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ABSTRACT

Customer-facing information systems have received very little research attention, especially in the context of healthcare. As hospitals begin to provide healthcare consumers with online patient portals to view and manage personal health records and diagnostic results, little is known about whether or not the 'dominant paradigm' (Fichman 2004) of diffusion of innovations theory is sufficient for explaining the characteristics of early adopters. We suggest that a more nuanced understanding of early adoption of patient portals is needed because early adopters are not only the largest hospitals with substantial resources and capabilities residing within competitive environments. Specifically, we suggest that patient-portals are impacted by market characteristics and require Electronic Medical Records (EMRs) systems to be adopted first. We develop a non-linear, two-stage, econometric model with sample selection correction that controls for EMR adoption and estimates the impact of diffusion of innovation and market characteristics on the early adoption of patient portals by U.S. hospitals.

Keywords

Patient portal, hospital, adoption, diffusion of innovations, two-stage, non-linear probit sample-selection model

INTRODUCTION

Consumer portals are being adopted with ever greater frequency by organizations to reduce in-person costs, increase customer convenience, enhance communication options, and maintain lasting customer relationships. However, only limited research has explored what types of firms adopt Type III customer-facing information systems (Swanson 1994 is the basis for the typology). Within the limited number of studies conducted in the context, Chatterjee et al. (2002) find that *top management championship, strategic investment rationale,* and *extent of coordination* positively affects adoption of Type III customer-facing systems. Additional Type III customer-facing information system research has found *that technology integration, web functionalities,* and *web spending* are significant predictors of adoption while *partner usage* is an inhibitor of adoption (Hong and Zhu 2006) and that *relative advantage, competitive pressure,* and *technical resource competence* are significant predictors of adoption (To and Ngai 2006). Yet, relatively little is known about what types of organizations adopt such systems.

We utilize diffusion of innovations theory (Swanson 1994, Rogers 1995, Fichman 2004) as a basis for examination of adoption of patient portals by U.S. hospitals. The 'dominant paradigm' of diffusion of innovations suggests larger organizations within a competitive environment with more resources, capabilities, and more management support are more likely to adopt innovative information systems (Fichman 2004). Yet, much diffusion of innovations research in the information systems domain has primarily focused on the adoption of internal (Type I and Type II) information systems (e.g. Grover et al. 1997, Thong et al. 1999) and not on customer-facing information systems. Therefore, this 'dominant paradigm' has not been fully applied to this newly emerging context. In addition, many unique characteristics of Type III customer-facing information systems have not been considered.

We conduct this research in the context of healthcare and we specifically focus on patient portal adoption in hospitals. Recent policies directed towards Health Information Technology (HIT) (Blumenthal and Tavenner 2010), demand for patient-centered care (Berwick 2009), chronic disease management concerns (Green et al. 2006), and physician technology adoption incentives (Town et al. 2004) highlight the significance of understanding patient portal adoption decisions. The *consumer* is increasingly becoming a focal point in the delivery of care. For healthcare consumers to truly be involved in

their care and assume the requisite responsibilities, they too require a support infrastructure that gives them access to records, information, results, multiple communication channels, connections to other providers, and even connections to patients with similar diagnoses. Patient portals have begun to emerge to fill the infrastructure gap necessary to facilitate patient-centered care and patient self-service.

We consider a patient portal to be a Type III customer-facing information system. For the context of this paper, we suggest that a patient portal is a web-based application that provides access to services and information provided by a hospital. This definition is consistent with Smith (2004) who defines a portal as, "an infrastructure providing secure, customizable, personalizable, integrated access to dynamic content from a variety of sources, in a variety of source formats, wherever it is needed" (p. 94). We also suggest that patient portals are unique from typical internal information systems (e.g. financial information systems, databases, etc.) in a number of ways:

1. Patient portals are nearly always built on top of an existing infrastructure of information systems. Therefore, Type II information systems (EMR, in this context) are often a pre-requisite for patient portals.
2. Patient portal adoption is characterized by innovation sophistication including the choice of whether to offer self-service capabilities, decision-aid capabilities, or both.
3. Market characteristics are likely to significantly influence patient portal adoption in addition to the traditionally studied supply-side characteristics (firm size, management support, etc.).

