MANAGING INFORMATION TECHNOLOGY INTEGRATION AND IMPLEMENTATION IN HEALTH CARE SUPPLY CHAINS:

TWO ESSAYS

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Asoke Kumar Dey

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Dr. Kingshuk K. Sinha

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Abstract

Information-intensive and customer-centric technologies available today promise substantial improvements in operational performance for both manufacturing and service supply chains. This abundance of technology is overwhelming for managers who, more often than not, find it challenging to determine which technologies they should invest in and how they should integrate the technologies to realize the promised performance benefits. Using data from the health care industry, I investigate the phenomena of technology integration and technology implementation, its antecedents, and its impact on organizational performance.

The dissertation is comprised of two complementary parts, the first of which focuses on understanding the selection of a level of technology integration within an organization and its implications for performance. Electronic Medical Records (EMR) is the technological context of this research, and the empirical analysis is based on data from acute care hospitals in the U.S. (n=1011). My findings suggest that health care providers self-select into different levels of technology (EMR) integration. While some health care providers are better off investing in higher levels of EMR integration and benefit from doing so, not all providers choose to follow suit.

The second part of my dissertation focuses on understanding factors that best explain successful technology implementation within a health care organization and its implications for performance, given a specific level of technology integration. Here I investigate the computerized physician order entry (CPOE) system and the empirical analysis is based on data from 188 acute care hospitals. I develop a research framework linking organizational readiness, user readiness, and levels of technology integration with the use of CPOE systems. I also hypothesize the relationship between use of CPOE systems and organizational performance under the moderating influence of the levels of technology integration. Study results show that each of the research hypotheses is supported, save that which links organizational readiness with the use of a CPOE system. Finally, implications of the dissertation findings, limitations, and directions for future research are identified.

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CHAPTER 1

INTRODUCTION

In his famous book, *The Third Wave* (1984), Alvin Toffler suggested that developments in communication and computer-based information processing technology are creating a new economic civilization. Indeed, information processing technologies have transformed new-age, technology-driven organizations at the operational as well as the tactical and strategic levels. These technologies not only help managers control the operations and work of employees, they also provide competitive advantages to organizations by effectively interfacing with changes in their external environment, competitors, and target customers (Gehani 1998).

Despite huge investments in information technology (IT), however, recent empirical studies testing the impact of IT on performance and/or productivity at the organizational and application levels find mixed outcomes (Devaraj and Kohli 2003). Extant research offers several reasons for these seemingly paradoxical findings[1] including the manner in which IT is used within the organizational context, misaligned management practices, mis-measurement of economic performance, and lags due to learning and adjustment (Sanders 2007). Still, little work informs managers about (i) the choice of technology applications, (ii) the relationship between IT and performance when multiple technologies are used in conjunction (Waring and Wainwright 2000), and (iii) factors that influence successful implementation after a chosen technology is adopted in a technology-integrated environment (Zhu et al. 2006).

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[1] IT literature commonly refers this phenomenon as the ‘productivity paradox’. Nobel prize-winning economist Robert Solow made a strong statement on this phenomenon when he commented, ‘You can see the computer age everywhere but in the productivity statistics’. A decade later he reaffirmed this, saying, ‘There’s not a shred of evidence to show that people are putting out more because of investments in technology.’

I attempt to address these three concerns with my dissertation, comprised of two essays grounded in real-world health care. While Chapter 2 provides a general background for all of the research, Chapter 3, "Self Selection in Electronic Medical Record Integration and its implications on Operational Performance," examines the performance implications of technology integration in health care organizations. The second research stream is presented in Chapter 4, "Antecedents and Consequences of Computerized Physician Order Entry System Implementation," which studies the antecedents of technology implementation and its implications on organizational performance. I conclude with Chapter 5, wherein I conceptually synthesize the findings of these two studies and present research questions to guide future investigations.

1.1 Electronic Medical Record (EMR) Integration and Health Care Provider Performance

As business models and constituent processes become more technology enabled, IT is touching more parts of the business and in more fundamental ways. Increasingly, IT is integrated with umbrella concepts like enterprise resource planning (ERP), electronic commerce, and data warehousing applications, where each refers to a cluster of related technologies. Such developments shift an organization's focus from managing a narrowly defined, single technology to developing the capability to manage an array of possibly interrelated information technologies. Managers often fail to achieve the promised benefits of new technologies, as they find it hard to determine what each of these technologies do, which ones to select, and how to integrate those they do select in order to improve performance (McAfee 2006). Although the inappropriate choice of technologies and a lack of integration across the selected technologies are cited as dominant factors in the failure of some organizations to realize the full potential of innovations (Colombo and Mosconi 1995), extant research has not paid enough attention to technology integration and its relationship to performance.

The first of my studies works to address this gap and is focused on decisions to select and integrate technologies within acute care health care organizations (i.e., those in which care is generally provided for a short period of time to treat a certain illness or condition; this might include short-term hospital stays, doctor's visits, outpatient surgery, or X-rays). To provide quality care and reduce cost, health care providers must share information across various elements of the total care delivery system, and personnel use clinical and administrative technologies to facilitate the process. For example, when integrated with pharmacy, radiology and other ancillary systems, computerized physician order entry (CPOE) systems can create a health information system that enables patients and their physicians to access real time, patient-specific information from points of care (Davidson and Chismar 2007).

Electronic medical record (EMR) systems are automated clinical systems that generally include patient demographics, medical history, clinicians' notes, drug information, electronic prescriptions, and diagnostic test orders (Venkatraman et al. 2008). It is estimated that the use of EMR systems could save the health care industry $142 to $371 billion a year by increasing efficiency and reducing errors while also increasing social and other benefits (Hillstead et al. 2005). EMR integration, the focus of Chapter 3, results from the integration of several clinical information technologies. Based on prior work, I identify five distinct levels of EMR technology integration, where each level represents a bundle of clinical information technologies adopted by a health care provider. I posit that those health care providers that have implemented the highest level of technology integration are the most advanced, have the highest level of EMR preparedness, and provide superior service for their patients, as measured by quality and efficiency.

Building on this conceptual foundation, I examine the selection of technology integration levels by health care providers. Extant research suggests that a variety of factors (institutional, organizational, and technological) affect a provider's decision to select into a given level of technology integration. I theorize that health care providers respond strategically to institutional influence by selecting into the most appropriate level for their characteristics. Then, I assess the operational performance implications of technology integration levels. My research design involves the use of a two-step selection model to account for endogenous selection effects (since factors that influence a provider's decision to select a level of technology integration and its performance are often unobservable). Using data from 1011 acute care providers in the U.S., I test my hypotheses. While I find support that health care providers with higher levels of technology integration realize better operational performance on average (conditional on observed and unobserved factors), health care providers do select themselves into different technology integration levels. In other words, while some health care providers select into higher levels of technology integration and benefit from doing so, not all providers choose to follow suit. Finally, I discuss the contributions of this study, the implications of the study's findings, the limitations and directions for future research.

1.2 An Integrated Model of Computerized Physician Order Entry Implementation

CPOE systems are complimentary to EMR systems and are often implemented as part of an overall migration from paper records to electronic medical records.

Interfacing CPOE with a pharmacy application and/or with an electronic medical administration is found to realize medication-related benefits and improve efficiency (Kuperman and Gibson 2003). However, one of the most difficult challenges encountered by health care organizations after they invest in electronic clinical information systems such as CPOE is getting physicians to use them (Kralewski et al. 2008). While IT implementation research has shown that some organizations reject the same technology that other organizations successfully implement, these studies do not provide adequate insights into determinants that could explain those behaviors (Edmondson 2003). Also, the majority of current implementation studies are merely anecdotal and descriptive in nature, particularly when the targeted users of the implemented technology are knowledge workers (e.g., physicians, lawyers, and scientists) in a health care setting. As such, this gap in the current body of knowledge reveals the need for the development of theory-driven empirical work, and my effort to understand the implementation of a critical health care IT application used primarily by physicians will address this need.

Two primary research questions drive the second essay: (i) What are the antecedent factors that influence CPOE implementation, and (ii) What are the performance implications of CPOE implementation for health care providers? Addressing these questions, I draw on three streams of literature to develop an integrated theoretical model. First, I employ structuration theory (Orlikowski et al. 1995) to explain how organizational practices like top management participation and provision of resources influence CPOE system usage within health care providers. Current research is of limited assistance in explaining what organizational managers can do to proactively motivate organizational end-users in utilizing organizational IT such as enterprise resource planning systems, forecasting systems, or CPOE systems. This paper specifically focuses on those organizational practices that can be directly controlled by managers and examines the relationship between organizational readiness and CPOE usage within organizations. Next, I apply the theory of planned behavior (Ajzen 1991) and the innovation diffusion theory (Rogers 1995) to explain how individual user attributes and specific behaviors influence CPOE system usage. Finally, I assess the operational performance implications of the CPOE system usage under the moderating influence of the level of technology integration for each organization using detailed cross-sectional empirical data from 188 acute care hospitals in the U.S. My results show that each of the research hypotheses is supported, save that which links organizational readiness with the use of a CPOE system.

This second study makes important contributions to both research and practice. The research framework can be used to study implementation of e-business technologies, wireless technologies, and radio frequency identification (RFID) systems. Statistical significance of the user readiness variable informs us of the important role that knowledge workers play in the successful implementation of new technologies. From a practical standpoint, an improved understanding of organizational factors that influence organizational CPOE usage may also help practitioners formulate intervention strategies for enhancing CPOE usage in a health care provider. I conclude Chapter 4 with a discussion of the study's limitations and future research implications.

CHAPTER 2

RESEARCH BACKGROUND

2.1 Introduction

Previous research on advanced technologies, particularly information and communication technologies, has primarily examined five industry groups (manufacturing, high-tech, retail, insurance, and finance) without paying much attention to other industries, such as the health care industry. The information-intensive nature of the health care industry and the perception of information technology (IT) as a way to ease health care costs and improve quality, though, have led to increased use and experimentation of IT-based innovations in this industry. Highlighting this fact, Chiasson and Davidson (2005) suggest the health care industry as an ideal research context that can provide an important contextual space to build new theory and evaluate the boundaries of existing theory. In this research, I focus on electronic medical records (EMR) and computerized physician order entry (CPOE) systems, which represent a subset of IT-based innovations in the health care domain.

In this chapter, I provide a general background for my study. First, the current status of information technologies in the health care industry is provided. Then I describe the EMR system and the significance of technology integration with respect to it. Next, I describe the CPOE system and review previous research that has investigated its implementation by health care providers. Finally, I present reasons that explain physician acceptance (or reluctance) and use (or non-use) of clinician information technologies in their regular work routines.

2.2 Information Systems in the Health Care Industry

Pursuing the delivery of cost efficient and high quality patient care and responding to the challenges caused by uncertainties in the industry's environment[2], health care providers have (i) broadened organizational missions to include provisions for a continuum of care, (ii) reengineered business processes, and (iii) implemented total quality management work practices (Watson et al. 2001). Unfortunately, these managerial initiatives put significant additional pressure on health care providers who often "lack reliable mechanisms to integrate their set of individual functions into a coherent whole required for safe, effective care" (Spear 2005, page 82). IT, then, emerged as a strategic necessity to develop an integrated technology infrastructure with the potential[3] to improve service quality, cut costs significantly, and further operational excellence and financial success for health care services in the U.S. (Mantzana et al. 2007, Herzlinger 2006). IT investments in the health sector alone reached $23.6 billion in 2003, rising at an annual rate of 9.3 per cent (Dorenfest 2004).

The U.S. has the highest per capita spending on health care of any industrialized nation[4], but with an aging population and increasing social spending, health care has become one of the most inefficient and poorly managed sectors in the U.S. economy (Anderson et al. 2006). The authors further added that the American health care service quality in 2003 was lower than that of the median OECD country with fewer

[2] Significant growth of managed care in the 1990s, the Clinton health care initiative, the prospective payment system, the Balanced Budget Act of 1997 and an increasingly consumer-driven market are just a few important factors that have created the current environmental uncertainty in healthcare (Burke 2002).

[3] According to a report by the U.S. Department of Health and Human Services (2004), IT has the potential to save the U.S. economy $140 billion a year or 10% of current health care costs and at the same time reduce medical errors in hospitals.

[4] In 2003, U.S. health care spending per capita was $5,635 – two-and-a-half times that of the comparable median of OECD (Organization for Economic Co-operations and Development) countries at $2,280 (Anderson et al. 2006).

physicians, nurses, and hospital beds. Annually, 44,000 to 98,000 deaths are estimated due to unexplained variations in health care (IOM 1999). In 2001, the Institute of Medicine reported that many errors in the health care industry are due to failures in organizational systems and various other organizational factors, and the group recommended implementing clinical information technologies that could achieve effective coordination of clinical services and improve health care quality (IOM 2001, 2003). The report noted that when several health care practitioners treat a patient, each one often does not have complete information about the medicines prescribed by the others or details about their patient's illnesses. Additionally, most medical records are still stored on a paper, which makes it difficult to properly coordinate care and provide detailed information to consumers about health care costs and quality to help them make informed decisions about their care (Hillstead et al. 2005).

Although the amount of clinical knowledge available to medical practitioners has grown exponentially, health care providers lack an efficient information infrastructure that can connect those who produce and archive medical knowledge to those who must apply that knowledge (Weed 1997). In 2004, a group of providers in the health care industry[5] identified two potential clinical information technologies that would help providers connect with information they need at the point of care: EMR and CPOE. The federal government[6] and many state governments have also promoted these two systems, and announced lucrative initiatives for health care providers who adopt these systems (Saathoff 2007).

[5] National organizations such as the Institute of Medicine, Joint Commission on Accreditation of Health care Organizations, President's Information Technology Advisory Committee, and Leapfrog Group identified EMR and CPOE as important technologies based on their potential to improve quality of care (Cutler et al. 2005).

[6] During his 2004 presidential campaign, President Bush unveiled his goal for all health care providers to have EMR within ten years and proclaimed that EMR could reduce health care costs by billions of dollars (Cohen 2005).

2.3 Electronic Medical Record (EMR) Systems

Weed (1997, page 88) said, "Knowledge should be held in tools that are kept up to date and used routinely - to extend the human mind's limited capacity to recall and process large numbers of relevant variables." Health care needs clinical tools to retrieve and organize information in a usable form, thereby empowering human judgment to make decisions based on reliable information. Such tools may include knowledge coupling software that retrieves medical knowledge and links it with medical records that hold patient data, including information on the actions and thought processes of other medical professionals.

Traditional paper charts, still widely used to record patient interactions and to serve as instructions for treatment, provides only one-third of the data a physician needs to provide comprehensive patient care (Anderson 1997)[7]. An EMR system, however, is a structured and integrated approach to managing patient data. EMRs are designed to improve patient care by reducing the waiting time for paper-based test results, reducing the number of incomplete charts, and enhancing clinical decision-making with real-time and/or on-line access to patient information (U.S. Department of Health and Human Services 2004). EMR systems enable a physician to have a complete view of a patient's medical history, which may allow them to check for duplicate prescriptions, overdosing, and over-treatments; in short, they reduce medical errors (Ilie et al. 2009). Further, they add speed to accuracy: a nurse can access patient records without waiting for charts to be physically transferred (Venkatraman et al. 2008).

[7] The President's Information technology Advisory Committee (2004) noted, "The enormous complexity and sophistication of medical practice involving multiple care providers, the geographic mobility of citizens, and the critical requirement for adequate patient information in medical decision-making have stressed the traditional modes to the breaking point."

Health care literature cites benefits accrued from EMR systems that can be organized into four categories: clinical, process, administrative, and revenue enhancement (Tang et al. 2006). Clinical benefits include better access to medical charts, improved clinical decision-making, enhanced documentation, and increased free time to spend with patients, all of which ultimately result in better delivery of patient care (Drazen 2001). Process related improvements save in reduplication of efforts, reduced labor costs, reduced transcription costs, and better management of referrals, lab results, prescriptions, and drug recalls (May 2002). Administrative benefits include better monitoring of physician practices, outcomes research, and disease management (Willey and Struckhoff 1999), and EMR systems increase revenue through effective management of information at the point of care, improved workflow, and improved administrative functions (Erstad 2003).

Despite these numerous benefits, the integration of clinical information technologies needed to develop the EMR system is challenging, and implementation remains an underachieved goal. Health care providers that have successfully deployed integrated systems are, mostly, the exception (Overhage 2003, Kolodner and Douglas 1997). For instance, while the IOM called for replacing paper-based patient records with computerized patient records as early as 1991, their 2002 report observed that, "In most of the nation's hospitals, orders for medications, laboratory tests, and other services are still written on paper and many hospitals lack even the capability to deliver laboratory and other results in an automated fashion." Four years later, the 2006 Robert Wood Johnson Report reiterated this problem, noting considerable variation in the composition of integrated health care information systems across providers.

Another obstacle to successful implementation is the absence of a universal definition of EMR. Health care providers have a difficult time selecting the different technologies for an integrated system, and IT vendors do not exactly know what to supply (Tang and Hammond 1997). Drazen (2001) suggests defining EMR systems by focusing primarily on clinical information technologies that facilitate patient care to improve the rates of EMR implementation at health care providers. In this study, I conceptualize EMR capability by way of a classification scheme of five levels of technology integration. My grouping of technologies and classification of technology integration levels is informed by Garets and Davis's (2006) clinical transformation staging model. In Chapter 3, I examine whether health care providers self-select into one of the levels of EMR technology integration and the implications on operational performance.

2.4 Computerized Physician Entry (CPOE) Systems

CPOEs are information systems that allow physicians to enter orders electronically rather than manually writing the orders (Kuperman and Gibson 2003). Rochon et al. (2005, page 1780) describe CPOE as "an electronic application used by physicians to directly enter orders for drug therapy, diagnostic tests, and requests for consultations." The clinical application then transmits the doctor's order to the appropriate department or individuals, so that the order for medication, a laboratory or radiology test, or a procedure can be carried out (Sittig et al. 2005). Early promises of CPOE include process improvement, increased order accuracy, integration of clinical decision support into the order-entry process, and optimization of physician, nurse, and pharmacist time (Tierney et al. 1993)

Empirical studies in health care demonstrate a number of benefits associated with the implementation of CPOE systems (Sittig et al. 2005, Aarts et al. 2004). These include a reduction in the incidence of serious medication errors, reduced length of patient stays, reduction of medication costs, improved accessibility of patient data, and increased time spent with patients. Researchers also found medication-related benefits that can be realized if CPOE is well integrated with other components of the medication process. The benefits of interfacing a CPOE application with an electronic medical administration record result in reduced transcription errors (Mekhjian et al. 2002). Further, health care studies consider CPOE systems important building blocks for the successful implementation of the EMR (Hwang et al. 2002) and demonstrate evidence that health care providers have similar experiences in implementing these two systems (Simon et al. 2007).

However, the evidence of the benefits of CPOE systems is not consistent across all CPOE implementations. Negative outcomes reported in the literature include decreased ordering efficiency for physicians, the introduction of IT-related errors into care processes, errors in communication and coordination, and decreased time with patients (Poissant et al. 2005, Ash et al. 2004, Weiner et al. 1999). Studies that cite ineffective CPOE implementation which might have caused negative patient care outcomes (Han et al. 2005, Koppel et al. 2005) may make other health care providers skeptical about full CPOE deployment[8]. These conflicting findings motivated this study to better understand what factors might predict successful implementation of a CPOE system in order to realize its benefits and avoid possible drawbacks.

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[8] Only 10 to 15 percent of U.S. hospitals have implemented CPOE system (Ash et al. 2004)

2.5 Physicians and the Health Care Information Systems

While health care information systems seem to hold a great promise for improving overall patient care, not many physicians are willing to adopt and use these technologies. In fact, as Fitzhenry et al. (2000) note, physicians' use of IT systems to enter data or get expert advice is very low at only 6% to 8%. Before these technologies existed, a physician would go to a health care facility, ask a nurse for the patient's chart, scan through it quickly, scribble in the fields, and move on to the next patient. With the new CPOE systems, a physician would need to find an available computer, log in, and begin to check boxes to indicate a patient's symptoms, allergies, diagnosis, tests, and medications. If these tasks took about three minutes with a paper chart, they might take thirty to forty minutes with an electronic health care information system (Connolly, 2005).

