Physician-hospital integration and hospital efficiency investigation

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Background: To improve hospital efficiency, there has been an increase in physician-hospital integration (PHI) in the United States (U.S.) over time. However, mixed results of empirical findings suggest there has not been conclusive evidence of PHI adoption is associated with hospital efficiency.

Methods: A cross-sectional study was conducted using secondary data from the 2020 Centers for Medicare and Medicaid Services Hospital Compare datasets, the 2020 American Hospital Association Survey, and the 2023 updated Health Service Areas Files of National Center for Health Statistics. After matching on these datasets and outcomes evaluated, the final analytic sample included 434 short-term U.S. acute care hospitals. Using a newly proposed objective-based PHI categorization: both hospital-level and system-level financial PHI, clinical PHI, and financial and clinical hybrid PHI, we categorized hospitals as efficient or inefficient by conducting data envelopment analysis (DEA). Multiple linear regressions were then employed to examine the associations between the three aforementioned PHI types and the logged DEA efficiency score.

Results: Using an objective-based PHI categorization, DEA analysis revealed that hospitals with financial and clinical hybrid PHI (represented by Open & Closed Physician-Hospital Organizations) had the highest proportion of efficient hospitals, followed by those with clinical PHI (represented by Independent Practice Association) and, lastly, hospitals with financial PHI (represented by Integrated Salary Model). Additionally, the results of multiple linear regression analyses indicated that the impact of adopting system-level financial and clinical hybrid PHI on hospitals efficiency is stronger, compared to the hospital-level hybrid PHI.

Conclusions: Relying exclusively on PHI centered around a single objective, whether financial or clinical, may not be an effective strategy to foster hospital efficiency. Instead, incorporating an analysis of specific hospital characteristics, such as ownership type and case mix index, and adopting a dual-focused PHI strategy that integrates both financial and clinical aspects might hold greater promise for improving hospital performance.

Keywords: Hospital efficiency; physician-hospital integration (PHI); data envelopment analysis (DEA)

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Introduction

In the healthcare landscape, efficiency, an indicator of how healthcare resources are being used to provide the best value for patient care, is essential for hospitals (1). It calls for hospitals to provide high-quality care while controlling costs, and it measures the relationship between resource inputs (such as healthcare labor resources) and healthcare outputs (such as care quality). To tie the quality of care delivered to payments for care delivery, multiple value-based care (VBC) programs have been implemented nationwide (2,3), such as the Hospital Value-Based Purchasing Program, Hospital Readmission Reduction Program, and the Hospital Acquired Conditions Reduction Program Studies have shown that VBC adoption was associated with improved quality of care. For instance, a study examining 3,387 United States (U.S.) hospitals from 2007 to 2015 revealed that the Hospital Readmission Reduction Program decreased readmission rates as a result of program incentives (4). Furthermore, Pandey and colleagues conducted a systematic review and concluded that higher-intensity Value-Based Purchasing Programs were more consistently associated with improvements in desired quality processes, utilization measures, and reductions in spending, compared to lower-intensity programs (5).

Increasingly, U.S. hospitals have prioritized efficiency promotion through strategies, such as improving patient safety care, shaping patient-centeredness care culture (6-8), and managing waste reduction (9,10). However, efficacious adoption of these strategies requires a mechanism that aligns staff interests and behaviors with the goals of the hospitals. The need to become more efficient has led hospital executives to physician-hospital integration (PHI), which encompasses a closer collaboration between physicians and hospitals through various contractual forms, including employment contracts, joint ventures, and other partnerships (6-8).

Based on a study that analyzed 2014–2018 American Hospital Association Annual Surveys, more than 60% of U.S. hospitals were involved in various formats of PHI (11). Research has suggested that PHI could play an important role in reshaping and harmonizing physician-hospital relationships and navigating physician behaviors toward hospital goals (6,12,13); thereby improving hospital performance. Hospital management is also interested in building mechanisms to facilitate physician-hospital relationships so hospitals can better navigate physicians' inputs and achieve desirable outputs. However, studies have shown that PHI has exerted mixed impacts on hospital performance, especially on hospital efficiency (14-16).

In the literature, the most popular hierarchical categories use high, medium, and low controlled levels, or little to full controlled levels (11,12,17-20). The high-controlled level PHI, usually through employment-based arrangements, is characterized by a stable, close relationship between physicians and hospitals to foster care coordination and financial sustainability (12,21). By contrast, the low-level controlled PHI, is usually based on collaborative contracts, emphasizes physician autonomy and loose financial risk sharing (12). However, these broad categories fail to clearly define the boundary of each category or the level of integration for certain PHI models (11,12,20,22); setting clear boundaries can improve the effectiveness of explaining predictors for examining the effects of PHI on hospital performance (15).

Highlight box

Key findings

- Findings from this study highlight that hospitals implementing a hybrid model of physician-hospital integration (PHI), (represented by Open & Closed Physician-Hospital Organization) exhibited the greatest efficiency. This was followed by hospitals employing a clinical PHI approach (represented by Independent Practice Association), and then by those adopting a financial PHI model (represented by Integrated Salary Model). furthermore, the study revealed that the impact of adopting system-level financial and clinical hybrid PHI on hospitals efficiency is more pronounced, compared to the hospital level.

What is known and what is new?

- This study reinforces prevailing beliefs about the effect of PHI adoption on hospitals. Furthermore, it provides new insights that by focusing on a single objective-based PHI, e.g., financial PHI or clinical PHI, might not be the most effective strategy for hospital efficiency improvement. Rather, employing a dual-focused approach combining both clinical and financial aspects in a hybrid PHI model could prove to be a more successful tactic.

