The Effects of Health Information Technology Adoption and Hospital-Physician Integration on Hospital Efficiency

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ABSTRACT

Objectives

To determine the impact of health information technology (HIT) adoption and hospital-physician integration on hospital efficiency.

Study Design

Using 2010 data from the American Hospital Association's (AHA) annual survey, the AHA IT survey, supplemented by the CMS Case Mix Index, and the US Census Bureau's small area income and poverty estimates, we examined how the adoption of HIT and employment of physicians affected hospital efficiency and whether they were substitutes or complements.

Methods

The sample included 2173 hospitals. We employed a 2-stage approach. In the first stage, data envelopment analysis was used to estimate technical efficiency of hospitals. In the second stage, we used instrumental variable approaches, notably 2-stage least squares and the generalized method of moments, to examine the effects of IT adoption and integration on hospital efficiency.

Results

We found that HIT adoption and hospital-physician integration, when considered separately, each have statistically significant positive impacts on hospital efficiency. Also, we found that hospitals that adopted HIT with employed physicians will achieve less efficiency compared with hospitals that adopted HIT without employed physicians.

Conclusions

Although HIT adoption and hospital-physician integration both seem to be key parts of improving hospital efficiency when one or the other is utilized individually, they can hurt hospital efficiency when utilized together.

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Policy makers and academics have long tried to reduce healthcare costs while simultaneously improving the quality of care. Recently, they have been particularly interested in utilizing health information technology (HIT) and strengthening hospital-physician integration. In an effort to enhance HIT infrastructure, the American Recovery and Reinvestment Act of 2009 (ARRA) set aside approximately $20 billion in stimulus funds to encourage physicians and hospitals to adopt HIT systems, which are expected to reduce medication errors and enhance monitoring.[1,2] Furthermore, the US government and researchers have also been focusing on hospital-physician relationships.[3,4] With the recognition that independent hospital-physician arrangements can lead to inefficiencies, the Patient Protection and Affordable Care Act of 2010 (ACA) emphasized the importance of this integration of healthcare delivery. Thus, physicians, who have traditionally worked independently with hospital systems, are increasingly being encouraged to find employment within a hospital system, or to work under other forms of contractual arrangements to try to reduce inefficiencies and improve the quality of care.

While the government's efforts have increased the adoption of HIT systems and accelerated the growth of hospital employment of physicians, it is unclear how integration and HIT adoption interact to affect outcomes, such as hospital efficiency. Previous researchers have found that the probability of HIT adoption is positively associated with hospital-physician integration, positing that the 2 are complementary.[5,6] To achieve the ultimate goal of reducing costs and increasing efficiency, however, it is important to investigate how both HIT adoption and hospital-physician integration affect outcomes, and if and how they interact to affect those outcomes.[5]

If HIT adoption and hospital-physician integration complement each other, finding the optimal level of HIT utilization, given the specific type of physician-hospital arrangement (eg, employment of physicians or other contrac-

Take-Away Points

The US government has made significant efforts toward both increased health information technology (HIT) adoption and hospital-physician integration as solutions to reduce healthcare costs while simultaneously improving the quality of care.

- Our findings suggest that both HIT adoption and hospital-physician integration have positive effects on hospital efficiency.
- However, our work suggests that the HIT adoption and the hospital-physician integration are substitutes.
- The US government may want to pay more attention to this substitute relationship, as hospitals using both together are less efficient.

tual relationships) that can lead to the best outcomes, should become the next step for both policy makers and academics. However, if HIT adoption is a substitute for hospital-physician integration, then the government's efforts encouraging both HIT adoption and integrated systems warrant reconsideration. Despite its potential for important implication, the interaction between HIT and hospital-physician integration has received little attention in the literature.

Carefully considering its policy implications, we investigated the effects of HIT and hospital-physician integration on hospital efficiency. First, we used data envelopment analysis (DEA) to calculate hospital efficiency. Second, we examined the main effects of the adoption of the electronic medical record (EMR)—which is one of the prominent HIT applications—hospital employment of physicians, and the interaction effects of both on hospital efficiency.

METHODS

Data Source

We used data from the American Hospital Association's (AHA) annual survey, the AHA Information Technology (AHA-IT) survey, the CMS Case Mix Index (CMI), and the US Census Bureau's small area income and poverty estimates for 2010. The AHA annual survey provides information on hospital characteristics, including number of beds, service mix, nonphysician full-time equivalent (FTE) employees, nonlabor expense, total facility admissions, outpatient visits, hospital employment of physicians, hospital ownership, and urbanness. The AHA-IT survey notes whether a hospital uses an EMR system and if it electronically shares patient data with hospitals or ambulatory providers inside and/or outside its system. Lastly, we obtained the case mix data from the CMS CMI and county-level median household income data from the Census Bureau. After merging these 4 data sets, the sample consisted of 2173 hospitals observed in 2010. The sample represents 67% of 3233 hospitals that participated in the AHA-HIT survey.