Practitioner reports have also drawn attention to the fact that critical issues affecting physicians' use of information systems are not necessarily technical, but social (Fitzhenry et al., 2000). The new breed of clinical information systems interferes with a physician's traditional practice routines (Anderson 1997) and requires physicians to change the traditional ways they have recorded, retrieved, and utilized clinical data. The loss of these individual characteristics may make physicians resistant to using electronic systems because they see the new technology as a threat to their professional autonomy. Clinical information systems do not directly benefit the individual physician, but benefit the patients as well the health care provider. In sum, physicians considering CPOE may not perceive any direct, visible benefits to warrant changing their long-standing practice patterns (Treister 1998).

In a study on physicians' perceptions of IT, Chau and Hu (2001) use a model comparison approach, using the technology acceptance model, the theory of planned behavior, and the decomposed theory of planned behavior to investigate the adoption of "telemedicine" by health care professionals. The authors found that attitudes, together with system usefulness, are the major determinants of physicians' acceptance of telemedicine. The study also showed that physicians may differ from other groups, such as clerical, administrative, and system development teams, in areas such as their adaptability to new technologies, mental and cognitive capacity, and work arrangements (Chau and Hu 2001). These findings suggest that evaluations of technology for knowledge workers like the physicians may also differ from those of other subject groups previously examined in technology implementation research.

Though the top management and technology managers are primarily involved in deciding what technologies an organization should invest and the infrastructural initiatives an organization should pursue, the real benefits and impacts of technology investments depend on the end users of the technology (Lewis et al. 2003). Physicians are the drivers of care and, so long as they do not accept and use these systems in their clinical work, the benefits of a new clinical IT such as a CPOE system cannot be realized. Without doctor buy-in, health care providers will find it very difficult to achieve higher levels of technology integration for their EMR systems. Chapter 4 focuses on understanding the underlying organizational, user-related, and technological factors that influence the implementation of CPOE systems by health care providers.

CHAPTER 3

SELF-SELECTION IN ELECTRONIC MEDICAL RECORD INTEGRATION AND ITS IMPACT ON OPERATIONAL PERFORMANCE

3.1 Introduction

Technological developments in recent years have significantly impacted supply chain operations. An array of information-intensive and customer-centric information technologies (IT) available today for manufacturing and service supply chains promise enormous benefits including improved quality, increased flexibility, and reduced costs realized through enhanced coordination and integration (Moody 2006, Kearns and Lederer 2003). However, managers often fail to achieve the promised benefits of new technology, as they find it hard to determine what each of these technologies does, which ones they should select, and how the technologies should be integrated to improve performance (McAfee 2006). Providers in the health care supply chain, the context of this research, are faced with similar issues. In an attempt to improve the quality and timeliness of health care delivery, providers are increasingly drawn toward clinical information technologies (Bates 2009). Investments in information technologies in the health care industry grew from $6.5 billion in 1990 to $23.6 billion in 2003 (Carpenter 2004). The proliferation in the variety of clinical and medical information technologies, however, have left providers overwhelmed with the challenge of selecting and integrating these technologies and realizing their promised potential.

Health care services form one of the most complex, crucial, and technology-intensive service industries in the U.S. (Chiasson and Davidson 2005). Health care delivery involves more variability and uncertainty at the point of service than in any other economic activity, and in health care supply chains, the inability to share information represents one of the major impediments to progress toward quality care and cost containment (Grimson et al. 2000). Integration of the various elements of health care service is critical to such information sharing; it enables a greater degree of process automation of routine tasks, comprehensive data analysis, and reporting capabilities, thus improving physician and management decisions.

Electronic Medical Record (EMR) systems, the focus of this research, result from the integration of clinical information technologies. It entails the capture, storage, retrieval, transmission, and manipulation of patient-specific health care-related data, including clinical, administrative, and biographical details (Brailer and Terasawa 2003, Raghupathi 1997). Such integrated systems are posited to have the potential to improve operational efficiency and patient safety while also increasing health and other social benefits to the health care industry (Hillstead et al. 2005). Highlighting the potential benefits of EMR systems, President Bush cited in his State of the Union Address in 2004 that, "By computerizing health records, we can avoid dangerous medical mistakes, reduce costs, and improve care."[9] However, developing EMR capability to improve performance is challenging and remains an underachieved goal. Health care providers that have successfully deployed integrated systems are mostly the exception (Overhage 2003, Kolodner and Douglas 1997). For instance, while the Institute of Medicine (IOM) called for replacing paper-based patient records with computerized patient records as early as 1991, in 2002 it observed that, "In most of the nation's hospitals, orders for

[9] In an attempt to increase the quality of health care and lower costs at the same time, President Bush outlined plans to have electronic medical records for most Americans by the year 2014 and encourage the use of Health Care Information Technology by providers (The White House, http://www.whitehouse.gov/infocus/technology/economic policy200404/chap3.html)

medications, laboratory tests, and other services are still written on paper and many hospitals lack even the capability to deliver laboratory and other results in an automated fashion" (Institute of Medicine 2002, p. 3).

Extant research has focused on the complex issues of technology innovation and development, but the choice of technology applications and the inter-relationships between technology integration and performance are relatively unexplored (Barki and Pinsonneault 2005, Waring and Wainwright 2000), particularly as they relate to health care supply chains (Housman et al. 2006, Javitt et al. 2006). Understanding technology integration and its performance implications is central not only to advancing theory, but also in informing managers so that they can make effective technology decisions in health care delivery and realize the performance benefits of these technologies. My research serves to address this need.

First, I conceptualize the different levels of EMR technology integration[10]. Health care providers vary in their technological capability to centrally consolidate, access, and analyze electronic medical information in a timely manner from disparate sources in the health care delivery process. This capability of a health care provider is determined by the extent to which the various clinical information technologies are integrated. Providers achieve a progressively superior capability by increasingly selecting various clinical information technology bundles that enable unique capabilities. Health care providers that have the highest level of technology integration are posited to be the most advanced in terms of capabilities with the highest level of EMR preparedness, which facilitates superior quality and timely clinical decision-

[10] Given that technology integration is focused on developing EMR capability in this study, I use the terms 'technology integration' and 'EMR technology integration' interchangeably in this study.

making. The different levels of technology integration are identified based on the bundle of clinical information technologies implemented by a health care provider. Based on prior work in this area (HIMSS 2007), I identify five distinct levels of technology integration with progressively increasing capability to extract and utilize medical information.

Building on the conceptual foundation, I then examine the selection of technology integration levels by health care providers. Synthesis of the extant literature suggests that a variety of factors affect a provider's choice to select into a given level of technology integration (Galloway 2009). While the institutional pressures of the environment (regulatory agencies, competitors, network partners, patients, etc.) influence health care providers toward selecting higher levels of technology integration, the organizational and technological characteristics of the providers qualify this institutional influence. Health care providers respond strategically to institutional influences (Ang and Cummings 1997) by selecting into the technology integration level that is most appropriate for their characteristics.

Next, I assess the operational performance implications of technology integration levels. Since all factors that affect a provider's decision to select a level of technology integration and also its performance are often unobservable (more on this later in the paper), the research design involves the use of a two-step selection model to account for the endogenous selection effects (Shaver 1998) in the firm's choice of technology integration level. The empirical analysis is based on data from 1011 acute care providers in the U.S. The findings from the study suggest that, while health care providers with higher levels of technology integration realize better operational performance on average, conditional on observed and unobserved factors, health care providers select themselves into different technology integration levels. In other words, while some health care providers select into higher levels of technology integration and benefit from doing so, not all providers choose to follow suit.

The remainder of the paper is organized as follows. Section 2 presents the theoretical background for the study. In this section, I provide a brief description of technology integration and Electronic Medical Record (EMR) capability in the context of health care operations. Next, I develop a research hypothesis linking the technology integration and operational performance of health care providers. Further, based on arguments from the extant literature, I discuss the selection of levels of technology integration by health care providers and develop a hypothesis describing the normative implications of selection. Section 3 presents the methodological foundation for the study. In this section, I discuss the underpinnings of statistical models that account for selection into a level of technology integration. Section 4 presents the research design for this study. In this section, I discuss the explanatory variables, the data collection effort, and the study results. Section 5 presents the conclusions of the study and directions for future research.

3.2 Conceptual Foundation and Hypotheses Development

3.2.1 Technology Integration in Health Care

The concept of integration in an organization can be broadly defined as “the extent to which distinct and interdependent organizational components constitute a unified whole,” and integration can be internal/external and functional/operational (Barki and Pinsonneault 2005, p.166). In this research, I focus on the operational integration of internal processes in the delivery of health care by linking the various clinical information technologies involved.

Integration has always been challenging, but the proliferation of technologies and technology vendors have made it more consequential and relevant than ever before (Iansiti and West 1997). Technological "push" in the form of enormous increases in computing power and the software sophistication achieved in the last few decades have enabled integration of the various islands of automated information processing and decision support systems to form broader systems (De Meyer and Ferdows 1985). These integrated systems have gained acceptance as necessary components of successful, competitive businesses, despite their high costs, and in some cases, risk (Kumar and Hillegersberg 2000). When integrated, the various information systems create an environment that provides a degree of inter-operability which stand alone, componentized systems fail to achieve. Integrated systems not only enable process automation, but also provide the ability to disseminate timely and accurate information, resulting in improved managerial and employee decision-making (Hitt et al. 2002). A notable example of such cross-functional integrated systems is the enterprise resource planning (ERP) system.

Like in other operational settings, health care providers are faced with the complex task of managing and integrating disparate processes. Table 3.1 lists the Clinical Information Technologies used in integrating the primary activities of health care delivery today. Integration of the clinical information technologies[11], as mentioned earlier, enables the capture, storage, retrieval, transmission, and manipulation of patient-

[11] It was not until the 1990s that health care supply chains attempted to integrate and network many information systems (Borzekowski 2002).

specific health care-related data, including clinical, administrative, and biographical details (Brailer and Terasawa 2003, Raghupathi 1997). This provides the opportunity to improve patient safety and operational efficiency (Hillstead et al. 2005). However, such integration is often challenging given the ambiguity about what the different stages of integration are and what constitutes a completely integrated EMR system. In this study, I draw from research by the Health Care Information and Management Systems Society (HIMSS)[12] to identify five levels of technology integration based on the composition of clinical information technologies implemented by a health care provider.

Building on the clinical transformation staging model by Garets and Davis (2006, HIMSS Analytics) and the IOM report (2002), I group the clinical technologies into four capability groups (see Table 3.1) with each group giving the health care provider a unique set of information storage and access capabilities[13]. The first capability group (C1) concerns the electronic integration of the ancillary systems and the results management (laboratory, radiology, and pharmacy systems) at the provider. This capability group provides physicians with easy access to results when needed, increases patient safety owing to the timely treatment to medical problems, improves task efficiency due to quicker turnaround, reduces treatment costs, and increases speed by eliminating redundancy in medical tests (IOM 2002, Bates et al. 2003, Shea et al. 2002, Tierney et al. 1987, Overhage et al. 2001, Schiff et al. 2003). The second capability group (C2) provides the capability to store patient medical information from

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[12] HIMSS is a non-profit organization serving to promote the best use of Information and Management Systems in the delivery of health care.

[13] It must be realized that health care providers can still provide care without the nine clinical information technologies. However, the primary activities in such an environment would be stand alone, and the health care delivery would be inefficient and ineffective. Integrating the key components of the health care delivery by progressively building the four capability groups facilitates the improvements described above.

various sources and provide decision support capabilities based on the information stored. This improves the quality of patient care by, for example, supporting effective physician decision-making in drug prescription (selection, dosage, and interactions) based on patient medical information (IOM 2002, Bates and Gawande 2003, Abookire et al. 2000). The third capability group (C3) provides the ability to store and retrieve medical imaging, and the last capability group (C4) provides the physician with the ability to build on all the information available to prescribe medications electronically. A significant benefit of this capability is reducing the number of non-intercepted medication errors by up to 83% by using “forcing functions” for medication dose and frequency (Bates and Gawande 2003), displaying relevant laboratories, and checking for drug-allergy and drug-drug interactions (IOM 2002, p.8). This capability also enables the simplification of the prescription process, highlighting cost-saving options and prescribing practices consistent with the formulary (IOM 2002). Davidson and Chismar (2007) find that the clinical outcomes associated with this capability group include a reduction in medication errors, more effective medication use, increased compliance to clinical standards, and improved clinical administration at the research site in their study.

Progressively integrating technologies corresponding to the four groups described above leads to a progressively increasing ability of a provider to consolidate, access, and utilize critical medical information for effective decision-making. The higher the level of technology integration at a health care provider, the superior their capability, with additional technologies at each level building on capabilities from technologies at the lower levels. Health care providers that do not have any one of the three technologies in capability group C1 belong to Level I, the lowest level of technology integration, and health care providers that have integrated all their clinical technologies (as mentioned in Table 3.1) belong to Level V, the highest level of technology integration. While the clinical transformation staging model (HIMSS Analytics) involves eight levels of technology integration, in this study I focus on only five levels of technology integration owing to the fact, in the U.S., there are currently almost no providers corresponding to Levels VI, VII, and VIII (0.5%, 0.1%, and 0.0% providers in the U.S. correspond to these levels (HIMSS Analytics 2007)).

Lawrence and Lorsch (1967) suggest that for organizations that have multiple subunits with specialized tasks and focused efforts, increased levels of information coordination can lead to improved performance. A higher coordination level may be the result of application of integrated information systems, since it expands an organization's overall processing capacity (Galbraith 1974). Integration of the primary activities of an organization can also lead to increased efficiency, from increased information sharing, and lowered production and coordination costs (Barki and Pinsonneault 2005). In an empirical study of approx 7000 U.S. manufacturing plants, Beede and Young (1998) find that plants with integrated technology applications have higher labor productivity and production worker earning levels as compared to plants that do not. Similarly, Ward and Zhou (2006) find internal IT integration aimed at generating information and facilitating information sharing has a positive influence on customer lead time when mediated with lean/Just-In-Time practices. Overall, integrating (internally or externally) the key activity (primary or secondary) of an organization has been found to be generally beneficial (Mukhopadhyay and Kekre 2002, Pinsonneault and Kraemer 2002, Srinivasan et al. 1994, Truman 2000).

Health care services, as mentioned earlier, are particularly information intensive in which the need for information sharing and coordination is very high. Hence, the scope for performance improvements from enhanced information capabilities enabled by the availability and integration of the different clinical information technologies is likely to be large. When clinical information technologies (like decision support systems) are enabled to exchange information with storage technologies (like medical imaging) and ancillary technologies (like radiology or pharmacy), not only are repetitive and routine processes automated, but there is also enhanced physician decision support for making rapid, skilled judgments. Such timely and quality decision-making results in the effective execution of health care operations by organizational members and will directly impact operational performance. In essence, greater technology integration enables health care providers to perform better. Thus, I propose:

> ***Hypothesis 1***: Ceteris paribus, operational performance for health care providers at a higher level of technology integration will be greater than that of health care providers with a lower level of technology integration.

3.2.2 Selection of the Level of Technology Integration

In the previous section, I defined levels of technology integration and argued that providers with higher levels of technology integration have better operational performance than providers with lower levels of technology integration. It must be realized, however, that technology integration involves the investment of considerable organizational resources toward the costs of technology, infrastructure, employee training, and other relevant management initiatives. Integration requires economic justification (Devaraj and Kohli 2003). Extant literature suggests that managers make choices to generate sustainable competitive advantage and superior performance outcomes, and their choices are based on expectations of how each option aligns with their organizational constraints and objectives (Hamilton and Nickerson 2003). For example, when faced with the *make* versus *buy* decision, organizations that choose to *make* may have particular production capabilities that make it a highly profitable choice, while those that lack the production capabilities may instead choose to *buy*. Similarly, it is conceivable that the choice among technology integration[14] levels by providers is influenced by their internal and external organizational constraints.

Institutional theory provides a conceptual lens to frame the concept of EMR technology integration by health care providers. More specifically, institutional theory has enabled the understanding of organizational decision-making in the presence of (institutional) pressures of homogeneity and conformance from the environment across a variety of settings (DiMaggio 1983, Burns and Wholey 1993, Ang and Cummings 1997, Teo et al. 2003). The premise of this theoretical perspective is that organizations are subject to notions of socially appropriate organizational form, behavior, and policies from their institutional environment (e.g., suppliers, network partners, customers, competitors, and regulatory agencies). Failure to conform to such shared notions questions the legitimacy of organizational practices and is often associated with penalties, thus providing a major impetus toward the homogeneity of organizations (Teo et al. 2003, Ang and Cummings 1997, DiMaggio and Powell 1983). Drawing on

[14] EMR Technology Integration can be likened to a Type III Innovation. Swanson (1994) classifies all Information Systems (IS) innovations into three types, where Type I innovations are focused on the core Information Systems in place in an organization, Type II innovations such as the Payroll system are focused on the administrative core of the organization, and Type III innovations such as Computer Integrated Manufacturing are at the core of the business and have a strong influence on the value chain.

institutional theory, Teo et al. (2003) posit that an organization's decision to adopt an inter-organizational system (IOS) is influenced by mimetic, coercive, and normative pressures from the environment that an organization operates in. Specifically, Teo et al. (2003) identify the institutional pressures arising from the adoption of IOS by competitors; greater perceived success of competitors that have adopted the IOS; greater adoption by and perceived dominance of suppliers, customers, or parent corporations; and participation in associations that promote and disseminate information on the IOS. Health care providers are faced with similar institutional pressures from their environment (government and regulatory agencies, network partners, competing providers, patients and employer groups, suppliers, and insurance providers) to select a level of technology integration to develop EMR capability.

Regulatory forces such as the CMS mandates (Medicare Modernization Act of 2004), the Leapfrog recommendations (www.leapfroggroup.org), and the P4P initiatives (Deficit Reduction Act of 2005) and the more recent HIMSS recommendations (HIMSS 2008) exert a strong influence on provider organizations in moving toward an integrated EMR environment. According to the White House's Health Care Policy and Technology Agenda[15]:

> The President is working to improve the adoption of health information technology. Electronic health records show promise as a tool to help improve the efficiency and effectiveness of medical treatment. In 2004, the President launched an initiative to make electronic health records available to most Americans within the next 10 years. Health IT systems can give citizens better access to their health information, resulting in informed decisions about their care and a better understanding of the quality of the care they are receiving. In 2006, the President directed Federal agencies to use improved health IT systems to facilitate the rapid exchange of health information.

[15] http://www.whitehouse.gov/infocus/technology/economic policy200404/chap3.html

> Using the Federal Government to Foster the Adoption of Health Information Technology: As one of the largest buyers of health care in Medicare, Medicaid, the Community Health Centers program, the Federal Health Benefits program, Veterans medical care, and programs in the Department of Defense the Federal Government can create incentives and opportunities for health care providers to use electronic records, much like the private sector is doing today.

In a similar vein, more recently, in an Address to the Joint Session of Congress (on Feb 24 2009), President Obama stated that "Our recovery plan will invest in electronic health records and new technology that will reduce errors, bring down costs, ensure privacy, and save lives".

Owing to the benefits associated with EMR, providers also feel pressure to achieve EMR technology integration from their networks. For example, Partner's Community Health Care Network, an integrated health care system of teaching, community and specialty providers, community health centers, physicians, home health and long-term care services, and other health care services requires its participating providers to move toward EMR capabilities (primary care physicians by end of 2008, specialists by end of 2009) for continued participation in the network (Partners 2008, FierceHealthIT 2007). The benefits of a personal health record also induce patients, the customers of health care providers, to influence providers in developing EMR capability. For example, results from surveys conducted by Harris Poll indicate that a majority of people like to have EMR capture medical information (64%) and believe that an EMR capability could potentially decrease medical errors (55%), decrease health care costs (60%), and improve the quality of their care by reducing unnecessary tests (68%) (Harris Interactive 2007, p. 2-3). Similarly, the potential clinical, financial, and strategic benefits of EMR also incentivize employer groups (e.g., Leapfrog Group) and public and private insurers to influence providers to develop EMR capability (FierceHealthIT 2007). Overall, health care providers face mimetic, coercive, and normative institutional influences from their environment to integrate EMR technologies.

