The Digital Transformation of Healthcare: Current Status and the Road Ahead

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Abstract

As the United States expends extraordinary efforts towards the digitization of its healthcare system, and as policy makers across the globe look to information technology as a means of making healthcare systems safer, more affordable, and more accessible, a rare and remarkable opportunity has emerged for the information systems research community to leverage its in-depth knowledge to both advance theory and influence practice and policy. Although Health IT (HIT) has tremendous potential for improving quality and reducing cost in healthcare, significant challenges need to be overcome to fully realize this potential. In this commentary, we survey the landscape of existing studies on HIT to provide an overview of the current status of HIT research. We then identify three major areas that warrant further research: 1) HIT design, implementation, and meaningful use, 2) measurement and quantification of HIT payoff and impact, and 3) extending the traditional realm of HIT. We discuss specific research questions in each domain and suggest appropriate methods to approach them. We encourage IS scholars to become active participants in the global discourse on healthcare transformation through information technology.

Keywords: health information technology, healthcare transformation, electronic health records, meaningful use

1. Introduction

It is perhaps not an overstatement to assert that among the most pressing problems confronting nations today such as poverty and climate change, the health and well-being of populations is of central importance and consumes significant national resources. Healthcare is a critical part of the economy of the United States, accounting for more than one of every six dollars of spending in 2009. While the relative resource munificence of the US enables such spending that is significantly higher than in any other developed nations, despite these large investments, there are serious concerns over the quality of care Americans receive. The Institute of Medicine, a branch of the National Academies of Science, estimates that as many as 100,000 Americans die each year due to preventable errors (IOM 2000).

Paper-based medical records are part of the reason that the US healthcare system is both inefficient with suboptimal delivery of high quality care. These record systems do not allow for critical pieces of clinical information to be consistently available to decision-makers at the time they are making their clinical decisions, leading to redundancy in services as well as medical errors. There is substantial consensus that the digital transformation of healthcare through broad and deep use of health information technology (HIT) across the healthcare ecosystem, in conjunction with other complementary changes, can reduce costs and improve quality (IOM 2001), although significant challenges exist to realize the benefits, and the possibility of unintended consequences has been acknowledged. Overall, HIT in general and technologies such as electronic health records (EHR) in particular have the potential to fundamentally transform almost every aspect of health services and, in the hope of realizing this promise, the government has provided strong support for broad-based diffusion of HIT. In 2004, the Office of the National Coordinator for Health Information Technology (ONC) was created to coordinate the nation's efforts to promote a nationwide HIT infrastructure. In 2009, the Health Information Technology for Economic and Clinical Health Act (HITECH) provided more than $30 billion in stimulus funds for practitioners to adopt HIT.

HIT represents an important and consequential area of opportunity for information systems (IS) scholars. Our contributions to IS problems in other sectors have interesting overlaps and subtle

distinctions with the healthcare context. The digital transformation of healthcare offers us a platform to use our collective expertise and scholarship to conduct research that can inform policy debates, and to become active participants in the national discourse on healthcare transformation. In this commentary, we survey the landscape of existing studies on HIT to provide an overview of the current status of HIT research. We then identify important research questions that remain unaddressed and warrant further study, and suggest appropriate methods to approach them.

2. Overview of existing research

There is a growing literature in HIT and a systematic summary and review of all published work is beyond the scope of this commentary. Our review reveals that HIT research has largely focused on two topics: the impact of HIT on healthcare performance and issues related to HIT adoption. We present broad themes into which this literature can be conceptually organized, as illustrated in Figure 1, and synthesize the findings from past research. A list of selected exemplars is provided in the online appendix.

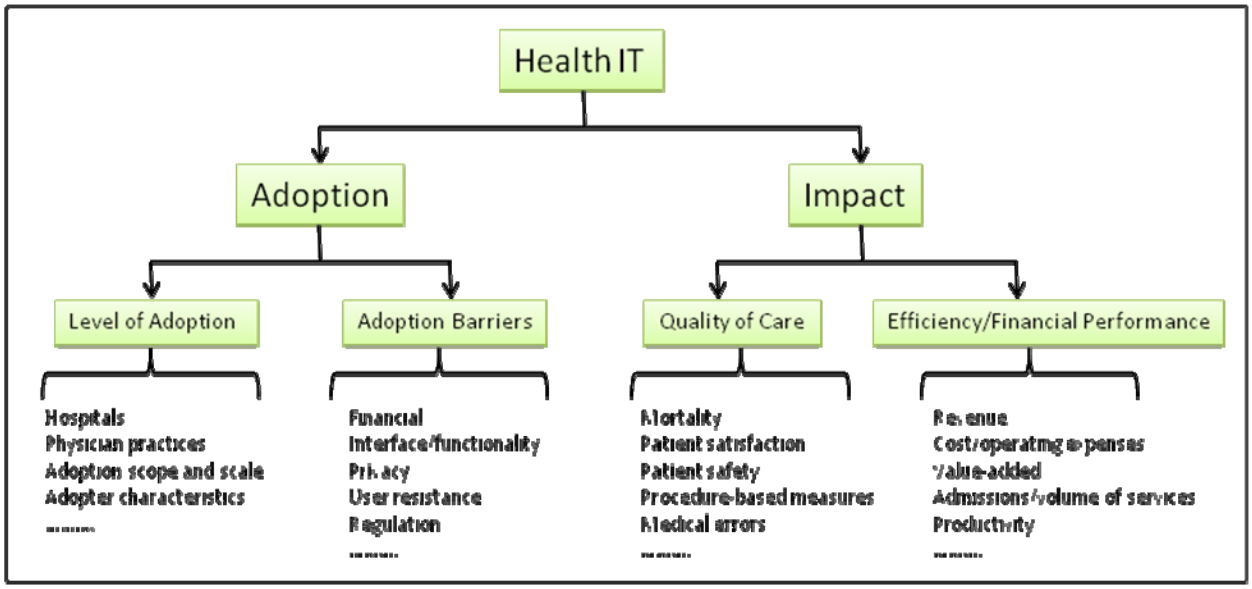

Figure 1. Overview of Major Research Themes in HIT

2.1 Impact of HIT

A large number of studies have examined HIT's impact on various aspects of health services and health outcomes. In 2006, Chaudhry et al (2006) identified 257 such studies published between 1995 and 2005. An updated survey (Golzweig et al 2009) found another 179 published studies from 2005 to June

2007, suggesting that HIT research on HIT impact has gained even more momentum in recent years as practitioners and policy makers seek evidence for the "business case" for HIT investments. A majority of these studies are published in clinical journals, though there is a growing, albeit small, number of papers published in IS journals. We summarize several representative clinical studies published in recent years and refer the reader to existing literature reviews as appropriate[1]. We focus in particular on summarizing IS papers as no comprehensive literature review is currently available in this field.

