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DISSERTATION

Accelerating the Adoption of Clinical IT Among the Healthcare Providers in US

Strategies & Policies

Katya Fonkych

This document was submitted as a dissertation in November 2006 in partial fulfillment of the requirements of the doctoral degree in public policy analysis at the Pardee RAND Graduate School. The faculty committee that supervised and approved the dissertation consisted of Emmett Keeler (Chair), James Dertouzos, Federico Girosi, and Glenn Melnick.

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As complex and fragmented as it is, US healthcare system cannot deliver high-quality care in an efficient manner without having timely and appropriate clinical information and decision support at the point of care. Moreover, there are substantial difficulties with proper monitoring of quality, safety and efficiency of delivered health care in the absence of appropriate infrastructure for capture and analysis of clinical information. Healthcare and IT experts argue that nationwide adoption of advanced clinical health information technology (HIT) is essential tool to transform US healthcare into the system that delivers consistently high quality of care with greater efficiency for more patients. The goal of this dissertation is to analyze the adoption process and derive policy strategies that can promote the nationwide adoption of Healthcare Information Technology (HIT) in the US.

To this end, the current status and dynamics of HIT adoption in US is assessed, as well as its implications for the menu of policy options. The dissertation provides an economic analysis of adoption decision in hospitals and healthcare systems, as well as analysis of market failures that stymie the diffusion and require policy interventions. Finally, the hypotheses on the factors of clinical HIT adoption are evaluated in the empirical analysis of adoption in the US hospitals, helping to identify the facilities that are disadvantaged or least likely to adopt. The conclusions call for greater CMS involvement and reimbursement models that would reward higher quality and efficiency achieved through HIT.

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CHAPTER 1: INTRODUCTION

The United States leads the world healthcare expenditures per capita that are at least twice as high as median spending in OECD countries, while healthcare outcomes and access to care lag behind many developed nations. The situation requires urgent measures, as it threatens the competitiveness of the US industries and compromises the quality of life of the American people. Healthcare and IT experts argue that nationwide adoption of advanced clinical health information technology (HIT) is essential tool to transform US healthcare into a system that delivers consistently high quality of care with greater efficiency for more patients. The goal of this dissertation is to analyze the adoption process and derive policy strategies that can promote the nationwide adoption of Healthcare Information Technology (HIT) in the US.

1.1 HIT is a Key Tool to Transform US Healthcare System

As complex and fragmented as it is, US healthcare system cannot deliver high-quality care in an efficient manner without having timely and appropriate clinical information and decision support at the point of care. Moreover, there are substantial difficulties with proper monitoring of quality, safety and efficiency of delivered health care in the absence of appropriate infrastructure for capture and analysis of clinical information.

Nationwide adoption of advanced clinical HIT, and electronic health records in particular, would, it is argued, provide many benefits and needed improvements in the American health care system: improve quality of care by providing access to the best practice guidelines and relevant information at the point of care, reduce medication errors, provide continuity of care through portability of patient information among providers, reduce administrative costs, improve patient outcomes increase targeting and use of preventive care and improve patient empowerment and satisfaction. The Institute of Medicine, in its report, Patient Safety: Achieving a New Standard of Care, recognized that "the EHR improves the quality and timeliness of decision-making by providing nurses, physicians and other clinicians with comprehensive and up-to-date information, and it provides a source of data for error reporting and analysis." (Aspden *et al*, 2003)

Moreover, the indirect effects of accountability and transparency related to IT include better-informed and more extensive consumer's choice, introduction of incentives to improve quality of care, and an increase in the efficiency of care delivery. Finally, IT can help collect and analyze clinical data at the organizational and national level that will substantially benefit medical research, development and implementation of public health policies.

A recent study by RAND estimated that nationwide adoption of HIT could save $81 in efficiency savings alone while greatly reducing morbidity and mortality. HIT-enabled improvements in prevention and disease management could more than double these savings while lowering age-adjusted mortality by 18 percent and reducing annual employee sick days by forty million. Transaction efficiencies could add another $10 billion or more in annual savings. RAND findings also identify an important factor affecting hospital adoption of HIT – providers must incur the full cost of adopting HIT systems but they do not capture all the benefits (Hillestad et al, 2005, Taylor et al 2005).

The Institute of Medicine (IOM) recommended a national shift to computer-based medical records over 14 years ago, but little progress has been made thus far. While administrative IT systems, such as billing, scheduling and inventory management have been already installed in most hospitals and physicians' offices, there has been little progress in the broader diffusion of clinical IT, including electronic medical records, clinical decision support tools and e-connectivity among healthcare provides. To this date majority of medical doctors use paper-based medical records, and miss the benefits of electronic ordering and decision support systems. Current median spending on HIT is about 2% of the operating costs, towards administrative HIT, like billing and patient registration. In contrast, other information-intensive industries spend over 5% on IT.

There are many reasons that adoption in the medical field has been so slow, including the high cost and complexity of IT infrastructure, fragmentation of healthcare services, the limitations and difficulty of proprietary applications and the lack of standards. Healthcare is ridden with multiple market failures that preclude complete accumulation of quality-related benefits from HIT adoption to the investing healthcare providers. To reimburse providers for the efficiency and quality of care, one need to measure it properly, but this is hardly possible without broad diffusion of Electronic Medical Record (EMR) systems. Thus, the recent Institute of Medicine report predicted that "without national commitment and financial support to build a national health information infrastructure, the progress on quality improvement will be painfully slow".

1.2 Dissertation Addresses Policy-makers' Interest in HIT Diffusion

Today, a great variety of initiatives to define and promote healthcare IT are underway within the Department of Health and Human Services (HHS), the President's eHealth Initiative, federal and state legislatures, numerous IT and healthcare industry organization and patient safety groups such as Leapfrog. In April 2004, President Bush issued Executive Order 13335 calling for widespread adoption of interoperable Electronic Health Records (EHRs) within 10 years and for health information to follow patients throughout their care in a seamless and secure manner. The President established the position of National Coordinator for HIT with a mandate to develop and implement a strategic plan that will guide the nationwide implementation of interoperable HIT. The strategic plan that National Coordinator, David Brailer, released in July of 2004 includes the following goals and strategies:

- Goal 1 - "Inform Clinical Practice:" Bringing information tools to the point of care, especially by investing in EHR systems in physician offices and hospitals.
- Goal 2 - "Interconnect Clinicians:" Building an interoperable health information infrastructure, so that records follow the patient and clinicians have access to critical health care information when treatment decisions are being made.
- Goal 3 - "Personalize Care:" Using health information technology to give consumers more access and involvement in health decisions.

- Goal 4 - "Improve Population Health:" Expanding capacity for public health monitoring, quality of care measurement, and bringing research advances more quickly into medical practice.

In addition, the report identifies potential policy options for providing incentives for EHR adoption, which include:

- regional grants and contracts to stimulate EHRs and community information exchange systems;
- improving availability of low-rate loans for EHR adoption;
- updating federal rules on physician self-referral that may unintentionally restrict investment and networks;
- using Medicare reimbursement to reward use of EHRs;
- using demonstration projects to test new concepts in Medicare of "paying for performance" -- linking payments to quality of care rather than volume of services only.

Numerous private and public groups and state and federal agencies have endorsed the *Framework for Strategic Action* or have published plans and roadmaps that build on the *Framework*.

These initiatives on development of National Healthcare IT infrastructure do require the analysis on which to base long-term policy and investment decisions, and against which to check the suggested policies. However, virtually no rigorous research exists today on the current level and speed of IT adoption across different types of healthcare organizations, and factors that affect HIT diffusion. Despite significant and growing interest in HIT there is very little in the published literature to help policymakers understand current patterns of HIT adoption and why, given the apparent substantial system-wide benefits, adoption has been so slow. The existing literature is sparse, and shows high heterogeneity in the HIT adoption behavior among different healthcare providers.

My dissertation can provide policy initiatives with data and analysis on the current state and trends in HIT adoption, and will identify the areas where policies are most necessary and suggest incentives and strategies to stimulate HIT adoption by healthcare providers. In particular, it provides an economic framework for understanding the factors driving and inhibiting adoption of HIT and applies an empirical model to test them. The multivariate empirical analysis studies the role of the provider characteristics and market factors, such as reimbursement policies and competition, on HIT adoption among acute short-term care hospitals in US. The empirical results are useful to understand market incentives and to suggest policies that could be considered to stimulate adoption, and identify groups of providers that are potential targets for such policies.

This dissertation research focuses on HIT adoption in hospitals and integrated delivery systems. Most of the hospitals and large ambulatory clinics are a part of integrated healthcare delivery systems, which allows for common management and care coordination across multiple providers. Currently, integrated delivery systems provide most of the American health care, and there is a trend towards their expansion.

1.3 Current developments in HIT policy environment

At this time, a number of policy and industry efforts are under way that may impact HIT diffusion. The most important developments include:

1) Federal investment in HIT systems at federally-owned healthcare facilities;
2) Standardization and certification that are necessary to achieve interoperability and reach functionality benchmark;
3) Development of Regional Healthcare Information Organizations (RHIOs), designed to provider interoperability at local and regional level, where most care is delivered.

Federal Investment in HIT

The role of government-owned healthcare systems as the pioneers of HIT adoption can not be overestimated. In addition to contributions in technology development, federally sponsored HIT systems provide much needed evidence about the benefits of system-wide adoption of advanced clinical HIT infrastructure.

VHA is the largest single medical system in the United States, providing care to 4 million veterans. It introduced The Veterans Health Information Systems and Technology Architecture (VISTA) in 1996. VISTA's electronic health records provide patient-specific information that support time and context sensitive clinical decision-making. In the last 10 years, VISTA has helped improve operating efficiencies approximately 6 percent per year and, adjusted for inflation, VHA care is 32 percent less expensive than a decade ago, with measurably better outcomes in quality, satisfaction, access and patient function. VHA has created multimedia online patient records that integrate traditional medical chart information with medical images. Computerized Patient Record System Graphical User Interface (VistA CPRS GUI) enables clinicians to enter, review and continuously update all order-related information connected with any patient. Bar Code Medication Administration (BCMA) automates the medication administration process by providing a real-time, point-of-care solution for validating the dispensation of unit dose and intravenous medications to inpatients. BCMA also electronically updates the patient's medication administration history. Currently, DoD is implementing a similar EMR system called AHLTA in the federal facilities that treat active duty military members and their families.

Standardization

A major breakthrough in standardization was achieved recently, when the HIT Standards Panel was formed by the American National Standards Institute, with the support of a $3.3 million contract from HHS, to harmonize the many existing standards for exchanging health information. The mission of the Healthcare Information Technology Standards Panel is to serve as a cooperative partnership between the public and private sectors for the purpose of achieving a widely accepted and useful set of standards specifically to enable and support widespread interoperability among healthcare software applications, as they will interact in a local, regional and national health information network for the United States. The first task it undertook last summer was developing cookbook-like instructions aimed at helping IT users and vendors implement a targeted group of data transmission activities, or "use cases" for biosurveillance, personal health-record development and electronic health-record interoperability.

HIT Certification

For a long time the high uncertainty about performance and reliability of HIT systems stifled their adoption and was perceived as one of the major barriers. Last September, HHS awarded a $2.7 million contract to CCHIT to develop an efficient and sustainable process to certify health IT products first for the outpatient or ambulatory setting; and then for inpatient and hospital EHRs. CCHIT was created in 2004 by three Chicago-based organizations: the American Health Information Management Association, the Healthcare Information and Management Systems Society and the National Alliance for Health Information Technology.

The total number of certified EHRs is now 22. On July 18, CCHIT had released the names of the first 18 certified EHRs and two with "conditional pre-market certification." Only products that score 100% on the CCHIT tests for interoperability, functionality and security earn certification, and the names and number of products not certified are not being disclosed. Earlier, CCHIT Chairman Mark Leavitt said that "more than two dozen" vendors had submitted products for testing and paid the $28,000 testing fee.

Developing National and Regional Networks – RHIOs

The experience of Hurricane Katrina offered a strong case for an electronic health network. The disaster highlighted the necessity for doctors and other health professionals to have access to patients' medical records as they were moved around the country.

Because care is delivered locally, regional health information organizations (RHIOs) can serve as a patient-centric building blocks of a national network. With RHIO, diverse healthcare stakeholders voluntarily band together, usually within a specific geographic area such as those in Santa Barbara County, California, or the entire state of Massachusetts. RHIOs are conceived to maintain critical clinical information for each patient, representing a major subset of the patient's full EHR. The RHIOs would provide instant access to data across the interoperable national network.

The Center for Health Transformation further elucidates that RHIOs are seen as "the building blocks to create the National Health Information Network, a secure, interoperable system where all stakeholders involved in an individual's care can appropriately access and share electronic health information in real time at the point of care." Just as there are many organizational and service models in the RHIO space, there are different definitions. The "Regional" aspect, for instance, is not universal, as there are some multi-state HIEs that organize under an Integrated Healthcare Delivery Network umbrella. Some RHIOs encompass regions as small as individual communities, others as large as entire states, and others something in between or even larger. Depending on definition, there are either 66 RHIOs at some stage of development, or 100. According to the latest survey, one in six of the RHIO's reported they are fully operational, while 27% are in the implementation stage (eHealth Initiative, 2006). The same survey indicates that engagement of the multiple stakeholders in healthcare exchange initiates is expanding considerably with the largest increases occurring in hospital, health plan, employer and primary care physician involvement. Engagement of hospitals, health plans, employers, and primary care physicians is up with 96 percent, 69 percent, 54 percent, and 91 percent of respondents now actively engaging such stakeholders, respectively, in their efforts. Increasingly, health information exchange efforts are tapping into users of their services to provide funding for ongoing operations. While the primary funding source for health information exchange efforts continues to be the federal government, increasingly HIE efforts are deriving funds from other sources--those who both provide and use data--to fund ongoing operations. Based on the 2006 survey results, 24 percent of respondents cited that they were currently receiving funds from hospitals, while 21 percent cited they were receiving funds from payers. In addition, 16 percent were receiving funds from physician practices and 13 percent from laboratories.

Although good financial analysis can help overcome RHIO resistance, some areas of the country have intrinsic advantages that could provide momentum for RHIO adoption, health IT experts say. Massachusetts organizations have a history of collaboration, for example, while Indiana is investing in a big bioresearch community for which it sees the RHIO as a foundation.

1.4 HIT Systems and their Features

There are numerous IT applications and devices that are used in healthcare to improve its administration and clinical care. This study focuses on sophisticated clinical HIT systems that directly matter for the patient care: Electronic Health /Medical Records (EMR), picture archiving and communication systems (PACS), and computerized physician order entry (CPOE).

Difference between EHR and EMR

These days, strategic vision in the healthcare arena migrates towards a global concept labeled "Electronic Health Records" (EHR), which in addition to computerizing patient records requires connectivity among the providers involved in the patient's care, as well as patient himself. Unless one healthcare provider takes care of all patients' medical needs (like Kaiser does), EHR is not confined to one provider organization. In contrast, EMR is an organization-level system with intra-organizational connectivity for electronic patient records. An EMR system collects all organization-related clinical information and can be conceived as a building block for EHR. In the current literature the distinction between these two concepts is often blurred: HIMSS defines the EHR as "a secure, real-time, point-of-care, patient-centric information resource for clinicians". This dissertation focuses on the analysis of an organization-level EMR system, which exists today, considering it a part of a more global EHR system of the future.

EMR system

EMR system can be considered a backbone of the entire hospital IT infrastructure, and its functionality varies widely. In essence, EMR systems should provide all relevant clinical information about the patient in electronic form, including patient demographic information, doctor's notes, nursing documentation, diagnosis and allergies, orders, lab results, etc. Since this information comes from multiple clinical software applications, EMR is rather integration architecture that aggregates all clinical information about a patient in his electronic record, and provides an interface for accessing and inputting such information. Thus, a sophisticated EMR system requires CPOE and PACS to have full information on prescriptions and test results.

The EMR aids clinicians' decision-making by providing access to patient health record information where and when they need it and by incorporating evidence-based decision support. The EMR automates and streamlines the clinician's workflow, closing loops in communication and response that result in delays or gaps in care. The EMR also supports the collection of data for uses other than direct clinical care, such as billing, quality management, outcomes reporting, resource planning, and public health disease surveillance and reporting (HIMSS, 2003).

The EMR system requires major changes in existing HIT infrastructure and clinical workflow, while its implementation can be risky. Adoption of EMR systems has network externalities: the value of an EMR system increases when there are other providers that are willing to exchange EMR information on the common patients. The ROI of EMR system is potentially high for an adopting hospital, but reportedly difficult to measure.

CPOE

CPOE in its basic form is typically a medication ordering and fulfillment system with some decision support capabilities, while more advanced CPOE also includes order entry for lab and radiology tests and clinical procedures. Unlike basic order system where a nurse inputs in a computer the order handwritten by physicians, CPOE requires a physician to enter his orders directly into system. Order entry by physician eliminates the problem of illegible handwriting, alerts physician about potential allergies and drug interactions, and helps to pick the right drug and dosage. Despite potential clinical benefits, higher demands on physician time spent on order entry often impedes CPOE system user acceptance. If integrated with an EMR system, CPOE can retrieve patient information directly from a patient record, which can make decision support process more efficient and save time for the user. A CPOE system usually doesn’t have high ROI for the provider organization, because the benefits form quality and safety improvement may not accrue to the healthcare provider.

PACS

PACS captures and integrates diagnostic and radiological images from radiology or cardiology devices, stores them, along with the reports, and disseminates them to medical records, clinical data repositories and other care points. It is capable of eliminating film-related costs, reducing test duplication due to misplaced film and speeding up the workflow. PACS systems have been reported to have high ROI in large hospitals due to considerable economies of scale, as a result of relatively fixed capital cost and benefits that scale with the patient volume. PACS doesn’t require a major change in existing HIT software infrastructure, and it can be worthwhile to implement without a sophisticated EMR system in place, although the benefits are reported to increase when these systems are interacted. Radiologists generally support PACS adoption, because it increases their throughput and overall efficiency.

Virtually every hospital has some information technology in place – adoption of master patient index application or billing systems is practically universal, while basic departmental systems such as pharmacy and radiology are also wide spread. However, various costs and benefits of clinical HIT applications may accrue to different participants in the health care system, resulting in differences in social value and expected economic benefits to the hospital.

1.5 Theory of Technology Diffusion and its Application to HIT

Most of the research on technology adoption investigates either the macro pattern of technology diffusion or the differences in adoption behavior among the potential adopters. The former type of research is also useful to predict overall speed of adoption of HIT technologies and its challenges, while the latter one could help understanding the differences between early adopters and laggards.

Major stylized fact of adoption theory (Stoneman, 1984) is that diffusion of most innovations takes an S-curve, when cumulative number of adopters is plotted over time. The diffusion process usually starts out slowly among pioneering adopters, reaches "take-off" as a growing community of adopters is established, and levels-off as the population of potential adopters becomes exhausted, thus leading to an "S-shaped" cumulative adoption curve. In the early models of diffusion (Mansfield, 1961, 1968) this pattern was explained mostly by epidemic effects of spreading the knowledge about the existence and value of a new technology in the community of adopters through their communication channels. According to this approach, such communication is a driving force of technology diffusion, which emphasizes the role of the actions of opinion leaders and change agents (government officials, consultants, etc.), who can accelerate adoption (Rogers, 1995).

For an individual adopter, the adoption decision unfolds as a series of stages flowing from knowledge of the innovation through 1) knowledge, 2) persuasion, 3) decision, 4) implementation and 5) confirmation of innovation (Rogers, 1995). Therefore, definition and empirical measure of adoption vary depending on which stage is considered. Adopters are predisposed towards different kinds of influence (e.g., mass market communication versus word-of-mouth) at different stages.

Another explanation of the S-curved diffusion process explicitly treats a firm’s decision to adopt a new technology or to delay its adoption. It is the heterogeneity in the population of potential adopters with respect to expected benefits or costs of adoption that generates different preferred adoption dates. Different expected benefits from adoption could arise from objective differences among the organizations, such as economies of scale (Karshenas and Stoneman, 1993, 1995), or their subjective perception of technology's profitability and strategic value (Jensen, 1982). The distribution of expected net benefits of adoption across organizations is likely to have a bell-shaped distribution. Organizations with lower expected benefits adopt later, since the cost and risk of a technology adoption decreases over time. The combination of a normal distribution of adoption benefits among adopters and linear decline in the cost of adoption can generate S-shaped diffusion curve.

In the adoption literature, factors that influence the diffusion process could be grouped into characteristics of innovation, characteristics of adopting population, characteristics of supplying industry and characteristics of the adoption environment. Rogers' research, dating back to the 1960s, defines five adopter categories derived by partitioning a continuum of innovativeness: innovators, early adopters, early majority, late majority, and laggards. According to his classification, for any innovation, the innovators and early adopters together generally represent 16% of all adopters. The early majority represents 34% of the population, followed by the 34% called the late majority. The final 16% of all adopters are laggards. This categorization does not include nonadopters since there is an implicit assumption that everyone will eventually adopt. These categories of adopters differ in how innovative they are and how they make they make their adoption decisions:

(1) innovators who are the first adopters, interested in technology itself with positive technology attitudes;

(2) early adopters who are also interested in technology and are willing to take risks;

(3) early majority who can be considered pragmatists and process oriented;

(4) late majority who are more or less skeptical about technology with negative technology attitudes; and

(5) laggards who have extremely negative technology attitudes and therefore never adopt technology among the mainstream (e.g. Rogers, 1995).

Early diffusion research suggested that the speed and pattern of innovation diffusion in a population of potential adopters depends on the characteristics of innovation as perceived on average by that population. In general, innovations possessing favorable characteristics tend to be more attractive and easier to adopt, and therefore tend to diffuse more rapidly (Rogers, 1995). In his work, Rogers mentions five such characteristics:

:

a. relative advantage, which could be expressed as economic profitability, social prestige, or other benefits;
b. compatibility with existing processes and systems,
c. complexity of the innovation for use and implementation;
d. trialability, which is ability to try the technology on a small scale;
e. observability of technology development and its benefits;

In a meta-analysis that involved 75 empirical studies of innovation characteristics, Tornatsky and Klein (1982) reported that first three characteristics - relative advantage, complexity and compatibility – have been found to consistently influence adoption in a significant number of published studies.

Finally, in case an innovation is associated with a high level of uncertainty, potential adopters will be less inclined to purchase it (Ostlund 1974; Nooteboom 1989). Gerwin (in: Rogers 1995) distinguishes three types of uncertainty: (1) technical uncertainty: the extent to which it is difficult for a potential adopter to determine how reliable an innovation is and how well it will function, or whether a better innovation will soon be (Gatignon and Robertson 1991); (2) financial uncertainty about the extent to benefits from implementing of the innovation would cover its costs; and (3) social *uncertainty*: the extent to which it is acceptable that conflict will occur in the immediate environment of the potential adopter with regard to the purchase and implementation of an innovation.

These technology characteristics came from the studies of simple innovations adopted by individuals, rather than of complex technologies adopted by organizations. More recent research emphasizes the role of network externalities and inter-organizational dependencies, knowledge barriers, market structure of supply and demand industries, and incomplete technologies – the factors that are particularly relevant for the industry-level diffusion of modern information technologies.

Although all technologies require some measure of organizational learning to be adopted, some fall on the extreme end of the spectrum in the demands they place on adopters for associated knowledge and skills. Such technologies are said to be subject to *knowledge barriers*, because the difficulty of acquiring the knowledge required to deploy them creates a barrier to diffusion (Attewell,1992). Exemplars of IT innovations subject to knowledge barriers include technologies like Expert Systems (Gill, 1995), CAD/CAM (Liker, et al., 1992), and CASE (Fichman and Kemerer, 1999).

Attewell (1992) has argued that the speed and pattern of diffusion of complex organizational technologies is more driven by decreasing such knowledge barriers than by communication and social influence. According to this theory, diffusion pattern depends greatly on the development of institutions for lowering knowledge barriers (e.g., service firms and consultants, intensive buyer-seller collaboration) and technology simplification.

The use of the technology can be intertwined with organizational routines (Nelson and Winter 1982), which means any individual's interaction within the system must fit within some larger organizational process. HIT systems are a prime example of such technologies, since information flows are the integral part of care delivery process. For technologies that are intertwined with organizational routines, the implementation characteristics of the technology can become important factors impacting adoption and diffusion (Leonard-Barton 1988). Implementation characteristics include the transferability (maturity and communicability), organizational complexity (number of people and functions affected), and divisibility (ability to divide implementation by stages or by sub-populations) of the innovation.

The technology can be also be subject to network externalities (Katz and Shapiro 1986; Markus 1987), which means that the value of use to any single adopter is a function of the size of the network of other users. Many technologies that involve communication of information are subject to strong network externalities, including E-mail, voice messaging and computer conferencing. Such technologies get more inherently attractive with each additional adoption, and hence, are said to possess *increasing returns* to adoption (Arthur, 1996). When a technology is subject to increasing returns, this sets the stage for a distinctive pattern of diffusion, one driven by positive feedback loops in adoption and associated "bandwagon" effects (Abrahamson and Rosenkopf, 1997; Arthur, 1996; Shapiro and Varian, 1998, Chp. 7). Achieving critical mass with a community of users becomes crucial for ultimate diffusion of technology. Markus argues that the distribution of adoption thresholds among potential adopters, and the actions of early adopters in particular become especially important to determining whether critical mass will occur. Other determinants of critical mass include sponsorship and adopter expectations: sponsors can help achieve critical mass by coordinating adoption and subsidizing early adopters; adopter expectations that a technology will eventually be widely adopted can become a self fulfilling prophecy (Farrell and Saloner 1987; Katz and Shapiro 1986). EMR is prone to network externalities to the extend it requires the exchange of information between different providers

In addition to general network externalities, the adoption decisions among two or more particular firms for some IT innovations are tightly linked because the innovation changes the way they transact business. Examples include EDI, integrated supply-chain planning systems, extranets and other inter organizational systems (Hart and Saunders, 1997). When adoption decisions are intertwined this way, organizations may develop new roles of initiator or followers in the adoption process within their networks of business transactions (Iacovou, et al., 1995; Premkumar, et al., 1994; Hart and Sanders, 1997). In some cases, a powerful firm may encourage adoption with subsidies or even compel adoption as a condition of doing business with partnering organizations. As a result, different models of adoption may be required depending on a firm's role and relative power in the network. In addition, since this sort of systems creates new dependencies and vulnerabilities among firms, trust emerges as a key explanatory variable (Hart and Saunders, 1997; Hart and Saunders, 1998).

Many IT innovations initially emerge as incomplete products that provide only partial solutions to the problems they aim to address, or they are only suitable for very specialized applications (Levitt, 1986; Moore, 1992; Rosenberg, 1994, pg. 4). Sometimes, an innovation may require the presence of supporting *infrastructure*. RISC and document imaging systems are just few examples of such incomplete technologies, which to be broadly adopted need to be developed into a *whole product* solution (Moore, 1992). For, example, for object-oriented (OO) programming to be attractive to most potential users, it must be combined with development methodologies, modeling tools, and databases that are compatible with OO (Fichman and Kemerer, 1997b). However, the primary means by which a technology is broadened and deepened is through self-reinforcing cycles of adoption and use (Fichman and Kemerer, 1999). Among adopters, incomplete products present especially high adoption risks. Since these technologies are also often subject to knowledge barriers, it can be difficult for managers to assess the full array of supporting components for a complete product (Fichman and Kemerer, 1997b).

Same factors that determine the overall speed of diffusion may affect the decision of a particular organization to adopt earlier or later than its peers. The perceptions of benefits, costs and risks of innovations are likely to differ across the organizations. For example, knowledge barrier for the same innovation could be perceived differently by different organizations. Cohen and Levinthal (1990) develop the idea that an organization's innovativeness is determined by its absorptive capacity, defined as the organization's ability to recognize the value of new information, assimilate it, and apply it to productive ends. High absorptive capacity in a domain increases the organizational capacity to assimilate innovations in that domain (Cohen and Levinthal, 1990). This, in turn, suggests that the primary antecedents of absorptive capacity – related knowledge and diversity of knowledge – will also predict innovativeness with respect to particular innovations (Fichman and Kemerer, 1997a). Cooper and Zmud have shown that high compatibility between organizational tasks and the innovation predicts adoption of MRP (Cooper and Zmud, 1990).

Early pioneering adoptions of a technology are more often driven by personal characteristics, preferences and strategic visions of the key decision-makers in those organizations. Roger (1995) emphasized this factor, and labeled it as adopter's attitude towards change.

The ability to adopt a costly or complex innovation is often related to the size and/or structure of an organization. Most empirical studies of adoption find that larger organizations tend to adopt earlier than the smaller ones (for the review see Damanpour, 1991). Still, theoretically, the relationship is not so straightforward. On the one hand, larger organizations often enjoy economies of scale, and they have more R&D and slack resources for the new projects, to devote to investment project. For example, wealthy organizations are particularly well positioned to adopt high cost innovations (Downs and Mohr, 1976). On the other hand, larger organizations can be more bureaucratic, have more inertia and less flexibility, all of which may impede implementation of an adopted technology. Zaltman, Duncan and Holbek (1973) propose that more formalized and centralized organizations (often the larger firms) are less likely to initiate innovation adoption decisions, but are better equipped to actually implement innovations. Also, coordination of innovation project among multiple departments and layers of bureaucracy could be more problematic in a large and complex organization. It is suggested in the literature that size of an organization serves as a proxy for related characteristics, such as scale, wealth, specialization, slack resources and market power (Tornatzky and Fleischer, 1990, p. 162).

Market power is a firm's characteristics, while market concentration is an important characteristic of industry that could influence overall speed of diffusion. The diffusion literature is ambiguous on the effect of market power or competition among adopters on diffusion. According to Shumpeterian (1942) logic, market power provides incentives to adopt, allowing firms to appropriate higher profits from adoption of a cost-saving or quality enhancing innovation. In support of this hypothesis, Hannan and McDowell (1984) found that market concentration had positive and significant effect on ATM adoption by banks. A number of similar studies reinforced this finding.

In contrast, Robertson and Gatignon (1986) suggested that in a highly competitive market innovation is necessary to gain or maintain the market position of a competing firm, and supported their hypothesis in an empirical study (1989). When the innovation is cost-saving or revenue-enhancing, delaying or refusing its adoption could result in a competitive disadvantage for the firm. The model of diffusion developed by Gotz (1999) also predicts that increased competition speeds up the diffusion. In line with this prediction, empirical studies by Kamien and Schwartz (1982) and Colombo and Mosconi (1995) found a negative but insignificant influence of Herfindahl concentration index on diffusion in their studies.

Theory Implications for the Clinical HIT Adoption Process

Most HIT systems, and especially EMR systems, possess characteristics that suggest a long diffusion path and considerable challenges in the adoption process. Despite producing large benefits from a social standpoint, quality-improving systems like EMR or CPOE may not be profitable for healthcare providers, who have to pay for the adoption. Moreover, HIT systems are complex innovations that are not directly compatible with the existing workflows and processes of care. Clinical HIT systems are also likely to have substantial knowledge barriers, because they require knowledge of redesigning processes of care for their successful implementation. They often require intensive planning and training, which are challenging for the organizations with low absorptive capacity.

Individual EMR software applications that most vendors currently offer stop short of being a comprehensive system, requiring integrations with many other software applications and systems to have a real impact on efficiency and quality of care. Thus decision-makers have to take into account their existing infrastructure, and consider other add-ins to a core EMR system, while adopting. As theory suggests, adoption in the case of incomplete product presents especially high risks and requires extensive knowledge for adoption planning.

HIT applications that involve information sharing across multiple organizations, such as EMR/EHR systems, are prone to network externalities. Adoption theory predicts that achieving that a critical mass of adoption is necessary to secure the fast diffusion of EMR/EHR system. The adoption of clinical HIT involves linked decisions in different healthcare providers in the community, which emphasizes the role of dominant players in the regional healthcare markets and implies the importance of trust and cooperation. The common effort and of spread of adoption experiences play an important role in the development of RHIOs (regional health information organizations), where clinical information on the patients has to flow across different health settings in the community: hospitals, physician offices, pharmacies and labs.