However, the institutional influences of the environment *favoring* EMR technology integration are not the only pressures faced by a provider. Understandably, providers are also faced with organizational and technological constraints that influence decision-making for or against EMR technology integration. A variety of factors have been highlighted in the extant literature to influence the technology selection and integration process by organizations. For example, according to the Congressional Research Service (CRS) Report for Congress (2005), the financial resources for investment in EMR technology integration and the uncertainty in the resulting payoffs strongly affect the EMR investment decisions of providers, a key consideration also echoed in studies (Miller and Sim 2004, DesRoches et al. 2008) on the EMR adoption and use by physicians. Similarly, according to David J. Brailer (co-coordinator for National Health Information Technology from 2004 to 2006) and the CRS report to the Congress (2005), while providers make huge upfront investments, the biggest beneficiaries may be the insurers and patients, thus making the incentives awry (*New York Times* June 11, 2007). Another factor that influences a provider's choice of the level of technology integration is their prior investments in other clinical and administrative information technologies. Forman (2005) found prior technological investments and geographical investments strongly affected the Internet adoption decisions of an organization.

Other factors that influence the choice of technology integration levels by providers include technology characteristics such as the compatibility of the technology with existing systems and the complexity, relative advantage, cost, and communicability of the benefits of the technology (Premkumar et al. 1994); top management support (Chatterjee et al. 2002); and managing redesigned processes that affect physicians, nurses, and other medical personnel (FCG 2003, Chatterjee et al. 2002). Ang and Cummings (1997), in a study of the adoption of the information systems outsourcing route by commercial banks, highlight the strategic nature of a firm's response to the institutional pressures of their environment. The authors identify factors such as the perceived gain in production economies, financial capacity to resist institutional influence, and transaction costs of sourcing that influence the relationship information systems outsourcing and institutional pressures. Overall, the choice of an organization to select a new technology is dependent not only on the institutional pressures faced by the organization (Ang and Cummings 1997), but also on idiosyncratic organizational and technological circumstances, such as the characteristics of the technology innovation, prior technological investments, workplace decisions, organization size, and resource availability.

Chatterjee et al. (2002, p. 66) suggest that successful assimilation of web technologies requires concerted institutional efforts "to blend technology, marketing, and business strategy knowledge and mutually adapt the organization processes." Similarly, research on service and manufacturing systems advocates the adoption of a focused approach to managing operations that is aligned with the business and the competitive strategy (e.g., Skinner 1974, Lapre and Tsikritsis 2006, Huckman and

Zinner 2008). As highlighted earlier, managerial choice to generate superior performance outcome is based on assessments of how appropriate the choice is with respect to the organizational constraints and objectives (Hamilton and Nickerson 2003). In this vein, I argue that health care providers choose a level of EMR technology integration that would generate superior performance outcomes and is aligned with their organizational circumstances, technological characteristics, and environmental considerations. While the institutional pressures of the environment (e.g., regulatory agencies, competitors, network partners, and patients) influence health care providers toward selecting higher levels of technology integration, the organizational and technological characteristics of the providers moderate these pressures. Health care providers strategically respond to the institutional pressure by selecting into the technology integration level that is most appropriate for their idiosyncratic characteristics.

In other words, while health care providers may be motivated to select higher levels of technology integration given the promise of integration and the institutional pressures, they may not necessarily choose to do so. They strategically select into an appropriate technology integration level that would enable them to achieve superior performance given their organizational constraints and objectives (Ang and Cummins 1997). Health care providers at a level of technology integration that is inappropriate given their idiosyncratic characteristics are likely to face negative performance consequences. Thus, I propose that:

> ***Hypothesis 2***: Ceteris paribus, the operational performance of health care providers who strategically select into a level of technology integration will be greater than that of others in that level of technology integration.

3.3 Methodological Foundation

Identifying the performance benefits of the different levels of technology integration forms the key objective of my research. However, it must be realized that many of the factors affecting the choice of a provider to select a technology integration level also affect the performance of the provider. Further, while some of the factors can be observed, more often than not, it is difficult or impossible to capture data on all of the factors. This has methodological implications for assessing the performance implications of technology integration. In this section, I discuss my methodological foundation and the underpinnings of my model specification for this study.

If managers select themselves into different levels of technology integration that are optimal given their attributes, an empirical model that does not account for selection would be misspecified and the empirical estimates and the normative conclusions drawn from the analysis could be misleading (Shaver 1998, Masten 1993). When managers make a strategic decision in their choice of level of technology integration, a comparison of performance of health care providers that have chosen one level of technology integration to those that chose another is not feasible given that the providers are not randomly assigned to these "treatments" (Rubin 1974).

From a methodological perspective, the failure to explicitly take into account the nonrandom sorting leads to endogeneity bias – the statistical bias that arises when an endogenous variable is treated as exogenous (Heckman 1974). The bias associated with endogeneity arises due to the existence of unobserved heterogeneity (i.e., differences across observations affecting both the selection and performance that are nonrandom and unobserved). This can lead to contemporaneous correlation between that explanatory variable and the error term, resulting in biased coefficient estimates. To estimate unbiased coefficient estimates in such situations requires econometric methods that statistically account for a manager's selection into a particular level of technology integration (Masten 1996). A traditional regression analysis with performance as the dependent variable and the level of technology integration as the independent variable would be inappropriate unless it was assumed either that health care providers *randomly* select different levels of technology integration or that all factors affecting performance can be measured and included in the model (Shaver 1998), conditions that hardly ever hold true in actual settings.

Consequently, I adopt an econometric selection model introduced by Heckman (1979) and Lee (1978) that takes into account the manager's estimation of the performance implications of different levels of technology integration. The selection procedure involves two key steps. In the first step, I model the particular level of technology integration under consideration by the health care provider. And in the second step, I assess the normative effect of the choice of the level of technology integration on performance of the health care provider. Further, I conduct additional analyses to assess the costs of failing to choose the normatively correct decision. This involves the use of counterfactual analysis where alternative what-if scenarios are empirically evaluated to serve as decision tools for health care providers in their choice of the level of technology integration. I provide a brief overview of the selection model and the counterfactual analysis below.

3.3.1 Model Formulation

Step One: Level of Technology Integration Selection

This step models the technology integration level choice of the health care provider. The five levels of technology integration discussed earlier in reference to Table 3.1 form the five discrete choices. I use an ordered probit model to predict the level of technology integration each health care provider has selected. The level choice is modeled as a continuous latent variable $Capability_i$, which is given by:

$$Capability_i = \delta \mathbf{Z}_i + \alpha \mathbf{X}_i + \upsilon_i, \qquad \textbf{(1)}$$

where i denotes the health care provider, δ and α are the vector of parameters to be estimated, $\mathbf{Z}_i$ represents factors that affect level choice but that do not affect performance, $\mathbf{X}_i$ represents all characteristics that affect the choice of the technology integration level and performance, and υ_i represents the unobserved factors influencing the level choice and is assumed to be normally distributed with zero mean and unit variance. The provider's technology integration level choice is based on its $Capability_i$ value relative to four cut-off points – Cut_1, Cut_2, Cut_3, and Cut_4 – which are maximum likelihood estimates (Maddala 1983, Idson and Feaster 1990) from the selection equation (1). For example, providers would select Level II if $Cut_1 < Capability_i < Cut_2$.

Step Two: Normative Effects

In this step, I assess the performance benefits of the selection of level of technology integration by providers, accounting for the selection process. The performance outcome for each level of technology integration Π_{ij} is given by:

$$\Pi_{ij} = \beta_j \mathbf{X}_i + \varepsilon_{ij} \qquad (j = 1, 2, 3, 4 \text{ and } 5). \qquad \textbf{(2)}$$

This equation can be estimated by ordinary least squares (OLS) using the sub-samples of organizations choosing that particular level choice. However, as discussed earlier, this equation can be estimated only when all the factors affecting performance and choice of technology integration level are observable and included in the regressions. If there are unobserved factors affecting the choice of the technology integration level and performance, then $E(\varepsilon_{ij} \mid j) \neq 0$ which leads to biased estimates of β_j (Hamilton and Nickerson 2003).

Accounting for the non-zero covariances arising out of unobserved factors in the selection and performance equations above, performance for health care providers that choose each level of technology integration can be re-specified as:

$\Pi_{i1} = \beta_1 \mathbf{X}_i - \sigma_1 * (ø [cut_1 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) / (\Phi [cut_1 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) + \varepsilon_{i1}$ **(3)**

$\Pi_{i2} = \beta_2 \mathbf{X}_i + \sigma_2 * (ø [cut_1 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] – ø [cut_2 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) / (\Phi [cut_2 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] –$

$\Phi [cut_1 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) + \varepsilon_{i2}$ **(4)**

$\Pi_{i3} = \beta_3 \mathbf{X}_i + \sigma_3 * (ø [cut_2 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] – ø [cut_3 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) / (\Phi [cut_3 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] –$

$\Phi [cut_2 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) + \varepsilon_{i3}$ (**5**)

$\Pi_{i4} = \beta_4 \mathbf{X}_i + \sigma_4 * (ø [cut_3 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] – ø [cut_4 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) / (\Phi [cut_4 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta] –$

$\Phi [cut_3 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) + \varepsilon_{i4}$ **(6)**

$\Pi_{i5} = \beta_5 \mathbf{X}_i + \sigma_5 * (ø [cut_4 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) / (1 - \Phi [cut_4 - \mathbf{X}_i \alpha + \mathbf{Z}_i \delta]) + \varepsilon_{i5}$ **(7)**

For each equation in **(3)** through **(7)**, the error terms in the performance equations capture the performance effects of variables that are not identified or measured in the specified $\mathbf{X}_i$. Here I assume that the error terms υ_i, and the ε_{ij} are jointly normally distributed so that expressions for $E(\varepsilon_{ij}|j)$ are tractable. The expected values for each error term are now zero due to inclusion of the second component in each equation which is referred to in the literature as the inverse Mills ratio and can be mathematically expressed as $\lambda = ø [.] / \Phi [.]$, where ø [.] is the normal density and Φ [.] is the cumulative normal distribution. The terms σ_1 through σ_5 are the coefficients of the inverse Mills ratio terms in the performance equation for health care providers opting for each level of technology integration respectively. $\sigma_1 \neq 0$ or $\sigma_2 \neq 0$ or $\sigma_3 \neq 0$ or $\sigma_4 \neq 0$ or $\sigma_5 \neq 0$ indicates the presence of endogeneity. When $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = \sigma_5 = 0$, the level choice is exogenous. The OLS estimation of equations (3) through (7) will give the unbiased estimates of β_1, β_2, β_2, β_4, β_5, σ_1, σ_2, σ_3, σ_4, and σ_5.

3.3.2 Counterfactual Analysis

Thus far, I have assessed health care providers' selection of levels of technology integration and subsequent performance implications. Next I focus on the question: What if the health care provider had chosen any other level of technology integration? How would their performance change under the counterfactual scenario? In other words, in this step I address the costs of making mistakes, failing to choose the normatively correct decision (Masten et al. 1991, Masten 1993). In this research, health care providers choose from five ordered levels of technology integration. Hence, in this step, I conduct counterfactual analysis for all the possible ordered pairs of technology integration levels (i.e., Levels I and II, Levels I and III, Levels I and IV, Levels I and V, Levels II and III, Levels II and IV, Levels II and V, Levels III and IV, Levels III and V, and Levels IV and V).

I illustrate the estimation of the counterfactual performance under the what-if scenarios using a two-level strategy comparison. I describe the model for the first pair (Levels I and II) below. Similar to the analysis for multi-level strategy earlier, for a two-level strategy (Level I and Level II) choice, I can estimate the expected performance of providers that select into Levels I and II, respectively. Consider a provider that has chosen Level II. Using the notations described earlier, its expected performance under this chosen strategy is obtained as

$E\,[\Pi_{i2}/\ j=2] = \beta_2\ \mathbf{X}_i - \sigma_2 * ((ø\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta]\ /\ (\Phi\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta]))$

Similarly, consider a provider that has chosen Level I. Its expected performance under this chosen strategy is obtained as

$E\,[\Pi_{i1}/\ j=1] = \beta_1\mathbf{X}_i + \sigma_1 * ((ø\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta])\ /\ (1 - \Phi\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta]))$

Now, the expected performance of a provider that has chosen Level II can be contrasted with its expected performance had it chosen Level I. To calculate the expected performance under the counterfactual (other) choice, I multiply the vector of attributes X_i, with the corresponding coefficients from the performance equation for the Level II. This is given as:

$E\,[\Pi_{i1}|\Pi_{i2} > \Pi_{i1}] = \beta_1\mathbf{X}_i - \sigma_1 * ((ø\ [(\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta])\ /\ (\Phi\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta]))$ **(8)**

Similarly, the expected performance of a provider that has chosen Level I can be contrasted with its expected performance had it chosen Level II. Following the reasoning applied above, I compute the expected performance under this counterfactual scenario as:

$E\,[\Pi_{i2}|\Pi_{i1} > \Pi_{i2}] = \beta_2\ \mathbf{X}_i + \sigma_2 * ((ø\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta])\ /\ (1 - \Phi\ [\mathbf{X}_i\ \alpha + \mathbf{Z}_i\ \delta]))$ **(9)**

3.4 Research Design

3.4.1 Variables and Model Specification

In this section, the key variables for my study and the specification of the selection model (Eqn. 1), performance model (Eqns. 3-7) and the counterfactual models are described. Following the Technology-Organization-Environment (TOE) framework (Tornatzky and Fleischer 1990), the variables in the specifications include *organizational*, *technological*, and *environmental* variables. Organizational variables account for the governance and decision-making characteristics and the size and scope of the operations at the health care provider (Zhu et al. 2006), technological variables account for the role of existing technologies at the provider, and environmental variables control for the institutional influence in the selection and performance implications of technology integration level.

As discussed earlier, the selection of the technology integration level by a provider can be specified as an ordered probit model driven by variables indicative of manager's choice of different technologies in a technology integration level. While it is desirable to include all the factors affecting the level of technology integration selection process, it is often not possible to observe or measure all the variables. Consequently, in the probit specification I include variables for which I have information and the error term is set to include the effects of the unobserved and unmeasured factors. Specifically, in this study, I model the health care provider's technology selection process as a function of the technological variables, such as *Business Office*, *Financial Management*, *Human Resources*, *Decision Support*, *Managed Care*, *Medical Charts,* and *Clinical Applications;* organizational variables, such as *Number of Licensed Beds, Service Type, Profit Status*, *Formal Steering Committee*, *Number of Executives in Steering Committee, Number of Non-Executives in Steering Committee, CIO Reporting Status to CEO*, and *Presence of Purchasing Sub-Committee;* and environmental variables, such as *Number of Members in IHDS, Member of Purchasing Group,* and *Member of Voluntary Purchase Alliance*.

Health care providers usually employ a large number of various administrative support information systems[16] apart from the clinical technologies. Though not specifically related to patient-care, these information systems serve to address administrative functions (e.g., billing, personnel), strategic decision support applications, strategic planning, resource allocation, etc. (Austin and Bowerman 2003). These technologies have an important role to play in the health care provider's objective of efficient service and can be considered complementary[17] to the clinical technologies considered for the different levels of technology integration. Hence, in the selection of technologies considered in the levels of technology integration, managers will be influenced by the availability of the other information systems such as *Business Office, Financial Management, Human Resources, Decision Support, Managed Care, Medical Charts, and Clinical Applications*.

The *Number of Licensed Beds* at the acute care facility, a commonly used measure of organizational size, is included as a key control variable for this study. Controlling for size is important since it has been found to play a significant role in the adoption of improvement initiatives and technologies including total quality management programs, administrative innovations, medical record imaging (MRI) technology (Friedman and Goes 2000, Westphal et al. 1997, Kimberly and Evanisko 1981), advanced manufacturing technologies and flexible manufacturing systems (Ettlie

[16] Table A-3 in the appendix provides a brief introduction to the various types of information systems used by health care providers.

[17] According to complementarity theory, organizations selecting a set of complementary technologies will perform better than those without the possible set of complementary technologies (Fennel 1984, Colombo and Mosconi 1995).

et al. 1984), integrated service digital networks, open systems technology, and electronic data interchange (Chau and Tam 2000, Premkumar et al. 1997).

In health care supply chains, the information and, consequently, the technology requirements vary with the type of care offered (Burke 2002). Hence, I control for the *Service Type* (general medical and surgery, academic, long term acute, and others comprising critical access, pediatric, and orthopedic hospitals).

I account for the *Profit Status* of health care providers, a dichotomous variable that captures the type of governance (for-profit or not-for-profit). It is considered to be an important factor affecting not only performance (Shukla et al. 1997) but also technology selection decisions.

Steering Committees are high-level teams of representatives from across organizational subunits which are entrusted with the task of linking IT strategy with business strategy (Nolan 1982). Steering committees not only communicate the benefits and implications of IT investments to top management and user groups, but also influence strategic IT planning and its effectiveness (Drury 1984, Gupta and Ragunathan 1989, Doll and Torkzadeh 1987, Premkumar and King 1992). I control for the presence of a *Formal Steering Committee* and the membership structure of such committees (*Number of Key Executives in Steering Committee* and *Number of Non-Executives in Steering Committee*) to account for their influence on the managerial decision-making in the selection of technologies.

Support from top management (especially chief executive officers) is found to be a key factor in the successful adoption of medical records imaging (Friedman and Goes 2000). A structure with the Chief Information Officer (CIO) reporting directly to the Chief Executive Officer (CEO), a practice by "leading edge" adopters of IT (Smaltz et al. 2006), sends a visible signal to other organizational actors of the value of IT, aligns IT considerations with the business model of the organization, and places the CIO in a position of considerable power, a predictor of innovation adoption in organizations (Baldridge and Burnham 1975). Also, organizations differ in terms of the availability of a purchasing sub-committee, which decides on issues relating to technology procurement. The presence of such sub-committees clearly indicates the top-management willingness to focus on the information technology sophistication of the provider. Based on these findings, I control for the *CIO's Reporting Status to CEO* and the *Presence of a Purchasing Sub-Committee* to account for the influence of top management on technology selection decisions.

Membership in Integrated Health Care Delivery Systems (IHDS), or simply networks of health care providers, significantly affects investment in IT (Burns et al. 2001). As members of the IHDS, health care providers benefit from network learning since all member organizations share their experiences from technology selection through implementation stages (McCullough 2005). The higher the *Number of Members in IHDS*, the greater the network learning; this affects the choice of level of technology integration, and I include it in the selection model.

I consider two variables, *Member of Purchasing Group* and *Member of Voluntary Purchasing Alliance*, to account for the influence of communication channels in a health care provider's selection of the level of technology integration. Communication within and across organizations from exposure to professional associations plays a pivotal role in selection of technologies, particularly in health care

(Tabak and Jain 2000, Bobrowski and Bretschneider 1994). Health care providers participate in strategic hospital alliances (SHA) that increase the number of communication channels available to the participating members.

For the performance models in Equations 3-7, *Discharges per Licensed Bed* forms the dependent variable (operational performance), and the explanatory variables in the specification include technology characteristics such as *Clinical Applications, Medical Charts, Total Networking Applications, Total Outsourced Services, Presence of Wireless, Presence of Intranet,* and *Usage*; organizational characteristics such as *Service Type* and *profit Status*; environmental characteristics such as the *Number of Members in IHDS*; and the inverse Mills ratio terms.

