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Adoption of Health Information Technology Systems among U.S. Hospitals 2007-2012

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

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Health information technology (HIT) systems are diverse and play varied roles in improving healthcare delivery. Despite the current push for the advancement of HIT infrastructure in the U.S., adoption rates of HIT systems have been slower than expected. In addition, most studies that examine adoption rates focus on specific systems or use non-weighted aggregation. This study investigated the diffusion of HIT systems by employing a novel, weighted scale aggregating 18 different clinical IT systems. We employed proportional hazard modelling to estimate the time to adoption for basic, medium and advanced levels of HIT infrastructure, and control for hospital organizational factors. Our results indicate that small hospitals (<100 beds) are falling the furthest behind in HIT adoption, and may be failing to implement even rudimentary HIT technologies. Also, rural and for-profit hospitals, as well as hospitals with poor network involvement are lagging behind national averages. As the U.S. moves toward a nationwide network of intercommunicating health technologies, these hospitals may become stumbling blocks in the provision of safe, timely, and effective care. Policy should be targeted to lagging hospitals in order to meet HIT adoption goals and prevent the technological gap from widening.

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List of Abbreviations

Health information technology (HIT), information technology (IT), Health Information Technology for Economic and Clinical Health (HITECH) Act, Electronic Health Records (EHR), Computerized physician order entry (CPOE), Picture archiving and communication systems (PACS), Clinical information technology adoption (CITA) scale, Information Exchange Initiative (IE)

INTRODUCTION

Health information technology (HIT) systems are diverse and play varied roles in improving healthcare delivery. Examples of clinical HIT systems include electronic health records (EHR), computerized physician order entry (CPOE), picture archiving and communication systems (PACS), and other various departmental information systems (e.g., cardiology, pharmacy or surgery information systems). Various studies have linked the presence of HIT systems to better health practices and outcomes.[1-4] In light of these benefits, many organizational champions and policy makers have set goals for HIT adoption, including the National Coordinator for Health Information Technology calling for hospitals nationwide to adopt complete EHR systems, data warehousing, radiology PACS, and CPOE.[5]

Despite strong support for HIT adoption, actual adoption rates have traditionally been slower than expected. Studies on adoption rates show slow adoption for EHR, CPOE and PACS[8-10] systems, although studies on other clinical IT systems, and studies examining overall HIT infrastructure by aggregating multiple systems, are sparse.[6] In recent years, Congress has taken further lengths to incentivize EHR and CPOE adoption through incentive payments to hospitals.[11] This study seeks to further investigate the diffusion of HIT systems and the advancement of HIT infrastructure among U.S. hospitals in recent years. Through longitudinal analysis and application of a novel, weighted scale of 18 clinical information technology systems, this study will more accurately describe the adoption rates of HIT for early adopters and laggards in light of the recent incentive initiatives.

LITERATURE REVIEW

Health information technology systems

Health information technology (HIT) describes a broad set of systems that have a great deal of promise in improving the quality and efficiency of the health care system. Examples of clinical HIT systems include electronic health records (EHR), computerized physician order entry (CPOE), picture archiving and communication systems (PACS), and other various departmental information systems (e.g., cardiology, pharmacy or surgery information systems).[30] Clinical HIT systems are distinct from nonclinical systems, such as HIT systems used in business offices, financial management and human resources.[17] Various studies have linked the presence of HIT systems to better health practices and outcomes. Research on EHR has shown that it can provide a range of benefits such as increased communication speed, care coordination, productivity, and health outcomes for certain patient populations (e.g., diabetes and HIV patients).[1,2] Studies focusing on CPOE systems indicate that they reduce medical errors, and aid in the ordering of diagnostic tests,[3] and PACS systems enable providers to have around-the-clock access to radiology services.[4] In light of these benefits, building of HIT infrastructure is considered critical to the improvement of the health care system,[36] and many organizational champions and policy makers have set goals for HIT adoption. Examples of these goals include the National Coordinator for Health Information Technology calling for “nationwide adoption of EHRs” by 2015, and developing an adoption framework prioritizing data warehousing, CPOE and radiology PACS systems[5].

Adoption trends before the HITECH Act

Adoption rates of HIT systems were slow throughout the late 2000's. A survey of over 2,500 physicians in 2007 found that only 13% reported having access to even a basic EHR system.[15] Similarly, a survey of hospital CEOs in 2008 revealed that only 8% of acute care hospitals in the U.S. had basic EHR systems, and that more advanced systems existed in less than 2% of hospitals.[7] CPOE system adoption rates were also shown to be low, at less than 5% in 2005.[9] Studies examining the adoption rates of HIT systems outside of EHR and CPOE during this time are sparse.

These studies describe early adopters of HIT to be primarily large, urban and/or academic hospitals.[1,15-17] The gap in technological advancement between these early adopters and their smaller, rural, non-teaching counterparts became known as the "digital divide," and raised concerns about diffusion of HIT systems for providers who treat underserved populations.[8] Another concern is that, due to the prevalence of basic, "minimally functional" EHR systems rather than more advanced systems, these systems are perhaps not being used in ways that improved patient outcomes or efficiency.[13] Some studies pointed out that organizational goals of IT adoption focused on administrative and financial systems, rather than clinical systems which have a stronger effect in improving patient outcomes.[37]

HITECH Act

In response to lagging adoption trends and concerns about quality and utilization, Congress put forth the Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009, causing dramatic change in the HIT landscape. The HITECH Act appropriated $25.9 billion to support HIT adoption, and carried with it new definitions and standards that would be used to certify HIT systems and the healthcare providers that use them.[12] HITECH incentivizes providers to adopt EHR systems by offering monetary incentives for adoption of systems meeting certain criteria. These criteria, known as "meaningful use," focus primarily on implementation of key EHR system capabilities, as well as appropriate utilization of these systems.[13] Providers who meet meaningful use criteria are given increased payments through Medicare and Medicaid over 5-6 years; disbursement of these payments began in 2011.[10,12] According to CMS reports as of January, 2015, over half of all eligible providers have begun receiving these payments, with more than $19.5 billion paid out through the Medicare EHR incentive program, and more than $9 billion paid out through the Medicaid EHR incentive program.[38] The specific focus on EHR systems in HITECH's provisions was due to the fact that EHR systems are seen as the "first important step" in establishing HIT infrastructure.[11] EHR systems have specificity, measurability, and a large evidence base supporting their positive effect on health care delivery.[12] Through these new incentives and definitions, the HITECH Act aims to increase the health of Americans by nurturing HIT adoption and innovation.[11]

Adoption trends after the HITECH Act

Since the enactment of the HITECH Act, HIT adoption has accelerated, though some disparities still remain. The American Hospital Association annual hospital survey supplement, added in 2009, indicates modest increases in EHR adoption in 2009 (11% increase)[27] and 2010 (15% increase).[28] By 2011, the share of hospitals reporting any EHR system had grown to 27%.[20] The most recent studies in 2012 estimate that up to 44% of acute care hospitals had implemented EHR systems.[21] Using proxy variables for meaningful use, researchers have also found that 11% of hospitals displayed meaningful use across all clinical units. What little research exists documenting the adoption of HIT systems other than EHR suggests that advanced systems like CPOE may be proving more challenging for hospitals to implement.[21] Despite accelerating EHR adoption, all evidence also indicates that small, nonteaching and rural hospitals are still lagging behind other hospitals,[20] and that the digital divide might even be widening.[11] There are a number of factors both internal and external to a hospital that may be correlated with adoption of HIT systems.

The Digital Divide – Differences between early and late adopters

It is well established that hospital size, urbanicity, and teaching status are major factors in HIT adoption, with large, urban, teaching hospitals outpacing their smaller, rural counterparts.[20,21,27,28] Other factors that may play a role in HIT adoption include payer mix, with higher percentages of Medicare patients positively associated with EHR adoption rates,[18,22] and patient mix, with a higher percent of elderly patients has been found to be negatively associated with EHR adoption rates.[23] Notably, proportions of impoverished patients and minority patients have not been shown to have any relation to EHR adoption rates.[18,24] Also, research implicates hospital ownership has been as being a possible influence in HIT adoption, as non-profits have been shown to have higher percentages of EHR adoption.[22] Finally, procedure mix may be correlated with HIT adoption, as hospitals that have surgical procedures as a higher percent of their overall case load have less EHR systems.[14]

Evidence also suggests that geographic location may play a role in the disparity of hospital HIT adoption rates. Vest et. al., 2012 found differences in EHR presence by hospital referral region after controlling for the confounders listed above.[25] Other studies that have investigated regional differences in EHR adoption are often limited to defining region very broadly – dividing the United Stated into around 5 general regions.[14,17,18,22] These studies also have mixed results – while some studies show that the Northeast as the highest adopters of EHR with the Midwest being the slowest,[14] other studies have shown the exact opposite.[22] These conflicting results show the need to define differences in HIT adoption in a more in-depth manner, using more robust measures of HIT adoption.

Measures of HIT adoption

In order to assess HIT adoption, many studies take one of two approaches – the presence or absence of a specific HIT system, or an aggregated measure of multiple systems. To date, most studies that factor in multiple HIT systems view HIT systems as equally-weighted, with no quantitative value placed on how advanced a system is or how difficult it is to implement. While these studies seek to describe overall HIT infrastructure rather than just adoption of one system, they are limited in that more advanced HIT systems are weighted equally to basic systems. A recent study by Lee and Park (2013) has proposed a new scale – the clinical information technology adoption (CITA) scale – which uses factor analysis to weight more advanced HIT systems over basic systems. This scale may more accurately represent a hospital's advancement along the adoption continuum by grouping HIT systems into four levels, with systems in the same level sharing similar characteristics, challenges to implementation, and time to adoption.[6] This lends support to the hypothesis that increasing EHR rates may be linked to increasing use of other HIT systems. At this point, the CITA scale has not seen widespread use in the literature.

Gaps in literature

Although a better picture of HIT diffusion through the U.S. healthcare system has begun to form, existing research is limited in a number of ways. While longitudinal analysis of HIT adoption has become more effective in recent years with the advent of new survey methods, understanding of the effects of HITECH is still lacking. The HIT adoption landscape will continue to change as the program moves forward with incentive payments. Also, many recent descriptions of adopter and non-adopter population are often performed through surveys of a small number of hospitals within a state.[2,4,22-24] Finally, the majority of studies have been limited in by how they define HIT adoption, often focusing solely on EHR.[14-18,21,23,25] This study will draw on a novel scale of overall HIT adoption and survival analysis to examine the complex continuum of HIT adoption for hospitals.

