakes in hospitals happen most often at boundaries (Tucker, 2004; Gittell, 2002; Argote, 1982). Because boundaries grow exponentially as more subspecialists with deep knowledge in narrow areas become involved in delivering care (Lee, 2010), IT that codifies knowledge and processes and facilitates coordination should increase efficiency (Davidson and Chismar, 2007; Gattiker and Goodhue, 2004). Although previous work has shown that routines can be a double-edged sword by creating rigidities (Holweg and Pil, 2008; Leonard-Barton, 1992), CPOE promotes routines through suggestions and warnings, but allows physicians to make all final decisions, thus allowing for breaking routines where appropriate (Davidson and Chismar, 2007).

Given that CPOE use and IT adoption can routinize care and improve processes, a process model proposed by Soh and Markus (1995) provides a useful framework from which we can test several relationships proposed by those authors (p. 39). Their model is a set of three interlinked processes: (1) an IT conversion process, (2) an IT use process, and (3) a competitive process. The IT conversion process suggests that firms convert IT expenditures into IT assets only when firms enact good IT management policies and procedures consistently and effectively. The resulting IT asset then is some combination of useful, well designed applications, flexible IT infrastructure, and high levels of user knowledge and skill (Soh and Markus, 1995). The IT conversion process has a well-established base in the literature (Weill, 1992; Ives and Olson, 1984), thus testing it is beyond the scope of this paper. However, we suggest that conversion effectiveness determines the degree to which an IT is being used for its intended purpose. In summary, if the IT expenditure is managed properly, it should produce value-added services that increase commensurate with increasing usage.

Our research focuses on the IT use and competitive processes linkages, specifically examining CPOE use, IT infrastructure, and patient satisfaction, and links between these three constructs. IT Infrastructure is generally regarded as a set of shared, tangible IT resources (i.e., hardware, operating systems, networks, data, and data-processing applications) that provide a foundation to enable present and future business applications (Duncan, 1995). Several studies have investigated the link between CPOE adoption and process quality (Dexter et al., 2001; Bates et al., 1999; Overhage et al., 1997; Overhage et al., 1996; Tierney et al., 1993), with the vast majority showing positive benefits. Other studies have examined the link between CPOE use and clinician satisfaction (Murff and Kannry, 2001; Weiner et al., 1999; Lee et al., 1996) but to our knowledge none explore the link between clinician CPOE use and patient satisfaction. Using the process model proposed by Soh and Markus (1995) as the basis for our study, we argue that by preventing errors through the use of CPOE and IT infrastructure, a hospital can realize "IT impacts" that translate to patient satisfaction (see Fig. 1).

The utility of this model rests on the premise that CPOE use creates quality-improving IT impacts and subsequently that patient satisfaction is a function of quality. According to Mohr (1982) and Soh and Markus (1995), IT assets are necessary but not sufficient to produce IT impacts. IT impacts can take the form of new products and services, redesigned business processes, better decision making, and/or improved coordination flexibility (Soh and Markus, 1995), but these can only occur when organizations use IT assets wisely. We contend the IT assets (CPOE and IT infrastructure) provide the means to better manage quality procedures and routines vis-à-vis improved business processes, decision making, and coordination flexibility. Because hospitals invest in CPOE to reduce failures, we apply the prevention–appraisal–failure model (Harrington, 1987; Feigenbaum, 1956) to operationalize the cost of quality (Crosby, 1979) (see Fig. 2). This model illustrates the increasing progression of quality costs, from prevention to appraisal, to internal failure, and finally to external failure costs.

Prevention costs are those associated with preventing errors before they happen. Because humans can retain and retrieve only limited amounts of information at any time (Simon, 1991) – for

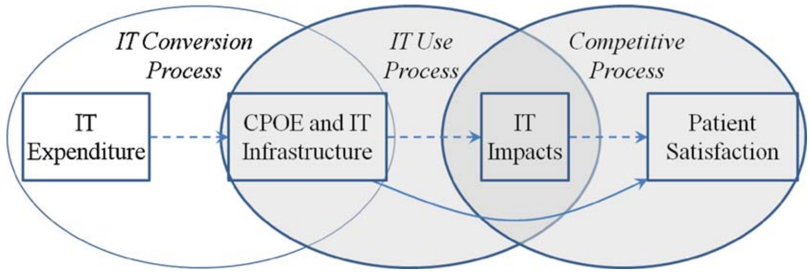

Fig. 1. Soh and Markus model in the context of CPOE use in the hospital setting.

example patient allergies and medication interactions – a CPOE can alleviate the cognitive load on the physician, which not only can improve decision making but also can free up cognitive capacity for other decision-making efforts. Numerous studies have shown positive relationships between CPOE use and the features they provide related to reminders and alerts for medications (medication errors and adverse drug events) (Wolfstadt et al., 2008; King et al., 2003; Bates et al., 1999; Bates et al., 1998; Evans et al., 1998; Classen et al., 1997), errors of omission (Overhage et al., 1997), and duplicate tests (Bates et al., 1999; Bates et al., 1998; Tierney et al., 1990). In addition, CPOE can increase efficiency because using the CPOE provides the clinician with the ability to review results of prior tests so new tests are not ordered (Tierney et al., 1987).