There is significant evidence that there is a direct link between effective capacity management in hospitals and performance (McDermott and Stock 2007). *Discharges per Licensed Bed* (also referred as *case flow* in extant literature) is defined as the total discharges divided by the number of licensed beds in service at the health care provider. It measures the number of patients who use a health care provider's beds during a given period and it varies directly with occupancy rate and inversely with average length of stay. Since it indicates the relationship between inputs (beds) and outputs (discharges), discharges per licensed bed is often used in health care research as a measure of productivity and patient turnover (Shortell et al. 2005), with higher and increasing values indicating efficient providers, and lower values indicating unfavorable levels of occupancy and/or utilization (Younis 2005). Thrasher et al. (2006) find that health care providers that have achieved both high information technology integration and organizational maturity exhibit greater improvements to both average length of hospital stay and operational cost than health care providers who are at a lower level of information technology integration and organizational maturity. Unlike financial performance metrics that may be affected by a host of other inputs, operational performance metrics such as discharges per licensed bed are a more direct indicator of the efficiency and effectiveness of an integrated EMR environment. Also, unlike financial performance where there may be some time lag before the benefits can be observed and recorded in reports, operational performance is affected fairly quickly by improvements to the processes and systems. Hence, I argue that information technology integration would speed up customer care and shorten hospital stays for patients[18]. I believe that a discharge per licensed bed metric is at the heart of understanding the benefits of EMR technology integration.

Clinical Applications and *Medical Charts* include technologies implemented by the health care provider, such as Surgery systems, Cardiology systems, Nurse Staffing systems, Intensive Care (Critical Care) and Point of Care (Medical/Surgical Bedside terminal) systems, Master Patient Index, Abstracting, Encoder, Chart Tracking/Locator, etc. It is conceivable that health care providers implementing these technologies would be able to perform better than those that do not. I control for *Clinical Applications* and *Medical Charts* to account for such variation.

Integration of the different clinical information technologies and consequently performance benefits are influenced by the availability of networking technologies and integration equipments, the availability of Intranet within the organization, and the availability of wireless technologies on the premises of the health care organization.

[18] For this study, the patient mix (commonly called case-mix index) (Friesner et al. 2007) and the nature of critical care provided for each of the health care providers is assumed to be same.

Each of these, in turn, affects the operational performance. Hence, I consider the variables *Total Networking Applications*, *Presence of Intranet*, *Presence of Wireless*, and the *Total Outsourced Services* in the estimation model to predict operational performance. I also account for the usage of these technologies, an often-overlooked factor (Devaraj and Kohli 2003), in the performance model. I define *Usage* as a ratio: (number of technologies in use)/ (number of technologies in use + number of technologies not in use).

As mentioned earlier, *Service Type* refers to the type of health care service (general medical and surgery/academic/long term acute/others comprising of critical access, pediatric, and orthopedic hospitals). I control for the service type to account for variability in process and outcomes across different types of care. I also control for the membership of in an IHDS, to account for the performance benefits gained from learning from the network partners. Finally, I control for the *Profit Status* of health care providers since it is found to be an important factor affecting the performance of health care organizations. Next, I describe the data collection process for these variables.

3.4.2 Data Collection

This research seeks to understand the selection of different levels of technology integration by health care providers and its impact on their operational performance. The unit of analysis for this research is the health care provider organization, and the sampling frame consists of acute care providers in the U.S. The data for this study combines two databases: (i) The Dorenfest Complete IHDS+ Database and (ii) The Medicare Cost Reports Database. The Dorenfest Complete IHDS+ Database contains detailed information about the health care providers associated with 1,444 integrated health care delivery systems in the U.S. Detailed information on the technological and demographic characteristics of health care providers is collected annually by Dorenfest and Associates (now part of the Health Care Information and Management Systems Society) using mailed surveys and telephone interviews. The respondents to the survey and interviews include the Chief Information Officers (CIOs), who report the specifics about information technology, and the Vice Presidents of Marketing and/or Strategic Planning, who provide data on the demographic characteristics. The database contains detailed data on health care information system applications, purchase plans for information technology activities, information system decision-making processes, steering committee composition for each health care provider, demographic data of all health care providers by type (e.g., acute care, sub-acute care, ambulatory care, home health), sizing statistics (e.g., bed size, full time equivalents, etc.), contact information for key executives at each health care provider, the overall information technology strategy, etc. The Medicare Cost Reports database from the Health Care Cost Report Information Systems (HCRIS) formed my source for data on the operating performance. It is the only national database that uses standard definition and carries information on performance variables (annual financial and operational characteristics) for acute care providers in the U.S.

To construct the research sample, I started with data from the Dorenfest database for acute care providers. For each health care provider I tabulated the information on their identifier, demographics, and technology characteristics. Based on this information I also identified the technology integration level at each provider, as discussed earlier. In the next step, the data was linked with the Cost Reports dataset using Medicare Identification Numbers. Approximately 80% of available health care providers from the Dorenfest database could be matched successfully with the cost reports information. The Cost Reports enabled me to compute the operating performance measure for acute care providers included in the dataset. Overall, this information was gathered for 1011 acute care providers.

3.4.3 Results and Discussion

Table 3.2 provides descriptive statistics of the key variables for providers belonging to the five technology integration levels identified in the study. The descriptives reveal some patterns in the investments in and usage of information systems across providers belonging to different levels of technology integration. Providers at lower levels of technology integration tend to be of smaller size (as indicated by the *Number of Licensed Beds*). Further, while investments in both administrative information systems (*Business Office, Financial Management, Human Resources*) and clinical information systems (*Decision Support, Managed Care, Medical Charts,* and *Clinical Applications*) tend to be higher at higher levels of technology integration, the usage of these technologies is high and comparable across the levels. A quick statistical comparison of the investment levels between the low level of integration (Levels I and II combined) and the high level (Levels III, IV, and V) supports this observation.

Table 3.3 provides estimates of the ordered probit model representing the selection process for the five levels of technology integration discussed earlier. I observe that there are many variables that affect the selection of the level of technology integration by health care providers. First, I find that coefficients for the *Business*

Office, Decision Support, Medical Charts, and *Clinical Applications* are positive and significant. This suggests that providers that have invested in these complementary technologies are more likely to invest in higher technology integration levels. In other words, providers that have invested in administrative and clinical technologies toward improving their efficiency and effectiveness are also likely to invest in technology integration toward achieving an EMR environment. I also find that the *Number of Licensed Beds* (indicative of size) has a positive and significant coefficient. This suggests that bigger providers are more likely to invest in higher levels of technology integration. This may be attributed not only to the availability of resources at bigger providers but also to the need for coordination in a large complex operating environment. The coefficient of *Profit Status* is negative and significant. This suggests that Not-for-Profit hospitals are more likely to invest in higher levels of technology integration. This may be attributed to the lack of attention to short-term financial payoffs from investments in technology integration evidenced in for-profit organizations in general. The coefficient of *Number of Members in IHDS* is positive and significant. This suggests the presence of strong network learning across all members of the IHDS, which, in turn, is associated with a greater likelihood of investment in higher levels of technology integration. The significant negative coefficients of the *Number of Non-Executives in the Steering Committee* and the *Membership of Voluntary Purchase Alliance* highlight the structural influences on the likelihood of a provider to invest in technology integration.

Overall, these variables reflect the technological (*Business Office, Decision Support, Medical Charts,* and *Clinical Applications*), organizational (*CIO Reporting*

Status, Number of Non-Executives in the Steering Committee, Number of Licensed Beds, Profit Status, Number of Members in IHDS) and environmental (*Membership of Voluntary Purchase Alliance*) influences of the health care provider. As stated previously, while identifying the factors that drive and moderate/mediate the technology integration selection process is beyond the scope of my research, accounting for selection is critical in assessing the performance implications of technology integration. In the next step, I report the results from the performance analysis accounting for the selection.

Table 3.4 reports the results from separate regression analysis for the five levels of technology integration. The regression models correspond to Equations 3-7 described earlier. The regression models for each of the five integration levels account for the selectivity bias through the inclusion of inverse Mills ratios calculated from the ordered probit selection equation (a statistically significant coefficient of the inverse Mills ratio term indicates the presence of self-selection). I observe that the coefficients for the inverse Mills ratios for columns 2, 3, and 4 are statistically significant. This suggests that providers self-select into the different technology integration levels. The significant selection effects indicate the existence of unobservable effects common to both selection process and performance, which, if not explicitly treated as endogenous, would bias the estimates of the relationship between levels of technology integration and operational performance[19]. Since the error of the reduced-form probit selection is

[19] Table A-2 in the Appendix provides the results from simple regression analysis with operational performance as the dependent variable and the explanatory variables discussed in the performance model specification above. The coefficient of the level of integration is positive and significant, suggesting that, as the level of technology integration increases, the operational performance of a health care provider improves. However, the estimates from the regression analyses are misleading owing to the selection effects. The results serve to highlight the idiosyncratic

truly a composite of the managerial choice and performance equations, it is difficult to economically interpret the signs of the inverse Mills ratios (Idson and Feaster 1990). It can only be inferred from the results in Table 3.4 that there is self-selection (i.e., that health care providers choose a level of technology integration which they believe will provide them operational performance benefits), although factors affecting this choice are not all observable by the researcher[20].

To further understand this selection process and its performance impact, I conducted analyses of providers belonging to two technology integration levels at a time; I conduct separate analyses with providers belonging to Levels I and II, Levels II and III, Levels II and IV, Levels III and IV, and Levels IV and V. I followed the two-step econometric technique described earlier for these analyses. I ran a probit selection equation and estimated the inverse Mills ratios from the probit model. In the second step, I ran two OLS regressions, one for each level of technology integration with the inverse Mills ratio and the variables that influence the operational performance as explanatory variables and discharges per licensed bed as the dependent variable. While reading into the sign of the coefficient of the inverse Mills ratios in a multi-level strategy is difficult, in a two-level strategy analysis the inverse Mills ratios are positive by construction (estimated as a ratio of probability functions) and so the sign of the coefficient of the inverse Mills ratio determines the selection bias. In the study, a

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conditions (technological, organizational, and environmental) faced by providers which make investments in higher levels of technology integration not a uniformly beneficial strategy for providers.

[20] While the focus of the analysis in this step is to assess the significance of selection effects, we do note two key results from the analysis. First, the coefficient of *Medical Charts* is positive and significant only for Levels III and IV. This is understandable given that the utility of this group of technologies is greater at higher levels of technology integration. Second, the coefficient of *Clinical Applications* is not significant, suggesting that, while providers adopting clinical technologies are more likely to adopt higher levels of technology integration (observed earlier in Table 3.3), that alone does not necessarily lead to an increase in the operational efficiency. A possible explanation for this observation is that the benefits of investments in clinical applications serve to improve the clinical tasks of the personnel but do not directly influence the patient turnover.

significant positive selection into a technology integration level indicates the presence of unobserved forces (technological, organizational, and environmental) that are not only conducive to choice of the technology integration level but also enhance performance. I conducted the counterfactual analyses described earlier to analyze the what-if scenarios.

Table 3.5 reports the results from separate OLS regressions for the two levels of technology integration, Level I and Level II. I observe that the coefficient for the inverse Mills ratios for Level I is positive and statistically significant. The positive coefficient indicates a positive selection by the 176 health care providers into Level I of technology integration. This suggests that the average performance for these providers will be higher than the average performance of all the 363 (= 176 + 187) providers if all of them were randomly assigned to Level I of technology integration. On the other hand, the coefficient for the inverse Mills ratios for Level II is not statistically significant. This means that providers who have selected Level II have no unobservable advantage or disadvantage above and beyond the average performance. Table 3.9[21] provides the mean counterfactual estimates. The diagonal elements in the table correspond to the predicted performance for the observed choices and the off-diagonals correspond to the predicted values under the counterfactual (alternative) option. Consistent with the results above, the counterfactual estimates suggest that if the health care providers that chose Level I had instead chosen Level II, their performance would have been lower than the performance of providers who actually chose Level II (41.71

[21] Table 3.9 provides the counterfactual analysis results of pairs formed from any two levels of technology integration. In the chapter, interpretation is provided for pairs of Levels I and II, Levels II and III, Levels II and IV, and Levels III and IV.

< 43.82, p < 0.01). Similarly, if providers that chose Level II had instead chosen Level I, then their performance would have been lower than the performance of providers who actually chose Level I (18.36 < 27.77, p < 0.01). Further, the pattern of estimates also suggests that, while performance increases from Level I to Level II, some providers nevertheless choose Level I owing to unobservable factors affecting their selection process.

Table 3.6 reports the results from separate OLS regressions for Level II and Level III, corrected for selection bias. I observe that the coefficient for the inverse Mills ratios for Level II is positive and statistically significant. The positive coefficient indicates a positive selection by the 187 health care providers into Level II of technology integration. This suggests that the average performance for the 187 providers who have selected Level II of technology integration will be higher than the average performance of all 684 (= 187 + 497) providers if all of them were randomly assigned to Level II of technology integration. The coefficient for the inverse Mills ratios for Level III is not statistically significant. This suggests that providers in Level III of technology integration have no unobservable advantage or disadvantage over the average performance. Results from the counterfactual analysis (see Table 3.9) suggest no statistically significant difference in the performances between the counterfactual options and the observed choices. This suggests that while there is no significant performance difference between Level II and Level III, some organizations choose Level II owing to unobserved factors affecting their selection process.

Table 3.7 reports the results from separate OLS regressions for the two levels of technology integration, Level II and Level IV, corrected for selection bias. I observe that the coefficient for the inverse Mills ratios for Level II is not statistically significant. This suggests that providers in Level II of technology integration have no unobservable advantage or disadvantage over the average performance. On the other hand, the coefficient for the inverse Mills ratios for Level IV is positive and statistically significant. The positive coefficient indicates a negative selection by the 124 health care providers into Level IV of technology integration. This suggests that the average performance for the 124 providers who have selected Level IV of technology integration will be lower than the average performance of all 311 (= 187 + 124) providers if all of them were randomly assigned to Level IV of technology integration. A possible explanation for the negative selection is that providers invest in higher-level technologies with the intention to grow with the payoffs from the investment realized over a long-term. Results from the counterfactual analysis (see Table 3.9) suggest that if the health care providers that chose Level II of technology integration had instead chosen Level IV, their performance would have been higher than that of health care providers that actually chose Level IV (53.04 > 50.68, $p < 0.01$), consistent with the negative selection observed earlier. Similarly, if providers that chose Level IV had instead chosen Level II, then their performance would have been higher than the performance of providers who actually chose Level II (50.32 < 43.82, $p < 0.01$). This suggests that, while performance increases from Level II to Level IV, some providers nevertheless chose to adopt Level II owing to unobservable factors affecting their selection process.

Table 3.8 reports the results from separate OLS regressions for two levels of technology integration, Level III and Level IV, corrected for selection bias. I observe that the coefficient for the inverse Mills ratios for Level III is positive and statistically significant. The positive coefficient indicates a positive selection by the 497 health care providers into Level III. This suggests that the average performance for the 497 providers that have selected Level III will be higher than the average performance of all 621 (= 497 + 124) providers if all of them were randomly assigned to Level III of technology integration. The coefficient for the inverse Mills ratios for Level IV is positive and statistically significant. The sign of the coefficient indicates a negative selection (i.e., the performance of the 124 organizations in Level IV will be lower than the average performance of all 621 organizations in a random allocation to Level IV). While this seems counter-intuitive, a possible explanation for the negative selection is that providers invest in higher-level technologies with the intention to grow with the payoffs from the investment realized over a long-term.

The counterfactual estimates (see Table 3.9) suggest that if the health care providers that chose Level III had instead chosen Level IV, their performance by way of discharges per licensed bed would have been higher than that of organizations that actually chose Level IV ($58.96 > 50.68$, $p < 0.01$), consistent with the negative selection observed earlier. However, if providers that chose Level IV had instead chosen Level III, their performance would have been lower than that of organizations that actually chose Level III ($31.56 < 42.72$, $p < 0.01$). This reinforces my earlier finding that, while performance may be higher for providers choosing Level IV, some providers choose Level III owing to unobserved factors affecting the selection process. The results from two-step analyses for Level IV and Level V, revealed no significant endogeneity bias. Consequently, I do not report the results of further analyses here.

Overall, the pattern of results suggests that operational performance improves with (the higher) the level of technology integration. This provides conditional support for Hypothesis 1, the argument that performance for health care providers that select a higher level of technology integration will be greater than those that select a lower level of technology integration. This empirical result supports the theoretical perspective that higher coordination between multiple organizational subunits with specialized tasks can be achieved with the application of a higher level of integrated information technologies. As an increased number of functional technologies gets integrated, it expands an organization's information processing capacity, resulting in increased information sharing and eventually increased efficiency.

However, I also find that providers select into lower levels of technology integration owing to unobserved factors that affect the selection process. And the performance of providers who have selected into different levels is generally greater than the average performance under a random allocation into those levels, supporting Hypothesis 2, at least partially. For example, as noted earlier, performance of providers selecting into Level I is higher than the performance of providers in Level II had they been assigned to Level I instead (27.77, > 18.36, Table 3.9).

With the growing interest in integrating health care information systems and drive toward achieving an EMR environment, it is imperative for providers to understand the process and performance implications of technology integration. The findings of this study show that, while technology integration may be generally beneficial, selecting into the highest levels of technology integration may not be a dominant strategy. The findings are consistent with the theoretical arguments earlier that health care providers strategically select into the technology integration level that is most suited to their idiosyncratic characteristics. The implication of this finding for practice is that, with increasing institutional pressures for moving toward an integrated EMR environment, *providers need to assess the appropriateness of technology integration levels to their organizational characteristics* before readily investing resources into such efforts.

The findings of this study also point to an important direction for further research in this area. Specifically, the study highlights the need to understand the factors underlying the selection of different levels of technology integration. Achieving the promised benefits of technology integration and the EMR capability (as envisioned in the President Bush's plan for improving the health care delivery in the U.S.) requires an investigation of the enablers and barriers and potential moderating and mediating factors in achieving EMR technology integration. Devoid of such understanding, pure regulatory forces would be ineffective in achieving the goals of EMR for most patients.

3.5 Conclusions

Despite the growing significance of information technologies in health care supply chains, little is known about the selection and integration of technologies. Decision makers in the health care supply chain are increasingly being posed with questions about what technologies to select and what performance implications may be expected from the selection decision. This paper is an effort to address such questions. To that end, the paper makes a three-fold contribution.

First, I conceptualize technology integration by way of a classification scheme of levels comprised of various clinical technological applications employed in health care supply chains. While focused on technology integration within health care organizations, the proposed conceptualization has the potential to be extended more generally to technology integration across organizations in the health care supply chains. *Second*, I account for self-selection by organizations into different levels of technology integration. In this research, I show that there is systematic selection into technology integration levels: while the conventional wisdom that higher levels of technology integration provide better performance is partially supported, I find that managers choose their organization's level of technology integration based on both observable and unobservable factors. *Third*, I demonstrate the link between levels of technology integration and operational performance based on an econometric analysis of data from approximately 1011 health care providers. From the standpoint of managerial practice, the paper sheds light into how technology integration affects operational performance and highlights the significance of selection into a level of technology integration. Also, this study provides new explanations about the inconsistencies in the extant literature on the actual benefits of IT investments, referred to as the "productivity paradox".

There are several possible research extensions of this study that could prove to be fruitful lines of inquiry, including some that could overcome the potential limitations of this study. *First*, while this study identified (both conceptually and empirically) the need to account for selection in assessing the performance implications of technology integration, identifying the key drivers and the moderating and mediating factors of selection was not one of the study's objectives. However, as evidenced in the study, selection is at the heart of technology integration and performance improvements by health care providers. Hence, understanding the technology integration selection process forms a key direction for future research in this area. *Second*, while this study was focused on understanding the performance differentials across different levels of technology integration, future research could focus on the performance differentials within the *same* level of technology integration. This would reveal reasons why some health care providers selecting the same level of technology integration perform better than others. *Third*, while this research is a cross-sectional study, future research could study the phenomenon of technology integration over time and investigate how organizational performance is affected by changes in the levels of technology integration. Finally, future research could also focus on the role of supply chain readiness in the effective implementation of technologies by health care providers. Specifically, research could look into the role of three key participants (administration, physicians, and support staff) and the moderating effects of the technology infrastructure.

Table 3.1: Clinical Information Technologies and Integration Levels

Capability Group	Clinical Information Technologies[22]
C1	Laboratory Information Systems, Pharmacy Systems, and Radiology Information Systems
C2	Clinical Data Repository, Clinical Documentation, and Clinical Decision Support Systems
C3	Picture Archiving Communication Systems, and Medical Records Imaging
C4	Computerized Physician Order Entry

Integration Level	Criterion for Level Membership
Level I	Not all technologies belonging to Capability Group C1
Level II	All technologies belonging to Capability Group C1
Level III	All technologies belonging to Capability Groups C1 and C2
Level IV	All technologies belonging to Capability Groups C1, C2, and C3
Level V	All technologies belonging to Capability Groups C1, C2, C3, & C4

[22] Appendix A-3 has a brief description of each of the clinical information technologies.

