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THE EFFECT OF INFORMATION SYSTEMS ON THE QUALITY AND COST OF HEALTHCARE PROCESSES: A LONGITUDINAL STUDY OF U.S. HOSPITALS

Research-in-Progress

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ABSTRACT

Our study focuses on the adoption and use of hospital information systems and their impact on the quality and cost associated with delivery of patient care. Archival data on hospital IT usage obtained from the Dorenfest Institute is combined with archival data on the quality of hospital care processes from the U.S. Department of Health and Human Services to conduct a three-year longitudinal study of a balanced panel data set consisting of 2,848 U.S. hospitals. Our analyses extends earlier research on the association between healthcare IT usage and efficiency improvements in healthcare organizations that have primarily focused on outcomes associated with operating cost reduction. Preliminary results from our study indicate a positive impact of clinical information systems, patient scheduling applications, and human resource management information systems on the quality of health care processes. However, quality increase comes at a cost as clinical systems usage and patient scheduling system usage increase hospital operating expenses.

Keywords: Healthcare, IT business value, Clinical information systems, Patient Quality, Operating Expenses.

Introduction

Understanding factors affecting clinical healthcare processes is of critical importance as healthcare provider processes directly affect patient outcomes. Information systems used in healthcare settings have the potential to improve both the quality and effectiveness of healthcare providers (Lee et al. 2000). The purpose of this study is to examine the impact of adoption and usage of different types of information systems on the quality of hospital care processes. Drawing upon the capabilities perspective associated with the resource-based view of the firm (Kohli & Devaraj, 2004), we argue that IT usage is associated with improvements in decision-support capabilities that allow physicians and staff to provide higher levels of patient care over time.

Another important factor that must be considered when analyzing the effect of IT adoption on decision-support capabilities is the business value associated with IT usage. IT business value research attempts to explain the effect of investments in IT on financial performance (Kauffman & Weill, 1989). Assessing the financial benefits derived from IT is one of the most challenging problems faced by organizations as investment in IT is not always associated with improved financial performance; rather, the effect of IT adoption and usage on financial performance is multifaceted and may be attributed to a range of interrelated factors (Brynjolfsson & Hitt, 1998). Therefore, in addition to studying the effect of IT usage on improvements in the quality of patient outcomes, this study also examines the effect of clinical and administrative IT adoption and usage on financial performance thereby providing additional insight into the relationship between IT cost and quality of healthcare processes.