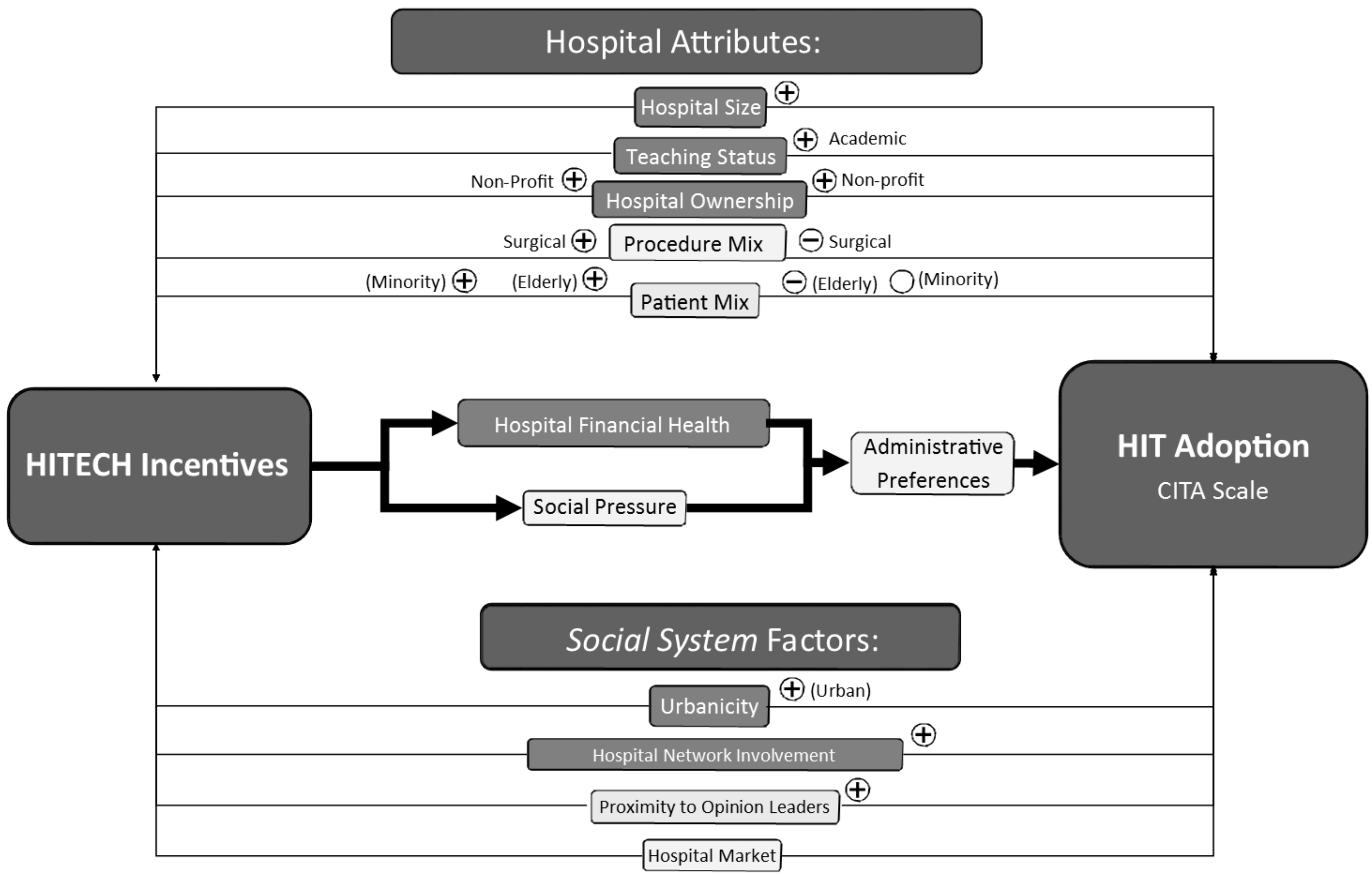
METHODS

Conceptual Framework – Diffusion of Innovation Theory and Dissemination Science

In order to understand how internal and external factors influence the HIT adoption process, this study used diffusion of innovation theory and dissemination science to develop a conceptual framework. This framework focuses on organizations as the unit of analysis, adoption as the key dependent variable, and seeks to operationalize diffusion theory-based constructs to examine their impact on ultimate adoption or non-adoption.[31] A visual representation of these constructs and the pathways through which they influence HIT adoption can be seen in Figure 1, with constructs measured in this study in dark grey and unmeasured constructs in light grey. These constructs include traits of the organization and social system factors.[31] Specifically, this study seeks to investigate how hospitals with certain characteristics that exist in particular societal sectors adopt an innovation (HIT).

Organizational attributes of hospitals determine their "degree of readiness" and influence their time until adoption. In terms of relative earliness of adoption, innovations are first adopted by "innovators", or organizations with very little risk aversion, and a focus on novelty.[31] The small percentage of hospitals which had implemented HIT systems before the HITECH Act and development of HIT adoption initiatives fall into this category. The second group of adopters are known as "early adopters" and consist of the early majority of organizations who at minimum keep pace with average adoption rates in a social system (in this case, we consider the entire U.S. hospital system). Early

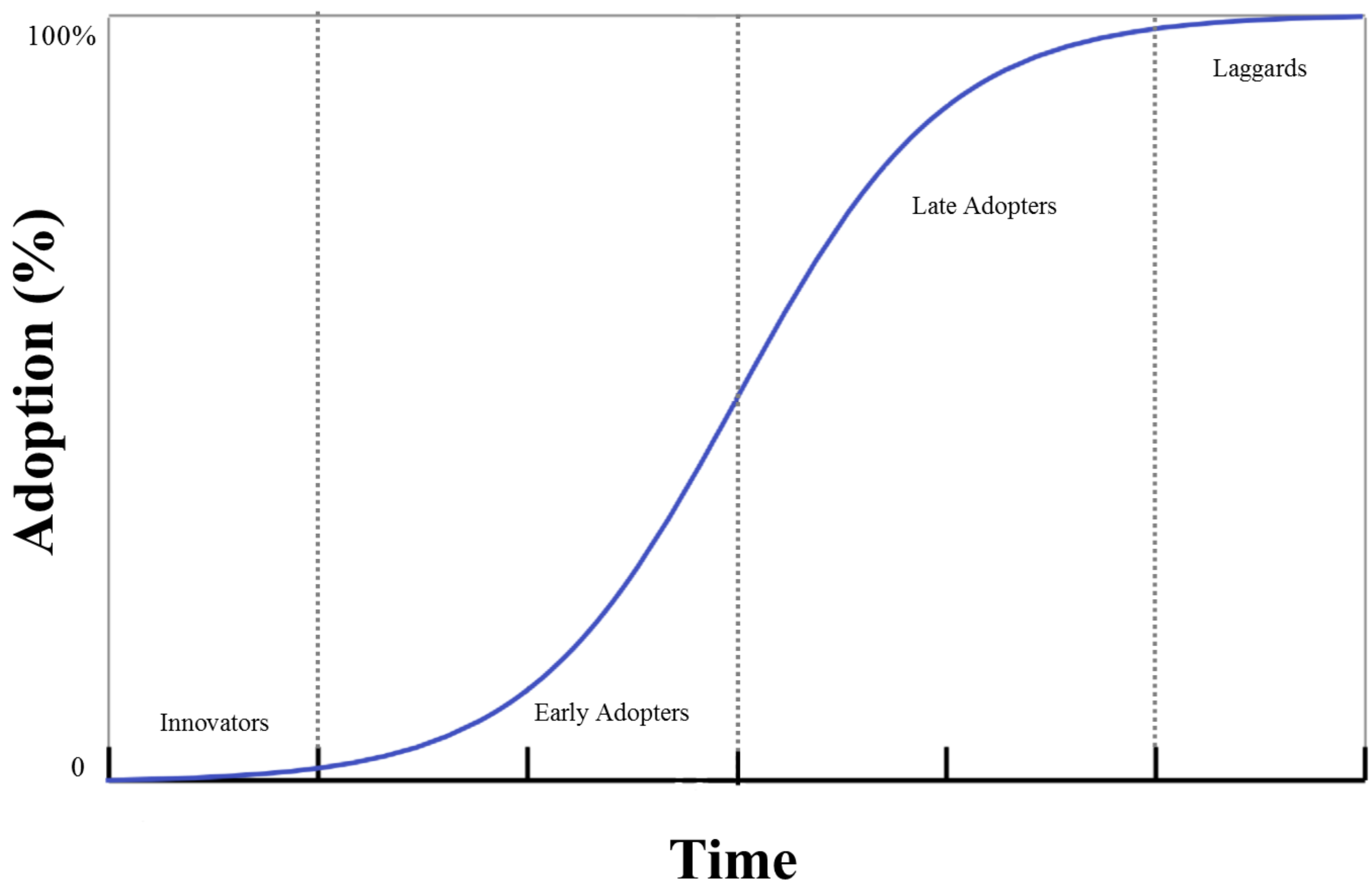
Figure 1: Conceptual Framework



adopters evaluate the innovation's attributes as information becomes available, and make the decision to adopt based on its merits.[31] The final two groups to implement an innovation on the adoption timeline are "late adopters" and "laggards". These two groups are highly risk averse, may face significant organizational or informational barriers to adoption, and only adopt in response to falling far behind the status quo.[32] Figure 2 shows a graphic representation of this S-shaped cumulative adoption curve. It is often the case that a diffusion system must be put in place in order to aid the late adopters and laggards in adoption of an innovation.[31] It is the goal of these study to assess which hospitals fall into these two final adoption categories, and to describe the effects of the HITECH Act as a diffusion mechanism.

