Does Health Information Exchange Improve Long-Term Care Service Quality? Evidence from the Panel Data Analysis of the U.S. Long-term Care Facilities

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Abstract

This paper examines the impact of health information exchange (HIE) on the service quality of long-term care (LTC) facilities based on a five-year period (2013-2017) panel data of the U.S. LTC facilities. Our results show a reverse impact of the HIE adoption on the readmission rate of LTC facilities. The readmission rate of an LTC facility with an operational HIE is reduced by 2% on average as compared to the rate of a facility without operational HIE. We also estimate the heterogeneous effect of HIE by two innovative healthcare ITs (EHR and Telemedicine). We find that the applications of EHR and Telemedicine in LTC facilities are still at a very early stage. Our findings empirically demonstrate the importance of promoting effective data exchange in LTC facilities as well as improving the use of EHR and Telemedicine to increase the value that HIE can create.

Keywords: healthcare IT, long-term care, service quality, nursing homes, information technology

1. Introduction

Health information particularly has high standards of interoperability among institutions among all kinds of information exchange (HIMSS, 2020). Health information exchange (HIE) is becoming an integral part of the national healthcare reform efforts. The Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the American Recovery and Reinvestment Act of 2009 (ARRA), established regional extension centers to support programs for HIE development(Lin et al., 2019). The implementation of HIE in hospitals has demonstrated their potential impact on cost reduction and quality enhancement in healthcare services (Adjerid et al., 2018; Adler-Milstein & Jha, 2014). However, the adoption of HIE in long-term care (LTC) facilities is not a straightforward decision. A LTC facility provides rehabilitative, restorative, and ongoing skilled nursing care to residents who need assistance with daily living. It includes board and care homes, assisted living facilities, nursing homes, continuing care retirement communities, and long-term chronic care hospitals (National Institute on Aging, 2020). LTC providers, among all the healthcare entities, are facing unprecedented challenges with rising demand for services for elderly people but limit staffing support and resources (Freedman et al., 2005). As a result, LTC providers have lagged behind hospitals in the adoption of HIE for a long period of time (Abramson et al., 2014).

While LTC facilities have traditionally been one of the weakest links when it comes to health information exchange and care coordination, it is believed that technology-based interventions have the potential to relieve the stress of nationwide staffing shortage, lower the cost, and ultimately improve the quality of life for residents in LTC facilities. The exchange of accurate, complete, and timely information between hospitals and nursing homes can be complicated. HIE enables data sharing within a LTC facility, and improve the electronic communication with its designated hospitals. Alexander et al. (2015) introduced the efforts of University of Missouri researchers who helped 16 nursing homes acquire HIE capabilities. The project is aimed to reduce avoidable re-hospitalizations among nursing home residents. It is widely believed that efficient and timely HIE is essential to a high-quality service of LTC facilities by providing adequate and informed

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follow-up care of the residents. However, there are few researches on nursing home information technologies. Studies of regional surveys show a mixed influence of HIE on service quality (Cross et al., 2019; Vogelsmeier et al., 2021). With financial and staffing constraints, the stakeholders of LTC facilities need more evidence of the impact of HIE to make a wise investment plan in IT implementations.

In this paper, we study the impact of HIE on the service quality of long-term care facilities based on a five-year period (2013-2017) panel data of the U.S. LTC facilities with operational HIE and those without implemented HIE. We use facility and time fix effects in our model and control for a set of observables relevant to the measures of LTC facility, staffing, residents, and market. The service quality of a LTC facility is measured by the readmission rate of its residents. We construct different data samples according to the Propensity Score Matching (PSM) mechanism to improve the robustness of our method. From our results, we identify a consistent significant reverse impact of the HIE adoption on the readmission rate. The readmission rate of a LTC facility with an operational HIE is reduced by 2% on average as compared to the rate of a facility without operational HIE. Also, HIE improves the performance of innovative health ITs by providing seamless information exchange. We estimate the heterogeneous effect of HIE by two innovative health ITs (EHR and Telemedicine). We find that the adoption of HIE further lowers the readmission rate in collaboration with EHR or Telemedicine components in the system. Particularly, our empirical results show that the integration of HIE and Telemedicine supports boundaryless data exchange and timely remote medical care, which significantly reduces the readmission rate and ultimately improves the service quality of LTC facilities.