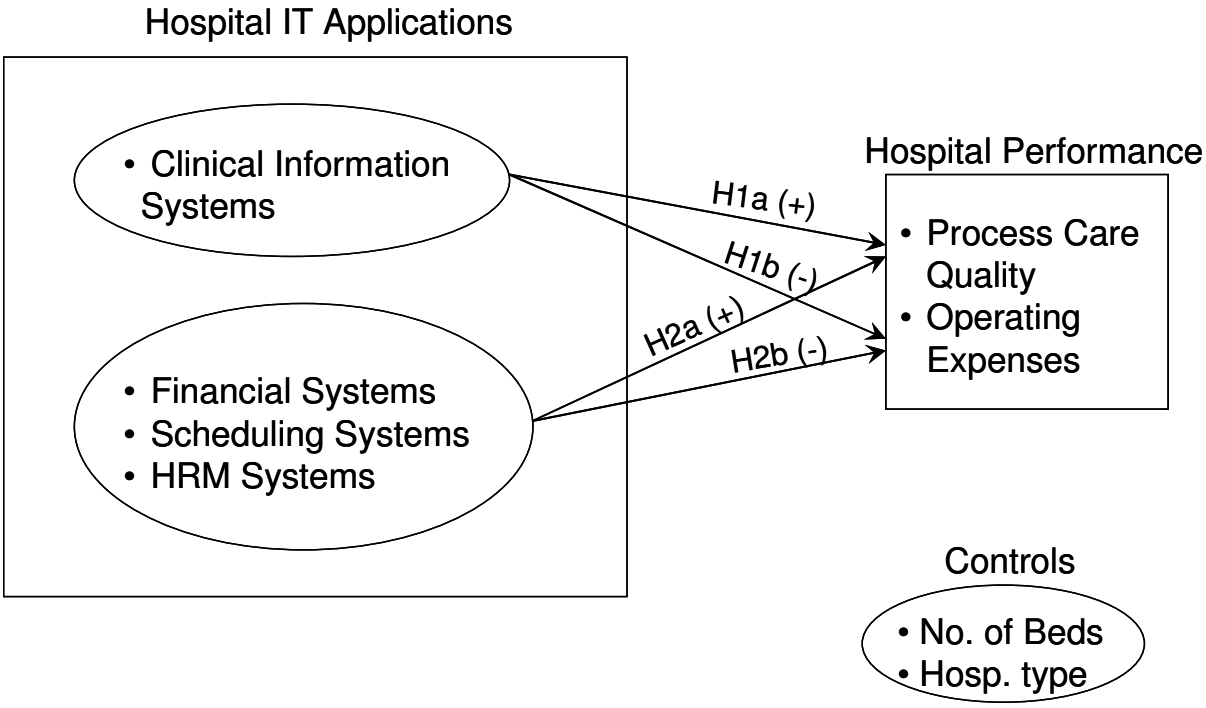
Theory Development

Drawing upon the process-centric role of IT in terms of its impact on business process value (Melville et al. 2004), we study the impact of hospital clinical and administrative information systems usage on the quality associated with four types of hospital care processes: *treatment of acute myocardial infarction, heart failure, pneumonia,* and *surgical infection prevention*. We posit that healthcare IT improves the capabilities associated with various business processes associated with delivery and management of patient care in a hospital setting (Amarasingham et al. 2009). For instance, IT-enabled capabilities can enable physicians to use computerized physician order entry (CPOE) systems at the point of contact with patients. This not only speeds up the transmission of the patient's prescription to the pharmacy, thereby reducing delay time, but has two added advantages: (a) it reduces the need for nurses or other physician assistants to transcribe the physician's prescription thereby reducing the potential for medical errors, and (b) it provides the decision support capabilities necessary to flag possible drug interactions at the time that the physician enters the prescription in the systems. The above example provides an illustration of the benefits of using clinical information systems which harness business intelligence and analytics capabilities and enable users to make better decisions.

In a similar manner, other types of supporting hospital information systems play important roles in the management of hospital resources. Billing systems and benefits management portals enable cross-functional integration of data across multiple departments, while scheduling systems provide "intelligent and dynamic" decision support for scheduling patients to the right types of doctors/nurses based on case volume, patient condition, and diagnosis. Hence, we posit that healthcare IT applications will have a positive impact on both patient care processes as well as the efficiency of supporting business processes.

We develop our conceptual, process-centric research model as shown in Figure 1.

Figure 1. Conceptual Research Model



Our hypotheses can be framed as follows:

H1a: Usage of clinical hospital information systems is associated with improvements in quality of patient care processes.

H1b: Usage of clinical hospital information systems is associated with a reduction in operating expenses.

H2a: Usage of supporting hospital information systems (such as financial, administrative, and HR management systems) is associated with improvements in quality of patient care processes.

H2b: Usage of supporting hospital information systems (such as financial, administrative, and HR management systems) is associated with a reduction in operating expenses.

Methodology

To empirically test the research hypotheses, time series regression analysis was used to analyze secondary survey data for the period 2004 through 2006. The effect of clinical and administrative information systems usage on quantitative process of care measures were analyzed for a balanced panel of 2,848 U.S. hospitals. Each hospital included in the sample reported measures for each year in the study. The analysis focused on the near-term effect of clinical and administrative information system usage on quality process of care measures (e.g. the effect of clinical information systems usage in 2004 on quality process of care measures in 2004, the effect of clinical information systems usage in 2005 on quality process of care measures in 2005, and the effect of clinical information systems usage in 2006 on quality process of care measures in 2006). Time specific and individual random effects were included in the model of the error term using the Fuller-Battese method. Hospital IT usage characteristics were obtained from the Dorenfest Institute for Health Information Technology Research while quantitative assessments of hospital quality of care processes were obtained from the U.S. Department of Health and Human Services. A secondary analysis of the effect of IT usage on operating efficiency was also conducted using publically available data obtained from the U.S. Department of Health and Human Services Centers for Medicare and Medicaid Services.