Table 3.2: Descriptive Statistics of the Key variables in the Study

Variable	Column Two **Level One N=176**	Column Three **Level Two N=187**	Column Four **Level Three N=497**	Column Five **Level Four N=124**	Column Six **Level Five N=27**
Business Office (max = 5)	4.11 (0.829)	4.31 (0.632)	4.67 (0.495)	4.82 (0.407)	4.85 (0.456)
Financial Management (max = 4)	2.74 (0.788)	2.96 (0.400)	3.42 (0.519)	3.13 (0.363)	3.19 (0.396)
Human Resources (max = 4)	3.07 (1.224)	3.48 (0.827)	3.92 (0.295)	3.90 (0.394)	3.74 (0.526)
Decision Support (max = 5)	2.06 (1.384)	2.73 (1.28)	4.64 (0.787)	4.54 (0.706)	4.30 (1.265)
Managed Care (max = 3)	0.32 (0.618)	0.69 (0.882)	1.61 (0.912)	1.52 (1.13)	1.37 (1.006)
Medical Charts (max = 7)	4.89 (2.01)	6.23 (1.145)	6.82 (0.554)	6.73 (0.59)	6.59 (0.747)
Clinical Applications (max = 9)	1.24 (1.381)	3.23 (1.443)	6.34 (1.813)	7.05 (1.641)	6.48 (1.369)
Number of Licensed Beds	87.15 (86.094)	171.82 (119.17)	188.98 (139.418)	328.16 (215.104)	327.93 (212.203)
Profit Status (0 or 1)	0.22 (0.414)	0.19 (0.392)	0.54 (0.49)	0.06 (0.234)	0.04 (0.192)
Formal Steering Committee (0 or 1)	0.87 (0.333)	0.88 (0.330)	0.88 (0.329)	0.95 (0.217)	0.81 (0.396))
# of Key Executives in Steering Committee	3.45 (2.34)	3.40 (1.952)	2.85 (1.744)	3.56 (2.121)	3.19 (1.798)
# of Non-Executives in Steering Committee	2.52 (3.846))	1.66 (1.981)	5.25 (6.199)	2.36 (2.709)	1.85 (2.032)
Number of Members in IHDS	34.01 (27.333)	34.33 (64.77)	79.51 (74.095)	11.93 (37.644)	13.70 (40.175)
Purchasing Sub-Committee (0 or 1)	0.29 (0.456)	0.18 (0.383)	0.43 (0.495)	0.16 (0.3720	0.22 (0.424)
Member of Purchasing Group (0 or 1)	0.29 (0.457)	0.36 (0.481)	0.23 (0.422)	0.34 (0.477)	0.15 (0.362)
Member of Voluntary Purchasing Alliance (0/1)	0.77 (0.422)	0.81 (0.396)	0.91 (0.288)	0.75 (0.437)	0.78 (0.424)
Total Networking Technologies	12.17 (5.045)	12.87 (4.903)	13.50 (3.6760	12.80 (4.157)	13.26 (3.437)
Presence of Wireless	0.19 (0.393)	0.06 (0.246)	0.33 (0.472)	0.20 (0.405)	0.30 (0.465)
Presence of Intranet	0.80 (0.402))	0.79 (0.408)	0.85 (0.355)	0.92 (0.275)	0.89 (0.32)
Usage	0.991 (0.031)	0.998 (0.012)	0.995 (0.018)	0.998 (0.011)	0.989 (0.028)
Discharges per Licensed Bed	28.05 (17.486)	43.755 (15.335)	42.782 (18.906)	50.793 (15.669)	48.613 (15.055)

Note – Columns 2-6 report mean values with standard errors in parentheses.

Table 3.3: Selection Equation for Five Levels of Technology Integration

Variable	Ordered Probit Selection Equation
Business Office	0.261*** (0.091)
Financial Management	0.001 (0.104)
Human Resources	0.067 (0.075)
Decision Support	0.375*** (0.050)
Managed Care	0.028 (0.053)
Medical Charts	0.123** (0.050)
Clinical Applications	0.406*** (0.029)
Number of Licensed Beds	0.340*** (0.056)
Profit Status	-0.688*** (0.127)
Formal Steering Committee	-0.218 (0.156)
# of Key Executives in Steering Committee	0.021 (0.025)
# of Non-Executives in Steering Committee	-0.072*** (0.018)
# of Members in IHDS	0.004*** (0.001)
Presence of Purchasing Sub-committee	-0.193 (0.127)
Member of Purchasing Group	-0.125 (0.100)
Member of Voluntary Purchasing Alliance	-0.287** (0.131)
CIO reports to CEO	-0.173* (0.100)
N	1011
Wald χ^2	680.72
Log-likelihood	-794.97
Prob > χ^2	0.0000

Model additionally contains a control for Service Type.
Note – Numbers in parentheses are Standard Errors.
*indicates significant at 10%, ** significant at 5% and *** significant at 1%

Table 3.4: Performance Equation Estimates for Levels of Technology Integration

Variable	Level One N=176	Level Two N=187	Level Three N=497	Level Four N=124	Level Five N=27
Clinical Applications	1.238 (1.445)	-0.206 (1.211)	-0.148 (0.832)	-1.694 (1.961)	3.791 (6.209)
Medical Charts	0.049 (0.780)	-0.677 (0.934)	2.72** (1.279)	4.108* (2.37)	6.682 (5.303)
Total Networking Technologies	0.323 (0.413)	0.052 (0.350)	0.268 (0.349)	0.094 (0.448)	0.174 (1.679)
Total Outsourced Services	-0.008 (0.601)	-0.816 (0.683)	0.736* (0.427)	1.395 (0.968)	0.073 (3.62)
Presence of Wireless	0.510 (3.583)	-2.414 (3.932)	2.746 (2.298)	0.758 (2.999)	-11.27 (7.789)
Presence of Intranet	-0.065 (3.667)	-0.402 (3.159)	-4.307* (2.608)	-0.828 (5.759)	9.559 (5.494)
# of Members in IHDS	-0.087* (0.048)	0.092* (0.053)	-0.010 (0.026)	-0.102 (0.087)	-0.595 (0.652)
Usage	24.773 (28.423)	44.739 (112.38)	67.356 (46.197)	-158.06 (139.39)	10.891 (67.90)
Profit Status	4.547 (4.786)	0.543 (3.869)	-7.938* (2.851)	-5.797 (5.76)	111.65 (98.397)
Mills Ratio Coefficient	-7.619** (3.331)	6.756*** (2.112)	4.351* (2.491)	5.164 (4.399)	-0.292 (11.982)
R square	0.2819	0.1299	0.3660	0.1252	0.5316

Note – Regressions additionally contain a constant and control for Service Type. Numbers in parentheses are the standard errors. *indicates significant at 10%, ** significant at 5% and *** significant at 1%

Table 3.5: Performance Equation for Technology Integration Levels – I and II

Variable	Level One (N=176)	Level Two (N=187)
Clinical Applications	-0.031 (1.718)	2.246 (1.303)
Medical Charts	0.162 (0.761)	-0.119 (0.977)
Total Networking Technologies	0.319 (0.414)	0.141 (0.358)
Total Outsourced Services	-0.191 (0.615)	-0.887 (0.705)
Presence of Wireless	0.621 (3.523)	-3.281 (4.585)
Presence of Intranet	0.846 (3.574)	-1.769 (3.268)
# of Members in IHDS	-0.104 (0.055)	0.094 (0.057)
Usage	23.046 (28.312)	36.041 (104.538)
Profit Status	7.123 (5.943)	-0.252 (3.985)
Mills Ratio Coefficient	12.067*** (4.479)	2.439 (5.589)
R square	0.2422	0.0830

Note – Both regression additionally contain a constant and control for Service Type. Numbers in parentheses are the standard errors. * indicates significance at 10%, ** at 5% and *** at 1%

Table 3.6: Performance Equation for Technology Integration Levels – II and III

Variable	Level Two (N=187)	Level Three (N=497)
Clinical Applications	0.728 (1.213)	1.438 (0.701)
Medical Charts	0.002 (0.884)	3.303*** (1.284)
Total Networking Technologies	0.049 (0.342)	0.410 (0.356)
Total Outsourced Services	-0.821 (0.699)	0.913** (0.406)
Presence of Wireless	-2.868 (4.209)	1.651 (2.208)
Presence of Intranet	-0.034 (3.244)	5.003 (2.641)
# of Members in IHDS	0.098* (0.054)	-0.025 (0.026)
Usage	64.839 (109.04)	31.481 (45.549)
Profit Status	-1.377 (3.948)	-8.081*** (2.909)
Mills Ratio Coefficient	9.124** (3.597)	-1.896 (3.036)
R square	0.1116	0.0801

Note – Both regression additionally contain a constant and control for Service Type. Numbers in parentheses are the standard errors. * indicates significance at 10%, ** at 5% and *** at 1%

Table 3.7: Performance Equation for Technology Integration Levels – II and IV

Variable	Level Two (N=187)	Level Four (N=124)
Clinical Applications	2.366** (0.987)	-0.813 (1.075)
Medical Charts	0.099 (0.921)	3.755 (2.305)
Total Networking Technologies	0.137 (0.356)	-0.069 (0.443)
Total Outsourced Services	-0.855 (0.708)	1.394* (0.829)
Presence of Wireless	-3.395 (4.59)	1.352 (2.855)
Presence of Intranet	-1.459 (3.229)	-0.489 (5.529)
# of Members in IHDS	0.094* (0.056)	-0.087 (0.075)
Profit Status	-0.435 (10.05)	-6.923 (5.744)
Usage	29.148 (103.921)	-166.585 (132.753)
Mills Ratio Coefficient	3.415 (3.359)	7.013** (3.111)
R square	0.0844	0.1264

Note – Both regression additionally contain a constant and control for Service Type. Numbers in parentheses are the standard errors. * indicates significance at 10%, ** at 5% and *** at 1%

Table 3.8: Performance Equation for Technology Integration Levels – III and IV

Variable	Level Three (N=497)	Level Four (N=124)
Clinical Applications	0.426 (0.529)	-0.683 (1.057)
Medical Charts	2.641** (1.303)	4.123* (2.27)
Total Networking Technologies	0.279 (0.344)	0.052 (0.444)
Total Outsourced Services	0.649 (0.406)	1.657 (1.027)
Presence of Wireless	2.008 (2.191)	0.902 (2.906)
Presence of Intranet	-4.19 (2.633)	-0.725 (5.377)
# of Members in IHDS	0.001 (0.026)	-0.106 (0.092)
Usage	56.97 (45.506)	-150.223 (146.329)
Profit Status	-4.46 (3.279)	0.129 (7.065)
Mills Ratio Coefficient	11.756*** (3.806)	9.778*** (5.669)
R square	0.0938	0.1437

Note – Both regression additionally contain a constant and control for Service Type. Numbers in parentheses are the standard errors. * indicates significance at 10%, ** at 5% and *** at 1%

Table 3.9: Counterfactual Estimates for Five Levels of Technology Integration

	Level One (N = 176)	Level Two (N = 187)	Level Three (N = 497)	Level Four (N = 124)	Level Five (N = 24)
IF Level One	27.77	18.36	36.13	DNC	DNC
IF Level Two	41.71	43.82	43.23	50.32	DNC
IF Level Three	40.44	41.61	42.72	31.56	DNC
IF Level Four	DNC*	53.04	58.96	50.68	45.95
IF Level Five	DNC	DNC	DNC	58.36	48.6

Note – * Did not converge (DNC) means that the counterfactual analysis between the pairs did not converge and produced erroneous results. Those results are not considered for the research.

CHAPTER 4

ANTECDENTS AND CONSEQUENCES OF COMPUTERIZED PHYSICIAN ORDER ENTRY SYSTEM IMPLEMENTATION

4.1 Introduction

Organizations today are increasingly adopting information technologies (IT) to facilitate transactions both in-house and externally with partners in the supply chain. Extant literature has documented the huge organizational investments and its positive link to operational and financial performance (Sanders 2008, Determirhan et al. 2007, Ward and Zhou 2006). However, the decision to acquire innovative technologies does not always lead to favorable outcomes, with a large number of organizations failing to achieve widespread usage beyond initial adoption (Chatterjee et al. 2002). For example, a study of computer-aided software engineering (CASE) found that, although 42% of the surveyed organizations had adopted the technology, only 7% of them had achieved "widespread deployment" (Fichman and Kemerer 1999).[23] Studies on technology implementation also show that some organizations reject the same technology that other organizations successfully implement (Katz and Allen 1988).

Providers in health care, the context of this study, are faced with similar issues. Computerized physician order entry (CPOE) system, the focus of this study, is an information system that enables physicians to directly enter medical orders for patient treatment and/or diagnostic tests and provide real-time information to physicians, nurses, pharmacists, and patients (Ash et al. 2007). The anticipated benefits of CPOE system adoption for health care organizations include a lower potential for human error,

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[23]Fichman and Kemerer (1999) define deployment as the use of CASE in at least 25% of software development projects.

reduced time to care (time between order placement and clinician availability, improved order accuracy, and quicker order confirmation turnaround time), better clinical decision support at the point of care, and enhanced communication throughout the organization (Veltri 2008, Porter 2007). Despite the potential benefits of CPOE systems, studies show that only 10 to 15% of U.S. hospitals have successfully implemented a CPOE system (Ash et al. 2004). The challenge for health care providers are to ensure that their newly adopted CPOE system is properly implemented and its large financial investment is justified (Edwards 2006).

Although some research exists in the area of health care information technology use, there is still much to be learned (Poon et al. 2006). More generally, while considerable research exists on technology adoption, relatively little attention has paid to the implementation of technologies. The implementation literature is characterized by large-scale, qualitative case studies (Orlikowski 1993, Leonard-Barton 1988, Nord and Tucker 1987) which do not provide adequate insights into factors that affect the successful implementation of a technology in the operational settings of organizations. As Yin (1994) points out, statistical inferences drawn from the analyses of large sample databases on operational settings of organizations are more likely to provide insights into the antecedents of technology implementation than the process. Further, it must be realized that although senior executives and technology managers are primarily involved in deciding in which technologies to invest, the real benefits and impacts of technology investments depend on the end users of the technology (Lewis et al. 2003).

In health care settings, physicians are the primary users of technology who ultimately determine which technologies and equipment will be used to deliver services for each patient (Goldstein and Ward 2004, page 364). Unless the physicians readily accept and utilize clinical information technologies in their daily routines, the benefits of these systems cannot be realized by health care providers. While the majority of IT implementation studies in the literature have been focused on end users such as clerical and administrative staff and system developers, little systematic attention has been paid to the role of knowledge workers such as scientists, lawyers, engineers, or physicians in the successful implementation of the adopted technologies. Given that CPOE can increase cooperation across clinical disciplines and standardize clinical decision-making allowing the health care provider to realize significant benefits (Davidson and Chismar 2007), it is imperative that we understand the drivers of CPOE use and empirically examine its performance implications. The study is a step in that direction. Specifically, it is guided by the following questions:

- What are the key antecedents of CPOE implementation?
- What are the performance implications of CPOE implementation on health care providers?

The remainder of this chapter is organized as follows. Section 4.2 provides the research model and theoretical support for the testable hypotheses. Section 4.3 provides the research design of the study (the independent variables and data collection) and presents a discussion of the study results. Section 4.4 concludes with the theoretical contributions, the limitations of the research design, and implications for future research and practice.

4.2 Conceptual Background

Extant literature (e.g., Fichman 2000, Rogers 1995, Meyer and Goes 1988) views technology diffusion as a multistage process that starts with an organization's initial awareness of the technology (also called initiation). This is followed by its adoption and, subsequently, its widespread deployment or implementation. Technology implementation is the "extent to which developmental/adjustment activities are performed and the adopted technology ingrained within organizational business activities" (Thompson 1965). Implementation activities consists of all the actions and decisions involved in actually putting a new technology to use (Rogers 1995), usage[24] being a key indicator of the extent to which the technology is deployed in an organization (Yi et al. 2006). In this study, CPOE implementation refers to the organizational effort directed toward diffusion and use of CPOE system within the user community. Following Klein and Sorra's (1996) operationalization of *use* as ranging from avoidance (nonuse), unenthusiastic (compliant) use, to consistent and enthusiastic (committed) use, in this study the use of CPOE is assessed on a continuous scale ranging from no-use (none of the physicians use the system) to full usage (100% of the physicians use the system).

It must be noted that the adoption of a new technology does not always result in widespread usage of the technology, often because organizational members do not have sufficient knowledge of the technology or/and misalignments occur between the technology and the user environment (Fichman and Kemerer 1997). A study of materials requirements planning (MRP) systems found that while 73% of the surveyed organizations had adopted MRP, only 27% of them had integrated the technology into their capacity planning activities (Cooper and Zmud 1990). Katz and Allen (1988)

[24] Extant literature has conceptualized usage as either the *use of a system* (Rai et al. 2002, Hartwick and Barki 1994) or as the *use of information from a system* (Szajna 1993). Measures that have been used in earlier studies for *use of a system* include duration and frequency of use, dichotomy of use versus nonuse, and specificity of use (Venkatesh et al. 2003).

observed the “Not Invented Here” syndrome can also lead an organization to reject a new technology based on an implicit assumption that the technology does not fully recognize or accommodate this individual organization’s needs and idiosyncrasies. When organizations fail to regularly use new technology, the technology naturally fails to deliver the promised benefits and the organizational expectation that technology investments will contribute to performance is never met (Lucas and Spitler 1999).

Few studies have investigated the antecedents of IT implementation in organizations, particularly in the context of health care providers. For example, Grover and Goslar (1993) identify environmental uncertainty and decentralized decision-making as key factors in the successful implementation of telecommunications technologies. Chatterjee et al. (2002) identify management support and cross-department coordination as significant organizational enablers of the implementation of web technologies. Zhu and Kraemer (2005) examine the role of organizational, technological, and environmental factors in the post-adoption usage of e-business in the retail industry, and Liang et al. (2007) describe the mediating role of top management on the impact of external institutional pressures on the degree of usage of enterprise resource planning systems. Overall, while the extant literature highlights the significance of technology implementation and the need for developing measures of actual usage of the technology, there is still much to be learned (Poon et al. 2006).

Next, I present a brief description of my research framework investigating the key factors that influence the implementation of CPOE systems and the performance implications of the use of CPOE by health care providers are outlined. Specifically, research hypotheses (see research model in Figure 4.1) are discussed to link organizational readiness, user readiness, and technology integration with the extent of CPOE use and, in turn, its impact on the operational performance of health care providers.

4.2.1 Organizational Readiness

Organizational readiness is the involvement of managers in setting strategies that facilitate fast and smooth implementation of the new technology. Organizational readiness captures the extent of explicit top-management support, resource commitment, and processes that facilitate successful implementation of the new technology. As shown in Figure 4.2, organizational readiness can be conceptualized as consisting of four formative properties: (i) the reporting status of the CIO, (ii) presence of the chief executive officer (CEO) in the information systems (IS) steering committee, (iii) the health care provider's effort to improve communication and training to increase physician usage of the new system, and (iv) provision of handheld devices by the health care provider for physicians to enter medication order.

When the CIO reports directly to the CEO, a practice by "leading edge" adopters of IT (Smaltz et al. 2006), it sends a visible signal to other organizational actors about the value of IT, aligns IT considerations with the business model of the organization, and places the CIO in a position of considerable power – a predictor of innovation adoption in organizations (Preston et al. 2008). For health care providers, the CIO, beyond being well versed in his or her responsibilities (e.g., how to select the right technology for the organization, benchmarking health care IT spending, etc.), also needs to have organizational status to influence IT implementation and leverage a new system to drive results (Burke et al. 2006). It is highly likely that the CIO's reporting status (that is, whether the CIO reports directly to the CEO) for a health care provider will influence the use of the CPOE system.