In contrast to EMR systems, PACS systems demand less integration and often can be cost-efficient as a stand-alone application or when installed in a separate facility. Therefore, they are also less prone to network externalities and impose fewer requirements on compatibility with other IT infrastructure and organizational processes, which implies faster diffusion.

Specifics of Health Care Markets

Healthcare is very different from other information intensive industries which in the last decade widely employed information technology to improve productivity and raise the quality of services. Large share of healthcare providers, especially hospitals, are non-profit organizations, which may use other criteria for technology adoption than just improving efficiency and increasing profits. The theory that makes predictions entirely on models of costs and benefits from technology adoption may not predict the actual decisions well. Alternatively, healthcare technologies adopted by majority and believed to be beneficial could be regarded as "standard of care", and adopted by the rest of the providers just for this reason. The adoption of many treatment technologies, such as bypass heart surgery, was explained mainly through this contagion effect.

In addition, the industry is heavily regulated, both because the government is the largest payer, and because health services are regarded as a public good. Government requirements, reporting mandates and reimbursement policies shape the healthcare market environment and provide incentives or barriers for the adoption of certain technologies. For example HIPAA regulation act could provide incentives to formalize the handing of private patient information, but may also cause rejection of electronic data capture as less secure.

Unlike other industries, there is a third party payer in healthcare and the system of incentives between patients, payers and providers often don't produce the most efficient outcome. Healthcare customers – patients - are interested in higher perceived quality and convenience, while payers are interested in reducing costs of treatment. At the same time, the product of healthcare – health improvements due to treatment – cannot be measured appropriately which makes it difficult to compare and compete on the basis of its price and quality. As a result, the private payment system reimburses hospitals for procedures performed and supplies used, or days of hospital care delivered. Under service-based reimbursement, a hospital is interested in technologies that create reimbursable procedures and increase revenue, such as MRI machines, CAT scans or new laser surgery tool. Studies of these technologies demonstrate their fast diffusion, sometimes beyond necessary for the local area served. On the other hand, investments that improve overall efficiency of care delivered, reducing patient's outpatient visits, length of stay and redundant procedures, may not be profitable for the provider under most common reimbursement schemes. Compared to other industries, healthcare providers face less of price and quality competition, and lower incentives for quality improvement and cost saving through the use of new technologies. However, in many metropolitan markets, healthcare systems struggle to attract the best clinical staff by providing technology that is perceived as up-to-date by them. Also, patients are more likely to choose a hospital that possesses elaborate diagnostic and surgical equipment.

1.6: Organization and Methodology of the Dissertation

In chapter 2, I derive a measure of population-wide adoption level of administrative and clinical HIT applications and compare the derived estimates with those from other studies. The data for the study come from the survey of HIT adoption in US hospitals and hospital systems from Healthcare Information and Management Systems Society (HIMSS) database[1]. In addition, I derive a composite measure of clinical HIT adoption, which is useful to show the current state of adoption in a given facility. This measure is further used in empirical analysis of Chapter 4. I also produce diffusion curves for the major clinical HIT technologies and discuss the dynamics of their diffusion process. Finally, I offer an appropriate menu of potential policies given the current state and dynamics of major clinical HIT applications

Chapter 3 uses economic concepts to review and analyze the adoption decision-making process of the healthcare provider in relation to the following research questions:

1. Which provider is less likely to adopt and why?
2. What are the market failures and barriers to socially-optimal HIT adoption?
3. What are the potential policy levers that can stimulate adoption?

The analysis utilizes theory of technology diffusion presented in the literature review section of Introduction Chapter, case studies from trade literature and interviews

[1] formerly the Dorenfest IHDS+TM Database, 2004

conducted by RAND as a part of HIT project. In this chapter I create a conceptual model of the hospital's adoption decision, which includes hospital's objectives and constraints with respect to the adoption of new technology. Costs and benefits of three major technologies are discussed in this respect, as well as related barriers and enablers mentioned in the literature and interviews. In particular, I discuss the origin of the major market failure in the HIT adoption – the fact that adopters are not fully rewarded for the use of quality-enhancing applications and processes. Finally, I demonstrate how the monetary benefits that the technology brings could vary due by reimbursement type and source. Based on this conceptual framework, I can suggest which factors are important for adoption, and which hospitals are expected to be early versus late adopters. I conclude the chapter summarizing current barriers and adoption factors related to potential policies. Factors that are important for adoption are linked with the characteristics of hospitals and their environment, and tested with the empirical analysis in Chapter 4.

Chapter 4 contains an empirical analysis of adoption factors, as well as the characteristics of the early and late adopters. This empirical analysis focuses on adoption of major clinical HIT systems, that are defined and measured in Chapter 2: Inpatient CPOE and radiology PACS systems, outpatient EMR, as well as a composite measure of clinical HIT sophistication in hospitals. I perform the analysis of the HIT adoption pattern in various types of hospitals and office practices, using the HIMSS database, AHA survey of hospitals, and other data sources to answer two questions:

1) "What types of hospitals are less likely to adopt HIT";
2) "Which factors may influence the adoption of HIT."

First, the empirical studies that represent earlier findings on adoption factors and organizational characteristics that are related to HIT adoption are reviewed. Second, a descriptive univariate analysis is conducted with a primary purpose to identify which types of providers are least or most likely to adopt. Third, multivariate cross-sectional regression analysis identifies the separate effects of factors responsible for adoption behavior, based on the conceptual model developed in the previous chapter. The differences in the effects of various organizational and market factors on EMR, versus CPOE versus PACS, provide additional insights on the incentives that drive adoption of clinical HIT systems with different types of benefits and characteristics. The chapter concludes with a summary of evidence on the role of various factors in the adoption of clinical HIT.

In Chapter Five, the findings of the earlier chapters are summarized. Policy recommendations are developed based on the preceding analyses.

CHAPTER 2: MEASURING CURRENT HIT ADOPTION

This chapter presents a measure of population-wide adoption of administrative and clinical HIT applications according to information in the Healthcare Information and Management Systems Society (HIMSS) database (formerly the Dorenfest IHDS+TM Database, 2004). These estimates are then compared with those from other studies. Based on these data, the current state and dynamics of HIT adoption is summarized and a brief review of existing empirical studies on the HIT-adoption process is provided. Estimation of the current adoption rates is useful for keeping policymakers informed so they can accurately develop policies to promote the adoption and use of EHR and other clinical technologies.

2.1: Theory and Approach

There is no unique way to measure the adoption of a particular technology, because the definition of *adoption* varies by the stage in the adoption process and by the locus of adoption (Fichman, 1992). Moreover, complex technologies, such as HIT software and hardware, have multiple unique functionalities, components, levels of sophistication, and generations, which make it difficult to identify a particular technology at a specific point in time.

Diffusion theory distinguishes between inter-organizational and intra-organizational adoption. Many IT innovations involve a two-part adoption decision process, where a formal decision to make the innovation available to the organization as a whole is then followed by local decisions (by departments, workgroups, projects or individuals) about whether to actually use the innovation, and how (Leonard-Barton, 1988). Similarly, there are two major levels at which HIT is adopted: the organization level, at which the HIT system is invested in and installed, and the clinical level, at which the intended users of the information system – doctors, nurses, administrative personnel, etc., within that organization – decide whether or not to incorporate that technology in their daily practice. In turn, healthcare organizations themselves may have several levels: a larger parent corporation (multi-hospital system or integrated healthcare delivery system [IHDS]), a hospital or ambulatory care center, and departments within a facility or individual physician offices. Technology adoption at the organization level may be more relevant for policy analysis, since it is the "organization" that makes an acquisition decision. The adoption of technology by the end users within an organization largely belongs in the sphere of organizational management. Nevertheless, the adoption process is related to both levels: An organization would likely invest in a technology only if its users are ready to accept the technology in the near future.

Because of data limitations and definitional problems, this analysis focuses on organization–level adoption, the healthcare facilities, their parent healthcare system, and affiliated physicians. The study depends on general survey data to provide insights into use of the technology at the level of individual clinicians.

The concept of adoption can be defined broadly as moving from not having to having technology, which most often refers to the point of purchase of technology. Sometimes, it refers to some kind of the authoritative commitment (Lambright, 1980). If organizations always rapidly implemented innovations that they purchased, then the timing of adoption could be compared based on the purchase decision. However, post-adoption behaviors can vary considerably across organizations. In fact, some research suggests that thorough and rapid implementation is the exception rather than the rule for many technologies (Fichman and Kemerer, 1999; Howard and Rai, 1993; Liker, et al., 1992).

In the IS literature, the best-known model describing the process of technology adoption is the six-stage model proposed by Zmud and colleagues (Kwon & Zmud, 1987; Cooper & Zmud, 1990). The stages in this model of organizational adoption and implementation are defined as follows (Cooper & Zmud, 1990, p. 124):

1) Initiation - a match is found between an innovation and its application in the organization

2) Adoption/ Purchase - a decision is reached to invest resources to accommodate the implementation effort

3) Adaptation - the innovation is developed, installed and maintained. Procedures are developed and revised. Members are trained both in the new procedures and in the innovation

4) Acceptance - organizational members are induced to commit to the innovation's usage

5) Routinization - usage of the technology application is encouraged as a normal activity

6) Infusion - increased organizational effectiveness is obtained by using the IT application in a more comprehensive and integrated manner to support higher level aspects of work.

Similarly, adoption of a HIT system takes substantial amount of time and, nominally, starts with a contract to purchase a HIT application, system, or service, or an initiative for in-house development. After that, a HIT application is installed and integrated in some way with the organization’s information system and infrastructure. It is hoped that doctors and other end users are trained to use the system and that the necessary changes in workflow and processes of care are initiated. As implementation progresses, the share of users of the new technology increases within a provider organization and the technology’s functionality expands. Some organizations make use of Electronic Medical Records (EMR) and Computerized Physician Order Entry (CPOE) mandatory for everyone at once; other organizations allow for a gradual increase in adoption within the organization.

As Tornatsky and Fleisher put it, “neither adoption nor implementation can be unambiquously defined as occurring at a sharp, well-defined point in time” (1990, p.180). There is no strict definition of what *adopted* or *implemented* means in terms of the percentage of active HIT users among doctors or the depth of their use. Thus, a question in a HIT-adoption survey on whether an organization has implemented HIT could mean different things, ranging from "just have installed it" to "everybody is using it to its full potential."

To understand the differences in the adoption levels reported, it is useful to apply the modified adoption framework to HIT adoption in healthcare facilities, collapsing it to four major stages:

1. 1. Realizing the need for an HIT system and searching for options
2. 2. Signing a contract to purchase a HIT system from a particular vendor or starting a project for an in-house development of a system (measured by "contracted" in our analysis)
3. 3. Installing the system, so that it is ready to use, and proving the basic training (measured by "automated" in our analysis)
4. 4. Learning how to use the system, integrating the system into the process of care, and broadening the use of the system's applicable functionalities. This stage may involve multiple levels of improvement in the use of the system, both in terms of the percentage of staff utilizing the system to support patient care and in the degree to which the organization takes advantage of HIT-enabled opportunities to restructure the way that care is delivered or that patients are integrated into the care process.

When comparing the estimates of HIT-adoption rates across the many published surveys, one must keep in mind that stages 2 and 3 can be documented and measured directly, whereas stages 1 and 4 are much more ambiguous. But when experts in the field observe HIT implementation, they are usually observing points in time during stage 4, rather than during stages 2 and 3. As a result, the judgment of experts on HIT adoption rates tends to be lower than what the HIMSS database or other survey-based studies that measure the point of buying the system would report.

The HIMSS database surveys provider organizations on whether or not they have installed a particular HIT system or have just signed a contract with a vendor or developer of the software to buy such a system. The estimates of adoption developed in this chapter reflect whether a provider organization (e.g., hospital or physician office) has just purchased a HIT application by signing a contract with a vendor or has an application already installed. The sum of these two measures, in percentages, shows the share of healthcare providers that are committed to implementing a HIT application. For the policy-related purposes, this sum is the preferred measure of adoption, because it best reflects the level of commitment to HIT adoption and factors associated with it, and it helps to better identify the organizations that have not yet made a purchase decision. The newly contracted HIT systems are included in the estimate of policy-relevant adoption, although the "installed" category better reflects the commonly held meaning of *adoption*.

Such measures of adoption are estimated for various HIT applications based on HIMSS data.

2.3 ESTIMATED ADOPTION OF MAJOR CLINICAL HIT SYSTEMS

2.3.1 Developing Measures of Clinical HIT Systems

The HIMSS database directly measures adoption of ambulatory[2] EMR and inpatient CPOE, but it does not measure ambulatory CPOE and comprehensive hospital EMR system. Instead, the database provides information on adoption of numerous clinical software implications, a combination of which may have a functionality of an inpatient EMR system. Theoretically, 3 of those applications are the necessary components of any EMR-S:

- CPR: Computerized Patient Records
- CDS: Clinical Decision Support
- CDR: Clinical Data Repository.

According to the information from the site visits and technical literature, the basic inpatient EMR-S has to include these components that need to be integrated into one system. The functionality of an EMR-S depends on the functionality and interoperability of these and additional components, such as outcomes and quality measurement applications, CPOE, and PACS. The composition of a typical EMR-S is illustrated with a system from St. Jude Children's Research Hospital (SJCRH):[3]

> **The Components of the Electronic Record: OCF, PowerChart, and Discern Expert**
>
> The electronic medical record system at SJCRH has several components. The Open Clinical Foundation (OCF) is the repository at the center of the new electronic medical record. The OCF is an Oracle database that stores clinical and administrative information. This new database functions as a data warehouse and has the ability to group information based on any one particular patient parameter. For example, patient clinical outcomes with regard to a particular protocol can easily be grouped and presented by the electronic medical records system, thus eliminating the need for data managers to collect the information manually.

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[2] Technically, the database includes only ambulatory facilities that are owned or managed by IHDSs.

[3] See http://www.dcpress.com/frolick2.htm

> PowerChart is the graphical user interface that caregivers access at the clinical workstation. It is composed of two parts: the Organizer and the Chart. The Organizer allows the user to quickly check for new patient test results immediately after logging onto the system. In addition, it allows the user to indicate which test results they have reviewed. The Chart is the electronic form of the patient medical record. It is through this interface that the user can review clinical lab results, nurses' notes, physicians' notes, and patient demographics. Features that are available in the Chart such as the problem list, visit list, and growth chart also allow caregivers to track a patient's medical progress. This electronic medical record makes gathering patient information more efficient because it automatically groups similar data together.
>
> Discern Expert is a program that evaluates best clinical practice criteria and monitors events in the system for compliance. It is part of a decision support system that assists healthcare providers at the point of care by linking historical patient data with current clinical data and assessing that data based on built-in clinical rules. Historically, work in clinical decision support systems has been concentrated on designing alerts and reminders for physicians, however more recent systems are focused on overall compliance with patient care plans (Broverman, 1999). A "starter set" of rules was developed in Discern Expert for the lab, radiology, pharmacy, PowerChart, admitting/registration, and the Chart modules (Milli project scope document, 1998). Managing patient care through the use of decision support systems ultimately means that a patient's quality of care improves.

Thus, one measurement of inpatient EMR requires a hospital to have CPR, CDR, and CDS. When these components come from the same vendor, their integration is much more likely. Of course, many organizations may have interfaced these components from different vendors' software in a way that allowed a level of integration; however, that information was not captured in the HIMSS database.

Despite having high predictive power, this measure of EMR has errors both due to under-reporting and over-reporting. When checked across sure cases of EMR adopters, it became clear that some hospitals do not report CDR as a separate application when they report their broad EMR system with multiple components as a CPR application, and do not mention decision support module or CDR separately. Also, in some cases hospitals that do not have most basic HIT systems like pharmacy and radiology, report having CPOE and PACS – which may indicate an over-reporting problem. To avoid these problems, an additional composite measure was constructed and checked against at least 100 sure cases of EMR adoption.

2.3.2 Composite measure of HIT adoption

A truly advanced hospital EMR system requires an interaction with multiple software applications. The HIMSS database does not provide such a composite measure, in part because there is no single standard for determining a sophisticated EMR-based HIT system. Further, some clinical applications measured in the HD database lack common definitions, and misreporting is quite likely[4]. To work around these limitations, an HIT sophistication scale was developed, based on the number and combinations of applications adopted from certain clinical HIT groups. Groups of clinical applications from HD database were formed based on factor analysis, application's adoption rate, and augmented with additional rationale from case studies found in trade literature and site visits. These groups are:

1) Basic departmental IT systems, which most hospitals have (over 85%): Radiology, Pharmacy and Laboratory information systems.
2) Advanced departmental IT systems, which less than 80% hospitals have: Surgery, Emergency Department, Intensive Care, Cardiology and Obstetrics information systems.
3) General clinical applications that are likely to be the components of an EMR system: Computerized Patient Records, Clinical Data Repository, Clinical Decision Support, Clinical Documentation, Order Communication and Results, and Outcomes and Quality Management.
4) Sophisticated clinical applications: PACS (radiology or cardiology), CPOE, EMAR (Electronic Medicine Administration Record), and Point of Care information systems that many fewer hospitals have in place.

[4] One finds that in some instances hospital underreports the components of its EMR system (such as CDR or CDS), assuming that CPR includes them. On other instances, hospitals that don't have even most common clinical applications or departmental systems claim to have a sophisticated application, which is highly unlikely.

Next, I used these application groups to define five categories of hospitals according to their clinical HIT system sophistication. I have developed a composite measure of clinical HIT system sophistication on a scale from 1 to 5 where hospitals with a value of 1 are considered “laggards” while hospitals with a value of 5 are considered “leading edge” adopters that have HIT systems that include both efficiency and quality enhancing elements. To be the “edge” HIT adopter, a hospital needs PACS and CPOE systems, and at least 11 clinical applications out of 17. Hospitals that belong to the “advanced” category are required to have either CPOE or PACS system, and at least 9 clinical applications. In addition, top 2 categories of hospitals, must have at least one advanced departmental system, at least two basic departmental systems, and at least three general clinical applications including Computerized Patient Records. These constraints ensure high likelihood of having a comprehensive EMR system in the hospital. The “laggards” – the lowest adoption category, cannot have more than 5 clinical applications or any of the sophisticated applications. The “slow” adopters cannot have: PACS or CPOE, more than 10 clinical HIT applications, more than one sophisticated system, or CPR coupled with Clinical Data Repository. The hospitals that don’t fit in the top two or bottom two categories are assigned to the “middle” category. This measurement of clinical HIT sophistication was validated against a survey of top 100 most wired hospitals in the US (REF): about 90% of top 100 hospitals fit in the top two categories that were derived. All 14 hospitals that came from case-studies also fit in the first two categories. Table 2.1 summarizes the HIT scale and shows the distribution of hospitals in the HIMSS sample of US the community hospitals and California hospitals.

Table 2.1

HIT scale definition and distribution

	HIT Scale	Definition	%
5	Cutting Edge	Have EMR with CPOE and PACS	11%
4	Advanced	Have CPOE or PACS, and very likely to have EMR	22%
3	Middle	May have EMR, but unlikely	38%
2	Slow	No CPOE, no PACS, no EMR, less than 10 clinical HIT applications	19%
1	Laggards	Less than 5 clinical HIT applications, only basic ones	10%

2.3.3 Extrapolating estimates to the hospital and ambulatory population

The HIMSS database can produce more-or-less generalizable estimates for hospital adoption, because it accounts for the majority of U.S. community hospitals, including about 90 percent of non-profit, 90 percent of for-profit, and 50 percent of government-owned (non-federal) hospitals. However, it excludes hospitals that have less than 100 beds and are not members of healthcare systems, which under-represents small rural hospitals.[5] Thus, to make the sample more representative, the EMR and CPOE adoption rates were adjusted by accounting for lower adoption rates in the providers that were not captured in the HIMSS database. In particular, it was assumed that adoption rates are about one-quarter lower[6] in the non-represented hospitals in each ownership category and weighted ownership categories to derive adoption rates for the true community-hospital population. Size categories were used to adjust PACS adoption for the entire

[5] Technically, the HIMSS-Dorenfest database covers all the community acute care hospitals that are larger than 100 beds and all other facilities, including smaller hospitals (less than 100 beds), chronic care facilities, and ambulatory practices, that belong to the same healthcare system as the hospital.

[6] This adjustment is primarily based on the lower HIT adoption in hospitals smaller than 100 beds, and on the fact that HIMSS-Dorenfest database under represents those hospitals. It captures only about one-third of those hospitals smaller than 100 beds, but over 90 percent of larger hospitals. The difference between average adoption in the HIMSS-Dorenfest database sample and adoption in smaller hospitals is around 25 percent.

hospital population, because hospital size seems to be the most important factor in the adoption of such a system.

Table 2.2

Raw and Adjusted Estimates of Clinical HIT Adoption

	HIMSS sample		**Population-Adjusted**	
	Installed	Adopted	Adopted	Adopted per bed
Inpatient EMR, likely (top 2 on HIT scale)	N/A	33%	29%	40%
Inpatient EMR, basic (CPR + CDR+ CDS)	27%	34%	31%	36%
Inpatient CPOE	10%	22%	20%	26%
Radiology PACS	33%	42%	38%	54%
Ambulatory EMR	9%	13%	11%	15%*
* Adopted per MD				

The final estimate of inpatient EMR (CPR+CDS+CDR) in non-federal acute care hospitals is around 32 percent. This estimate must be treated as an upper bound even for a basic EMR, because the decision support or patient record components of such a system may be limited to individual departments or have limited functions. Adoption of CPOE in hospitals reaches 22%, while adoption of PACS systems is around 40 percent.

As for ambulatory settings, the HIMSS database covers about 20% of the U.S. physicians practicing in office settings. Because it covers only those practices that are owned, leased, or managed by hospitals or integrated healthcare systems, the HIMSS sample is biased toward larger practices that may have access to the technology through their parent healthcare system. Assuming that practice size is the major driving factor of EMR adoption, the adoption rates in the ambulatory practices of different sizes were weighted by their true distribution[7] in the physician population in order to arrive at the adoption rate per practice and per physician in Table 2.2 (also see Chapter 4 on factors that effect adoption in clinics). The resulting estimate indicates that 11% of EMR adoption in ambulatory physician offices. Because these adoption rates are projected from hospital-affiliated physician adoption, they likely represent an upper bound of adoption estimates.

The adoption of HIT per ambulatory physician and per hospital bed was also calculated to get a crude estimate of the share of patient and physician population exposed to HIT technology (which is not the same as adoption on the user level, because it does not guarantee that every doctor in a hospital or practice with HIT will use it for every patient case). These estimates are generally higher than adoption rate per facility, reflecting the fact that larger facilities generally have higher HIT adoption.

Clinical information technology systems in hospitals include a wide variety of applications above and beyond basic EMR and CPOE. A majority of the hospitals have already adopted such clinical HIT "basics" as Master Patient Index, Order Communication and Results, Clinical Documentation software, and Clinical Data Repository. Most hospitals also have HIT applications for managing medical records, including Dictation, Transcription, Chart Locator, Encoder, and Abstracting. Other HIT applications are earlier in their diffusion process--with relatively lower adoption rates: Electronic Medicine Administration Record (22 percent), Point of Care (Bedside Monitoring) software (42 percent), and Medical Record Imaging (39 percent).[8]
Over 80 percent of all hospitals also have basic IT systems in their radiology, laboratory, and pharmacy departments, including medicine-dispensing software applications. However, except in surgical and emergency departments, adoption of other departmental

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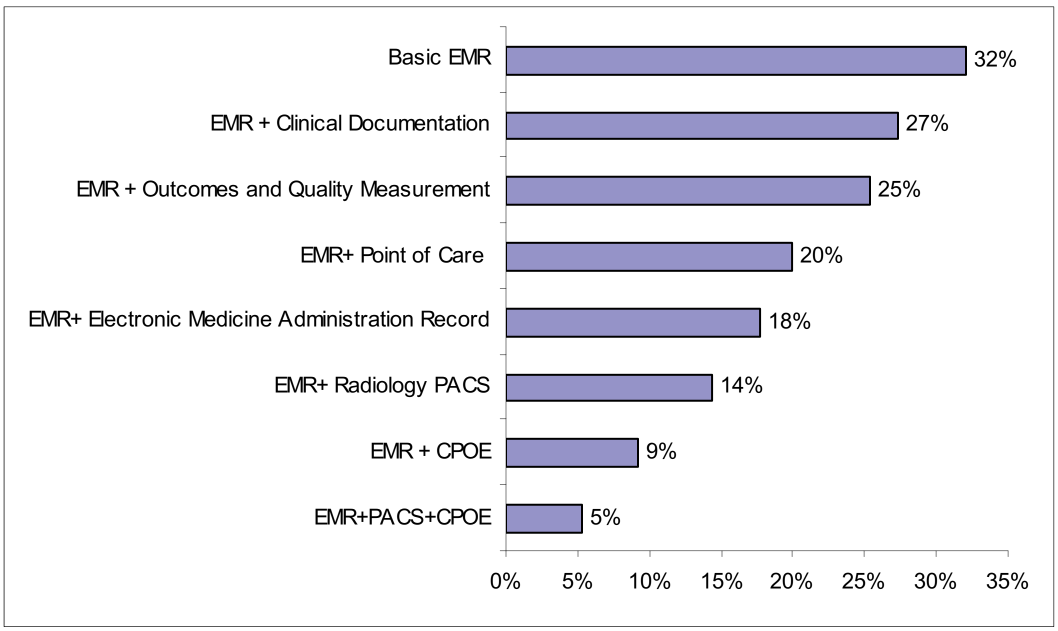
[7] True distribution of the physician practices by size was derived from the American Medical Association (AMA), *Physician Socioeconomic Statistics* (2003) and AMA, *Medical Group Practices in the US* (2002). The estimates of adoption rates for the corresponding distribution derived from the HIMSS database were adjusted to account for the true distribution of the physician practices by size.

[8] These adoption rates are not adjusted for the bias in HIMSS sample. They would be a little lower if they had been.

information systems – such as clinical information systems in critical care, cardiology, and, especially, obstetrical systems – is much lower. In contrast, PACS have gained in popularity in recent years. In 2004, 42 percent of acute hospitals in the HIMSS sample were committed to adopting radiology PACS, with 33 percent having already installed the system and 9 percent having signed a contract to buy a system. Adoption of cardiology PACS is lower, only about 9 percent (7 percent having installed the system and 2 percent having signed a contract).



SOURCE: Estimated from the HIMSS database(HIMSS, 2004) sample, non-adjusted.

Figure 2.1--Adoption of Basic EMR, Combined with Other Clinical HIT Applications

The level of sophistication and breadth of a hospital HIT system can be measured as a combination of a basic inpatient EMR and CPOE, PACS, and other clinical HIT applications (see Figure 2.1). While the adoption of basic EMR is around 32 percent, only 14.5 percent has both a basic EMR system and radiology PACS, and only 9 percent has EMR adopted together with CPOE. Only about 5.5 percent of hospitals has already adopted (installed or contracted) the three important clinical HIT applications, EMR, PACS, and CPOE. Only one out of every 20 hospitals (or even less, accounting for hospitals not included in the HIMSS survey) has an EMR-S that contains digital radiology images and has physician order entry with all the decision support capabilities.

2.4 Comparison of HIT Adoption Estimates from Alternative Sources

In comparison with the literature (see Table 2.3), these HIT-adoption estimates ("this report") are conservative.

Table 2.3

Measurement of HIT-Adoption Rates in the Alternative Surveys

	Inpatient EMR		**Inpatient CPOE**		**Ambulatory EMR**	
	Install	Contract	Install	Contract	Install	Contract
This study	30%	32%	10%	22%	8%	11%
HIMSS, 2004b	19%-56%	>56%				40%
MRI, 2004	21%-42%		17%		21%-42%	
Modern Physician, 2003						>42%
MGMA, 2004					20%	<40%
Deloitte, 2002					<13%	
Leapfrog, 2004			4%	<20%		
CDC, 2001-2003	29-31%				17%	

NOTE: The numbers in the table should not be compared directly without reference to the text, because the definition of the HIT systems and the sampling vary significantly among the surveys.

Our estimates are considerably lower than the HIMSS survey of Corporate Information Officers (CIO; HIMSS Leadership Survey, 2004b) results on HIT (EMR) adoption in healthcare facilities[9]: up to 56 percent, at least twice as high as our estimate of 20 to 30 percent. This 56-percent estimate includes the following stages of EMR implementation:

- 19 percent has a fully operational system
- 37 percent has begun installation
- 23 percent has developed a plan to implement in the future.

It is likely that the HIMSS CIO surveys report a higher level of adoption due to the bias in the sample of providers. Responding to the HIMSS CIO survey is voluntary, and the selection of potential respondents is neither comprehensive nor random. Response rates were around 20 percent in the CIO survey and 9 percent in the physician survey (HIMSS, 2004b and 2004a). The organizations represented are more likely to be those with IT leadership, because they are more likely to be interested in this survey and respond to it. The total number of respondents is relatively low: about 200 physicians and practice managers in the ambulatory HIT survey (HIMSS 2004a), and 300 CIOs of healthcare facilities in the other survey (HIMSS, 2004b). In both surveys, the size of the hospitals/physician practices is biased toward larger facilities. Another explanation for the high estimates of HIT adoption in the HIMSS CIO survey is that CIOs reported the EMR adoption in their organization (often a healthcare system), not necessarily in *each* healthcare facility of their organization. Thus, if the CIO of a large IHDS knows that there is an EMR in one of the IHDS's six hospital facilities, he might have answered yes to the question on whether his organization implemented an EMR.

The latest annual survey by the Medical Records Institute (MRI) reports on the adoption of various HIT/EMR functions in 2004. The respondents were invited by email broadcasts to fill in the survey on their website. Thus, MRI authors warn against extrapolating the reported adoption levels to all U.S. healthcare providers, owing to response bias. One of the functions reported in the MRI (2004) report is close to our

[9] Of respondents, 86 percent represents hospital settings; the rest is physician offices and chronic care facilities.

definition of a *basic EMR:* a Clinical Data Repository (CDR) that supports storage of EMR data; text codes and reimbursement codes, which had an adoption rate of 42.2 percent in use at the beginning of 2004 and additional 15 percent for planned use in the next year (2005). About 21 percent of the respondents claimed that their CDR also supports clinical codes, such as SNOWMED, a clinical code standard; another 25 percent plans to have this system in use within a year. In addition, the survey shows that over 90 percent of hospitals with an EMR-S also have it available in their outpatient departments--a result that can be extrapolated to our HIMSS–based estimates. MRI surveyed over 400 respondents, but it is difficult to identify which segment of healthcare their estimates represent, since the survey lumps together organizations and users within organizations, hospitals and physician offices, integrated systems, and home care services, and includes non-U.S. providers as about 15 percent of its sample.

The HIMSS *Survey of Ambulatory Technology* (2004a) claims that 39 percent of the practices it surveyed have an EMR, including:

- 24 percent that has an EMR in all departments
- 15 percent that has an EMR in some departments.

Another 36 percent planned to buy an EMR in 2004. This percentage is several times higher than our estimate of 12 percent among practices or 17 percent among physicians.

The Deloitte *Research Survey on Physician Use of IT* (Miller et al., 2004), conducted in ambulatory practices at the end of 2001, was a relatively well-designed phone-interview study on HIT adoption of a national stratified random sample of 1,200 physicians. Despite a low response rate of about 6 percent, the sample of respondents presents a wide range of demographic characteristics and specialties. According to this study, 13 percent of respondents reported use of EMR, although the study notes it might be an overestimate, due to a response bias and physicians' broad definition of *an EMR*. Taking into account these considerations and the fact that the survey was conducted in 2001, I believe that our estimate of 12 percent for EMR adoption at the beginning of 2004 is comparable.

