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ORIGINAL ARTICLE

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Abstract

This study examines the relationship between hospital financial performance and operational efficiency. Using data from the American Hospital Association (AHA), we find that profitability, debt coverage, and working capital efficiency are positively associated with hospital efficiency, while liquidity and capital structure exhibit a negative correlation. Fixed-asset efficiency, however, shows no significant impact on hospital operational efficiency. Furthermore, we find that the operational efficiency of urban hospitals is, in general, more sensitive to financial performance than that of rural hospitals. These findings provide practical insights for healthcare administrators and policymakers aiming to enhance hospital operational efficiency and promote equitable care delivery.

Keywords: Hospital operational efficiency, Hospital financial performance, Hospital location, Data envelopment analysis (DEA)

JEL classification: I1, L3, R00

1 Introduction

Operational efficiency is a cornerstone measure of hospital performance and a critical determinant of healthcare system sustainability. In an era of mounting cost pressures, workforce constraints, and growing demand for services, hospitals are under increasing scrutiny to optimize their use of financial and physical resources. Efficient hospitals are better positioned to improve patient outcomes, reduce waiting time, manage costs, and reinvest in clinical innovation. Conversely, inefficiency can lead to waste, operational bottlenecks, and, in severe cases, financial insolvency and closure. The implications of hospital efficiency extend beyond internal operations, influencing community health access, health equity, and the overall resilience of the healthcare infrastructure.

A great number of studies have emphasized the importance of improving operational efficiency within the healthcare sector. Burkey et al. (2012) find evidence that hospital administrators manage geographic placement effectively to enhance accessibility, a central component of operational efficiency. Tsagaankhuu et al. (2018) further find that hospitals that adopt hospital information systems see partial improvements in patient safety and quality of care, suggesting that technological and operational enhancements can translate into better healthcare efficiency. Ali et al. (2019) argue that key efficiency improvements, such as reducing patient length of stay, increasing day-case (outpatient) surgery rates, and minimizing medical errors, substantially boost hospital productivity and that these gains are underpinned by strong human capital and management practices.

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Parallel to operational efficiency, financial performance also plays a vital role in the viability and effectiveness of healthcare institutions. Financial metrics such as profitability, debt coverage, working capital efficiency, and capital structure are commonly used to assess organizational health and long-term sustainability (Watkins, 2000; Zeller et al., 1996). A hospital's ability to meet its financial obligations, generate operating margins, and allocate resources efficiently supports its capacity to maintain service quality and invest in capital improvements. For instance, using data from Polish hospitals, Krzeczewski et al. (2018) find that hospitals in large cities demonstrate significantly stronger financial performance compared to their rural counterparts. These urban hospitals also deliver higher-quality care and greater healthcare equity, which suggests a potential correlation between hospital efficiency and financial performance. Similarly, Carroll et al. (2023) highlight that financial distress and operational inefficiency have contributed to hospital closures, thereby restricting patients' access to timely and essential care. These financial challenges have disproportionately impacted underserved communities, where existing underinvestment in healthcare infrastructure and limited hospital availability already pose significant health risks.