2. Research Background and Contribution

Our work contributes to two streams of literature. The first stream relates to the research of inter-organizational information exchange, especially health information sharing. The research of inter-organizational electronic exchange focuses on the outcomes and the factors that influence inter-organizational system (IOS) adoption. Studies have shown that HIE highlights a modern demonstration of IOS to which the fundamental value proposition from information exchange is largely relevant (Adjerid et al., 2018). Health information sharing requires a high level of security and accuracy. Comprehensive information about patients' medical history allows providers to access the relevant data that informs the clinical decisions which drive the quality of care (Lammers et al., 2014). The literature of HIE research mainly focuses on the adoption and outcomes of HIE. While the use of HIE in hospitals is shown to prevent redundant tests, reduce medicare spending, and avoid hospitalizations (Adjerid et al., 2018; Ayer et al., 2019; Janakiraman et al., 2017; Johnson et al., 2011), little research has been done on the topic of HIE implementation in LTC facilities where most residents need assistance to live independently. To close this gap, we study the impact of operational HIE on the readmission rate of the U.S. LTC facilities with nationwide panel data. Our results reveal that the adoption of HIE significantly reduces the readmission rate of LTC facilities. It facilitates data exchange and communication between the residents and the healthcare providers. To our knowledge, our research is the first to use nationally representative samples and robust approaches to evaluate the impact of HIE on the service quality of the LTC facilities.

Additionally, our research contributes to the stream of studies on health ITs in LTC facilities, especially the effect of integrating advanced health ITs. The research mainly focuses on two types of health ITs, EHR and Telemedicine, since they are the most recent innovative health ITs that lead to potential improvements in health services. Chaudhry et al. (2006) show that the impact of EHR on quality and efficiency is not overwhelmingly positive, nor is it sufficiently big with large-scale samples. One possible reason is that the HITECH Act encourages 3 stages of meaningful use of EHR: structured data entry in the EHR, guide clinicians on the use of technology toward advanced clinical processes, and lastly aim at achieving and measuring improved patient outcomes. Each stage incrementally requires advanced use of technology (Marcotte et al., 2012). A large portion of the adoptions of EHR in nursing homes stay in the first stage. HIE is a critical component of stage 2 of the meaningful use of EHR system (Rajapakshe et al., 2020). There is scope for improving the use of EHR systems through the incorporation of HIE functions to support collaborative nursing care. Telemedicine has also been attracting much research attention. Various studies of Telemedicine find that it is a feasible means of delivering multidisciplinary care to frail nursing home residents and result in increased productivity as well as reduced hospitalizations (Biglan et al., 2009; Grabowski & O'Malley, 2014; Hui et al., 2001). Driessen et al. (2018) surveyed 524 physician and advanced practice providers and found the use of Telemedicine could improve access to remote specialty

providers. HIE provides secured and seamless data exchange between health providers, which is essential to support the concept of Telemedicine as a modality of care that can be used to offer specialty consults to nursing home residents

Therefore, innovative health ITs are able to affect service quality through their role in collaboration with HIE. However, few studies have been done on the heterogeneous effect of HIE with other health ITs that may magnify or diminish the impact on the service quality of LTC facilities. Our study extends the health IT research by identifying and empirically validating the conditional factors of health IT influence. The results provide insights on health IT selection with a tight budget of LTC facilities.

3. Hypothesis Development

3.1. HIE on Service Quality

Readmission rate is widely used in healthcare research as an important indicator of LTC service quality. Individuals discharged from the hospital to a LTC facility are often more vulnerable than other individuals hospitalized for similar conditions. They require extended rehabilitation and posthospitalization support (Carnahan et al., 2016). Readmission to hospitals may harm patients by increasing the risk of additional morbidity, mental instability, and physical injuries. The quality of care they received in LTC facility is critical to their long-term recovery. Approximately, 20% of Medicare beneficiaries are readmitted within 30 days of discharge (Carnahan et al., 2016). New strategies for transitions of care focused on reducing 30-day readmission rates have been attracting research attention. HIE supports efficient information exchange and has been considered as one of the most effective tools to increase the efficiency of healthcare transitions.