According to an annual survey by *Modern Physician*/PriceWaterhouseCoopers (PWC), conducted in 2003, 42 percent of physician practices already invested in an EMR and another 15 percent was planning to invest in one within a year. A total of 80 percent planned to invest by 2005. The generalization of these numbers to the entire physician-practice population is questionable, since the results are based on a Web-based survey, which physicians were invited to complete on the *Modern Physician* website. This method clearly introduces a substantial response bias, because the website is viewed disproportionately more by HIT adopters, who are also more inclined to answer a survey on HIT use and adoption.

A preliminary finding from the 2004 MGMA survey of EMR adoption in physician group practices indicates that about 20 percent of members have an *electronic medical record,* defined as a system that is accessible through a computer terminal and stores medical and demographic information in a relational database. In addition, fully 40 percent of those surveyed indicated that they would implement an EMR System within the next two years. An additional 8 percent of MGMA respondents indicated that they had a system that could combine electronically stored physician notes from dictation and transcription with paper charts scanned into an electronic document-imaging system, and 3 percent had a system just with scanned documents. These estimates represent adoption in practices with three or more physicians, and they are a little higher than this report's HIMSS–based estimate (unadjusted) for practices with two or more physicians, which shows 14 percent of the practices having an EMR in place and another 4 percent having a contract to install one. MGMA estimates are also based on an email survey limited to MGMA members and group practices, which may introduce a response bias.

Burt and Hing (2005) presents the adoption rates based on 2003 NAMCS survey of the office-based physicians, and 2001-2002 NAMCHS survey of emergency and outpatient department in acute-care hospitals. According to their report, 17% of physician practices, 29% of hospital outpatient departments and 31% of hospital emergency departments reported the use of electronic medical records. The survey samples are representative of the office and outpatient visits in the facilities, which corresponds to the estimates per hospital bed or per physician. These adoption rate estimates are higher than the ones developed in this dissertation, especially given earlier date of these surveys and the measurement of EMR use rather than its purchase. Since the primary purpose of these surveys is healthcare utilization, one might expect smaller self-selection based on the HIT use compared to other surveys. The selection bias is not a problem in the survey of hospital outpatient and emergency departments, as it boasts 95% response rate.

As for CPOE adoption, the recent Leapfrog survey (2004) reports that 4 percent of hospitals fully implemented[10] CPOE in 2003, and another 16 percent will have it implemented by 2006. In total, 20 percent of hospitals will have CPOE fully implemented by 2006.

Our estimates show that about 7 percent of hospitals has CPOE in place (although not necessarily fully implemented), and another 9 percent has contracted for it, implying that at least 16 percent will have a CPOE system fully implemented in 2006 (if it takes 1-1/2 years from contracting to full adoption). Another 3 to 5 percent of hospitals that contracted for CPOE in 2004 may not have been captured in the survey yet, which makes our estimates practically identical to Leapfrog's.

The MRI survey in 2004 also provides a recent estimate of CPOE that all kinds of providers have in use today – 11 to 17 percent, depending on whether these are pharmacy, lab, or radiology order systems – and another 28 to 32 percent is going to install the system within a year.

The HIMSS database also contains some data on CPOE use on the user level in organizations, showing that, among 9.8 percent of hospitals with CPOE in place, only 15

[10] The Leapfrog definition of a *fully implemented CPOE system* is as follows: Prescribers enter at least 75 percent of all medication orders via a CPOE system.

percent (1.3 percent of the total) mandates CPOE use, and only 40 percent (3.5 percent of the total) uses CPOE to enter all orders (including prescriptions, labs, diagnostic, and patient care). The 3.5 percent of hospitals that enters most of their orders through CPOE approximate what conventionally is meant by "fully implemented," and is equivalent to the adoption rate of 3.5 to 4 percent cited in the Leapfrog study. Also, about 50 percent of those IHDS with CPOE in some of their hospitals has over 50 percent of physicians using it (a much higher rate than on the hospital level, because a system may include some hospitals with CPOE and some without).

There are many other sources of HIT-adoption data with similar design flaws and response problems similar to those of the sources already cited. Until recently, the data from the HIMSS database appeared to be the most representative of clinical HIT adoption in hospitals and integrated healthcare delivery systems, despite their shortcomings, such as the absence of a well-established measurement of an inpatient EMR system. The definitions of clinical HIT applications, such as inpatient CPOE and outpatient EMR in HIMSS are not ambiguous. However, inpatient EMR can only be approximated with reaching top levels of HIT scale (4 and 5), or by as CPR+CDS+CDR measure that represents an upper bound of functionality rather than a realistic estimate of the technology in use.

2.5 Dynamics of the HIT Diffusion Process

The HIMSS survey (2004) contains adoption dates, which enabled the construction of the diffusion curves for major clinical HIT applications (see figure 2.2). These diffusion curves represent the cumulative percentage of adopters in any given year, based on the year when the application was contracted for as reported by the organization. For inpatient EMR, which consists of CPR, CDS, and CDR, the year represents when its last component was contracted for. This diffusion curve should be interpreted with most caution, because it represents the diffusion of basic infrastructure necessary for EMR rather than complete EMR system.

Since only about two-thirds of the adopters reported the contract date of every application, the adoption date was extrapolated for the remaining one-third to correspond to the reported pattern of diffusion, assuming that the missing data follow the same pattern. The extrapolation may introduce a slight bias if those who did not report the contract date did adopt predominantly in the early years rather than proportionally to those who reported. The diffusion curves are displayed for the period beginning in 1991, when the estimated adoption levels were less than1 percent. The diffusion curve shows adoption levels by the end of each calendar year and ends at 2004, based on available data at the time of this analysis. The adoption in the last year is projected to reflect the adoption by the end of the year, since the adoption in different hospital systems is measured at different dates throughout the year.

Because very few hospitals report the actual date of installing the HIT application, it was not possible to generate the diffusion curves for the date when the system was installed in the hospital, rather than the date it was contracted for. The average difference between the date of contract and the date of automation is from one to three years (average 1.5 year), with longer periods in the early years and shorter periods recently. Thus, if someone is particularly interested in the diffusion of HIT systems based on the date of installation, it could be approximated by shifting the contract-based diffusion curve one or two years to the right (e.g. to show "installation"-based diffusion the years in labels in Figure 2.2 should be changed from 1991-2004 to 1993-2006, adding two years from the date of contract to allow for installation.)

The diffusion curves were constructed from the HIMSS respondents, and then adjusted downwards to reflect lower adoption in the rest of the hospital population, based on estimates in the preceding section, Estimated Adoption of Major Clinical HIT Systems Components (see Figure 2.2).

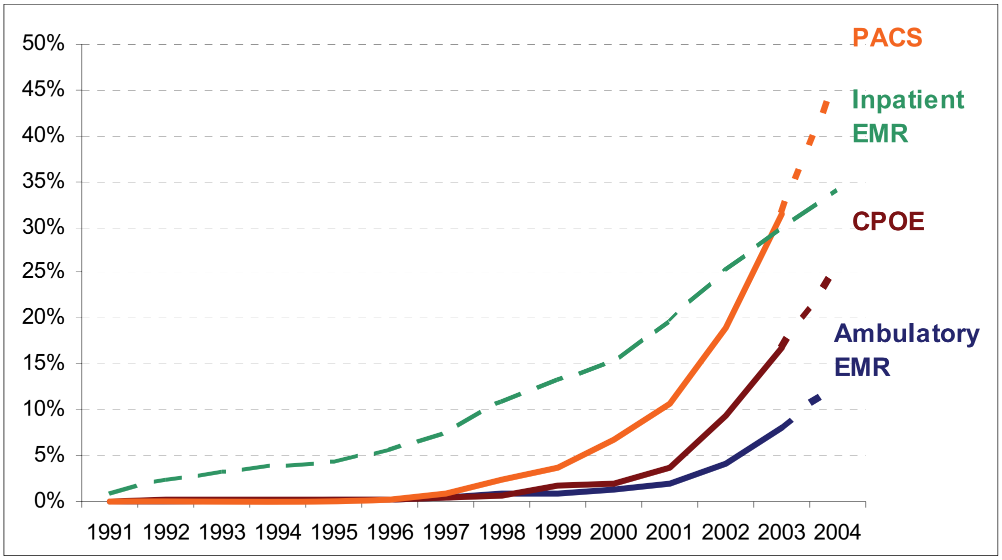


Figure 2.2 Diffusion of Inpatient EMR, CPOE, PACS and of Ambulatory EMR Systems

Inpatient basic EMR (that represents IT infrastructure necessary for EMR) has the slowest acceleration, in relative terms (if one compares the time to change from 5 to 10 percent; the Inpatient curve is the slowest) of diffusion in recent years, and would probably take the longest to diffuse. In contrast, ambulatory EMR diffusion appears more dynamic since 2000, despite its slow start. Although Radiology PACS achieved 5 percent diffusion almost five years later than inpatient EMR, it exceeded EMR diffusion in 2002. From the years 2000 to 2004, the CPOE adoption level increased eightfold, which might be caused by unprecedented policy attention to the role of CPOE in reducing medical errors. If this is the case, the rapid start may not reflect the natural diffusion pattern and any extrapolation might be overly optimistic, especially if policy attention recedes.

2.6 Summary of Findings and Policy Application

Definitions of HIT systems, stage of the adoption process measured, sample of providers and user versus organization level of measurement all may produce differences in the assessment of current HIT adoption rates. Using a policy-relevant measure of commitment to HIT adoption, this dissertation produces quite realistic estimates of 13% ambulatory EMR adoption per physician and about 20% adoption of CPOE among hospitals in 2004. Adoption of PACS shows a reasonably optimistic picture – fast uptake and adoption of over 40% in 2004. The complexity of an inpatient EMR system and requirement of interoperability with other HIT software presents a real problem in measuring EMR adoption in hospitals. This study addresses this problem by developing a scale of HIT sophistication, which predicts that about 10% of hospitals have fairly sophisticated clinical HIT system including an EMR, and another 20% are very likely to have EMR system.

According to Roger (2005), adoption of innovation usually accelerates after 15-20%, when early majority starts adopting. According to estimates in this report, adoption rates of sophisticated clinical HIT ranged from 10% to 30% in 2004, depending on definition. Now, as two years have passed these providers most likely have implemented the systems and new adopters have bought the systems. The diffusion has already passed 15% covered by the categories of innovators and early adopters that tend to adopt primarily for the reasons of increasing their social status and technological preemptiveness (Roger 1995). These categories of adopters are technological leaders in the industry that are less concerned about having proven financial returns on their investment, usually because they have more spare capital. The next category of adopters – early majority – covers 16% to 50% diffusion period, which is the current stage of sophisticated clinical HIT diffusion, such as inpatient EMR, PACS and CPOE. Early majority is also technologically adept, but it requires proven benefits and tends to adopt for utilitarian reasons. Late majority starts adopting only when majority of population have adopted. It is skeptical and more techno-phobic, but will follow the herd, if the benefits are apparent. To be effective, current policies have to cater to early and late majority categories: helping to uncover potential HIT ROI for providers and spurring the epidemic effects.

Still, it is a long way to go: It took 15 years for similar IT, such as Large Scale Relational Database (like ERP), to diffuse from 15% to 80% in the industries that are much more market-driven than healthcare (Bower, 2005). Although the diffusion of advanced clinical HIT systems accelerated in the recent years, there is a need for policy interventions to achieve a rapid diffusion through the rest of the provider population. In their absence, the President's goal of "EHR for every American in ten years" (now 8 years left) will be grossly over optimistic

CHAPTER 3

ECONOMICS OF HOSPITAL'S DECISION TO ADOPT A CLINICAL HIT SYSTEM

This chapter uses economic concepts to review and analyze the adoption decision of the healthcare provider, and connect them with the following research questions:

4. Which provider is less likely to adopt and why?
5. What are the current barriers to a faster diffusion of major clinical HIT systems?
6. What are the potential policy levers to stimulate adoption?

The analysis utilizes the theory of technology diffusion presented in the section 1.4 of this dissertation, case studies from trade literature and interviews conducted by RAND as a part of HIT project.

3.1 Benefits and Adoption Cost of Major Clinical HIT Applications

HIT infrastructure consists of many software components and IT systems with clinical and administrative functions that could be integrated to a different degree into one comprehensive system. Benefits that various HIT systems can deliver determine whether or not a provider wants this applications, and their costs imply the feasibility of investment. To understand the drivers and barriers in the adoption of key clinical HIT systems, the benefits and costs of PACS, CPOE and EMR are reviewed, as well as the peculiarities of their implementation.

PACS

PACS captures and integrates diagnostic and radiological images from radiology or cardiology devices, stores them, along with the reports, and disseminates them to medical records, clinical data repositories and other care points. It is capable of eliminating film-related costs, reducing test duplication due to misplaced film and speeding up the workflow. PACS systems have been reported to have high ROI in large hospitals due to considerable economies of scale, as a result of relatively fixed capital cost and benefits that scale with the patient volume. PACS doesn't require a major change in existing HIT software infrastructure, and it can be worthwhile to implement without a sophisticated EMR system in place, although the benefits are reported to increase when these systems are interacted. Radiologists generally support PACS adoption, because it increases their throughput and overall efficiency.

According to several case studies of PACS installations, its capital cost is relatively fixed at around 3.5 million, while maintenance costs are equal to 0.5 million per year (Health Imaging & IT, 2005). When a PACS system is adopted as a part of a comprehensive radiology and EMR system, its marginal capital cost might be lower. Also, vendors usually offer discounts on software and hardware when a hospital system contracts PACS system for several facilities, and costs of implementation planning and managing could be shared between the facilities. For example, Bronx system spent about 6 million on PACS system in their two hospitals with 870 beds in total (Webster, 2004). It doesn't take too much time to install PACS and learn how to use it. For example, Christus hospital was able to make PACS operational just in three months, while Shannon Medical Center did it in six months (Health Imaging and IT, 2005).

PACS allows for an immediate availability of high-quality images and diagnostic reports, which improves diagnosis and reduces waiting time. Through PACS, a doctor is able to view test results immediately after they are done and even request image modifications in real time. Saved turnaround time can reduce LOS for the inpatient care and eliminate the need for repetitive outpatient visits. In an emergency situation, speed of a diagnosis can substantially improve clinical outcomes and even save lives.

Most of PACS efficiency savings come from elimination of film-related costs, such as film processing, storing and result distribution. For an average hospital with about 100000 radiology procedures per year (typical for a hospital with 200-300 beds), and cost of film processing of about $3, PACS can potentially save up to $300000 (derived from Health Imaging, 2005). Substantial labor reductions are possible in the file room staff due to PACS, because physical search and delivery of images is no longer needed. For example Bethesda hospital (272 beds) was able to eliminate seven positions of their file room staff. In addition, PACS saves processing time for the radiologists and waiting time for physicians, which can result in the increased volume radiology service by 10 to 17 percent (HealthImaging, 2004). PACS virtually eliminates the problem of lost or unavailable images, so there are less duplication of tests. Film processing equipment maintenance and film storage space reduction are often cited among the savings attributable to PACS. PACS may also increase reimbursement rate through better documentation of tests conducted.

CPOE

CPOE in its basic form is typically a medication ordering and fulfillment system with some decision support capabilities, while more advanced CPOE also includes order entry for lab and radiology tests and clinical procedures. Unlike basic order system where a nurse inputs in a computer the order handwritten by physicians, CPOE requires a physician to enter his orders directly into system. Order entry by physician eliminates the problem of illegible handwriting, guards against medication mistakes, alerts physician about potential allergies and drug interactions, and helps to pick the right drug and dosage. Despite potential clinical benefits, higher demands on physician time spent on order entry often impedes CPOE system user acceptance. If integrated with EMR system, CPOE can retrieve patient information directly from a patient record, which can make decision support process more efficient and save time for the user. CPOE system usually doesn't have high ROI for the provider organization, because the benefits form quality and safety improvement may not accrue to the healthcare provider.

According to the six CPOE adoption case studies that First Consulting Group (FCG, 2003) conducted, the capital cost of a CPOE system ranges from $3 to $10 million, depending on a hospital size, existing infrastructure and CPOE capabilities. Based on their data, the FCG study developed a representative cost model for implementing CPOE at a single, 500-bed hospital, which estimated total one-time capital plus operating costs of $7.9 million and annual ongoing costs of $1.35 million. However, marginal cost of CPOE software could be considerably lower when it is installed as a part of a comprehensive EMR system. Smaller hospitals or hospitals with existing integrated systems may experience lower costs (Kuperman & Gibson, 2003). IT capabilities of a facility allow for an in-house development, home-grown CPOE system can be much cheaper than commercial CPOE (Kaushal, Shojania, & Bates, 2003). For example the capital cost of CPOE system developed in 1992 at Brigham and Woman's Hospital was only about $1.9 million. Aside from its high capital cost, CPOE is a complex system, which needs at least 18 months for its successful implementation (FCG, 2003).

CPOE plays an important role in improving patient safety and quality of care, which is well documented in the studies of CPOE effects at Brigham and Women's Hospital. Bates (1998) reported that CPOE reduced medication errors by 55% and adverse drug events (ADEs) by 17%. Equipped with extensive decision support capabilities, CPOE could reduce medication errors by 87% (Bates, 1999). In general, CPOE improves compliance with treatment guidelines and helps to pick the most effective drug for a given case. Sometimes, improvements in patient safety can benefit a hospital financially. CPOE that causes reduction in ADEs may cut some malpractice litigation costs, especially when insurance companies offer a discount on malpractice insurance with CPOE implementation and use.

CPOE is capable of improving efficiency of hospital operations by reducing the time spent on processing paper orders and speeding-up clinical workflow. For example, Montefiore Medical Center in New York demonstrated a 58% reduction in medication turn-around times after CPOE implementation, and estimated time savings of two hours per day for each ward clerk, 20 minutes per day per nurse, and 200 minutes per day per pharmacist. (Manso *et al* in FCG, 2003) In addition CPOE with test ordering capabilities can potentially reduce duplicate and redundant test ordering. (Bates *et al*, 1999)

Finally, CPOE helps to automatically produce prescription documentation, which could improve billing and reimbursement . In one randomized control study of CPOE usage, charges in the intervention group were 12% higher and captured more accurately than in the control group (Tierney, Miller, Overhage, & McDonald, 1993).

EMR system

An EMR system can be considered a backbone of the entire hospital IT infrastructure, and its functionality varies widely. In essence, EMR systems should provide all relevant clinical information about the patient in electronic form, including patient demographic information, doctor's notes, nursing documentation, diagnosis and allergies, orders, lab results, etc. Since this information comes from multiple clinical software applications, EMR is rather like integration architecture that aggregates all clinical information about a patient in his electronic record, and provides an interface for accessing and inputting such information. Thus, a sophisticated EMR system requires CPOE and PACS to have full information on prescriptions and test results. Real time access and decision support based on structure information from the record are necessary features of a sophisticated EMR system for clinical staff. Ideally, a comprehensive EMR system is supposed to completely eliminate paper records and documentation in a hospital, as well as automatically provide all relevant information for billing systems.

An EMR system requires major changes in existing HIT infrastructure and clinical workflow, while its implementation can be risky. Adoption of an EMR system has network externalities: the value of EMR system increases, when there are other providers that are willing to exchange EMR information on the common patients. ROI of an EMR system is potentially high for an adopting hospital, but reportedly difficult to measure.

According to the RAND study, the capital cost of an EMR system is usually proportional to the size of a hospital and ranges from $10 to $15 million for an average size hospital (Girosi et al, 2005). When EMR is installed throughout local hospital system, its costs includes EMR modules installed in satellite long-term care facilities, ambulatory clinics and other hospitals, as well as an integration infrastructure that allows exchange of medical records across the setting. For example, Schmitt et al. (2002) estimated a total project cost of approximately $19 million for a 7-year long EMR installation in a 280-bed acute care hospital with 16 satellite clinics, a research institute, and a network of about 400 employed physicians. In the ambulatory setting, estimates for the initial costs of implementing an EMR are $50-$70K for a 3-physician office

(Agrawal, 2002). Other estimates from the ambulatory setting average $10-$20K per provider for an EMR installation (Carter, 2001).

EMR systems have tremendous potential to affect quality of care. They provide timely access to all relevant patient information and improve compliance with best-practice treatment guidelines, particularly when they include features such as CPOE and CDSS (Agrawal, 2002). Research indicates that EMR technology is linked to improved outcomes including better infection control (Fitzmaurice, Adams, & Eisenberg, 2002), improved prescribing practices (Teich et al., 2000) and improved disease management (Erstad, 2003) in hospitals. In the outpatient setting, improvements in quality are also possible. For example, Cooper (2004) improved practice immunization rates and quality review scores in a private pediatric solo practice with EMR use.

Due to instant electronic availability of all patient information, EMR use eliminates the need to pull, route, and re-file paper charts (Agrawal, 2002). RAND study used an estimate of 50% reduction in the costs of medical record management due to EMR system. EMR can also improve the efficiency of clinical workflows: it saves 10% of nurses' time, and reduces lab and radiology tests by 12 % by avoiding duplications (effects generalized in Federico et al, 2005).

EMR systems can speed up clinical workflow by ameliorating various delays in the process of inpatient care, such as waiting for written orders to be transcribed and communicated; delays caused by errors in test ordering and duplications; delays in task prioritization; delays in ordering ancillary services following nursing assessment, in searching for charts paper documents before visiting a patient, and in coordinating all of the information and communications necessary for discharge planning. Integrated clinical information systems equipped with standardized care plans such as the one implemented at Ohio State University Medical Center or Maimonides Medical Center promise to have a larger impact on inpatient length of stay (LOS). Tierney and Miller (1993) find LOS reduction of 10.5 percent in a randomized control trial on the effect of one of the first EMR system from Regenstrief Institute. The Davies Award–winning Maimonides

Medical Center in New York reported a 30-percent reduction in LOS (Baldwin, 2003), from 7.26 to 5.05 days.

Interaction of EMR with billing system assures accurate and timely capture of charges for medications, medical supplies, and clinical services, thus increasing charge capture (Schmitt & Wofford, 2002; Williams, 1990). EMR also provides more complete clinical documentation which helps to reduce claim denials and receive payments much faster.

Ambulatory EMR systems can be configured to generate reminders to both patients and clinicians when health maintenance visits are due. This can aid in modifying patient flows under varying reimbursement arrangements and enhance revenues (Mildon & Cohen, 2001).

3.2 Economic models of a hospital's behavior

There is no agreement on economic model that describes hospital behavior, because unlike other industries healthcare is dominated by non-profit institutions and is ridden with multiple market failures. Feldstein (2005, p 273) offers three major models that are used in health economics to explain the behavior of the non-profit hospitals. One model assumes that a non-profit hospital acts by maximizing its profits, just like a for-profit one. However, a non-profit hospital spends these "profits" in a public interest, improving quality of care and providing more charity care for the community. In this model, a hospital will invest on the basis of which investment offers the highest rate of return, choosing cost-saving technologies or expanding services and facilities. In the alternative model, hospital managers and trustees are the beneficiaries and decision makers. They maximize their own utility, which emphasizes the prestige of their institution reflected in hospital's size, complexity of services provided, quality of staff and latest equipment, as well as reasonable level of financial well-being. The preferences of decision makers determine the exact trade-off between the quantity and quality of hospital services. In this model, hospital executives might have an incentive to adopt an unprofitable technology, if it raises the prestige of their institution. A third model assumes that physicians capture the control over the hospital and maximize their own income, which may not be directly related to the hospital's profit. For example, physicians may desire investments in costly hospital services that are complimentary to the physician's labor and attractive to the patients, such as MRI machines or outpatient screenings.

To generalize, all economic models include both profit and quality of care or community service components in a hospital's objective function. It is likely that for-profit hospitals maximize their profits subject to a reasonable quality constraint, and non-profit hospitals maximize quality subject to a positive-profit constraint, or they maximize a mix of quality and profits (Phelps, 2002). However, recent empirical studies have found little difference in the behavior of for-profit and non-profit hospitals (except major teaching hospitals), including quality of care and even the amount of charity care provided (in Feldstein, 2005, p. 281).

In either case, the decision to adopt an expensive HIT system will largely depend on the hospitals' assessment of the cost of an investment versus monetary, strategic and quality of care benefits that it generates for this hospital. The major constraint that hospitals face in making an adoption decision is the availability and cost of capital necessary for the investment. When a decision-maker can see how a particular technology could benefit his organization, the adoption decision has to deal with three major contraints:

1. Can the hospital afford buying and successfully implementing an HIT system at this moment?
2. If adopted now, will the technology pay for itself within a reasonable period of time?
3. Does the hospital expect technology's price to change favorably over time (and how soon) relative to its benefits and features?

Even if the answer to the first two questions is "Yes", the hospital's leadership may still defer the investment if adoption at a later date seems to be much easier, or less costly. Therefore, the kind of decision that a healthcare organization faces at any point in time is not a choice between adopting and not adopting, but a choice between adopting now and deferring the decision until later.

According to diffusion literature, before making an adoption decision a potential adopter has to 1) learn enough about the innovation to become potentially interested, and 2) evaluate feasibility and value of investment. Today, practically all healthcare providers are well aware of existence EMR, CPOE, PACS and other major clinical HIT systems. Healthcare providers learn about the technologies and their benefits from trade literature, conferences, experience of their peers, and vendors that advertise and offer their systems. Policymakers, healthcare experts, professional associations and RHIOs broadly advocate and promote adoption of quality-improving HIT systems. When this information convinces a provider that an HIT system can potentially address his own needs, the formal decision and evaluation process begins.

Decision on the adoption of an HIT in healthcare organizations most often follows a top-down approach. The HIT investment decision is initiated by the leaders of organization, like CEO, discussed with the staff and approved by the Board of Trustees or Board of Directors. Most hospitals belong to multi-hospital systems, where the adoption decision in a given facility depends on what happens in the rest of the system. The degree of investment decision centralization and hospital autonomy generally depends on the type of the system. In strongly centralized hospital systems, the adoption decision is made at the system level for all member hospitals. The roll-out schedule, however, may depend on organizational and financial capacity of an individual facility. A multi-hospital system has an additional advantage at getting purchasing discounts on software, hardware and installation of IT systems. In loosely integrated multi-hospital systems, individual facilities often make more or less independent adoption decisions, as long as they are in line with the strategy for the entire system (Coye, 2006).

3.3 Healthcare Providers are Looking for Economic, Strategic and Quality-of-Care Benefits in Clinical HIT Adoption

The theories of hospital behavior suggest several motivations that a provider may have for a major medical investment: profit, prestige through technological preeminence and clinical excellence. Teplensky *et al*. (1995) empirically tested these explanations for hospital adoption behavior on the example of MRI - a major capital-intensive hospital technology of the last decade. The authors utilized a survey of hospital CEOs and proxied for adoption motivations with financial, technology and clinical measures. The composite model that incorporated all of them identified the importance for a hospital of being a technological leader, hospital's clinical requirements, and the change in revenues associated with the adoption of MRI as the major determinants of adoption behavior. As the technology-related measures were the strongest determinants of MRI adoption, the authors concluded that a hospital's adoption behavior is strongly linked to its strategic orientation.

The motivations for HIT adoption in hospitals found in case studies, trade literature and site visits confirm that motivations could be classified into three intertwined categories: clinical excellence, economic and strategic. Clinical excellence motivations include quality and safety of care as well as community outreach; economic motivations are focused on short term ROI for the adopting provider (rather than for the community or entire system); strategic motivations include long-term benefits, such as improving competitive position, expanding their network, anticipation of higher accountability in the future and incentives for quality improvement and attracting best-quality staff. Definitely, quality improvement and strategic benefits may also transfer in the higher profits in the future, but they are less certain than short run ROI and attainably primarily in the long run. The hospital adoption decision probably involves all three factors, but different hospitals may weight them differently.

Mission-related concerns about quality and safety of care delivered are among top stated motivations to adopt clinical HIT systems. Over 75% of hospitals and physicians from 2004 MRI survey (MRI, 2004)[11] cite quality improvement and patient safety as their most important reasons for adoption of EMR and CPOE systems. Most of early adopters are the healthcare systems with an image of top quality providers, who need clinical HIT to support their quality of care initiatives and build their reputation. For example, Women's Hospital of Birmingham has committed to become a pioneer in patient safety improvements by installing CPOE system (Bates, 1998). EMR and CPOE systems have tremendous potential to affect quality of care, documented in improved clinical outcomes and better compliance with guidelines. EMR provides timely access to all relevant patient information, alerts about follow-up and preventive care and improves compliance with best-practice treatment guidelines, particularly when they include features such as CPOE and CDSS (Agrawal, 2002). CPOE is capable of reducing medication errors by up to 87%, which in turn reduces adverse drug events. In general, CPOE improves compliance with treatment guidelines and its decision support component may helps to pick the most effective drug for a patient case.

Currently, however, the growing number of providers becomes interested in clinical HIT systems primarily due to economic reasons, including increased billing levels and potential savings from medical records management. Even when the primary reason of a HIT investment is not financial, the adoption decision often requires ROI planning that demonstrates a reasonable financial payoff. The financial benefits of clinical HIT benefits are often related to the quality of care objectives, such as continuity of patient care. For example, an integrated EMR system is capable of speeding up patient data exchange among clinicians from different sites and saving money for organizations that spend a lot of resources trying to provide continuity of care for the patients. Sharing patient-record information among healthcare practitioners and professionals was named among the top reasons to adopt an EMR system by over 75% of respondents of a MRI survey.

[11] Surveys and studies of HIT adoption patterns often fail to deliver clear or reliable estimates of HIT adoption because of sampling issues, but they are quite useful for forming hypotheses on causes of the difference in adoption among different types of healthcare providers, through the reported enhancers of and barriers to HIT adoption. The MRI survey (2004) lists the top motivating factors for adoption of an EMR System in ambulatory and hospital settings.

The common part of every ROI analysis is a calculation of benefits from overall improvement of workflow efficiency, such as savings in FTEs and supplies with electronic medical records management. Improvement of workflow efficiency was cited as one of the top reasons in the MRI survey, and practically every interview or case study of an adopter. Clinical HIT systems are also capable of answering the challenges in the hospitals operations, such as lack of nursing or other clinical staff, increased data reporting requirements, etc.

Those who already adopted universally agree that HIT systems do not automatically deliver higher efficiency and quality of care gains due to clinical. Technology needs to be complemented with profound changes in the processes of care, which require planning, monitoring and extensive training of the clinical staff.

Fully integrated clinical HIT systems can directly improve efficiency of certain clinical procedures (e.g. PACS effect on cost of a radiology exam), but major additional benefits come from better informed decisions and optimization of clinical workflows, which result in greater efficiency of care. Having all relevant information readily available along with decision-support tools can improve diagnosis and optimize treatment, which can result in more cost effective use of health services and better health outcomes. In turn, this quality of care improvement might reduce length of stay in the hospital (LOS), decrease readmissions and reduce recovery time, as well as reduce unnecessary deaths due to medical errors. Instant availability of relevant clinical information from PACS, CPOE and EMR can speed clinical workflow, also reducing LOS, and eliminate costs of labor spent on search and delivery of clinical information (e.g. chart pulls).

Better documentation of care process (EMR) can reduce transcription costs, as well as improve code capture, eliminating under-coding of procedures and diagnoses. Over 50% of respondents of the same MRI survey mentioned improving clinical documentation to support appropriate billing service levels as one of the top reasons to adopt EMR. Clinical HIT systems allow capturing complete clinical information that feeds directly into the billing system. As such, all procedures and supplies are captured and reimbursed reducing so-called “under-billing”, there are fewer claims denials due to incomplete information, and billing-reimbursement cycle becomes shorter. EMR documentation enables the monitoring of quality and efficiency of care delivered, and malpractice discounts are additional benefits of proper clinical documentation.