Appraisal costs are those associated with identifying quality problems once they have occurred. Coupled with preventive measures, CPOE use allows clinicians and administrators to appraise the level of care being delivered to the patient at the point of care. For example, physicians often order tests to verify a specific disease or condition. Given a patient's symptoms, family history, and other factors, the decision support embedded in the CPOE calculates the probability that the test would reveal the disease or condition posited (Tierney et al., 1987). Based on this appraisal, a physician can decide whether the test is warranted. A CPOE can alert physicians that clinical guidelines recommend that a particular patient receive preventive care, such as a vaccination. Administrators can check CPOE reports to verify whether the patient was informed by the clinician that s/he was eligible to receive said preventive care, thus appraising how well clinicians follow hospital guidelines (Dexter et al., 2001; Overhage et al., 1997; Overhage et al., 1996). Finally, CPOEs can corroborate drug formulary recommendations (Teich et al., 2000), and check whether drug dosing was appropriate (Chertow et al., 2001).

Finally, it is critically important in a hospital setting to invest in prevention because subsequent failure costs are extremely high. For example, a 1997 study showed that failures such as adverse drug events are estimated to cost the U.S. hospital system between \$1.56 and \$5.6 billion annually because of readmission and hospitalization costs, and malpractice and litigation fees (Bates et al., 1997). CPOEs and health IT create an electronic 'paper-trail' that can be used to identify where failures occurred. Therefore, if a doctor overrides an electronic alert or reminder – a behavior that is very common (Van Der Sijs et al., 2006; Weingart et al., 2003) – and sends an order for a medication that is subsequently filled by a pharmacist and administered by a nurse, the CPOE would identify all responsible parties. The fact that this information is tracked and easily accessible is likely to deter non-compliance and provide data for the hospital to analyze and use to further improve the process in order to prevent external failures in the future.

2.1. CPOE use and patient satisfaction

As noted earlier, patient satisfaction is a key hospital performance metric, which has become increasingly important to the medical community due to its relationship to adherence to practice guidelines, clinical quality, and mortality (Glickman et al., 2010). Each of the costs of quality identified in prevention–appraisal–failure can be related to patient satisfaction. For example, duplicating tests not only increases cost to the patient but also results in unnecessary inconveniences, additional pain,

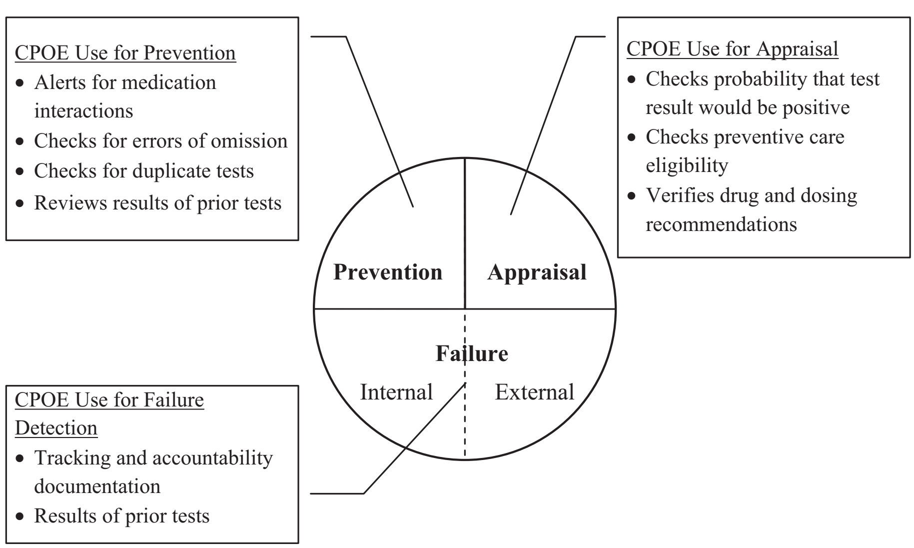

Fig. 2. Prevention–appraisal–failure model in the context of CPOE Use.

and/or delays. Additionally, reducing adverse drug events and medication errors positively relate to satisfaction. Because the patient is the recipient of the benefits of CPOE use, we propose the following:

H1. CPOE use is positively related to patient satisfaction.

2.2. IT infrastructure impact on CPOE use–satisfaction relationship

Hospitals typically adopt CPOE systems after implementing a suite of other IT applications due to the inherent complexity of the CPOE system itself and the required close integration with multiple systems including pharmacy, laboratory, and other administrative systems (Kaushal et al., 2001; Massaro, 1993). Clinicians use CPOEs within the broad sociotechnical context of the hospital (and healthcare system) while oftentimes simultaneously interacting with other health IT. The CPOE not only populates other databases and systems with information, but it is also populated by other systems, to the extent that these other systems are present and being used. We next provide justification for two alternative perspectives related to the role that other IT plays with respect to CPOE use and satisfaction. On the one hand we present theory suggesting existing IT infrastructure *complements* CPOE use in its relation to patient satisfaction. On the other hand, we reason that existing IT infrastructure can *substitute* for CPOE use, specifically in its relation to patient satisfaction. In simple terms, patients may perceive the same benefits from a robust IT infrastructure as from CPOE use.