HIT and Quality: Improvements in healthcare quality are clearly a core component of the value expected from HIT. Several studies have found that HIT has a positive impact on quality, including lower mortality rates (Devaraj and Kohli 2000, 2003, Amarasingham et al 2009), improved vaccination rates (Dexter et al 2004), increased use of recommended procedures (Kucher et al 2005), and patient safety (Parente and McCullough 2009, Aron et al 2010). However, in contrast to these "positive impact" studies, most of which were of specific, custom developed IS systems at leading institutions, broader assessments of the impact of such systems have offered a less promising view of the quality gains associated with HIT adoption and implementation, including Linder et al (2007), DesRoches et al. (2010), Himmelstein et al (2010), and McCullough et al (2010). Further, in addition to these "marginal or no effect" studies, negative effects have also been reported in the literature. Some studies indicate that HIT, if improperly applied, might in fact be harmful to care quality, including Ash et al (2004), Han et al (2005), and Koppel et al (2005). Thus, the collective evidence based on large-scale samples suggests that HIT's impact on clinical quality is still equivocal or minimal in magnitude.

HIT and Efficiency and Financial Performance: The second component of health IT's value proposition is the extent to which it can contribute to "bending the cost curve" in healthcare by introducing efficiencies. Using production function or stochastic frontier analysis, authors have reported that HIT leads to lower costs (Menon and Lee 2000, Borzekowski 2002), higher revenue (Menon et al 2000, Devaraj and Kohli 2000, 2003, Ayal and Seidmann 2009), and higher productivity (Hitt 2010, Lee

[1] Besides Chaudhry et al (2006) and Golzweig et al (2009), other literature reviews include Kaushal et al (2003) and Dorr et al (2006).

et al 2010). However, the positive findings from aggregate economic analyses become less robust when more granular measures are used (Kazley and Ozcan 2009, Devine et al 2010, Himmelstein et al 2010). Although HIT has been argued to have important effects on cost savings in some instances (Wang et al 2003, Hillestad et al 2005, Kaushal et al 2006), the evidence is not overwhelming.

To summarize, the evidence thus far for HIT's impact on performance is equivocal, with prior research reporting positive, negative, and non-existent effects. There are several plausible explanations for the discrepant findings that present important opportunities for further work. First, studies differ in sample and in time period. Studies based on individual hospitals and on early adopters most often find prominent positive effects from HIT. These systems tend to be "home-grown" (as opposed to vendor-based systems) and are often customized and optimized for the clinical setting. The benefits seen from these institutions tend to disappear in large-scale analyses, casting doubt on the generalizability of such findings (Chaudhry 2006). Second, the focal technology varies in different studies, and the complexity and variety of the suite of artifacts that are generally labeled health IT limits the extent to which findings from one type of technology can be applied to predict the effects of another. Third, methodology might contribute to the differences. HIT adoption is obviously an endogenous decision, limiting the ability of cross-sectional studies to render a causal explanation. It is fair to say that the impact of HIT on quality and efficiency is not overwhelmingly positive nor is it sufficiently big with large scale samples, indicating that the majority of health providers have not been able to successfully manage the implementation process to turn HIT investment into tangible benefits. Not surprisingly, researchers have sought to develop explanations for this, as discussed below in our survey of the next topic that has attracted scholarly attention–HIT adoption.

2.2 HIT adoption

The second general theme of HIT research is centered around adoption. In reviewing the related literature, two sub-streams of studies emerge. The first sub-stream concerns itself with the level of HIT adoption,

and asks questions related to scale, scope, and pervasiveness. The second stream examines the barriers and facilitators to the spread and effective use of HIT.

HIT Levels of Adoption: Various studies have examined the rate of HIT adoption among US hospitals and physicians. In the interest of brevity, we restrict our review to studies that have been published in recent years as they are more relevant to the current status. Although the estimation of adoption rate varies due to different focal technologies and depending on the definition of adoption, the general consensus is that HIT adoption in the U.S. is slow, especially when compared to other developed countries. A recent survey of all American Hospital Association (AHA) member acute care hospitals in 2008 found that only 1.5% had a comprehensive EHR; another 7.6% had a basic system (Jha et al 2009), echoing earlier findings in Cutler et al (2005) and Jha et al (2006). Similarly, few physicians actively use HIT in their practices (Jha et al 2006, Simon et al 2007, DesRoches et al 2008).

Several studies have examined the characteristics of hospitals that have adopted HIT, including hospital ownership and teaching status (Cutler et al 2005), size and location (Kazley and Ozcan 2007, Jha et al 2009), and competition (McCullough 2008). Studies have also found that physicians who adopted HIT are more likely to be in large groups (Simon et al 2007, DesRoches 2008), suggesting that practice scale is an important driver of HIT investments.

Barriers to adoption: Prior research identifies four major factors that influence HIT adoption: finance, functionality, user, and environment. As reflected in two recent surveys (Jha et al 2009, and DesRoches et al 2008), financial factors are often listed as the primary obstacle for HIT adoption. Hospitals and physicians are also concerned with the functionality of currently-available HIT solutions (England et al 2000, Poon 2004, DesRoches et al 2008), which leads to user resistance, a factor more extensively studied by IS researchers (Wilson and Lankton 2004, Bhattacherjee and Hikmet 2007, Reardon and Davidson 2007, Agarwal et al 2010). With respect to environmental factors, researchers have identified the important role of regulation. As the healthcare industry is heavily regulated by the government, changes in regulation, especially to payment systems, tend to have a big impact on how hospitals adopt HIT

(Borzekowski 2002, Menon et al 2000). Besides regulation, HIT adoption decisions are likely, through a process of social contagion, to be influenced by the actions of peer institututions (Angst et al 2010).