Factors external to the organization are also taken into account in diffusion of innovation theory. Societal systems influence organizations to adopt innovations in a few key ways. First, there are social pressures present in a social system that influence innovation adoption. Advocacy groups, laws and marketing campaigns all potentially exert influence on a hospital's decision to adopt an innovation. Second, advice-seeking networks exist in societal systems. It is through these networks that knowledge and innovation is transferred. Each network has local 'opinion leaders' - respected organizations that are looked to as models for all the organizations in the system. Opinion leaders reduce organizational risk and uncertainty in the system by serving as the standard of behavior.[31] Using this framework, the dissemination of health innovations (everything from new surgical techniques to updated treatment protocols) can be evaluated and targets for stimulation of diffusion can be identified.[32]

Figure 2: Adoption curve: Innovators, early adopters, late adopters and laggards



Dataset and Analytic Sample

We used the Healthcare Information Management Systems Society (HIMSS) database, which includes annual survey data on hospitals' health information technology (HIT) systems, as well as their application of these systems. This data is collected from hospital chief information officers or designees and, although HIMSS does not publish exact survey response rates, refusal to participate is reported to be about 2%.[30] Using 2007-2012 HIMSS data, we created a cohort of 4,283 hospitals for analysis. We excluded hospitals with any missing data on HIT systems needed for CITA calculation or statistical modelling in any data year from the sample, as well as non-acute care hospitals, as these hospitals are not eligible for incentive payments through the HITECH Act.

Research Questions and Hypotheses

The objectives of this study were to:

1. Determine if HITECH has increased rates of HIT system adoption between 2007 and 2012,
2. Investigate which hospital factors are associated with being categorized as an early adopter, a late adopter or a laggard.

Our hypothesis is that the HITECH act significantly increased advancement of HIT infrastructure among U.S. hospitals, and that small, non-teaching, rural hospitals will be significantly more likely to be late adopters and laggards.

Dependent Variable

The measure of HIT adoption we used in this study will be an application of a clinical information technology adoption (CITA) scale recently developed by Lee and Park (2013). This scale aggregates multiple, clinically-relevant HIT systems into a single score, using factor analysis to weight more advanced systems over basic systems.[6] This scale can better describe the advancement of a hospitals HIT infrastructure than measuring a single system, or aggregating HIT systems using non-weighted scores. Using adoption rates and factor analysis, we placed 18 clinical IT systems into four levels of adoption. The systems and groups can be seen in Figure 3:

Figure 3: Clinical Information Technology Adoption (CITA) scale systems[6]

Adoption stage	Name of clinical IT
First level	Laboratory Information System
	Order Communication/Results
	Pharmacy Information System
	Radiology Information System
	Surgery Information System
Second level	Clinical Data Repository
	Clinical Decision Support
	Clinical Documentation
	Computerized Patient Record
	Nursing Documentation
	Point of Care
Third level	Cardiology Information System
	Emergency
	Intensive Care
	Obstetrical Systems
Fourth level	Cardiology Picture Archiving and Communication System
	Computerized Physician Order-Entry System
	Radiology Picture Archiving and Communication System

The systems in the group at each level have similar characteristics in terms of the rate at which they are adopted, as well as clinical effectiveness and value. The first level consists primarily of passive information storage systems, while the groups at levels 2 and 3 add the ability to transport and communicate information quickly and support decision making, while level 4 systems allow advanced communication of large amounts of information between networked providers.[6] We confirmed appropriateness and validity of the CITA scale by assessing covariance using a correlation matrix, and checking the consistency of the difference in CITA across hospital characteristics with other studies.[1-4,6-9,14-19] Three cut points on the CITA scale were chosen as reference points for basic, medium and advanced level HIT adoption. Basic, medium and advanced-level adoption scores were equivalent to adoption of all systems in level 1, levels 1 and 2, and levels 1, 2 and 3, respectively. This corresponds to a CITA score of 5 for a basic system, 17 for a medium system, and 29 for an advanced system. Adoption of all systems in each level were not required to qualify for reaching adoption at that level, only that their total CITA score meets or exceeds that level.

Independent Variables

We included hospital characteristics including bed size, urbanicity, teaching status, profit status, hospital network involvement and hospital financial health in our analysis. All variables were recorded for the base year of 2007; variables were not recorded as time-variable. Hospital bed size, teaching status and profit status were directly reported in the HIMSS database. Hospital network involvement was indicated by the hospitals' participation or plan to participate in Information Exchange Initiatives (IE). These two variables were mutually exclusive – a hospital participating in an IE was not recorded as a hospital with a plan to participate in an IE, and vice versa. Urbanicity was determined from the hospital zip code mapped to the Metropolitan Statistical Area (or-lack thereof) associated with the zip code. The measure of financial health was calculated as total operating expense of the hospital divided by the number of admissions in the base year.

Research Design

This study follows a cohort of 4,283 U.S. acute care hospitals longitudinally from 2007-2012 years in order to assess the effect of the instatement of the HITECH act and beginning of incentive disbursements on hospital HIT adoption. CITA scores were calculated for each year, and used as the outcome variable for statistical analysis.

We used Cox proportional hazard modelling to assess the time until basic, medium and advanced levels of HIT adoption occurred. Hazard modelling allows for the evaluation of the impact of time and covariates on the likelihood of an event occurring. In this study, we assessed the effect of the instatement of HITECH, as well as the beginning of disbursement payments increased the likelihood that hospitals achieved basic, medium and advanced levels of HIT adoption on the CITA scale. To do this, we estimate a model where the probability that a hospital has not adopted by t-1 adopts by t is:

$$(1)\quad h(t) = h_0(t)e^{\lambda(HITECH)+ \lambda_t * I(year=t)*(HITECH)+X_i\beta_t*I(year=t)}$$

In the above formula, λ is effect of HITECH on adoption in 2007. λ_t adds the effects of HITECH on adoption in each subsequent year after 2007, and $h_0(t)$ is a baseline hazard function for hospitals in year t. Covariates, represented by X_i, include bed size, urbanicity, teaching status, profit status, hospital network involvement and hospital financial health. Likelihood of adoption was assessed in the final data year, 2012.

RESULTS

Cohort descriptives

Table 1: Summary of hospital characteristics (2007)

Cohort	N	
All hospitals	4,283	
	N	%
Number of Beds		
<100	1971	46.0
100-249	1188	27.7
250+	1125	26.3
Urbanicity		
Urban	2391	55.8
Rural	1893	44.2
Teaching Status		
Non-Teaching	3995	93.3
Teaching	289	6.7
Profit Status		
Not For Profit	3679	85.9
For Profit	605	14.1
Information Exchange Initiative Involvement		
Plans/Participates in IE	3573	83.4
No IE plan/participation	711	16.6

The cohort consisted primarily of not-for-profit hospitals (85%) and non-teaching hospitals (93%). The majority of hospitals did not participate (88%) or plan to participate (93%) in IEs. The cohort was more evenly split for bed size, with 46% of hospitals having <100 beds, 28% having 100-249 beds, and 26% having more than 250 beds. Urban and rural hospitals represented 56% and 44% of the cohort, respectively.

CITA scores

Table 2: CITA scores by year

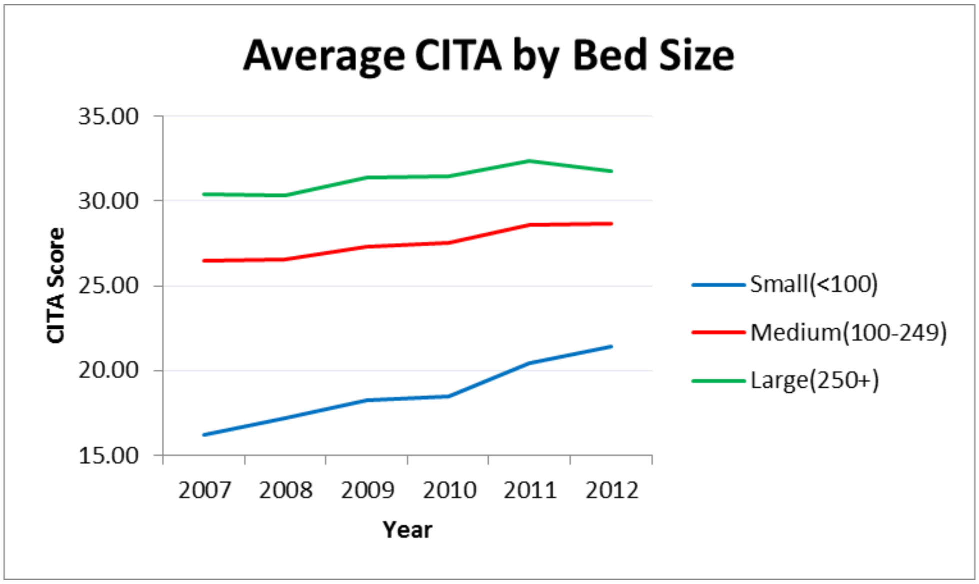
Year	Mean	Std Dev	Difference
2007	22.78	11.09	----
2008	23.25	9.89	0.47
2009	24.19	9.33	0.94
2010	24.38	9.43	0.20
2011	25.83	8.89	1.45
2012	26.15	7.83	0.32

Nationwide mean CITA score grew each year. In all years, the national mean CITA score was between the cut points set for a medium level HIT infrastructure (CITA>17), and an advanced system (CITA>29). By 2012, the average CITA score across the nation grew by 6.3 points, with the greatest increases from years 2008-2009 (+0.94) and 2010-2011 (+1.45). In addition, standard deviation decreased each year.