Analysis

We employed a 2-stage approach to investigate the impact of HIT and hospital-physician integration on hospital efficiency. In the first-stage, DEA was used to estimate technical efficiency for the 2173 hospitals. Following previous studies,[7,8] we estimated technical efficiency using 4 input measures (number of beds, service mix, FTE employees, and nonlabor expenses) and 2 output measures (case-mix adjusted admissions and outpatient visits). Service mix is a measure of the diversity of diagnostic and special services provided by each hospital. Using the same formulation that was created by Dr Ozcan,[8] we obtained the service mix input.

In the second stage, we used instrumental variable (IV) approaches, notably 2-stage least squares (2SLS) and the generalized method of moments (GMM), to examine the effects of HIT adoption and integration on hospital efficiency. This 2-stage approach of first estimating efficiency scores and then regressing these scores on several explanatory variables was influenced by prior research. Ray (1991) regressed DEA scores on various social and economic variables to identify performance drivers in school districts.[9] Banker et al evaluated the impact of HIT investment on public accounting firm productivity.[10] Forsund and Sarafoglou noted that the 2-stage DEA approach has been used for over 20 years.[11] Banker and Natarajan provided theoretical justification for the application of the 2-stage models to evaluate contextual variables that affect DEA efficiency scores.[12] **Table 1** shows descriptive statistics of efficiency scores, input and output measures, and independent variables such as HIT adoption and hospital-physician integration.

First Stage: DEA and Hospital Efficiency

DEA is a linear programming approach for constructing a nonparametric piecewise linear production frontier using observed hospital-level input and output data. DEA allows for the consideration of multiple inputs and outputs simultaneously and makes very few a priori assumptions about the underlying technology of the production frontier, thus rendering DEA less susceptible to specification error. Only a brief discussion of the relevant aspects of DEA is presented in the current paper; for de-

Table 1. Descriptive Statistics

Variable	Description	Mean
Dependent variable		
EFF	The Farrell input-oriented measure of technical efficiency for the hospital	0.54
Input measures		
Number of beds	Number of operational hospital beds in the hospital	237.80
Service mix	The diversity of diagnostic and special services provided by each hospital	268.33
FTE employees	Number of nonphysician FTEs employed	1388.53
Nonlabor expenses	Operating expenses minus payroll and capital expenses	113,348,820.82
Output measures		
Case-mix adjusted admissions	Total facility admissions multiplied by case mix index	17,984.90
Outpatient visits	Number of visits to outpatient facilities minus outpatient surgeries and ED visits	164,821.47
Explanatory variables		
IT (in Table 2): EMR adoption	A binary indicator equal to 1 if the hospital has adopted EMR, one of the prominent HIT applications, and 0 otherwise	0.57
IT (in Table 3): IT utilization	A continuous variable indicating the hospital's level of IT utilization	6.09
INT	A binary variable equal to 1 if the hospital has adopted an integrated salary model (hospital employment of physicians), and 0 otherwise	0.39
GOV	A binary indicator that takes a value of 1 if the hospital is a government hospital, and 0 otherwise	0.16
URBAN	A binary indicator equal to 1 when the hospital is located in an urban area, and 0 otherwise	0.91
MEDINCOME	Median household income of the county in which the hospital is located	48,759.01

ED indicates emergency department; EFF, technical efficiency; EMR, electronic medical record; FTE, full-time equivalent; GOV, government hospital binary variable; INT, integrated salary model binary variable; IT, information technology; MEDINCOME, median household income.
Mean value of EMR adoption binary variable (IT), 0.57, indicates that 57% of hospitals (1240 hospitals = 0.57 × 2173 hospitals) have adopted EMR. Also, mean value of hospital employment of physicians' binary variable (INT), 0.39, indicates that 39% of hospitals (844 hospitals = 0.39 × 2173 hospitals) have adopted an integrated salary model. Lastly, mean value of government hospital binary variable (GOV), 0.16, indicates that 16% of hospitals (349 hospitals = 0.16 × 2173 hospitals) are government owned.

tailed technical descriptions of DEA, we refer the reader to a variety of papers.[13-16]

In DEA, the efficiency of a hospital is typically estimated using either an input-oriented or output-oriented approach. The input-oriented approach assumes that the hospital holds output constant, while decreasing the quantity of inputs used to produce the given level of output. The output-oriented approach maximizes output while holding the quantity of inputs constant.[17] In this paper, we adopt the input-oriented approach since many hospitals tend to face resource constraints such that incentives are often oriented toward minimizing inputs, such as length of stay.