3. The road ahead

As illustrated in the brief review above, in response to growing concerns about cost, quality of care, and access to healthcare, research focused on the role that HIT can play in alleviating the healthcare burden has been steadily growing. Both in the Unites States and globally, the importance of information technology in healthcare is expanding as policy makers look to technological developments as a means of making healthcare safer and more affordable, and broadening its reach. Against this backdrop, a number of consequential research opportunities exist for IS researchers to leverage existing IS research domains and craft new ones. We summarize these opportunities next (see Figure 2).

3.1 HIT Design, Implementation, and "Meaningful Use"

Since 2009, the landscape of HIT has changed dramatically. The American Recovery and Reinvestment Act (ARRA), passed in February 2009, included a $20 billion stimulus payment to eligible providers, including physicians and hospitals, in an attempt to increase the adoption of EHRs. Approximately $27 billion is being provided for incentive payments through the Medicare and Medicaid reimbursement systems, although some estimates suggest that the number could be substantially larger. To accelerate the development of critical mass and encourage early adoption, incentive payments will be larger early on and decrease in later years. On average, it is expected that eligible professionals will get as much as $48,400 per practice for the adoption of EHR; each eligible hospital will get up to $11 million. Additionally, penalties will be triggered through reduced Medicare reimbursement payments if the provider does not become a "meaningful" user of EHR by 2015.

We expect and are already observing that the stimulus plan will significantly accelerate EHR adoption. Lack of financial incentive has been the most commonly-cited barrier to EHR adoption (DesRoches et al 2008; Jha et al 2009), and the stimulus should largely remove that hurdle. Additionally, technical advances such as cloud computing and service offerings including the growing ubiquity of

application service providers could, in principle, reduce installation and maintenance costs, and provide another boost to adoption. Thus, a critical issue that emerges in the horizon is to improve the meaningful use of HIT after adoption: "..HITECH's goal is not adoption alone, but 'meaningful' use EHRs – that is, their use by providers to achieve significant improvements in care" (Blumenthal and Tavenner 2010). Although the criteria for meaningful use of HIT are still under development, the ultimate goal is clear: improvements in the quality and efficiency of healthcare.

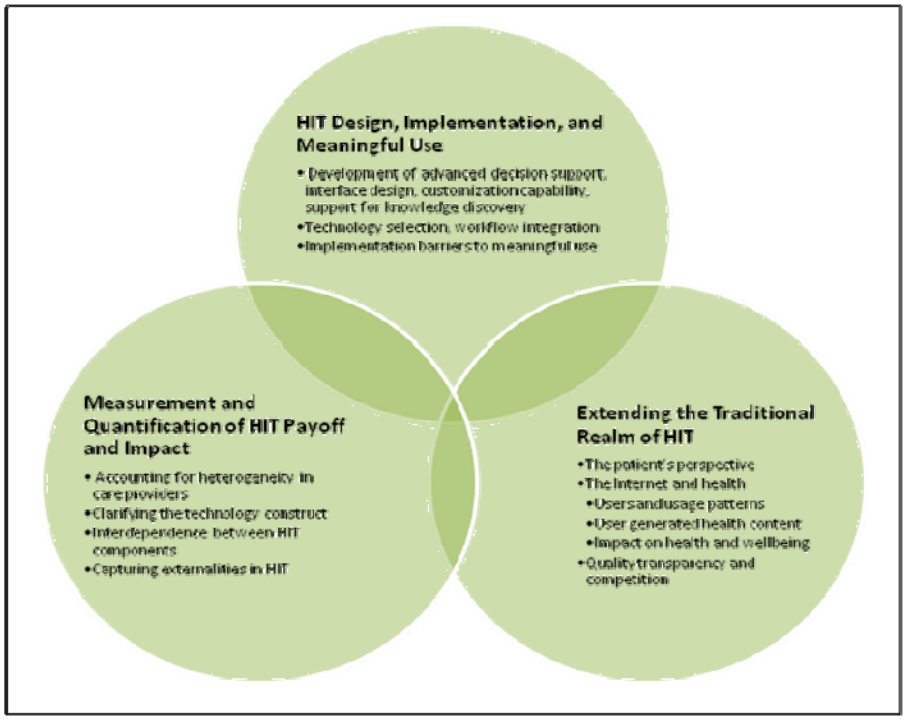

Figure 2. The Road Ahead: Research Opportunities in HIT

In this context, three areas urgently require further research. The first area is the *design of HIT*. It should be understood that HIT is a means, not an end. HIT enhances performance by providing better support for clinical workflows. Most of the leading organizations in HIT have, over the years, chosen to go the route of in-house application development with extensive involvement of care givers (Chaudhry et al 2006). This helps tune the system to their work practices. For most providers, however, in-house development is neither feasible nor economical. Further, ONC has specified that incentives for HIT adoption will be available only for the use of systems that are "certified." Therefore we expect that commercial applications, especially web-based services, will be the mainstream of HIT adoption in the

next few years, much in the same way as the financial services industry has progressed from in-house to COTS solutions. In healthcare, this movement implies that care providers will adopt systems with pre-defined interfaces and functionality, which might not be compatible with existing practice. The existence of this type of incongruence between the health IT artifacts and work practices is reflected in several recent surveys and studies (Lindenauer 2006, DesRoches et al 2009, 2010). Clearly, there is a need for EHR applications to fit more naturally into workflow, and for studies that analyze, map, and isolate inefficiencies in existing work practices.

Another prominent function that is lacking in most current HIT systems is support for "rapid-learning", where physicians are able to access and swiftly apply findings related to the efficacy of treatments and drugs from biomedical studies to the delivery of care (Etheredge, 2007). This requires HIT to be able to connect to large research databases and synthesize and present findings for consumption at the point of care. More importantly, the HIT system needs to provide advanced and intelligent decision support functions such as "does this new procedure apply to my patient?" Additionally, with the digitization of health records, HIT systems can capture real-time information on patients' response to prescribed treatments, providing additional data for the design and refinement of new treatments. This virtuous cycle of learning is an important function for HIT systems of the future. IS scholars, based on their proficiency in the theory, design, and development of health IT artifacts can play a significant role in helping EHR vendors to improve the functionality of EHR and other HIT applications. By offering input on HIT design issues such as advanced decision support, interface design, the capacity for customization, and knowledge discovery and sharing, we can capitalize on the rich expertise of IS researchers.