Table 3: Changes in CITA score from 2007-2012 by hospital characteristics

	2007		2008		2009		2010		2011		2012		Linear Slope	Significance
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	β	p-value
Number of Beds														
<100	16.20	(10.21)	17.22	(9.04)	18.22	(8.48)	18.47	(8.72)	20.44	(8.38)	21.43	(7.47)	1.03	<0.05
100-249	26.47	(8.72)	26.56	(7.73)	27.29	(7.03)	27.50	(7.23)	28.62	(6.98)	28.67	(6.15)	0.50	<0.05
250+	30.41	(7.57)	30.32	(6.41)	31.36	(5.40)	31.45	(5.35)	32.34	(5.02)	31.77	(4.26)	0.37	<0.05
Urbanicity														
Urban	27.06	(9.30)	27.13	(8.16)	27.96	(7.61)	28.02	(7.73)	29.05	(7.49)	28.89	(6.55)	0.43	<0.05
Rural	17.37	(10.82)	18.35	(9.70)	19.43	(9.13)	19.80	(9.38)	21.76	(8.86)	22.70	(7.94)	1.06	<0.05
Teaching Status														
Non-Teaching	22.12	(11.04)	22.66	(9.85)	23.60	(9.29)	23.79	(9.40)	25.29	(8.89)	25.70	(7.86)	0.74	<0.05
Teaching	31.82	(7.18)	31.44	(6.15)	32.36	(5.03)	32.61	(4.77)	33.37	(4.25)	32.36	(3.68)	0.25	0.12
Profit Status														
Not-For-Profit	23.05	(11.32)	23.62	(10.07)	24.55	(9.49)	24.77	(9.53)	26.24	(8.95)	26.63	(7.75)	0.74	<0.05
For-Profit	21.09	(9.43)	21.02	(8.36)	21.99	(7.95)	22.03	(8.41)	23.34	(8.08)	23.26	(7.68)	0.25	<0.05
Information Exchange Initiative Involvement														
Plans/Participates in IE	26.76	(10.20)	26.89	(9.36)	23.84	(9.28)	27.45	(8.66)	27.78	(8.68)	28.69	(6.90)	0.53	<0.05
No IE plan/participation	21.98	(11.09)	22.53	(9.83)	26.77	(9.29)	23.54	(9.32)	23.71	(9.43)	25.65	(7.90)	0.46	<0.05

Figure 4: Average CITA score by bed size



After stratifying by hospital characteristics, most hospital types showed a significant trend of increased CITA scores from year to year. Trends for most hospitals mirrored national trends, with the biggest jumps in CITA advancement coming in years 2009-2010 and 2010-2011. In a few cases, CITA scores declined between years, however these losses were typically very small, and the overall trend continued toward an increase from year to year. Large hospitals with 250 beds or more had higher average CITA scores than medium sized hospitals with 100-249 beds, which, in turn, had higher average CITA scores than small hospitals with less than 100 beds. A graph of this trend for hospital bed size is represented by Figure 4. Graphs of average CITA score growth for all hospital characteristics can be found in Appendix 1.The widest gaps in average CITA score were between large vs. small hospitals, urban vs. rural hospitals, and teaching versus non-teaching hospitals, with the former in each category outpacing the latter by 7 or more points each year. Small hospitals and rural hospitals displayed the sharpest increase in CITA scores across all years. Not-for-profit hospitals also showed higher CITA scores across the years than or for-profit hospitals, and hospitals with participating or planning to participate in IEs had higher CITA scores than those who did not.

Proportional Hazard Models

Table 4a: Proportional Hazard Models of Basic, Medium and Advanced HIT adoption by 2012

	Basic System Adoption Haz. Ratio	Medium System Adoption Haz. Ratio	Advanced System Adoption Haz. Ratio
Bed Size			
Small (<100 beds)	Ref.	Ref.	Ref.
Medium (100-249 beds)	1.049**	1.422***	3.319***
	(-2.74)	(-17.94)	(-35.62)
Large (250+ beds)	1.045*	1.447***	4.270***
	(-2.21)	(-16.63)	(-40.48)
Urbanicity			
Urban	Ref.	Ref.	Ref.
Rural	0.973	0.852***	0.795***
	(-1.66)	(-8.69)	(-7.89)
Teaching Status			
Teaching	Ref.	Ref.	Ref.
Non-Teaching	0.996	1.003	0.880***
	(-0.15)	-0.1	(-4.04)
Profit Status			
Not for Profit	Ref.	Ref.	Ref.
For Profit	0.999	0.872***	0.539***
	(-0.04)	(-6.39)	(-17.20)
Information Exchange Involvement			
No IE plan/participation	Ref.	Ref.	Ref.
Plans/Participates in IE	1.012	1.071***	1.206***
	(-0.71)	(-3.71)	(-7.76)

Exponentiated coefficients; t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4b: Proportional Hazard Models of Basic, Medium and Advanced HIT adoption by 2012

	Basic System Adoption Coeff.	Medium System Adoption Coeff.	Advanced System Adoption Coeff.
Expense per Admission (per $100,000)	-1.06**	-1.73***	-6.88***
	(-2.65)	(-3.38)	(-6.52)

Coefficients; t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 shows the results of three proportional hazard models of the likelihood of adoption of a basic (CITA>5), medium (CITA>17) and an advanced system (CITA>29). There were no hospitals at any data year implementing every HIT system (CITA=42). For basic levels of HIT adoption, hospital size showed a statistically significant effect, with small hospitals being marginally (about 5%) less likely to reach this level than medium or large hospitals. Expense per admission also had a significant effect, with every $100,000 more a hospital incurs per admission resulting in a 1.05% decreased likelihood of basic system adoption. Almost all hospitals (97.8%) had reached this level of implementation.

With regards to medium level HIT advancement, hospital bed size rural location, profit status, IE plans and expense per admission proved to be significant factors in achieving implementation. Medium-sized hospitals were about 42%, and large hospitals 46% more likely to reach medium level HIT adoption than small hospitals, rural hospitals were about 15% less likely to reach medium level HIT adoption than urban hospitals, and for-profit hospitals were about 13% less likely to reach this level of adoption than not-for-profit hospitals. Hospitals with plans to participate in IEs were approximately 12% more likely to reach medium level adoption, and each increase in $100,000 per admission resulted in a 1.7% decreased likelihood of achieving medium level HIT adoption.

In reaching advanced HIT system implementation, all hospital characteristics showed significant influence. Hospital size showed an extremely strong effect on advanced implementation, as medium-sized hospitals were 332%, and large hospitals 427% more likely to implement advanced HIT systems than small hospitals. Rural hospitals were about 20% less likely to reach advanced system adoption than urban hospitals, and non-teaching hospitals were about 12% less likely to adopt advanced systems. For-profit hospitals were 54% less likely to reach advanced HIT adoption than not-for-profit hospitals, and hospitals participating in IE or having IE plans were about 14-17% more likely to have advanced HIT systems. Finally, the magnitude of the effect of expense per admission was also much greater for advanced HIT system adoption, with each increase of $100,000 per admission associated with a 6.8% decrease in likelihood of advanced system adoption.

<u>Figure 5: Comparison of time to adoption of basic, medium and advanced level system for hospital bed size</u>

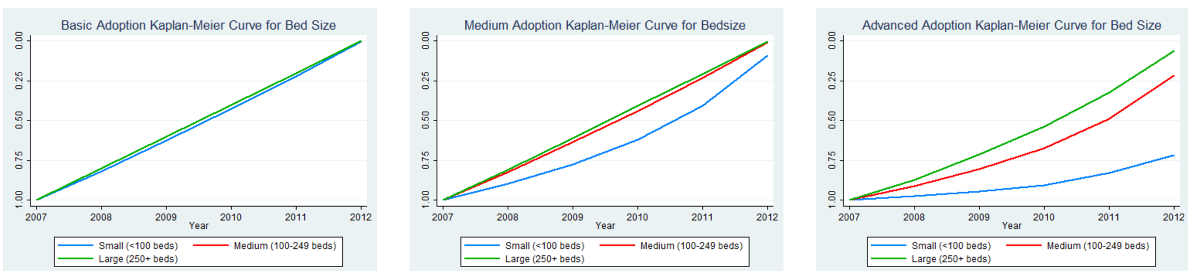


Figure 5 shows the differences in time to adoption of basic, medium and advanced level HIT systems for hospital bed size. Time to basic level system adoption shows a small (but still significant) difference between small hospitals and their medium and large counterparts. With regards to medium and advanced levels of HIT adoption, this gap between small hospitals and medium and large hospitals increases greatly; small hospitals have a very long time to adoption for medium level systems, and are very unlikely to reach advanced levels of adoption. Kaplan-Meier curves for all significant hospital characteristics can be seen in Appendices 2-4.

DISCUSSION

Summary

This study found that overall HIT infrastructure is steadily advancing, although there are several important patterns in this growth. Examination of yearly average CITA scores shows positive progress each year, with two large leaps forward in 2009 and 2011. These are significant years, as the HITECH Act was enacted in 2009, with incentive payment disbursement beginning in 2011.[12] The fact that the enactment of the policy itself had a strong effect on nationwide HIT growth suggests a “call-to-action” effect. Hospitals may have been motivated to adopt new HIT systems (more than just the incentivized EHR) by the passing of an HIT-focused piece of legislation and as opinion leaders set firm adoption goals. Late adopters tend to adopt only when they feel that they are falling behind the status quo and nationwide HIT initiatives may signal these hospitals to readjust their technology adoption plans.[31,32] Unsurprisingly, the greatest progress in HIT advancement came in the year the incentive payments began to be disbursed. However, while these gains were persistent, they were not consistent; in between the “call-to-action” years, and the year payments began, gains in nationwide CITA scores were modest. This may indicate a limited temporal effect of HIT advancement initiatives.

Through application of theoretical concepts of dissemination science, this study sought to describe the differences between early adopters, late adopters and laggards. In our models, “advanced” system adoption has been achieved by the early majority and innovators, as this level of adoption was indicative of adoption of multiple complex clinical IT systems, and representative of a score higher than the national average.

"Medium" system adoption is equal to HIT infrastructure slightly behind the national average, and is descriptive of systems adopted by late adopters. Finally, "basic" system adoption corresponds to a level of HIT infrastructure that is nearly universally adopted in our current health care system, only failing to be adopted by laggards.[32] With these concepts in mind, as well as the adoption timeline that these different adopters face, we examine the organizational factors of basic, medium and advanced level HIT adopters.

This study identified several meaningful differences between those hospitals that are adopting HIT systems at a normal pace, and those that are lagging behind. Hospital bed size was a strong predicting factor for all levels of HIT adoption, with small hospitals being less likely to adopt even the most basic HIT systems, and multiple orders of magnitude less likely to reach advanced levels. This confirms our hypothesis, and underscores previous findings that small hospitals are the slowest to adopt HIT systems.[15-17,20] Rural and for-profit hospitals, as well as hospitals without plans to participate in IEs were more likely to be late adopters. Higher expenditures per admission also had significant effects for reaching any level of adoption, with a greater magnitude of effect for more advanced levels. As care becomes increasingly reliant on HIT systems, not only for delivery of quality care but for communication and coordination, laggard and late adopter hospitals may become stumbling blocks in the U.S. hospital system. These hospitals may have increasing organizational difficulties as they are less able to coordinate and communicate with other hospitals, and may cause problems for the patients that try to move through them.[21]

Using this definition of early adopters versus late adopters, teaching status is not shown to be a trait of slower adopters. While some studies include non-teaching hospitals in the group of slow adopters,[20,22] our findings indicate that they are on pace with national averages. As expected, teaching hospitals seem to be the most advanced innovators in the U.S. hospital system, however non-teaching hospitals are not falling behind the adoption curve.