The potential efficiency benefits of sophisticated, fully integrated HIT systems are substantial and wide-ranging but many do not accrue to the hospital under most common reimbursement methods. For example, the benefits of improved health outcomes such as faster recovery time, reduced pain and suffering, and reduced days lost of activity or work can be substantial but all accrue directly to the patient, his employer or insurance plan, rather than to the hospital. Table 1 summarizes types of benefits that hospitals derive from adoption of EMR, PACS and CPOE systems (see 3.1 for a detailed review of benefits and costs of individual clinical HIT systems: EMR, CPOE and PACS).

Table 3.1

Potential savings from clinical HIT applications in major cost categories

Improvements:	PACS	CPOE	Comprehensive EMR
General savings	Elimination of film storage space		Elimination of a file room
Labor resources per procedure	Radiologists' processing time, clinicians' waiting time	May increase physicians ordering time, but saves time of nurses and pharmacists	Time spent on chart pulls, dictation and transcription of medical records, waiting for chart to arrive
Medical and other supplies per treatment or per procedure	Film costs and some paper costs are eliminated	No paper order forms; less drugs because most appropriate drugs are picked from the start (with CDS)	Paper and printing costs
Number of procedures	Less test duplications		Less lab and radiology test duplications
LOS and number of outpatient visits	Speeds up diagnosis	Less adverse drug events; more effective drugs and procedures prescribed	Speeds up diagnosis and treatment through instant availability of patient information; CDS helps choosing most effective treatment
Re-admissions and LTC needed		Less adverse drug events; more effective drugs and procedures prescribed	CDS helps choosing most effective treatment, disease management tools
Malpractice litigation costs		Fewer medical errors, insurance discounts for CPOE use	Better documentation protects high-quality providers
Floor space	No need for film storage space		No need for paper records storage space

HIT investment has both immediate as well as long term economic and strategic elements. For example, the Kaiser healthcare system states that their clinical HIT system is "a key element of Kaiser Permanente's long-term strategy to provide market flexibility, regulatory compliance, and the ability to better manage the organization's cost structure by means of the clinical and operational data that the system will generate" (Garrido *et al.*, 2004).

There may be situations where the economic benefits in the short run are not sufficient to justify HIT adoption but that may make sense in the long run. One such scenario relates to the role of quality improvement and quality competition. For some organizations strategic reasons are more important than short-term benefits listed in the ROI planning. Such strategic considerations may include establishing a competitive advantage and progressive image, attracting and retaining clinical personnel, and expectation of changing payment environment towards capitations or pay-for-performance.

Another set of reasons listed in the MRI survey includes meeting regulatory requirements or accreditation standards (e.g. Leapfrog and HIPAA). In a 2005 survey of twenty health care delivery systems conducted by HealthTech and the Monitor Group, chief executive officers (CEOs) overwhelmingly stated their beliefs that hospitals should become more adept at technology innovation and adoption and that technology should play a larger role in their organizations' strategy (HealthTech, 2005).

3.4 Implementation Barriers and Costs of HIT Adoption

While there is some uncertainty regarding the costs of HIT related to changing technology, learning process, obsolescence and long term supply from a specific vendor, the estimation of major part of the costs is relatively straightforward and direct with regard to the HIT investment decision. The costs of adopting most components of HIT systems include both immediate up-front costs plus on-going operating costs. Up-front costs are generally much higher than annual on-going operating costs and include both software and hardware acquisition costs plus implementation costs, which for some systems can be quite substantial and can be incurred for several years after the purchase. For the most part these up-front costs cannot be recovered and are considered sunk, especially non-pecuniary “learning” costs. On-going operating costs are the annual recurring costs of running the system, maintaining the system and updating the system.

Despite many good reasons to adopt an EMR system, many organizations face considerable barriers that make them delay their decision. The most notorious barrier is the lack of a strong business case (ROI) for quality-enhancing applications like EMR or CPOE. The MRI report (2004) provides information on the perceived barriers to EMR system adoption and implementation, lumping together hospital and ambulatory respondents. The majority of respondents mentioned the lack of adequate funding or resources as a barrier to adopting an EMR system, confirming the conventional wisdom and opinion of the experts on this subject. The same barrier tops the list in the HIMSS CIO survey (2004). A well-known HIT expert, David Blumenthal, also says that major barriers to the HIT adoption on the organizational level include a lack of a trained health IT workforce, "timidity among leaders," and a lack of both accountability and "surplus capital"(Blumethal and Rosenbaum, 2006). High acquisition and implementation costs and uncertain financial pay-offs make decision-makers wonder whether the investment will pay for itself within a reasonable time period. Without projected positive ROI for at least 5 years it can be difficult to receive the approval for the investment from the hospital’s board.

Even when the expected financial benefits of an investment exceed its costs, it could be difficult to raise the sufficient amount of capital upfront. Hospitals generally derive capital for the investment from their profits or bonds, which could be unattainable for a financially unstable hospital or hospital system. Hospitals are relying more on earnings from operations to finance capital investments, which makes technology acquisition more challenging for low-margin institutions (HFMA/GE Healthcare Financial Services, 2004). Moreover, capital budget is often torn between many urgent needs, such as hiring more nurses or buying a new CAT machine. In addition, successful implementation of a complex EMR system also requires slack labor resources. Not only is experienced healthcare IT staff is short supply right now, but there is also a need for extra clinical personnel during the implementation phase, when learning takes their time and decreases productivity. Most HIT systems especially EMR and CPOE, may have an adverse effect on productivity during implementation and learning period, which adds to the costs of implementation and provokes users' resistance.

In addition to concerns about resources that are necessary for an investment, there are a number of technical challenges. Implementation of an integrated enterprise-wide EMR system is not as easy as installing one separate EMR application. Usually hospitals (or other providers) already have disparate IT systems and applications that constitute their IT infrastructure. A truly integrated EMR system requires communication between many clinical and administrative applications, which could be difficult to obtain due to lack of standards. Often, a major part of the old HIT infrastructure has to be replaced in order to achieve integration with a new EMR system. The respondents of an MRI survey among the top barriers quoted difficulty in finding an EMR solution that is not fragmented across vendors or IT platforms. Additional concern is the uncertainty about which technology and vendor will be sustainable in the future, as a condition for future upgrades and integration into regional information networks.

Some systems on the market offer insufficient functionality or ease of use. EMR systems may not be flexible enough to serve the needs of different department and providers within the same organization, and many healthcare systems follow the "best of breed" approach buying different software components and integrating them in-house (e.g.. Maimonides Medical Center, 2002), while others find one vendor that can adapt their system for the needs of a particular organization (e.g. Epic for Evanston Northwestern and Kaiser). As the market matures, these problems are likely to dwindle.

User acceptance issues were broadly cited as a top barrier for adoption of CPOE and EMR in healthcare organizations (Brailer and Terasawa, 2003). In the early days, there was a perception that the reason for the resistance came from a physician's "fear of computers" and his addiction to handle information on paper. Now, when computer literacy has increased, physicians' resistance mostly depends on ease of use of an application. Physicians still dislike applications and new workflow procedures that require spending more time on information inputting (especially true in the case of CPOE), even if this means safer care, and could save overall labor costs in the future. Also, physicians could be afraid of loss of autonomy, because integrated EMR systems provides administration of a healthcare system with information on physician's pattern of care, compliance with the guidelines, etc. This information will allow administration to better monitor the care that physicians deliver and impose their rules.

3.5 Economic Model of Hospital Adoption Decision

Although adoption decision making in hospitals includes many complex and interacting factors, it is useful to simplify it to a formal economic model. As I mentioned in the section 3.2, a hospital or rather its decision-maker could derive utility from the short-run profits, strategic position of the institution, and/or clinical excellence. Hospital adoption decision probably involves all these factors, but their importance varies amongst the hospitals of different types.

The profit dimension of the decision is captured by ROI or financial cost-benefit analysis of the HIT investment that most providers usually perform to justify costly investments. This involves calculating the present value of financial benefits and present value of the costs of an HIT investment over the investment period, while the difference between benefits and costs makes up a net present value of an innovation: present value of benefits minus present value of costs. Usually, the time horizon, over which monetary benefits and costs of clinical HIT are assessed, spans from five to ten years for the majority of hospitals. The return on investment (ROI) calculation shows a magnitude of returns by dividing the net present value of an investment by its total costs. In the case of clinical HIT, and especially EMR and CPOE, the expected stream of financial benefits from efficiency and quality improvement greatly depends on the reimbursement model. The resulting net present value of an HIT investment could be positive, justifying the investment on the ground of its financial returns alone, or negative. However, in many cases healthcare providers do value improving quality and strengthening strategic position of the organization that don't have obvious financial returns, and are willing to pay for it. These are different from the financial benefits that hospital can derive from improved quality or strategic position in the short run, as they are incorporated in the calculation of the financial returns. The basic decision rule could be represented with a simple formula, where the sum of financial benefits (B), quality-related and strategic benefits evaluated in monetary terms has to be bigger than the costs of HIT investment:

$$\mathbf{B + \beta Q + \gamma S > C \quad (1)}$$

, where **β** and **γ** are the value factors that transform the vectors of different quality-of-care and strategic benefits of HIT into how much hospital decision-makers would be willing to pay for them. Alternatively, this formula could be converted in ROI-like calculation by dividing both sides by total costs. One can imagine that some specialized for-profit hospitals may not value quality-improvement benefits if they don't transform into financial rewards (β close to zero), while some non-profit religious hospital would be willing to pay just for improving patient safety (high β). It is also possible that some county hospitals that provides indigent care don't value improved market power at all (in this case **γ=0).** In the simplest case, when a provider cares about neither quality nor strategic benefits, the decision turns into cost-benefit analysis with a condition of discounted financial benefits exceeding discounted costs of adoption.

The complexity of the investment decision is often exacerbated by the uncertainties present in the financial, clinical and strategic gains of an HIT adoption. It is a common assumption that large companies are risk neutral, which could refer to the large integrated multi-hospital systems. In this case, expected values of benefits and costs are taken into account in the investment decision.

Formula (1) is a necessary condition for HIT adoption, but it may not sufficient. In cases when there are many investment options ROI of clinical HIT investment should be not only positive, but also higher than the alternative use of capital, which transforms the decision rule:

$$\mathbf{B_{HIT} + \beta Q_{HIT} + \gamma S_{HIT} > C_{HIT} * (1 + ROI_{ALT}) \qquad \{2\}}$$

Another way to represent this formula is that economic returns have to be positive, where economic returns are net of opportunity costs.

Hospitals have many urgent needs that require major spending, such as buying new surgical equipment or hiring and retaining enough nurses. If capital required for HIT investment takes a small part of the overall hospital budget and all other important uses for capital are realized, then alternative ROI is probably as low as the interest rate. However, the higher share of the capital budget is required for an HIT investment, the more it could interfere with other important projects and their potentially high returns. It is a realistic assumption that the opportunity cost of the capital (ROI of alternative investment) increases when the amount of capital needed for HIT investment approaches total capital available to the hospital.

The time it takes to achieve break-even status on the monetary side is influenced by heavily front-loaded costs, while the bulk of the financial benefits are back-loaded. Thus, the decision very much depends on the time period over which costs and benefits are assessed. For a median community hospital the acceptable time period to pay off a major investment is from five to seven years. A sophisticated integrated clinical HIT system often takes more than that, even in the large and capitated healthcare systems, which are best positioned to collect benefits from efficiency and quality improvement due to HIT. For example, it is projected that Kaiser's clinical HIT investment will take 8.5 years to break even (Garrido et al, 2004).

Many hospitals can raise only a limited amount of capital necessary for the initial HIT investment ($\mathbf{C_I}$), which adds a constraint:

$\mathbf{C_I \leq C^*}$ **-** where C* is the maximum amount of capital that an organization can devote to an HIT investment. Since most hospitals finance their HIT investments from their operational revenue, C* is likely to depend on the size of hospital patient revenue and contributions. The data used in a RAND report suggest that the costs of EMR system acquisition are more-or-less linear in operating expenses, and range from 1.8 to 3 percent of hospital total expenditures (Girosi, 2005).

Another restriction is whether a hospital has enough organizational capacity to deal with an implementation hassle, such as user resistance and strain on the labor resources during the implementation period. The condition is represented by $\mathbf{O_I < O^*}$.

The level of organizational resources (in addition to the costs of implementation) required for implementation of an advanced HIT system ($\mathbf{O_I}$) depends on the complexity of the organization and the services it delivers, and the complexity of its current information infrastructure, the level of computer literacy and technology acceptance by its intended users. The maximum organizational resource available (**O***) is limited by the expertise of its leaders, availability of slack labor resources and organization's experience in implementation similar investment projects. **O*** can possibly be increased by hiring more clinical and IT staff and outsourcing project management to a consulting company with a great deal of experience, but it does not happen immediately and has to be planned for.

If all the constraints are satisfied in a given year, an organization may still prefer to postpone the investment if they expect a decrease in cost or increase in benefit that is big enough to exceed the opportunity cost of a one year delay in implementation.

3.6 Costs and Benefits of HIT Adoption Vary Across Provider Organizations

The model predicts the obvious: A healthcare organization with higher net benefits of adoption and/or lower cost of adoption (**C**) will adopt sooner. The value of costs and benefits that a hospital derives from clinical HIT adoption differ among the providers, depending on their size, type, patient mix, payer mix and the reimbursement methods used by different payers and characteristics of the hospital's market.

Similarly, organization with higher maximum investment capital (C*) or organizational capacity (Q*) will adopt earlier, everything else being equal. Financial and organizational capabilities of a hospital to adopt a sophisticated clinical HIT system are also related to hospital's characteristics, such as payers mix or academic status.

Generally, quality and safety benefits of HIT adoption, as well as potential strategic benefits of HIT adoption are more pronounced than the financial benefits from improved efficiency and quality of care due to HIT. Therefore, hospitals that put higher weight on strategic benefits from HIT adoption and clinical excellence would have higher utility of adoption, and will adopt sooner. Mission-driven hospitals that emphasize high quality care might adopt quality-improving technology, even if it doesn't pay for itself. Non-profit hospitals could be more willing than their for-profit counterpart to sacrifice profits for such a mission. Moreover, improved reputation due to quality-improving technology, such as CPOE, might help them attract more donations. This is even truer in the case of academic hospitals, which derive additional benefits from sophisticated EMR systems to support their research function and build their reputation. Academic hospitals also receive additional grants and public support which improves their financial capability (C*) to have discretional investments.

Most of the sophisticated HIT systems have economies of scale in some dimensions – while their acquisition costs do not differ dramatically with the size of the hospital, their efficiency benefits usually scale by the patient volume (e.g. PACS). For example, the more radiology tests the hospital does (especially on the outpatient side), - the more savings will materialize when the PACS system is installed.

For this reason, large hospitals would be more inclined to adopt clinical HIT. Further, acquisition costs per hospital could be reduced in a hospital system, when the system can purchase multi-site licenses at a discount. At the same time, larger hospitals and hospital systems have more complex healthcare services and existing IT architecture, which can make its implementation and integration a cumbersome and costly enterprise (increasing $\mathbf{O_I}$ and $\mathbf{C_I}$). Capital costs also depend on how developed is the hospital's current HIT infrastructure, and how easy it is to build interaction between a chosen software and current systems.

It is a reasonable assumption that sophisticated clinical decision support in CPOE and EMR is especially valuable in the care of complex and very sick patients, where the risks of medical error and wrong treatment are particularly high. Thus, hospitals that treat more complex patient mix might be more inclined to adopt a clinical HIT.

The costs of implementing HIT also depend on hospital's implementation capacity (O*). High-end hospitals, such as such as academic hospitals, may have experience of other complex innovations, large IT departments, and the clinical staff that is more open to changes. In such an environment, fewer resources are spent on learning and persuasion of end-users, and more technical problems can be resolved in house. In contrast, hospitals with insufficient implementation capacity are likely to be laggards, and may need special policy incentives.

Usually, the productivity of clinical staff falls during training and implementation of the system, when they devote their time to learning the new system and processes. For this reason, hospitals and practices that constantly operate at their full capacity may put off complex investment even when they can afford it financially. One can also expect that provider organizations with limited capital as well as smaller organizations would lag in adoption of EMR Systems because of the large fixed cost of such an investment.

Financial capability (C*) of a hospital is related to its payers mix – e.g. reimbursements for Medicare and Medicaid patients are usually lower than that for commercial patients. Hospitals with a less favorable mix of payers will have less financial resources on an ongoing basis to finance the substantial initial investment, as well as the ongoing operating costs of HIT, such technical support, continued integration and education that can run upward of 1-2 million dollars per year. In general, hospitals with easy access to capital can adopt more sophisticated HIT earlier, since they have less of a constraint on their capital budgets and can afford the risk of early adoption. Access to capital is related to how profitable the hospital was in the recent years, and other financial characteristics.

In the local markets, where hospitals share patient populations with other hospitals and physicians, network externalities may be present – hospitals derive higher value from

EMR adoption when others do the same. Hospitals can overcome coordination failure when they form a local healthcare system or network, and can decide on common adoption of compatible EMR systems and communication infrastructure. Connectivity benefit is especially relevant for the local integrated delivery system with multiple sites, such as Mayo clinic, which named the need for fast patient information exchange as a major driver for their investment in EMR system. Potential inter system referrals may be greater in local systems and thus sharing data on the same patient has greater value (RAND, site-visit interview).

Various clinical and efficiency benefits may or may not translate into financial returns (**B**), depending on a variety of factors related to organization and its environment. Hospitals may lack incentives to adopt clinical HIT, because quality of care is not systematically measured and is not fully rewarded in the healthcare marketplace. Currently, while there is intense price competition amongst hospitals in some markets, quality competition is much more limited. The reasons for the lack of quality of competition are not well understood but are generally tied to lack of incentives and absence of information on the part of patients. In the absence of quality competition, where hospitals with higher quality could charge higher prices, the incentives to adopt expensive HIT systems are limited. Ironically, a broad adoption of electronic medical records systems and evidence-based care standards could enable universal measurement and comparison of quality of care across hospitals, and allow for its reimbursement. However, there is a growing policy focus and interest on providing economic incentives to spur quality competition and improvement. This is seen in terms of increasing use of "pay for performance" reimbursement programs as well as related to the growth consumer directed health plans which provide consumers with incentives to shop for both price and quality.

To the extent that quality competition continues to grow, hospitals that invest in HIT systems early will be in a better strategic position to compete successfully on both price and quality. A hospital's assumptions regarding the role of quality competition in the future may depend in part on the hospital's current operating environment. Hospitals facing more competition today with more of their revenue covered by capitation may be more likely to envision a future health care system where managed care, capitation and quality competition are increasingly important market factors. Such hospitals could be interested in adopting HIT to both strengthen their strategic market position in a quality competitive market and be able to capture more of efficiency savings under capitation.

Market competition provides mixed incentives on quality improvement initiatives, such as clinical HIT adoption in hospitals. Feldstein (2005, p. 287) provides two conflicting views on competition effect on quality:

1) Health plans compete on their premiums as well as their provider network, which would include those hospitals with good reputations and that perform a large volume of complex procedures. If competition decreases, hospitals will have greater market power to increase prices, and would be less responsive to purchaser demands for quality. When the health purchaser is not interested in quality, then the HMO has an incentive to select the lowest priced hospitals.
2) Critics of price competition are concerned that in a price-competitive market, hospitals will be forced to compromise quality in order to compete on price. Only in more concentrate markets, hospitals will be able to raise their prices and have the necessary funds to invest in higher quality

On one hand, hospitals in more competitive markets face pressure to be more efficient and as such may have a greater incentive to adopt a cost saving HIT system. The market structure and the pressure that the providers face to control their costs may translate general efficiency improvement into dollars. With the growth of managed care and price competition, some hospitals are under greater pressure to control their costs in order to compete effectively on price in securing managed care contracts (e.g. reason cited by Maimonides[i]). Hospitals that are located in markets with greater competition and higher managed care penetration are more likely to feel the need to become more efficient in order to control their costs in a price competitive environment. Hospitals in less competitive markets or in markets with less managed care penetration may be able to charge higher prices and as such may be less willing to invest in expensive HIT systems that offer uncertain economic payoffs.

On the other hand, if quality-improving clinical HIT reduces profits through the costs of implementation, it could undermine price-competitiveness of a provider (to the extent that quality of care doesn't pay off). In addition, hospitals in less competitive markets and especially those with higher market shares may be able to charge higher prices over the long run and thus have increased financial capacity to adopt HIT. A different argument implies more opportunities for care coordination with HIT in the concentrated markets. When a hospital serves a large share of all patients in its market area, the opportunities to establish networks with local physician are also greater and more effective especially if local medical groups are wired and they all share patient clinical information.

3.7 Financial Returns on Clinical HIT Investment Depend on a Reimbursement Model

Efficiency improvements from HIT investment may or may not increase hospital revenues, depending on hospital's mix of reimbursement methods. Sophisticated clinical HIT systems that improve treatment outcomes, patient safety and reduce length of stay may generate benefits for patients and payers, which do not translate into higher revenues for the hospital.

Under traditional fee-for-service reimbursement, hospitals are paid for the number of services they provide including inpatient days, radiology and lab tests and medications administered. For example, CPOE adoption has been found to reduce medication errors, which can benefit patients in terms of reduced length of stay, reduced probability of readmission, improved likelihood of faster recovery and reduced pain and suffering from adverse effects of medication errors. Under fee-for-service arrangement, the net benefits of CPOE to the hospital are neither immediate nor straightforward: CPOE can reduce medical services by preventing complications and adverse drug events, reducing use of expensive drugs and procedures and decreasing length of stay – all resulting in a negative or zero impact on hospital revenues.

Most managed care plans currently pay a fixed negotiated price for each day of inpatient care (per diem rate). In this case hospitals may benefit from technologies that decrease resources spent per patient-day, such as eliminating duplicate procedures and allow them to substituting low cost drugs and tests for higher cost ones. However, when clinical HIT improves workflow efficiency and shortens patient's length of stay, the hospital may lose money. Marginal cost of an extra patient day usually goes down with an increase in length of stay. For example, Carey estimated cost elasticities of average length of stay in the range of 0.09 to 0.12. Taheri et al. reviewed cost accounting system records from a single academic medical center, and found that variable cost of the last full day of the hospital stay averaged only 2.4 percent of total cost for patients with lengths of stay of four or more days. While costs of additional days fall, marginal revenue of an extra patient day under a per-diem rate, stays the same, resulting in higher profits from longer stays. Reduced days per admission may be used to attract more patients, or could be lost completely if the demand for the hospital's services is not very strong. In the latter case, length of stay reduction can be particularly unprofitable for the hospital under per-diem reimbursement. Thus, in the hospitals with higher market power resources that become available with reduced LOS can be used productively for new patients.

Traditional payment for Medicare patients involves a flat per admission payment that differs across DRGs (diagnosis related groups). Under DRG-based payment the hospital does have an incentive to provide the least costly care for each admission, and reducing length of stay should potentially increase profit. However, DRG-based payments do not provide incentives to reduce patient readmissions or expensive long-term care that can follow the discharge. In theory, per case payment allows hospital to capture a large part of the benefit due to internal efficiency improvement. However, reimbursement levels for Medicare and especially Medicaid patients may be lower than they are for commercially insured patients which may constrain the financial capacity of the hospital to support costly HIT investments.

In general, the broader the unit of service under which the hospital is paid, the greater the share of benefits that will accrue directly to the hospital. Currently, the broadest measure used in the US is capitation, which pays hospitals a fixed amount (per month) for assuming the risk of all a patients' medical (hospital) needs. Under this arrangement, any HIT related quality or efficiency improvements that lead to reduced hospital resource use, such as length of stay and readmissions, translate directly into cost savings that are more fully captured by the hospital. Thus, hospitals that have a higher share of their patients covered by capitation would have greater incentives to adopt HIT systems. On the other hand, capitation might jeopardize hospital's financial capacity, if a hospital has sicker patient population covered by this agreement, spending more resources than its capitation revenue. Capitation plans may include both commercial and Medicare/ Medicaid patients.

Effects of different reimbursement models on revenues from HIT adoption are summarized in Table 3.2:

Table 3.2

Efficiency Improvements due to Clinical HIT Systems and their Financial Impact on Hospitals

Effect of HIT	**HIT with largest impact**	**FFS / Out-patient**	**Per diem (managed care)**	**Per case / admission (DRG)**	**Capitated Payments**
Reduced cost per billable procedure (e.g. radiology test); improved general efficiency	Mostly PACS, and some EMR	+	+	+	+
Less expensive tests and medications substituted	Mostly CPOE with EMR	- / 0	+	+	+
Reduced number of tests, drugs and procedures	EMR and PACS	-	+	+	+
Reduced Length of Stay	Mostly CPOE, some EMR and PACS	-	-	+	+
Reduced readmission rate and long-term care needed	Mostly CPOE	-	-	-	+
Code capture through better documentation	EMR, with PACS and CPOE	+	0	0/+	0
Better treatment outcomes, reduced pain and suffering	CPOE and EMR, some PACS	0	0	0	0

Reduction in the length of stay makes a sizable share of potential monetary benefits of HIT in a capitated system. Kaiser implements an integrated clinical HIT system including EMR, CPOE and PACS components and claims that about a third of the projected financial benefits will come from LOS reductions due to faster processes and fewer medical errors (Garrido et al, 2004). LOS reduction benefits are unattainable for a median hospital with over half of its patients paid on a fee-for service and per diem basis, and even can reduce its revenues.

Some HIT systems are more sensitive to reimbursement models than the others. Most PACS ROI come from reduced cost of radiology test, although it also produces some savings in LOS, and test duplication. For this reason PACS is equally profitable across all reimbursement models. In contrast, large part of EMR and CPOE benefits is their effect on length of stay, which makes them less profitable under the most common managed care reimbursement – per diem.

3.8 External Benefits and Costs of Clinical HIT

The previous section pointed at an important barrier to widespread HIT adoption – practicing cost-efficient health care with the help of HIT providers may experience a loss of revenues. Bigelow *et al.*, for example, show that HIT-enabled disease management and prevention may result in annual revenue decreases of $51.7 billion for hospitals, $11.6 billion for physician services, and $13.5 billion for pharmacies. At the same time the resulting health benefits that patients and their payers enjoy are evaluated at approximately $147 billion (Hillestad et al, 2005). Similar pattern arises with applying HIT and personal health care records to enhance patient self care. RAND studies identify an important factor affecting hospital adoption of HIT – providers must incur the full cost of adopting HIT systems but they do not capture all the benefits.

Although inpatient HIT adoption is performed by a hospital or hospital system, other parties in the healthcare system enjoy benefits or endure costs of this decision. HIT helps to improve efficiency of care and achieve better treatment outcomes that reduce the need for care (LOS, readmissions, long-term care). This benefits the payers, allowing insurance companies or CMS to save money they used to pay for excessive care. At the same time, the adopting hospitals, long-term care (LTC) facilities and hospices may lose money treating fewer patients, especially when they have excess capacity.

The benefits that a clinical HIT system delivers depend on the way it is implemented. The hospitals have a financial interest in using their HIT systems in order to increase the code capture and speed-up claim submission, rather than to improve quality and even efficiency of care. Potentially, insurance companies could lose money from increasing billing levels that come with better information capture by EMR. However, often claims with missing information go back and forth between the provider and the payer generating excessive administrative expenses on both parts. In such case having complete information to support the claim would save some money for insurance companies and other payers as well as for the hospital.

Better treatment outcomes, aside from the change in the amount of care provided, benefits the patient and, through increased productivity, his employer, but makes no difference to the hospital or to the patient's current insurance plan. A patient's health, however, could affect his future healthcare spending, which will be picked up by Medicare when (and if) one reaches 65.

In ambulatory care, better prevention and disease management enabled by good EMR system helps to avoid costly hospitalizations (Bigelow and Fonkych, 2005). Usually, disease management requires more ambulatory or on-line visits, but helps to prevent avoidable hospitalizations. If hospitals belong to a different system than ambulatory office with an EMR, they lose revenues due to disease management and prevention activities. Savings accumulate to the entire system only when ambulatory offices belong to the same hospital system. Disease management helps insurance companies to save money, because the cost of avoided hospitalizations is usually higher than the costs of disease management. Also disease management allows pharmacies to get more revenue due to higher drug utilization. From utilization to reductions in the total cots of care, patients enjoy better health outcomes and avoid pain and suffering.

Clinical decision support embedding in CPOE helps to choose less expensive or more effective medicines, in both inpatient and outpatient setting. This could save the payers some money, but could limit the sales of substitutable brand-name drugs, promoted by the pharmaceutical companies.

Exchange of patient information across settings and complete patient records in-house allows avoiding the duplications of some lab tests and radiology studies. It saves money for the payers, and time for the patients, but imaging or lab centers may lose some revenues.

On-line visits, having complete patient information, online refills, and other options available with advanced clinical HIT capabilities could help to avoid many redundant ambulatory visits. Under current reimbursement rules, the doctors generally lose from this arrangement, while insurance companies accumulate savings, and the patients save time.

3.9 Who has to pay for HIT adoption and connectivity in the presence of market failures?

The above examples demonstrate that a provider does not capture all the gains from its HIT adoption unless this provider belongs to a system with full capitation (e.g. Kaiser). The patients and their employers who pay for health insurance are the ultimate beneficiaries of improved quality and efficiency of care. In the short-run, insurance companies could benefit from improved efficiency of care, although in the long run they would pass savings to the employers or patients, who pay for the insurance (given competition in the insurance markets). Eventually, CMS is responsible for everyone's healthcare after the age of sixty five; therefore improved current health of future Medicare's beneficiaries may produce savings in terms of lower utilization when they become eligible for Medicare.

In a competitive market with full information, payers would reward the providers for the benefits that HIT brings them either 1) indirectly, by rewarding lower prices and better quality, or 2) directly, by financing the HIT investment. There are several reasons for why that may not work.

Normally, market forces reward efficiency improvement because cost savings allows sellers to lower the price, and in the long run, lower prices attract more customers.

Better quality of the products also attracts more customers and/or allows premium payments for the higher quality. However, healthcare output is difficult to price adequately. For example, per diem reimbursement policy punishes for the reduction in the length of stay, which does not allow lowering the price per day of care as a product of higher efficiency.

Higher safety and quality of care also have a limited effect on the number of customers or better prices, because patients and payers do not possess enough information on quality and safety of care in order to make an informed choice. So far, there is no systematic measurement of quality of care across the providers, and an insurance company faces known price but unknown quality when it chooses its network provider and negotiates prices. Given a hospital's trade-off between higher quality and lower price, an insurance company may actually discourage high quality of care by negotiating lower price and making the hospital compromise on quality.

The correction of these market failures could improve incentives for the adoption of technologies that enhance quality and efficiency. The payers could change their reimbursement policies so that they reward better quality and efficiency. For example, pay for performance initiative is becoming more popular among many payers and providers, and could be helpful in stimulating HIT adoption. Healthcare systems that serve the community with full range of services under a global capitation arrangement provide a perfect market solution, because they internalize most of the external benefits of improving healthcare quality and efficiency, such as through an HIT adoption. The government can play the role in stimulating the emergence of Kaiser-like systems.

An alternative market-based option involves direct payer's contribution to the HIT investment, as long as clinical HIT systems are expected to deliver higher efficiency and quality of care. Until recently providers were cautious, because there wasn't enough consistent evidence on the quality and efficiency gains of clinical HIT and their effect on payers. Recently, a number of studies were published that addressed this concern by calculating overall effects of HIT (Hillestad, et al, 2005). Another concern that the payers rightfully share is that the healthcare providers may use HIT to improve primarily charge capture rather than the efficiency and quality of care and safety, which aligns with the financial self-interest of a provider. However, the most important potential explanation for the lack of payer contribution is free-riding behavior on the part of the payers. Usually, there are many payers in every hospital or healthcare provider, and each hopes that someone else will pay for their HIT investment. Most often the fingers point at the federal government. This apparent public good problem requires cooperation among the payers in financing their part of an HIT investment. RHIOs are a good vehicle for this potential cooperation. To ensure that HIT systems are used in a way that improves quality and efficiency, payers could demand quality monitoring enabled by HIT in return for their participation in the investment.