What is the implication, and what should change now?

- Hospitals may be more successful at improving efficiency by focusing on a hybrid approach, emphasize on both financial performance and clinical performance improvement, thus need to focus on enhancing care quality and allocating resources effectively to boost efficiency as part of their sustainability strategy. This requires setting dual goals and fostering a supportive culture. Moreover, hospital management should take into account specific hospital characteristics, like ownership and case mix index, when devising strategies to fortify the physician-hospital relationship and enhance overall hospital efficiency.

Table 1 AHA definitions of PHI models

PHI model	AHA definition	Objective-based PHI type defined by the authors
Integrated Salary Model	"*Physicians are salaried by the hospital or another entity of a health system to provide medical services for primary care and specialty care.*" (30)	Financial PHI
Independent Practice Association	"*A legal entity that holds managed care contracts, which then contracts with physicians.*" (30)	Clinical PHI
Open PHO	"*A joint venture between the hospital and all members of the medical staff who wish to participate,*" which "*acts as a unified agent.*" (30)	Financial and clinical PHI
Closed PHO	"*A PHO that restricts physician membership to those practitioners who meet criteria for cost effectiveness and/or high quality.*" (30)	

AHA, American Hospital Association; PHI, physician-hospital integration; PHO, Physician-Hospital Organization.

Therefore, unlike previous studies, this study proposes using an objective-based framework to classify PHI types, including (I) financial PHI, which mainly aims to improve financial performance through economies of scale (23-25), (II) clinical PHI, which mainly aims to improve the quality of care through care collaboration (24,26), and (III) financial and clinical hybrid PHI, which has dual goals of improving care collaboration and financial performance.

Studies have suggested that clear-cut goals often significantly impact an organization's performance (27,28), we predicted that this objective-based classification of PHI would better evaluate the impact of PHI on hospital efficiency. Additionally, Li (29) found hospital-level PHI and system-level PHI demonstrated distinctly different hospital performance outcomes. These differences underscore the importance of examining the relationships between PHI and hospital efficiency in different organizational contexts. We thus examine hospital efficiency from both hospital-level PHI and system-level PHI.

The aim of this study was to examine the association between PHI and hospital efficiency with this objective-based classification of PHI. To better understand the contributors to hospital efficiency, we employed the data envelopment analysis (DEA) and performed a cross-sectional analysis, using the 2020 Americans Hospital Association (AHA) Annual Survey, the 2020 Centers for Medicare and Medicaid Services (CMS) Hospital Compare datasets, and the 2023 updated Health Service Areas Files (HSAF) from the National Center for Health Statistics. Our objectives were to (I) measure hospital efficiency of both hospital-level and system-level with three PHI types: financial PHI [represented by Integrated Salary Model (ISM)], clinical PHI [represented by Independent Practice Association (IPA)], and financial and clinical hybrid PHI [represented by Open and Closed Physician-Hospital Organization (Open-PHO and Closed-PHO)] (the definitions of each PHI model are shown in *Table 1*), respectively; and (II) identify other drivers for hospital efficiency, including organizational characteristics and market competition. The findings of this study were expected to assist hospital management in exploring pathways and developing strategies to better integrate with physicians in its PHI adoption process to improve hospital efficiency.

Conceptual framework & hypotheses

Conceptual framework

The conceptual framework of this study is built upon the X-inefficiency Theory and Agency theory. X-inefficiency is concerned with situations when an organization fails to fully utilize its resources to achieve the maximum possible output level, that is, the efficiency frontier (31). These inefficiencies can arise from numerous sources, such as outdated technology, inefficient production processes, suboptimal management practices, and insufficient competitive pressures, among others. They also manifest when employee behavior deviates from optimal performance, driven by a diminished motivation to pursue efficiency. However, when appropriately motivated, the employees can behave more optimally (32). X-inefficiency is a commonly used theoretical framework for describing hospital efficiency (33-35). The root cause of X-inefficiency is market imperfection, including information asymmetries and uncompetitive pressure, which may lead to irrational decisions of an organization and its employees (36).

In hospital settings, the efficiency of hospitals is greatly influenced by physicians since they are the primary decision-makers regarding how resources should be allocated to treat patients (37). A study has found that physician practice patterns were associated with higher levels of inefficiency, and physician costs were responsible for about four-fifths of total healthcare costs (38). Thus, it is expected that PHI adoption can motivate physicians to improve hospital efficiency.

On the other hand, Agency theory holds that principals, represented by hospitals in the PHI context, can delegate duties or decision-making authority to agents (39,40), represented by physicians. Physicians and hospitals are traditionally viewed by economists as buyers and sellers of services, while organizational theorists typically view the relationship as loosely coupled bureaucracies (41). Consequently, each of these two parties allocates resources to pursue its own objectives, which may lead to conflicting outcomes (42). Regarding the relationship between PHIs types (financial PHI, clinical PHI, and financial and clinical hybrid PHI), physicians, and hospital efficiency, it is expected that PHI can help tighten the relationship between physicians and hospitals economically and psychologically, enabling the two parties to align their goals more effectively (11,20,23).

Hypotheses

Among the three PHI types (the specific PHI models were defined in *Table 1*), since financial PHI (represented by ISM) is based on employment-based integration to build a more transparent information system to monitor and navigate physician behaviors, it is more likely that financial PHI could align physician behaviors with hospital interests and increase hospital efficiency. However, prior research on the association between hospital efficiency and financial PHI was mixed (13,16,24).