Another important aspect to consider when estimating measures of technical efficiency using DEA is whether to apply constant or variable returns to scale technology. Many studies apply constant returns to scale technology; however, as pointed out by Hollingsworth and Smith,[18] when the data are ratio data, variable returns to scale technology should be used. Since our inputs and outputs are ratio data, we assume variable returns to scale technology. It should be noted that the underlying results of this paper do not change when efficiency measures are computed assuming constant returns to scale technology. Those results are available upon request.

After determining the returns to scale technology, the input-oriented efficiency scores are calculated by radically decreasing the quantity of inputs relative to the frontier technology, while holding output constant. Only inputs and outputs are needed to obtain the efficiency ratios since the Farrell measure is independent of prices.[19] The technical efficiency scores lie between 0 and 1. A score of 1 indicates a technically efficient hospital—while a score less than 1 indicates inefficiency—and that it is possible to produce the observed output level using fewer inputs.

Second Stage: Instrumental Variables Estimation

While DEA is an appropriate framework for calculating efficiency scores to determine which hospitals are more efficient than others, it does not provide a framework for analyzing the underlying determinants of differences in hospital efficiency. As a consequence, a few recent studies have employed a 2-stage approach to examine the determinants of hospital efficiency.[20] In these studies, efficiency scores are calculated as described in the previous subsection, and then ordinary least squares (OLS) estimation is employed in the second stage. OLS estimation, however, has several limitations. First, OLS estimates cannot be interpreted as causal effects; they are estimates of partial correlations. Second, if the explanatory variables in the OLS regression are not exogenous, OLS estimation results in biased and inconsistent parameter estimates. To avoid these problems, we use IV approaches to estimate the effect of HIT and hospital integration on hospital efficiency in the second stage of our analysis. As pointed out by Imbens and Angrist,[21] the estimated coefficients from IV methods can be interpreted as causal effects in the absence of controlled experiments or when a treatment is not successfully delivered to every unit in an experiment. In particular, estimation is done using 2SLS. 2SLS, however, can sometimes be inefficient in certain cases, such as when heteroskedasticity is present in the regression residuals. Consequently, we also apply the GMM procedure in order to get more efficient estimations.

The baseline regression model we estimate has the estimated measure of technical efficiency for hospital *i*, EFF_i, as the dependent variable. The key explanatory variables are IT_i, a measure of HIT adoption by hospital *i*; INT_i, a measure of hospital-physician integration; $IT\ INT_i$, an interaction term between IT_i and INT_i that captures the simultaneous effect of HIT and integration on the efficiency of hospital *i*; and GOV_i, a binary indicator that takes a value of 1 if hospital *i* is a government hospital, and 0 otherwise.

$$EFF_i = \beta_1 + \beta_2 IT_i + \beta_3 INT_i + \beta_4 IT\ INT_i + \beta_5 GOV_i + u_i$$

IT_i is a binary indicator equal to 1 if a hospital has adopted an EMR, one of the prominent HIT applications, and 0 otherwise. This variable represents the broader construct of HIT adoption, which is designed to help healthcare providers better manage patient care through exchanging and sharing health information electronically. IT_i is expected to be positively related to hospital efficiency, as several studies have found that HIT improves efficiency by reducing redundant diagnostic tests and other medication errors.[1,2] INT_i is a binary variable that shows hospital employment of physicians. The value of INT_i is 1 if a hospital has adopted arrangements under which physicians become employees of the hospital, and 0 otherwise. Following Lammers,[5] we have restricted the definition of hospital-physician integration to hospital employment of physicians because it is the tightest form of integration between hospitals and physicians and the most common form of integration reported in the AHA annual survey. Compared with other, looser hospital-physician arrangements—such as independent practice associations, open physician-hospital organizations, closed physician-hospital organizations, and management service organizations— hospital employment of physicians is expected to improve hospital efficiency as hospitals can use hierarchy and fiat in allocating resources without the need for negotiation.[22]

Although we hypothesize that both IT_i and INT_i are positively related to hospital efficiency, it is unclear how the 2 will interact to affect the efficiency of hospitals. Since the underlying mechanisms behind HIT adoption and employment of physicians are increased control and monitoring of physician behavior, the 2 may work as substitutes. Conversely, utilization of HIT and employment of physicians may complement each other and further enhance efficiency. Consequently, we create an interaction variable between IT_i and INT_i ($IT\ INT_i$) to capture the simultaneous effect of the 2 variables.