CMS, as a single largest payer responsible for a good half of the healthcare delivered, could lead the cooperation of multiple payers and pay a major part of the HIT investment. Matching subsidies is a possible tool to stimulate contributions from other payers. Because of a limited CMS budget, it is important to identify and subsidize the providers that bring high value from social perspective but lack the access to capitals and sufficient internal ROI from HIT investment.

3.10 Summary of HIT Adoption Factors and Potential Policy Levers

Sophisticated clinical HIT systems and information exchange networks are disruptive innovations. They cause major transformations in the adopting organizations and their market environment, which are challenging both to finance and adjust to. Sophisticated HIT systems capable of delivering all the aforementioned clinical and efficiency benefits is rarely achieved through incremental changes to existing infrastructure. It often requires discarding old HIT systems and processes and developing a new integrated system enhanced with significant workflow changes. For these reasons, technological problems stifled the early diffusion of these technologies. This situation is changing currently.. Standards for information exchange and system's configurations are being developed and are being implemented in the design of the newest HIT systems, making it easier to integrate software components into one comprehensive system. The vendor market has matured to a level where several leaders have accumulated experience and reputation, thereby reducing investment risks for adopters. Certification of HIT systems guides purchasing decisions helping a provider to choose appropriate system. These latest changes make it adoption much easier for those provider organizations that lack technological expertise. Government support of certification and standardization in HIT markets remains an important condition of the fast development of HIT market.

User acceptance of HIT systems is improving, as clinicians are becoming for familiar with IT and its applications in healthcare, and aware of its clinical value. Fear of supervision and additional time demands remain important issues that threaten user acceptance of the technologies, especially CPOE module, and healthcare organizations have to tackle them by involving physicians in the adoption and implementation of HIT, as well as by education on HIT benefits.

In a current stage of HIT diffusion, most of providers that are highly interested in quality and strategic benefits of HIT adoption and have slack organizational and financial resources for such investment have already adopted sophisticated clinical HIT. For the rest of the provider population, the feasibility of capital and the lack of measurable ROI remain the major obstacles to widespread HIT adoption. Capital availability for a major investment could be a real problem for small and financially unstable provider organizations, such as hospitals that treat high share of Medicare, Medicaid and, especially uninsured patients, community clinics, etc. Policies can improve access to capital, e.g. low-rate government-sponsored loans offered specifically for modernization of HIT infrastructure. Empirical analysis of HIT adoption in Chapter 4 helps to identify the potential targets for such loans and subsidies. The lack of organizational resources for HIT project planning and management may be difficult to compensate even with available capital. Pulling organizational resources of different providers in the community may help to reduce this barrier, and RHIOs could serve as vehicles of such cooperation.

Adopting providers do not receive sufficient ROI on their HIT investment because a large part of the resulting efficiency savings accrues to payers and quality improvement is not sufficiently rewarded. Payers have to cooperate and contribute their fair share to the HIT investment. As a condition of their participation they can require to produce data produced with HIT systems that can demonstrate quality and cost of care delivered. Availability of this information will strengthen a market for quality and efficiency in healthcare, enabling payers to differentiate their prices and payer network based on demonstrated quality and efficiency.

Fragmentation of American healthcare gives a rise to network externalities. Each separate provider would benefit from information exchange with other facilities in the same market, which would be possible only if a majority of them adopts clinical HIT. Local multi-provider healthcare systems with hospitals and ambulatory offices in the same market can internalize the externalities with coordinated investment in HIT systems and their connectivity. However, individual providers in large healthcare markets do not have this advantage and need to coordinate their investment with other healthcare providers. A question remains whether competition can play the same stimulating role in the diffusion of efficiency-enhancing technologies as it did in other industries. RHIOs involve cooperation that is necessary to establish information exchange among different, often competing entities.

Table 3.3 summarizes the factors of adoption, as well as providers and markets most affected by them and corresponding potential policy levers. Chapter 4 provides empirical evidence on the influence of these factors, and suggests which providers are most disadvantaged and may need additional incentives or subsidies for adoption.

Table 3.3

Summary of HIT adoption factors, and corresponding policy levers

Barriers & Costs	**Organizations and Systems affected**	**Current Development**	**Policy levers**
User acceptance	EMR among affiliated or staff ambulatory physicians, CPOE in any organization	Computer literacy increases; ease of use improves	HO: Incentivize or mandate use; explain, monitor and advertise the benefits;
Integration of disparate HIT applications	Large, multi-service and multi-site providers	Standards are being developed; vendor market matures	G: Standardization
Insufficient functionality	Large, multi-service and multi-site providers	Vendor market matures	G: Certification
Feasibility of capital	Small and financially unstable organizations: disproportionate share of Medicare and Medicaid, community clinics, etc.	On average, hospitals gained more market power and increased profits Loans and grants are becoming available	G: Loans and subsidies for problem providers
Availability of organizational resources	Small, rural, non-academic providers		G and I: RHIOs and other community initiatives that help pull resources together and spread experience from those who already adopted
Network externalities	Independent providers in multi-provider areas	Growth of regional multi-provider HC systems; development of RHIOs	G and I: RHIOs and other community initiatives; policies targeting non-adopting systems; build RHIOs around HC systems
Insufficient ROI, because:			
- large part of efficiency savings accrues to payers	High share of FFS and per diem reimbursement, less capitation	Less capitation; but more pay-for-performance	Payers: should pay for efficiency-enhancing features, or pay for performance; Subsidies from major payers,

			especially CMS with condition to produce data on cost and quality
- quality improvement not rewarded	All	Anticipated accountability for low quality/safety.	Enhance quality competition by developing measures of quality; Measure with EMR e.g. measure guideline compliance; Pay for performance; Malpractice discounts when complete documentation and CPOE
- economies of scale couldn't be achieved	PACS in small hospitals/imaging centers	hardware and software price is falling slowly	Pulling resources together through RHIOs; multi-site discounts; Subsidies
G –government I – healthcare Industry HO – healthcare provider organizations Private payers – insurance companies, as intermediaries for the final payers (employers and patients)			

CHAPTER 4: EMPIRICAL ANALYSIS

Policymakers and experts often suggest policies designed to stimulate HIT adoption, which are based on their assumptions about the factors important for adoption. Another proposed set of potential policies offers subsidies or other incentives that target a group of providers with particularly small chances to adopt EMR and other clinical HIT systems.

This chapter provides the analysis of the HIT adoption pattern in various types of hospitals and office practices, using the HIMSS database, AHA survey of hospitals, and other data sources to answer two questions:

3) "What types of hospitals are less likely to adopt HIT";
4) "Which factors may influence the adoption of HIT."

4.1 Data and Methodology

The source of data on adoption is the HIMSS database for 2004, which covers nearly 4,000 acute care community hospitals in the United States (three quarters of the total number) and all physician practices owned by hospital systems. The dataset includes all acute care non-federal hospitals owned or managed by hospital systems and all free-standing hospitals that are larger than 100 beds in the US.

Although the HIMSS survey contains data on the adoption status of more than 45 administrative and clinical software applications, this analysis focuses on adoption of major clinical HIT systems, which were defined and measured in the preceding chapter: Inpatient CPOE and radiology PACS systems, outpatient EMR, as well as a composite measure of clinical HIT sophistication in hospitals (HIT scale that goes from one to five). As was mentioned in Chapter 2, inpatient EMR system is not measured directly in the dataset. Instead, high likelihood of having an integrated EMR system is reflected by being in the category 4 or 5 of HIT sophistication scale, and labeled as **"Top HIT"** variable in this chapter. In some cases a less reliable (see Chapter 2) **"Basic EMR"** measure is provided for comparison, which represents the adoption of major software components of an EMR system: Computerized Patient Record, Clinical Data Repository and Clinical Decision Support (see Chapter 2 for details).

The HIMSS dataset also includes basic demographic information at the hospital level, and some detailed characteristics of the hospital systems, such as financial characteristics, revenues by payer, etc. To provide additional demographic information, HIMSS dataset was merged with the AHA dataset (2002). A total of 3,660 observations were merged successfully, although about 300 of them had missing observations for most of the HIMSS data.

Because of the structure of HIMSS data, all absolute HIT adoption rates reported in this chapter apply only to the hospitals or physician practices owned or managed by systems, or independent hospitals that are larger than 100 beds. The absolute adoption rates in this chapter slightly overestimate the adoption in the entire hospital or physician practice population (see Table 2.2). However, with this caveat, relative differences in adoption between different categories can be applied to the rest of the population.

Adoption status is measured by whether a hospital signed a contract with a vendor to buy an HIT application ("contracted"), has an application already installed ("automated"), or didn't adopt it at all ("not automated"). For the purposes of this analysis "adoption" includes either contracted and/or automated since including new software contracts in the adoption category better reflects hospital's commitment to HIT adoption and factors associated with it and separates hospitals that have not yet made a purchase decision.

The following hypotheses on the adoption factors are examined:

Hypothetical Adoption Factors	Measurements in the data
Economies of scale make it easier for larger organizations to adopt	Hospital size, ambulatory practice size, hospital system size
Mission-driven hospitals are more interested to adopt quality-enhancing HIT when ROI are not high enough	For-profits versus non-profits, academic and pediatric hospitals
Financially challenged facilities adopt less	Cumulative profits and contributions, equity to assets ratio, share of Medicare and Medicaid patients, contract-managed hospitals
Capitated payment plans provide more adoption incentives	Shares of revenues from capitation and other risk-shared agreements
Hospital systems that can internalize network externalities are more likely to adopt	Local hospital systems versus single hospitals, number of ambulatory care offices linked to a hospital
Adoption may vary by location, e.g. rural facilities adopt less	Rural, large urban area and small urban area location of the hospital
Hospitals that treat more complex patient cases require more advanced HIT	Medicare case-mix index
Competition encourages adoption or market power provides more resources for adoption	Herfindahl index of market concentration

The empirical analysis consists of several sections. First, the review of empirical studies presents earlier findings on adoption factors and organizational characteristics that are related to HIT adoption. Second, a descriptive univariate analysis is conducted with a primary purpose of identifying which types of providers are least or most likely to adopt. Third, multivariate cross-sectional regression analysis is presented, isolating the independent effects of factors responsible for HIT adoption behavior. The differences in the effects of various organizational and market factors on EMR, versus CPOE versus PACS, provide additional insights on the incentives that drive adoption of clinical HIT systems with different types of benefits and characteristics.

4.2 Review of Empirical Literature

Although key policy makers have broadly discussed the gap in the adoption of HIT across different healthcare providers (Brailer, 2005), the published empirical literature on the organizational factors of adoption and effects of HIT systems is quite limited.

Moreover, even a current adoption level of major clinical IT in the hospitals is a subject for major debates (see Chapter 2).

Borzekowski (2002a) examines adoption of the early hospital information systems (HIS) in connection with the payment changes in 70s and 80s. In particular, he shows that hospitals increased their adoption of HIS (hospital information systems) in response to the implementation of Medicare's prospective payment system, possibly because of the additional incentive to lower the costs. Another study by Borzekowski (2002b) measures the impact of early IT use on hospital operating costs during the late 1980s and early 1990s. He finds that the most thoroughly automated hospitals are associated with declining costs three and five years after adoption.

Parente and Dunbar (2001) found that hospitals with integrated information systems have higher total margins and operating margins than those hospitals that do not have integrated information systems. The multivariate regression analysis that Parente and Dunbar conducted showed no effect of HIT on the operating margin, suggesting that healthcare IT had little effect on performance and that the presence of IT could simply be a wealth effect. From a financial perspective, their findings indicate that hospitals with higher cash flows, revenues per bed, and operating margins are more likely than others to adopt healthcare IT systems. Parente and Van Horn (2003) investigated differences in clinical HIT adoption behavior between for-profit and non-profit hospitals, using a total number of software applications adopted as a dependent variable. They found that the marginal effect of IT on for-profit hospital productivity is to reduce the number of days supplied, whereas, in non-profits, the marginal effect of IT is to increase the quantity of services supplied. For-profits are less likely to have an IT system, and, when they do, it is positively affected by the financial position of the hospital. Non-profits, on the other hand, are more likely to have an HIT system, to adopt the system earlier (negative coefficient on the time trend), and to make the investment when they have poor financial performance. Hospitals with a higher Medicare case mix (sicker patients) were more likely to invest in IT. Parente and Van Horn also found that the higher the share of government-financed revenues (Medicare and Medicaid) is the lower is the probability of clinical HIT adoption.

There are virtually no published papers on the effect of market factors and managed care on IT adoption in hospitals. Burt and Sisk (2005) have studied IT adoption among physicians and found that practices with more physicians and those owned by health maintenance organizations (HMOs) were significantly more likely to use this technology, but use varied little by the characteristics of individual physicians, the practice's scope of services, or the practice's sources of revenue.

4.3 Univariate Descriptive Analysis

The Pattern of HIT adoption in for-profit versus non-profit hospitals

The profit status of a hospital is likely to affect its technology adoption decisions, since by definition for-profit hospitals are more interested in a financial outcome of their investments. The analysis of HIMSS data shows that the pattern of HIT adoption differs substantially between for-profit and non-profit hospitals. For-profit hospitals lag behind non-profits in clinical HIT adoption. Only 9% of for-profit hospitals are among top two categories of HIT sophistication scale12, versus 40% of non-profits in the same category.

[12] Top two categories of HIT scale imply adoption of either PACS or CPOE systems, and high likelihood of having an integrated EMR system.

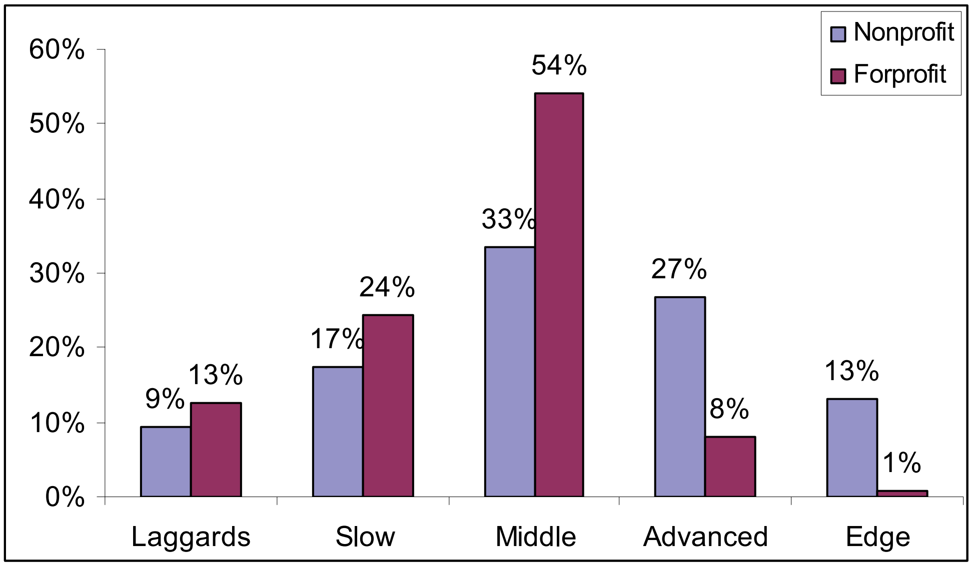


Figure 4.1: Distribution of non-profit and for-profit hospitals on clinical HIT sophistication scale

Basic EMR and PACS adoption rates in for-profits are as much as half the rate of adoption in non-profit hospitals, and CPOE adoption is one-fifth the rate of adoption in non-profit hospitals. The dynamics of their adoption also differs: Since 2001, non-profits have accelerated adoption of clinical HIT, and particularly EMR, whereas for-profits' adoption has stagnated. Non-profits also have a much higher percentage of new contracts for acquiring clinical HIT systems: Eight percent of non-profit hospitals currently have contracted for an EMR, 12 percent for CPOE, and 9 percent for PACS; for-profits have contracted for such systems at the rate of 2, 2, and 4 percent, respectively.

However, for–profits are ahead in adoption of other IT applications that assist with hospital management and improve efficiency, such as Executive Information Systems, Managed Care Contract Management software, Enterprise Resource Planning software, and Time and Attendance software. For-profit's higher adoption of Outcome and Quality Measurement application stands in contrast to its lower adoption of clinical systems; but the description of the functionality of this application includes "measuring and analyzing the hospital performance, costs and efficiency of care provided," all of which are helpful in managing profitability. Table 4.1 demonstrates the distribution of the clinical and managerial HIT applications and systems.

There is also a considerable difference in the IT budget in for-profit and non-profit hospitals. For example, hospitals with very high HIT budgets are mostly non-profit: only 0.5 percent of for-profit hospitals and hospital systems spend over 4 percent of their operating budget on IT, whereas 8 percent of non-profit hospitals do so. However, more for-profit hospitals are making significant budget commitments to HIT. In particular, 41 percent of for-profits have 3 to 4 percent of its budget spent on IT, whereas the corresponding number for non-profits is only 22 percent. These findings may suggest that some pioneering non-profits are investing heavily to adopt new and expensive HIT systems while for-profits might be catching up in building a HIT infrastructure. We need longitudinal data on the dynamics of HIT acquisition and spending to really understand the origins of these differences and the degree to which they represent high start-up costs versus ongoing maintenance costs.

Table 4.1

Adoption of HIT Applications and Systems in For-Profit and Non-Profit Hospitals

	HIT System or Application	**For-profit**	**Non-profit**
Non-Profit Hospitals Lead:	CPOE	4%	21%
	Obstetrical Information Systems	6%	17%
	E-Medication Administration Record	9%	20%
	Premium Billing	15%	26%
	Partially integrated EMR	18%	29%
	Radiology PACS	18%	41%
	Basic EMR (CPR+CDS+CDR)	25%	34%
	Medical Record Imaging	26%	41%
	Computerized Patient Record	40%	58%
	Patient Scheduling	62%	73%
For-Profit Hospitals Lead:	Enterprise Resource Planning	26%	14%
	Eligibility	38%	30%
	Intensive Care	40%	32%
	Point of Care application	45%	40%
	Outcomes and Quality Management	70%	57%
	Clinical Decision Support	65%	58%
	Executive Information Systems	77%	59%
	Managed Care Contract Management	72%	60%
	Clinical Data Repository	70%	63%
	Clinical documentation	72%	65%
	Time and Attendance	94%	84%

Our findings regarding differences in adoption are consistent with findings in the literature, but the reasons for these differences are not perfectly clear. One study (Parente and Van Horn, 2003) reports that for-profit and non-profit hospitals adopt clinical IT in order to achieve different outcomes. For-profits are reducing costs and lengths of stay, and non-profits are trying to increase quality and quantity of their services provided. This result implies that for-profit hospitals do not yet expect major clinical IT (EMR and, especially, CPOE) to substantially reduce their costs and improve efficiency, and that non-profit hospitals adopting clinical HIT are being guided by considerations other than efficiency improvement. To the extent these implications are true, different sets of policies may need to be crafted to stimulate adoption in these two groups.[13]

Hospital Type

Among different hospital types, the real leaders in the HIT adoption process are academic and pediatric hospitals. A majority of these hospital reached top HIT categories, which indicates adoption of an integrated EMR system. Adoption of key clinical HIT systems in academic hospitals is up to two times higher than that in non-academic hospitals, although this relationship is partially determined by other factors, such as larger size. The fact that pediatric hospitals have much higher adoption rates might be explained by a higher relative benefit of using EMR and CPOE while caring for children (i.e., children are not as reliable a source of their medical histories, medications, etc., as are adults), or by the fact that a major multi-hospital pediatric system happened to be a leader in EMR system adoption.[14]

[13] For-profit hospitals may increase adoption when clinical IT is developed enough to improve efficiency of care delivery or when incentives are realigned so that they allow hospitals to reap the benefits of improvements in quality and efficiency of their healthcare services. On the other hand, non-profit hospitals are very likely to adopt clinical systems just because “this is a right thing to do” if they have organizational capacity and financial resources for them; therefore, subsidies or organizational help for the needy non-profit hospitals might be helpful.

[14] The Shriners’ system of hospitals for children developed an EMR and CPOE information system and began the installation process in all 20 of its hospitals in 2004.

Table 4.2

Clinical HIT Adoption in Acute Care Hospitals of Various Types

Hospital Type	No. of Hospitals	Top HIT	Basic EMR	CPOE	PACS
Long-Term Acute	114	3%	12%	4%	4%
Critical Access	91	17%	15%	17%	22%
General Medical	55	13%	17%	8%	23%
General Medical & Surgical	3235	31%	34%	20%	42%
Specialty	51	33%	28%	18%	45%
Academic	343	59%	46%	47%	80%
Pediatric	116	71%	62%	63%	51%
All hospitals	3989	33%	34%	23%	43%

Critical access hospitals have very low adoption rates, possibly because of their tiny size and rural location. They also typically offer a limited range of services, with the more-complex cases being stabilized and transferred to larger facilities. Thus, low adoption in these hospitals may suggest that the perceived benefits of HIT are lower in such a setting. Long-term acute[15] care hospitals, as a category, have the lowest HIT adoption. The reasons for such a dramatic difference are unclear, but we know that long-term care hospitals are much smaller in size and, until very recently, were exempt from the Medicare prospective payments system, which was historically an important driver in increasing HIT adoption according (Borzekowski, 2002a).

Size and Rural Status of the Hospital

Experts in the trade literature have often reported that small size of a hospital or medical practice was the major predictor of low HIT adoption. Our analysis supports this qualitative statement, showing over 30% positive correlation between clinical HIT

[15] This is a separate category from chronic long-term hospitals, which were not considered in this analysis.

sophistication scale and various measures of a hospital's size: staffed hospital beds, inpatient admissions adjusted for the amount of outpatient care, patient-days and visits, number of full-time equivalent personnel and total hospital expenditures. Among the variables that reflect the size of a hospital, adjusted admissions have the highest correlation[16] with HIT adoption: 38 percent for HIT scale and 40 percent for PACS. The size of a hospital has the most effect on adoption of a PACS system, which has the particularly high economies of scale (see Figure 4.2). The difference in adoption between smaller and larger hospitals is substantial and statistically significant: hospitals with more than 100 beds have up to a 1.5 times higher adoption rate of CPOE and over a 2 times higher adoption rate of PACS than hospitals with less than 100 beds (see Figure 3.1). Since the type, location, and other characteristics of the hospital affect its size, we cannot directly attribute the entire relationship to the effect of hospital's size.

Table 4.3

Biserial Correlations of Alternative Measures of Hospital Size with Clinical HIT Adoption

Size of the hospital	Sample	HIT scale	EMR (basic)	CPOE	PACS
Beds staffed in acute facility	3989	32.2%	11.4%	14.6%	34.1%
Adjusted admissions	3660	38.3%	13.4%	18.0%	39.5%
Inpatient days	3660	30.3%	10.1%	14.9%	33.5%
Outpatient visits	3660	31.6%	9.5%	21.0%	32.1%
FTE personnel	3660	34.8%	12.3%	20.7%	36.9%
Total facility expenses	3660	33.9%	11.2%	20.3%	36.7%
All correlations are significant at 5% significance level					

[16] The correlation between the dichotomous variable (HIT adoption) and continuous variable (hospital) size is a biserial correlation, and could be compared with other bisearial correlations presented in this paper. The hypothesis testing of non-zero correlation is based on the two sample (0 and 1 dichotomous variable) t-test with equal variances, and is equivalent to the test of non-zero correlation between two continuos variables, under the assumption that continuous variable is distributed normally.

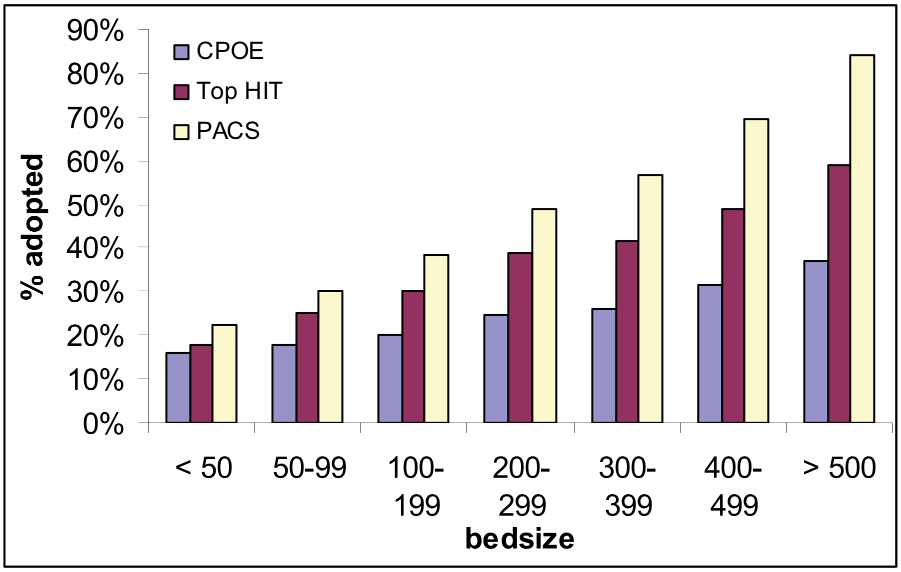


Figure 4.2 HIT Adoption by AHA Hospital Bed Size Category

Rural status is another widely quoted factor related to the lower adoption of HIT. AHA provides data on hospital location in metropolitan statistical area by its size, while Medicare Impact file classifies hospitals by the area it serves: large urban, other urban and rural. Both measurements yield similar results with hospitals located in rural or non-metropolitan areas exhibiting about 40% lower adoption rates for CPOE, PACS or top HIT. These relationships would be even stronger if the data included small stand-alone hospitals that are omitted in the HIMSS survey. However, clinical HIT adoption does not seem to vary much with the size of the urban area.

Table 4.4

HIT Adoption by Location

	Sample	CPOE	PACS	Top HIT
Large Urban Area	1411	26%	52%	36%
Other Urban Area	850	25%	51%	43%
Rural	914	16%	30%	24%
Metropolitan	2647	26%	50%	39%
Non-Metropolitan	1295	15%	29%	22%

Medicare and Medicaid

The share of Medicare seems to be an important factor in the adoption of clinical HIT. One third of the community hospitals have the majority of their patients' claims paid by Medicare, and they are almost twice less likely to have major clinical HIT systems than are other hospitals (see Figure 4.3). The magnitude of correlation for this relationship is comparable with the effect of the hospital size, and shows up in each of different measures of Medicare share: Medicare admissions, patient-days, and, system-level revenues[17]. Also, higher share of Medicare is correlated with the later adoption date of CPOE and PACS.

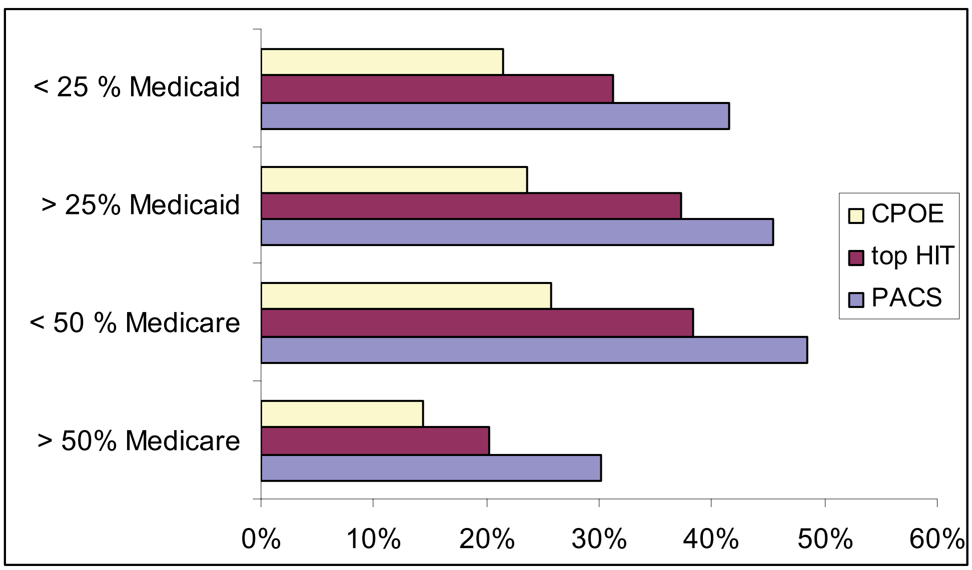


Figure 4.3 – Clinical HIT Adoption in Hospitals with larger and smaller shares of Medicare and Medicaid Discharges

In contrast to Medicare, the share of Medicaid does not have a significant relationship with adoption of clinical HIT (see Table 4.5). Indeed, Figure 4.3 demonstrates that those hospitals with over one-quarter of their patients on Medicaid have a little higher adoption rate than those with less than 25 percent of their patients on

[17] Share of revenues from Medicare or Medicaid are measured for the entire multi-hospital system rather than for an individual hospital (from HIMSS dataset).

Medicaid, although the difference is not statistically significant. Medicaid share measured as a percentage of the hospital revenue[18] has a small positive correlation with adoption of EMR and CPOE. Lower reimbursement rates of Medicare compared with other insurers can explain, at least in part, its negative effect on hospitals' investment in HIT; but it is surprising to find no effect of Medicaid, which has even lower reimbursements.

Table 4.5

Biserial Correlations of Alternative Measures of Medicare and Medicaid Share with Clinical HIT Adoption

Share of Medicare & Medicaid	N	HIT scale	Basic EMR	CPOE	PACS
% Medicare inpatient days	3660	**-20%**	**-12%**	**-16%**	**-13%**
% Medicaid inpatient days	3660	2%	1%	2%	2%
% Medicare discharges	3660	**-29%**	**-14**	**-17%**	**-18%**
% Medicaid discharges	3660	3%	2%	-1%	2%
% Medicare revenues	3032	**-18%**	**-7%**	**-19%**	**-7%**
% Medicaid revenues	3031	1%	0%	1%	-2%
Note: Correlations significant at 5% significance level are highlighted in **bold**					

This ambiguous relationship is partially explained by the fact that academic hospitals treat a large share of Medicaid patients. Another explanation is the high share of managed care among Medicaid patients, which positively affects HIT adoption.[19] In addition, we hypothesize that hospitals with a large share of Medicaid patients are

[18] This relationship is derived from only 970 freestanding hospitals. The HIMSS-Dorenfest database provides data on the sources of revenue at the level of a hospital system or stand-alone hospital. We can evaluate the relationship between various types of revenue and adoption by limiting the results to stand-alone hospitals and single-hospital systems.

[19] Medicaid managed care and Medicare managed care have a positive relationship with HIT adoption, whereas Medicaid and Medicare from traditional sources have a negative one. This analysis is based on Californian hospitals (Office of Statewide Health Planning and Development [OSHPD] financial dataset for the year 2003, http://www.oshpd.cahwnet.gov/HQAD/Hospital/financial/hospAF.htm). Medicaid in California has a larger share of managed care than does Medicare.

generally considered disadvantaged and often receive grants and disproportionate share payments, which could be devoted to HIT investment (e.g., these are likely to be publicly financed hospitals that do not depend primarily on fee-based revenue for their operating budgets).

This result is counterintuitive because one would expect hospitals with a larger share of Medicare patients to be interested in the potential efficiency savings promised by HIT. With Medicare patients, DRG reimbursement that creates risk-sharing means that hospitals may keep the savings associated with shorter stays, and HIT can help to achieve reduced resource utilization. Indeed, the research by Borzekowski (2002a, b) has reported that the introduction of the prospective payment system for Medicare has speeded the adoption of early hospital information systems. Despite this apparent incentive, there could be factors, such as capital constraints related to a higher share of Medicare and its relatively lower reimbursement levels when compared with commercial patients, causing the delay in the adoption of HIT in these hospitals. The lower HIT adoption rate in hospitals with a larger share of Medicare patients suggests the importance of Center for Medicare and Medicaid Services (CMS) involvement in HIT policies.