Closely related to the vendor-side EHR design problem is the *technology selection problem* from the client perspective. Because of the HIT stimulus plan, most healthcare providers feel pressed to adopt EHR rapidly, possibly circumventing a thoughtful and rational selection process. There are over 100 EHR vendors in the US market and this number is growing. Existing studies have largely focused on in-house developed software in leading institutes; and commercial applications are rarely examined (Chaudhry et al 2006). As they receive very little guidance, it proves challenging for hospitals and

physicians to pick the right system to adopt. Research providing insights on HIT selection and how to optimally execute the complex set of trade-offs involved in selection would be extremely valuable.

The third area that could benefit from additional study is determining how best to manage the *HIT implementation process*. This is possibly one of the most pressing health policy issues facing the nation. Given the substantial investments being made in EHR systems and the widespread expectation of payoffs in quality improvements and cost reduction, understanding how best to adopt, integrate, and use EHR applications is critical. Regardless of superior functionality, these systems will have little impact on performance if they are not well-integrated into the daily workflows of care providers, as illustrated in the implementation challenges faced even by large and highly successful healthcare organizations like Kaiser Permanente (Scott et al. 2005). Introducing a new system can cause disruption and turmoil, decreasing efficiency and threatening patient safety. Our review of clinical journals found very few studies on the contextual factors and process changes that are believed to be crucial for the successful implementation of health IT systems (Goldzweig et al 2009). Clearly, this is a critical area that needs more research, and the wealth of research in IS on implementation, including recent studies in the healthcare context (e.g., Lapointe et al. 2007, Goh et al. 2010) provides a robust foundation upon which to build further.

In order to help design, select, and implement HIT applications, one promising approach is to focus analysis at the level of the physician's workflow. Workflows play a central role in care delivery and are directly linked to performance (Bradley et al 2006). There is a strong culture in healthcare aimed at routinizing workflows to minimize risk and enhance efficiency (Greenhalgh, 2008), and emerging care protocols and standards are reinforcing this trend. Therefore, routinization of HIT into daily workflows for better performance might well be the key to achieving meaningful use. As such, EHR systems need to be designed to better support clinical workflows, and hospitals and medical practices need to pick the HIT solution that best fits their workflows. During the implementation process, it has been shown that technology tends to disrupt existing routines (Edmondson et al 2001, Campbell et al 2009), and there are complex and dynamic interactions between routines, agency, and technology during the process (Goh et al 2010). As noted, an extensive literature exists in IS and organization studies on socio-technical

relationships and organizational routines which can inform future work in this area (e.g., Feldman and Pentland, 2003; Orlikowski and Scott 2008).

3.2 Measurement and Quantification of HIT Payoff and Impact

Given the substantial investments being made in HIT, quantifying HIT's impact on performance should and almost surely will continue to be an important focus of research in the future. An estimation of the overall impact of HIT across various care settings is still much-needed but it has become apparent that we need more granular and micro-level studies to generate useful insights. In designing and conducting studies quantifying HIT's impacts, future researchers might want to pay more attention to the factors outlined below.

Heterogeneity in Care Providers: When measuring the impact of HIT on performance, it is important to explicitly take into account the diversity in various types of care providers. For example, hospitals differ along many dimensions including ownership (for-profit, non-profit, and federal), location (rural, urban), teaching status, affiliation with a system or not, size, integration with physicians, culture, leadership, IT history and capability. In ambulatory settings (e.g., medical practices, clinics, etc.) differences exist with respect to a number of factors including clinical specialties, practice size, and nature of population served. The heterogeneous nature of care providers has several important implications for future studies on the impact of HIT. First, the utility function might be different across providers (Newhouse 1970). For example, studies have shown that economic incentives differ between for-profit and non-profit hospitals; these incentives, in turn, influence the primary goal of adopting HIT (Parente and Van Horn, 2006). Researchers, then, must closely examine a care provider's motivation to adopt HIT in order to determine the appropriate performance measures. Second, because care providers vary in both technology capability and financial constraints, they might adopt different types of applications that vary in functionality, interface, costs, and technical support. Third, the actual usage of technology can be heavily influenced by the prevailing culture, leadership, organization, and management (Kane and Alavi 2007, 2008).

Therefore, to gain deeper insights into HIT's impact on performance, closer attention must be paid to the heterogeneity among care providers. It is reasonable to expect that HIT's impact on performance is contingent upon both the technology and the characteristics of the care providers. Additional research is needed to specify the conditions under which findings based on a particular sample of care givers in a specific context can be generalized to others in the field.

Clarifying the Technology Construct: Not all artifacts are created equal, and in order for future research to obtain a more accurate measure of HIT' impact, a deeper understanding of technology is required. Extant IS research has examined various components of IT, including EDI, ERP, CRM, SCM, electronic marketplaces, etc. Similarly, there are multiple components in HIT: HIMSS (2007) specifies about 100 clinical and administrative HIT applications. In estimating the impact of HIT, it is important to understand the pathology of HIT's impact on performance. Focusing on the right match between technology and performance can illuminate a deeper understanding of HIT's impact.

Second, even for systems that bear the same name (e.g., CPOE), factors such as functionality and ease of use can vary significantly. Equally important, an application's compatibility with existing workflow tends to have direct impact on the success of adoption and resulting performance (Goh et al. 2010). Assessment of these issues requires measurement of HIT at more granular level than is currently commonplace. Third, researchers must pay closer attention to the inter-dependence that exists among HIT components. Research has shown that technologies that can affect providers' decision-making tend to have a bigger impact on performance (Dexter et al. 2004; DesRoches et al. 2009). However for the decision support function to work well, it needs input from other components of HIT. Therefore, early investment in digitizing patient information may produce no obvious benefit to performance, until the decision support component is added. This partly explains the findings of Borzekowski (2002) and Hitt (2010), who both find that hospitals in more advanced stages of HIT adoption demonstrate greater benefit. Thus, it would be useful to explore what the characteristics and components of the "infrastructural" health IT are that must be in place in order for the tipping point in performance gains to be reached.