Measurement of Variables

The level of adoption and usage of healthcare information systems used to support clinical, financial, scheduling, and human resource management functional process areas was assessed (Devaraj and Kohli, 2003). For each defined functional process area, information systems used to support the functional process area were identified. A total of six clinical, six financial, one scheduling and two human resource management (HRM) systems were identified. For each information system, a hospital in the sample indicated whether or not the information system was currently being used to perform the associated clinical or administrative process. Hospitals indicating use of a particular type of information system were coded as "1", while hospitals indicating the type of information was not currently being used were coded as zero. Next, an overall measure of IT usage in each functional process area was obtained by averaging the individual information systems used in the functional process area. Thus, the maximum possible score in a functional process area is 1.0, which would indicate information systems were used to support all healthcare processes for the given functional area. Similarly, a score of 0 would indicate no business processes in the category were supported by information systems. Values between zero and one indicate a hospitals level of automation in a functional process area. The following table lists the functional process areas analyzed along with the information systems supporting the functional area processes.

Table 1. Classification of Hospital Information Systems

Functional Process Areas	Information System
Clinical	Clinical Data Repository Clinical Decision Support Enterprise Electronic Medical Records (EMR) Laboratory Information System Order Communication Radiology Information System
Financial	Budgeting Electronic Claims Encoder Enterprise Master Person Index General Ledger Materials Management
Administration	Patient Scheduling
Human Resource Management	Benefits Administration Personnel Management

The primary dependent variable of interest concerns the quality of a hospital's healthcare processes. Quality processes were assessed and measured using evidence-based data obtained from the U.S. Department of Health and Human Services' Hospital Compare program. The program identifies agreed upon best practices for treating four types of hospital care processes associated with *patient treatment quality*: treatment of acute myocardial infarction, heart failure, pneumonia, and surgical infection prevention (Amarasingham et al. 2009). Each quality process area defines specific process of care measures to assess the frequency with which a hospital follows recommended best practices. Each process of care measure is known to achieve the best result for a given condition and following standard processes of care is an indication of quality. The following table lists the healthcare quality process areas and the quality measures used in each process area.

Table 2. Evidence-based Quality Measures of Hospital Care Processes

Process Care Areas	Quality Process Measures
Acute Myocardial Infarction	Patients Given ACE Inhibitor for Left Ventricular Systolic Dysfunction (LVSD) Patients Given Adult Smoking Cessation Advice/Counseling Patients Given Aspirin at Arrival Patients Given Aspirin at Discharge Patients Given Beta Blocker at Arrival Patients Given Beta Blocker at Discharge Patients Given PCI Within 120 Minutes Of Arrival Patients Given Thrombolytic Medication Within 30 Minutes Of Arrival
Heart Failure	Patients Given ACE Inhibitor for Left Ventricular Systolic Dysfunction (LVSD) Patients Given Adult Smoking Cessation Advice/Counseling Patients Given Assessment of Left Ventricular Function (LVF) Patients Given Discharge Instructions
Pneumonia	Patients Assessed and Given Pneumococcal Vaccination Patients Given Adult Smoking Cessation Advice/Counseling Patients Given Initial Antibiotic(s) within 4 Hours After Arrival Patients Given Oxygenation Assessment Patients Given the Most Appropriate Initial Antibiotic(s) Patients Having a Blood Culture Performed Prior to First Antibiotic Received in Hospital
Surgical Infection Prevention	Surgery Patients Who Received Preventative Antibiotic(s) One Hour Before Incision Surgery Patients Whose Preventative Antibiotic(s) are Stopped Within 24 hours After Surgery

Each hospital reports the frequency with which a particular quality process measure is followed for all patients treated for the corresponding condition. A hospital scoring 1 in a quality process measure followed the recommended quality process for every patient treated for a given condition while a hospital scoring 0 in a process measure did not follow the recommended quality process for any of the patients treated for a given condition. Values between 0 and 1 indicate the percentage of patients receiving the recommended treatment prescribed by the quality process measure for a given condition. The average of quality process measures for a process area was used to obtain an indication of overall quality for the quality process area. The average of all four quality process areas was taken as an indication of a hospital's overall quality of healthcare processes and was used as the primary dependent variable in the model.