The access to HIT for different payers is best measured by the share of patients in each payer group (including Medicare, Medicaid and commercially insured) that are treated in the hospitals with sophisticated clinical HIT systems. To produce these estimates for the entire hospital population, adoption rates in the hospitals that are not in HIMSS sample were calculated[20]. Table 4.6 shows the percent of patients that have access to HIT in California and nationwide: number of patients in the hospitals with HIT divided by the total number of patients in the payer category. Both in California and nationwide, Medicare and Medcaid patients have less access to HIT than do commercially insured patients: 42% and 44% respectively compared with 47% for other

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[20] The AHA hospital survey was used for the estimates in the national hospital population, and, for California, the California OSHPD dataset was used. The later data are audited and are allow distinguishing uninsured from commercially insured patients. The likelihood of "top 2 HIT" adoption in non-HIMSS was predicted with the OLS regression of HIT adoption on hospital size, profit status, shares of Medicare and Medicaid patients, and non-Metropolitan area location.

patients in the national dataset[21]. The gap is even wider in California, especially for Medicaid population: 30% of Medicaid patients versus 48% commercially insured patients are in the hospitals with sophisticated HIT. To an extent that advanced clinical HIT means higher quality and safety of care for the patients as well as long-term efficiency for the payer, Medicare and Medicaid payers and their patients lack those benefits. Targeted subsidies or changes in the reimbursement policies by these payers may be necessary to close this gap.

TABLE 4.6

Share of Patients Treated in Hospitals with Advanced Clinical HIT

	National	**CA**
Medicare patients	42%	40%
Medicaid patients	44%	30%
Non – Medicare/ Medicaid patients	47%	45%
- Commercially insured patients	N/A	48%
- Indigent & self-pay patients	N/A	36%

Managed Care

Managed care, and especially capitation, can potentially stimulate a hospital to invest in efficiency-improving or even quality-enhancing technology (see Chapter 3). Managed care involves a contract negotiation mechanism that may induce providers to improve their efficiency and reputation with HIT investment and offer better prices. By paying a fixed price per patient enrolled, capitation allows providers to enjoy the full savings from their efficiency improvement with HIT investment.

AHA hospital survey dataset provides several self-reported measures on revenue share of capitation or other risk shared payments for the majority of their sample. All of

[21] Because these estimates measure HIT adoption using the entire population of hospitals in the US and in California, statistical significance does not apply here.

these measures have positive and significant correlation with the adoption of different clinical HIT systems (Table 4.6), although the size of correlation is not very large, ranging from 5 to 10 percent.

Table 4.6: Correlations of Capitation and At-Risk Revenues with Clinical HIT Adoption

	Sample	HIT scale	Top HIT	CPOE	PACS
% of risk-shared revenue	2701	7%	6%	6%	5%
% of capitation revenue	2753	7%	9%	10%	5%
% of risk shared & capitation revenue	2693	8%	9%	9%	6%
# of lives covered under capitation	1799	7%	6%	10%	5%
All correlations are significant at 5% significance level					

Review of the trade literature as well as interviews site visits reinforced the sense that fully integrated and budgeted delivery systems, such as Kaiser, Group Health, and the Veterans' Administration (VA) system have high EMR system adoption rates. For less-integrated systems, managed care contracts from capitation delivery systems may pay hospitals on a per-diem basis, providing less incentive for HIT-enabled restructuring for efficiency. Nevertheless, even the weaker affiliation between managed care and adoption in the HIMSS and AHA data somewhat supports the opinion of experts that having a captive patient population in a closed HMO system would internalize the benefits of healthcare quality improvement and stimulate HIT adoption.

System-Level Factors and Regional Factors

A number of findings may support the importance of network externalities (i.e., the value of technology investment for the provider depends on whether other providers have adopted this technology) in the decision to adopt HIT. The majority of community hospitals belong to multi-hospital systems. Thus, their adoption behavior is related to their system's adoption behavior. The data demonstrates that clinical HIT adoption by other hospitals from the same multi-hospital system is the single-largest determinant of a hospital's adoption from that system. For example, the correlation between HIT scale in a hospital and average HIT scale in the rest of its system is about 75%, while correlation between CPOE adoption in a hospital and the rest of the system is 83%. The magnitude of this correlation is several times stronger than the one with the hospital's size. This result may indicate that

- a decision on HIT adoption and its strategy is determined by the hospital system rather than by an individual hospital;
- there may be economies of scale when a HIT system is deployed to all hospitals in a system, decreasing the costs of the system for each individual hospital;
- hospitals derive additional benefits from sharing clinical information available through clinical HIT systems in the networked hospitals;
- hospitals in a system benefit from sharing their HIT-adoption experiences.

Table 4.7

Biserial Correlations of the Adoption Rate in other Hospitals from the same System or MSA with Clinical HIT Adoption

	Sample	**HIT scale**	**CPOE**	**PACS**
Adoption % among others from same system	3001	75%	83%	60%
Adoption % among others from same MSA	2611	17%	26%	15%
Note: All coefficients are significant at 5% significance level				

If the link between adoption in the system and hospital adoption is causal, it is clearly important for policy to target those hospital systems that don't have advanced clinical HIT systems in any of their hospitals. In this case, however, the spread of the HIT-adoption experience to other hospitals within the system can be expected in the very near future, since 41 percent of hospitals have CPOE and 76 percent of hospitals have

PACS either in their hospital or in their system. Over 65 percent of hospitals belong to hospital systems where at least one hospital reached top HIT level (value 4 or 5 of the HIT scale).

Another curious fact is that smaller multi-hospital systems with fewer than 15 hospitals have higher adoption of clinical HIT than larger ones do, particularly when they are geographically concentrated[22]. Top HIT adoption is at least twice as high in the hospitals that belong to small geographically concentrated systems than in the hospitals from large or dispersed systems (see Figure 4.4), despite the fact that some most advanced HIT adopters - Kaiser Permanente and Intermountain Healthcare systems - are large. The probability of HIT adoption in an individual hospital generally falls as the number of hospitals in a hospital system increases, which may indicate that the investment might become more difficult to coordinate as the system gets larger, and that the smaller locally concentrated systems derive additional value from information exchange among the hospitals. Surprisingly, though, adoption in stand-alone hospitals is higher than in hospitals from large or geographically dispersed systems.

[22] If the mean distance between the hospitals in from the same system is less than 80 miles, the system is labeled as “geographically concentrated”, when the distance is more than 80 miles – the system is “geographically dispersed”.

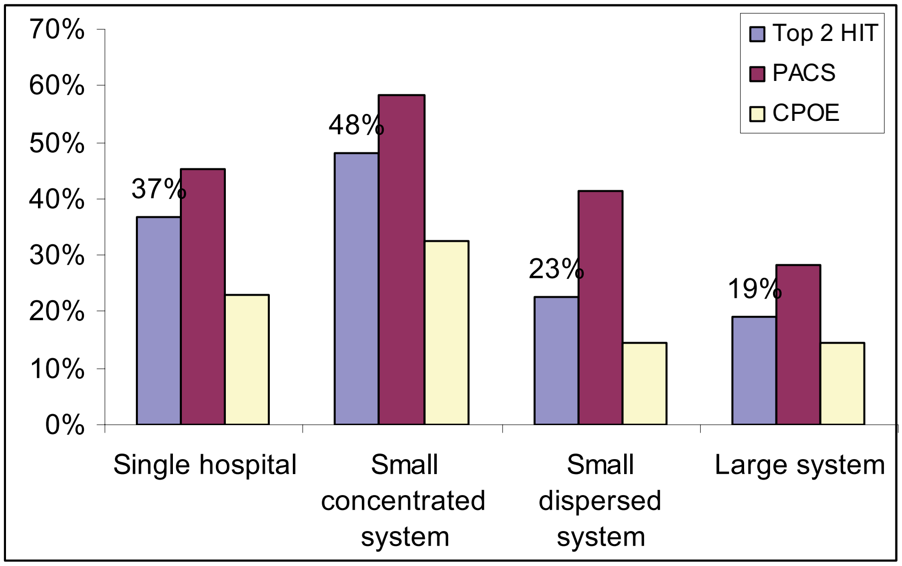

Figure 4.4 - HIT Adoption by the Size of Hospital's System, and in Stand-Alone Hospitals

About 15 percent of all community hospitals are managed[23] rather then owned or leased by the systems. These contract-managed hospitals have less than a half of the HIT adoption rate of owned hospitals (see Figure 3.6). This difference is partially explained by the fact that contract-managed hospitals are about half the size of owned hospitals, are predominantly rural, and are often government-owned. Thus, they may have insufficient management capacity, making the adoption of complex technologies nearly impossible. Additionally, many non-profit hospitals enter into management contracts as a strategy for coping with tough fiscal constraints (Carey and Dor, 2004, p. 194) – a major barrier to HIT adoption in of itself.

[23] Under contract-management, a hospital's board of trustees retains an outside organization to manage the facility, and, usually, that organization also makes decisions on HIT investment.

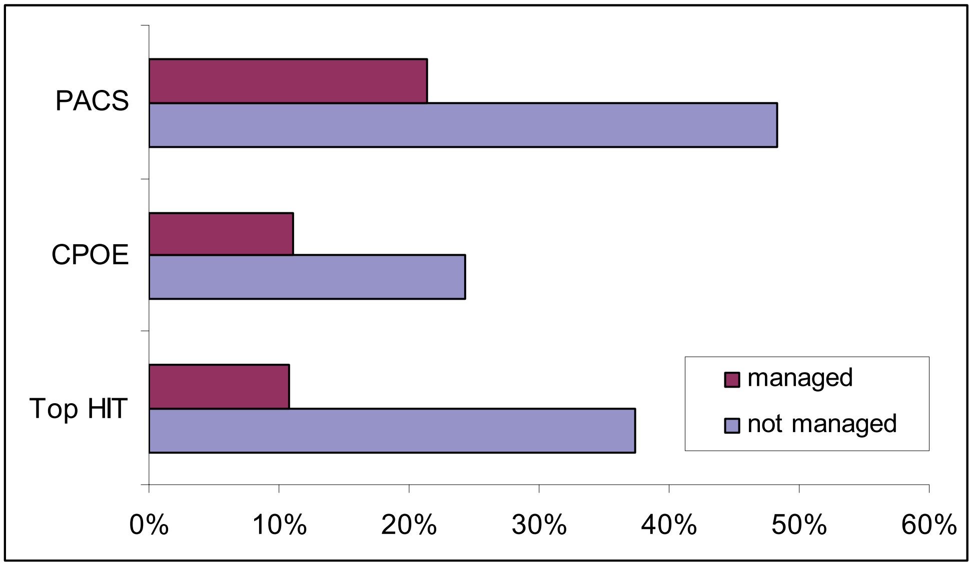

Figure 4.5 – HIT Adoption in Contract-Managed Hospitals

Additional characteristics of healthcare systems available from the AHA database are the type of system, based on the degree of differentiation and centralization of its services, physician arrangements, and insurance products among the member hospitals. HIT adoption is highest in systems that have highly centralized physician arrangements and insurance products at the system level, with less centralized delivery of the healthcare services. These systems are predominantly non-profit, have a small number of hospitals, and their hospitals are close to each other. As one would expect, the laggards in HIT adoption are independent hospital systems[24] and decentralized hospital systems. Over a third of system-owned hospitals belong to decentralized hospital systems, which offer highly differentiated services and insurance products and may lack an overarching structure for coordination. These systems have a large number of hospitals spread over a broad geographic area. It may be that smaller, more localized hospital systems may have higher adoption rates because they may better benefit from coordination of patient care and a common strategy for HIT investment. They may also have a much stronger network effect (i.e., a hospital derives additional benefits from having EMR adopted by

[24] *Independent hospital systems* are largely horizontal affiliations of independent hospitals.

the rest of the hospital network) from affiliated hospitals in the same local area that treat the same patient populations. See Figure 3.6.

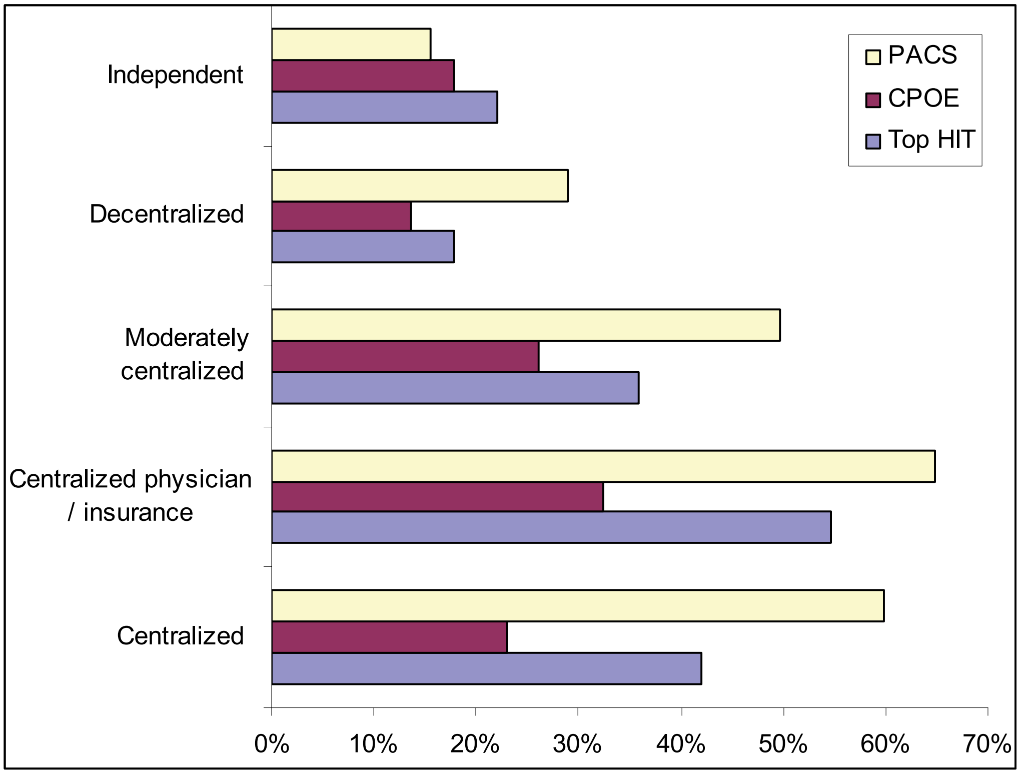

Figure 4.6 – HIT Adoption in Healthcare Systems of Different Types

Competition

The degree of market concentration[25] in the market (inversely, its competition) has negative and significant correlation with adoption of clinical HIT systems, ranging from 13 to 23 percent. The finding could imply that competition provides incentives for adopting up-to-date clinical HIT systems. Alternatively, this relationship could be

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[25] The inverse of competitiveness is measured by the Hirschman-Herfidahl Index (HHI) of market concentration, which is equal to the sum of each hospital's squared market share based on hospital beds over hospitals within a hospital market. The market is measured as a radius that covers 90 percent of a hospital's admissions. The competition is higher when HHI is lower, indicating that there are more hospitals in the market and that their market shares are more even. The data on HHI comes from Melnick, et al(XXXX), where they predicted market concentration for most community acute care hospitals.

explained by the fact that rural areas are characterized by low hospital competition, and low HIT adoption at the same time.

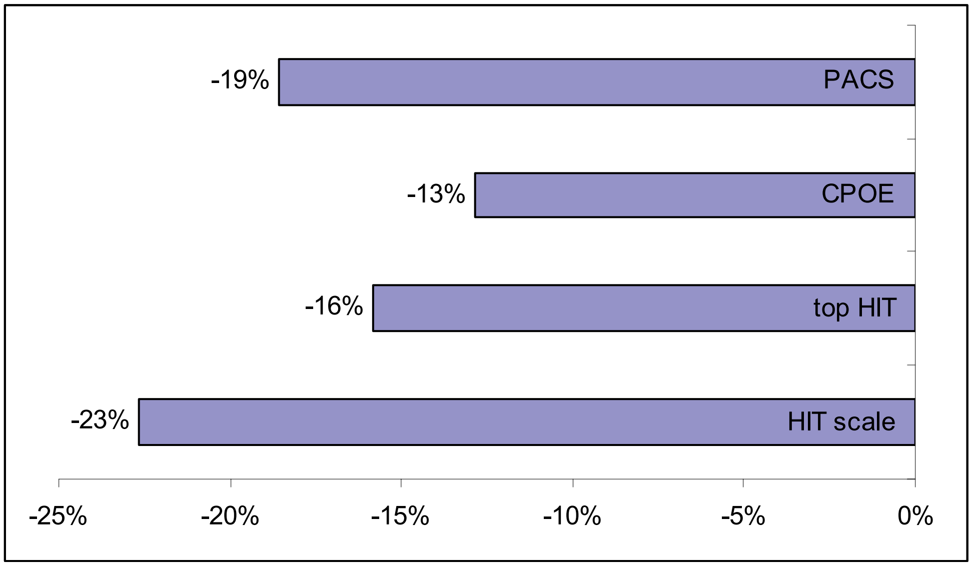

Figure 4.7— Biserial Correlation of HIT Adoption with the Index of Market Concentration (the Inverse of Competition)

Also, for-profit hospitals show much lower correlation of competition and HIT adoption, than non-profit hospitals. One suggestion is that non-profits may compete on the quality and prestige that the EMR system may deliver, whereas for-profits may substitute clearer ROI-driven investments when the market pressure is higher. Alternatively, for-profits may have more-independent physician staffing arrangements, increasing the complexity of making and implementing an adoption decision.

Link to Primary Care

Exchange of clinical information between acute and ambulatory care is quite important for realizing full benefits of clinical HIT. Therefore, one hypothesis is that those hospitals and hospital systems that provide primary and ambulatory care would derive higher value from HIT adoption. This idea is supported by some empirical evidence, namely, that hospitals that have primary care departments, and, especially, hospitals that have primary care locally in their hospital system, have higher rates of clinical HIT adoption (see Figure 3.10). HIT scale at the hospital has positive 20%

correlation with the number of ambulatory clinics linked to that hospital and, as 17% correlation with average EMR adoption rate at the linked clinics. It is possible that the need for information exchange between a hospital and its related primary care departments would stimulate the adoption of clinical HIT.

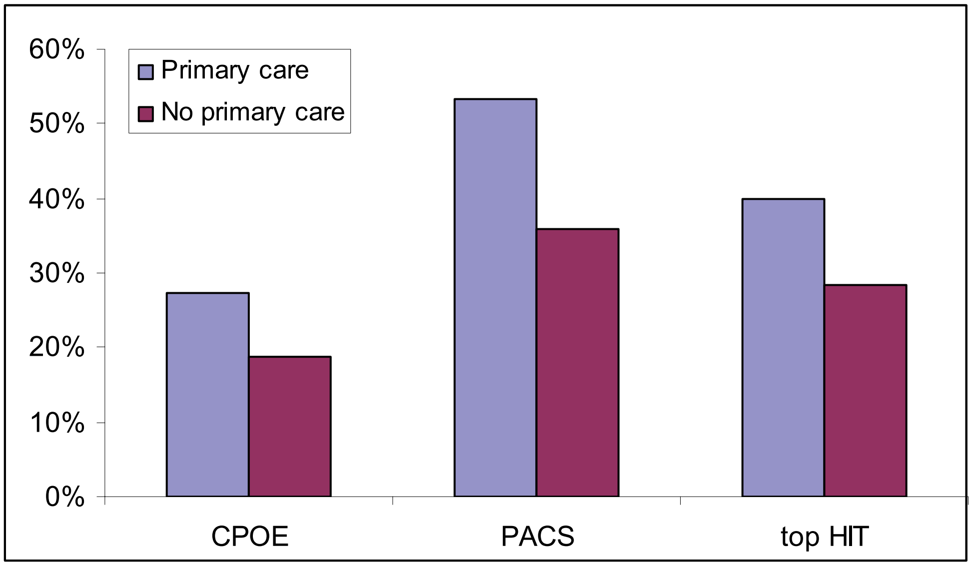

Figure 4.8 – Adoption in Systems and Hospitals with a Primary Care Department

4.4 Factors that Influence HIT Adoption in Ambulatory Clinics

The HIMSS data on ambulatory practices are limited to those practices that are owned by healthcare delivery systems, which constitute less than one-fifth of office-based physicians in the United States.

The measures of characteristics of the ambulatory clinics in the HIMSS database are mostly limited to their size and type. The size effect is very important in the ambulatory clinics: practices with over 25 physicians are at least twice as likely to adopt an ambulatory EMR system as is a solo practitioner (see Figure 4.9).

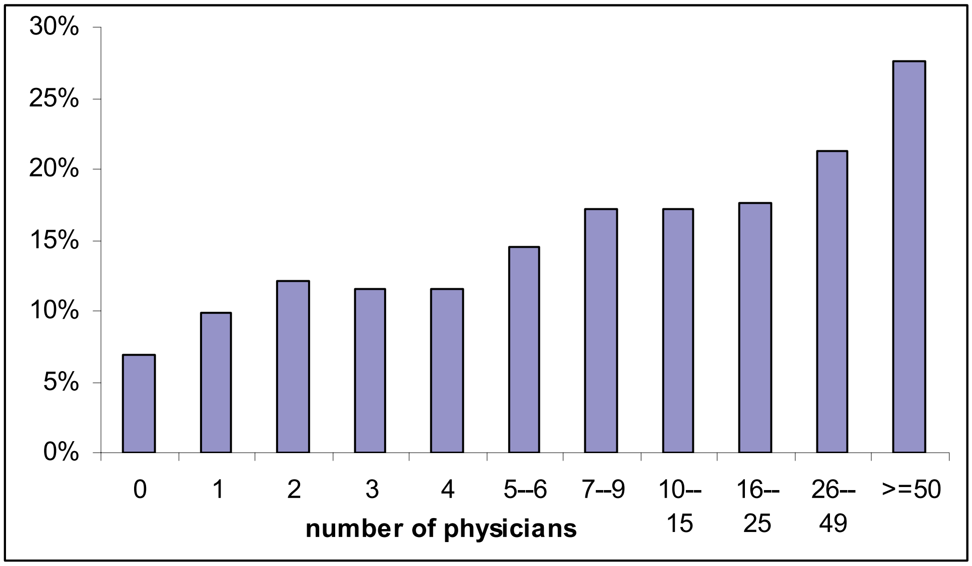

Figure 4.9 –Adoption of EMR in Ambulatory Practices, by Size

EMR adoption rates also vary by the type of ambulatory practice. Majority of ambulatory practices are in primary care, including primary care, family practice, internal medicine, OB/GYN, pediatrics and geriatrics specialties. Average adoption rate in all primary care specialties is about 12%, with the highest rate in primary care (16%), and lowest adoption in pediatrics and geriatrics (9% and 8%). Single specialty practices, such as cardiology and oncology, have a bit higher EMR adoption rate at 14%. The leaders in EMR adoption are multi-specialty clinics, with an EMR adoption rate of 21 percent--more almost 2 times higher than adoption in primary care practices. Multi-specialty clinics are large: They account for only 10 percent of all system-owned practices, yet they cover over 40 percent of the office-based physician population. Thus, their size and, consequently, their larger organizational and financial resources may explain the higher adoption rate, as well as the fact that there is greater organizational value to be derived from exchanging information among doctors in multi-specialty clinics.

Adoption in any given ambulatory practice owned by an integrated healthcare delivery system is most related to the adoption rate in the rest of the system. The correlation reaches 97 percent, which is even higher than the corresponding relationship for the hospitals. This result demonstrates that investment in ambulatory EMR might be decided on and paid for at the level of the system and determined by the characteristics of the system, and/or it might have a higher value for the practice because of its connectivity within a system. Alternatively, there might be a measurement failure, with the reported adoption of ambulatory EMR at the IHDS level not reflecting the actual adoption patterns of the practice sites associated with the IHDS.

A similar argument applies to the positive relationship between EMR adoption in a hospital and its affiliated ambulatory practice, where adoption in the practice affiliated with the EMR-equipped hospitals is twice as high as in practices affiliated with hospitals not equipped with EMR.

There is also a significant correlation between an ambulatory EMR adoption by the clinic and a high share of managed care revenues in the affiliated hospital system. The correlation with HMO revenues reaches 60 percent. However, these high correlations may partially result from the fact that ambulatory EMR is mostly adopted by the parent IHDS, and correlations on the level of practices might be spurious. Thus, aggregated ambulatory EMR adoption rates at the IHDS level were examined (see Figure 3.12). This resulted in a somewhat weaker correlation, but with the same direction of effect. As in the case of hospitals, a high share of Medicare revenues (but not Medicaid revenues) is associated with reduced ambulatory EMR adoption in the healthcare system. Managed care, and especially HMO share, is strongly correlated with EMR adoption.

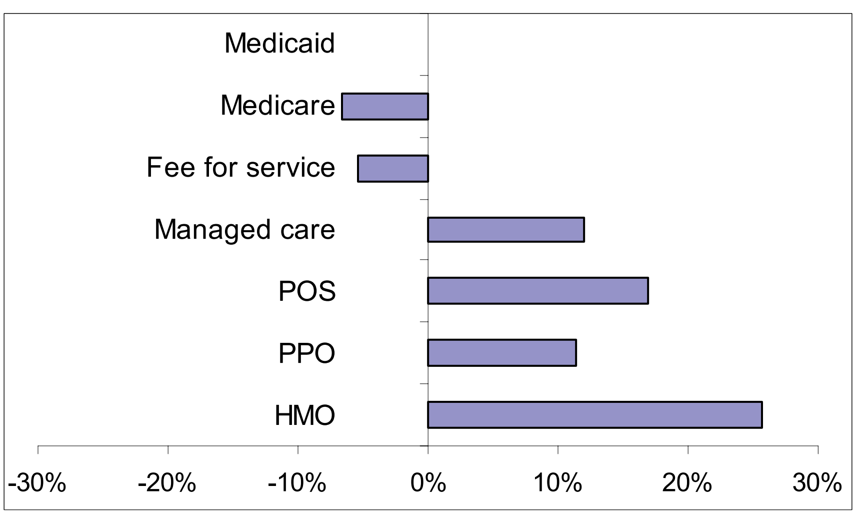

Figure 4.10 – Biserial Correlation of Ambulatory EMR Adoption Rate in a Healthcare System, with the Share of System's Revenues Derived from Various Sources

4. 5 Regression analysis

Multivariate regression analysis is applied to a composite measure of clinical HIT adoption that would affect overall efficiency and quality of care, PACS – a component of hospital HIT system that mostly improves efficiency, and CPOE – application that primarily affects safety and quality of care. The composite measure of clinical HIT sophistication developed in Chapter 2 is a scale from one to five, therefore an OLS model, which provides most interpretable coefficients, can be applied to estimate the relationships with hospital characteristics. The sensitivity of the results is tested with an ordered logit model, which is technically the most appropriate model for the ordinal dependent variable – HIT scale. I use regular logit to estimate the relationships with dichotomous adoption variables – adoption of advanced clinical applications such as PACS and CPOE. All regression models involve estimation with robust standard errors that are clustered within hospital systems, because adoption behavior is interrelated within the same hospital system [26].

4.5.1 Models and Data

The ideal regression model should include the following groups of factors, which according to economic theory (see Chapter 3) may effect the adoption of clinical HIT:

- For-profit or non-profit ownership status of the hospital to test the importance of different hospital's objectives for HIT adoption;
- Hospital service specialization, such as academic, pediatric, long-term, etc – to test whether hospital of different types value HIT differently or have varying financial capacity to adopt;
- Size of an adopting facility to test the role of facility-level economies of scale, organizational capacity; as well as technical difficulties from integrating systems in a complex environment ;

[26] Most of the hospitals in our sample belong to multi-hospital systems and hospital outcomes are likely to be non-independent within hospital systems. Random and fixed effects are not possible in the sample that has both stand-alone hospitals and multi-hospital systems.

- Financial state of the hospital to test the availability of capital for adoption;
- Environmental factors such as rural or urban location to test whether more technologically advanced environment improves adoption;
- System factors like size of the hospital's system, its geographical spread or number of doctors in ambulatory clinics it owns to test for externalities and system-wide economies of scale, as well as coordination challenges in a large multi-site organization;
- Patient or revenue composition such as Medicare and Medicaid to test for the effects of different payers and reimbursement models in terms of both the adoption incentives they provide and financial pressures they impose;
    - In particular, managed care models like PPO/HMO-per diem, HMO per case, capitation and other at risk payment models that have different incentives on improving efficiency through the use of technology;
- Market factors such as competition to test whether it presents additional incentives or challenges to adopt.

The above concepts are represented with independent variables constructed from several different datasets. The HIMSS dataset has 3989 facility-level observations with basic hospital characteristics, such as size of a hospital and its system, its ownership and hospital type. There are also data on revenue sources at the hospital system level for a limited sample of about 1100 hospital systems (that include 3000 hospitals), and even smaller sample of about 400 hospital systems (1000 hospitals) with the data on detailed managed care revenue sources, such as HMO and PPO. Medicare Impact (MI) file provides a classification of hospital location into rural, large urban and other urban areas for 3175 HIMSS-merged hospitals, as well as data on case mix index (CMI). The AHA dataset supplies additional facility level data for 3660 successfully merged hospitals, such as share of Medicare and Medicaid patients, outpatient to inpatient ratio, and additional variables for a smaller sample, such as percent of capitated and at-risk revenue[27] (non-

[27] Data on % of revenues from capitated and at risk contracts in AHA dataset is possibly not reliable enough, because it is reported voluntarily, and is not audited. Cross-checking with audited data from California showed discrepancies.

audited data). None of these data sources have good data on hospitals' financial state. Additional data on predicted hospital competition developed at RAND[28] (Gresenz et al, 2003) are available for a national sample. However its use is problematic, because it is predicted with the same data on hospital size, location and type that is used in the regression model, and is less reliable than California data.

California Office of Statewide Health Planning and Development (OSHPD) provides a complete dataset of audited financial variables for all Californian hospitals, which includes reliable measures of hospital's revenue distribution by payer category and capitation, as well as various financial items. In addition, Melnick and Keeler (2006) derived an up-to-date competition measure based on California OSHPD data, which is available for this analysis. However, the final Californian sample is too small to identify the effect of some important variables, such as system size or rural status. Along with complete model for California, several alternative models are employed with the data on national sample and look for consistency in the results across them. Sample sizes of seven national models vary from 1090 to 3903, because the models consist of variables combinations from different datasets.

The California sample for a complete regression is constructed by merging HIMSS data on HIT adoption with the OSHPD annual financial dataset for the year 2003[29]. After hospitals with non-comparable revenue structure, such as Kaiser, were excluded, 288 observations were merged successfully. However, of those hospitals only 260 have case-mix variable available from the Medicare Impact files[30]. The resulting Californian sample is biased towards larger hospitals from urban areas that treat Medicare patients. The sample size of the alternative regression models and the mean values of independent variables are presented in appendix tables A 2 and A 3.

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[28] http://www.rand.org/pubs/working_papers/WR103/index.html

[29] Preceding years of OSHPD data were also used to derive financial variables for the past five years.

[30] Patient case-mix Medicare index exists only for the hospitals that treat significant share of Medicare population.

The first set of independent variables describe hospital characteristics that may affect the value and cost of HIT investments for the hospital. In the California model, these include for-profit and academic status of a hospital, while national regression models also have other hospital types, such as pediatric, critical access, and long-term care hospitals. Size of the hospital is measured as log of adjusted[31] hospital days in the California model, and as log of hospital beds in the national models (because adjusted days are available only for a limited sample of AHA hospitals).

Variables on hospital location come from Medicare Impact file, including location in rural, large urban and other urban (excluded category) areas. Missing values of hospital location were replaced using hospital zip-codes from HIMSS data merged with additional geographic data[32].

An important set of variables describes payer mix, as well as their reimbursement methods. In the Californian sample that has information both of revenues and days by payers, the mix of payers is captured by their respective shares in adjusted patient days, including Medicare, Medicaid, indigent and self-paid, and commercially insured (omitted category) patients. The California regression model allows a test for the effect of capitation reimbursement, including variables on capitation shares for commercial, Medicare and Medicaid payers.