A strong belief in the importance and relevance of a new technology can motivate top management participation in shaping the organization's vision and strategies and exploring ways in which new technology's functionalities could be leveraged into business processes and activities (Chatterjee et al. 2002). IS steering committees, formed by representatives from various organizational subunits, not only communicate the benefits and implications of IT investments to management and user groups, but also influence strategic IT planning and its effectiveness (Doll and Torkzadeh 1987, Drury 1984, Nolan 1982). When the CEO actively participates in IS steering committees and expends time and energy in making sense of the adopted technology, he or she can legitimize the willingness of every user to embrace the technology (Lane 1985, Vanhommel and De Brabander 1975). CEO participation not only signals management commitment to the implementation process but also motivates technology users to put extra effort into embracing the new technology (Sharma and Yetton 2003, Leonard-Barton and Deschamps 1988). Indeed, in health care settings, support from top management (especially CEOs) is found to be a key factor in the successful adoption of medical records imaging (Friedman and Goes 2000).

IT implementation methodologies highlight the importance of using communication plans to manage user expectations and developing training strategies that teach end users the skills needed to use the system (Kimball 1998). During the early stages of technology use, organizations initiate actions like (i) training their employees on the technical aspects of new technology, (ii) informing users about possible changes in business processes and/or job descriptions caused by the technology, and (iii) providing around-the-clock technological support (Igbaria et al. 1997). Organization-wide training and presence of help desks and technical support teams motivates users to accept the technology and enable new users to gain experience with and learn about the technology (Taylor and Todd 1995). This is found to be a significant facilitating condition that influences user acceptance of the technology (Thomson et al. 1991).

Similarly, extensive communication about the new system not only guides potential users, gathers information, and reduces uncertainty (Rogers 1995), but it also significantly influences system acceptance and subsequent use (Zmud 1983). Empirical support for communication as an organizational technique to enhance system use is observed in the context of individual acceptance of spreadsheet software (Brancheau and Wetherbe 1990). In a survey of senior health care managers, Poon et al. (2004) identify a few essential strategies that top management needs to follow during the initial phase of IT implementation: aggressively communicate vision, demonstrate commitment, and provide training and support to end users. Hands-on-training and other learning methods to acquire the skills and knowledge to use the technology are found to help potential users of clinical information technologies to effectively adapt to changes in their work routines (Edwards 2006). A case study of successful CPOE implementation in a community setting identifies consistent communication and persistent support from top-level managers as key actions in fostering the technology's success (Levick and O'Brien 2003). An organization must also provide intensive and structured training following the purchase of a CPOE system. As more and more physicians feel comfortable with the technology, they will embrace it and use it more frequently. Hence, it is highly likely that efforts by the health care provider to increase communication about and training with a CPOE system will positively influence use of the CPOE system.

To receive all of the strategic benefits of a new technology during the implementation phase, organizations need to make appropriate technological, financial, and human resources available (Ein-Dor and Segev 1978). Iacovou et al. (1995), studying EDI implementation in small firms, also observed that other technological and financial resources is necessary. A study of telemedicine implementation in home health services shows positive significant association between organizational support and employee job satisfaction (Dellifraine el al. 2006) when the organization makes significant effort to build an infrastructure that facilitates the smooth deployment of the new technology. A handheld device, used to enter medication orders is found to (i) improve usability and usefulness, (ii) facilitate training and support, and (iii) promote CPOE use (McAlearney et al. 2005). Handheld devices can also be used from remote locations and physicians feel much more comfortable using these devices as compared to computer workstations in a crowded hospital. Hence, procuring technological resources like handheld devices motivates physician use of the CPOE system.

These organizational initiatives motivate the managerial and user community (Purvis et al. 2001) to get strongly involved with the process of implementation and provide necessary resources to enhance the use of CPOE system in their organizations. Orlikowski et al. (1995) call these organizational initiatives meta-structuring actions since they either reinforce the existing institutional structures or alter those structures to create conditions more conducive to technology implementation. Further, the authors argue that senior management can manipulate the institutional structures of signification and legitimation and thereby influence, guide, or motivate individual structuring actions. For example, through advocacy, senior management can articulate a new organizational vision that regards CPOE as strategic. This, in turn, introduces a new structure of signification whereby physicians start recognizing the connections between the technology and business initiatives. This is consistent with the innovation diffusion theory (Rogers 1995, p. 376-383), which emphasizes the internal characteristics of the organization as drivers of technology diffusion.

Drawing upon the structuration theory of technology use and innovation diffusion theory, it is conceivable that organizational readiness is a key enabler of the technology structuring actions of CPOE users, and, thereby, the use of CPOE system. When managers get involved in strategic decision-making and support investments/initiatives targeted to increase user involvement, it is more likely to influence user behavior toward the CPOE system. This leads to the following hypothesis:

Hypothesis 1 (H1): Organizational readiness is positively associated with the use of CPOE.

4.2.2 User Readiness

User readiness captures s the preparedness and intention of physicians to use the CPOE system. User readiness may be conceptualized as consisting (see Figure 4.3) of four formative properties: (i) whether physicians find use of CPOE system easy to use, (ii) if training on how to use the system is provided to the physicians, (iii) if the CPOE system is accessible for use by physicians, and (iv) if physicians find the time required to enter orders using the system less than doing it manually. Though extant literature identify the use of the technology as the single most important factor for IT success, very few studies actually account for organizational user readiness to use new technologies (Lewis et al. 2003, Parasuraman 2000). Empirical studies on the initial use of information technologies find user attitude towards the technology as a significant predictor of implementation success (Bhattacherjee 2001, Karahanna et al. 1999). Users with a less favorable attitude toward information systems might feel lower psychological involvement and may not use the technology (Hartwick and Barki 1994). On the contrary, users favorably inclined toward the adopted technology will view it as more useful and be more likely to actually use it (Igbaria 1990).

Physicians, traditionally, are socialized to guide their practices from personal knowledge and experience (Anderson 1997). Physicians resist using computerized systems because either they view these systems as a threat to their professional autonomy (Fitzhenry et al. 2000) or because they do not perceive any direct, visible benefits from using the systems (Treister 1998). Sittig et al. (2005) investigate physician's emotional reactions to CPOE, concluding that the use of CPOE systems generates positive, negative, or neutral responses and that negative physician emotions prohibit the system from becoming a routine part of the clinical care delivery process. Similarly, according to Guimares and Igbaria (1997), an individual's prior experience (either positive or negative) with the technology influences the way they view the new technology (either as an enabler or not) and is a significant predictor of whether the intended users will actually utilize the new technology.

In their survey of physicians, residents, and nurses, Van der Meijden et al. (2000) find that those with computer experience rated the a new CPOE system more positively than inexperienced respondents. The first-hand exposure to the system during training may have moderated the influence of computer experience on attitude. This finding informs us that users expect training on a new system and lack of training can influence their behavior with regard to use of the system. This is consistent with the extant literature that observes that the extent to which an individual has been trained on the technology facilitates user participation, with trained users making greater contributions during the implementation phase than untrained users (Agarwal and Prasad 2000). Hence, it is highly likely that the user belief that they have less training on the new technology will negatively influence the use of CPOE system.

Many health care providers lack a hardware strategy (as evidenced by the number and the type of devices available to use: tablets, computers on wheels, computers in a patient's room) and provide physicians access only to computers on wheels that they must share with nurses and which are located in the hallways. This issue is important in a hospital setting, as physicians do not have physical offices (and, thus, constant access to a computer) (Ilie 2005). Accessibility is a major concern for physicians, and less access to computers can influence physician willingness to use the CPOE system. This observation is consistent with Taylor and Todd's (1995) finding that access to using a technology impacts perception of behavioral control and, thereby, significantly influences individuals' intention to use a new information technology. It is likely that accessibility of the CPOE system will affect the use of the CPOE system.

In a meta-analysis of 121 IT-related implementation studies, Sabherwal et al. (2006) find that user prior experience with the technology significantly influences their future technology use. Implementation of CPOE systems involves major changes in organizational and individual workflows and ways of practicing medicine. With these systems, a physician needs to find an available computer, log in, and check boxes in many different categories to indicate a patient's symptoms, allergies, diagnosis, tests, and medications (Fitzhenry et al. 2000). Physicians and other health care employees often complain that working with clinical information technologies takes more time than manually completing the tasks (Van der Meijden et al. 2000, McLane 2005). It is interesting to note that in a study at a Dutch hospital, few respondents expected the clinical information technology to reduce time on administrative tasks (Van der Meijden et al. 2001). A survey of physicians using CPOE system at hospitals find 69-75% report spending more than 60 minutes every day working directly with the system (Connolly 2005). These studies suggest that technology users are skeptical as to whether the IT use actually takes less time than it takes to perform the same task manually. Such a belief can deter them from using the technology. Hence, it is likely that the user perception that the new system will take more time than the existing one will influence the use of CPOE system.

In summary, each of the user-related factors discussed above identifies a unique aspect of user reactions when a new information system is implemented in an organization and their decision as to whether or not to use the new system. These findings that individuals' intentions to engage in an activity affect their specific behavior are consistent with the theory of planned behavior (TPB) (Ajzen 1991). Also, the innovation diffusion theory (IDT), which suggests that users in all likelihood will use those technologies that are easy to use, have a clear advantage over existing ways of doing work, and are less complex (Rogers 1995), explains physician behavior in the use (or nonuse) of clinical IT such as CPOE. Drawing upon ideas in TPB and IDT, it is conceivable that user readiness is a key enabler of the use of CPOE system. This leads to the following hypothesis:

> ***Hypothesis 2 (H2)***: User readiness is positively associated with the use of CPOE.

4.2.3 Technology Integration Level

Recent advances in information and telecommunication technologies enable the integration of various islands of automated information processing and decision support systems to form broader systems (De Meyer and Ferdows 1985). Technology integration, the operational integration of various information technologies, enhances the responsiveness of information systems and represents the organization’s ability to effectively convert stand alone technologies into capabilities (Mata et al. 1995). Technology integration that helps to leverage existing information and data resources across key processes along the value chain has a strong impact on the implementation of e-business by organizations (Zhu et al. 2006).

In the health care setting, apart from order entry, CPOE systems also provide comprehensive medical information, real-time decision support, and faster information retrieval for efficient data management (Saathoff 2007). These CPOE characteristics require interactions with other clinical information technologies such as clinical decision support systems, data repositories, and documentation systems. Availability of these clinical technologies ensures the flow of relevant and intelligent information throughout the health care delivery process when physician orders are communicated to ancillary departments like the laboratory or the pharmacy. Hence, users of a CPOE system at health care providers with higher levels of technology integration may find it more appropriate to use the system since they will be able to reap greater benefits by interacting with other integrative clinical information systems. Based on these arguments, it can be posited that:

> ***Hypothesis 3 (H3)***: The level of technology integration is positively associated with the use of CPOE.

4.2.4 Use of CPOE and Organizational Performance

CPOE systems enable order entry for patient treatment and/or diagnostic tests and provide real-time information to all healthcare providers. CPOE systems improve patient care through better communication across departments and standardization of procedures across the organization (Poon et al. 2004). Also, CPOE systems replace the manual ordering process with standardized, cross-functional automated transaction process and reduce the service time along the health care delivery process (Ash et al. 2003). Reduction in ordering time results in improved throughput and delivery of service and positively impact operational efficiency of the healthcare provider. Hence, it leads us to expect that performance of healthcare providers will improve with an improved patient care delivery process enabled by the newly implemented CPOE system. This leads to the following hypothesis:

> ***Hypothesis 4 (H4)***: The use of CPOE system is positively associated with the operational performance.

4.3 Research Design

4.3.1 Data Collection

The study uses a cross-sectional design. The unit of analysis for this study is the health care provider (that is an acute care hospital who has already adopted the CPOE system). All variables for this study are collected with reference at the health care provider level. The data for this study combines two databases, the Dorenfest Complete IHDS+ Database and the Medicare Cost Reports Database.

The Dorenfest Complete IHDS+ Database contains detailed information about the health care providers associated with 1,444 integrated health care delivery systems in the U.S. Detailed information on technological and demographic characteristics of health care providers is collected annually by Dorenfest and Associates (now part of Healthcare Information and Management Systems Society) using mailed surveys and telephone interviews. The respondents to the survey and interviews include the CIOs, who report specifics about information technology, and the Vice Presidents of Marketing and/or Strategic Planning, who provide data on the demographic characteristics. The database contains detailed data on health care information system applications, purchase plans for information technology activities, information system decision-making processes, steering committee composition for each health care provider, demographic data of all health care providers by type (e.g., acute care, sub-acute care, ambulatory care, home health), sizing statistics (e.g., bed size, full time equivalents, etc.), contact information for key executives at each health care provider, the overall information technology strategy, etc. The Medicare Cost Reports database from the Health Care Cost Report Information Systems (HCRIS) formed our source for data on operating performance. It is a widely-used national database [two other sources being American Hospital Association (AHA) and Health Care Industries Association (HCIA)] that carries information on performance variables (annual financial and operational characteristics) for acute care providers in the U.S.

To construct the research sample, a subset of the data from the Dorenfest database (the acute care hospitals which have installed a CPOE system) is used. For each hospital, information on the variables that measure the organizational readiness, user readiness, and the use of CPOE system is tabulated. Of the 264 acute care hospitals that had CPOE systems, 51 did not disclose[25] either their CPOE implementation strategy or physician-related information on CPOE systems. Of the remaining 213 acute care hospitals, 22 had missing values on the endogenous variable (i.e., use of CPOE systems) and were removed, resulting in a sample size of 191 hospitals. Next, the data was linked with the Cost Reports dataset using the Medicare number[26] of the health care providers. Except for three health care providers, the data from the Dorenfest database matched successfully with the Cost Reports information. The Cost Reports enabled the computation of the operating performance measure for the acute care hospitals considered in the study for the year 2004. The final study sample included 188 acute care hospitals where information is available for all the relevant research variables.

4.3.2 Formative versus Reflective Indicators

To operationalize latent variables with multiple indicators, extant literature recommends the use of either reflective or formative measurement. The relationship

[25] Out of 51 hospitals, 19 did not disclose the physician-related variables, 4 did not disclose the CPOE implementation strategy and 27 did not disclose both physician-related and CPOE implementation strategy variables.
[26] The Medicare number is a unique identification number for each hospital. The two research databases are matched based on the Medicare number.

between the observed indicators and their respective latent variables as informed by theory primarily dictates the choice of a formative versus a reflective model (Jarvis et al. 2003, Bagozzi et al. 1991). In a reflective model, latent variables are the underlying causes for the indicators and the indicators are considered effects of the corresponding latent variables. On the contrary, in the formative approach, the indicators are perceived as causing the latent variable and the latent variable is measured by the indicators (McCallum and Browne 1993). Furthermore, the objective of the study is an important consideration in the choice between these two approaches. As focus of this research is to explain the abstract variance and not the observed variance, use of formative indicators is recommended (Diamantopoulos and Winklhofer 2001, Fornell et al. 1991).

This study models organizational readiness and user readiness using the formative indicator approach and assumes both constructs as the effect of their respective indicators. In other words, to improve organizational readiness for new technology, health care providers can opt to pursue the following actions: make their CIO report directly to the CEO; make their CEO a participating member of the IS steering committee; provide communication and training to increase physician usage of the new system; and/or purchase handheld devices for physicians to enter medication orders. The health care provider's organizational readiness score will change with a change in any of these observed indicators. But a change in the score of organizational readiness will not always be accompanied by a change in all the observed indicators. Further, the study attempts to capture the variance of the unobserved latent variables (i.e., organizational readiness and user readiness) and not the variance of the observed indicator variables (indicator variables are listed in Table 4.1).

Relationships among individual indicators exhibit different patterns when conceptualized using the reflective and the formative approach (Jarvis et al. 2003). Since all of the indicators result from the same underlying latent variable in a reflective model, it is necessary to evaluate the internal consistency among the indicators. On the contrary, for a formative model, the indicators do not capture the same aspects of the latent variable and covariation among indicators is not necessary or implied. These reasons make statistical techniques such as internal consistency and factor analysis inappropriate to assess the quality of the causal indicators (Arnett et al. 2003, Homburg et al. 2002). In a formative approach, such as the one I've used, changes in one of the observed indicators will not always be accompanied by a change in any one of the other observed indicators. For instance, purchase of handheld devices would not be accompanied by a change in the reporting status of CIO. Each of the indicators independently contributes[27] to the total value of the corresponding latent variable (i.e., organizational readiness).

Though the measurement literature provides extensive guidelines for developing scales for a reflective indicator model (Anderson and Gerbing 1982), there are very few studies to suggest ways to construct an index using the formative approach (Diamantopoulos and Winklhofer 2001). One recommended empirical approach to evaluate a formative indicator model is to assess its external validity using a multiple indicator and multiple cause (MIMIC) model (Arnett et al. 2003, Bollen and Lennox 1991). There are two issues that restrict the use of this validation method. First, additional reflective indicators in the data are needed for this method. Second, Burt

[27] Such reasoning provides additional justification for the choice of a formative indicator model for the research constructs of organizational readiness and user readiness.

(1976) observed that when external validity is assessed in a large model that contains the relationship between the latent variables of interest and other criterion variables, the problem of "interpretation confounding" arises. Burt (1976) added that confounding results in a shift of emphasis from epistemic to structural criteria in determining factor loadings for the latent variable. This makes the validation of a formative indicator model using the MIMIC method difficult to interpret.

Usually the latent variable is estimated as a linear combination, a composite of its respective indicators for the formative indicator model (Diamantopoulos and Winklhofer 2001). Ideally, the latent variable is modeled as the sum of a linear combination of formative indicators and a disturbance term. But since the residual term is not identifiable or estimable, the latent variable is viewed directly as the linear combination or sum of formative indicators (Diamantopoulos and Winklhofer 2001). This study measures organizational readiness and user readiness as the sum of the corresponding indicators.[28]

4.3.3 Research Variables

This section provides a discussion of the measurement of organizational readiness and user readiness using the formative indicator approach, where each construct is a combination of few indicator variables. Measures of other research variables such as technology integration level, use of CPOE, organizational performance, and the control variables are also described below.

[28] Both latent variables were also measured as the simple average of the corresponding indicators. No significant difference was observed between using the sum and the simple average of the corresponding indicators. Therefore, this study only reports the results using the sum of indicators.

As mentioned earlier, organizational readiness assesses the involvement of managers in setting an organizational strategy that facilitates technology implementation. It is assessed using four indicators: the CIO's reporting status, whether the CEO is a member of the IS steering committee, the health care provider's efforts to improve communication and training to increase physician usage of the new system, and the health care provider's purchase of handheld devices for physicians to enter medication order (refer Table 4.1). User readiness is the user's intention to accept and use a technology selected by the organization. To measure user readiness four indicators are used: physicians find it easier to use the CPOE system, physicians are provided training to use the system, the CPOE system is accessible for use to physicians, and physicians find that entering orders using the systems takes less time than doing it manually (refer Table 4.1).

Technology integration refers to the operational integration of various information technologies and represents the organizations' ability to effectively convert stand alone technologies into integrated information systems. For a health care provider, technology integration signifies operational integration of the several clinical processes of the health care delivery system by the interface of different clinical information technologies. This study identifies four levels of technology integration, where each level consists of a set of clinical technologies used by health care providers for patient care applications. The grouping of technologies is informed by Garets and Davis's (2006) clinical transformation staging model, developed to assess the status of electronic medical record (EMR) implementation in health care providers. Table 4.2

provides a description of the four levels of technology integration and lists the clinical information technologies.

Use of CPOE systems is measured by the percentage of physicians who report using the CPOE system. Physician usage of CPOE is important to examine because, as front line care providers, physicians are in the best position to observe the effects of CPOE use (Weiner et al. 1999). Organizational performance is assessed using discharges per licensed bed (also referred as *case flow* in extant literature), which is defined as the total discharges divided by the number of licensed beds in service at the health care provider. It measures the number of patients who use a health care provider's beds during a given period and varies directly with occupancy rate and inversely with average length of stay. Since it indicates the relationship between inputs (beds) and outputs (discharges), discharges per licensed bed is used in health care research as a measure of productivity and patient turnover (Shortell et al. 2005), with higher values indicating efficient providers and lower values indicating unfavorable levels of occupancy and/or utilization (Younis 2004). Unlike financial performance metrics that may be affected by a host of other inputs, operational performance metrics such as discharges per licensed bed are a more direct indicator of the efficiency and effectiveness of an advanced clinical information technology such as CPOE system. Also, unlike financial performance where there may be some time lag before the benefits can be observed and recorded in reports, operational performance is affected fairly quickly by improvements to the processes and systems. Hence, I argue that use of CPOE system would speed up customer care and shorten hospital stays for patients.