RESULTS

The OLS, 2SLS, and GMM estimates are given in Tables 2 and 3. Heteroskedasticity-robust standard errors are reported in parentheses. Table 2 shows the results when IT_i is measured as an indicator variable equal to 1 if a hospital has adopted an EMR, and 0 otherwise. The first column of the table shows the OLS estimates. Neither IT_i nor INT_i are statistically significant at any conventional level of significance, while IT_i, INT_i, and GOV_i are statistically significant at the 5% level.

As mentioned before, a concern with the OLS regressions is that the IT_i and INT_i variables may be correlated with unobserved factors that can also affect the technical efficiency of hospitals. As a result, the OLS estimator is generally biased and inconsistent for the causal effects of IT_i and INT_i on hospital efficiency. A standard solution to this endogeneity problem is to find an instrumental variable for IT_i and INT_i.

A good instrument is one that is correlated with the key explanatory variables but not with the dependent variable. Extant literature has shown that hospitals in urban centers are more likely to adopt HIT than those in rural areas.[23,24] Also, several studies suggest that hospitals in high-income areas are more likely to adopt HIT than those in low-income areas.[23,25] Consequently, in addition to all the explanatory variables, we include the degree of urbanization of the county in which the hospital is located (urban) and county-level median household income (medincome) as instruments. If we used only urban and medincome as instrumental variables, the regression would just be identified, and there would be no difference between 2SLS and GMM because when the number of instruments is equal to the number of regressors, all GMM estimators reduce to the standard IV estimator.[26]

Table 2. Effect of IT and Integration on Hospital Efficiency Measure of IT[a]

Variable	OLS (1)	2SLS (2)	GMM (3)
Constant	**0.5491** (0.0057)	–0.2439 (0.3676)	–0.2226 (0.3572)
IT	–0.0134 (0.0072)	**1.5660** (0.7309)	**1.5232** (0.7101)
INT	–0.0144 (0.0086)	**0.7999** (0.3744)	**0.7784** (0.3637)
IT INT	**0.0027** (0.0008)	**–1.5580** (0.7301)	**–1.5153** (0.7094)
GOV	**–0.0259** (0.0089)	**–0.1218** (0.0577)	**–0.1187** (0.0561)
R^2	0.0102		
Tests of Overidentification		0.7339 (0.3916)	0.7338 (0.3916)

2SLS indicates 2-stage least squares; GMM, generalized method of moments; GOV, government hospital binary variable; INT, integrated salary model binary variable; IT, information technology/EMR variable; IT INT, the interaction variable to capture the simultaneous effect of the IT and INT variables; OLS, ordinary least squares.
[a]Effect of IT and Integration on Hospital Efficiency Measure of IT is an indicator variable that is equal to 1 if a hospital uses electronic medical records (EMRs) and 0 otherwise.
Boldfaced numbers indicate statistical significance at the 5% level. Quantities in parentheses are standard errors that are robust to general heteroskedasticity. For 2SLS estimates, the test of overidentification is the score test, while for the GMM estimates, the test of overidentification is the Hansen test.

Columns 2 and 3 of Table 2 show the 2SLS and GMM results, respectively. As the table shows, the estimates using 2SLS and GMM are qualitatively and quantitatively similar, and they are noticeably higher than the OLS estimates on IT_i and INT_i. As previous literature suggests, we find that HIT adoption and hospital-physician integration each have statistically significant positive effects on hospital efficiency. Interestingly, the interaction term is negative and significant, indicating that hospitals that electronically exchange patient data with other hospitals or ambulatory providers inside and/or outside its system, while simultaneously employing physician groups, are less efficient. As expected, we find a significant negative association between government hospitals and efficiency scores.[7]

As a robustness check, we use an alternative measure of HIT to verify how sensitive the signs and significance of estimates in columns 2 and 3 of Table 2 are to the choice of the HIT measure. Thus, we use as an alternative measure of HIT, the level of HIT utilization. This measure shows how broadly the hospital electronically exchanges patient data with hospitals or ambulatory providers inside and/or outside its system. Looking at column 1 of Table 3, the OLS estimates are similar to those in Table 2. Importantly, columns 2 and 3 of Table 3 show that the signs and significance of the baseline results remain unchanged, indicating that the results in Table 2 are robust to the choice of the measure of HIT. With the high *P* values, it is also worth noting that the tests of over identifying restrictions indicate that the instruments in the 2SLS and GMM estimations are valid.

