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Temporal Impacts of Health Information Technology on Hospitals' Financial Performance

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Abstract

Investments in health information technology (HIT) are known to improve financial and operational performance in hospitals. However, it is less understood whether this improvement is short-term, medium-term, or long-term. This paper investigates the effect of HIT investments on hospitals' cost-to-charge ratio, a financial metric that accounts for both costs and revenues, at different time lags after the initial investment. Using panel data on U.S. hospitals from 2010 to 2021, we report that the impact of HIT on hospital cost-to-charge ratio is realized with a lag of zero to four years, when controlled for hospital differences such as rural vs urban location, public vs private ownership, proportion of uncompensated care, and year-over-year variations. This effect becomes non-significant after four years as the effect of HIT wears out. We also quantify the returns from HIT investment. A 100% increase in HIT investment results in a reduction of 3.3 to 6.0% in cost-to-charge ratio between years 0 through 4 after the HIT investment. Implications of these findings for research and practice are described.

Keywords

Health information technology, cost-to-charge ratio, financial impact, panel data model.

Introduction

In recent years, hospitals and private physician practices have made sizable investments in health information technologies (HIT) such as electronic health records (EHR) and clinical decision support systems. In the year 2022, healthcare providers in the U.S.A. spent an estimated $17.90 billion on cloud-based HIT (Insider Intelligence, 2023). Studies document that HIT has helped improve patient safety (Menachemi et al., 2007), quality of care (McCullough et al., 2010), operational performance (Bhattacherjee et al., 2006; Alolayyan et al., 2020), and financial performance (Collum et al., 2016, Wang et al., 2018). However, these effects appear to be somewhat inconsistent, with prior meta-analyses reporting beneficial effects in 70.0-72.4% of published studies (Bassi et al., 2013; Tarver et al., 2016) and others reporting no benefit (Agha et al., 2014) or even negative returns (Sharma et al., 2016) in the year of investment. Given the cross-sectional nature of these studies, one potential reason for the above inconsistent results may be that the effects of HIT investments may not realized in their year of investment but rather take a few years to materialize (Collum et al., 2016). Hence, longitudinal analysis is the most accurate approach to estimate these effects.

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There are a few longitudinal studies in the HIT literature (e.g., Lee and Choi, 2016; Das et al., 2011; Bardhan and Thouin, 2013; Wang and Bidermann, 2010; Collum et al., 2016; Sharma et al., 2016; Furukawa et al., 2016). These studies examined a single type of HIT (e.g., EHR), a single hospital, or a single state, and studies that analyzed financial outcomes focused on costs or revenues but not both. Moreover, most of these studies examined the pre-2009 Health Information Technology for Economic and Clinical Health Act (HITECH) era when HIT adoption was less pervasive. To examine HIT's impact on a hospital's overall financial health, we should (1) analyze hospitals across different states, (2) consider both hospital costs and revenues to evaluate financial impact, and (3) examine post-HITECH data now that HIT use has became more widespread and accepted. Furthermore, very little is known about when health care organizations start realizing the expected benefits of HIT investments and how long do these benefits last.

In light of the above gaps in the literature, this paper examines the temporal relationship between HIT investment and hospitals' financial health using post-HITECH data from hospitals from all 50 states in the U.S.A. Specifically, we are interested in answering two research questions: (1) when do hospitals start and stop realizing financial returns from their HIT investments, and (2) what is the magnitude of such financial returns? The dependent variable in our analysis is hospital cost-to-charge ratio - a holistic metric of hospitals' overall financial health that takes into account both hospital costs and charges (revenues). Using 10-year panel data (2010-2021) from the Centers for Medicare & Medicaid Services (2023), we investigate short (0-1 years), medium (2-5 years) and long (over 5 years) term effects of HIT on cost-to-charge ratio using lagged data models, while controlling for hospital differences such as rural vs urban location, public vs private ownership, amount of uncompensated care, and state-level and year-level random effects.

We report that HIT investments have an immediate effect of reducing hospitals' cost-to-charge ratio by 4.2% in the year of investment and subsequent reductions between 3.6% and 6.0% between one and four years after investment, when controlled for hospital differences, state effects, and year-over-year fluctuations. This effect becomes non-significant after the fourth year as the effect of HIT wears out. Policy implications of these findings are described.