In this research-in-progress study, we develop and empirically examine a research model that extends existing diffusion of innovations research in a few important ways. First, we consider a *two-stage adoption model* where we control for a pre-requisite, late-stage Type II administrative information system (an EMR, in this context) when considering the characteristics associated with early adoption of a Type III patient portal. Second, we examine the influence of *market characteristics* on patient portal adoption. Third, we consider a patient portal to be a *sophisticated innovation* that can consist of self-service capabilities (Personal Health Record, PHR) and/or decision-aid capabilities (Diagnostic Results).

RESEARCH BACKGROUND

Diffusion of Innovations Theory

Swanson's (1994) seminal article on information systems innovation provides an often-cited typology for organizing and categorizing the adoption of innovative information systems within organizations. Swanson (1994) defines information systems innovation as, "…innovation in the organizational application of digital computer and communications technologies" (p. 1072). The typology suggests that organizations progress through various 'types' of information systems innovation from Type 1a, "IS Administrative Process Innovation", to Type IIIc, "IS Product and Business Integration Innovation," as their focus moves away from the IS department and towards full integration of business processes and information systems. Three specific business "cores" are addressed within the suggested tri-core model: information systems core (Type I), administrative core (Type II), and the technical core (Type III).

Fichman (2004) points out that a large number of studies related to IS adoption have shown that variance in the "quantity of innovation" is well known to be explained by increasing levels of: organizational size and structure; knowledge and resources; management support; compatibility; and the competitive environment (p. 317). He suggests that new adoption of innovations knowledge will often (but not always) require new approaches beyond this "dominant paradigm." Jeyaraj et al. (2006) affirms a portion of this argument in a very thorough review of diffusion of innovations literature (covering the period of 1992 to 2003) when finding that *organizational characteristics* have a strong relationship with organizational adoption of information systems. Jeyaraj et al. (2006) extends the Fichman (2004) 'dominant paradigm' argument by also finding that *innovation characteristics* also have a strong relationship with organizational adoption. With few exceptions, little is known about how any of these categories affect the adoption of Type III patient portals.

Only a limited number of studies have considered firm adoption of Type III consumer systems and the majority of these studies have been conducted in the context of e-commerce. One study that is particularly relevant in our context is that of Chatterjee et al. (2002). Chatterjee et al. (2002) assert that very little research has been done on Type III innovations, and focus on *assimilation* (usage and routinization, in addition to adoption) of e-commerce systems by firms. They find that the influence of *top management championship, strategic investment rationale,* and *extent of coordination* significantly influence the assimilation of e-commerce strategies and activities. However, even though there is a limited presence of research on adoption of Type III customer-facing systems, such as Chatterjee et al. (2002), a general consensus of constructs (or theory) that would be most appropriate for the study of firm adoption of consumer portals does not emerge when reviewing this relevant literature. Unlike the business-to-consumer (B2C) context, consumer portals often play a supporting role rather than

directly facilitating a transaction (as would be the case when purchasing something online, for instance). Additionally, extant research on firm adoption of consumer portals does not fully consider two-stage adoption, market characteristics, or innovation sophistication. Therefore, a full understanding of which firms would expose content on their internal information systems to consumers is currently elusive.

Patient Portal Adoption in Healthcare

For the purposes of this study, we consider Electronic Medical Records (EMRs) to be a Type II innovation ("[application of] IS products or services to the administrative core of the organization," Swanson, 1994, p. 1077) and consumer patient portals to be Type III innovations ("[integration of] IS products and services with core business technology", Swanson, 1994, p. 1077). Patient portals can bridge the gap between patients and healthcare providers by providing patients the tools needed to be a central part of their care (Tang and Lansky 2005).