The correlation between a hospital's financial efficiency and operational efficiency is not intuitively clear. For example, when hospitals focus excessively on maximizing margins, they may prioritize revenue-generating procedures (e.g., elective surgeries, imaging services) over essential but less profitable services such as primary care, mental health, or emergency care. This shift can lead to a misalignment between hospital operations and community health needs. Additionally, cost-cutting strategies aimed at preserving profitability, such as understaffing, limiting patient length of stay, or restricting access to charity care, can compromise care quality and patient safety. High-profit institutions may also reduce investment in less lucrative but socially important programs, including preventive care or rural outreach, thereby contributing to healthcare disparities. In this context, a negative correlation may be observed between a hospital's financial efficiency and operational efficiency. On the other hand, high profitability can be positively correlated with a hospital's delivery of healthcare services because financial strength often enables better resource allocation, operational efficiency, and patient care. Profitable hospitals typically have more capital to invest in modern medical technologies, facility upgrades, and clinical innovations that enhance diagnostic accuracy and treatment outcomes. Financial stability also allows for the recruitment and retention of highly skilled healthcare professionals, improved staffing ratios, and ongoing training programs. All of these factors will contribute to higher-quality care and patient satisfaction. As a result, profitability not only reflects strong financial management but may also indicate a hospital's ability to sustainably deliver high-quality, accessible, and efficient healthcare services. Based on this rationale, a positive correlation may be observed between a hospital's financial performance and its operational efficiency. Similar arguments may apply to other financial factors. While prior studies have provided international evidence on the relationship between hospital financial performance and operational efficiency (Guerra et al., 2022; Matos et al., 2021), most of this work focuses on healthcare systems outside the United States. Given the distinct structural and financial characteristics of the American healthcare system, further investigation is needed to understand how these dynamics operate in U.S. hospitals. Our study specifically aims to address this gap by examining the relationship between hospitals' financial performance and their operational efficiency, using the comprehensive American Hospital Association (AHA) data set, which covers thousands of U.S. hospitals. Following Zeller et al. (1996), we measure financial performance with seven financial ratios, including profitability, fixed-asset efficiency (FAE), capital structure, liquidity, debt coverage, working capital efficiency, and fixed-asset age (FAA). We employ data envelopment analysis (DEA), as developed by Charnes et al. (1978) and extended by Banker et al. (1984), to assess the relative operational efficiency of hospitals. Efficiency scores are derived using three inputs, number of beds, number of staff, and total operating expenses, and three outputs, number of inpatient days, number of outpatients, and total patient revenue. We find that profitability, debt coverage, and working capital efficiency are positively associated with hospital efficiency, while liquidity and capital structure exhibit a negative correlation. FAE, however, shows no significant impact on hospital operational efficiency. These findings have valuable implications for healthcare administrators who focus on optimizing hospital efficiency and ensuring fair access to care. For healthcare administrators, these findings underscore that robust financial management is key to improving operational efficiency. Hospitals with higher profitability and strong debt coverage tend to achieve greater efficiency, which suggests that initiatives to boost margins, for example, through cost control and revenue optimization, can translate into more efficient operations. Likewise, efficient working capital management, such as optimizing billing, collections, and inventory, is crucial. Hospitals can improve their financial performance and thus operational efficiency through efficiently managing receivables and payables effectively. In contrast, maintaining excessive liquidity or an imbalanced capital structure may signal underutilized resources and limit operational effectiveness.

Moreover, prior research has shown that urban hospitals generally exhibit stronger operational and financial performance than rural hospitals, due to differences in patient volume and access to external funding (Mestre et al., 2011; Younis, 2003). The moderating effect, specifically, a hospital's location in an urban, suburban, or rural area, on the relationship between financial indicators and operational outcomes remains understudied. Regarding data, existing studies often rely on narrowly defined location proxies or omit detailed classifications that capture the diversity of healthcare delivery environments. Our study addresses the gap by leveraging AHA's CBSATYPE classification, which offers a more sophisticated categorization of hospital locations. Through the subgroup analysis, we find that the operational efficiency of urban hospitals is, in general, more sensitive to financial performance than that of rural hospitals. This finding carries an important implication for healthcare policymakers. For policymakers, the urban–rural disparity in sensitivity to financial performance highlights the need for providing comprehensive support to rural hospitals. Because rural facilities often face structural financial challenges, policies such as enhanced funding, incentives for technology adoption, or adjusted payment models are important to boost their efficiency and ensure equitable access to high-quality care. That being said, our research contributes to the broader literature on hospital performance by clarifying the mechanisms through which financial health affects operational outcomes across varying healthcare environments.

2 Literature review and hypothesis development

2.1 *Financials and hospital efficiency*

While the literature emphasizes technical efficiency in hospitals, more studies have expanded interest in hospitals' financial performance as a critical driver of operational outcomes. In one of the earliest works on hospital finance, Mueller (1972) laid a foundation for later studies linking financial health to operational effectiveness in healthcare organizations. Mueller's research emphasized the need for hospitals to practice sound financial management similar to that in other industries. Particularly, the paper documents the importance of rigorous budgeting, cost control, and the use of financial ratios to monitor hospital performance. Matos et al. (2021) conduct a comprehensive analysis of Portuguese public hospitals by constructing composite indicators for quality, efficiency, access, and financial performance. They find that hospitals often perform unevenly across these dimensions. For example, a hospital with strong financial indicators might score lower in quality or access. Overall, they conclude that achieving operational efficiency requires balance; meanwhile, gains in financial performance should not come at the expense of patient care quality or accessibility. They suggest that policymakers and managers should balance financial performance evaluation and operating improvements. Guerra et al. (2022) analyze the financial performance of Brazilian hospitals by examining key indicators such as liquidity ratios, debt levels, profitability, and return on investment (ROI). They find that variations in financial health are tied to certain institutional characteristics. For instance, better-funded or larger hospitals often exhibit stronger profitability and efficiency metrics, whereas smaller or resource-constrained hospitals may struggle financially and operationally. Given Brazil's mix of public and private healthcare providers, their findings emphasize that financial sustainability is a prerequisite for efficient operations across diverse hospital settings. Carmo Filho and Borges (2024) provide a systematic review of how financial management practices intersect with operational efficiency and care quality in the era of Health 4.0. They note that effective financial management is crucial for hospitals adopting advanced technologies and data-driven approaches.