To account for the lag effect of information technology on organizational performance, information on the discharges per licensed bed of health care providers is collected for the year 2004 (Brynjolfsson and Hitt 1996). Curley and Pyburn (1982) suggest that because of the unusual complexity and novelty of IT, organizations and individual users may require some experience before becoming proficient. Brynjolfsson and Hitt (1996) and Loveman (1994) found a lag in the impact of information technology in the context of organizational productivity. Brynjolfsson and Yang (1996) argue that if significant lags between cost and benefit exist, then poor short-term performance could ultimately result in proportionately larger long-term pay-offs. For CPOE systems in particular, this explanation is consistent, since researchers note that health care providers need to wait for some time before they reap positive benefits from CPOE implementation.

To test the effect of antecedents on use of CPOE (Hypotheses H1 through H3), the study employs two control variables: voluntariness of use of the new technology and the network effect. Voluntariness of use is defined as "the degree to which use of the technology is perceived as being voluntary or of free will" (Moore and Benbasat 1991). Use of a particular technology within an organization may be mandated and such policies take the freedom to reject a technology out of individuals' hands. The research also control for the membership in a multi-hospital network to account for the performance benefits reaped from learning from the network partners.

To investigate the implications of the use of CPOE on the organizational performance (Hypothesis H4), the study employs control variables that capture the influence of different technological, structural, and organizational characteristics of a health care provider. The control variables include: levels of technology integration, type of service, medical record applications, clinical applications, profit status, total number of networking applications, total number of outsourced services, and the availability of wireless and intranet at the health care provider. To keep the analysis consistent for Chapters 3 and 4, identical control variables are considered to test the hypotheses relating to performance. Table 4.3 provides descriptive statistics of all the variables used for the study, and Table 4.4 provides the correlation between the dependent and the independent variables.

4.3.4 Results and Discussion

With the purpose of studying CPOE use and impact of CPOE use on organizational performance, the study developed a research framework and tested the model with data collected from acute care hospitals. The empirical analysis demonstrated several major findings. Interpretations based on these findings and implications for researchers and practice are discussed below.

The empirical analyses involve the use of ordinary least squares (OLS) regression in two stages to analyze: (i) the effects of antecedents on use of CPOE and (ii) the effect of use of CPOE on organizational performance. To test Hypotheses H1 through H3, OLS regression is employed with organizational readiness, user readiness, technology integration level, voluntariness, and membership in hospital networks as independent variables and use of CPOE as the dependent variable[29]. Table 4.5 reports the results from regression for use of CPOE. The regression model is statistically

[29] To test the effect of the indicator variables (four variables that are combined to develop organizational readiness and four variables that are combined to develop user readiness) and technology integration level on the use of CPOE, I ran OLS regression. Appendix (Table A-4) provides a brief discussion of the results of the simple regression analysis.

significant at $p < 0.01$ (F-value = 43.32). Differences in organizational readiness are reflective of the variation in the top management involvement to set strategies (such as resources, routines) in an effort to successfully implement the CPOE system. While this is posited in Hypothesis H1 to affect the implementation outcomes (i.e., use of CPOE), the coefficient of organizational readiness was statistically insignificant (β= -0.008, p=0.820), failing to support this argument. While this result is contrary to my expectations, it may be attributed to the strength of the theoretical premise that health care administrators are able to identify and secure all of the necessary resources to promote organizational survival, an assumption that may be untrue. If health care providers cannot identify all of the necessary inputs, it is unlikely that providers could rationally select appropriate implementation strategies to enable CPOE use and consequently promote organizational survival. While an empirical assessment of the robustness of this theoretical premise is beyond the scope of this research, future research may delve into alternate models of CPOE implementation strategies.

The coefficient of user readiness is positive and significant (β= 0.129, p=0.053), supporting Hypothesis H2. The study uses a coded scale for the user readiness construct. In other words, a higher score is reflective of a higher user readiness and vice versa, and the user readiness for the technology is highest when the scale score is four. Hence, the positive coefficient is consistent with my research proposition that user readiness is positively associated with CPOE implementation effectiveness. This result is consistent with the theoretical premise of the theory of planned behavior (TPB) which states that the technology usage behavior of an individual is determined by his/her attitude (positive/negative) toward the technology, with users who view the system as useful being more likely to use the system. This finding also supports the theory of innovation diffusion that posits the importance of relative advantage and results demonstrability for the innovation to be accepted and effectively implemented.

The coefficient of technology integration level is positive and significant (β = 0.070, p = 0.038), supporting Hypothesis H3, which posits that health care providers with higher levels of technology integration will have greater use of the CPOE systems when implemented. This suggests that when CPOE systems are used together with other clinical information technology, users experience the desired benefits of technology integration and may be inclined to use the new technology. This finding also supports other studies on technology implementation that suggest technology integration strongly impacts the deployment of advanced information systems in organizations (Zhu et al. 2006). Among the control variables, voluntariness of use (β = 0.511, p = 0.000) is significant, whereas membership in hospital network (β = 0.080, p = 0.131) is not.

Testing Hypothesis H4 involves the OLS regression of use of CPOE as the independent variable and operational performance of the health care provider as the dependent variable. The regression equation also includes several control variables as described earlier. Table 4.6 reports results from the regression for the operational performance of acute care hospitals. The overall model was statistically significant at $p < 0.01$. The control variable profit status (β= -0.173, p=0.013) is found to have statistically significant coefficients. The results show significant impact of the Use of CPOE (β = 0.208, p = 0.045) on the operational performance. In other words, the results suggest that use of CPOE positively impacts operational performance, taking into account the lag effect, and, thus, supports Hypothesis H4. The results also tells us that the control variable, levels of technology integration do not significantly impact the operational performance of the health care provider. The revised research model of CPOE implementation is shown in Figure 4.2.

4.4 Conclusions

The use of a CPOE system by health care providers may not only serve to improve operational efficiency, an important critical success factor in health care organizations, but it may also appeal to patients as customers with the superior services outcomes. As health care providers increasingly seek to implement CPOE systems to streamline clinical information flows and enhance clinical decision-making, it is important to understand the factors that enable the successful implementation of CPOE. This study makes several contributions in this regard. Drawing upon theoretical perspectives on organizational and user related predictors of technology implementation such as the theory of planned behavior and innovation diffusion theory, this study develops an integrative model to examine the influence of three contextual factors (namely organization readiness, user readiness, and technology integration) on CPOE implementation. Further, the study identifies the performance implications of CPOE use for a health care provider. The model conceptualizes the organizational readiness and user readiness factors as a formative construct constituting the key variables related to the construct as discussed in the literature.

Based on data collected from 188 acute-care hospitals in the U.S., the study provides an empirical assessment of the model. The study results not only identify significant factors shaping the implementation but also highlight the impact of CPOE use on the operational performance of health care providers. Further, the study provides an assessment of the implementation of an emerging technology designed specifically for use by knowledge workers (i.e., physicians) in a health care setting. The significance of the user readiness factor in the analysis highlights the critical role of physicians in the successful implementation of the CPOE system. Understanding the determinants of professional users' intention to use a new technology will help providers identify organizational initiatives facilitating an effective implementation of technology. The conceptual model can be used as a theoretical framework for studying other types of technology implementations not only in other industries as well.

There are several possible research extensions to this study that could prove to be fruitful lines of inquiry, some of which could overcome the potential limitations of this study. First, while my study was conducted within the context of health care organizations, it is possible that the nature and substance of organizational readiness and user readiness in health care organizations may differ from those in other settings. Hence, studies regarding the role of the two important independent variables in motivating IT use in other industry contexts such as manufacturing or service forms a key direction for future research.

Second, this study utilized a cross-sectional survey with a single respondent for each health care provider. There are at least two potential concerns related with such a research design: common methods variance and the respondent's biases and knowledge base. The issues examined in this study pertain to organizational actions, and the individuals responding to the questions were CIOs, who are expected to have specific organizational responsibility for the actions in question. Therefore, the organizational role of the respondents and the nature of the issues examined reduce the severity of concerns about the biases and knowledge base of respondents. However, future research may look in to temporal processes that shape IT use in organizations using longitudinal designs.

Third, this study does not consider the different ways CPOE systems are used by different health care providers. This arises from the variation in CPOE systems and features designed by different manufacturers. It is also likely that the level of information technology support for clinical staff using the CPOE system varies from one health care provider to the next. Future research accounting for the technology variations and other organizational/user related factors of relevance to CPOE use may be a fruitful line of inquiry.

Table 4.1: Definitions of Research Variables

Variable	*Data Type*	*Description*
Levels of Technology Integration	FACTOR	Technology Integration Levels* (1 through 4)
Organizational Readiness	ORGVAR	ORGVAR = CIOR + CEO + COMMN + HHELD
CIO's reporting status to CEO	CIOR	Score 1 = Yes; 0 = No
Presence of CEO in the IS steering committee	CEO	Score 1 = Yes; 0 = No
Efforts to increase communication and training	COMM	Score 1 = Yes; 0 = No
Purchase of handheld devices to enter the medication orders	HHELD	Score 1 = Yes; 0 = No
User Readiness	USEVAR	USEVAR = EASY + NACC + MTIME + LESS
System is easy to use	EASY	Score 1 = Yes; 0 = No
Training provided to use the system	LESS	Score 1 = High; 0 = Low
Can access computers to use the system	NACC	Score 1 = Yes; 0 = No
Time required to order entry using the system	MTIME	Score 1 = Low; 0 = High
CPOE use is mandated	MAND	Score 1 = Yes; 0 = No
Member of a multi-hospital network	YNNETW	Score 1 = Yes; 0 = No
Use of CPOE	USAGE	Percentage of physicians who are using the CPOE system (value varies from 0 to 100% i.e.1)
Medical Charts	MEDREC**	Quantitative
Clinical Applications	CLINICAL**	Quantitative
Profit Status	ProfitStatus	Score 1 = Yes; 0 = No
Total number of networking Applications	TotalAppsNet	Quantitative
Total number of outsourced services	ServTot	Quantitative
Availability of wireless	WirelessYN	Score 1 = Yes; 0 = No
Availability of Intranet	IntranetYN	Score 1 = Yes; 0 = No
Organizational Performance	LDIS03 LDIS04	Total discharges per beds in service (for year 2003 and 2004)

Note – * Refer Table 4.2 for detailed description of the levels of technology integration.
** Refer A-1 for composition and description of MEDREC and CLINICAL.

Table 4.2: Clinical Information Technologies and Integration Levels

Capability Group	Clinical Information Technologies
C1	Laboratory Information Systems, Pharmacy Systems, and Radiology Information Systems
C2	Clinical Data Repository, Clinical Documentation, and Clinical Decision Support Systems
C3	Picture Archiving Communication Systems, and Medical Records Imaging

Integration Level	Criterion for Level Membership
Level I	Not all technologies belonging to Capability Group C1
Level II	All technologies belonging to Capability Group C1
Level III	All technologies belonging to Capability Groups C1 and C2
Level IV	All technologies belonging to Capability Groups C1, C2, and C3

Table 4.3: Descriptive Statistics of Key Study Variables (N=188)

Variable Name	Mean	S.D.	Maximum	Minimum
Use of CPOE	0.396	0.361	1.00	0
Organizational Readiness	1.78	0.709	4	0
CIO's reporting status to CEO	0.43	0.496		
Presence of CEO in the IS steering committee	0.78	0.418		
Efforts to increase communication and training	0.55	0.498		
Purchase of handheld device to enter medication order	0.03	0.161		
User Readiness	3.27	0.553	4	2
System is easy to use	0.93	0.263		
Training provided to use the system	0.61	0.489		
Application is accessible for use by physicians	1.00	0.434		
Time required to enter orders using the system	0.98	0.126		
Levels of Technology Integration	3.05	0.744	4	1
CPOE use is mandated	0.23	0.421	1	0
Member of a multi-hospital network	0.66	0.475	1	0
2004 Discharges per Bed*	3.793	0.452	4.516	0.916
Medical Charts	6.45	0.733	7	3
Clinical Applications	5.81	1.796	10	1
Profit Status	0.28	0.451	1	0
Total number of networking Applications	11.74	3.442	25	2
Total number of Outsourced Services	1.89	2.783	17	0
Availability of Wireless	0.47	0.500	1	0
Availability of Intranet	0.92	0.272	1	0

Note – * Total discharges per beds in service for 2004 are logarithmic values.

Table 4.4: Correlations among Key Research Variables (N = 188)

	Variable	1	2	3	4	5
1	Use of CPOE	1				
2	Organizational Readiness	-0.086	1			
3	User Readiness	0.517***	0.155**	1		
4	Levels of Technology Integration	0.335***	-0.069	-0.162***	1	
5	2004 Discharges per Bed	0.216***	-	-	0.136	1

***Significant at 1%, ** Significant at 5% and * Significant at 10%

Table 4.5: Regression Estimates Linking Use of CPOE with Antecedents

Variable	Estimates	t-value (p-value)
Technology Integration Level	0.070	2.10 (0.038**)
Organizational Readiness	-0.008	-0.23 (0.820)
User Readiness	0.129	1.96 (0.053*)
CPOE use is mandated	0.510	6.65 (0.000***)
Member of a multi-hospital network	0.080	1.52 (0.131)
F-value	43.32***	
R square	0.6225	
No. of observations	188	

Note – Regression additionally contains a constant term and variance inflation factor is lower than 2.0
***Significant at 1%, ** Significant at 5% and * Significant at 10%

Table 4.6: Regression Estimates linking the total discharges per bed with the Use of CPOE system

	2004 performance	
Variable	Estimates	t-value
Use of CPOE	0.208	2.03**
Levels of Technology Integration	0.037	0.068
Medical Charts	0.039	0.820
Clinical Applications	-0.030	-1.12
Profit Status	-0.173	-2.52**
Total number of networking Applications	-0.023	-1.46
Total number of Outsourced Services	0.013	1.53
Availability of Wireless	0.080	1.04
Availability of Intranet	0.042	0.280
F-value	7.97***	
R square	0.0998	
No. of observations	188	

Note – ***Significant at 1%, ** Significant at 5% and * Significant at 10%

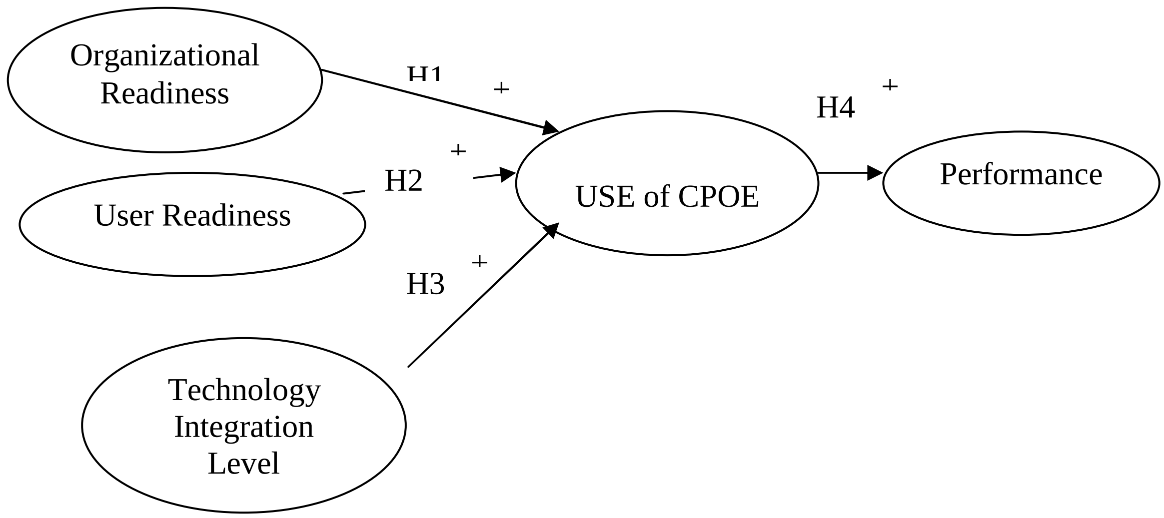

Figure 4.1: Proposed Model of CPOE Use and Performance

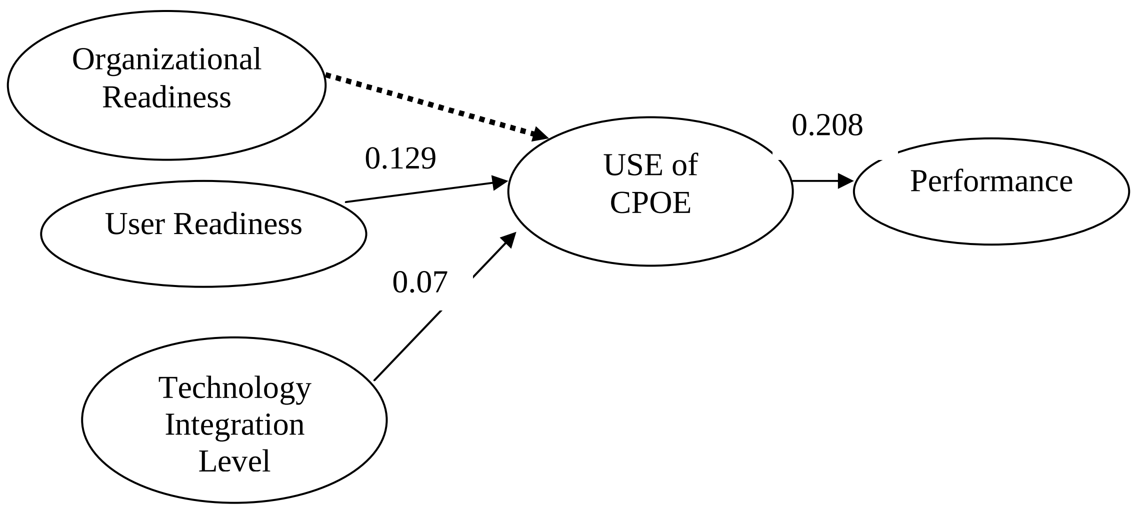

Figure 4.4: An Integrated Model of CPOE Use and Performance

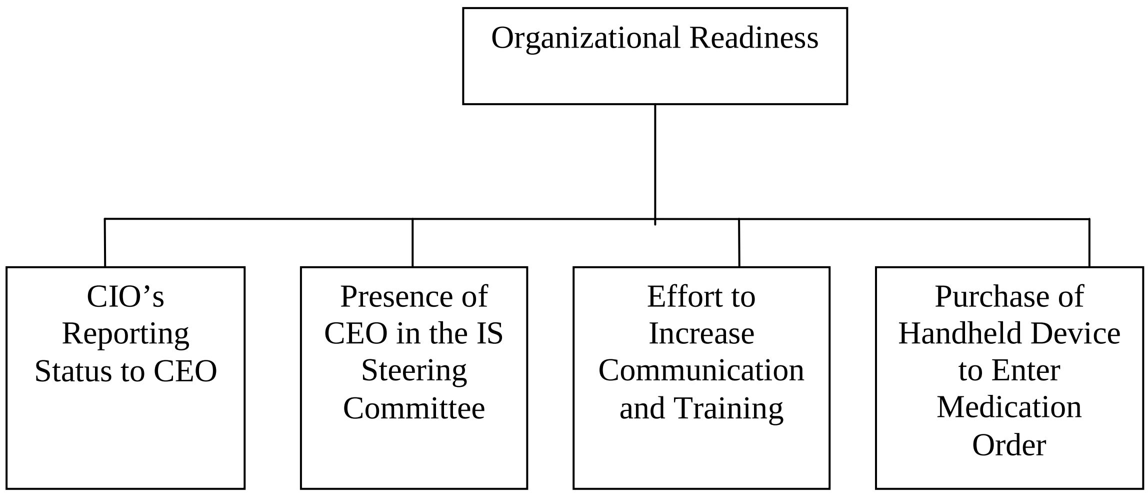

Figure 4.2: Properties of the Organizational Readiness Construct

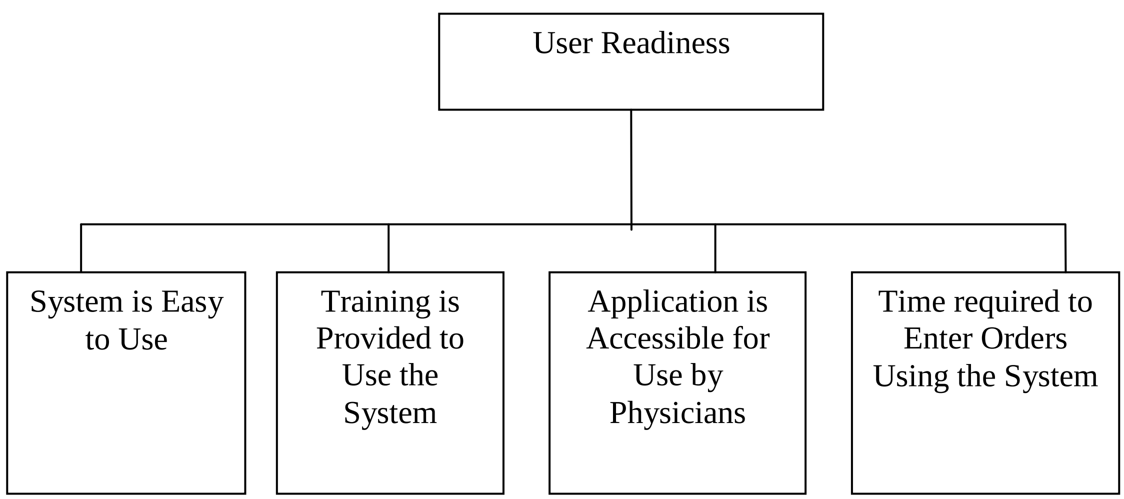

Figure 4.3: Properties of the User Readiness Construct

CHAPTER 5

CONCLUSION

The overall contribution of this dissertation is in providing a better understanding of the process of the integration of a group of advanced information technologies in an industry that can be characterized by a complex and uncertain environment. Furthermore, I made an effort to understand what factors influence the process of technology implementation immediately after an organization decided to adopt an advanced information technology. Specifically, for a health care setting, this dissertation (i) conceptualized different levels of EMR integration and empirically tested performance implications of EMR integration and (ii) studied the antecedents for implementation of CPOE systems and subsequently tested impact of CPOE systems on organizational performance. In this concluding chapter, I summarize the two studies that make up the dissertation, conceptually synthesize the findings of these studies, and present research questions to guide future investigations.