Empirical work in patient portals is primarily concentrated on the *communication* and/or *interaction* between patients and providers with many of the studies utilizing survey methodologies to ascertain usage, satisfaction, and perceptions with patient-provider e-mail (see Ye et al. 2009 for a systematic review of patient-provider e-mail). Some studies have focused on specific cases of patient-centric information system adoption and discuss the process of designing, developing, and implementing specific cases of such systems (e.g. Grant et al. 2006, Schnipper et al. 2008, Bourgeois et al. 2009). A few studies extend this type of analysis by also including patient-provider usage, acceptance, and satisfaction analysis (e.g. Ralston et al. 2007). While there has been some empirical work on PHR adoption and usage (e.g. Cimino et al. 2002) and quite a bit of research on the efficacy of decision-aids in healthcare (see O'Connor et al. 1999 for a review), most patient-portal studies are context specific (e.g. Weingart et al. 2006, Nordqvist et al. 2009) and very few are conducted on large, nationwide samples.

RESEARCH MODEL

While controlling for the adoption of a mature, pre-requisite information system (EMR), we develop a model that assesses the impact of *diffusion of innovation characteristics (*organization size and structure, resources and capabilities, management support, and competition) and *market characteristics* on the adoption of patient portals by U.S. hospitals.

Hypothesis 1 ("Two-Stage Adoption"): When controlling for a pre-requisite, Type II system (EMR):

a. Diffusion of innovation characteristics will have a significant impact on Type III (patient portal) adoption.

b. Market characteristics will have a significant impact on Type III (patient portal) adoption.

Our research model is summarized in the following figure:

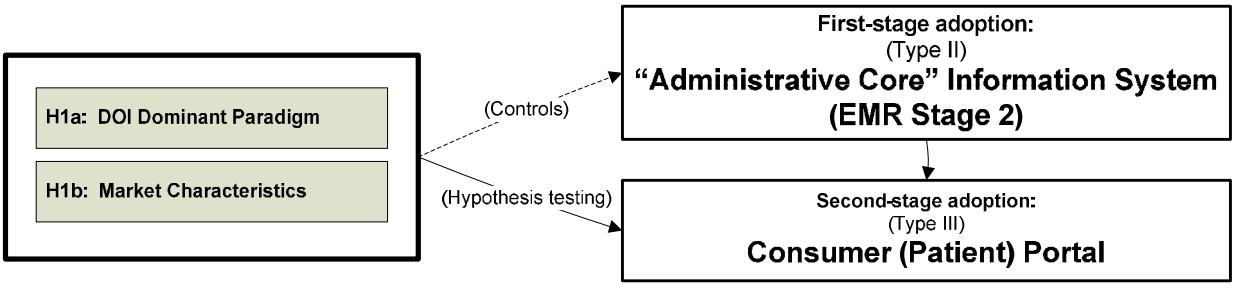

Figure 1: Research Model

DATA

We developed a cross-sectional dataset by merging data from the Health Information Management and Systems Society (HIMSS) 2010, the Area Resource Files (ARF) 2009/2010, and the Bureau of Labor and Statistics (BLS) May 2009. HIMSS is well-known for conducting U.S. health care provider surveys of technology adoption (and related characteristics) of nearly all, non-federal hospitals in the U.S. The ARF data contains U.S. county level census data and health information statistics. The BLS data contains wages by profession by BLS area (roughly equivalent to a U.S. County).

Our merged dataset contains data for 4,736 U.S. hospitals throughout the U.S. This is a near census of non-federal U.S. hospitals. Of these 4,736 hospitals, 3,398 hospitals have achieved what HIMSS refers to as EMR Stage 2 (out of a seven

stage model) in their EMR Adoption Model by implementing a Pharmacy Information System (PIS), a Laboratory Information System (LIS), and a Radiology Information System (RIS) (PIS, LIS, and RIS constitute the requirements for EMR Stage 1) as well as a Clinical Decision Repository (CDR). The implementation of all four of these clinical systems results in receiving the designation of achieving EMR Stage 2 adoption and, as of the writing of this paper, approximately 70% of non-federal U.S. hospitals are EMR Stage 2 compliant. We do acknowledge that hospitals could do much more to fully digitize their operations, but this high percentage suggests that *basic* EMR adoption is well beyond early adoption stages.