For clinical PHI (represented by IPA), it is generally built through contractual collaboration. For example, through setting care managers and building a sharable medical record, physicians can easily access patient records, build registrars, and develop a variety of care coordination (24). However, hospitals that implement clinical PHI may not have sufficient control over physician behaviors, and physicians may be more likely to focus on care quality improvement without paying much attention to care inputs. Under such circumstances, clinical PHI may be negatively linked to hospital efficiency.

Additionally, for financial and clinical hybrid PHI (represented by Open & Closed PHO), although its dual goal is to improve both quality of care and financial performance, and hospitals may be able to manage and monitor physician behaviors to some degree, it may divert hospital efforts to both goals, resulting in lower hospital efficiency than financial PHI. It's important to acknowledge the distinctions between Open PHOs and Closed PHOs, especially in terms of management and control. However, as noted by Alexander *et al.*, the differences between Open-PHOs and Closed-PHOs might predominantly be semantic rather than substantive (43). We thus categorize both Open-PHOs and Closed-PHOs into financial and clinical hybrid PHI.

These perspectives have informed our following hypotheses to this study:

- ❖ H1: hospital efficiency is positively associated with both hospital-level and system-level financial PHI (represented by ISM).
- ❖ H2: hospital efficiency is negatively associated with both hospital-level and system-level clinical PHI (represented by IPA).
- ❖ H3: hospital efficiency is positively associated with both hospital-level and system-level financial and clinical hybrid PHI (represented by Open & Closed PHO).

Methods

Data source

We conducted a cross-sectional analysis using the 2020 AHA Annual Survey data, the 2020 CMS Hospital Compare dataset, and the 2023 updated HSAF. These datasets provide information on hospital characteristics, market characteristics, and hospital inputs and outputs. The Medicare provider number was used for merging the datasets.

Study samples

This study focused on short-term general acute care hospitals in the U.S. There were 6,156 hospitals that participated in the 2020 AHA Annual Survey. From this initial group, 257 hospitals were removed due to missing Medicare provider numbers. Additionally, 1,887 hospitals were excluded for lacking data on either IPA, ISM, Open-PHO, or Closed-PHO at the hospital or system level. Furthermore, 1,998 hospitals were omitted because they had not implemented any of the aforementioned models at either level. After merging data from the AHA Survey with the 2020 CMS Hospital Compare dataset (specifically, the Hospital General Information dataset), several other exclusions were made: 455 government-owned hospitals, 74 hospitals not included in the merged dataset, and 389 non-acute care hospitals (comprising 31 children's hospitals, 298 critical access hospitals, and 60 psychiatric hospitals). Additionally, 422 hospitals were excluded for not being classified as "short-term hospitals" in the Hospital Cost Report of CMS Hospital Compare dataset. Finally, exclusions were made for hospitals missing specific outcome data: 165 for acute myocardial infarction (AMI) mortality, 38 for AMI readmission, and 37 for central line-associated bloodstream infection (CLABSI) data. Consequently, the final sample comprised 434 non-government-owned short-term general acute care hospitals.

Measures

Outputs

The outputs of quality of care were composed of desirable outputs and undesirable outputs. Based on literature review (11,18,20,44), desirable output indicators included the total facility admissions and inpatient and outpatient surgical operations, aligning with previous PHI efficiency research (18). The data came from the 2020 AHA Annual Survey.

Three components included in undesirable output indicators were: (I) CLABSI score in Intensive care units (ICUs), (II) the AMI 30-day mortality rate, and (III) the AMI 30-day readmission rate. A higher CLABSI score indicates a worse central line-associated blood infections infection performance in a hospital. The CLABSI score came from the 2020 CMS Healthcare-Associated Infections data of the 2020 CMS Hospital Compare datasets; the AMI 30-day mortality was calculated as the death rate for patients discharged from hospitals with a principal diagnosis of AMI within 30-day post-discharge divided by admissions for patients discharged from hospitals with a principal discharge diagnosis of AMI who had a complete claims history for the previous 12 months before discharge. A higher AMI 30-day mortality score indicates a higher AMI 30-day mortality in a hospital. The AMI 30-day mortality data were obtained from the Complications and Deaths data of the 2020 CMS Hospital Compare datasets (45). The AMI 30-day readmission rate, which was calculated by dividing the number of unplanned all-cause readmissions within 30 days after a hospital discharge by the number of admissions for AMI inpatients with the previous 12 months before discharge (45) was obtained from the Unplanned Hospital Visits data of the 2020 CMS Hospital Compare datasets. The selection of CLABSI score, along with AMI mortality and readmission rates, as indicators of care quality was made to maintain consistency with prior research on PHI (11,20,46,47). This alignment ensures that our study builds on the established body of knowledge and facilitates comparability with existing findings in the field.

To prepare the data for DEA analysis, we addressed the issue of zero values in the dataset. Because DEA requires all output and input values to be positive, we substituted zero values in CLABSI, AMI mortality, and AMI readmission rates with a small positive number (0.0001) in order to avoid distortions in the analysis. Furthermore, the negative indicators were inverted in accordance with the DEA model's requirement that higher values should always indicate better performance. Therefore, the CLABSI, AMI mortality, and AMI readmission rates were transformed by taking their reciprocals. As a result of this transformation, a higher transformed value within the DEA model indicates a decrease in the undesirable outcome, thus maintaining compatibility with the DEA's principle of optimizing performance indicators.