2.2.1. IT Infrastructure as a complement to CPOE use

Organizational scholars have noted that even if a resource itself is valuable, rare, and inimitable, it may not result in a competitive advantage unless it is bundled with complementary resources (Amit and Schoemaker, 1993; Barney, 1992). Particularly when resources are tacit, socially complex, or cognitively challenging, bundling has been demonstrated to be more effective than deploying a resource in isolation (Coff, 1997; Barney, 1992; Penrose, 1959). CPOE implementations are known to be highly complex and disruptive: in fact, within the medical literature on CPOE, one paper specifically states, "CPOE is a complex undertaking and should not be the first computerized clinical system attempted by an organization. A CPOE application is more likely to be accepted if the existing clinical systems are well received," (Kuperman and Gibson, 2003, p. 37). Prior research has shown that when complex IT is implemented, the presence of similar or supportive IT is beneficial for more comprehensive appropriation (Zhu, 2004; Bucklin and Sengupt, 1993). It has also shown that organizations having a robust IT infrastructure also have high organizational learning ability regarding IT and can more effectively assimilate new IT into their routines and processes (Wachter, 2006; Fichman and Kemerer, 1999). According to this line of reasoning, firms having a base IT knowledge are better suited than less IT-savvy firms to adopt new, more complex technologies and to realize value from them. It could be argued that IT-savvy firms are better suited because they have developed and codified routines for implementing new technologies, but the value of routines and codification does not stop at the implementation. One of the primary benefits of using IT is the ability to extract codified knowledge from it, resulting in greater opportunities for organizational learning. Knowledge that has progressed through to codification, such as knowledge built into IT, implies a desire by organizations to learn how information leads to improvement (Zollo and Winter, 2002). This organizational learning accrues in two ways: by integrating diverse knowledge and by building upon related knowledge (Cohen and Levinthal, 1990). Therefore, each new implementation and each use of the system provides an opportunity for firms to learn and accumulate knowledge (Cohen and Levinthal, 1990). It follows that hospitals that have deployed highly innovative technology should have a greater stock of knowledge to draw upon in order to better understand how to implement and benefit from CPOE.

From a practical standpoint, adoption of IT beyond the CPOE enables hospital staff and clinicians to increase coordination among diverse stakeholders and reduce or eliminate redundant tasks such as reentry of patient information or duplicate tests. Furthermore, economies of scale (Chari et al., 2008; Clemons and Row, 1991) occur from: (1) sharing technology assets (hardware, software, and employees), (2) sharing technology know-how, and (3) exploiting new applications for old technology (Clemons and Row, 1991). Hospitals that have adopted innovative technology can leverage the hardware, software, and technical staff and their know-how to better realize the benefits of CPOE. For example, an IT staff which has successfully implemented innovative technology knows how hospital processes function and how individuals within the hospital prefer to work. The technical staff can leverage this process and personnel knowledge to better build and support a well designed CPOE system, which should translate into more effective use.

In summary, we argue that CPOE benefits can increase in the presence of a robust IT infrastructure. Hospitals learn as they adopt innovative technologies, and they realize benefits from economies of scale. While a hospital's IT infrastructure does not duplicate the major features or functions of the CPOE, there are similarities in routines related to use of the systems and it is our contention that additional benefits can be realized as a result of the cumulative knowledge acquired from other adoptions. Taken together, all of this suggests that IT infrastructure complements the effects of CPOE use, thus we test:

H2a. IT infrastructure will complement the relationship between CPOE use and patient satisfaction.

2.2.2. IT infrastructure as a substitute for CPOE use

An alternative viewpoint suggests that IT infrastructure could substitute for CPOE use with respect to its impact on patient satisfaction. In the organizational literature, a *substitute* is said to replace or "act in place of" a specific behavior (Kerr, 1977). Empirically, a substitute is modeled as a moderating variable, however depending upon the directionality of main effects and interactions, the moderator can enhance, suppress, or substitute for the predictor (we discuss this in greater detail in the methods section) (Podsakoff et al., 1993; Howell and Dorfman, 1981; Kerr, 1977). The argument for a substitution effect is considerably more complicated than a simple moderation because one must convincingly argue that a variable can take the place of the predictor in its relation to the outcome of interest and also empirically validate the relationship. For this reason, several scholars have noted that a substitute is much more than just a moderator variable (Podsakoff et al., 1993).

In our context, the important distinction is that we are not suggesting IT infrastructure offers the same functions as CPOE; but instead, from the patient's perspective, the use of other IT may generate similar benefits that impact their satisfaction of care. We know from prior research that both process quality (working efficiently and effectively) and clinical quality (performing technical aspects correctly) influence patients' overall satisfaction (Donabedian, 2005; Marley et al., 2004; Collier, 1994). Because these two aspects of quality collectively form the basis for patient satisfaction (Marley et al., 2004; Collier, 1994), it is reasonable to assume that the plethora of systems used, and the extent to which they are used in the delivery of care, will heterogeneously impact quality perceptions. For example, CPOE systems generate electronic orders for medications, transports, and tests and provide decision support related to identification of drug interactions or other adverse events. Some of these functions contribute to clinical quality and some to process quality. In the absence or minimal usage of CPOE, other IT systems could provide similar effects on quality perceptions while not serving these specific functions. For example, low usage of a CPOE may create a poor experience with a duplicate test or erroneous transfer and result in excessive wait times, but this could be made up for by a very good experience with an accurate and timely billing process afforded by the use of a comprehensive and integrated billing IT system. From a functional standpoint, the billing system certainly does not take the place of a CPOE; however, collectively the patients' satisfaction is a reflection of both, therefore the limited use of a CPOE may not negatively impact a patient's aggregate view of the hospital.