Patient-portal adoption, however, is in the very early stages of diffusion. At the time of this writing, 242 hospitals in the HIMSS dataset had either adopted a Personal Health Record (PHR) or had given patients electronic access to Diagnostic Results. This adoption rate is reasonable and expected due to the fact that mature EMR information systems are nearly always prerequisites to patient portal adoption. Without the requisite backend systems, patient portals would offer very little functionality or benefits. Therefore, in our model, we control for EMR Stage 2 adoption (considered to be the prerequisite for patient portal adoption due to the connection between systems provided by CDR[1]) while estimating the impact of diffusion of innovation (DOI) characteristics and market characteristics on the adoption of at least one of these two patient portal systems (PHR and Diagnostic Results).

[1] Less than 10% of hospitals that had adopted a patient portal system (either PHR and/or Diagnostic Results) and *did not* yet have the requisite systems for EMR Stage 2.

Table 2: Descriptive statistics

Category	Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Selection Dep. Var.	EMRSTAGE2	1 = Hospital has implemented Stage 1 systems (PIS, RIS, LIS) as well as the requisite Stage 2 system, CDR	4,736	0.717	0.450	0.000	1.000
Dep. Var.	PPANY	1 = Hospital has implemented PHR or diagnostics results available to patients	3,421	0.071	0.256	0.000	1.000
Market Characteristics	RURAL	1 = Rural location	4,736	0.227	0.419	0.000	1.000
	UNINS	% of uninsured residents (by U.S. County)	4,736	14.436	4.598	0.000	37.900
	POP65	% of residents over the age of 65 (by U.S. County)	4,736	14.097	3.970	4.351	36.188
	LINCOME	log of the average per capita income (by U.S. County)	4,736	10.391	0.713	0.000	11.796
	MCAREPCT	% of residents utilizing Medicare (by U.S. County)	4,407	48.029	15.181	0.000	100.000
Diffusion of Innovation (DOI) Characteristics	LHHI	Log of Herfindahl-Hirschman Index (HHI) measure of market concentration	4,403	0.546	0.186	0.127	0.693
	LBEDS	Log of the number of staffed beds at the hospital	4,736	4.531	1.155	0.693	7.533
	SYSTEM	1 = Hospital is owned by a system	4,736	0.525	0.499	0.000	1.000
	OWNNFP	1 = Not-for-profit hospital	4,407	0.590	0.492	0.000	1.000
	IPANY	1 = Hospital offers an insurance plan	4,407	0.203	0.403	0.000	1.000
	COTH	1 = Member of the Council of Teaching Hospital of the Association of American Medical Colleges	4,407	0.065	0.247	0.000	1.000
	MEDSCHL	1 = Hospital is part of a medical school	4,407	0.176	0.381	0.000	1.000
Exclusion Restriction	RELRNWAGE	log of the following ratio (within each U.S. County): Registered Nurse wage / Computer Programmer wage	4,736	-0.047	0.166	-0.575	0.654
Note: A test of correlations between these variables confirms that all correlations are below 0.60.							

METHOD

Due to the fact that our sample-selection variable (EMR Stage 2) is dichotomous and our dependent variable is also dichotomous (adoption of either PHR or Diagnostic Results called PPANY for 'Patient Portal Any'), we adopt a non-linear sample-selection model that uses 'probit' models at both stages (sample-selection and full-estimation stages). Instead of using OLS and the inverse mills ratio in the second stage (as originally identified by Heckman 1979), correlation is assumed between the two error terms and maximum likelihood is applied for parameter estimation (Van de Ven and Van Pragg 1981).

Based on Wooldrigde (2002, p. 569), at least one variable is needed in the first-stage model that is not present in the second-stage model (exclusion restriction) for a two-stage binary sample-selection model to be "convincing." However, if the exclusion restrictions are endogenous (correlated with both error terms) the model coefficients are subject to bias. Due to the fact that our dependent variable is information technology (IT) related, any variable that is also IT related is also likely to be endogenous (even if the IT performs a different function). Therefore, we obtained wage data from BLS on Registered Nurses and Computer Programmers in each U.S. County. The ratio of these two wages (RN Wages / Computer Programmer wages) forms the basis for our exclusion restriction. We chose to use the ratio of these two wages because (Furukawa et al. 2010) found partial support for reductions in nursing costs when EMR was implemented and Goss and Philips (2002) find that information technology skills often result in higher wages for those with such skills. Since EMR adoption is likely to increase the demand for such technology related skills, we account for the potential of such wage increases by including a technology related wage in our exclusion restriction.