Inputs

Input measures in this study included (I) case mix index, (II) number of beds, and (III) the full-time equivalent (FTEs) total personnel. Case mix index since was associated with hospital efficiency, although empirical results were mixed (32,48). To keep consistency with prior studies on PHI and its impact on efficiency, we have incorporated the case mix index into the input measures (18). Case mix index represents a hospital's average diagnosis-related group (DRG) relative weight. It was calculated by adding up the DRG weights across all Medicare discharges, and then the number was divided by the number of discharges (49). The data came from the CMS Inpatient Prospective Payment Systems (IPPS) Final Rule and Correction Notice 2019 File; Number of beds refers to the facility beds set up and staffed at the end of the reporting period [2020]. Hospital bed size represents hospital size and has been commonly used as an input for examining hospital efficiency differences (18,44,50); FTEs, excluding medical and dental residents, interns, and other trainees, has been considered an important measure for hospital efficiency (44,51,52). Both hospital bed size and FTE data came from the 2020 AHA Annual Survey.

Key organizational factors—PHI models

The key organizational factors in this study were the three PHI types: financial, clinical, and financial and clinical hybrid PHI, which are represented by ISM, IPA, and Open-

PHO and Closed-PHO, respectively. The data came from the 2020 AHA Annual Survey.

Organizational characteristics

Since many studies have suggested that for-profit hospitals' efficiency outperformed nonprofit ones, we classified hospital ownership (a dichotomous variable) into two categories: (I) nonprofit hospitals and (II) for-profit hospitals (investors-owned for-profit hospitals) derived from the 2020 AHA Annual Survey. Moreover, a study found that teaching hospitals performed better than non-teaching hospitals (18), although teaching hospitals typically yielded lower efficiency than nonteaching hospitals (53,54). We thus categorized the hospitals into two categories (dichotomous variables): (I) teaching hospitals (recognized for Accreditation Council for Graduate Medical Education accredited programs) and nonteaching hospitals. In addition, since divergent results were observed regarding efficiency in different hospital locations (rural *vs.* urban) (55,56), two hospital locations from the 2020 AHA Annual Survey were used in this study: (I) metro, and (II) micro and rural to further investigate the difference in hospital location regarding hospital efficiency.

Market characteristic

The Herfindahl-Hirschman Index (HHI) is widely used to measure market concentration (57). Typically, when the HHI of a hospital rises, market competition decreases, and market power increases (58), hence being associated with a decrease in hospital efficiency. In this study, information regarding each hospital's admission was obtained from the 2020 AHA Annual Survey, which was summed up at the health service area (HSA) that was from the National Center for Health Statistic. Then, we obtained the value of the market share for each hospital by dividing the individual hospital's admission by its total admissions from the same HSA data. The value of HHI of a hospital then was calculated by squaring the market share of each competing hospital and then summed up at the HSA level. HHI calculations can be explained as $HHI_k = \sum_i \left(\frac{n_{i,k}}{N_k} \right)^2$, where $n_{i,k}$ represents the market share (percentage) of hospital n, and N_k represents the total number of the hospitals in a given HSA.

Statistical analyses

We performed descriptive statistical analyses for hospital inputs and outputs, and organizational and market characteristics. We used frequency and percentage to characterize categorical variables and mean and standard deviation to characterize continuous variables.

We employed a DEA, a nonparametric method that is often applied to assess Decision-Making Unit's (DMU's) performance (59) and evaluate efficiency in operation management (60). In essence, DEA compares each DMU with a set of peers. A measure of efficiency in DEA is the ratio of the weighted sum of outputs to the weighted sum of inputs. We employed an "rDEA" package that is a conservative DEA-based method, to handle data uncertainties in DMUs, ensuring stable and reliable performance evaluation (61).

Our analysis categorized outputs into two categories: "undesirable" outputs, including CLABSI score, AMI 30-day mortality rate, and AMI 30-day readmission rate, which should be minimized, and "desirable" outputs, including total facility admissions and inpatient and outpatient surgical operations, which should be maximized. A DEA with an output-oriented approach and variable returns to scale were used to evaluate hospital performance. This approach was chosen to maximize outputs within a given input, which is particularly relevant to healthcare settings where maximizing patient care outcomes is often the objective. Based on this output-oriented DEA model, technical efficiency scores reflect how well hospitals utilize their healthcare inputs to maximize outputs. A score of "1" indicates optimal efficiency, indicating the hospital is operating at the forefront of best practice. On the other hand, a score greater than "1" indicates inefficiency, indicating that a hospital has the potential to improve its output levels without increasing its inputs.

To mitigate the potential limitations of DEA, which may not always distinguish between inefficiencies caused by operational factors and external factors beyond the control of the DMUs (62), we also performed multiple linear regression analyses to examine the associations between PHI types and efficiency scores. Before conducting the regression analyses, we checked that all necessary linear regression assumptions had been met. After removing outliers using Cook's distance method, we determined that a log transformation of the dependent variable (efficiency scores) was more appropriate to meet the assumptions of linear regression. As a result of this transformation, the variance of our model was stabilized, and its interpretability was improved. Also, we selected the best model for our study after performing model selection. Additionally, to address the limitations of DEA for making statistical inferences,

Table 2 Hospital outputs and inputs outputs descriptive statistics (N=434)

Measures	Values, mean ± SD
Bad outputs (undesirable outputs)	
CLABSI score	0.88±0.75
AMI mortality within 30 days, %	12.27±1.09
AMI readmission within 30 days, %	14.89±0.93
Good outputs (desirable outputs)	
Admissions	15,980±10,968
Inpatient and outpatient surgical operations	11,570±9,375
Inputs	
Case mix index	1.83±0.27
Number of beds	352±238
Staffing/FTE	2,614±2,842

SD, standard deviation; CLABSI, central line-associated bloodstream infection; AMI, acute myocardial infarction; FTE, full-time equivalent.