Methodology

Data for our analysis was sourced from the U.S. Centers for Medicare & Medicaid Services' (CMS, 2023) Hospital 2552-10 Cost Report Data. This data is reported annually by Medicare-certified institutional providers to CMS which maintains a consolidated annual record in its Healthcare Provider Cost Reporting Information System. We extracted data files for the years 2010 through 2021 and merged records for each hospital (by provider number) across the eleven years of data. The merged dataset included 128 unique variables on various aspects of hospital operations such as facilities, utilization, location (rural versus urban), type of control (public versus private), type of service (Medicare, Medicaid, and Children's Health Insurance Program), different categories of HIT investments, different types of costs and revenues (e.g., net patient inpatient revenues, etc.), and more. We filtered the data to include only those hospitals with a fiscal reporting date range of at least one full year and HIT designated assets greater than zero. Data quality checks were undertaken to verify the accuracy of cost-to-charge ratio from net patient revenue and cost metrics. The process led to a final dataset of 5,027 complete observations.

From our initial list of 128 variables, we identified 30 independent variables as relevant to hospital overall financial health, which we narrowed down further by combining variables (such as summing different types of HIT assets into one asset variable) into a final set of seven independent variables and one dependent variable. The dependent variable was cost-to-charge ratio, which was measured as the total amount of money required to operate a hospital, divided by the sum of the revenues received from patient care and all other operating revenues. Our primary independent variable of interest was hospitals' HIT investments, which was measured as HIT designated assets or the acquisition costs of HIT acquired assets. In addition, our analysis accounted for six control variables that were expected to influence hospitals' HIT budgets, efficiency, and/or costs: hospital location (rural or urban), hospital ownership (public or private), hospital size (number of beds), hospital activity (number of discharges), unreimbursed or uncompensated care, and hospital financial stability (debt-to-asset ratio).

We tested for the effects of HIT investments on hospital cost-to-charge ratio in the year of investment (zero lag) using the panel linear models (PLM) approach, employing random effects of hospital (provider number) and year to control for hospital-level differences and annual variations in healthcare costs and revenues. Our lagged model specification, with lags from zero to seven years to account for short, medium, and long-term effects of HIT, is shown in the equation below. Log transformations were used for HIT investments and unreimbursed or uncompensated care, in view of their skewed distributions.

$$\text{Cost-to-charge Ratio}_{it} = ß_{0\,i,t-j} + ß_{1\,i,t-j} * \text{Urban}_{\,i} + ß_{2\,i,t-j} * \text{Private}_{\,i} + ß_{3\,i,t-j} * \log(\text{Total Unreimbursed and Uncompensated Care})_{\,i,t-j} + ß_{4\,i,t-j} * \text{Total Discharges} + ß_{5\,i,t-j} * \text{Number of Beds}_{\,i,t-j} + ß_{6\,i,t-j} * \text{Debt to Asset Ratio}_{\,i,t-j} + ß_{7\,i,t-j} * \log(\text{HIT}_{\,i,t-j}) + \gamma_i * \text{Provider\_Num}_{\,i} + \gamma_t * \text{Year}_{\,t} + \varepsilon_{\,i,t-j}$$

where subscript i corresponds to a specific hospital (Provider_num), t to a specific year (between 2010 and 2021), and j to a lag time in years (between 1 and 7 years) between the independent and dependent variables.

Results and Discussion

Descriptive analysis show that average HIT assets by year across hospitals declined continually from $9.5 million in 2010 to $6.2 million in 2013 and then increasing to $13.4 million in 2021. In contrast, average cost-to-charge ratio stayed within a range between 0.30 to 0.40, with the lowest value of 0.38 in 2021.

Results of our lag analysis across eight years (year 0 through 7) are shown in Table 1. We observed a significant negative main effect of HIT investments on cost-to-charge ratio for the first five years of investment (from year 0 through 4), demonstrating both near-term and medium-term effects, when controlled for hospital differences and year-over-year variations. A 100% increase in HIT investment led to a 4.2% reduction in cost-to-charge ratio in the year of investment, followed by 6.0%, 4.8%, 5.4%, and 3.6% reduction respectively in the following four years. This effect became non-significant after four years as the effect of HIT wears out.