Our empirical specification is an operationalization of the Van de Ven and Van Pragg (1981) econometric model and explains EMR adoption by vectors of explanatory variables (*Z*) and controls (*C*) and explains adoption of patient portal systems by the same vectors (minus the exclusion restrictions), but patient portal adoption is only observed when EMR Stage 2 has also been adopted (EMR=1).

First-stage probit selection equation:

$$Prob(EMR = 1 \mid Z, C) = y_1 = (Z\gamma_1 + C\gamma_2 + u_1 > 0) \quad (1)$$

Second-stage probit equation:

$$Prob(PatientPortalSys = 1 \mid EMR = 1, X, C) = Y_2 = (X\beta_1 + C\beta_2 + u_2 > 0) \quad (2)$$

Where, Y_2 is a binary dependent variable that represents patient portal adoption of at least one patient-centric system (either PHR and/or Diagnostic Results) and is abbreviated, PPANY, in our models. y_1 is a binary representation of EMR Stage 2 adoption and represents the basis for sample-selection, *X* is a vector of exogenous explanatory variables, *Z* contains *X* as well as the exogenous exclusion restriction (RELRNWAGE) described above, *C* is a vector of control variables that are proxies for constructs from diffusion of innovations (DOI) theory, u_1 is the random error term in the first-stage, and u_2 is the random error term in the second-stage. This model assumes that the error terms are independent and have a bi-variate normal distribution, but also that the errors are correlated (Wooldridge 2002, p. 570). The correlation between the error terms is the reason for using sample-selection correction and the correlation between u_1 and u_2 is represented by ρ.

RESULTS

The model controls for a mature, late-stage information system (EMR Stage 2)[2] and assesses the ultimate impact of diffusion of innovation characteristics and market characteristics on the adoption of a PHR and Diagnostics Results by U.S. hospitals. Standard diffusion of innovation characteristics are confirmed for EMR Stage 2, which is expected given the maturity of this technology (some hospitals have been at or beyond EMR Stage 2 adoption for over 10 years). Nearly all proxies for size and structure, capabilities and resources, competition, compatibility, and management support had a significant impact on EMR Stage 2 adoption. One important caveat to note, however, is that the proxy for competition (LHHI) is positive and significant which would suggest that as a market becomes more consolidated (less competition), EMR adoption is more likely. This is counter to the standard diffusion of innovations assumption that more competition results in a higher quantity of innovative information systems adoption. One potential reason for this contrary finding is that EMR systems are very expensive to implement, especially for hospitals, and that competitive markets may result in the 'competing away' of additional resources that could be applied towards EMR if more of a cushion was available.

[2] We initially included a variable for EMR Stage 2 Age (defined as the count of number of years since the hospital first implemented EMR Stage 2), but the variable had an insignificant impact on the adoption of patient-portals and was dropped from the final model.

The impacts on the early adoption of patient-portals are the primary area of interest in this model. While most dominant paradigm characteristics also had significant impacts on patient portal adoption (IPANY, SYSTEM, OWNNFP, MEDSCHL, COTH were all positive and significant), competition (LHHI) and size (LBEDS) did not have a significant impact. In addition, market characteristics including per capita income (LINCOME) and the percentage of Medicare recipients (MCAREPCT) also had a significant impact on adoption. (We do acknowledge, though, that MCAREPCT has a nearly negligible impact due to very low magnitude.) In addition, a higher percentage of uninsured (UNINS) had a negative impact on EMR Stage 2 adoption and did not have an impact on patient-portal adoption. This suggests that higher income patients may be the most likely to be early adopters of patient-portals while uninsured patient populations may be less likely to live in areas where hospitals are digitizing their operations. We also note that Teaching Hospitals (COTH) and hospitals associated with Medical Schools (MEDSCHL) are more likely to adopt patient-portals, but these variables did not have an impact on EMR Adoption. This result is somewhat counter-intuitive and warrants further exploration. In the future, perhaps additional proxies of management support and knowledge resources could be used to further exploration this relationship. The full results are summarized in the following table.