An important secondary question concerns the effect of information systems usage on operational expenses. To measure a healthcare provider's operational expenses, the operating expense per bed was used by taking the total annual operating cost for a hospital and dividing it by the number of beds used in the hospital. The total annual operating cost was obtained from Form CMS-2552-96 of the U.S. Health and Human Services Centers for Medicare and Medicaid Services while the number of hospital beds was obtained from the U.S. Department of Health and Human Services Hospital Compare program.

In addition to the primary variables of interest, several variables known to affect quality and operational expenses were also included in the study. Specifically, a variable indicating the size of the hospital, as measured by the number of beds, and a variable indicating whether or not the hospital was for-profit or not-for-profit were included. The following table summarizes the variables used in the two regression models analyzed and the measures used for each variable.

Table 3. Model Variables and Definitions

Variable	Measure
Total Quality of Healthcare Processes	Average of the four quality process areas of acute myocardial infarction, heart failure, pneumonia, and surgical infection prevention.
Operational expenses	Total annual operating cost divided by number of beds.
Clinical Information System Usage	Percentage of clinical processes supported by information systems.
Financial Information System Usage	Percentage of financial processes supported by information systems.
Scheduling Information System Usage	Percentage of scheduling processes supported by information systems.
HRM System Usage	Percentage of human resource management processes supported by information systems.
No. of Beds	The total of number of beds in the hospital.
Hospital Type	The status of the hospital as either for-profit or not-for-profit.

Empirical Model

Time series regression analysis of a balanced panel of 2,848 U.S. hospitals was used to analyze the effect of information systems usage on total quality of healthcare processes for the years 2004 through 2006. Specifically, we estimate the regression equation defined in (1).

$$\begin{aligned}\Pr ocessQuali\ ty &= \beta_0 + \beta_1 \times ClinicalSy\ stemUsage\ + \beta_2 \times FinancialS\ ystemUsage \\ &+ \beta_3 \times Scheduling\ SystemUsag\ e + \beta_4 \times HRMSystemU\ sage + \beta_5 \times No.ofBeds + \beta_6 \times Type + e\end{aligned} \quad (1)$$

The process quality model analyzed the effect of the level of clinical systems usage, the level of financial systems usage, the level of scheduling systems usage, and the level of HRM usage on healthcare process quality while controlling for the number of beds and type of the hospital.

Time series regression analysis of a balanced panel of 2,803 U.S. hospitals was used to analyze the effect of IT usage on operational expenses for 2004 and 2005. Specifically, we estimated the regression equation in (2).

$$\begin{aligned}OpExpPerBed &= \beta_0 + \beta_1 \times ClinicalSystemUsage + \beta_2 \times FinancialSystemUsage \\ &+ \beta_3 \times SchedulingSystemUsage + \beta_4 \times HRSystemUsage + \beta_5 \times Type + e\end{aligned} \quad (2)$$

The operational expenses model analyzed the effect of the level of clinical systems usage, the level of financial systems usage, the level of scheduling systems usage, and the level of human resource systems usage on operational expenses while controlling for the size of the hospital.

Results

We report the time series estimation results for equations (1) and (2) in Tables 4 and 5, respectively. The estimation model allows us to explicitly account for time trends as well as correct for possible heterogeneity in our study sample.

As shown in the Table 4, clinical information systems usage is found to have a positive effect on patient care quality thereby finding support for the hypothesis H1a. However, quality has a cost as evidenced by the significant and positive relationship between clinical information systems usage and operational expense per bed shown in Table 5. Specifically, expense per bed increases as clinical information systems usage increases. Hence, our results do not provide support for hypothesis H1b.