Limitations

This study has several limitations. We excluded federally-owned hospitals from our analysis due to data limitations, and results should not be applied to these types of hospitals. Federally owned hospitals likely have very different adoption timelines, as the decision making process for HIT adoption is done through sweeping mandates handed down by federal decision makers, rather than hospital administrators. Also, this study was not meant as an in-depth economic analysis of HIT system adoption. Financial factors are naturally crucial to the capital investment required for implementation of HIT systems, and hospital financial health and payer structure are important confounding factors. We did, however, include a measure of hospital expenditures per admission, which has been used in previous literature[39,40] to assess some of these effects. Robust measures of social pressures were also not included in this study. Social factors external to a hospital such as patient mix, advocacy rates and proximity to opinion leaders may affect HIT adoption rates. [8,24,34,35] We did, however, include some measure of hospital network involvement, and participation in IEs may be descriptive of a hospital's approach towards information gathering in regards to HIT adoption. Also, we did not assess the decision-making process of hospital administrators in charge of HIT systems adoption in this model. Factors such as hospital board composition, awareness, perception, and uncertainty of

HIT systems, and value placed on innovation play key roles in the decision to adopt or not adopt an HIT system.[22,31,35]

The weights and cutoffs used in CITA calculations, though determined using statistical methods and grounded theory, were arbitrary. The 18 HIT systems in the scale were clustered into groups through statistical methods, weights assigned according to the time to adoption for each group (earlier vs. later). This was necessary in order to rank hospitals and assess adoption outcomes, but scores could have been weighted differently. This would not change the rank order of hospitals, however, and similar results would be seen for HIT adoption rates. Also, this would not have changed the assessment of a hospital's HIT advancement relative to national averages, and early and late adopters would still be identified as such. Last, covariates were not assessed as time-variable, but held constant for the base year (2007). This may have an effect on how results could be interpreted, however most hospital characteristics used in this study are not likely to change over time. Despite these limitations, this study is the first to describe HIT infrastructure using a novel approach that allows for the assessment of multiple HIT systems and their relative complexity, as well as longitudinal, post-HITECH data.

Policy Implications

The findings of this study have several relevant implications regarding HIT infrastructure in the United States. First, the HITECH act, designed to incentivize EHR adoption, has had significant effects on more systems than it targeted. Many different HIT systems are seeing increased adoption rates as policy makers and opinion leaders create goals for HIT adoption. It is important to look at more than just EHR systems, as HIT systems of similar levels of complexity tend to be adopted at similar points in time.

This, in combination with the new HIT adoption models which call for adoption of multiple systems, suggest that future HIT policy initiatives should think holistically about HIT systems in order to best predict their effects.

Second, late adopters may be uniquely sensitive to stimulus by setting of firm goals by institutes and policy makers. A large jump in HIT adoption rates happened in the year that HITECH was enacted; indicating that simply signaling the potential change in the status quo may spur late adopters to prioritize adoption. Utilizing the effectiveness of such a call to action and providers' desire to keep up with the national advancement of HIT adoption could be an avenue to lend greater effectiveness to policy application.

Third, the so-called "digital divide" is widening between early adopters, and late adopters and laggards. Of most concern are the small hospitals that seem to be very far behind the curve. It is possible that these hospital require increased resources, either financially, or through a greater allowance of time to take advantage of HITECH incentives, in order to make up for this technological deficit. Alternatively, small hospitals may lack the extra labor required to devote to the application and accreditation process for HITECH incentives. Extra provisions have already been given to critical access hospitals under the HITECH act, and it may be necessary to consider similar targeted policies towards small hospitals.

For-profit and rural hospitals are also delayed in their adoption time, and are prime targets for encouragement into the more advanced majority. Research suggests that the difference in organizational goals in for-profit hospitals may have something to do with their slower adoption rates, due to profit-maximizing and cost-minimizing duality.[33] These hospitals may be coaxed through an appeal to their organizational goals, or through further information or cost analyses. Rural hospitals can also be brought into the fold through greater network involvement and promotion of HIT systems. Targeting interventions to late adopter and laggard hospitals will promote HITECH, strengthen these organizations, and close the gaps in our national HIT infrastructure.

Future Research

There are several areas of future research that could more fully describe the HIT adoption process as well as aid in policy implementation. First, we recommend continued use of weighted, aggregate scales to properly assess the advancement of HIT infrastructure. One area in need of elucidation is the decision-making process that leads hospital administrators to adopt an HIT system, especially with regards to the unique challenges and pressures faced by those lagging behind in HIT adoption. While some studies have interviewed hospital administrators about their HIT adoption choices, these have been limited to small, state-specific samples, do not investigate multiple HIT systems, and are not focused on the needs of the slowest adopters. It is likely that small hospitals have organizational structures that make the process leading to their adoption decision vastly different those hospitals currently studied. Qualitative analysis of small hospital administrators and their perceptions of HIT systems implementation would be an effective way to explore this question. Deeper financial analysis would also describe in more detail the monetary barriers facing late adopting hospitals. More understanding of the effects of investment and implementation of HIT systems for small, for-profit and rural could help inform the development of targeted policies that address the monetary and informational needs of these hospitals. Also, analyses of the cost and non-cost related benefits of HIT systems for for-profit hospitals could aid in informing these hospitals' decision makers and encouraging them to reach national standards of adoption.

Finally, the social systems of early adopting and late adopting hospitals should be further studied. Social pressures are key factors in the diffusion of innovation, as the leap forward in national HIT scores in 2009 illustrates.[31] Understanding the influences of patients, medical professionals, policy makers, organizational champions, and other players inside and outside a hospital is crucial to form policy that is effective in promoting adoption of HIT.

CONCLUSION

This study supports growing evidence of the existence of a digital divide between those hospitals keeping pace with HIT infrastructure advancement and those falling behind. Of most concern are small hospitals, which are more likely to fail in establishing even basic HIT systems. For-profit and rural hospitals and hospitals with poor network involvement also seem to be starting to fall behind national averages of HIT adoption. This widening gap should be addressed in order to achieve nationwide HIT adoption goals. Our findings also indicate that policies aimed at incentivizing rates of HIT systems should take on a more holistic view of HIT infrastructure, as focusing on single systems such as EHR may not fully address the costs and patterns of HIT system adoption that hospitals face. Also, our results indicate that HIT adoption may be uniquely sensitive to stimulus by setting of firm goals by institutes and policy makers. Future policy should take into account the call to action their initiatives may have in influencing providers' desire to keep up with the national advancement of HIT infrastructure.