Finally, although abundant datasets already exist in healthcare for researchers (including HIMSS Analytics, AHA surveys, MEPS, and state initiatives like OSHPD), with clinical data being increasingly digitized, a unique opportunity has emerged for utilizing statistical approaches such as data mining for discovering more innovative ways to measure performance impacts of HIT than currently available. Greater digitization of clinical data should also yield more accurate measurements of quality than the norm today, thereby increasing the precision with which the effects of HIT on healthcare performance can be isolated.

Capturing Externalities: Blumenthal and Glaser (2007) defines three types of HIT: EHR, personal health records (PHR), and clinical data exchange. Most existing studies are focused on EHRs, while very few have examined PHRs and data exchange. Additionally, studies on EHR tend to link each individual hospital's HIT investment only with its own performance, as if the hospitals are isolated from each other. However, it has been shown that HIT produces strong externalities, and it is highly plausible that a significant portion of the value of HIT is not captured by the entity that makes the investment.

The benefit from information exchange between hospitals and practices can be significant (Miller and Tucker 2009). Miller and Tucker (2010) found that larger firms were more likely to exchange electronic patient information internally and less likely to do so externally. Current national interest in health information exchanges (HIE) and the burgeoning number of efforts across the nation are testimony to the expectation of externalities from HIT (Adler-Milstein et al. 2010).

This raises two intriguing research questions. First, how can we internalize the externalities? Physician practices might be reluctant to invest in HIT if they alone will bear the cost of digitizing information, but most benefits are garnered by hospitals. As another example, reduced duplicate lab tests and visits implies that revenues for some facilities might be negatively influenced by EHR adoption. Second, how can we maximize the externalities? This challenge includes data standards and interoperability (Walker et al 2005) as well as the development of viable business models for health information exchanges. Research pertaining to the design of networks and the regulation of user behavior to maximize the value of HIT is vitally needed.

3.3 Extending the Traditional Realm of HIT

The landscape of HIT is fast moving and evolving yet until now, very few studies have been centered on patient-focused applications that are outside of the traditional EHR/EMR system (Goldzweig 2009). In recent years, new technologies and emerging policy initiatives are broadening the traditional definition of HIT and considerably expanding the space of research opportunities.

The Consumer Perspective on HIT: In much the same way as consumer technologies have altered how individuals communicate, consumer health IT tools such as PHRs are poised to alter patient engagement with their healthcare. The ONC is increasingly calling for a consumer-centric healthcare system where patients take active control of their health and well-being and personal health information management is a growing of interest (Agarwal and Khuntia, 2009). This presents a number of fruitful research opportunities for IS including issues related to adoption and patterns of use, the effects of such tools on health outcomes, and how these tools may change the doctor-patient relationship.

From the consumer's perspective, a second highly consequential and controversial area is the privacy and security of personal health information (PHI). As large quantities of clinical data are digitized, to the degree that the compromise of PHI can have significant negative consequences for the individual, patients are concerned about privacy and security (Anderson and Agarwal 2010). Further, with the interest in personalized medicine that depends on the availability of large bio-banks, issues related to privacy, security, and bio-ethics have assumed center stage (Lee and Gostin 2009). Public attitudes towards privacy are evolving, as is the surrounding policy infrastructure (Gostin and Nass 2009, McGraw 2009), giving rise to new research questions and challenges. IS scholars have traditionally studied privacy concerns raised by the ubiquity of digital information (e.g., Malhotra et al. 2006); several related issues remain to be explored with health information that may, by virtue of the increased sensitivity of such information, require distinctive theorizing. Relatedly, investigations of how to make digital information more secure and ensure anonymization of identified PHI are critical for ensuring patient trust in a digital healthcare system (Lunshoff et al 2008), and IS scholars can extend existing research in information security to shed light on the security of PHI.

The Internet and Health: It is undeniable that today, the Internet has become a major resource for consumers searching for health information, with 61% of adults searching for online for health information in 2009 (Fox and Jones, 2009). Online health communities and social networks are also booming. Additionally, companies are utilizing the Internet to deliver health programs to their employees, many insurance companies provide web-based health portals for their customers, and healthcare providers are experimenting with delivering service remotely via the Internet, such as in a notable pilot in Hawaii.

Abundant research opportunities exist in this area. First, who are these users and what are their usage patterns? Answers to these questions might have important implications for addressing disparities in the provision of healthcare services (Bundorf et al. 2006). Second, who creates online health information and what is the quality and accuracy of this content? There are multiple contributors, including government agencies, online health businesses, pharmaceutical companies, health professionals, patients, and non-licensed users. While there are a few studies assessing online health information quality (Maloney-Krichmar and Preece, 2005), little research exists that addresses more recent online developments. Third, and most intriguing, is the question of how the Internet impacts health and wellbeing. Despite some early studies reporting no effects (Baker et al. 2003), the Internet has progressed significantly in terms of its ubiquity, speed of access, and content, as well as the amount of time users spend online and their degree of engagement (Kane et al 2009). When patients give more credence to online health information, it can add tension to the relationship between patients and physicians. Even scarcer are studies on the interactions between mainstream HIT (EHR, PHR, health information exchange, etc.) and the Internet. Each one of these areas represents an opportunity for IS scholars to build on existing work in online behavior, user generated content, and search.

Quality Transparency and Competition: Over the last several years, there has been an increasing call for greater quality and transparency on the part of healthcare providers (IOM 2001, Porter and Teisberg 2007). Recently, a number of organizations have begun using the Internet to make care-quality data easily accessible to consumers. Several prominent cases include: *hospitalcompare* for hospitals, *AF4Q* for physician practice, and *nursinghomecompare* for nursing homes. In addition to websites from

government agencies, states such as New York, Pennsylvania, and Florida are also initiating various quality-reporting programs. Another growing trend is the development of user-generated content to communicate information and concerns about provider quality. Just as almost all major online retailers (e.g., Amazon.com) allow users to post reviews on their products and services, there have been multiple websites that provide patients' ratings for various physicians and hospitals (Lagu et al. 2010, Gao et al. 2010). In October 2009, the NHS of the United Kingdom enabled a new service on its official website to allow anonymous patients to post reviews on physician practices, believing it could help improve physician quality transparency. This provides a compelling example of how government strategies are also evolving and establishes an important precedent of a government health authority utilizing user-generated content on the web as part of accepted physician quality measures.