Although there are some international insights, the relationship between financial performance and operational efficiency remains understudied in the context of U.S. hospitals. We use the comprehensive AHA data set to investigate how various financial ratios (e.g., profitability, liquidity, debt coverage) correlate with hospital operating efficiency. We discuss the specific hypothesis as follows.

2.1.1 *Profitability and hospital efficiency*

There are two plausible, contrasting perspectives on how hospital efficiency relates to profitability. On one hand, a positive correlation posits that greater efficiency drives higher profitability. When hospitals enhance operations by reducing waste, shortening patient stays, and optimizing resource use, they lower their costs per service, which should improve profit margins. Some empirical evidence supports the view that more profitable hospitals achieve better operating efficiency. For example, Rosko et al. (2020) study nonprofit hospitals in the U.S. and find efficiency and profit go hand in hand. In particular, higher efficiency is associated with higher margins, supporting the idea that cost-effective operations improve both operating and financial performance. Based on this context and existing empirical evidence, we hypothesize:

Hypothesis 1A. *Hospital operational efficiency has a significant positive correlation with hospital profitability.*

On the other hand, a negative correlation argument suggests that pursuing profitability may hurt the delivery of healthcare services and cause lower hospital operating efficiency. Hospitals that aggressively pursue efficiency might limit the scope of services or compromise patient satisfaction and future volumes. Benton (2013) analyzes the top-ranked U.S. hospitals and find that high clinical quality does not always equate to high profit performance. He cautions against using profitability alone to rank high-quality hospitals. Büchner et al. (2016) find evidence that hospitals joining the health network yield lasting efficiency improvements but only a temporary boost to profitability. It is evidence that growth in profitability and efficiency do not match. Thus, based on this view, the alternative hypothesis is:

Hypothesis 1B. *Hospital operational efficiency has a significant negative correlation with hospital profitability.*

We expect Hypothesis 1A to hold rather than the negative alternative in our data for a couple of reasons. First, the contemporary healthcare environment of the U.S. rewards efficiency. For example, Medicare's Value-Based Purchasing programs provide financial incentives for hospitals that deliver cost-effective, high-quality care (Rosko et al., 2020). This means efficiency improvements, which are achieved without compromising quality, can translate into financial rewards and fewer economic penalties, aligning operational efficiency with stronger financial outcomes. Second, using data from nonprofit hospitals, Rosko et al. (2020) document a positive association between operational efficiency and hospital profitability. Our data is more comprehensive as it includes both nonprofit and for-profit hospitals. Because for-profit hospitals are typically more profit-oriented in their operational decision making, we expect the positive relationship between operational efficiency and profitability to be even stronger in our full sample.

2.1.2 Liquidity and hospital efficiency

Capital liquidity is a key indicator of hospital financial health, typically measured by the cash ratio, current ratio, and quick ratio, with recommended benchmarks of >20%, 2:1, and 1:1, respectively. Usually, adequate liquidity ensures timely payments to suppliers, staff, and operations, while excessive liquidity may signal underutilized resources that could be invested in equipment and technology to enhance service capacity. Hospitals today face intense financial pressures, which makes the relationship between liquidity and operating performance a critical area of interest. Prior research suggests that hospitals with ample cash reserves are better positioned to maintain high-quality care delivery (Dong, 2015). Dong (2016) finds that hospitals, particularly nonprofit institutions, often manage liquidity as a form of "window dressing" to improve their chance when seeking external financing. Consequently, hospitals with higher liquidity tend to exhibit stronger financial health, which enables greater capacity to invest in initiatives that enhance the quality and equity of healthcare delivery.

In general, hospitals with higher liquidity are better positioned to allocate resources effectively, invest in advanced medical technologies, and maintain financial stability, which can, in turn, enhance operational efficiency. Based on this reasoning, we propose our second hypothesis:

Hypothesis 2. *Hospital operational efficiency has a significant positive correlation with hospital financial liquidity.*

2.1.3 FAE and hospital efficiency

Hospitals are highly capital-intensive organizations, investing heavily in fixed assets such as buildings, surgical suites, advanced medical equipment, and IT infrastructure. The efficiency of how these assets are utilized is often measured through FAE/fixed-asset turnover or asset-specific metrics such as FAA. How effectively these assets are utilized can materially impact a hospital's operating costs, capacity, and the quality of healthcare delivery. Using international data, several studies highlight a general positive correlation between FAE and operational efficiency. For example, Leea et al. (2019) analyze financial indicators in Korean hospitals, finding that efficient use of fixed assets is linked to better operational outcomes. Similarly, Anjani et al. (2024) document that strong FAE, coupled with a healthy current ratio and collection period, contributes to overall operational efficiency in an Indonesian public hospital. Moreover, Da Silva et al. (2024) examine Brazilian hospitals and find that heavy investment in fixed assets reduces FAE in Brazil's hospitals; meanwhile, a large portion of underutilized assets hinders operational efficiency by making costs less flexible.