Table 3 DEA results (N=434)

Items	Efficient hospitals	Inefficient hospitals
Number	95	339
Percentage	22%	78%
Average DEA scores	1	1.093

DEA, data envelopment analysis.

we applied a two-stage semi-parametric modeling approach (63). The detailed results of this analysis are available in Appendix 1 (Figures S1-S2, and Tables S1-S3). All analyses were performed using R Programming software (R Foundation, Boston, MA, USA, Version 4.2.1). The significance level was set at P value =0.05.

Results

Descriptive statistics of DEA

Table 2 shows the descriptive statistics of the hospitals' undesirable outputs, desirable outputs, and inputs. Regarding undesirable outputs, both AMI 30-day mortality and AMI 30-day readmission have small variabilities, and the standard deviation values were 1.09 and 0.93, respectively. In contrast, the CLABSI score had relatively wide variability, and the value of standard deviation were 0.75 with a mean score of 0.88. Desirable outputs, both admissions and inpatient and outpatient surgical operations, demonstrated wide variabilities among the hospital samples. In terms of inputs, the variability of the case mix index of the hospital samples was relatively small, with a standard deviation of 0.27. In contrast, the variabilities of bed numbers and staffing/FTEs were significant.

DEA results

A score of "1" indicates an efficient subject in the DEA (64), and the DEA results are shown in *Table 3* and *Figure 1*. Among the 434 hospital samples, 95 (22%) hospitals were considered efficient, while 339 (78%) hospitals exhibited inefficiency. The mean of DEA scores of inefficient hospitals was 1.093.

Furthermore, we summarized hospital efficiency based on our hospital-level PHI and system-level PHI in *Table 4*. Among hospital-level PHI, financial and clinical hybrid PHI (Open-PHI) had the highest proportion (27%) of efficient hospitals, followed by clinical PHI (IPA) of 25%, financial and clinical hybrid PHI (Closed-PHI) of 24%, while financial PHI (ISM) had the lowest proportion (19%) of efficient hospital. Meanwhile, among the system-level PHI, financial and clinical hybrid PHI (Closed-PHI) had the highest proportion (34%) of efficient hospitals, followed by financial and clinical hybrid PHI (Open-PHI) of 26%, clinical PHI (IPA) of 21%, while financial PHI (ISM) was ranked last (18%).

Descriptive statistics of hospital organization and market characteristics

A description of the hospital organization and market characteristic of the sample is shown in *Table 5*. Altogether, 41% financial PHI (ISM), 16% financial and clinical hybrid PHI (Open-PHO), 5% financial and clinical hybrid PHI (Closed-PHO), and 11% of the hospital sample reported a presence of clinical PHI (IPA) Ninety-four percent of the sample was non-profit, while 6% was for-profit. Over three-quarters (77%) of the sample were teaching hospitals. Additionally, the majority of the hospitals (93%) were located in metropolitan areas, and 7% were found in micro and rural areas.

Multiple regression analysis

Table 6 shows the results of regression analysis for each

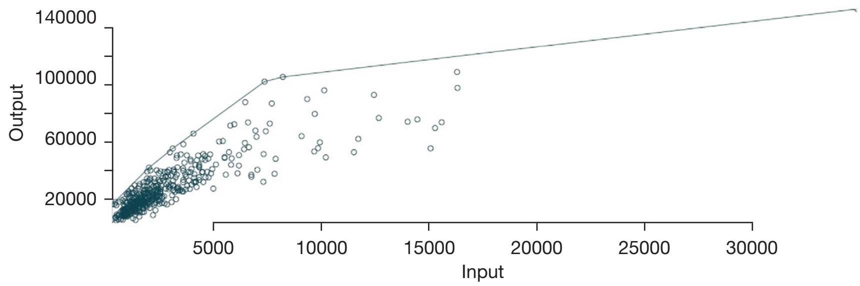

Figure 1 DEA efficiency plot. DEA, data envelopment analysis.

Table 4 DEA results with PHI at both hospital and system level

PHI type	Hospital-level PHI (N=296)		System-level PHI (N=303)	
	Efficient hospitals	Inefficient hospitals	Efficient hospitals	Inefficient hospitals
Financial PHI (Integrated Salary Model)	36 (19%)	149 (81%)	32 (18%)	145 (82%)
Financial and clinical hybrid PHI (Physician-Hospital Organization)				
Open Physician-Hospital Organization	17 (27%)	46 (73%)	18 (26%)	50 (4%)
Closed Physician-Hospital Organization	6 (24%)	19 (76%)	8 (34%)	15 (65%)
Clinical PHI (Independent Practice Association)	12 (25%)	36 (75%)	12 (21%)	46 (79%)

PHI, physician-hospital integration.

Table 5 Hospital organization and market characteristic descriptive statistics (N=434)

Measures	Values
PHI categorizations	
Financial PHI (Integrated Salary Model)	177 [41]
Financial and clinical hybrid PHI (Physician-Hospital Organization)	
Open Physician-Hospital Organization	68 [16]
Closed Physician-Hospital Organization	23 [5]
Clinical PHI (Independent Practice Association)	48 [11]
Organization characteristics	
Hospital ownership (non-profit)	409 [95]
Number of beds (hospital size)	352±238
Staffing/FTE	2,614±2,842
Teaching affiliation	334 [77]
Case mix index	1.83±0.27
Location rurality (metro)	410 [93]
Market characteristic	
Herfindahl-Hirschman Index	5,662±3,587

Data are presented as mean ± standard deviation or number [percentage]. PHI, physician-hospital integration; FTE, full-time equivalent.

of the key independent variables (hospital and system-level PHI types). Among hospital-level PHI, no statistical significances were found for all the PHI types. For hospital organizational characteristic covariates, holding all other variables constant, for-profit hospitals had a 3.3% higher DEA efficiency score (high efficiency scores indicates inefficiency) (P<0.01), compared to non-profit hospitals; for every one-point increase in case mix index, there was a 4.7% increase in DEA efficiency score (P<0.001); for a hospital in the metro area, there was a 2.1% increase in DEA efficiency score (P<0.05).