HIE is implemented in hospitals, laboratories, LTC facilities, and many other healthcare entities to transfer test results, medication lists, and other clinical information among institutions and providers. They could participate in a community or a commercial HIE to connect affiliated hospitals and physicians in their network. HIE enables secured and smooth data exchange. With more complete patient information, healthcare providers and LTC facilities are able to efficiently coordinate care for their residents. Researches find primary associations between HIE, reduced emergency department use, and cost of care in some cases (Rudin et al., 2014). For example, Jones et al. (2011) report a participation in HIE to exchange electronically patients' information with ambulatory providers outside of hospital system reduces the readmission rate of patients with acute diseases. HIE can also improve the analytic capabilities between health entities. Real-time risk analysis and comprehensive diagnosis of patients are based on the data transferred by HIE. An appropriate medical plan lowers the probability of over-treatment and prevents redundant rehospitalizations (Kilcup et al., 2013).

Therefore, HIE assists patients with their treatment and medications after hospital discharge, improves the collaborations between hospitals and LTC facilities, and eventually prevents readmission. We propose the following hypothesis to test the impact of HIE on the service quality of LTC facilities measured by readmission rate.

Hypothesis 1 (H1): Operational HIE helps the residents of LTC facilities avoid unnecessary rehospitalization, which leads to a reduction in the readmission rate of the LTC facility.

3.2. Integration of HIE and Other health ITs

Investing in health IT can improve the safety, quality, and value of health care. However, with tight budgets and insufficient staffing, many healthcare institutions have to make a strategic plan on building their IT framework. Health ITs support operations and services in a variety of ways. Instead of functioning independently, an ideal IT system has different IT components working in collaboration and serves as a complement to other applications. A system integrated with complemented health ITs is widely considered to provide enhanced performance in terms of quality and safety. HIE has shown its advantage in reducing avoidable readmission. We investigate the heterogeneous effect of HIE in collaboration with other health ITs to further understand the mechanism behind its impact.

EHR has become a very important and integral part of the healthcare system. EHRs improve efficiency and increase reimbursements while improving patient care. Most of the residents of LTC facilities have a long medical history and multiple chronic conditions. A complete set of patient records are available through EHR and HIE that will have a big effect on care given during patient visits. In LTC facilities, a patient discharge summary from a hospital can be brought into a patient's chart electronically by EHR and HIE after it is

reviewed by LTC staff. This timely information received could further influence a patient's care and save time by avoiding readmissions. To test the heterogeneous effect of HIE by EHR adoption, we propose the following hypothesis:

Hypothesis 2 (H2): The reductions of LTC readmission rate due to operational HIE will be greater in the LTC facilities with operational EHR.

Besides EHR, Telemedicine is another innovative health IT applying emerging technology to healthcare services. A majority of the residents of LTC facilities live with chronic conditions. Patients can be treated, by a certified physician in comfortably and effectively on the spot where no doctors are available. Besides the support from Telemedicine, the healthcare providers are able to access a complete medical history of the patients by HIE, which greatly increases the diagnostic accuracy. Eventually, patients are able to receive high-quality treatment without rehospitalization. Therefore, We hypothesize that:

Hypothesis 3 (H3): The reductions of LTC readmission rate due to operational HIE will be greater in the LTC facilities with operational Telemedicine.

4. Data

We construct a panel data set from 2013 to 2017 with yearly facility-level observations. We obtain the long-term care facility data from the Online Survey Certification And Reporting(OSCAR)/Certification and Survey Provider Enhanced Reporting(CASPER) as well as the Minimum Data Set(MDS) databases from LTCFocus.org. The facility-level IT adoption data are imported from the database of the Dorenfest Institute for Health Information supported by the Healthcare Information and Management Systems Society (HIMSS). The database includes data on annual information technology applications of healthcare providers across the nation. The HIMSS health IT data are merged with the long-term care facility data from LTCFocus to construct our facility-level panel data. After data cleaning, we eventually have health IT and facility information of 1967 nationwide long-term care facilities with 7355 observations from 2011 to 2015.