Finally, there are some overlaps between a robust IT infrastructure and the use of CPOE. Significant IT adoption enables hospitals to store and retrieve large amounts of data for analysis and potential patient treatment and overall operations improvement. Kuperman and Gibson (2003, p. 31) explain that one of the many benefits of CPOE is the ability to "capture data for management, research, and quality monitoring." Although CPOE enables a convenient location to retrieve patient orders, other IT systems may allow for similar retrieval and information analysis, therefore we test:

H2b. IT infrastructure will substitute for CPOE use in its relationship to patient satisfaction.

2.3. Academic status impact on CPOE use–satisfaction relationship

In the original model proposed by Soh and Markus (1995), the three interlinked processes exist within a broader context including IT management/conversion activities, appropriate/inappropriate use, and competitive position/competitive dynamics. We have addressed the first two contingencies but as yet have not incorporated the role of competitive dynamics. The Soh and Markus model suggests that IT impacts affect organizational performance dependent on the competitive position/dynamics within the organization's industry.

One key differentiator in the healthcare market is the decision of whether to affiliate with an academic institution (Goldstein et al., 2002). This is a strategic choice that not only determines the competitive direction of the hospital but also drives hiring decisions and organizational structures and processes. Research in healthcare typically distinguishes between academic (teaching/research) and non-academic hospitals because of the differences in staffing requirements, performance goals, cost structures, and technology adoption attitudes (Goldstein and Naor, 2005; Ayanian and Weissman, 2002; Li et al., 2002). Academic hospitals are also known to adopt advanced technology and to design care innovations more rapidly than non-academic hospitals (Ayanian and Weissman, 2002). Therefore we would expect several characteristics of academic hospitals to enhance the relationship of CPOE use to patient satisfaction.

There are other reasons why the academic environment should contribute to augmenting the CPOE–satisfaction relationship. First, academic hospitals tend to perform better than non-academic hospitals on several key quality metrics (McCullough et al., 2010; Patel et al., 2007). Some have attributed this difference to greater accessibility to knowledge and a larger cumulative organizational knowledge base, thus reducing the need to 'experiment' (Reagans et al., 2005). Second, academic hospitals generally enjoy increased prestige over non-academic hospitals and can more easily recruit and retain high-quality staff (Ayanian and Weissman, 2002). A high-quality, research-oriented staff is likely to include people with the aptitude to learn and apply new technology. As described earlier, research has shown that a firm's base of IT knowledge is a contingent factor in the IT adoption–value link. Because of this, we believe the staff within an academic hospital will be better able to convert the IT asset of CPOE into improved IT impacts and thereby improve the organizational performance metric of patient satisfaction. For these reasons, we expect the environmental conditions present within academic hospitals to be more conducive to supporting the CPOE–patient satisfaction relationship and test:

H3. The relationship between CPOE use and patient satisfaction is stronger in academic hospitals than in non-academic hospitals.

3. Data

We merged data from 806 U.S. hospitals from two separate data sources: the HIMSS Analytics Database and the Leapfrog Group CPOE database. The Leapfrog Group provided CPOE use data and HIMSS Analytics™ (derived from the Dorenfest IHDS+ Database™) provided all other data. The sample size of 806 resulted from matching across databases and keeping only those hospitals that had information in both. We conducted paired *t*-tests on several key hospital characteristics such as size, age, geographic region, and IT adoption and found no significant differences between hospitals in our sample and the overall population of hospitals. We operationalized CPOE use using a four-point scale, as developed by the Leapfrog Group. Leapfrog has three goals concerning CPOE adoption: (1) physicians enter at least 75% of orders via a CPOE, (2) CPOE provides system alerts for at least 50% of common, serious prescribing errors, and (3) physicians must document a reason for system overrides.

Leapfrog collects survey data annually from US hospitals and assigns CPOE scores based on responses regarding the extent of CPOE implementation (see Appendix). A hospital meeting the three previously stated goals will earn a score of 4 (fully meets progress goal), while a hospital that has not adopted CPOE at all but has answered the survey will earn a score of 1 (willing to report publicly). Any hospitals with partial use will earn a 2 (good early stage effort) or 3 (making good progress) accordingly. While this is a self-report survey and there may be some motivation to over-report CPOE use, results suggest that 76% of hospitals responded that they have not adopted but are willing to report (see Table 1).

We employ the Saidin index (Spetz and Maiuro, 2004) to measure IT infrastructure within each hospital. Instead of summing IT adoptions to count the number of technologies in the IT infrastructure, this index weights IT adoptions based on the proportion of hospitals in the sample population that have adopted the same IT. The Saidin index for a given hospital sums across all hospital technologies the product of a technology's weight and a 0,1 indicator variable signifying whether or not a hospital has adopted a given technology (Spetz and Maiuro, 2004). Through this weighting, the Saidin index accounts for not just the quantity of IT, but also the innovativeness of the IT infrastructure of a given hospital (Mark et al., 2004). More specifically, using the notation and formulas specified by Spetz and Maiuro (2004), the Saidin index $S_{i,t}$ is defined in the following manner:

$$a_{k,t} = 1 - \left(\frac{1}{N_t}\right)\sum_{i=1}^{N_t} \tau_{i,k,t} \quad \text{and} \quad S_{i,t} = \sum_{k=1}^{K} a_{k,t}\tau_{i,k,t}$$

where k = technologies available in a given year and indexed by $k = 1, \ldots, K$; t = year; $a_{k,t}$ = weight for a given technology across all hospitals; N_t = number of hospitals in year t; $\tau_{i,k,t} = 1$ if hospital i has technology k in year t, 0 otherwise.