DISCUSSION

Despite governmental efforts to promote the adoption of HIT and strengthen hospital-physician integration, we know little about the effects of HIT adoption and hospital-physician integration on hospital efficiency.

Using data from the 2010 AHA annual survey and the AHA-HIT survey, supplemented by the CMS CMI, and the US Census Bureau's small area income and poverty estimates, we examine how the adoption of HIT and employment of physicians affect hospital efficiency, and whether they are substitutes or complementary. For example, if the adoption of HIT and employment of physicians are substitutes, using them together will not help increase hospital efficiency. On the other hand, if the adoption of HIT and employment of physicians are complementary, using them together will add to the overall hospital efficiency. To the best of our knowledge, we are the first to argue that these 2 are substitutes, not complements. This finding may seem inconsistent with studies positing that these 2 are complements; yet those studies are different in that they examine the relationship between the HIT adoption and employment of physicians,[5,6] not how these 2 interact to impact hospital efficiency.

Implications for Policy and Practice

Our findings have important policy implications. Although HIT utilization and hospital-physician integration increase hospital efficiency when considered together, they may, in fact be substitutes, suggest that the government should reconsider its efforts toward both. It is possible the use of HIT and employment of physicians simultaneously imposes excessive and unnecessary costs to hospitals because of their overlapping functions to increase control and monitoring of physician behavior. Given that the

Table 3. Robustness Check Measure of IT[a]

Variable	OLS (1)	2SLS (2)	GMM (3)
Constant	**0.5405** (0.0055)	0.1479 (0.1050)	0.1489 (0.1044)
IT	0.0004 (0.0006)	**0.0748** (0.0110)	**0.0746** (0.0199)
INT	–0.0105 (0.0091)	**0.3856** (0.1056)	**0.3847** (0.1051)
IT INT	**0.0018** (0.0009)	**–0.0727** (0.0200)	**–0.0725** (0.0199)
GOV	**–0.0271** (0.0088)	**–0.0467** (0.0236)	–0.0465 (0.0235)
R^2	0.0088		
Tests of Overidentification		0.0187 (0.8910)	0.0187 (0.8911)

2SLS indicates 2-stage least squares; GMM, generalized method of moments; GOV, government hospital binary variable; INT, integrated salary model binary variable; IT, information technology/EMR variable; IT INT, the interaction variable to capture the simultaneous effect of the IT and INT variables; OLS, ordinary least squares.
[a]The robustness check measure of IT is a continuous variable that measures a hospital's level of IT utilization.
Boldfaced numbers indicate statistical significance at the 5% level. Quantities in parentheses are standard errors that are robust to general heteroskedasticity. For 2SLS estimates, the test of overidentification is the score test, while for the GMM estimates, the test of overidentification is the Hansen test.

ultimate goals of policies such as the ARRA and ACA are to reduce costs and improve outcomes, if hospitals achieve less efficiency by adopting HIT and employing physicians simultaneously, the government may want to consider focusing on one policy, rather than both.

Hospital administrators may also use the results of this study to enhance hospital efficiency. Although previous studies have found that hospital employment of physicians may increase the probability of adopting (or utilizing) HIT,[5,6] administrators may want to be careful in using hospital employment of physicians as a way to increase HIT adoption. As our study suggests, HIT adoption and hospital-physician integration, when working together, can hurt hospital efficiency. This is an example of when too much of a good thing may be bad. Administrators should be aware of other ways of enhancing adoption the and utilization of HIT rather than employment of physicians—for example, providing a financial incentive or penalty.

Limitations

This study has some limitations. First, this study may only capture a snapshot of the effect at a particular point in time. Future research based on multi-year data would enrich our understanding. Also, the fact that we restricted the definition of hospital-physician integration to hospital employment of physicians can limit our understanding. Although employment of physicians can be understood as the most common form of integration between hospitals and physicians, other forms of hospital-physician arrangements, such as group practices without walls, equity models, and foundation models, could be considered tight physician-hospital integration.[27] These arrangements should be further studied in the context we have discussed.

More broadly, although our study suggests that HIT adoption and hospital-physician integration are substitutes, the underlying mechanisms that seem to prevent complementarity need to be examined. Case studies that examine the mechanisms behind our results can increase our understanding.

CONCLUSIONS

The findings of this study indicate that the government's efforts to encourage both HIT adoption and integrated systems warrant consideration.

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