The choice of variables on payer mix is more limited in the national models. Those models utilize Medicare, Medicaid and managed care share of revenues on a level of system, rather than a hospital, from the HIMSS dataset. In a smaller sample, which has more variables available, there is an opportunity to separate system-level managed care revenues into finer categories of HMO, PPO and POS payer plans. In addition, shares of

[31] Adjusted for the outpatient visits.

[32] Geographic Correspondence Engine with Census 2000 Geography is available at http://mcdc2.missouri.edu/websas/geocorr2k.html

Medicare and Medicaid patients on the hospital level derived from AHA data provide hospital-level payer mix for a couple of alternative regression models.

The California model employs additional patient-mix variables – shares of long term care days and outpatient visits. These variables may reflect different reimbursement mechanisms for long-term and outpatient care, as well as different clinical benefits of HIT for these categories of patients. Several national models also use outpatient-inpatient patient mix based on AHA data, although they lack data on long-term care days. Both California and national models utilize the measure of a complexity of treated conditions (Medicare patient case mix) from the Medicare Impact file dataset.

The mix of payers and their reimbursement methods can affect adoption through their effects on financial capacity of hospital, and through the incentives that they create for HIT investment. To control for the financial capacity of a hospital in the California sample, average profits and unrestricted contributions for the past four years, as well as equity to assets ratio were employed. Unfortunately, the national data sets lack variables on financial status.

Finally, the models include a set of variables for market and system characteristics in order to capture the effects of network externalities, system-wide economies of scale and competition or market power. The following variables describe hospital system: Single hospital, hospital that belong to a small local system, hospitals that belongs to a small geographically-dispersed system or hospitals that belongs to a large system. Large hospital systems are those that that include fifteen and more acute-care hospitals. Small local systems have an average distance between its hospitals below 80 miles, while dispersed systems have the average distance above 80 miles. An additional variable that relates to system-wide network externalities is the number of ambulatory office doctors that belong to the hospital. The degree of competitiveness in the hospital market is measured by Herfindahl index of market concentration derived in Melnick and Keeler (2006), which is the sum of squared market shares of the hospitals from the same market, where hospitals that belong to the same hospital system are treated as one firm.

To test the effect of the factors of adoption it would be ideal to conduct a survival analysis and use independent variables for the year when adoption occurred or the previous year. Inferior data on the timing of adoption and incremental nature of adding components to hospital's HIT system (reflected in HIT scale measurement) preclude performing time-based analysis of sufficient quality. Instead, a simple cross-sectional regression analysis was performed, relying on the assumption that most of hospital characteristics have not varied much in the period since 2000, when most of HIT adoption occurred. Longitudinal data on hospital characteristics in California allowed using averages for the variables that may vary from year to year, such as patient mix, revenue mix or profits and contributions. The results in California model do not differ much whether current year data or four-year averages of independent variables were used.

4.5.2 Regression Results and Discussion

Table 4.10summarizes the relationships of the independent variables to adoption of PACS, CPOE and overall HIT scale estimated in 7 national and one California regression models that are presented in Tables A.4 – A.8. The "National" column shows the number of models where the variable has a significant coefficient out of total number of national models where it is employed. The significance is evaluated at 5% significance level, but the alternative results for 10% significance level are shown in the brackets. The plus or minus sign provides a direction of a statistically significant coefficient, while zero stands for the variables that are insignificant in all national models. Table 4.11 presents marginal effects of the variables that are statistically significant on the probability of reaching top two HIT categories for a stand-alone community hospital from a small urban area (the detailed characteristics of the base-case hospital are presented in the table). Model 2 has much smaller sample than other models, and its estimated coefficients may not be as reliable as the effects calculated in other models.

Rural hospital location has a negative and significant effect on HIT scale only in comparison to small urban areas, when a variable indicating a large urban area is also included in the regression. Surprisingly, hospitals located in large urban areas have even less HIT adoption than their rural counterparts when other factors such as size is taken into account[33]. The large urban area coefficient is consistently significant across most` regression models of HIT scale. Probability of reaching top two HIT categories drops 10% - 13% both when a hospital is rural and when it is from a large urban area versus a small urban area (see Table 4.11). Therefore, those hospitals located in small urban areas (base category) have the most developed clinical HIT systems. This effect is less consistent for adoption of separate clinical HIT systems, CPOE and PACS. For example, in the California model, large urban area location is associated with the higher probability of PACS adoption.

For-profit ownership of a hospital is significant factor across all national models for the adoption of CPOE and PACS. For-profit hospitals are 20% to 30% less likely to appear in the top two categories of the HIT scale than non-profits are (see Table 10.11). This size of this effect is larger than the effects of system membership, location or the effect of doubling the size of the hospital. At the same time, this relationship is not very strong for the overall HIT adoption level, since for-profit hospitals are mostly concentrated in the middle of sophistication HIT scale. The same pattern is evident in the California model with for-profit being highly significant for PACS, CPOE and the top HIT level, but insignificant for the overall HIT adoption scale. Relatively to for-profit hospitals, non-profits may put more weight on the quality improvement and system-wide efficiency produced by clinical HIT than on ROI for their own hospital. However, it's surprising that there is the same negative and significant relationship between for-profit status and adoption of PACS – a system with reportedly high ROI for large hospitals.

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[33] This result is robust to alternative specifications of the size effect on adoption. Alternative models where size is represented as a quadratic form produce same coefficients on rural and large urban location as does regression model with the log-size relationship.

TABLE 4.10

Summary of the Regression Results from 7 Alternative National Models and a California Model:

	HIT scale National	HIT scale CA	CPOE National	CPOE CA	PACS National	PACS CA
Rural	-5(6) / 7	+	-1(2) / 7	+	-2(3) / 7	0
Large urban area	-6 / 7	0	-2(4) / 7	0	-1 / 7	+
For profit	-1(2) / 7	0(-)	-6 / 7	-	-7 / 7	-
Contract-managed	-7 / 7	0	-0 / 7	0	0 / 7	0
Academic	+6(7) / 7	+	+7 / 7	0	+7 / 7	0
Pediatric	+4 / 4	N/A	+4 / 4	N/A	0 / 4	N/A
Long-term	-3 / 6	N/A	-1+1 / 5	N/A	-3 / 5	N/A
Critical access	-(1) / 6	N/A	0 / 6	N/A	0 / 6	N/A
Log of bedsize	+7 / 7	+	0 / 7	+	+7 / 7	+
Small local system	+7 / 7	0	+2 / 7	0(+)	+7 / 7	0
Small dispersed system	-1(2) / 7	-	-1 / 7	-	0/7	0
Large system	-3(4) / 7	0	0/7	0	0/7	0
N of ambulatory MDs	+5 / 7	-	+4(5) /7	0	+3(5) /7	0
% Medicare patients	-3 / 3	-	-2 / 3	0	-1(3) / 3	0(-)
% Medicaid patients	-3 / 3	-	-1 / 3	-	-2 / 3	0
% Uninsured	N/A	-	N/A	0	N/A	-
% Medicare system revenues	-3 / 4	N/A	-1(2) / 4	N/A	+(1) / 4	N/A
% Medicaid system revenues	-4 / 4	N/A	-1(2) / 4	N/A	-3 / 4	N/A
% managed care	0//3	N/A	+2(3) /3	N/A	0 / 3	N/A
% HMO	+1/1	N/A	+1 / 1	N/A	0 / 1	N/A
% PPO (system revenues)	0/1	N/A	-1 / 1	N/A	+(1) / 1	N/A
% POS (system revenues)	0/1	N/A	0/1	N/A	0 / 1	N/A
outpatient-inpatient mix	+3 / 3	+	+2 / 3	+	+2 / 3	0
% capitated and at risk	0 / 1	+	+1 / 1	+	0 / 1	0
Market concentration	0 / 1	0	-1 / 1	0	0 / 1	+
Case-Mix Index	+2 / 2	0	0 / 2	0	+2 / 2	0
Profit margins	N/A	0	N/A	0	N/A	+
Contributions	N/A	+	N/A	+	N/A	+
Equity to assets ratio	N/A	0	N/A	-	N/A	0
Sign of the significant coefficient, number of models where the coefficient is significant at 5 % significance level (at 10% significance level), out of total number of models. 0 denotes an insignificant coefficient; N/A– variable not present in the model.						

Contract-managed status of a hospital has a negative relationship with the composite HIT index (HIT scale) across the national models, but it is insignificant for individual applications – PACS and CPOE. Contract managed status decreases the probability of reaching top two HIT categories by 10% to 15%. However in the California model, this variable does not exhibit any significant relationship, possibly due to small sample.

Academic status is positive and significant for overall HIT scale, as well as CPOE and PACS across all national model specifications. However, academic status has insignificant relationship with "top two" HIT adoption. Pediatric is positive and significant for HIT scale and CPOE, but not for PACS, in all the models, and the size of coefficient is larger than the one for academic status. Coefficient on a pediatric status implies a 30% to 40% increase in the probability of reaching top two HIT categories. In a California model, academic status is also positive for all HIT systems, but not significant for PACS and CPOE, possibly due to a small sample. Theoretically, academic hospitals might be interested in EMR system implementation for the research and teaching purposes and for this reason have higher adoption of clinical HIT. They also have more funding sources for such investment than a regular community hospital.

The mix of hospital services and patient cases also appears to make a difference in clinical HIT adoption. Ratio of outpatient visits to inpatient days in a hospital is positive and significant in some national models and in California, which is a surprising result. According to the national regression results, those hospitals that treat sicker patients (higher case-mix index) have higher level of clinical HIT and likelihood of PACS adoption, which might be explained by greater potential for quality and efficiency improvement due to HIT in a more complex treatment process. Radical increase in case-mix index of 0.5 (equal to 2 standard deviations) is associated with 10% in the probability of reaching top two HIT level. The coefficient on this relationship is positive but insignificant in the California model, and insignificant for CPOE in national models.

TABLE 10.11

Marginal Change in the Probability of Reaching Top 2 Categories on the HIT Scale for a Base-Case Hospital

	Base	M 0	M 1	M 2	M 3	M 4	M 5	M 6
Rural area	0	-0.12	-0.11	-0.13	-0.06	-0.07	-0.11	-0.09
Large urban area	0	-0.11	-0.14	-0.12	-0.10	-0.13	-0.14	-0.16
For-profit	0	-0.28	-0.29	-0.42	-0.24	-0.26	-0.23	-0.29
Contract managed	0	-0.15	-0.13	-0.10	-0.11	-0.09	-0.15	-0.11
Academic	0	0.06	0.06	0.18	0.04	0.07	0.04	0.07
Pediatric	0	0.36	0.33	0.39	NA	NA	NA	0.31
Long-term	0	-0.36	-0.19	NA	NA	NA	NA	-0.15
Critical access	0	-0.03	0.01	0.03	0.28		0.36	0.04
Log of bedsize	4.8	0.07	0.05	0.11	0.04	0.4	0.3	0.09
Small concentrated system	0	0.11	0.10	0.17	0.09	0.08	0.08	0.09
Small dispersed system	0	-0.11	-0.07	-0.05	-0.13	-0.09	-0.13	-0.08
Large system	0	-0.02	-0.13	0.09	-0.05	-0.15	-0.10	-0.14
Number of MDs (in 100)	0	0.07	0.06	0.00	0.05	0.06	0.03	0.06
Medicaid, % system revenue	0.12	NA	-0.69	-0.47	NA	-0.57	NA	-0.77
Medicare % system revenue	0.38	NA	-0.61	-0.65	NA	-0.46	NA	-0.50
Managed Care % revenue	0.27	NA	-0.39		NA	0.15	NA	0.08
- HMO % revenue	0.20	NA	NA	0.18	NA	NA	NA	NA
- PPO % revenue	0.05	NA	NA	0.22	NA	NA	NA	NA
- POS % revenue	0.02	NA	NA	0.12	NA	NA	NA	NA
% Medicare adjusted days	0.45	NA	NA	NA	-0.36	NA	-0.44	-0.38
% Medicaid adjusted days	0.2	NA	NA	NA	-0.08	NA	-0.2	-0.09
Outpatient to inpatient	5	NA	NA	NA	0.00	0	0.01	0.00
Herfindahl (Concentration)	0.3	NA	NA	NA	NA	NA	-0.03	NA
Case-mix index	1	NA	NA	NA	0.20	0.23	0.24	NA
% revenue from capitation	0	NA	NA	NA	NA	NA	0.003	NA

Marginal effects that are significant at 10% are underlined in yellow.
Model 2 produced the estimates on the smallest and least comparable sample.

Long-term care specialization is significantly negative in some PACS and HIT scale models in a national sample. A continuous variable that measures share of the proportion of long-term care inpatient days doesn't have any significant effect in California model.

The coefficient on the size of the hospital (log of beds or adjusted patient days) is positive and significant in the analysis of PACS, top two HIT and composite HIT scale in all specifications of national and California model. The magnitude of the relationship is rather modest: increase in hospital size from 100 to 275 beds (equivalent to 1 point increase on log scale) would only yield about 0.2 increase of a 5-point HIT scale, or increase the probability of reaching top two HIT categories on additional 7% (4% to 11% range depending on a model). The result is consistent with the theory on the economies of scale that larger hospitals would reap higher net benefit from the technology adoption. With the increase in patient volume in the hospital the benefits of the HIT system like PACS increase, while its costs are relatively fixed. In addition, larger facilities might have more resources and organizational capacity to buy and implement a complex technology. However, adoption of CPOE does not have a strong relationship with a hospital size in any of national models.

Hospitals that belong to small local systems (with up to fourteen hospitals located on average less than 80 miles apart) also have significantly higher HIT adoption than stand-alone hospitals – the probability of reaching top two HIT categories is approximately 10% higher. The relationship is particularly strong and consistent for PACS, HIT scale and top two HIT categories that are necessary for the exchange of clinical information, while CPOE has a less robust relationship. RHIOs that allow coordinating HIT investment locally may resemble the effect that local healthcare systems have. On the opposite, large or geographically dispersed hospital systems have lower HIT scale and CPOE adoption compared to stand alone hospitals, although this effect is not consistent. Their probability of reaching top two HIT level is on average 10% lower than if they were a stand alone hospital. It is possible that geographically dispersed systems lack the benefits of the HIT-enabled information exchange and have additional challenge of coordinating HIT investment in multiple facilities.

Local hospital systems that include ambulatory care practices are particularly interested in the exchange of clinical information between ambulatory and inpatient care facilities. The number of system-owned ambulatory clinics that are linked to the hospital is positive and significant in five HIT scale models, four CPOE models and three PACS models out of seven. Increasing a number of ambulatory MDs that belong to a hospital system (in a local area to the hospital) would correspond to about 5% to 7% increase in the probability of a hospital reaching top two HIT categories. This is the effect that one would expect based on network externality theory – hospitals that have ambulatory clinics in the same system are able to internalize the benefits from the information exchange. In California, having positive number of ambulatory doctors has significant positive relationship only with top two HIT categories.

The payer mix in the hospitals may have an effect on HIT investment through the generosity of the reimbursement and through the incentives that reimbursement policies have for improving efficiency. On a facility level, higher shares of Medicaid, Medicare and, in California model, uninsured patients (versus commercially insured patients) have significantly negative relationship with overall level of clinical HIT in both national and California models. The magnitude of the coefficients in a more complete California model imply that increase in Medicare patient share from zero to fifty percent is associated with a one point decrease in HIT scale (i.e. from 4 to 3). Similarly, Medicare and Medicaid patient shares exhibit negative relationship with the adoption of PACS and CPOE, but these relationships are less robust across the models. In the national model every 10% increase in the share of Medicare patients would predict about 4% decrease in the probability of reaching top two HIT categories, while Medicaid does have a significant relationship (Table 10.11).

On the level of the hospital system, shares of hospital system revenues that comes from Medicare and Medicaid (versus fee for service commercial plans) have robust negative relationships with the HIT scale, while the adoption of PACS and CPOE mode have less consistent relationships. The coefficients of system-level Medicare and Medicaid share of revenue remain significant in HIT scale models even when hospital-level shares of Medicare and Medicaid patients are included in the same regression model. According to table 10.11, 10% increase in Medicaid share of hospital system revenues in is associated with up to 7.7% decrease in the probability of top two HIT adoption, while for Medicare the corresponding decrease is up to 6.9%.

The share of managed care (versus commercial fee for service) revenues in a hospital system is significantly positive for CPOE in only two out of four models, possibly because managed care encompasses a variety of different plans and reimbursement methods. When managed care is divided into HMO, PPO and POS plans in one regression with a limited sample, only share of HMO shows a positive and significant effect on HIT scale and CPOE adoption. HMO possibly has this effect through the high prevalence of capitation, as well as most aggressive contract negotiations between payers and providers for lower prices and services provided. It is possible that managed care plans provide an opportunity for hospitals to negotiate higher price or patient volume when hospitals possess a sophisticated HIT system, while they miss such an opportunity under a traditional payment system.

The percent of hospital-level capitation and at-risk payments from AHA survey have insignificant (although positive) relationship with HIT scale and PACS, but significant relationship with CPOE. The California model has better measures of capitation and produces more concrete results. In particular, Medicare capitation brings a significant and substantial improvement in overall HIT adoption scale, while Medical capitation has a positive effect on CPOE adoption. Among the alternative reimbursement models, capitation payment provides the strongest incentive to improve efficiency and quality of care through clinical HIT adoption. PACS, however, generates efficiency benefits per radiology procedure, and hospitals capture those benefits regardless of the payment mechanism. Thus, it is not surprising that capitation has no significant relationship with PACS adoption.

Because all major payer categories that are present in the California model have negative relationships with HIT adoption, the revenues from commercially insured patients have a positive association with HIT revenue. Commercial insurance pays substantially more for its patients than the government does, therefore it bring more financial resources to the hospitals that treat those patients.

The national model with a poor measure of market concentration produces a negative and significant relationship with CPOE adoption. This negative sign of the market concentration coefficient might indicate that hospital competition creates additional incentives to improve safety and quality of care. However, California model, which utilizes a more refine competition measure, does not support this hypothesis. Herfidahl index is insignificant for HIT scale and CPOE, but it has a positive relationship with PACS. In some alternative specifications on the California sample (e.g. without variables on small and large system, CMI, etc.) it becomes significantly positive for all HIT systems. This result suggests that hospital's market power better allows for costly and risky investments, as well as for enjoying the profits from efficiency improvements with HIT adoption.

The California model has an additional set of variables intended to capture a hospital's financial state and predict availability of capital for investment. Of these variables, unrestricted contributions in the last four years have positive and significant relationships with all 3 clinical HIT systems, while profit margin is positive and significant for PACS adoption only. For an average hospital, increasing unrestricted contributions by one million are related to a 7% increase in the probability of adopting PACS, 2% increase in the probability of adopting CPOE, and 4% increase in the probability of reaching top two categories. Unrestricted contributions increase hospital's capital budget, part of which could be spent towards an investment in HIT. Adding one percent to a hospital's profit margin is associated with 1% in the probability of investing in PACS. Equity to assets ratio, which could be related to the ability of a hospital to borrow funds for their investment, does not have a significant relationship with HIT adoption. It is surprising that the variables that directly measure hospital's financial capacity have weak effects, but the proxy measures of reimbursement generosity, like patient mix, have much more consistent effect on HIT adoption.

4.5 Summary of Empirical Evidence and Policy Implications

Univariate and multivariate analysis serves to identify those facilities and hospital systems that lag in HIT adoption and may require additional incentives or government policies. The most common perception that small and rural hospitals and other facilities are less likely and less able to adopt HIT was confirmed in this study. Hospital size exhibits a strong relationship with overall HIT and PACS, even after all other factors are taken into account. Subsidies might be necessary to stimulate HIT adoption in smaller hospitals, because they lack the necessary capital for HIT investment or may not derive enough benefits from HIT investment to cover initial high cost due to economies of scale. However, benefits of HIT adoption to the patients and payers are also proportional to the number of patients that the hospital treats. At this stage, when advanced clinical HIT system remains an expensive investment and a complex project, government subsidies and incentives targeted at larger non-adopting hospitals may bring higher societal returns. Government could potentially play a role in developing an open-source clinical HIT application (i.e. based on Vista) specifically for small community hospitals. These hospitals offer more-or-less generic services and are quite similar among each other, which could allow developing a generic EMR system for them. Collaboration through RHIOs may help to build organizational resources necessary for adoption in the smaller hospitals. Small government subsidies or loans could be offered to small hospitals after the majority of large facilities have adopted and vendors developed inexpensive clinical HIT systems for this market segment. Some clinical HIT systems, such as PACS, may not be worth full public subsidies, because most its efficiency-related benefits accrue to the hospital rather than the payer.

Although at first glance rural hospitals have lower adoption of clinical HIT system, this difference is primarily explained by their smaller size. Once factors like size, ownership and patient distribution are taken into account, adoption in rural hospitals is comparable to the adoption in the hospitals from large urban areas. Both rural hospitals and hospitals from large urban areas have lower HIT adoption than the hospitals from smaller urban areas. Thus, the relationship could be influenced by the income of the population that the hospital serves, and not by the high-tech environment. HIT investment in inner-city hospitals from large metropolitan areas would bring more benefits per dollar of subsidy than rural hospitals would, if the former treat more patients and more complex cases.

The study also confirmed that academic hospitals are ahead of the curve in terms of their clinical HIT adoption – a majority of them have adopted EMR, PACS and even CPOE by now. A bit more surprising is the finding that pediatric hospitals have higher EMR and CPOE adoption rates. It is possible that because of their perceived social value both academic and pediatric hospitals have more opportunities to attract capital for funding their quality-of-care and patient safety initiatives.

Unlike small size and rural location, hospital's for-profit status is rarely quoted by experts and policy-makers as a barrier to adoption of the clinical HIT systems. However, the present empirical analysis along with the findings by Parente and Van Horn (2003) suggests that adoption of quality-enhancing HIT applications is particularly rare among the for-profit hospitals, despite their better financial health. Surprisingly, for profits also lag behind in adoption of a PACS system – an application with reasonably high ROI for a large hospital. Changes in reimbursement policies, or other incentives that reward providers for the improved efficiency and quality of care might be necessary to stimulate the adoption of clinical HIT in this group.

The majority of community hospitals belong to multi-hospital systems. Thus, their adoption behavior is related to their system's adoption behavior. The unique nature of the HIMSS dataset allows investigating HIT adoption at both hospital level and hospital system level. Based on HIMSS sample, less than 30% of the hospitals belong to the systems that didn't reach top HIT level (proxy for EMR) in any of their hospitals. The data demonstrates that clinical HIT adoption by other hospitals from the same multi-hospital system is the single-largest determinant of a hospital's adoption from that system. The correlation is 75% for the HIT scale, and even higher for CPOE system. This result may support the importance of network externalities in the decision to adopt

HIT (i.e., the value of technology investment for the provider depends on whether other providers have adopted this technology).

If the link between adoption in a hospital and adoption in its maternal system is causal, it is clearly important for HIT policies to target those hospital systems that don't have advanced clinical HIT systems yet in any of their hospitals. In this case, however, the spread of the HIT-adoption experience to other hospitals within the system can be expected in the very near future, since 41 percent of hospitals have CPOE and 76 percent of hospitals have PACS either in their hospital or in their system. Over 65 percent of hospitals belong to hospital systems where at least one hospital reached top HIT level (value 4 or 5 of the HIT scale).

Another curious fact is that small local multi-hospital systems with fewer than 15 hospitals have higher adoption of clinical HIT than stand-alone hospitals or geographically dispersed systems: top HIT adoption is at least twice as high in the hospitals that belong to small geographically concentrated systems than in the hospitals from large or dispersed systems, despite the fact that some most advanced HIT adopters - Kaiser Permanente and Intermountain Healthcare systems - are large. Much higher adoption rates among local multi-provider systems may indicate that the investment is more difficult to coordinate when hospital system is larger, and that the smaller locally concentrated systems derive additional value from information exchange among the hospitals. Hospitals can also derive benefits from clinical information exchange with the local ambulatory care providers, especially when both belong to the same multi-provider system. The regression results in the nationwide model support this hypothesis, although Californian data provides contradictory story. In general, higher adoption rate in local multi-provider systems suggest the importance of coordinating HIT investment and the high value of clinical information exchange among the providers from the same region. Regional health information organizations (RHIOs) are being currently developed around the idea of regional coordination of EMR investment and local information exchange among the community providers. These organizations could potentially speed-up diffusion in stand-alone hospitals and hospitals from the dispersed systems, in a way similar to the effect of local multi-provider hospital system.

Medicare, Medicaid and uninsured patients have less access to potential benefits of clinical HIT than commercially insured patients do. Lower reimbursement levels from these payers limit capital availability for a serious HIT investment and could be responsible for lagging HIT adoption in the hospitals with high shares of these payers. Changes in reimbursement policies by Medicare and Medicaid, subsidies or other incentives provided by these payers might be necessary to stimulate the adoption of clinical HIT.

A capitation reimbursement model potentially enables a provider to appropriate most of the benefits from efficiency and quality improvement due to HIT investment. Empirical analysis produced positive evidence on the effect of capitation, especially capitation for the government programs. If this effect is causal, then introducing capitation and other risk-sharing reimbursement policies would reward efficiency improvements including HIT adoption.

The theory isn't clear on the potential effect of competition on adoption of technologies that improve efficiency and quality of care. The classic argument that competition promotes investment in efficiency is supported by the result for CPOE adoption in the national model. The alternative argument that market power allows to spend money on risky investments is supported by the positive effect of market concentration on PACS investment.

There is plenty of indirect empirical evidence that limited financial and organizational resources constrain HIT diffusion. For example, small providers, contract-managed providers and providers that mostly treat Medicare, Medicaid and uninsured patients reimbursed at much lower rate than the commercial patients have much lower diffusion, even when other factors are taken into account. However, the variables that directly measure financial state of the hospital, such as profit margins and equity to assets ratio are insignificant in the regression analysis. Also, unrestricted contributions (including grants for quality-of-care initiative or HIT investment) demonstrate a strong positive influence. Therefore, while direct subsidies in the form of contribution might promote HIT adoption, the size of profit margins is a poor predictor of which hospitals require such subsidies.

CHAPTER 5

CONCLUSIONS AND POLICY OPTIONS

5.1 The current state of HIT adoption and menu of policy options

This dissertation produces estimates of current adoption levels for the major clinical HIT applications, and develops a measure of overall clinical HIT sophistication in the hospitals. In 2004 approximately 30% of the hospitals had installed or signed a contract for an EMR system. Assuming an average two-year gap in HIT system implementation, in 2006 there are about 30% of the hospitals with at least a basic EMR system installed. Similarly, by this time about 10% of the hospitals can boast an advanced integrated system including EMR, CPOE, PACS and some sophisticated departmental systems.

According to Roger (1995), adoption levels above 16% demonstrate that innovators and early adopters, who value the non-monetary gains from innovation such as social status, have already adopted. Currently, as the early majority is adopting (next 34%) the utilitarian value of clinical HIT becomes a most important adoption driver.

The tipping point in the adoption of a comprehensive EMR system is being reached and it requires a new set of policies. Spreading information about the general value of the system has to be replaced with the efforts to facilitate the financing and ease of implementation for the less adept adopters. A current cohort of potential adopters needs a quantifiable return on investment, and policies have to address that. Potential changes in reimbursement models that reward improvements in efficiency and quality of care and incentivize clinical HIT adoption are discussed below.

The next challenge is to attract the late majority, which is skeptical but may follow the rest of the community if they demonstrate positive experience. Healthcare technologies adopted by majority and believed to be beneficial are regarded as "standard of care", and adopted by the rest of the providers just for this reason. Information policies may capitalize on this property: e.g. regional government bodies or provider associations should publicize the current progress and early successes that early adopters demonstrate.

HIT diffusion is speeding up, as some barriers are going away and adoption costs are decreasing. Increased computer literacy among physicians and improved ease of use of some HIT applications were helpful in combating clinicians' resistance to HIT adoption.

Currently, standards are being developed though public-private partnerships, and once introduced they would address the problems of integrating disparate HIT systems. In addition, clear market leaders and proven technologies emerge as the vendor market matures, and certification effort still may further decrease the product search costs that delay HIT adoption among less experienced provider organizations. For the same reason, hardware and software prices are falling slowly and functionality of a new generation of EMR system is increasing

5.2 Hospitals that May Require Subsidies

The most relevant barrier for potential adopters remains the availability of capital and organizational resources that are necessary for adoption of a complex HIT system. However, identification of the organizations that may need subsidies or other financial help is not straightforward. Clearly, not all non-adopters suffer from capital constraints – for-profit hospitals boast better margins, but are behind on the adoption of most clinical HIT systems. Due to recent merger activity in the healthcare markets both for-profit and non-profit hospitals gained more market power and increased their profits. The current empirical results do not support the idea that the level of profits or profit margin is an important factor in HIT adoption. However, other factors that affect hospital revenue do matter: e.g. hospitals with a larger share of Medicare, Medicaid and uninsured patients are less likely to adopt. In contrast, hospitals that receive large contributions, which they can use for HIT adoption, are more likely to adopt. Larger facilities that enjoy economies of scale have a higher propensity to adopt than the smaller facilities.

Healthcare experts often view rural hospitals as most disadvantaged and suggest subsidizing their HIT adoption. According to the regression results, rural hospitals do not differ significantly in their adoption rate from urban hospitals, when their size is taken into account. When the regression model separates urban status into the small urban and large urban areas, rural hospitals, along with large metropolitan area hospitals have lower adoption than the hospitals in small urban areas. Hospitals in the large urban areas care for much larger number of patients, than the rural hospitals do, and hospitals in the large urban areas is a more robust factor of lower HIT adoption than rural location is. Lower adoption rate in large urban areas and in some rural areas could be explained by the fact that they are located in poorer neighborhoods treating low income patients.

Given this evidence, low-rate loans and subsidies for problem providers could target small and financially unstable organizations, which include hospitals with the disproportionate shares of Medicare and Medicaid and community clinics in poor neighborhoods, rather than just rural hospitals.

Insufficient organizational capacity in smaller, rural and contract-managed facilities can be addressed with RHIOs and other community initiatives that help to pull the local resources together and spread the experience from early adopters to the potential adopters.

5.3 Market Failures: Who Should Pay?

The economic analysis of the effect of reimbursement on adoption suggests that a healthcare provider does not capture all the gains from its adoption of clinical HIT unless this provider belongs to a system with full capitation (e.g. Kaiser). The patients and their employers who pay for health insurance are the ultimate beneficiaries of improved quality and efficiency of care. In the short-run, insurance companies could benefit from improved efficiency of care, although in the long run they would pass savings to the employers or patients, who pay for insurance (given competition in the insurance markets). Eventually, CMS is responsible for everyone's healthcare, when they age. Therefore, better health status of the future Medicare beneficiaries may produce savings for Medicare in terms of lower utilization in the future (Bigelow and Fonkych, 2005).

Given the large share of clinical HIT benefits that accumulate to the payers, they should be paying their part of HIT investment either 1) indirectly, rewarding higher quality and lower price through competition forces or 2) directly, by financing the investment, in a case of competitive market with full information. However, this market solution doesn't work well in healthcare for a number of reasons.

Competitive forces should reward efficiency by attracting customers with a lower price, and reward higher quality by attracting more customers or allowing premium payments for the higher quality. However, healthcare output is difficult to price adequately. For example, per diem reimbursement policy punishes for the reduction in the length of stay, which does not allow lowering the price per day of care as a product of higher efficiency.

Higher safety and quality of care also have a limited effect on the number of contracts or better prices, because patients and payers do not possess enough information on quality and safety of care in order to make an informed choice. So far, there is no systematic measurement of quality of care across the providers, and insurance company faces a known price and unknown quality when choosing a provider for their network and negotiating the prices. To an extent a hospital has a trade-off between higher quality and lower price an insurance company may actually discourage high quality of care by negotiating a lower price.