HIMSS analytics tracks the adoption of IT in hospitals and other care delivery organizations in the U.S. To calculate our IT Infrastructure variable, we use their exhaustive list of 88 ITs found in hospitals and omit CPOE in the Saidin index calculation in an effort to reduce endogeneity between the two independent variables. We differentiate hospitals based on academic/non-academic status (Goldstein and Naor, 2005; Li et al., 2002) by using the Council of Teaching

Table 1
CPOE score and sample characteristics.

Description	Leapfrog CPOE score			
	1 Have not adopted	2 Good early stage effort	3 Making good progress	4 Fully meets progress goal
Number of hospitals in sample	747	142	31	62
Percentage of hospitals in sample	76.1%	14.5%	3.1%	6.3%

Hospitals classification, as have others (McCullough et al., 2010). Finally, we include a collection of commonly used hospital-level control variables such as location (urban versus rural), size (number of staffed beds), hospital age (years), hospitals within the same health system, and vendor of CPOE systems adopted (see Table 2).

To measure patient satisfaction, we used results from the Hospital Consumer Assessments of Healthcare Providers and Systems (HCAHPS) survey, which is said to be the standard for capturing patient assessments of care (O'Malley et al., 2005). The HCAHPS survey asks recently discharged patients several questions, two of which assess overall satisfaction: (1) Overall, how would you rate this hospital on a scale from 0 to 10? and (2) Would you recommend this hospital to family and friends? A three-point scale is used to quantify the responses as follows: definitely yes, probably yes, no. The Center for Medicare and Medicaid Services (CMS) presents hospital-level summarized data by calculating the percentage of respondents who answered a 9 or 10 on the first question and the percentage of respondents who answered "definitely yes" to the second question. Previous research has shown a high correlation between these two measures ($r = 0.87$) (Jha et al., 2008). Our results were robust to using only one measure or an average of the two items. We chose to average the two and create a composite measure of patient satisfaction to avoid the use of a single-item dependent variable.

Table 2
Construct description and operationalization.

Variable/construct	Description and operationalization
Number of staffed beds	Number of beds available for which the hospital has staff to care for a patient in that bed
Age	Age of hospital in years
Location	Dummy variable for hospital location. Variable value = 1 if hospital is in urban location; variable value = 0 if hospital is in rural location
Academic status	Dummy variable to differentiate between academic/non-academic hospital, as defined by the Council of Teaching Hospitals (COTH). Value = 1 for academic hospital; 0 for a non-academic hospital
Vendor (1,. . ..,7)	Series of dummy variables to define the CPOE software system used by each hospital
Health system (A,. . .,E)	Series of dummy variables to define hospitals that belong to the same health system
CPOE use	A four-point scale defined by Leapfrog. Value = 1 if hospital has zero or minimal use, to 4 if hospital uses CPOE for 75% or more of orders
IT infrastructure	A measure of the hospital's adoption of IT and the innovativeness of the IT, as assessed by the Saidin index
Patient satisfaction	The average percentage of patients providing the highest scores to two HCAHPS questions (1) How would you rate this hospital? (2) Would you recommend this hospital to family and friends?

Our independent variables of interest, CPOE use and IT Infrastructure, were measured in 2007. Previous work has shown that changes in technology take time to manifest in tangible gains, so a one-year lag between technology state and performance is appropriate; therefore we used patient satisfaction data from 2008 (McCullough et al., 2010; Devaraj and Kohli, 2000).

4. Results

Our sample includes significant variations in size, age, location, academic status, CPOE use, and patient satisfaction as highlighted in Table 3.

We report correlations between variables in Table 4, and use ordinary least squares regression and hierarchical regression to test our hypotheses.[3] In Model 1, Table 5, we report results for a regression of patient satisfaction in 2008 on CPOE use in 2007 (CPOEuse), which constitutes a test of Hypothesis 1. Results indicate that CPOEuse is significant and positively related to patient satisfaction (Regression coefficient = 1.51, $p < 0.01$) as hypothesized, thus H1 is supported.[4] We also performed the same analysis, substituting a dichotomous variable for CPOE adoption/non-adoption in place of the CPOE use variable. The results were insignificant, suggesting that extensiveness of use is the operative predictive variable rather than adoption.

Hypotheses 2a and 2b propose that IT infrastructure (ITInfra) either complements or substitutes, respectively, for CPOE use in its relationship to patient satisfaction. Testing for moderation provides insights into this relationship. Howell and Dorfman (1981) provide three criteria for assessing substitution: (1) there must be a logical explanation for how the substitution variable (ITInfra) could possibly take the place of the main effect (CPOEuse) in its relationship to the dependent variable (patient satisfaction), (2) both CPOEuse and ITInfra must have predictive power over patient satisfaction in the same direction (in the absence of the interaction term), and (3)

[3] Prior to analyzing the data, we performed data validity tests. We captured the residuals and conducted three tests. First, we conducted the Kolmogorov–Smirnov (KS) test and did not observe violations of normality. Plots of residuals confirmed this result. Next, White's test for heteroscedasticity did not suggest a violation of the constant variance assumption. Finally, we checked for multicollinearity using variance inflation factors (VIFs). All VIFs were under 3.0, indicating that multicollinearity is not an issue.

[4] For comparison purposes, we tested the relationship with a two-year lag and found that while directionally the relationship was correct, the regression coefficient of CPOEuse became non-significant. Recent findings suggest this is not uncommon and that competitive performance advantages diminish over time (Menon et al., 2009).

Table 3
Key characteristics of sample.