The quality of long-term care facilities can be measured in many ways for different research or healthcare purposes (Castle & Ferguson, 2010). Among all the quality measures, the readmission rate is the most common quality indicator for the service of long-term care facilities (Rahman et al., 2016; Thomas et al., 2014). This outcome estimates the risk-standardized rate of all-cause, unplanned, hospital readmissions for nursing facility patients within 30 days of discharge from a prior proximal hospitalization. Our main independent variable is the adoption of HIE in long-term care facilities. To study the heterogeneous effect of HIE, we include the adoption status of Electronic Health Records (EHR) and Telemedicine, to capture the most widely implemented technological advancements in health care. We use dichotomous variables to indicate if applications of these categories are "live and operational" (1) or in other statuses (0). Figure 1 shows the percentage trends of the U.S. LTC facilities adopting health information technologies from 2013 to 2017.

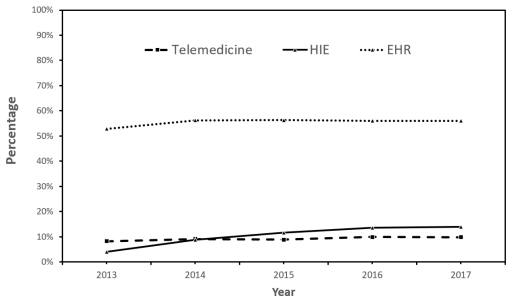

Figure 1. Percentage trend of US Long-term-care facilities adopting innovative health information technologies (2013-2017). Data source: Healthcare Information and Management Systems Society Database (HIMSS)

We use several control variables to capture the heterogeneity among LTC providers. These control variables fall into three categories. The facility characteristics include number of beds, occupancy rate, ownership type(binary), chain affiliation(binary), and availability of Alzheimer unit (binary). The staffing status is measured by direct care staff hours per resident day, the availability of nurse practitioner or physician assistance (binary), and skilled nurses ratio. Direct care staff hours per resident day are calculated by the sum of the corresponding hours from certified nurse assistant (CNA), licensed practical nurse (LPN), and registered nurse (RN) to demonstrate the mixed level of nurse staffing of the facility. The resident information includes the average acuity profile, Medicaid and Medicare residents ratios. Additionally, we control market concentration by Herfindahl-Hirschman Index(HHI) at the county level. In our context, HHI is defined as the sum of squared market shares of each LTC

facility located in the same market (i.e. the same county).

5. Research Methods

5.1. Model Specification

The first part of our empirical approach examines the effect of HIE on the service quality of LTC facilities. The service quality is measured by the adjusted 30-day readmission rate of a LTC facility in our research. To study whether the usage of HIE has an impact on the readmission rate, we deploy a difference-in-difference (DID) specification with panel data. We estimate the following main model:

$$Q_{it} = \beta_0 + \beta_1 AdoptHIE_{it} + \gamma LTC_{it} + \eta Market_{it} + \lambda_i + \tau_t + \mu_{it} \quad (1)$$

The variable $AdoptHIE_{it}$ is a dummy variable indicating whether a LTC facility i had adopted HIE at time t. It equals "1" if a HIE system is live and operational for the LTC facility in that year, and "0" otherwise. Therefore, $AdoptHIE_{it}$ is our main variable of interest and β_1 is the DID coefficient that captures the effect of HIE adoption status. LTC_{it} is a vector of controls that captures time-variant characteristics of a LTC facility. It includes facility, staffing, residents measures. $Market_{it}$ is the control for market concentration. A highly concentrated long-time care market has a higher demand for smooth information exchange between facilities. Thus, this variable may be correlated with the emergence of HIEs. We use HHI value to represent the market concentration intensity of LTC facilities at the county level.

Facility and time fixed effects are represented by λ_i and τ_t respectively. μ_{it} is the error term. Facility and time fixed effects allow us to control for time-invariant factors and time trends in our data that could simultaneously drive the decision of adopting HIE.

The dependent variable Q_{it} captures the service quality of LTC facilities. In our research, we use the adjusted 30-day readmission rate as the measure of service quality since it is one of the most commonly used standards for evaluating a LTC facility.