Among system-level PHI, holding all other variables constant, the presence of a financial and clinical hybrid PHI (Open-PHO) was associated with a 1.8% lower DEA efficiency score (indicating higher efficiency) (P<0.05). We did not find statistically significant associations between the presence of a financial PHI (ISM) or clinical PHI (IPA) and DEA efficiency score. We also observed no significant associations with the presence of a Closed-PHO. Notably, the P value for this association was 0.051, which is marginally above the threshold for significance but may suggest practical significance. For hospital organizational characteristic covariates, holding all other variables constant, for-profit hospitals had a 3.6% higher DEA efficiency score (indicating

Table 6 Regression results for DEA efficiency scores

Measures	Dependent variable (efficiency score), β (SE)	
	Hospital-level PHI	System-level PHI
PHI categorizations		
Financial PHI (Integrated Salary Model)	0.001 (0.027)	0.004 (0.005)
Financial and clinical hybrid PHI (Physician-Hospital Organization)		
Open Physician-Hospital Organization	0.004 (0.007)	–0.018* (0.007)
Closed Physician-Hospital Organization	0.009 (0.012)	–0.023 (0.012)
Clinical PHI (Independent Practice Association)	0.001 (0.009)	0.003 (0.008)
Organizational characteristics		
Hospital ownership (non-profit)	0.033** (0.012)	0.036** (0.012)
Number of beds (hospital size)	0.000* (0.000)	0.000 (0.000)
Staffing/FTE	0.000 (0.000)	0.000 (0.000)
Teaching affiliation	–0.008 (0.006)	–0.008 (0.006)
Case mix index	0.047*** (0.013)	0.038** (0.012)
Location rurality (metro)	0.021* (0.010)	0.020 (0.010)
Market characteristic		
Herfindahl-Hirschman Index	0.000 (0.000)	0.000 (0.000)
Constant	–0.071** (0.027)	–0.054* (0.027)
R^2	0.13	0.14
Adjusted R^2	0.10	0.12

*, P<0.05; **, P<0.01; ***, P<0.001. DEA, data envelopment analysis; SE, standard error; PHI, physician-hospital integration; FTE, full-time equivalent.

lower efficiency) (P<0.01), compared to non-profit hospitals; for every one-point increase in case mix index, there was a 3.8% increase in DEA efficiency score (P<0.01).

In summary, DEA analysis results have shown that hospitals with a financial and clinical hybrid PHI, encompassing both Open-PHO and Closed-PHO, had a higher proportion of efficient hospitals. Furthermore, multiple linear regression analyses have revealed that at the hospital level PHI types did not demonstrate statistically significant associations with logged DEA efficiency scores. In contrast, the system-level financial and clinical hybrid PHI (Open-PHO) exhibited a negative association with DEA efficiency scores, which suggests that Open-PHO was positively linked to higher efficiency, albeit in a relatively modest way.

Discussion

With the newly proposed objective-based framework for PHI categorization that proposed by Li (29), we anticipate the framework will be more effective in examining the association between PHI and hospital performance compared to previous PHI categorizations. A robust output-oriented DEA model was applied to set targets on the best practice frontier in this study to compare hospital efficiency among financial, clinical, and financial and clinical hybrid PHI. In addition, multiple linear regression analyses were conducted to further examine the underlying logic about efficiency scores, hospital organizational characteristics, and market characteristic, in addition to the relationship between efficiency and these three PHI categorizations at both the hospital and system-level.

One of our major findings indicates that hospitals adopting either hospital-level or system-level financial and clinical hybrid PHI were more efficient, based on the robust DEA results. This finding is inconsistent with previous research: some of which showed that a high level of controlled PHI or employment-based PHI was more efficient (18), while others suggested there was no difference or lower efficiency with PHI adoption (65). Highly controlled levels of PHI, or employment-based PHI usually have more clear-cut incentive mechanisms, such as risk sharing or salary incentives. Hence, it would be strongly tied to the relationship between physicians and hospitals and may increase the motivation of physicians to align their working goals with hospital goals (12,21). However, as we discussed previously, high levels of controlled PHI or employment-based PHI that share certain commonalities with financial PHI focusing on pursuing hospital financial performance improvement (29,66) may lead to negative side effects in clinical outcomes. As a result, the potential financial performance advantage, such as high volume of admissions, high level of controlled PHI or employment-based PHI, may be offset by the potential clinical performance drawbacks when measuring the efficiency of a hospital. In contrast, hospitals with financial and clinical hybrid PHI, which seeks to improve both financial and clinical performance, may more effectively balance hospital inputs and outputs, thus demonstrating greater efficacy based on our results.

Our study indicates that for-profit hospitals exhibit lower efficiency compared to non-profit hospitals, a finding that challenges the expectations set by theories such as agency theory, property-rights theory, and public choice theory (67). Despite the assumption that for-profit hospitals would prioritize financial stability through various incentives (68), the relationship between hospital ownership and efficiency is complex, as indicated by previous mixed empirical findings (69,70). For instance, for-profit hospitals have shown responsiveness to external financial incentives (71), yet this does not always translate into higher efficiency (67). Our study adds to this discourse by suggesting that despite the growing market share of for-profit hospitals in the U.S. (72), non-profit hospitals may still hold an edge in employing more effective resource allocation strategies, thereby optimizing the balance between their inputs and outputs.