Description	Value
Number of hospitals in study	806
Number of staffed beds: mean (std dev)	243.76 (185.42)
Hospital age (years): mean (std dev)	36.53 (77.57)
Location: urban/rural	87.41%/12.59%
Academic status: academic/non-academic	12.08%/87.92%
CPOE use: average (std dev)	1.38 (0.81)
IT infrastructure: average (std dev)	14.92 (4.61)
Patient satisfaction: average (std dev)	64.47 (8.91)

Table 4
Correlation table.

	Patient satisfaction	CPOE use	IT infrastructure	Academic status	Staffed beds	Age	Loc.
Patient satisf.	1						
CPOE use	0.112**	1					
IT infrastructure	0.089*	0.183**	1				
Academic status (1 acad, 0 non-acad)	0.117**	0.373**	0.183**	1			
No. staffed beds	0.210	0.321**	0.297**	0.574**	1		
Age (years)	0.160	0.023	−0.046	0.038	0.044	1	
Location (1 = urban, 2 = rural)	−0.077*	0.130**	0.176**	0.130**	0.034**	0.021	1

* Correlation significant at 0.05 level.
** Correlation significant at 0.01 level.

the interaction of the two (CPOEuse x ITInfra) must be significant in the opposite direction of the two main effects. If both main effects and the interaction are significant in the same direction, ITInfra is a complement to CPOEuse.

Following the procedure outlined by Howell and Dorfman (1981, pp. 720–721), we confirmed that ITInfra acts as a substitute for CPOEuse in its effect on patient satisfaction. Both CPOEuse and ITInfra (both mean-centered), in the absence of the interaction variable are significantly related to patient satisfaction (CPOEuse Regression coefficient = 0.990, $p < 0.05$ and ITInfra regression coefficient = 0.196, $p < 0.01$, respectively; Model 2, Table 5). The bivariate correlations are also supportive of this relationship (see Table 4). Furthermore, the interaction term CPOEuse × ITInfra (centered) is negative and significantly related to patient satisfaction (interaction coefficient = −0.178, $p < 0.05$, Model 3, Table 5), meeting all the criteria outlined for substitution. Therefore, our data provide support for Hypothesis 2b (substitute relationship) and not for Hypothesis 2a (complement relationship). To test the robustness of this finding, we used different operationalizations of ITInfra. The first one, reported above, includes a weighted value of all IT in each hospital (interaction coefficient = −0.178, $p < 0.05$). Recent research shows that clinical IT and administrative IT produce differential performance results (Menon et al., 2009), therefore we constructed these two IT infrastructure variables using Saidin weights. Results were similar, with clinical IT providing significant substitution effects for CPOE use (interaction coefficient = −0.305, $p < 0.05$) and administrative IT providing marginally significant substitute effects (interaction coefficient = −0.179, $p < 0.1$).

To test the third hypothesis, we split our sample between academic and non-academic hospitals, regressed patient satisfaction on CPOE use in the two samples, and compared results. We find that contrary to our expectation, CPOEuse is more strongly related with patient satisfaction in non-academic hospitals (see Table 6, Model 5) than in academic hospitals (Model 4). In fact, results from Model 4 show CPOEuse to be not significantly related with satisfaction for academic hospitals. Therefore, we find a significant but unexpected result that does not support Hypothesis 3.

5. Discussion

Our finding that CPOE use is positively related to patient satisfaction coincides with a growing body of medical research supporting the positive effects of CPOE adoption. However, it also raises an important issue that might explain the results of some prior CPOE research suggesting that there are unintended and/or negative consequences of CPOE adoption. Our study employs CPOE *use* as the predictor variable. As with any IT system, in order for benefits to accrue, if indeed there are benefits, employees must *meaningfully* use the system – by Leapfrog's definition, the hospitals with the highest level of use must enter at least 75% of orders using their CPOE system. Many publicly available databases simply report the presence of a specific IT but do not assess use in any direct or indirect way. It is therefore possible that IT systems may be present but significantly underutilized or completely abandoned, thus skewing the results of studies that attempt to show a link between IT and performance.

Our results suggest that not only does CPOE use impact patient satisfaction, but also that an aggregate suite of technologies can substitute for a specific technology as it relates to patient perceptions. One explanation is that patients notice IT use in their treatment and make broad conclusions about technology use/quality/patient satisfaction relationships. Media coverage of the nation's most tech-savvy hospitals ("The Digital Hospital" -CIO Magazine, Time, Newsweek, etc. and "100 Most Wired Hospitals

Table 5
Regression coefficients and model summary statistics for Hypotheses 1 and 2–CPOE use, IT infrastructure, and their interaction on patient satisfaction.

Independent variables	Dependent variable is patient satisfaction		
	Model 1	Model 2	Model 3
Location	0.035	−0.352	−0.404
No. of staffed beds	−0.001	−0.002	−0.002
Age	−0.003	−0.003	−0.003
Academic status	1.481	1.500	1.397
CPOEuse	1.151**	0.990**	1.323**
ITInfra		0.196*	0.206**
CPOEuse × ITInfra			−0.178*
R-squared	0.208	0.215	0.221
Adjusted *R*-squared	0.193	0.200	0.203
F-test (*n* = 806)	12.30**	12.15**	11.82**
Δ*F*-test		7.01**	6.50*

* Indicates $p < 0.05$.
** Indicates $p < 0.01$.

Table 6
Regression coefficients and model summary statistics for Hypothesis 3: the effect of academic hospitals.