Information systems used for patient scheduling also have a significant and positive effect on healthcare quality processes in Table 4. However, once again, the improvement in quality comes at a cost as evidenced by a positive coefficient on scheduling information systems usage being associated with an increase in operating expense per bed in Table 5.

Another interesting finding is that HRM system usage has a positive effect on process quality and a negative effect on operational expense per bed. Processes used to support personnel management achieve the highly desirable outcome of reducing costs and improving quality. Hence, HRM systems do support the dual goal of improving patient care quality while lowering overall operating expenses.

On the other hand, financial information system usage does not have a significant effect on healthcare quality processes. However, their usage is associated with a weak, negative coefficient for operating expenses, which suggests that usage of such systems to better manage the administrative and billing processes is associated with a reduction in hospital operating expenses. Hence, our results provide support for H2a but only marginal support for H2B as evidenced by the negative impact of HRM systems on operating expenses, while other types of hospital administrative and financial systems do not have a discernible impact on operating costs.

Examining other hospital characteristics reveals a significant and negative effect between for-profit hospitals and the quality of healthcare processes, providing an indication that not-for-profit hospitals are associated with superior quality processes. However, for-profit hospitals have lower operational expenses as evidenced by their lower operating expense per bed (negative coeff.). Finally, bed size is positively correlated with greater quality of hospital care processes which indicates that larger hospitals are more likely to exhibit greater quality of process care. This may be attributed to larger hospitals also having access to a larger base of doctors (presumably of higher quality) as well as access to greater financial and technological resources at their disposal.

Table 4. Quality of Hospital Care Processes: Regression Analysis (R^2 = 0.02)

Variable	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.75610	0.0231	32.75	<.0001
Clinical System Usage*	0.00339	0.0018	1.86	0.0626
Financial System Usage	-0.00063	0.0009	-0.68	0.4949
Scheduling System Usage***	0.01166	0.0025	4.67	<.0001
HRM System Usage*	0.00896	0.0051	1.76	0.0789
Hospital Type***	-0.01996	0.0035	-5.74	<.0001
Bed Size***	0.00006	7.20E-06	8.41	<.0001

Table 5. Operational Expenses: Regression Analysis (R^2 = 0.020)

Variable	Estimate	Standard Error	t Value	Pr > |t|
Intercept	611,146	27,103	22.55	<.0001
Clinical System Usage***	43,169	15,665	2.76	0.006
Financial System Usage	-2,595	1,904	-1.36	0.173
Scheduling System Usage*	14,009	7,678	1.82	0.068
HRM System Usage***	-43,819	14,857	-2.95	0.003
Hospital Type***	-115,861	12,343	-9.39	<.0001

*=Significant at 0.10 level, **=significant at 0.05 level, ***=significant at 0.01 level

Conclusions

Our results indicate a marked divergence in terms of the impact hospital IT systems on the quality and costs associated with hospital operations. On the one hand, clinical information systems, which include EMR and clinical decision support systems, are associated with significant improvements in patient outcomes and overall hospital quality measures. However, such improvements come at a price. We find that implementation and use of such systems are also associated with increases in hospital operating expenses. We observe similar results for patient scheduling systems.

On the other hand, implementation and usage of hospital financial information systems does not have an impact on the quality of patient care processes. However, they are associated with a weak reduction in overall operating expenses. The only class of hospital IS that has a dual beneficial impact are HRM systems which not only improve patient care but are associated with reduction in operating costs. These types of systems appear to make it easier for hospital employees to manage their own benefits and human resource needs, which in turn allow employees to run the HR function more efficiently and free up more time to provide high quality patient care.

Our findings have significant implications as they demonstrate the benefit of using clinical information systems in improving delivery of patient care. Our results have important implications for policy makers as they provide evidence of the effectiveness of the Hospital Compare program and the effectiveness of measuring IT-enabled process performance. It also extends earlier work by evaluating the impact of IT at an application cluster level instead of focusing on IT investments alone. Future research will focus on the role of other factors, including IT governance strategies to explore their role in improving hospital performance. A second area of research lies in exploration of these results using patient-level records to evaluate the impact on individual patient quality and costs of hospital stay (Amarasingham et al. 2009).