Furthermore, our findings show that the case mix index was positively associated with hospital inefficiency, which is consistent with existing studies (33,73). Studies have shown that a higher case mix index indicating a higher level of clinical complexity was more likely to have a lower care quality outcome (15), and care quality outcomes were predominant in the hospital efficiency model (74). Thus, hospitals with a high case mix index should devote more resources to improve the quality of care when striving to increase hospital efficiency.

Limitations

This study has limitations. First, as a cross-sectional study, it did not attempt to explain causality but the associations between efficiency and PHI categorizations. Second, the generalizability of this study could have been weakened by exclusion criteria, listwise deletion, and datasets sample inclusion. The focus on short-term performance of non-governmental, acute care hospitals engaged with ISM, IPA, and PHO (both Open-PHO and Closed-PHO) further narrows the scope, resulting in a modest sample size of 434. This sample also disproportionately represents nonprofit, teaching, and metropolitan-area hospitals, which may diminish the generalizability of our findings. Third, our dataset corresponds to 2020, a year marked by the COVID-19 pandemic, leading to significant disruptions in the healthcare industry, particularly within hospitals. This disruption could have influenced both the gathering and the integrity of the data that might have impacted the generalizability of our findings. In addition, due to the availability limitation of the CMS Hospital Compare dataset, not all variable data collection duration was exactly within the year 2020, which may have affected the accuracy of our findings. Furthermore, consistent with prior studies, we selected facility admissions, along with inpatient and outpatient surgical procedures, as the desired outputs for our analysis. However, it is important to note a potential limitation: in hospitals that serve as safety nets or where a significant portion of revenue comes from capitation arrangements or value-based plans, these outputs might not be as indicative of desired outcomes. Lastly, in line with prior research, we did not apply weights to output or input variables, which may introduce some unobserved biases.

Conclusions

The findings of this study suggest that a sole objective-based PHI, either financial PHI or clinical PHI, may not be an effective approach. Instead, a two-pronged PHI objective, namely a clinical and financial hybrid PHI model, may be a more effective strategy. It is important that hospitals commit to improving care quality as well as prioritizing resources to improve their operational efficiency to ensure their sustainability through dual goal setting and culture nurturing. In addition, it is also necessary for hospital management to consider hospital characteristics, such as hospital ownership and case mix index, when implementing strategies that aim to strengthen the physician-and-hospital relationship and improve hospital efficiency.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jhmhp.amegroups.com/article/view/10.21037/jhmhp-24-10/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. There is no need for IRB approval as no human subjects were involved.

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Appendix 1 Two-stage semi-parametric modeling analysis

To further improve the robustness of study analysis, we also employ a robust two-stage semi-parametric modeling approach. This methodology enhances the conventional data envelopment analysis (DEA) by integrating a second stage of statistical inference through bootstrapping, allowing for a better understanding of efficiency determinants (62). This appendix details the process and rationale behind this approach, drawing on insights from our comprehensive dataset.

Stage one: ***DEA efficiency scores***

The first stage of our analysis involved the computation of DEA efficiency scores. Utilizing the "rDEA" library in R, we adapted an output-oriented model with variable returns to scale, acknowledging the diverse operational scales of hospitals. The input and output measurements were the same as the ones in our main analysis in the manuscript. That is, inputs comprised three primary variables: case mix index, number of beds, and full-time equivalent total personnel as hospitals input, and the outputs included desirable metrics: total admissions and inpatient and outpatient surgical operations, alongside inverted metrics for undesirable outcomes: CLABSI rates, AMI mortality, and AMI readmission rates. To align with this two-stage semi-parametric modeling approach requirement, we included the following environmental variables hospital ownership, teaching affiliation, location rurality, and HHI. These variables encapsulate both operational and market conditions, offering a broader perspective on hospital efficiency.

Given the variability in operational environments and strategic positioning among hospitals, the DEA model was enhanced to reflect these factors. This approach underscores the complexity of healthcare service delivery, acknowledging that efficiency is influenced by a mosaic of internal and external factors.

Efficiency scores were derived, revealing a spectrum of performance across the evaluated hospitals. To illustrate, we plotted these scores, highlighting the distribution and identifying the threshold for the top 5% of efficient hospitals. This threshold was determined through a rigorous analysis of the distribution of DEA scores, identifying a cutoff that represents exemplary performance in the context of environmental constraints and opportunities.

Stage two: ***bootstrapping for statistical inference***

Building on the foundation of DEA scores, the second stage introduced bootstrapping, as implemented through the "boot" library in R. This technique enabled us to account for the inherent bias and variability in DEA scores, facilitating robust regression analysis. By resampling with replacement, we constructed a distribution of efficiency scores. We followed the same steps used in the main section of DEA analysis in the manuscript.

Before conducting the regression analyses, we checked that all necessary linear regression assumptions had been met. After removing outliers using Cook's distance method, we determined that a log transformation of the dependent variable (efficiency scores) was more appropriate to meet the assumptions of linear regression. As a result of this transformation, the variance of our model was stabilized, and its interpretability was improved.

Compared to DEA results, the number of efficient hospitals decreased from 95 to 22. Furthermore, the efficiency advantage of the financial and clinical hybrid PHI type was diminished in the new model, partly because we set the threshold for the top 5% of efficient hospitals. However, the regression outcomes from this two-stage model align closely with our main analysis. For detailed information, refer to *Tables S1-S3* and *Figures S1-S2*.