Independent variables	Dependent variable is patient satisfaction	
	Model 4 academic hospitals (*n* = 101)	Model 5 non-academic hospitals (*n* = 705)
Location	na	−0.21
No. of staffed beds	0.004	−0.01
Age	0.007	−0.003
CPOEuse	0.32	1.54**
IT infrastructure	−0.09	0.24**
R-squared	0.135	0.220
Adjusted *R*-squared	−0.006	0.201
F-test comparing CPOEuse across models	*F* = 85, $p < 0.001$	

na – not applicable because all academic hospitals were located in urban locations and therefore there was no variation.
** Indicates $p < 0.01$.

and Health Systems" -Hospitals & Health Networks), may have conditioned people to equate technology with performance. If so, it may not even matter which technology is being used, simply that some technology is assisting the clinicians.

In addition to the role that media plays in setting the expectation that there is a link between technology and patient satisfaction, by design and function many forms of IT are intended to improve performance as perceived by patients. Since most patients do not have the knowledge to accurately assess clinical quality, they factor both clinical and process quality into their assessment of overall quality (Marley et al., 2004). To the extent that IT infrastructure enables efficient and effective processes throughout the hospital, such as a reduction in errors, fewer duplicate tests, and less wait time, this is likely to translate into improvements in patient perceptions. Finally, in hospitals where IT infrastructure is robust, management is more likely to gather and analyze data in order to make improvements – even if the CPOE is absent or minimally used – and patients will notice these enhancements, supporting the finding that IT infrastructure substitutes for CPOE use in its relation to patient satisfaction.

The CPOE–patient satisfaction link proved significant only in non-academic hospitals – this was a surprising result considering that the majority of prior literature suggests that academic hospitals perform better on key indicators. Dr. Donald Berwick, the former leader of the Institute for Healthcare Improvement and current head of the Center for Medicare and Medicaid Services, provided one plausible explanation for this finding when he stated, "Right now if I needed something simple, I would tend to choose a great community hospital over a great academic hospital. There's a lot of reasons to suspect that for relatively routine things you need. . .you would be better off at a caring, smaller community hospital that's taking quality seriously than in a massive, complex teaching hospital that's taking quality seriously" (Bombardieri, 2008). Thus, it could be the case that relative to quality of care provided, academic hospitals outperform non-academic hospitals for complicated and rare cases, but non-academic hospitals perform just as well or better for routine cases. Berwick further elaborated that the downside of the expertise and knowledge in academic hospitals is the need to juggle multiple complex cases which leaves less time and focus for routine, uncomplicated cases. Under this scenario, it is possible that routine cases, which account for the majority of care, are not treated with the same urgency and attention to detail as highly specialized cases are, and this could translate into reductions in patient satisfaction scores for the majority of the patient population, thus explaining our result.

Hayes and Wheelwright's (1979) product-process matrix suggests that an operation's strategy and process should "fit." Specifically, firms producing a low-volume, highly customized product should run a job shop where each employee or piece of equipment can be used as needed, in any order. On the other hand, an organization producing a high-volume, standard product should run a flow shop where each resource is used in a given order, using standard processes throughout. While manufacturing theories cannot directly translate to healthcare since all patients are different, there is an increasing call for standardization in healthcare (Porter and Teisberg, 2004). As stated in Bombardieri (2008), care of a pneumonia patient with no other complicating factors follows a standard process. It is imperative that all steps in that process are followed for the patient to recover quickly, but it is routine care. In a non-academic hospital, the clinical staff typically receives less complex cases; therefore they can focus on applying standard processes of care to their patients, which related well to the power of CPOEs. Bohmer (2010) describes one hospital system which has 70 standard protocols for disease, covering 90% of the hospital's caseload. This standard protocol is included within IT systems and revised over time to refine the best practices. Clinicians are strongly encouraged to follow these guidelines when standard cases arrive, but to deviate when complications present themselves. In other words, the standard process works well for the vast majority of patients thus allowing the hospital to operate in a flow-shop configuration. In contrast, more difficult and unique cases are seen at academic hospitals, suggesting that less-standardized care is more prevalent in these facilities.

6. Conclusions

6.1. Limitations and future research

As with most research, this work has some limitations. A CPOE is a complex system which changes people's routines and impacts interdepartmental communications. In order for CPOE deployments to succeed, the technology implementation must be well planned and efficiently executed. In addition, the hospital staff must make fundamental process changes, and after rollout the hospital must provide adequate technical support. We are not able to obtain rich observational data about each hospital in our sample and therefore cannot assess the extent to which each hospital goes to ensure the success of a technology implementation. For example, we do not have information on several antecedents to successful IT implementations such as the extent to which end-users participated in the system design, the specifics of user training, or technical support details. We attempted to counter this weakness by moving beyond a dichotomous measure of adoption by using a four-point scale to assess use, but there is still likely to be considerable variation within each category of use, which is unaccounted for in our study. One area for future research is conducting smaller-scale observational studies that attempt to categorize and quantify different types of individual CPOE implementations, but there are limitations to this approach as well. Nonetheless, we still show a significant relationship between CPOE use and patient satisfaction and would expect this relationship to be stronger when more covariates are identified.

Another limitation is that we created a weighted aggregate measure of IT infrastructure. While we consider the use of the Saidin index to be a considerable improvement over simple counts, there is still the possibility that some of the technologies in the aggregate measure have a strong relationship with CPOE use–satisfaction and others have little to no impact. We have examined two different bundles of IT – clinical and administrative – and found similar effects, but future research could examine how CPOE interacts with specific technologies. Again, it is our belief that our result is conservative and identification of specific technologies will increase the magnitude of the relationship found.