Three interesting questions arise in this context. First, the quality disclosure behavior of patients and healthcare providers represents a fruitful area of study (Jin et al. 2005, Agarwal et al. 2009). For example, which providers are more likely to voluntarily disclose quality data on the Internet? Could incentives be used to induce care providers to participate in quality disclosure programs? How accurate is this type of quality information and to what extent does it correlate with other objective measures of quality? How can health IT be applied to generate better performance measures?

Second, what are the impacts of quality information disclosure on both provider and consumer behavior? It is widely believed that greater transparency in care-quality information could lead to a higher degree of competition, whereby market forces will drive down prices and improve efficiency and quality (Porter and Teisberg 2006; Herzlinger 2007). Studies have shown that consumers do respond to the quality information (e.g., Chernew, Gowrisankaran, and Scanlon 2008). On the other hand, quality report cards can lead to providers engaging in strategic behavior in order to "game" the quality measures, which in turn can hurt social welfare (Dranove et al. 2003).

Third, in examining the impact of care quality information on competition, it is important to recognize a number of special characteristics of the healthcare market. We highlight four that are especially relevant in this domain. First, health services are very complicated along several dimensions.

They require high-reliability and are often time-sensitive. The care process often involves multiple providers, and is personalized to suit each individual's needs. These characteristics necessitate different metrics than those that are often used in measuring the quality of care. Second, a severe information asymmetry problem exists between care providers and patients, where the former holds the clear advantage. It is difficult for patients to "shop around" for health care providers as they do when making other types of purchases. Third, the majority of payments for healthcare services come in the form of insurance, thereby rendering individual patients insensitive to the prices they pay. Finally, the healthcare industry is heavily regulated, and the government plays an influential role as both the chief policymaker and the biggest payer. All these suggest that the healthcare market is quite distinct from the classic market in economics and may require deeper theoretical investigation.

4. Conclusions

In this commentary we specified several essential research areas in the field of HIT which are important at the current stage of HIT adoption. This list is by no means complete. When the healthcare industry began to embrace IT, it confronted many of the same challenges that were encountered in other industries. Therefore, a substantial number of research questions with which IS scholars have accumulated significant expertise in various industry settings can easily find their counterparts in the healthcare field (Chiasson and Davison, 2004). These include business process re-engineering, decision rights allocation, transaction costs, search, and online trust, to name but a few. Underscoring the importance of "learning across sectors," the Agency for Healthcare Research and Quality, a division of NIH and the lead government agency that funds HIT research in the United States recently released a request for proposals asking for research that investigates how findings from other industries related to the design of consumer tools (such as Quicken and TurboTax) can help inform the design of consumer health IT[2]. At the same time, while healthcare shares many characteristics in common with other industries, researchers should be

[2] AHRQ, National Resource Center for Health IT: Request for Task Order "Understanding Development Methods from Other Industries to Improve the Design of Consumer Health IT, June 2010.

cognizant of the unique attributes of this sector. The distinct nature of the healthcare setting promises to help scholars generate new insights and theories.

Compared to other business sectors, the idiosyncratic nature of the healthcare industry implies that significant institutional knowledge is needed in order to research the sector competently. It would be useful for IS researchers to collaborate with government agencies, policymakers, and healthcare researchers from other disciplines, including public health and health informatics. These partnerships will help not only to identify important research questions and conduct research more competently, but also provide a channel through which research findings can influence practice and policy.

It is also important to note that the current juncture represents the very beginning of the digital transformation of the U.S. healthcare industry, and as such, this review has focused primarily on existing technologies. However, as the process of healthcare reform continues to unfold and becomes more far-reaching, we would expect new issues to arise – all of which could benefit from the insight of IS researchers. For example, the proposed health insurance plan exchange will need to be based on research about aspects of online market design.

Additionally, the pace of technological advances in HIT is extremely dynamic, much like the early days of the Internet boom. For example, online social networks are currently being used to curb the growth of obesity, and mobile devices to help deliver care to rural areas and in resource-constrained settings. HIT has attracted significant investments from the high-tech industry, including Google, Microsoft, Intel, Cisco, and others. Recently, Intuit Corporation, which owns the market leader Quicken product for personal financial information management, acquired MedFusion, a provider of health IT applications. This may be a bell-weather for an increasing number of consumer HIT applications entering the market.

The influence of HIT can be more extensive than the direct clinical and financial impacts. Just as technology played an important role in enabling new forms of firms in the 20th century (Milgrom and Roberts 1990), HIT can enable or facilitate new forms of care delivery, especially in preventive care, long-term care and out-patient care. HIT also has the potential to trigger the transformation of healthcare

delivery system, including the integration between physicians, hospitals, and insurance companies, and the emerging medical home, or even in a more disruptive way (Christensen et al 2009). The profound impact of IT on healthcare should be examined from a system perspective.

To conclude, as the biggest sector of the U.S. economy is being digitized, a rare and remarkable opportunity has emerged for the IS community to leverage its in-depth knowledge to both advance theory and impact practice and policy. Just as IT has fundamentally transformed virtually all industries, we believe IT holds the potential to transform the landscape of healthcare. Historically, HIT has not been a primary research stream in the IS community (Chiasson and Davidson 2002), but there has been a significant increase in the amount of research activities undertaken in this area in recent years. In various conferences and symposia, the topic of HIT has warranted enough interest to for a separate track. The growing importance of HIT is also reflected in top IS journals: both *ISR* and *EJIS* have published special issues on HIT in recent years, a separate HIT department has been established in CAIS (Wilson 2004), and a growing number of papers related to health IT are being published in *MISQ* and *Management Science*. We invite you to participate in and contribute to what is likely to be not only a significant scholarly endeavor, but also one with important implications for individuals, organizations, and society.