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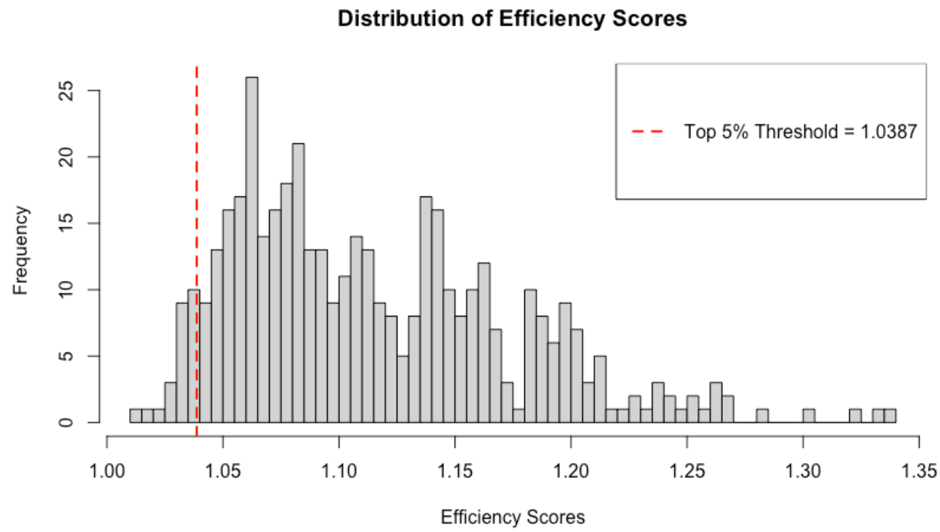

Figure S1 Distribution of efficiency score from DEA (with the two-stage modeling). DEA, data envelopment analysis.

Table S1 DEA results (with the two-stage modeling) (N=434)

Item	Efficient hospitals	Inefficient hospitals
Number	22	412
Percentage	5%	95%
Average DEA scores	1.031	1.119

DEA, data envelopment analysis.

Table S2 DEA results with PHI at both hospital and system level (with the two-stage modeling)

PHI type	Hospital-level PHI (N=321)		System-level PHI (N=326)	
	Efficient hospitals	Inefficient hospitals	Efficient hospitals	Inefficient hospitals
Financial PHI (Integrated Salary Model)	10 (5%)	175 (95%)	9 (5%)	168 (95%)
Financial and clinical hybrid PHI (Physician-Hospital Organization)				
Open Physician-Hospital Organization	3 (5%)	60 (95%)	4 (6%)	64 (94%)
Closed Physician-Hospital Organization	0	25 (100%)	2 (9%)	21 (91%)
Clinical PHI (Independent Practice Association)	1 (2%)	47 (98%)	1(2%)	57 (98%)

DEA, data envelopment analysis; PHI, physician-hospital integration; PHO, Physician-Hospital Organization.

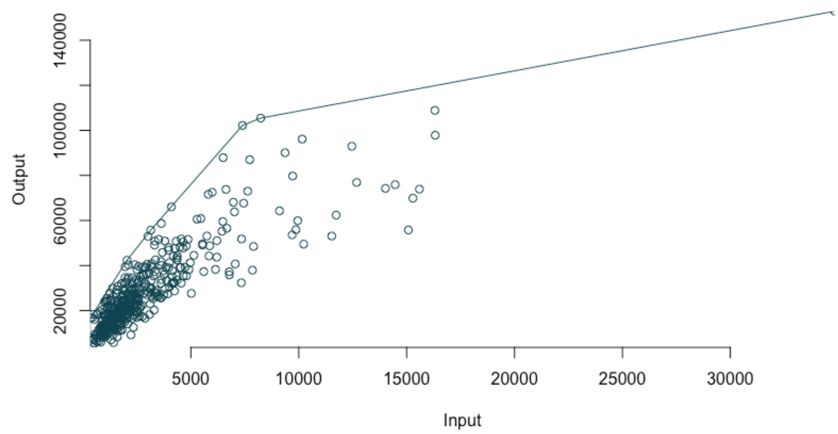

Figure S2 DEA efficiency plot (with two stage measures). DEA, data envelopment analysis.

Table S3 Regression results for DEA efficiency scores (with the two-stage modeling) (N=434)

Measures	Dependent variable (efficiency score), β (SE)	
	Hospital-level PHI	System-level PHI
PHI categorizations		
Financial PHI (Integrated Salary Model)	−0.002 (0.005)	0.001 (0.005)
Financial and clinical hybrid PHI (Physician-Hospital Organization)		
Open Physician-Hospital Organization	0.002 (0.006)	−0.014* (0.006)
Closed Physician-Hospital Organization	0.011 (0.009)	−0.015 (0.010)
Clinical PHI (Independent Practice Association)	−0.002 (0.006)	0.002 (0.006)
Organizational characteristics		
Hospital ownership (non-profit)	0.023** (0.008)	0.028*** (0.007)
Number of beds (hospital size)	0.000* (0.000)	0.000* (0.000)
Staffing/FTE	0.000 (0.000)	0.000 (0.000)
Teaching affiliation	−0.004 (0.005)	−0.005 (0.005)
Case mix index	0.042*** (0.010)	0.042*** (0.011)
Location rurality (metro)	0.023** (0.007)	0.024*** (0.007)
Market characteristic		
Herfindahl-Hirschman Index	0.000 (0.000)	0.000* (0.000)
Constant	−0.016 (0.022)	−0.022 (0.021)

*, P<0.05; **, P<0.01; ***, P<0.001. DEA, data envelopment analysis; SE, standard error; PHI, physician-hospital integration; FTE, full-time equivalent.

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