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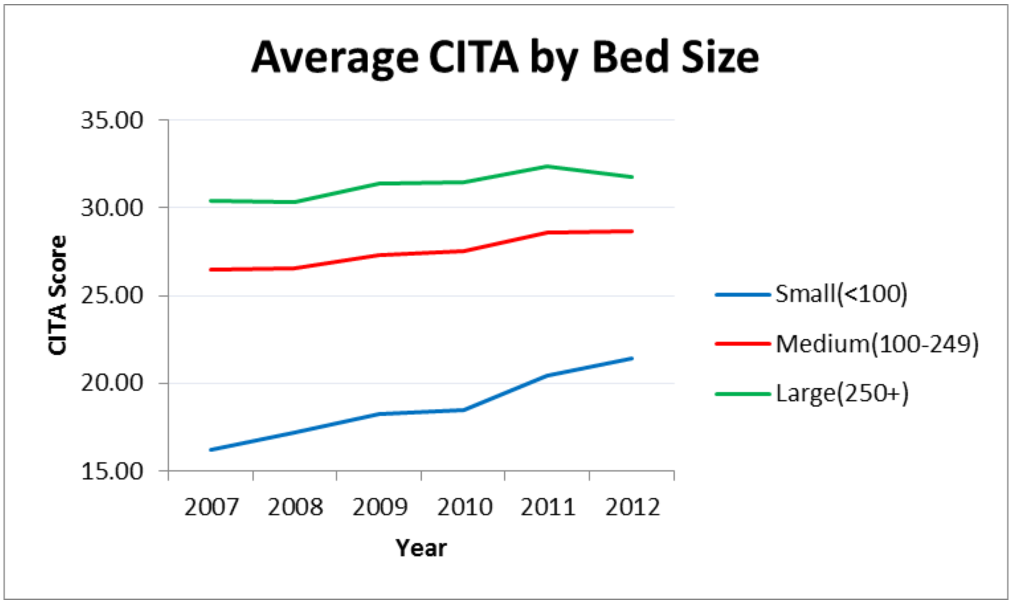
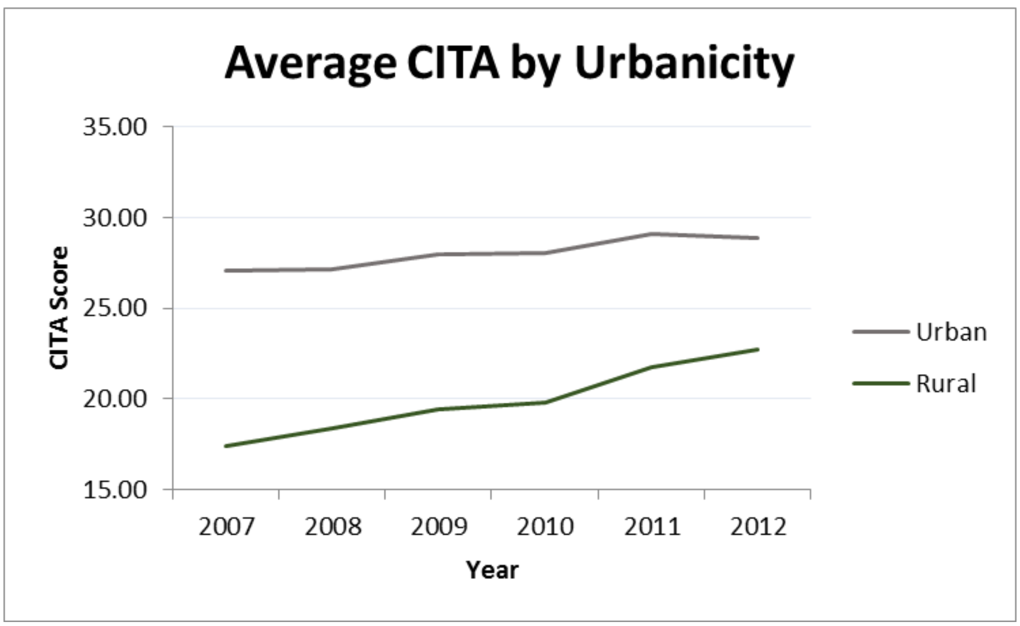
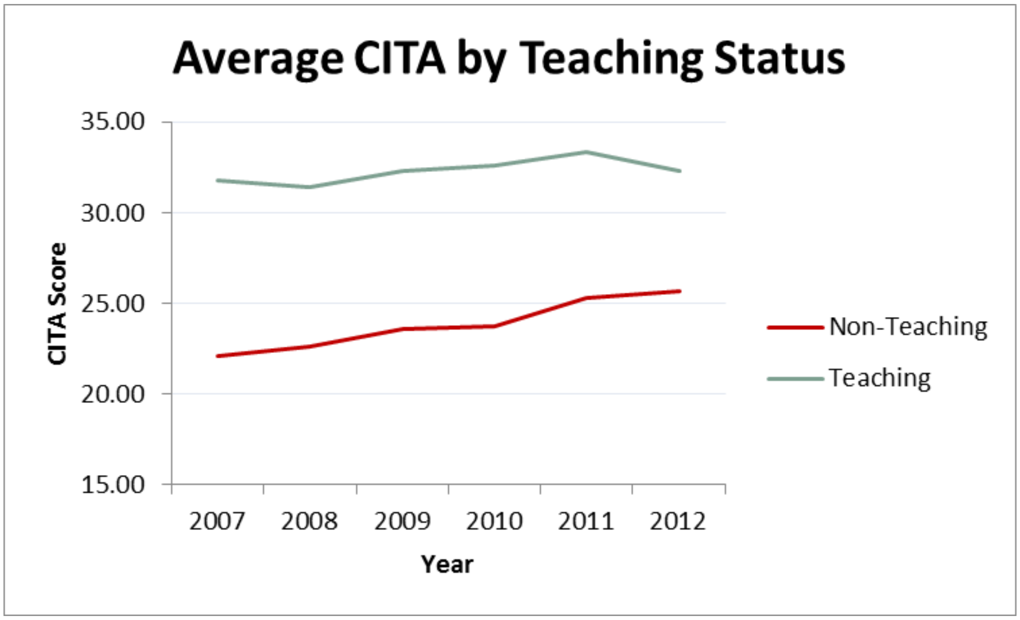
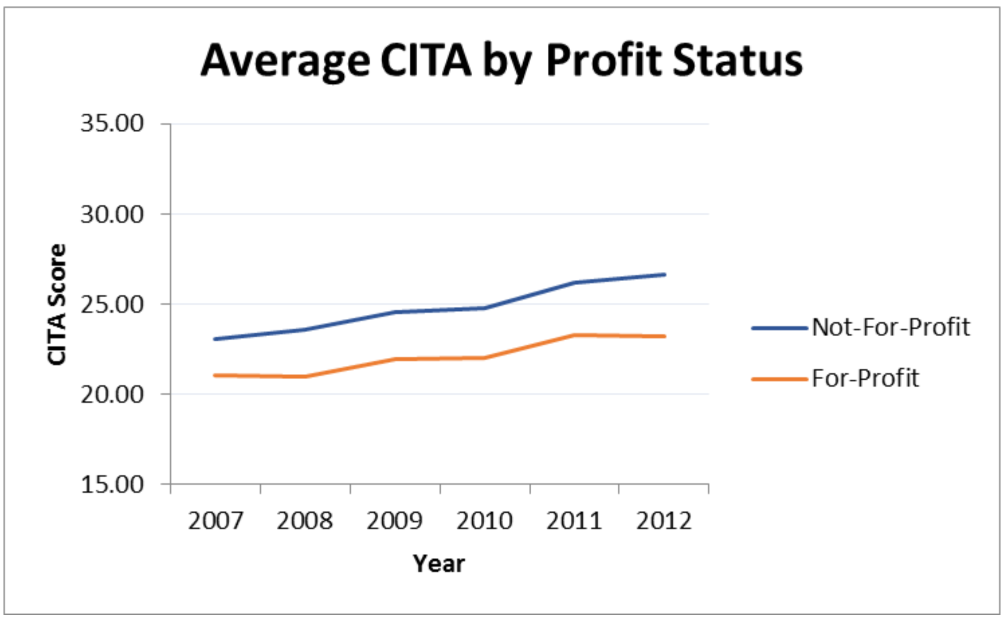
APPENDICES

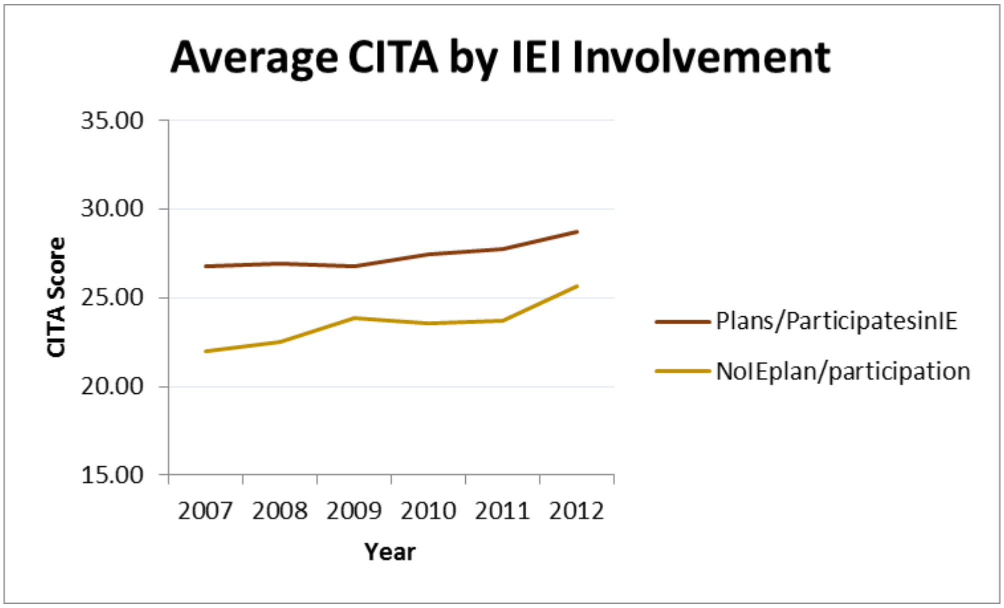
Appendix 1: Average CITA scores by hospital characteristics



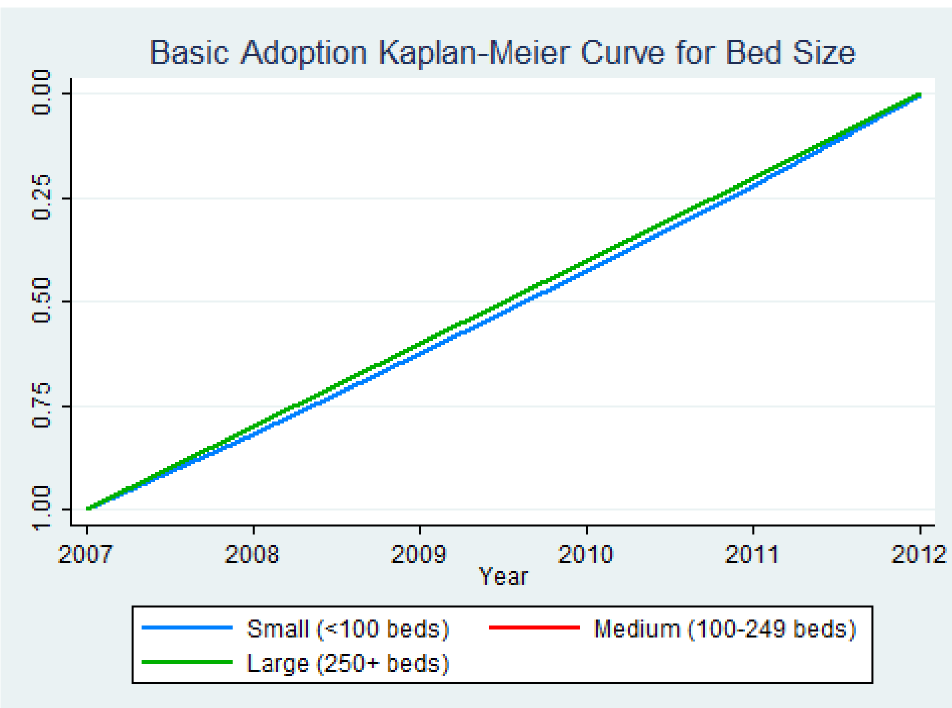



Average CITA by Teaching Status
35.00
30.00
25.00
20.00
15.00
CITA Score
2007
2008
2009
2010
2011
2012
Year
Non-Teaching
Teaching