Next, we estimate an extended model to test whether HIE has a heterogeneous effect on service quality (**H2**,**H3**). We use the following specification:

$$Q_{it} = \beta_0 + \beta_1 AdoptHIE_{it} + \beta_2 AdoptHIE_{it} \times OtherHIT_{it} + \beta_3 OtherHIT_{it} + \gamma LTC_{it} + \eta Market_{it} + \lambda_i + \tau_t + \mu_{it} \quad (2)$$

$OtherHIT_{it}$ indicates the adoption status of another HIT of LTC facility i in year t. We test whether the integration of HIE with other innovative health ITs increases the impact of HIEs on service quality. We choose EHR and Telemedicine as our targeted health ITs. We add to our main model the adoption status of EHR/Telemedicine and its interaction with HIE. In this extended model, a positive and significant coefficient on the interaction term would support our hypothesis.

5.2. Sample Construction

A DID specification measures the treatment effect by comparing the treatment group and the control group before and after the treatment period. To study the treatment effect of HIE adoption, we focus on two groups with respect to their adoption status of HIE systems in our research. The treatment group consists of the LTC facilities that adopt the HIE functionality between the beginning of 2013 and the end of 2017, while the LTC facilities in the control group do not have HIE live and operational before the end of 2017.

However, the HIE adoption of the LTC facilities in our treatment and control groups is certainly not random. For example, the effort of healthcare providers to improve service efficiency varies among LTC facilities. Those who take seamless information exchange as an important standard of high communication efficiency would promote the implementation of HIE. Our models partially capture the unobserved bias by including a broad set of control covariates. The facility and time fixed effect can also help exclude the impact of time-invariant differences between facilities and time trends.

We further reduce the endogeneity concerns by estimating our model using a propensity score matched (PSM) sample. PSM method uses relevant covariates to identify a control group of LTC facilities without operational HIEs that would have been most likely to have had an operational HIE. We conduct the matching using a cross-sectional sample of the facilities from the pre-matched treatment and control groups. We use LTC facility characteristics in 2012 as the matching variables since they have not been affected by the decision of HIE

adoption during our targeted time period (2013-2017). We specified the number of nearest neighbor as 1 and a caliper of 0.25 standard deviations of the propensity score (Lunt, 2014; Sun et al., 2020). As a result, we have 111 LTC facilities in the PSM matched treatment group and 946 LTC facilities in the PSM matched control group. Table 1 summarizes the descriptive statistics of the matched sample. Additionally, we did a balance test on the matched sample and the unmatched sample. Compared to the unmatched sample, the matching variables are not significantly different between the treatment group and the control group in the matched sample. It has a good balance between the treatment and control.

6. Results and Discussion

We firstly examine the effect of HIE on the readmission rate of LTC facilities. The results are presented in Table 2. Column 1-3 show the results from the unmatched sample of LTC facilities who adopted HIE during the targeted time period(2013-2017) and those who have not adopted HIE before the end of 2017. In an initial estimation with only facility and time fixed effects (Table 2, Column 1), our main concerned independent variable, the adoption status of HIE, shows significant influence under $p < 0.001$. The negative sign indicates a reverse impact of the adoption of HIE on the readmission rate. In other words, an operational and live HIE system reduces the probability that the residents of a LTC facility receive re-hospitalization. Our baseline specification also includes a full set of facility, staffing, residents, and market controls (Table 2, Column 2). We observe a smaller but still statistically significant estimate of reduced readmission rate due to HIE. The results are consistent with the PSM matched sample. Thus, we conclude that regardless of the differences in model specifications and sample constructions, the coherent results of Table 2 show that the adoption of HIE adoption leads to a significant reduction in readmission rate, thereby supporting **Hypothesis 1**.

Next, we estimate the heterogeneous effect of HIE adoption, and the results are presented in Table 3. The information technology framework of the U.S. LTC facilities consists of many modules. HIE allows health care professionals to appropriately access and securely share medical information electronically, and thus most likely have a confounding impact on service quality in the presence of integrating with other health IT components that facilitate information exchange. We choose EHR and Telemedicine as our targeted health ITs because they are the most promising health ITs that provide efficient and effective communication between healthcare institutions. Table 3 shows that by controlling the other two health ITs, the adoption of HIE still presents a significant impact of reducing the readmission rate. Moreover, the results show that adoption of Telemedicine can significantly lower the residents re-admission rate while EHR may not present the same impact.