Table 1. Panel Data Analysis with 1-7 Year Lags

Variable	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6	Lag 7
Urban (vs Rural)	-0.025*** (0.004)	-0.027*** (0.005)	-0.032*** (0.005)	-0.043*** (0.006)	-0.037*** (0.008)	-0.037*** (0.010)	-0.074*** (0.013)	-0.108*** (0.018)
Public (vs Private)	0.096*** (0.008)	0.087*** (0.009)	0.091*** (0.010)	0.089*** (0.011)	0.109*** (0.014)	0.135*** (0.017)	0.125*** (0.021)	0.149*** (0.026)
Debt to Asset Ratio	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.001 (0.005)	-0.001 (0.006)	0.015 (0.019)
Total Discharges	-0.000*** (0.000)	-0.000*** (0.00)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Number of Beds	-0.000*** (0.000)	-0.000 (0.000)	-0.000** (0.000)	-0.000 (0.000)	-0.000* (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
log (Total Unreimbursed Care)	-0.036*** (0.011)	-0.060*** (0.012)	-0.051*** (0.014)	-0.063*** (0.017)	-0.049** (0.020)	-0.045* (0.025)	-0.023 (0.033)	-0.047 (0.045)
log (HIT)	-0.042*** (0.012)	-0.060*** (0.013)	-0.048*** (0.015)	-0.054*** (0.017)	-0.036* (0.020)	-0.024 (0.025)	-0.001 (0.032)	-0.011 (0.044)
Intercept	1.123*** (0.170)	1.532*** (0.189)	1.390*** (0.217)	1.535*** (0.247)	1.299*** (0.291)	1.153*** (0.364)	0.802 (0.488)	1.086* (0.658)
Observations	5,027	3,802	2,958	2,274	1,696	1,201	782	473
R^2	0.190	0.215	0.211	0.226	0.249	0.261	0.345	0.421
Adjusted R^2	0.189	0.214	0.209	0.223	0.245	0.256	0.337	0.41
F Statistic	475.8***	508.4***	463.5***	418.5***	345.8***	277.7***	221.2***	215.9***

*p<0.1; **p<0.05; ***p<0.01

The objectives of this study were to investigate two previously unaddressed questions in the healthcare IT literature: (1) how long it takes for hospitals to realize the expected financial benefits of HIT investments and how long those benefits last, and (2) what is the magnitude of these benefits. These questions are important for HIT research and practice because although HIT investments are widely believed to reduce hospital costs, little is known about whether these effects are short, medium, or long-term and there has been little systematic attempt to quantify the financial benefit of HIT investments.

Our analysis indicates that HIT investments have a 4.2% immediate benefit on hospitals' cost-to-charge ratio in the year of investment. This was surprising given that we expected HIT to be a cost sink in the short-term, start to generate cost advantages over the medium-term, and then those cost effects wearing out over the long-term. In this case, it may be that the adoption barriers of HIT, such as high learning costs and costs of system integration, that hurt the immediate

realization of HIT benefits during the pre-HITECH Act era (pre-1990), are less of an issue in the post-HITECH Act era (post-1990), when HIT is pervasive in most hospitals, clinics, and physician offices, and HIT users have become comfortable with using these systems.

Consistent with our expectations, we did find significant negative impact of HIT investments on hospital cost-to-charge ratio during years 1 through 4. This effect was the highest in year 1 (6.0%), dropping to 4.8% in year 2, 5.4% in year 3, and 3.6% in year 4. This effect continued in year 5 (2.4%), although the effect was non-significant, before dropping out in both strength and significance in years 6 and 7. These findings confirm our expectation that the financial effect of HIT investments wears out over the long term (after five years), when previous HIT perhaps requires an upgrade or replacement with newer HIT.

Conclusion

Our findings should be of interest to both HIT researchers and practitioners. For practice, our findings quantify the financial benefits that may be expected from HIT investments (between 3.3% and 6.0%), as well as point out when a hospital may expect to see such benefits (year 0) and how long will such benefits last (year 5). These estimates will help hospitals make appropriate budgetary decisions regarding how to plan both the investment and obsolescence of their HIT assets.

For research, our results indicate that HIT effects, certainly on hospitals' financial performance and possibly also on operational performance, should be studied in a longitudinal context because many of these effects appear and disappear over time. Cross-sectional analysis may mask or confound the temporal effects unfolding over time, and thereby, conflate short-term effects with medium-term or long-term effects.