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Online Appendix: Literature Review

Impact of IT -Economics

Paper	Outcome	HIT measures	Data	Approach	Key findings
Menon and Lee 2000	Cost	IT capital	Washington State, 50 hospitals, 1976-1994	Translog form of cost function	Technical regress in pre-DRG more prominent in pre-DRG than post-DRG period. Medical capital substitute both medical labor and IT capital.
Menon et al 2000	A hospital's annual charges for services (in dollars)	Capital stock, prices, IT capital, prices, labor.	Washington State, 50 hospitals, 1976-1994	Stochastic frontier	IT has positive contribution to revenue. Moreover, the positive effect of the use of medical IT capital was larger than administrative IT capital,
Devaraj and Kohli 2000	Revenue, mortality, satisfaction.	IT labor, IT support, IT capital	8 hospitals that belong to the same system, 3 years, monthly	Regression, with lags on IT measures	IT-performance relationship is observed after certain time lags
Devaraj and Kohli 2003	Revenue, mortality, satisfaction.	Usage of IT: report, I/O, CPU	8 hospitals that belong to the same system, 3 years, monthly	Regression	Usage of IT links to better performance
Borzekowski 2002	Operating expenses	HIMSS, count of administrative and clinic systems.	3000 hospitals with >100 beds. 1987-1994	Cost function, with quadratic forms on HIT count	Adoption of new system at the most thoroughly automated hospitals is associated with lower operating costs, with three and five years lag after adoption. The least IT intensive hospitals, on the other hand, show higher costs after adoption.
Parente and Van Horn 2006	Length of stay, Volume of services	HIMSS. Define clinical IT as master patient indices, clinical decision support systems, CPOE, pharmacy and laboratory systems, EMR. The number of years the patient care information system has	National sample of US hospitals. HIMSS analytics 1990-1998. Financial data from Medicare.	Translog production function	HIT decreases length of stay for for-profit hospitals, but increases discharges for non-profit. Suggesting the former is to reduce cost, while the later is to increase services.

		been in place in the hospital			
Parente and McCullough 2009	Patient safety indicators constructed from MedPAR data using AHRQ's algorithms	EMR, nurse charts, PACS	1999-2002 2707 hospitals	Difference in difference, regression	Only EMR has an impact, effect very small.
Ayal andSeidmann2009	Turn around time, physician and staff satisfaction, and Revenue	PACS integrated to EMR	One hospital	Before and after comparison survey	HIT leads to higher operational efficiency, satisfaction and revenue.
Kazley and Ozcan 2009	Case mix adjusted admissions and outpatient visits	EMR	4606 hospitals in 2004	DEA	No significant relationship between EMR use and efficiency except for small hospitals
Lee et al 2010	Value-added	IT expenditure	California OSHPD 1997-2007	Value-added production function. Dynamic panel data structure for endogeneity	Positive, but very small impact of HIT. Ownership matters. For-profit larger marginal product than not-for-profit and government ones. Driven by the magnitude of health IT use and the types of health IT investments. For-profit devotes more resources to administrative IT than NFP and government hospitals.
Angst et al 2010	Cost- case mix index (CMI) adjusted cost per patient. Quality reflected in average length of stay.	HIMSS	555 hospitals' cardiology department, with at least 2 applications installed in that department by 2007.	Split sample, define success sequences in one sample. Test the impact in other sample	Sequence matters for the impact of HIT on cost and quality.
Hitt 2010	Cost, productivity	HIMSS	1999-2004, 2000 acute care hospitals	Translog cost function	Concave relationship between IT capital and hospital efficiency. The threshold for HIT to take effect is lower in for-profit hospitals.

Impact of IT –clinical

Paper	Outcome	HIT measures	Data	Approach	Key findings
DesRoches et al 2010	Quality on four clinical conditions, mortality rate, length of stay, readmission, cost ratio	Three levels of EHR usage: Basic, Comprehensive, and no adoption. From 2008 AHA hospital IT survey	2952 hospitals 2008	Cross-sectional comparison	HIT is not linked to significant improvement in quality and efficiency. Clinical decision support
McCullough et al 2010	Quality measures based on HQA	CPOE	3401 hospitals 2004-2007	Fixed effects model	HIT is statistically significantly associated with two pneumonia quality measures, and academic hospitals gain more from HIT than others. The magnitude of gain is mild.
Himmelstein et al 2010	Quality, costs, administrative costs	Administrative and clinical systems from HIMSS	approximately 4000 hospitals for the period from 2003 to 2007	Cross-section regression	Very moderate impact on quality, no relationship with administrative or overall costs.
Devine et al 2010	Time efficiency of prescribers	CPOE	3 primary care clinics 2005-2007	Time-motion	e-prescribing takes longer than handwriting.
Goh et al 2009	Time efficiency of rounding team and consulting routines	CCDS	One hospital, 2009	Time-Motion	CCDS reduces time to retrieve patient information
Yu et al 2009	Quality measures from HQA	CPOE	3,364 hospitals 2004 data	Cross sectional	Hospitals that had fully implemented computerized physician order entry outperformed other hospitals in five of eleven medication-related measures and in one of nine other measures.
Amarasingham et al 2009	Mortality, complications, length of stay, and costs in 4 common medical conditions	The degree of clinical information automation based on the Clinical Information Technology Assessment Tool (CITAT)	72 urban hospitals in Texas.	Cross-sectional analysis	Hospitals with automated notes and records, order entry, and clinical decision support had fewer complications, lower mortality rates, and lower costs.
Linder et al 2007 Arch. Internal Medicine	Quality of ambulatory care	EHR	2003-2004 national ambulatory	Cross-sectional analysis	EHR not associated with better quality ambulatory care