The correction of these market failures will revive the incentives for the adoption of beneficial technologies. The payers could change their reimbursement policies so that they reward better quality and efficiency. For example, pay for performance initiative is becoming quite popular among many payers and providers, and could be helpful in stimulating HIT adoption. Healthcare systems that serve the community with full range of services under a global capitation arrangement provide a perfect market solution because they internalize most of the external benefits of improving healthcare quality and efficiency, such as through an HIT adoption. The government can play the role in stimulating the emergence of Kaiser-like hospital systems that provide a comprehensive care for the regions under global capitation arrangements. The empirical evidence supports a positive role of managed care, HMO arrangements and, especially, capitation in clinical HIT adoption.

Another policy option for the payers is to finance an HIT investment directly, as long as clinical HIT systems are expected to deliver higher efficiency and quality of care. Until recently, providers were cautious about subsidizing HIT investment, because of insufficient evidence on the quality and efficiency gains and their effect on payers. However, a recent RAND study addressed this issue (Hillestad, et al, 2005). Payers are also concerned that the healthcare providers would primarily utilize their HIT system to improve charge capture, rather than to develop the complementary workflows for better quality of care and efficiency, which would be in line the financial self-interest of the provider. However, the most important impediment is a free-riding behavior on the part of the payers. Usually, there are multiple payers in every hospital or healthcare provider, and each hopes that someone else will pay for an HIT investment, e.g. government.

This apparent public good problem requires cooperation among the payers in financing their part of an HIT investment. RHIOs are a good vehicle for this potential cooperation. To ensure that HIT systems are used in a way that improves quality and efficiency, payers could demand quality monitoring enabled by HIT in return for their financing.

CMS, as a single largest payer responsible for over half of the healthcare delivered, should lead the cooperation of multiple payers and pay a major part of the HIT investment. Matching subsidies is a possible tool to stimulate contributions from other payers. Because of limited budget, it is important to identify and subsidize the providers, which do not have sufficient internal ROI from HIT investment, or do not have sufficient access to capital.

Theoretically, Medicare DRG-based reimbursement rewards efficiency improvement better than most common per-diem payment by commercial insurance. However, the empirical analysis shows that the higher shares of Medicare and Medicaid revenues are related to lower HIT adoption. Perhaps capital availability due to low level of Medicare reimbursement is responsible for low HIT adoption, rather than the incentives of Medicare DRG reimbursement scheme. As such, increasing reimbursement levels as a condition for HIT adoption, or distributing funds through subsidies to the hospitals with disproportionately high share of Medicare and Medicaid patients may help some providers to afford an HIT investment, and then use it to improve efficiency under the DRG payments. Hospitals with high share of Medicare, Medicaid and low-income patients already receive disproportionate share payments from federal and state government. Disproportionate share payments potentially could be used as a mechanism to deliver incentives on HIT adoption: e.g. making the size of DSH payments conditional on clinical HIT adoption.

It is a challenging task to support HIT policy initiatives with an empirical analysis of proven policies, because the situation develops rapidly and data on HIT adoption lags behind. The analysis of the newly emerging pay-for-performance incentives could help to discover whether market incentives can stimulate the adoption of technologies that improve efficiency and quality of care.

APPENDICIES

Table A.1

Distribution of HIT Scale by the Type of Hospital

HIT scale	Sample	*Laggards* 1	*Slow* 2	*Middle* 3	*Advanced* 4	*Edge* 5
All hospitals	3989	10%	19%	38%	23%	10%
Non-profit	3111	9%	17%	33%	27%	13%
For-profit	878	13%	24%	54%	8%	1%
Urban	3454	8%	19%	38%	24%	11%
Rural	415	27%	22%	38%	11%	2%
Metro	2647	6%	17%	38%	25%	13%
Non-Metro	1295	17%	22%	39%	17%	4%
Non-academic	3655	11%	20%	38%	22%	9%
Academic	334	1%	6%	34%	29%	30%
Large	2430	3%	17%	40%	26%	14%
Small	1559	21%	22%	34%	18%	5%

TABLE A.2

Mean values of variables used in the national models

	Data Sources	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Sample Size:		3930	2981	1099	3119	2465	2559	2793
Rural (versus other urban)	MI & geo data	0.31	0.32	0.36	0.29	0.30	0.36	0.34
Large urban area	MI & geo data	0.43	0.41	0.38	0.44	0.43	0.38	0.40
For-Profit (versus non-profit)	HIMSS	0.22	0.28	0.36	0.24	0.29	0.19	0.28
Contract-managed	AHA + HIMSS	0.12	0.13	0.09	0.10	0.11	0.15	0.14
Academic	HIMSS	0.08	0.08	0.05	0.09	0.08	0.09	0.08
Pediatric	HIMSS	0.02	0.02	0.03	N/A	N/A	N/A	0.02
Long-term care	HIMSS	0.03	0.01	0.02	0.00	N/A	0.00	0.01
Critical	HIMSS	0.02	0.02	0.02	0.00	N/A	0.03	0.02
Log of bed size	HMISS	4.81	4.81	4.72	5.02	5.00	4.87	4.83
Small local system	HMISS	0.32	0.295	0.21	0.306	0.275	.305	0.271
Small dispersed system	HIMSS	0.065	0.053	0.041	0.063	0.052	.060	0.052
Large system	HMISS	0.36	0.39	0.46	0.35	0.39	0.34	0.39
Number of ambulatory MDs linked to hospital	HIMSS	22.6	21.8	22.51	26	24.3	25.2	22.4
% MCD patients	AHA	N/A	N/A	N/A	0.16	N/A	0.15	0.16
% MCR patients	AHA	N/A	N/A	N/A	0.45		0.47	0.45
% major revenue sources:	HIMSS							
- Medicaid		0.12	N/A	0.12	N/A	0.11	N/A	0.12
- Medicare		0.38	N/A	0.39	N/A	0.38	N/A	0.38
- Managed care		0.26	N/A	N/A	N/A	0.27	N/A	0.26
- FFS (base)								
% of revenue from managed care:	HIMSS							
- HMO		N/A	N/A	0.14	N/A	N/A	N/A	N/A

- PPO		N/A	N/A	0.03	N/A	N/A	N/A	N/A
- POS		N/A	N/A	0.01	N/A	N/A	N/A	N/A
% revenues from capitation & other risk-shared sources	AHA	N/A	N/A	N/A	N/A	N/A	2.74	N/A
Ratio of outpatient visits to inpatient days	AHA	N/A	N/A	N/A	3.71	N/A	3.99	3.97
CMI	MI	N/A	N/A	N/A	1.33	1.33	N/A	N/A
Herfindahl index, predicted	RAND	N/A	N/A	N/A	N/A	N/A	0.38	N/A

TABLE A.3

Descriptive Statistics for the Variables Used in the California Model

CPOE	0.19
PACS	0.35
HIT scale	2.92
Rural hospital	0.07
Large urban area hospital	0.69
Small concentrated system	0.15
Small dispersed system	0.08
Large hospital system	0.51
% For-profit hospitals	0.25
% Academic hospitals	0.09
Contract managed	0.03
Log of adjusted patient days	11.00
Ratio of outpatient visits to inpatient days	3.03
% Long-term care days	0.14
Case-mix index	1.39
% of revenue from capitation/ Medicare (average of last 4 years)	0.02
% of revenue from capitation/ commercial insurance (average last 4 years)	0.03
% of revenue from capitation/ Medical (average last 4 years)	0.01
% Medicare adj days (average last 4 years)	0.39
% Medical adj days (vlast 4 years)	0.24
% adj days Indigent and Self-pay patients (average last 4 years)	0.09
Herfindahl index of market concentration	0.36
Over 5 MDs in ambulatory care practices owned by the hospital (dummy)	0.22
Average contributions in last four years (million)	0.50
Average profit margin in last 4 years	0.05
Equity to assets ratio	0.35

TABLE A.4

HIT Scale, OLS Regression Results

	Model 0	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Rural	-0.26**	-0.21**	-0.077	-0.094+	-0.105+	-0.21**	-0.145*
	(0.06)	(0.06)	(0.09)	(0.06)	(0.06)	(0.06)	(0.06)
Large urban area	-0.22**	-0.24**	-0.095	-0.190**	-0.23**	-0.32**	-0.28**
	(0.05)	(0.06)	(0.08)	(0.06)	(0.06)	(0.06)	(0.06)
For profit	-0.179	-0.165	-0.516*	-0.22	-0.247	0.014	-0.126
	(0.14)	(0.14)	(0.22)	(0.15)	(0.16)	(0.15)	(0.14)
Contract-managed	-0.37**	-0.35**	-0.35**	-0.310**	-0.36**	-0.42**	-0.33**
	(0.12)	(0.10)	(0.09)	(0.11)	(0.11)	(0.12)	(0.10)
Academic	0.189*	0.205*	0.532**	0.152+	0.235*	0.180*	0.203*
	(0.08)	(0.10)	(0.20)	(0.09)	(0.12)	(0.09)	(0.10)
Pediatric	0.723**	0.644**	0.517*	N/A	N/A	0	0.604**
	(0.17)	(0.14)	(0.21)	N/A	N/A	0.00	(0.17)
Long-term	-1.32**	-0.397	-1.08**	-1.494**	N/A	-0.138	-0.423
	(0.29)	(0.46)	(0.18)	(0.42)	N/A	(0.67)	(0.31)
Critical access	-0.152	-0.238	-0.418+	0.211	N/A	0.029	-0.209
	(0.15)	(0.19)	(0.22)	(0.28)	N/A	(0.14)	(0.19)
Log of bedsize	0.235**	0.235**	0.226**	0.180**	0.118**	0.276**	0.280**
	(0.03)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
Small concentrated system	0.298**	0.291**	0.430**	0.266**	0.275**	0.246**	0.282**
(<15 hospitals)	(0.06)	(0.07)	(0.14)	(0.06)	(0.08)	(0.07)	(0.07)
Small dispersed system	-0.104	-0.07	-0.118	-0.242*	-0.153	-0.255+	-0.171
(<15 hospitals)	(0.13)	(0.17)	(0.20)	(0.12)	(0.15)	(0.15)	(0.16)
Large system	-0.123	-0.311*	0.118	-0.105	-0.273+	-0.317*	-0.326*
(>=15 hospitals)	(0.14)	(0.14)	(0.25)	(0.16)	(0.17)	(0.15)	(0.14)
N of ambulatory MDs	0.001**	0.001**	0	0.001*	0.001**	0.001	0.001**
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Medicare patients	N/A	N/A	N/A	-0.641**	N/A	-1.02**	-0.61**
	N/A	N/A	N/A	(0.19)	N/A	(0.22)	(0.20)
% Medicaid patients	N/A	N/A	N/A	-0.226*	N/A	-0.79**	-0.19**
	N/A	N/A	N/A	(0.10)	N/A	(0.27)	(0.06)
% Medicare	N/A	-1.16**	-1.054*	N/A	-0.792	N/A	-0.930*
(system revenues)	N/A	(0.43)	(0.52)	N/A	(0.50)	N/A	(0.45)
% Medicaid	N/A	-1.37**	-0.97**	N/A	-1.195*	N/A	-1.41**
(system revenues)	N/A	(0.38)	(0.37)	N/A	(0.46)	N/A	(0.38)
% managed care	N/A	0.193	N/A	N/A	0.366	N/A	0.217
(system revenues)	N/A	(0.26)	N/A	N/A	(0.29)	N/A	(0.26)

% HMO	N/A	N/A	0.793**	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(0.27)	N/A	N/A	N/A	N/A
% PPO	N/A	N/A	0.643	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(0.56)	N/A	N/A	N/A	N/A
% POS	N/A	N/A	-0.111	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(1.02)	N/A	N/A	N/A	N/A
outpatient-inpatient	N/A	N/A	N/A	0.024**	N/A	0.021**	0.018**
(visits to days ratio)	N/A	N/A	N/A	(0.01)	N/A	(0.01)	(0.01)
% capitated and at risk	N/A	N/A	N/A	N/A	N/A	0.005	N/A
(hospital revenues)	N/A	N/A	N/A	N/A	N/A	(0.00)	N/A
Herfindahl	N/A	N/A	N/A	N/A	N/A	-0.059	N/A
(market concentration)	N/A	N/A	N/A	N/A	N/A	(0.08)	N/A
CMI	N/A	N/A	N/A	0.474**	0.458**	N/A	N/A
	N/A	N/A	N/A	(0.14)	(0.15)	N/A	N/A
Constant	2.111**	2.755**	2.531**	1.973**	2.530**	2.537**	2.666**
	(0.16)	(0.30)	(0.38)	(0.22)	(0.37)	(0.27)	(0.28)
Observations	3930	2980	1098	3119	2465	2558	2792
R-squared	0.27	0.27	0.4	0.2	0.23	0.27	0.28
Robust standard errors in parentheses							
+ significant at 10%; * significant at 5%; ** significant at 1%							

TABLE A.5

Top Two on HIT scale, Logit Regressions

	Model 0	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Rural	-0.52**	-0.46**	-0.55+	-0.282+	-0.294+	-0.47**	-0.387*
	(0.14)	(0.16)	(0.28)	(0.15)	(0.16)	(0.15)	(0.16)
Large urban area	-0.45**	-0.58**	-0.49+	-0.491**	-0.59**	-0.65**	-0.69**
	(0.13)	(0.15)	(0.25)	(0.13)	(0.15)	(0.15)	(0.14)
For profit	-1.454**	-1.37**	-2.88**	-1.431**	-1.36**	-1.173*	-1.37**
	(0.44)	(0.42)	(0.72)	(0.47)	(0.46)	(0.52)	(0.43)
Contract-managed	-0.668*	-0.527+	-0.403	-0.53	-0.405	-0.691+	-0.455
	(0.31)	(0.32)	(0.39)	(0.34)	(0.34)	(0.38)	(0.32)
Academic	0.227	0.234	0.736	0.152	0.278	0.155	0.269
	(0.18)	(0.22)	(0.46)	(0.19)	(0.25)	(0.20)	(0.21)
Pediatric	1.584**	1.520**	1.886**	N/A	N/A	N/A	1.357*
	(0.53)	(0.47)	(0.68)	N/A	N/A	N/A	(0.59)
Long-term	-2.363*	-0.831	N/A	N/A	N/A	N/A	-0.616
	(0.93)	(0.79)	N/A	N/A	N/A	N/A	(0.84)
Critical access	-0.133	0.053	0.121	1.138	N/A	1.576*	0.18
	(0.37)	(0.46)	(0.72)	(0.70)	N/A	(0.74)	(0.45)
Log of bedsize	0.304**	0.340**	0.437**	0.165+	0.168	0.138	0.346**
	(0.06)	(0.07)	(0.12)	(0.09)	(0.11)	(0.12)	(0.07)
Small concentrated system	0.428**	0.381*	0.683*	0.372**	0.329+	0.322*	0.346*
(<15 hospitals)	(0.13)	(0.16)	(0.31)	(0.14)	(0.17)	(0.15)	(0.16)

Small dispersed system	-0.463	-0.283	-0.205	-0.614+	-0.398	-0.565	-0.34
(<15 hospitals)	(0.34)	(0.42)	(0.80)	(0.35)	(0.42)	(0.39)	(0.44)
Large system	-0.097	-0.538	0.351	-0.24	-0.664+	-0.449	-0.568+
(>=15 hospitals)	(0.33)	(0.35)	(0.77)	(0.35)	(0.37)	(0.37)	(0.34)
N of ambulatory MDs	0.003*	0.003**	0.001	0.002	0.002*	0.001	0.002*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
% Medicare patients	N/A	N/A	N/A	-1.543**	N/A	-1.84**	-1.52**
	N/A	N/A	N/A	(0.46)	N/A	(0.53)	(0.51)
% Medicaid patients	N/A	N/A	N/A	-0.347	N/A	-0.843	-0.381
	N/A	N/A	N/A	(0.59)	N/A	(0.67)	(0.49)
% Medicare	N/A	-2.447*	-2.537+	N/A	-1.907+	N/A	-1.992+
(system revenues)	N/A	(0.98)	(1.40)	N/A	(1.08)	N/A	(1.04)
% Medicaid	N/A	-2.78**	-1.86	N/A	-2.350*	N/A	-3.11**
(system revenues)	N/A	(1.00)	(1.26)	N/A	(1.09)	N/A	(1.00)
% managed care	N/A	0.209	N/A	N/A	0.604	N/A	0.306
(system revenues)	N/A	(0.63)	N/A	N/A	(0.71)	N/A	(0.64)
% HMO	N/A	N/A	0.738	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(0.89)	N/A	N/A	N/A	N/A
% PPO	N/A	N/A	0.901	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(1.38)	N/A	N/A	N/A	N/A
% POS	N/A	N/A	0.493	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(2.95)	N/A	N/A	N/A	N/A
outpatient-inpatient	N/A	N/A	N/A	-0.002	0	0.025	-0.002
(visits to days ratio)	N/A	N/A	N/A	(0.01)	(0.00)	(0.02)	(0.00)
% capitated and at risk	N/A	N/A	N/A	N/A	N/A	0.014*	N/A
(hospital revenues)	N/A	N/A	N/A	N/A	N/A	(0.01)	N/A
Herfindahl	N/A	N/A	N/A	N/A	N/A	-0.117	N/A
(market concentration)	N/A	N/A	N/A	N/A	N/A	(0.22)	N/A
CMI	N/A	N/A	N/A	0.883**	0.972**	0.983*	N/A
	N/A	N/A	N/A	(0.33)	(0.37)	(0.39)	N/A
Constant	-1.750**	-0.55	-1.255	-1.466**	-1.325+	-1.145+	0.026
	(0.33)	(0.63)	(0.99)	(0.52)	(0.71)	(0.69)	(0.63)
Observations	3930	2980	1076	3117	2430	2286	2792
R-squared							
Robust standard errors in parentheses							
+ significant at 10%; * significant at 5%; ** significant at 1%							

TABLE A.6

PACS Logit Regressions

	Model 0	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
Rural	-0.311**	-0.326*	-0.32	-0.001	-0.171	-0.236+	-0.177
	(0.12)	(0.13)	(0.23)	(0.13)	(0.14)	(0.14)	(0.14)

Large urban area	-0.118	-0.161	-0.177	-0.082	-0.107	-0.296*	-0.197
	(0.12)	(0.13)	(0.18)	(0.12)	(0.14)	(0.14)	(0.13)
For profit	-0.908**	-0.980**	-2.209**	-0.870**	-1.029**	-0.871**	-0.88**
	(0.29)	(0.30)	(0.46)	(0.31)	(0.30)	(0.32)	(0.29)
Contract-managed	-0.136	0.023	0.1	0.007	0.063	-0.171	0.087
	(0.27)	(0.27)	(0.28)	(0.32)	(0.33)	(0.26)	(0.27)
Academic	0.571**	0.668**	1.300*	0.420*	0.641*	0.778**	0.653**
	(0.19)	(0.25)	(0.54)	(0.20)	(0.27)	(0.23)	(0.24)
Pediatric	0.142	0.159	-0.284	N/A	N/A	N/A	-0.043
	(0.40)	(0.52)	(0.79)	N/A	N/A	N/A	(0.64)
Long-term	-2.155**	-1.179*	-1.580**	N/A	N/A	0.811	-0.661
	(0.81)	(0.55)	(0.50)	N/A	N/A	(1.02)	(0.60)
Critical access	0.156	-0.149	-0.372	0.881	N/A	0.456	-0.116
	(0.31)	(0.47)	(0.73)	(0.55)	N/A	(0.31)	(0.48)
Log of bedsize	0.541**	0.570**	0.750**	0.432**	0.272**	0.662**	0.692**
	(0.06)	(0.07)	(0.11)	(0.09)	(0.10)	(0.08)	(0.08)
Small concentrated system	0.511**	0.544**	0.672*	0.546**	0.575**	0.498**	0.554**
(<15 hospitals)	(0.12)	(0.15)	(0.28)	(0.14)	(0.16)	(0.15)	(0.15)
Small dispersed system	0.179	0.29	0.943*	0.09	0.379	0.08	0.233
(<15 hospitals)	(0.31)	(0.38)	(0.40)	(0.36)	(0.43)	(0.34)	(0.40)
Large system	-0.024	-0.226	0.717	-0.132	-0.29	-0.244	-0.296
(>=15 hospitals)	(0.23)	(0.27)	(0.51)	(0.25)	(0.27)	(0.26)	(0.27)
N of ambulatory MDs	0.003**	0.003+	0.001	0.002*	0.002	0.002*	0.003+
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
% Medicare patients	N/A	N/A	N/A	-0.903+	N/A	-1.585**	-0.887+
	N/A	N/A	N/A	(0.49)	N/A	(0.49)	(0.46)
% Medicaid patients	N/A	N/A	N/A	-0.958	N/A	-1.794**	-0.393*
	N/A	N/A	N/A	(0.59)	N/A	(0.57)	(0.17)
% Medicare	N/A	-0.423	1.974+	N/A	-0.965	N/A	-0.068
(system revenues)	N/A	(0.79)	(1.08)	N/A	(0.78)	N/A	(0.78)
% Medicaid	N/A	-2.537**	-0.969	N/A	-3.839**	N/A	-2.46**
(system revenues)	N/A	(0.95)	(1.00)	N/A	(0.94)	N/A	(0.92)
% managed care	N/A	0.287		N/A	-0.311	N/A	0.273
(system revenues)	N/A	(0.54)		N/A	(0.50)	N/A	(0.52)
% HMO	N/A	N/A	0.958	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(0.63)	N/A	N/A	N/A	N/A
% PPO	N/A	N/A	2.154+	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(1.30)	N/A	N/A	N/A	N/A
% POS	N/A	N/A	1.491	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(2.69)	N/A	N/A	N/A	N/A
outpatient-inpatient	N/A	N/A	N/A	0.019		0.034**	0.034**
(visits to days ratio)	N/A	N/A	N/A	(0.01)		(0.01)	(0.01)
% capitated and at risk	N/A	N/A	N/A	N/A	N/A	0.002	N/A
(hospital revenues)	N/A	N/A	N/A	N/A	N/A	(0.00)	N/A
Herfindahl	N/A	N/A	N/A	N/A	N/A	0.145	N/A
(market concentration)	N/A	N/A	N/A	N/A	N/A	(0.20)	N/A
CMI	N/A	N/A	N/A	1.414**	1.666**	N/A	N/A
	N/A	N/A	N/A	(0.30)	(0.35)	N/A	N/A

Constant	-2.825**	-2.420**	-4.582**	-3.765**	-2.671**	-2.452**	-2.9**
	(0.33)	(0.65)	(0.93)	(0.53)	(0.64)	(0.59)	(0.71)
Observations	3930	2980	1098	3117	2465	2558	2792
Robust standard errors in parentheses							
+ significant at 10%; * significant at 5%; ** significant at 1%							

TABLE A.7

CPOE Logit Regression Results

	Model 0	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
Rural	-0.399*	-0.295+	-0.189	-0.223	-0.197	-0.181	-0.213
	(0.16)	(0.17)	(0.30)	(0.16)	(0.17)	(0.18)	(0.18)
Large urban area	-0.065	-0.320+	0.051	-0.056	-0.358*	-0.290+	-0.370*
	(0.14)	(0.16)	(0.25)	(0.15)	(0.17)	(0.17)	(0.17)
For profit	-1.17**	-1.138*	-1.403*	-1.197*	-1.145*	-0.622	-1.036*
	(0.45)	(0.47)	(0.60)	(0.48)	(0.48)	(0.45)	(0.46)
Contract-managed	-0.305	-0.196	-0.589	-0.176	-0.105	-0.489	-0.17
	(0.33)	(0.36)	(0.45)	(0.35)	(0.39)	(0.37)	(0.36)
Academic	0.655**	0.817**	1.368**	0.650**	0.919**	0.658**	0.932**
	(0.19)	(0.23)	(0.49)	(0.20)	(0.25)	(0.20)	(0.22)
Pediatric	1.526**	1.529**	2.343**	N/A	N/A	N/A	1.917**
	(0.49)	(0.52)	(0.83)	N/A	N/A	N/A	(0.68)
Long-term	-1.838*	0.635	N/A	N/A	N/A	-0.034	1.056+
	(0.93)	(0.60)	N/A	N/A	N/A	(1.10)	(0.59)
Critical access	0.112	0.274	-0.656	0.289	N/A	0.315	0.251
	(0.37)	(0.44)	(1.00)	(0.69)	N/A	(0.39)	(0.48)
Log of bedsize	0.016	0.067	0.188	0.012	0.014	0.085	0.127
	(0.07)	(0.08)	(0.13)	(0.11)	(0.12)	(0.09)	(0.09)
Small concentrated system	0.387**	0.226	0.463	0.339*	0.19	0.25	0.216
(<15 hospitals)	(0.15)	(0.19)	(0.35)	(0.16)	(0.20)	(0.17)	(0.19)
Small dispersed system	-0.349	-0.246	-3.01**	-0.586	-0.388	-0.542	-0.359
(<15 hospitals)	(0.42)	(0.46)	(1.11)	(0.46)	(0.49)	(0.50)	(0.49)
Large system	0.086	-0.419	-0.839	0.031	-0.505	-0.223	-0.49
(>=15 hospitals)	(0.35)	(0.37)	(0.64)	(0.40)	(0.40)	(0.37)	(0.36)
N of ambulatory MDs	0.003*	0.002*	0	0.002+	0.003*	0.001	0.002*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
% Medicare patients	N/A	N/A	N/A	-1.37**	N/A	-1.70**	-0.808
	N/A	N/A	N/A	(0.52)	N/A	(0.55)	(0.66)
% Medicaid patients	N/A	N/A	N/A	-0.276	N/A	-1.726*	-0.27
	N/A	N/A	N/A	(0.19)	N/A	(0.72)	(0.17)
% Medicare	N/A	-2.345*	-3.275+	N/A	-1.222	N/A	-1.806
(system revenues)	N/A	(1.13)	(1.68)	N/A	(1.22)	N/A	(1.19)
% Medicaid	N/A	-2.073+	-1.721	N/A	-0.462	N/A	-2.283*
(system revenues)	N/A	(1.13)	(1.59)	N/A	(1.09)	N/A	(1.12)

% managed care	N/A	1.318+		N/A	2.165**	N/A	1.435*
(system revenues)	N/A	(0.71)		N/A	(0.74)	N/A	(0.69)
% HMO	N/A	N/A	3.696**	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(0.89)	N/A	N/A	N/A	N/A
% PPO	N/A	N/A	-4.471*	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(2.11)	N/A	N/A	N/A	N/A
% POS	N/A	N/A	-3.949	N/A	N/A	N/A	N/A
(system revenues)	N/A	N/A	(4.48)	N/A	N/A	N/A	N/A
outpatient-inpatient	N/A	N/A	N/A	0.059**	N/A	0.038*	0.032**
(visits to days ratio)	N/A	N/A	N/A	(0.01)	N/A	(0.02)	(0.01)
% capitated and at risk	N/A	N/A	N/A	N/A	N/A	0.013*	N/A
(hospital revenues)	N/A	N/A	N/A	N/A	N/A	(0.01)	N/A
Herfindahl	N/A	N/A	N/A	N/A	N/A	-0.535*	N/A
(market concentration)	N/A	N/A	N/A	N/A	N/A	(0.24)	N/A
CMI	N/A	N/A	N/A	0.263	0.027	N/A	N/A
	N/A	N/A	N/A	(0.36)	(0.42)	N/A	N/A
Constant	-1.30**	-0.549	-0.817	-1.183*	-1.101	-0.452	-0.812
	(0.38)	(0.76)	(1.12)	(0.51)	(0.78)	(0.65)	(0.77)
Observations	3930	2980	1076	3117	2465	2558	2792
Robust standard errors in parentheses							

TABLE A.8

California Model Estimates

Model type	OLS	Ordered Logit	Logit	Logit	Logit
Dependent Variable	***HIT scale***	***HIT scale***	***Top 2***	***CPOE***	***PACS***
Rural area	0.352	0.659	1.461*	1.257+	0.59
	(0.22)	(0.52)	(0.63)	(0.70)	(0.59)
Large urban area	0.044	-0.003	-0.573	-0.731	1.287*
	(0.15)	(0.29)	(0.45)	(0.66)	(0.53)
Small concentrated system	-0.13	-0.245	-0.175	1.376	-0.032
	(0.25)	(0.59)	(0.66)	(0.93)	(0.70)
Small dispersed system	-0.708**	-1.510*	-5.623**	-3.095**	1.178
	(0.26)	(0.59)	(1.26)	(1.11)	(0.79)
Large system	-0.35	-0.724	-0.675	0.057	-0.56
	(0.33)	(0.71)	(0.77)	(0.96)	(0.58)
For profit	-0.042	-0.141	-1.572**	-1.812*	-1.821**
	(0.27)	(0.64)	(0.47)	(0.86)	(0.63)
Academic	0.312	0.589	0.796	1.401+	0.581
	(0.25)	(0.60)	(0.63)	(0.80)	(0.45)
Contract managed	-0.261	-0.545	-1.390+	-0.945	-0.222
	(0.29)	(0.64)	(0.73)	(0.80)	(0.97)
Log of adjusted days	0.367**	0.828**	0.880*	0.802*	1.055**
	(0.12)	(0.27)	(0.44)	(0.34)	(0.36)
Outpatient – inpatient ratio	0.061*	0.144**	0.114+	0.178**	0.06
	(0.02)	(0.06)	(0.06)	(0.05)	(0.06)
% long-term care days	0.261	0.433	0.21	0.738	-0.189
	(0.35)	(0.80)	(1.00)	(1.28)	(1.20)
Case mix index	0.122	-0.012	-1.336	0.299	0.412
	(0.30)	(0.70)	(1.06)	(0.94)	(1.11)
% revenues from Medicare capitation	4.042*	8.751*	12.245+	-2.792	4.705
(average of last 4 years)	(1.70)	(3.95)	(6.66)	(6.20)	(5.98)
% revenues from Third party capitation	-1.159	-2.585	-2.989	-5.372	-2.494
(average of last 4 years)	(1.43)	(3.26)	(4.03)	(5.43)	(4.77)
% revenues from Medical capitation	4.866*	10.743*	13.31	32.071*	-4.272
(average of last 4 years)	(2.40)	(5.24)	(11.50)	(12.52)	(12.51)
% Medicare adjusted days	-2.137**	-4.346**	-4.152	-3.301	-3.493+
(average of last 4 years)	(0.68)	(1.52)	(2.57)	(2.05)	(2.04)
% Medical adjusted days	-1.863*	-3.918*	-4.014	-6.820*	-2.91
(average of last 4 years)	(0.78)	(1.68)	(2.52)	(2.66)	(2.39)

% county & indigent adjusted days	-2.189*	-4.669*	-5.062	-0.364	-5.516+
(average of last 4 years)	(0.93)	(2.17)	(3.74)	(3.47)	(2.84)
Herfindahl index of market concentration	0.685	1.2	-0.115	-0.368	4.317*
(adjusted for system membership)	(0.67)	(1.45)	(1.63)	(2.06)	(2.08)
More than 5 Ambulatory MDs	0.196	0.426	0.982**	0.279	-0.21
(linked to hospital)	(0.13)	(0.30)	(0.34)	(0.37)	(0.37)
Average contributions in last 5 years	0.079**	0.189**	0.293**	0.204*	0.369**
($ millions)	(0.02)	(0.06)	(0.08)	(0.08)	(0.14)
Average profit margin in last 5 years	0.953	2.098	2.728	-2.811	4.495*
	(0.71)	(1.54)	(2.87)	(2.83)	(2.12)
Equity to assets ratio	0.075	0.173	-0.199	-1.184*	0.443
	(0.16)	(0.35)	(0.54)	(0.56)	(0.47)
Constant	-0.609		-6.831*	-8.163**	-12.500**
	(1.24)		(3.37)	(3.03)	(2.91)
Observations	260	260	260	260	260
R-squared	0.32				
Robust standard errors in parentheses					
+ significant at 10%; * significant at 5%; ** significant at 1%					

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