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Appendix A - Descriptive Statistics and Correlation Matrices

Table 6. Descriptive Statistics for Patient Care Quality

	Healthcare Process Quality	*Financial System Usage*	*Clinical System Usage*	*Scheduling System Usage*	*Human Resource System Usage*	*Beds*	*Type 1=for-profit 0=not-for-profit*
Mean	0.79	0.86	0.78	0.75	0.96	247.28	0.17
Standard Deviation	0.10	0.78	0.42	0.43	0.19	196.74	0.38
Sample Variance	0.01	0.61	0.18	0.19	0.04	38706.81	0.14
Kurtosis	1.10	3933.52	4566.27	-0.66	18.23	5.11	0.99
Skewness	-0.86	61.45	57.64	-1.16	-4.39	1.75	1.73

Table 7. Descriptive Statistics for Operational Expense

	Operating Expense per Bed	*Financial System Usage*	*Clinical System Usage*	*Scheduling System Usage*	*Human Resource System Usage*	*Type 1=for-profit 0=not-for-profit*
Mean	590,177	0.90	0.78	0.73	0.95	0.18
Standard Deviation	321,580	0.95	0.22	0.44	0.20	0.38
Sample Variance	103,413,893,885	0.91	0.05	0.20	0.04	0.15
Kurtosis	14	2,678.38	1.15	-0.91	16.88	0.78
Skewness	2	51.18	-1.10	-1.05	-4.24	1.67

Table 8. Correlation Matrix for Patient Care Quality

Pearson Correlation Coefficients, N = 8544 Prob > |r| under H0: Rho=0							
	Quality	Financial	Clinical	Scheduling	HR	Type	Beds
Quality	1	-0.03033 0.005	0.07872 <.0001	0.12385 <.0001	0.05441 <.0001	-0.11526 <.0001	0.15211 <.0001
Financial	-0.03033 0.005	1	0.03598 0.0009	0.0258 0.0171	0.0276 0.0107	-0.00474 0.6617	0.04963 <.0001
Clinical	0.07872 <.0001	0.03598 0.0009	1	0.11413 <.0001	0.09102 <.0001	-0.01265 0.2425	0.12482 <.0001
Scheduling	0.12385 <.0001	0.0258 0.0171	0.11413 <.0001	1	0.06123 <.0001	-0.09596 <.0001	0.09255 <.0001
HR	0.05441 <.0001	0.0276 0.0107	0.09102 <.0001	0.06123 <.0001	1	0.01037 0.338	0.07956 <.0001
Type	-0.11526 <.0001	-0.00474 0.6617	-0.01265 0.2425	-0.09596 <.0001	0.01037 0.338	1	-0.11918 <.0001
Beds	0.15211 <.0001	0.04963 <.0001	0.12482 <.0001	0.09255 <.0001	0.07956 <.0001	-0.11918 <.0001	1

Table 8. Correlation Matrix for Operational Expense

Pearson Correlation Coefficients, N = 5606 Prob > |r| under H0: Rho=0						
	OpExpPerBed	Financial	Clinical	Scheduling	HR	Type
OpExpPerBed	1	0.01555 0.2445	0.12177 <.0001	0.07061 <.0001	0.02042 0.1264	-0.19554 <.0001
Financial	0.01555 0.2445	1	0.05836 <.0001	0.02237 0.0939	0.02243 0.0931	-0.00423 0.7514
Clinical	0.12177 <.0001	0.05836 <.0001	1	0.24606 <.0001	0.15833 <.0001	0.03256 0.0148
Scheduling	0.07061 <.0001	0.02237 0.0939	0.24606 <.0001	1	0.03236 0.0154	-0.08237 <.0001
HR	0.02042 0.1264	0.02243 0.0931	0.15833 <.0001	0.03236 0.0154	1	0.0068 0.6107
Type	-0.19554 <.0001	-0.00423 0.7514	0.03256 0.0148	-0.08237 <.0001	0.0068 0.6107	1