For future research, since this analysis does not consider specific types of HIT, such as clinical, administrative, and operational HIT, future studies may investigate the differential impacts of different types of HIT on financial or operational performance.

References

Agha, L. (2014). The effects of health information technology on the costs and quality of medical care. *Journal of Health Economics*, *34*, 19–30. https://doi.org/10.1016/j.jhealeco.2013.12.005

Alolayyan, M. N., Alyahya, M. S., Alalawin, A. H., Shoukat, A., & Nusairat, F. T. (2020). Health information technology and hospital performance the role of health information quality in teaching hospitals. *Heliyon*, *6*(10).

Bardhan, I. R., & Thouin, M. F. (2013). Health information technology and its impact on the quality and cost of healthcare delivery. *Decision Support Systems*, *55*(2), 438–449. https://doi.org/10.1016/j.dss.2012.10.003

Bassi, J., & Lau, F. (2013). Measuring value for money: A scoping review on economic evaluation of health information systems. *Journal of the American Medical Informatics Association*, *20*(4), 792–801. https://doi.org/10.1136/amiajnl-2012-001422

Bhattacherjee, A., Hikmet, N., Menachemi, N., Kayhan, V. O., & Brooks, R. G. (2006). The differential performance effects of healthcare information technology adoption. *Information Systems Management*, *24*(1), 5–14. https://doi.org/10.1080/10580530601036778

Centers for Medicare & Medicaid Services. (n.d.). *Hospital 2552-10 form Cost Report Data files*. https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Cost-Reports/Hospital-2010-form

Collum, T. H., Menachemi, N., & Sen, B. (2016). Does electronic health record use improve hospital financial performance? Evidence from panel data. *Health Care Management Review*, *41*(3), 267–274. https://doi.org/10.1097/HMR.0000000000000068

Das, S., Yaylacicegi, U., & Menon, N. M. (2011). The effect of information technology investments in healthcare: A longitudinal study of its lag, duration, and economic value. *IEEE Transactions on Engineering Management*, *58*(1), 124–140. https://doi.org/10.1109/TEM.2010.2048906

Furukawa, M. F., Raghu, T. S., & Shao, B. B. M. (2010). Electronic medical records and cost efficiency in hospital medical-surgical units. *INQUIRY: The Journal of Health Care Organization, Provision, and Financing*, *47*(2), 110–123. https://doi.org/10.5034/inquiryjrnl_47.02.110

Insider Intelligence. (2023, January 1). US healthcare industry in 2023: Analysis of the health sector, healthcare trends, & future of digital health. https://www.insiderintelligence.com/insights/healthcare-industry/

Lee, J., & Choi, J.-Y. (2016). Texas hospitals with higher health information technology expenditures have higher revenue: A longitudinal data analysis using a generalized estimating equation model. *BMC Health Services Research*, *16*(1), 117. https://doi.org/10.1186/s12913-016-1367-9

McCullough, J. S., Casey, M., Moscovice, I., & Prasad, S. (2010). The effect of health information technology on quality in U.S. Hospitals. *Health Affairs*, *29*(4), 647–654. https://doi.org/10.1377/hlthaff.2010.0155

Menachemi, N., Saunders, C., Chukmaitov, A., Matthews, M., & Brooks, R. (2007). Hospital adoption of information technologies and improved patient safety: A study of 98 hospitals in Florida. *Journal of Healthcare Management*, *52*(6), 398–409.

Sharma, L., Chandrasekaran, A., Boyer, K. K., & McDermott, C. M. (2016). The impact of health information technology bundles on hSospital performance: An econometric study. *Journal of Operations Management*, *41*(1), 25–41. https://doi.org/10.1016/j.jom.2015.10.001

Tarver, W. L., & Menachemi, N. (2016). The impact of health information technology on cancer care across the continuum: A systematic review and meta-analysis. *Journal of the American Medical Informatics Association*, *23*(2), 420–427.

Wang, T., & Biedermann, S. (2010). Running the numbers on an EHR. Applying cost-benefit analysis in EHR adoption. *Journal of AHIMA*, *81*(8), 32–38.

Wang, T., Wang, Y., & McLeod, A. (2018). Do health information technology investments impact hospital financial performance and productivity? *International Journal of Accounting Information Systems*, *28*, 1-13.