In particular, the coefficient of the interaction term between EHR and HIE shows a negative correlation with re-admission rate, suggesting that the adoption of HIE further lower the re-admission rate with the integration of EHR applications. However, the effect is not statistically significant. Many LTC facilities use EHR as an alternative data-entry tool to save labor, which only stays at the first stage meaningful use of EHR recommended by HITECH. EHRs have to be created in certain ways to enable continuous quality improvement at the point of care and the exchange of information in the most structured format possible (Centers for Medicare Medicaid Services, 2022). The result shows that few LTC facilities incorporate advanced functions of EHR system in their operations. **Hypothesis 2** is not supported by our results.

The result of the effect of HIE integrated with Telemedicine is surprising. The significance of the coefficient of the interaction term between HIE and Telemedicine shows that the effect of HIE on re-admission rate significantly changes with an integration of HIE and Telemedicine. However, the positive sign suggests that the reduction of re-admission due to HIE adoption is less salient by integrating Telemedince. This result indicates that how HIE and Telemedicine is used in LTC facilities is fairly different from those in hospitals. In hospitals, doctors communicate with patients by Telemedicine while HIE transfers patients' records. However, HIE and Telemedicine are both implemented as a way of information exchange in LTC facilities. The residents in LTC facilities are mostly living with multiple chronic conditions. A sick resident can directly talk to a doctor from the partnered hospital through Telemedicine and may not rely on HIE to send the information since the resident already has a long patient history with the hospital. Telemedicine can help LTC facilities avoid unnecessary re-admissions without the support of HIE. In this way, Telemedicine and HIE have different pathways to reduce hospitalization, thus serving as a substitute for each other. Another possible reason is that the complexity of adopting both advanced HITs raises a technological barrier and a burden of responsibility for LTC facilities, which leads to a reluctant attitude towards using HIE. Therefore, HIE becomes a less

important role in reducing hospitalization in the presence of Telemedicine in LTC facilities. **Hypothesis 3** is not supported by our results.

7. Robustness Check

We leverage a relative time model to evaluate simultaneity or reverse causality concerns in our estimation. For example, healthcare providers who are concerned about communication efficiency may have already been making effort to lower the readmission rates in many other ways. We investigate these concerns using indicator variables for one and two years prior to an HIE becoming operational (HIE_{t-1}, HIE_{t-2}). The results are shown in Table 2 Column 3. We further extend our analysis to the data up to four years before the adoption year (see Figure 2). The results consistently show that the coefficients are both small and insignificant until the year of HIE being operational, suggesting that our data is less likely to suffer from a pre-trend issue.

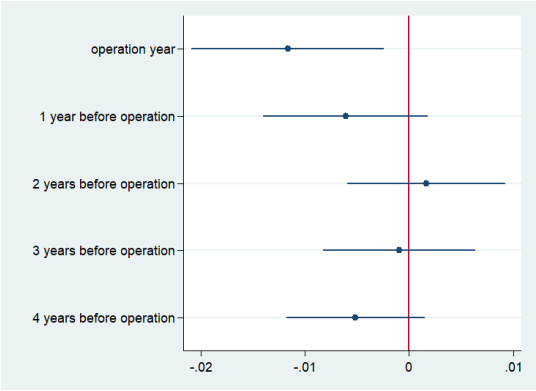

Figure 2. Pre-trend test. The plots markers show the coefficients that are up to 4 years before the HIE operation. The horizontal spikes show 95% confidence intervals.

8. Conclusion

In our research, we identify statistically significant and meaningful reductions in re-admission rate due to operational HIE of LTC facilities. We also explore the conditions under which HIE could probably create more value. Specifically, we argue that though EHR helps LTC facilities further lower the re-admission rate in the collaboration with HIE. The influence is not significant for the reason that EHR is mainly implemented for the purpose of internal use in LTC facilities. The use of EHR only stays with basic functions in LTC facilities. Compared to EHR, Telemedicine significantly helps the residents of LTC facilities avoid unnecessary rehospitalizations. However, it has not been utilized more than a means of information exchange. HIE becomes a less important role in reducing hospitalization in LTC facilities where Telemedicine and HIE are both implemented. We find that the applications of EHR and Telemedicine in LTC facilities are still at a very early stage. There is scope for improving the rudimentary use of EHR and Telemedicine systems through the incorporation of HIE functions to support collaborative nursing care. Decision makers can use our results as a reference to inform the design of IOS efforts in the future.