We also note that while our results strongly favor actual use as a predictor of performance, it is impractical to incorporate use in some situations. For example, when a large collection of ITs (such as a Saidin index) are being used to predict performance, there is no empirically valid way to include the use of each, even if the data were available. There are methodological and conceptual challenges associated with doing this that have yet to be addressed in a meaningful way.

Questions of variable omission and spurious correlations are important considerations as well. While it is possible that other factors contribute to patient satisfaction, we have controlled for a wide array of variables including hospital characteristics, resource levels, and regional effects, insuring that both CPOE use and IT Infrastructure offer unique explanatory power. Finally, while recent work has provided a link between patient satisfaction and medical outcomes, it is beyond the scope of our study to draw any connections between CPOE use and actual health outcomes.

6.2. Implications for practice

We have shown evidence of meaningful relationships between CPOE use and satisfaction, which will be useful for both managers and academics. Healthcare managers are keenly aware of the important role that patient satisfaction plays in the long-term success of their hospitals; patient satisfaction significantly influences word-of-mouth referrals and therefore hospital revenue. Because patient satisfaction passes not only from patient to patient in conversation, but now also through the readily available satisfaction scores accessible to the public on the Internet, managers have even more reason to want to understand how hospital actions can improve those scores.

Previous research has focused on the relationship between CPOE implementation and clinical quality scores. Clinical quality scores include outcomes such as number of medication errors or percentage of time that clinicians followed care protocol. While these are valuable measurements, they fail to tell the entire quality story. While recent research (Glickman et al., 2010) suggests that patients are good discriminators of the quality of care they receive, our contention is that patient satisfaction is not simply a function of the clinical care received but also the process of care they witnessed (Marley et al., 2004). Since most patients are not experts on care protocol, they often do not know when clinical mistakes occur. Therefore in addition to, or instead of evaluating clinical quality, they are likely to assess a hospital's quality using a combination of both process (which is more visible and salient to them) and clinical quality, which combine together to form "patient satisfaction." CPOE systems are designed to help hospitals improve both clinical and process quality, thereby substantially contributing to patient satisfaction. In the ever-increasing competition for patients, an investment resulting in increased patient satisfaction can significantly contribute to the bottom line of a hospital. There is an obvious tradeoff here in that a robust and innovative IT infrastructure can substitute for CPOE use as it relates to patient satisfaction, but questions still remain with respect to which configuration of IT yields the greatest benefits. What we can say from our research is that CPOE use is one technology that relates to satisfaction.

Finally, healthcare decision makers responsible for selection and implementation of IT are likely to be confused by conflicting results presented in studies of IT, specifically CPOE implementations. A small proportion of these studies show unintended consequences and negative effects. We have two points to make about this prior work. First, most of the studies were conducted within academic hospitals and our work shows that non-academic hospitals achieve greater benefit from CPOE use than academic hospitals do. Second, none of the studies take into account actual use of the system across a large sample of hospitals. Therefore our guidance to practitioners is to evaluate each study based on where it was conducted (academic or not) and what is being measured (adoption or use).

6.3. Implications for research

From an academic viewpoint, we contribute a number of new insights. First, we add to the scant research on large-sample-size CPOE studies, but more importantly have developed a theoretically grounded and empirically validated link between CPOE use and patient satisfaction. Our finding that non-academic hospitals reap more benefit from CPOE use than do academic hospitals in terms of patient satisfaction is important because most research has been conducted within academic hospitals, which only account for roughly 12% of the total population of hospitals in the U.S. It also provides a new lens with which to view the two types of hospital: prior research typically categorizes academic hospitals as more innovative and generally better on most quality and performance indicators, yet our study shows that these metrics are more nuanced and context-specific. If processes are highly standardized, certain technologies may contribute to specific quality indicators in a more profound way than in a highly customized setting.

Where our findings are similar to prior work is in the assertion that CPOE positively contributes to hospital quality. This adds to an ever-growing technology-value literature stream in healthcare research. Our study provides a more nuanced approach to the investigation by measuring 'CPOE use' instead of a binary variable for adoption, thereby strengthening the evidence for CPOE efficacy. By using patient satisfaction as a quality metric, this research again contributes to the literature on CPOE efficacy by examining quality through the customers' eyes.

Finally, we introduce to the operations audience an alternative IT concentration metric that takes into account the innovativeness of the IT portfolio – the Saidin index. Since this index more heavily weighs less common adoptions, it allows researchers to examine the effect of early technology adopters. This can be a very helpful distinction when testing for organizational IT learning and the marginal influence of new implementations. Most importantly, we acknowledge the important role that Operations Management can bring to healthcare (Boyer and Pronovost, 2010), and vice versa, and therefore encourage others to explore this fruitful domain with the hope of providing insights that can both improve health delivery and reduce costs.

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Appendix A.

Survey questions the Leapfrog group poses to hospitals to assess CPOE use

(1) Does your hospital have a functioning CPOE system in at least one unit of the hospital? (Yes/no)
(2) What percent of your hospital's **total inpatient medication orders** (including orders made in units which do NOT have a functioning CPOE) do prescribers enter via a CPOE system that:
   - includes decision support software to reduce prescribing errors; and,
   - is linked to pharmacy, laboratory, and admitting-discharge-transfer (ADT) information in your hospital _____%

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