			medical care survey		
Kaushal et al 2006	Cost savings and revenue	CPOE	Brigham and Women's Hospital	Interviews, review of existing studies	The CPOE system at BWH has resulted in substantial savings, including operating budget savings, to the institution over 10 years
Hillestad et al 2005	Economic gains from efficiency and safety improvement from HIT	EMR	US national survey	Projection	Estimated that clinical IT may yield savings of up to $142 billion annually
Koppel et al 2005	Examine medication errors facilitated by HIT	CPOE	Tertiary-care teaching hospital (2002-2004)	Field study	CPOE facilitates 22 types of medication errors
Pizziferri et al 2005	Impact on efficiency	EHR	Twenty physicians in five primary care clinics	Time and motion study	EHR does not prolong a clinic session, and leads to better quality
Kucher et al 2005	Best practice	Computer-alert program	One hospital 2500 patients	Randomized trial	Computer-alert program increased physicians' use of prophylaxis and led to better clinical outcome.
Ash et al 2004	Patient safety	Patient care information systems		Literature review and a series of qualitative research studies	An overview of unintended consequences occurring when PCISs are implemented
Dexter et al 2004	Vaccination rates	Computerized standing order system vs reminder system	3777 patients b/w 1998-1999	Randomized trial	Computerized standing order system is more effective than reminder system in improving vaccination rates.
Wang et al 2003	Savings from EMR adoption	Ambulatory EMR in primary care		Partners HealthCare System	Benefit of $86,000 per provider for a 5-year period, from savings in drug expenditures, better utilization of radiology test, better capture of charges, and decreased billing errors.

HIT adoption

Paper	Topic	HIT	Data	Approach	Key findings
Agarwal et al 2010	Physician's perception to HIT	ePrescription	Survey and field study conducted in 2008	Qualitative	Seven frames emerged from the qualitative analysis ranging from positive to neutral to negative
Angst et al 2010	Using social contagion to examine HIT diffusion in US hospitals.	EMR	HIMSS data 1975-2005	Quantitative	The authors find that older, larger hospitals are more likely to be influenced to adopt HIT, celebrity hospitals like "100 most wired" are more likely to be influential, and age is substitute for size.
Miller and Tucker 2009	State privacy protection's effect on adoption	EMR	HIMSS, AHA, census	Multiple analysis methods	State privacy protection of hospital medical information is inhibiting EMR adoption by 24%
Goh et al 2009	Adoption process	CCDS	One hospital, 2009	Field study	HIT needs to be integrated to daily organizational routines. Leadership and personal innovation plays a key role in routinized HIT.
Jha et al 2009	The status of EHR adoption in US hospitals	EHR	2008 AHA National Survey	Statistical analysis	Only 1.5% of U.S. hospitals have a comprehensive electronic-records system and an additional 7.6% have a basic system Major barriers to adoption are capital requirement, maintenance costs and physician resistance.
DesRoches et al 2008	The status of EHR adoption in US physicians in ambulatory care	EHR	A national sample of 2758 physicians between 2007-2008	Statistical analysis	4% percent of physicians reported having an extensive, fully functional electronic records system, and 13% reported having a basic system.
McCullough 2008	Factors that influence the diffusion of HIT among hospitals	Pharmacy, laboratory, and radiology systems	1965 hospitals for the years 1990–2000	Econometric analysis	IS adoption is related to multihospital system membership, payer mix, and hospital scale. Little effect from hospital competition or ownership.
Bhattacherjee 2007	Propose a model of physician resistance of HIT	CPOE	Field survey of 129 physicians in one large	Model based on technology acceptance and resistance to change	Highlights the importance of incorporating user resistance in HIT adoption

			hospital	literatures, tested using PLS	
Reardon and Davidson 2007	Assimilation of EMR among small physician practices	EMR	Survey to 780 Hawaii physicians in 567 practices	Statistical analysis	Learning-related scale, related knowledge, and diversity were positively associated with small physician practices' stage of assimilation of EMR technology.
Simon et al 2007	Correlates of EHR adoption in office practices	EHR	Survey of a stratified random sample of all medical practices in Massachusetts in 2005,	Statistical analysis	45% of physicians, and 23% of practices, were using an EHR. Adoption rates are lower in smaller practices, those not affiliated with hospitals, and those that do not teach medical students or residents
Kazley and Ozcan 2007	Determine the national prevalence of EMR adoption in acute care hospitals; examining the organizational and environmental correlates	EMR	HIMSS 2004 cross-sectional data	Regression	EMR adoption is associated with Environmental uncertainty, type of system affiliation, size, and urban-ness, but not competition, munificence, ownership, Teaching status, public payer mix, and operating margin
Jha et al 2006	How common are her	EHR	Thirty-six surveys conducted between 1995 and 2005	Statistical analysis	As of 2005, approximately 24 percent of physicians used an EHR 5 percent of hospitals had CPOE
Lindenauer et al 2006	Attending physicians adoption of CPOE in two community hospitals	CPOE	356 surveys to attending physicians	Statistical analysis	The adoption of CPOE by attending physicians at community Hospitals vary widely. Usage not correlated to Sex, years since medical school graduation, years in practice at the study institution, and use of computers in the outpatient arena.
Poon et al 2006	Assessing the adoption of HIT	Various components of HIT	Interviews at Boston and	Delphi approach	Overall HIT adoption rate is very low. Adoption of functionalities with

			Denver		financial benefits far exceeds adoption of those with safety and quality benefits. Despite growing interest to adopt HIT to improve safety and quality, adoption remains limited
Cutler et al 2005	Assessing the status adoption and correlates of HIT	CPOE	Leapfrog Group survey 2002-2003	Empirical analysis	Only 4 percent of U.S. hospitals have fully implemented CPOE by 2003. Adoption is related to hospital ownership and teaching status; government and teaching hospitals are much more likely than other hospital types are to invest in CPOE. Hospital profitability is not associated with CPOE investment.
Poon et al 2004 Health Affairs	Barriers to HIT adoption	CPOE	Interview with 52 hospital officials conducted in 2002	Grounded-theory approach	Three barriers are identified: physician and organizational resistance; high CPOE cost and lack of capital; and product/vendor immaturity.
Wilson 2004	Patients' acceptance of e-health	Provider-delivered e-health	Online survey	Statistical analysis	Technology acceptance model is useful in understanding patients' IT acceptance.
Borzekowski, 2002	How financing influences HIT adoption	Hospital information systems	National Survey on Hospital Data Processing 1982-1985	Multiple statistical methods	State price regulations in the 1970s changes hospitals' incentive to invest in HIT. Hospitals use HIT to reduce costs after 1970s.
England et al 2000	To understand barriers to HIT diffusion	HIT in general	Innovation diffusion theory	Theory development/qualitative	Both the technological and organizational characteristics limit HIT's rapid diffusion.

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