5.1 EMR Technology Integration at Health Care Providers

Though we find ubiquitous use of information technology applications, managers still look for answers with respect to selection of these technologies and what performance implications may be expected from their selections. The first essay in my dissertation makes an effort to provide managers with guidance on such questions by focusing on an issue in the field of technology management that has not previously been extensively researched. To illustrate the selection of the appropriate level of technology integration for a given organization, I conceptualize EMR technology integration into five levels, where each level comprises of various clinical information technologies employed at health care providers. Then, I show the link between levels of EMR technology integration and operational performance based on an econometric analysis of data from 1011 health care providers. Though the results show that a higher level of technology integration can bring greater organizational performance, I demonstrate empirically that selecting into higher levels of technology integration may *not* be a dominant strategy for health care providers. Managers must opt for that level of technology integration which they find most appropriate to their idiosyncratic organizational, technological, and environmental characteristics. Thus, for a health care manager, the essay identifies the relationship of technology integration and operational performance and sheds light on the significance of selection into a level of technology integration. Also, this study can be extended not only across organizations in the health care supply chains but also to study technology integration of organizational information systems within and between organizations in other industries.

5.2 CPOE System Implementation at Health Care Providers

CPOE systems are an example of advanced clinical information technologies that are identified not only as the most important and critical constituent to achieve the highest level of EMR technology integration for a health care provider but that are also sometimes used as proxies by researchers for EMR systems. A clear understanding of the factors that influence implementation of CPOE systems at health care providers will also guide us to implement other advanced organizational information systems like e-business technologies, electronic health record systems, or enterprise systems. In the second essay of my dissertation, I draw from existing theories of innovation, user behavior, and information system implementation to develop an integrated model that examine three contextual factors of CPOE system implementation. The research framework also investigates the impact of the use of the CPOE system on operational performance under the moderating influence of the level of technology integration of the health care provider. Based on cross-sectional data from 188 acute care hospitals in the U.S. that have adopted CPOE systems, my results show that usage of the CPOE system positively impacts operational performance under the moderating influence of technology integration. Also, the results identify a number of user-related factors and organizational practices that can influence the usage of the CPOE system by physicians after the system is adopted. The empirical results provide explanation for the primary motivation of this essay; after a technology is adopted by an organization (often with much fanfare), it must actually be used by its intended users. Variation in user acceptance and implementation of the new technology impact the organizational outcomes, including the realization of the expected benefits of adopting the technology in the first place.

5.3 Directions for Future Research

The environmental pressures to improve, measure, and report care quality, efficiency, and safety on one hand and the catastrophic rise in consumer demand (armed with personal health records and consumer-directed health plans on the other) is transforming the health care industry in the U.S. (Glaser and Foley 2008). This evolutionary change, accompanied by difficult-to-predict events and phenomena in the health care sector, will dictate the future of health care information systems for the next 10 to 15 years. Guided by this thought process, I identify EMR systems and CPOE systems as two of the major classes of technologies that should form the core of health care providers' efforts to prepare for the future. There is no doubt that with time the technologies will become technically superior and overcome their existing difficulties. The one aspect that will become more significant over time is the organizational competency and skill in leveraging technology investments to improve operational and financial performance for a health care provider. As a researcher myself, providing organizations guidance in developing skill in using the technology investments serves as my motivation to define directions for future research.

For technology integration, future work that could advance our knowledge and address some of the limitations of the first essay includes studies to understand the technology integration selection process. In the essay, I identified the need to account for selection while assessing the relationship of technology integration and operational performance. However, I did not focus on identifying important factors that drive the selection process for health care providers. Second, future research should look at the phenomenon of technology integration over time and investigate how organizational performance is affected by changes in the levels of technology integration over time. This will extend current work that investigates technology integration with cross-sectional data by considering panel data of at least five years. Third, researchers could look into factors that determine why some health care providers' integration outperforms other health care providers who select the same level of technology. Such a study might examine the organizational, technological, and environmental factors that might explain the performance differentials across health care providers.

The second essay, on CPOE system implementation, is an effort in the direction of identifying those factors. Still, my work on technology implementation can be further extended and some of the study limitations can be addressed with the following future research initiatives. First, researchers might conduct a longitudinal analysis of the research framework, as implications of the use of IT in organizations are sometimes better explained when organizational decisions to implement new technologies are examined over a period of time. Also, a study might look for different organizational practices other than those used in this research that might influence the use of the CPOE system by health care providers. In the same vein, it is worthwhile to look for different user-related factors that might explain the early usage pattern of the CPOE system.

In conclusion, I believe that the findings of this dissertation, along with the areas identified to guide future research, will motivate both researchers and practitioners to pursue this exciting line of inquiry.

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APPENDICES

Table A-1: Other Technologies in Health Care

Application Type	Key Constituent Technologies
Business Office	Patient Billing, Patient Registration, Patient Scheduling Credit / Collections, Electronic Claims
Financial	General Ledger, Account Payable, Enterprise Resource Planning Material Management
Human Resource	Payroll, Time and Attendance, Personnel Administration, Benefits Administration
Decision Support	Cost Accounting, Flexible Budgeting, Case Mix Analysis Executive Information System, Outcomes and Quality Management
Managed Care	Premium Billing, Eligibility, Contract Management
Medical Charts	Master Patient Index, Abstracting, Encoder, Transcription, Chart Tracking/Locator, Dictation, Chart Deficiency
Clinical Applications	Cardiology, Emergency Department, Surgery, Intensive Care (Critical Care), Nurse Staffing, Obstetrical, Order Communication / Results, Point of Care (Medical/Surgical Bedside Terminal)

Table A-2: Regression Estimates Linking Performance and Technology Integration

Variable	Estimates	p-value
Clinical Applications	1.915	0.000
Medical Charts	1.612	0.007
Total Networking Technologies	0.251	0.187
Total Outsourced Services	0.702	0.007
Presence of Wireless	-0.799	0.565
Presence of Intranet	-1.360	0.484
# of Members in IHDS	-0.037	0.134
Usage	17.94	0.384
Profit Status	-3.569	0.266
Integration Level	1.472	0.042
R square	0.3241	0.000
Performance: Discharges per Licensed Bed		

Note – Both regression additionally contain a constant and control for Service Type.
* indicates significance at 10%, ** at 5% and *** at 1%

Table A-3: Description of Clinical Information Technology[30]

Laboratory Information System
An application that manages the functions within the laboratory, the system receives patient information from registration system and reports laboratory results to nursing station units. The system must have functions such as specimen collection, quality control, automated instrument interfaces, and other aspects of laboratory management.

Pharmacy Information System
The focus of this application is to meet the administrative needs of the pharmacy and does not include pharmacy dispensing. The system provides functions such as patient medication profiles, drug interactions, dosing calculations, inventory control, and narcotic control. This system provides screening for a variety of drug alerts including drug-drug interactions, food-drug interactions, allergy alerts, therapeutic duplication, correct dosing, and dosage ranges.

Radiology Information System
This application specifically automates functions in the radiology department. The application must provide some of the following: order processing, permanent patient history index maintenance, film storage and location, transcribing and distributing results, prep instruction cards maintenance, appointment scheduling, and management reporting.

Clinical Data Repository
This is a database that integrates clinical data from several systems into one central repository so that data relationships can be examined and reported. The application includes an easy-to-use front-end interface to manipulate data views and the application is intended to provide long-term (lifetime) storage of clinical data.

Clinical Documentation
An application that allows nurses to create, modify, and evaluate patient care plans, producing appropriate documentation for patient charts. This application can also produce task lists by skill level for each shift.

Clinical Decision Support
An application that uses pre-established rules and guidelines and integrates clinical data from several sources to generate alerts and treatment suggestions. This application also produces physician clinical activity, physician cost and clinical utilization comparison, and clinical guidelines/protocol or standard of care exception reports.

Medical Records Imaging
An application that enables the storage of information electronically, the system includes electronic storage of patient paper charts, x-rays, images, scanned documents, etc. Medical records imaging does not include microfiche.

[30] Refer Table 3.1 and Table A-1 for conceptualization.

Picture Archiving and Communication System (PACS)
This application is a storage solution that automates images for multimedia review and clinical diagnosis. Features of this system include digital image retrieval, routing, and display. The system is integrated/interfaced to radiology and cardiology applications.

Computerized Physician Order Entry (CPOE) *System*
CPOE refers to a variety of computer-based systems of ordering medications that share common features for automating the medication ordering process. Basic CPOE ensures standardized, legible complete orders by only accepting typed orders in a standard and complete format. Almost all CPOE systems include or interface with a CDSS (Clinical Decision Support System) of varying sophistication. CDSSs may include suggestions or default values for drug doses, routes, and frequencies based on a predetermined guideline or rule. CDSSs can also perform drug allergy reminders and corollary orders or drug guidelines to the physician at the time of drug ordering.

Patient Billing System
An application to automate inpatient billing and discharged accounts receivable. The application automates billing and collection procedures daily, providing timely information in areas such as posting and audit, billing receivable management, and revenue and management reporting. It may also provide outpatient billing.

Patient Registration System
An application that automates the hospital's patient registration functions in an on-line, real-time mode. The system includes on-line census, pre-registration, patient history, and patient admission, discharge, and transfer (ADT). This must be more than an order entry system.

Patient Scheduling System
This application coordinates scheduling of all the provider components and flags conflicts with other appointments. It may include preparation requirements, staff workload lists, and patient care notifications.

Credit / Collections System
An application that manages the collection of billed services and bad debt. This application may automatically produce letters for overdue accounts and record collection data and terms of payment.

Electronic Claims System
This application electronically sends insurance claims from the provider to the insurance company. In some cases, the provider is also paid electronically. Medicare and other claims are sent directly to the health care system via modem or terminal.

General Ledger
This application automates general ledger accounting and provides the information necessary for financial analysis and planning. This application may include budgeting, cost allocations, consolidations, and on-line entry, update, and inquiry.

Accounts Payable System
This application provides control over cash flow with specific information on disbursement and invoices. The application includes on-line entry, inquiry, and reporting capabilities.

Enterprise Resource Planning System
An enterprise-wide business management system that integrates all administrative facets of the business, including human resources, payroll, materials management, supply procurement, accounts payable, general ledger, and/or patient scheduling. The system also provides an integrated view and reports on information from all areas.

Materials Management Information System
This application enables hospitals to better manage and negotiate vendor relationships and more effectively manage internal hospital inventories. This application may include purchasing, receiving, inventory control and distribution, bar coding, electronic order entry, and multi-location stock management.

Payroll Information System
An application that manages payroll processing, keeps records of all employees for timely compensation payment, and processes employees' paychecks.

Time and Attendance System
An application that automates the collection, processing, and reporting of employee hours, the functions of this system include real-time data on employee absenteeism, tardiness, total number of hours worked, and scheduling. Many of these systems also interface with the payroll system for paycheck processing.

Personnel Administration System
An application that manages administrative functions so that employment history can be seen easily including application tracking, salary administration, continuing education credits, employee health requests, evaluation history, and position tracking.

Benefits Administration
An application that manages human resource benefits including defined contributions, defined benefits, flexible benefits, and health and welfare plans.

Cost Accounting System
An application that attempts to match the exact cost of specific resources utilized with the associated revenue generating services. For example, supplies, costs of physical facilities, specific procedure costs, etc.

Flexible Budgeting System
This application accommodates different budgeting styles and permits budget revisions to reflect business fluctuation. Examples of fluctuation are acquisitions, divestitures, staffing cuts, etc.

Case Mix Analysis
An application that provides integrated information from ADT (Patient admission, discharge, and transfer), utilization review, patient billing, and medical records abstracting used to monitor and understand the mix of patient types and patient services provided.

Executive Information System
A specific application that provides sophisticated software tools to integrate, process, and present data to executives in an easy-to-learn and user-friendly format. An executive information system integrates and presents existing data but typically does not create data. An executive information system may provide facility utilization, staffing ratios, or revenue and profit figures.

Outcomes and Quality Management
An application that provides a clinical data set utilized in monitoring overall performance, efficiency, cost, and quality of clinical care by analyzing, comparing, and trending information of detailed clinical practice patterns and parameters.

Premium Billing System
This application automates managed care invoicing for both individual subscribers and employer groups. Features include determination of correct premium amounts and assignment of premiums and automatic adjustments for new subscribers.

Eligibility System
An application that allows on-line verification of participation in managed care organizations by members and groups. Features of this application include communication to obtain complete historical and demographic information on members, including benefit plan, deductible, co-payment, and primary physician information.

Managed Care Contract Management Information System
This application allows organizations to track and manage the contracts they hold with managed care organizations. Contract management allows providers to review contract terms prior to the provision of services to maximize profitability. Features include identification of covered and non-covered services, pre-authorization requirements, and other prerequisites to treatment.

Master Patient Index
An application to maintain an on-line master list of patients treated in a specific health care organization. Information maintained includes admission, registration, and discharge dates; all the data pertinent for re-registration; and capabilities to avoid/correct duplicates.

Abstracting
An application that facilitates the collection and maintenance of coded patient information with selected patient demographic and clinical and admissions data from

the medical record. This is usually performed post-discharge. This information can be used for internal control, analysis, regulatory reports, etc.

Encoder
An application that enables medical record technicians to determine and assign ICD-9-CM and CPT-4 codes on-line and provides complete and accurate codes and code modifiers.

Transcription System
An application utilized in translating dictated or recorded subject matter to an electronic narrative document.

Chart Tracking / Locator System
This application monitors current and previous chart location histories. Chart Tracking may additionally monitor the status of requests for records.

Dictation System
This application captures, stores, and makes voice-originated information available for referral.

Chart Deficiency System
An application that monitors the completion status of a patient's chart and length of time a record is delinquent before chart completion. Deficiencies in charts may also be classified into levels of severity.

Cardiology Systems
This application specifically automates functions in the cardiology department. The application must provide some of the following: order processing, permanent patient history index maintenance, image and EKG tracing storage, transcribing and distributing results, prep instruction cards maintenance, appointment scheduling, and management reporting.

Emergency Department
An application that identifies and collects data and reports on the patient care interactions for the entire emergency department visit.

Surgery Information System
This application specifically automates the functions of the surgical suite. The application also automates scheduling of surgical cases; produces schedules and case records; generates daily, monthly, and year-to-date statistics; provides inventory control; and maintains a permanent database pertaining to staff members, rooms, procedures and capital equipment.

Intensive Care (Critical Care) System
Entry and display devices in the intensive care unit that can be computer terminals, portable handheld units, or wall mounted units. The opposite of this would be to have terminals at the nurse stations.

Nurse Staffing System
This application automates decisions about staffing, nursing stations, and scheduling nurses' time. This may include functions that enable a hospital to quickly review and generate its nurse scheduling; adjust staffing and scheduling based on patient volume, acuity, and staff ability; keep records for budgeting; produce management reports on productivity and census; and maintain records on personnel qualifications.

Obstetrical Systems
Also called Peri-natal, this application gathers, records, and reports patient information across the continuum of care for the entire birthing process from labor and delivery, pre-natal through recovery.

Order Communication / Results
An elementary version of order entry may include significant levels of results reporting. This application includes the entry of patient care orders, communication of these orders to ancillary departments, and the collection of patient charges for entry into the accounting system. This must be done in an on-line, real-time mode. More extensive systems may also provide extensive results reporting capabilities.

Point of Care System (Medical / Surgical Bedside Terminal)
This application allows nursing personnel to record data into the system at the patient bedside.

Table A-4: Regression of Individual Indicator Variables with Use of CPOE system

To test the relationship of the indicator variables with Use of CPOE system, an OLS regression with the eight indicator variables along with technology integration level, voluntariness, and membership in hospital networks was estimated. The Use of CPOE formed the dependent variable. Table A-5 reports the results from regression for Use of CPOE system. The regression model is statistically significant at $p < 0.01$. The results show that two of the four indicator variables that are utilized to develop the construct user readiness are significant predictors of CPOE implementation. The two are – application is not accessible for use to physicians (p=0.018) and physicians find that entering orders using the system takes too much time (p=0.042). Also, technology integration level (p=0.023) is a significant predictor of CPOE implementation. However, the indicator variables used to assess organizational readiness and two indicator variables utilized to assess user readiness do not significantly impact use of CPOE system. Among the control variables, voluntariness of use (p=0.000) was found to be significant whereas membership in hospital network (p=0.383) was not. These results are consistent with our findings earlier.

Table A-5: Regression Estimates Linking Use of CPOE with Indicator Variables

Variable	Estimates	p-value
Technology Integration Level	0.0789	**0.023**
CIO's reporting status to CEO	0.0121	0.836
Presence of CEO in the IS steering committee	0.0355	0.552
Efforts by the health care provider to increase communication and training	-0.0869	0.186
Hospital purchased handheld devices for entering medication order	-0.1464	0.314
Physicians find it easier for other staff members to use the CPOE system	-0.0110	0.921
There is too little training provided to the physicians to use the system	-0.0397	0.619
Application is not accessible for use to physicians	-0.1711	**0.018**
Physicians find that entering orders using the system takes too much time	-0.2048	**0.042**
CPOE use is mandated	0.5034	**0.000**
Member of a multi-hospital network	0.0519	0.383
F-value	29.82	0.000
R square	0.6177	
No. of observations	188	

Note – Regression additionally contains a constant term and variance inflation factor is lower than 2.0