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Table 1. Descriptive Statistics of the Propensity Score Matched Sample

Variables	Observation	Mean	Std. Dev.	Definition
Quality measure				
Re_Admin	3,308	0.154	0.058	Adjusted 30 days readmission rate
HealthIT adoptions				
HIE	4,132	0.074	0.261	Health Information Exchange system adoption status
EHR	4,422	0.618	0.486	Electronic Health Record system adoption status
Telemedicine	4,022	0.072	0.258	Telemedicine tool adoption status
Facility				
Beds	4,422	95.409	66.484	Total number of beds
Occupancy	3,795	84.959	13.516	Percentage of occupied beds (%)
Profit	4,422	0.226	0.418	Indicates whether or not the facility is for-profit (1/0)
Chain	4,422	0.437	0.496	Indicates whether or not the facility is part of a chain (1/0)
Alzunit	4,422	0.130	0.336	Indicates whether or not facility has an Alzheimer's disease Special Care Unit (SCU) (1/0)
Staffing measure				
DR_hours	4,416	4.160	1.428	Direct care staff hours per resident day
Physician	4,422	0.421	0.494	Indicates whether or not facility has any nurse practitioner or physician assistant
RN_Ratio	4,422	0.410	0.221	Registered nurse to total nurses ratio
Residents				
Acuity	4,347	1.175	0.261	Indicator of average acuity profile of the residents in a facility
MediCaid	4,422	58.470	23.734	Percentage of Medicaid residents(%)
MediCare	4,422	14.297	17.448	Percentage of Medicare residents(%)
Market				
HHI	4,422	0.122	0.159	Herfindahl-Hirschman Index that measures the market concentration

Table 2. Effect of HIE Adoption on Adjusted Readmission Rate per LTC Facility

	Unmatched Sample			PSM Matched Sample	
	(1) Fixed effects	(2) Fixed effects & Controls	(3) Relative time	(4) Fixed effects	(5) Fixed effects & Controls
HIE	-0.0302***	-0.0141**	-0.0103*	-0.0225***	-0.0189***
	(0.0028)	(0.0045)	(0.0047)	(0.0043)	(0.0053)
HIE_{t-1}			-0.00567		
			(0.0039)		
HIE_{t-2}			0.00145		
			(0.0037)		
Constant	0.148***	0.155***	0.154***	0.157***	0.150***
	(0.0018)	(0.0114)	(0.0113)	(0.0019)	(0.0141)
Controls	N	Y	Y	N	Y
Facility FE	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y
N	5638	3805	3802	3308	2775
Adjusted R^2	0.017	0.123	0.127	0.010	0.127

Robust standard errors are shown in parentheses.

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

Table 3. Heterogeneous Effect of HIE Adoption on Adjusted Readmission Rate per LTC Facility

	Unmatched Sample			PSM Matched Sample		
	(1) HIT controls	(2) HIE & Telemedicine	(3) HIE & EHR	(4) HIT control	(5) HIE & Telemedicine	(6) HIE & EHR
HIE	-0.00978*	-0.0176**	-0.0108*	-0.0152**	-0.0228***	-0.0168*
	(0.0046)	(0.0054)	(0.0047)	(0.0056)	(0.0065)	(0.0074)
Telemedicine	-0.00962*	-0.0175***		-0.00500	-0.0138*	
	(0.0044)	(0.0047)		(0.0053)	(0.0057)	
HIE × Telemedicine		0.0257**			0.0246*	
		(0.0098)			(0.0117)	
EHR	0.00450*		0.00429	0.00230		0.00219
	((0.0018)		(0.0018)	(0.0022)		(0.0023)
HIE × EHR			-0.00437			-0.000803
			(0.0101)			(0.0118)
Constant	0.171***	0.174***	0.170***	0.173***	0.174***	0.172***
	(0.0122)	(0.0122)	(0.0122)	(0.0150)	(0.0151)	(0.0150)
Controls	Y	Y	Y	Y	Y	Y
Facility FE	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
N	3801	3801	3801	2775	2775	2775
Adjusted R^2	0.129	0.129	0.128	0.135	0.136	0.134

Robust standard errors are shown in parentheses.

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