(We note that we also tested the impact of hospital services—i.e. whether or not the hospital offered services for top chronic conditions including cardiology, oncology, diabetes, and arthritis—but such services were highly correlated with size (LBEDS) and had to be dropped from the final model.)

Table 2: Patient portal adoption results from sample selection correction model

Category	Variable	EMR (Stage 2)	Patient Portal Adoption (PHR or Diag.)
Market Characteristics	RURAL	-0.032 [0.020]	-0.011 [0.012]
	UNINS	-0.007*** [0.002]	-0.001 [0.001]
	POP65	-0.001 [0.002]	-0.001 [0.001]
	LINCOME	-0.012 [0.012]	0.040** [0.018]
	MCAREPCT	0.000 [0.001]	0.000* [0.000]
Proxies for DOI Characteristics	$LHHI^{CE}$	0.168*** [0.047]	-0.003 [0.021]
	$IPANY^{SS,KR}$	0.042** [0.019]	0.048*** [0.009]
	$LBEDS^{SS}$	0.095*** [0.008]	0.004 [0.004]
	$SYSTEM^{C}$	0.054*** [0.015]	0.035*** [0.008]
	$OWNNFP^{SS}$	0.028* [0.015]	0.040*** [0.010]
	$COTH^{MS,KR}$	-0.062* [0.035]	0.035** [0.014]
	$MEDSCHL^{MS,KR}$	-0.032 [0.020]	0.023*** [0.009]
Exclusion Restriction	RELRNWAGE	-0.072* [0.042]	
Statistics	Rho		0.734
	Test of Indep. Eqs. P-value (Wald Statistic)		0.000
	Psuedo R^2	0.074	
	N	4,403	4,403
	Censored Obs		1,271
	Uncensored Obs		3,132

Marginal effects from Probit regressions with sample selection; robust standard errors clustered by U.S. County in brackets; significant at ***p<0.01, **p<0.05, *p<0.10.

DOI Theory 'Dominant-Paradigm' Constructs (Fichman, 2004a)
C: Compatibility
CE: Competitive environment
MS: Management support
SS: Organizational size and structure
KR: Knowledge and resources (capabilities)

DISCUSSION AND CONCLUSION

The results provide partial support for both hypotheses 1a (diffusion of innovation dominant paradigm characteristics) and 1b (market characteristics). It is important to note that hospital size and competition did not have significant impacts on patient portal adoption, as the dominant paradigm of diffusion of innovations would suggest. This could be in part due to the early stage in the diffusion process of patient portals, but it may also indicate that Type III customer-facing systems are not only adopted by what is considered to be the typical innovator (i.e. the large firm with considerable resources in a competitive market), but also by smaller innovators that are also impacted by market characteristics (such as markets with higher levels of consumer income).

Other studies have found that consumers with more income are more likely to be early adopters of innovative information systems (e.g. Horsky 1990). Our findings extend this notion of consumer influence by suggesting that adoption of patient portals requires not only innovative firms, but also innovative consumers. Patient-centric information systems are not only a new way of managing records; they represent a paradigm shift away from the traditional control of records and information by physicians and health care providers. Consumers must also be willing to take on additional responsibilities and expend additional efforts if they are going to take an active role in their own health care. In addition, such consumers must have the drive to experiment with these emerging technologies and the available time to dedicate towards initial learning costs while recognizing that maturation of the technology may result in additional learning and switching costs.

In conclusion, we believe that patient portal adoption is a unique and interesting area of research that may provide new insights into the diffusion of innovations. Specifically, we suggest that market characteristics may also have an influential impact on adoption while not all standard diffusion of innovation characteristics (e.g. size and competition) may affect early adopters the same way as they affect late adopters. While the dominant paradigm is more-or-less confirmed for a late stage, Type II system (EMR), adoption of a Type III customer-facing system (patient-portal) appears to be more nuanced. We believe that future research needs to be conducted into how such adoption decisions are made and which constructs have the most significant impact as the diffusion of innovations cycle progresses.

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