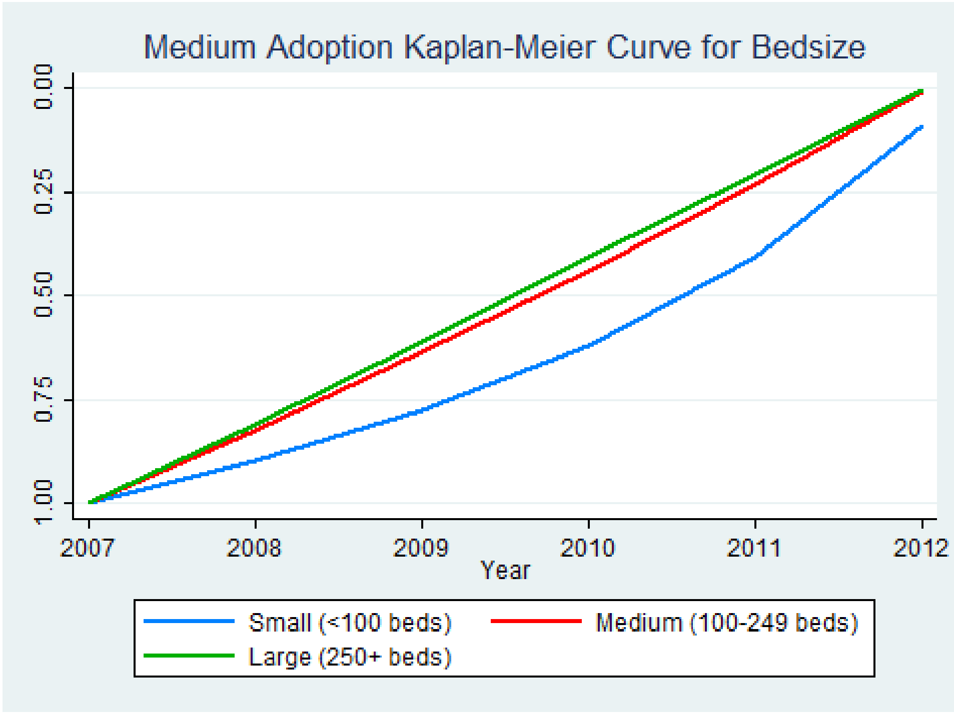

Average CITA by Profit Status
35.00
30.00
25.00
20.00
15.00
CITA Score
2007
2008
2009
2010
2011
2012
Year
Not-For-Profit
For-Profit

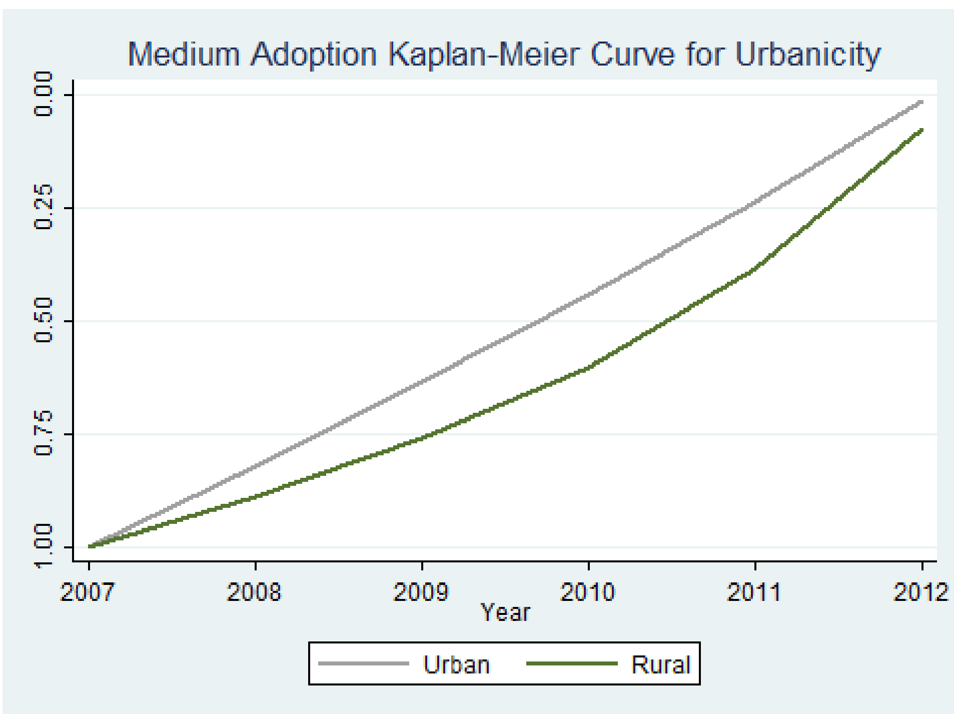


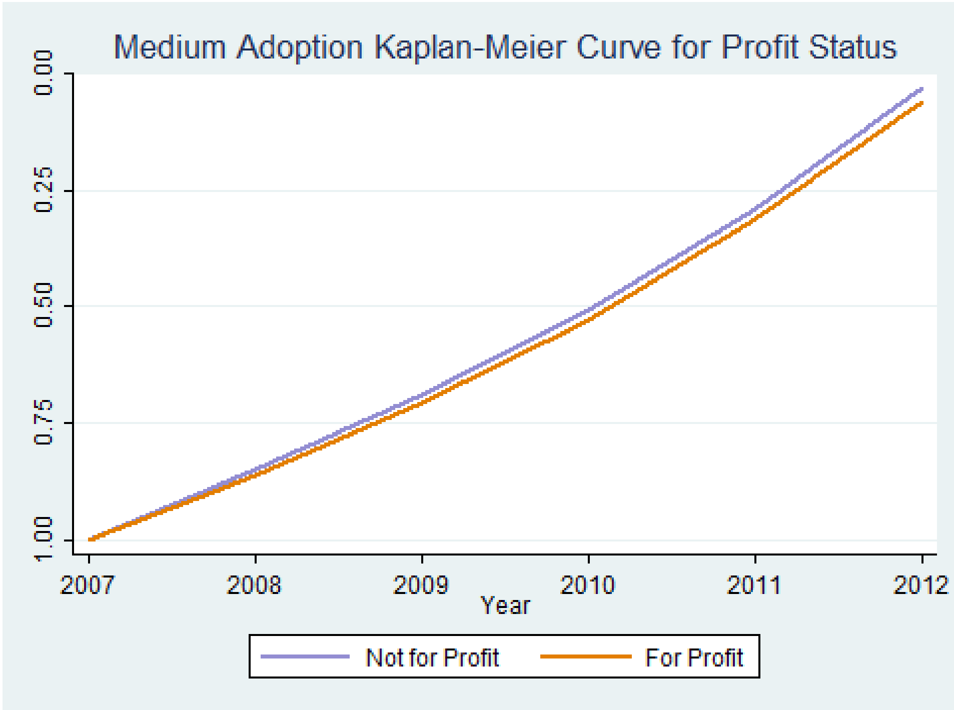
Appendix 2: Kaplan-Meier curve of time to adoption of basic systems

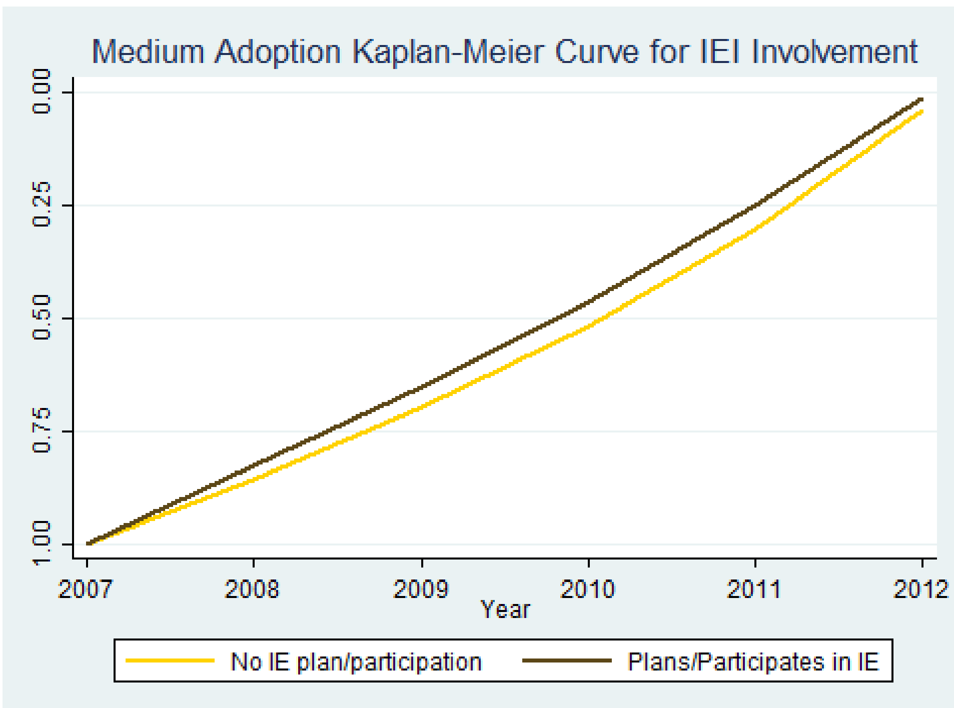


Appendix 3: Kaplan-Meier curve of time to adoption of medium systems

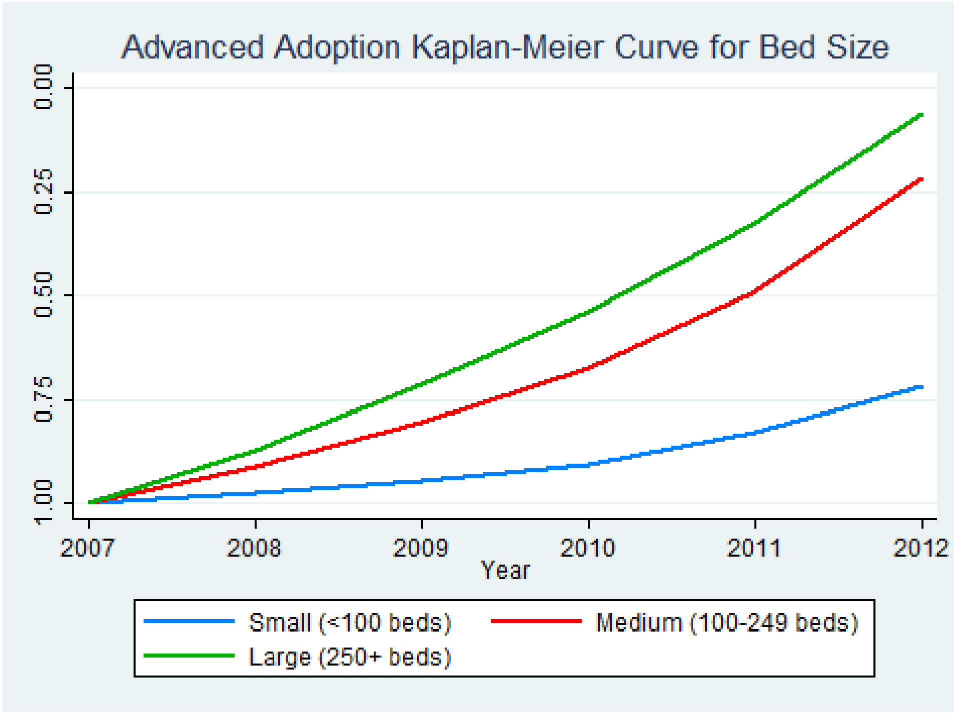


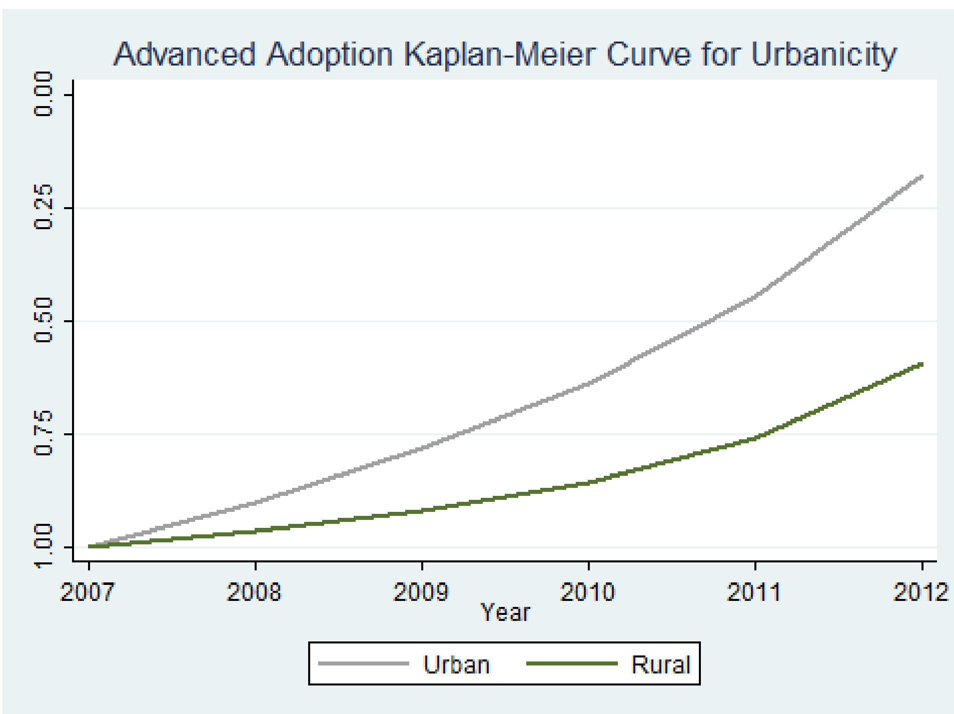


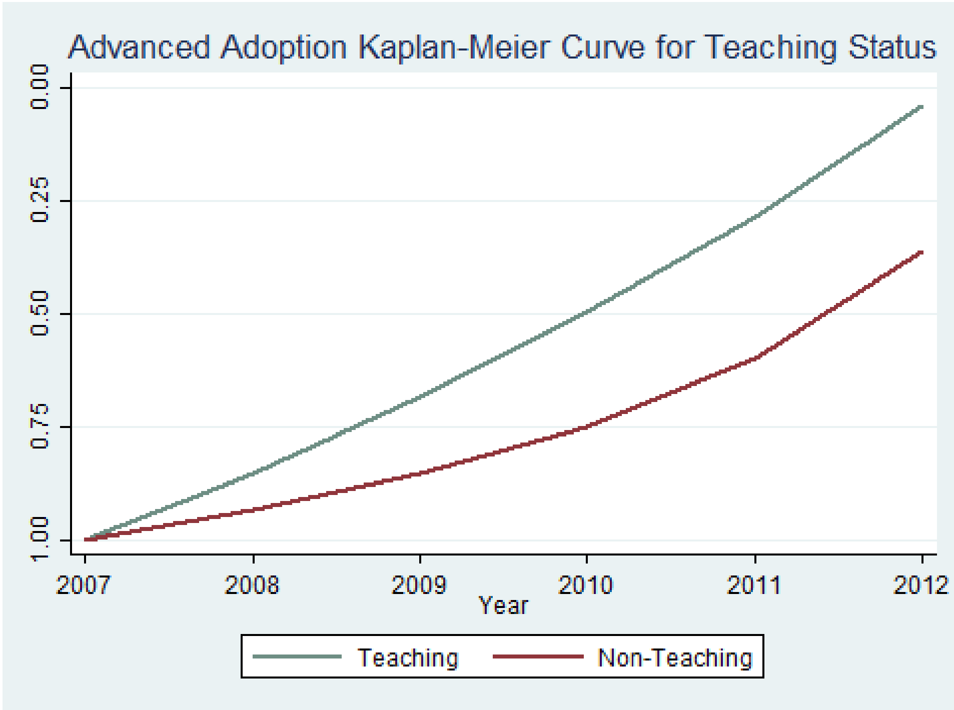

Medium Adoption Kaplan-Meier Curve for Profit Status
0.00
0.25
0.50
0.75
1.00
2007
2008
2009
2010
2011
2012
Year
Not for Profit
For Profit

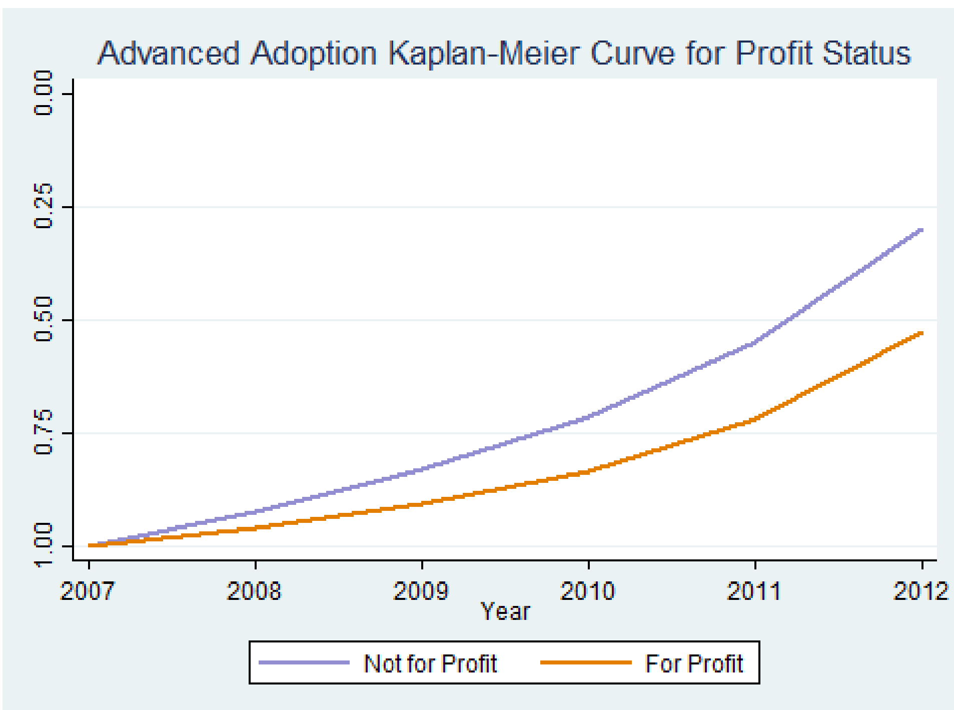

Medium Adoption Kaplan-Meier Curve for IEI Involvement
0.00
0.25
0.50
0.75
1.00
2007
2008
2009
2010
2011
2012
Year
No IE plan/participation
Plans/Participates in IE

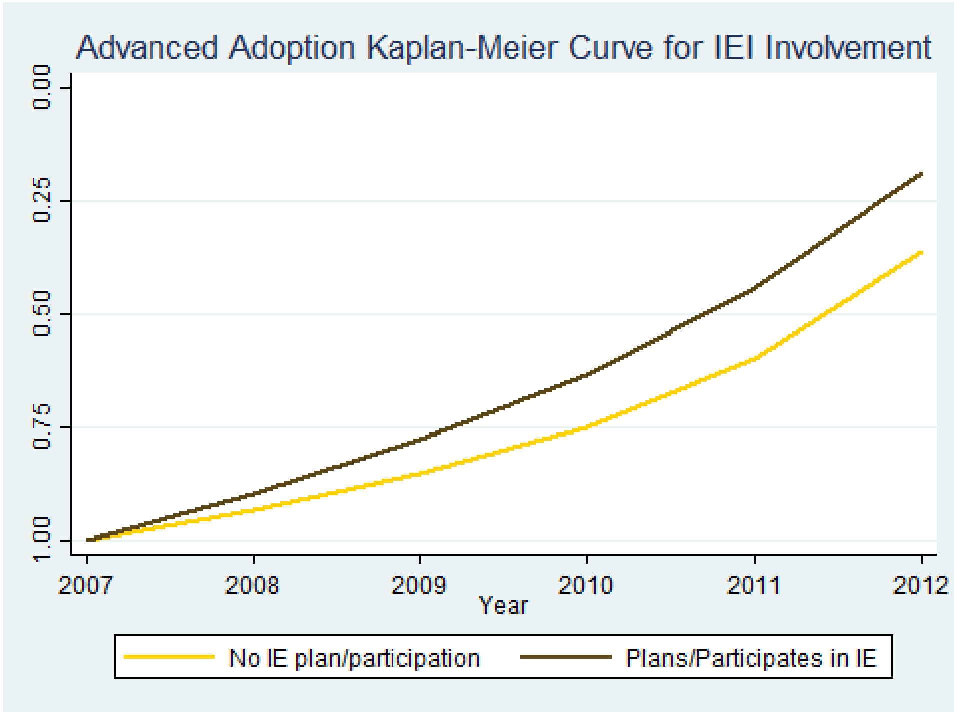
Appendix 4: Kaplan-Meier curve of time to adoption of advanced systems






Advanced Adoption Kaplan-Meier Curve for Teaching Status
0.00
0.25
0.50
0.75
1.00
2007
2008
2009
2010
2011
2012
Year
Teaching
Non-Teaching


Advanced Adoption Kaplan-Meier Curve for Profit Status
0.00
0.25
0.50
0.75
1.00
2007
2008
2009
2010
2011
2012
Year
Not for Profit
For Profit


Advanced Adoption Kaplan-Meier Curve for IEI Involvement
0.00
0.25
0.50
0.75
1.00
2007
2008
2009
2010
2011
2012
Year
No IE plan/participation
Plans/Participates in IE