Our hypothesis development is grounded in the distinctive institutional and operational environment of U.S. hospitals after 2015. In recent years, U.S. hospitals have faced financial constraints, for example, declining margins, which forced them to cut costs and seek greater efficiency of using fixed assets to deliver healthcare (Dong, 2015). Cutting expansion to fixed assets should enhance the fixed-asset turnover of hospitals, indicating higher FAE. Since the improvement of FAE in U.S. hospitals is mainly driven by investment cuts, if U.S. hospitals deliver a more efficient use of fixed assets (for example, more patients per bed) to maintain the operational performance, a positive correlation between hospital operational efficiency with hospital FAE can be expected:

Hypothesis 3A. *Hospital operational efficiency has a significant positive correlation with hospital FAE.*

Alternatively, hospitals facing high investment cuts may compromise operational performance in practice. Limited expansion of fixed assets can lead to asset overutilization, creating operational strains such as overburdened staff and reduced organizational flexibility. These constraints may, in turn, negatively affect the quality of care and limit patient access. This theoretical perspective therefore suggests a negative correlation between hospital operational efficiency and hospital FAE:

Hypothesis 3B. *Hospital operational efficiency has a significant negative correlation with hospital FAE.*

The expected influence of FAA on efficiency is also ambiguous. The more conventional theories suggest a negative correlation between asset age and operational efficiency. One might expect that older assets, meaning a high FAA, lead to inefficiencies due to maintenance issues and inefficiency of old technology. From a quality and capacity standpoint, outdated facilities might limit the hospital's ability to implement modern efficient processes or expand services. Indeed, empirical evidence shows that replacing or modernizing equipment can often improve healthcare's service quality. For example, Beauvais et al. (2021) find that hospitals in the youngest quartile of asset age had significantly higher efficiency in terms of clinical quality and patient experience scores than those in the oldest quartile. Based on this discussion, we hypothesize:

Hypothesis 4A. *Hospital operational efficiency has a significant negative correlation with hospital fixed asset age.*

However, Pink et al. (2006) interestingly document a positive relationship between FAA and performance. Their study suggests that a lower FAA, such as newly constructed facilities, may temporarily reduce efficiency due to learning curves and the burden of high capital costs. This possibility gives rise to the alternative hypothesis:

Hypothesis 4B. *Hospital operational efficiency has a significant positive correlation with hospital FAA.*

2.1.4 Capital structure and hospital efficiency

Several studies have explored the interplay between hospital capital structure and operational efficiency, yielding mixed findings. On one hand, heavy debt burdens can undermine a hospital's financial performance by diverting resources to debt repayments and constraining the resources allocated to patient care. For example, Lombardi et al. (2021) find that as nonprofit health systems' long-term debt-to-capitalization ratios increased, their total and nonoperating margins declined, that is, there was a negatively correlated relationship between leverage and financial performance. Such a decrease in margins implies that excessive debt may undermine financial stability and limit funds available for quality improvements or community services. Similarly, in a study of rural hospitals, Williams et al. (2020) observe that rural hospitals with heavier debt burdens were more likely to be merged with other hospitals with better financial health. Such consolidation can reduce patients' accessibility due to the closure of branch units and raise concerns about equity in access to care. Accordingly, we propose the following hypothesis:

Hypothesis 5A. *Hospital operational efficiency has a significant negative correlation with hospital debt level.*

On the other hand, other research suggests that a well-managed capital structure and efficient use of assets raised from bonds can support better operational outcomes. For example, Bazzoli et al. (2000) suggest that a hospital's collective debt capacity is linked to operational efficiency and the quality of healthcare delivery. Martin (2015) finds that the debt-related measures in Puerto Rico's private hospitals met or exceeded U.S. industry benchmarks. This study emphasized that balanced financing strategies are closely linked to quality of services, highlighting how maintaining a sound capital structure, for example, adequate debt levels and liquidity, is crucial for sustaining high-quality care. Especially for smaller or resource-constrained providers, adequate use of debt can serve as a lifeline to maintain operations and patient services. McCue and Ozcan (1992) identified factors influencing hospitals' borrowing, noting that greater uncompensated care load was associated with higher short-term debt use and that smaller hospitals tended to borrow more heavily due to limited internal funds. In other words, debt financing often helps underresourced hospitals maintain their operations and continue serving patients, though at the risk of financial strain if overextended. Taken together, this argument suggests a possible positive correlation between a hospital's debt level and operational efficiency:

Hypothesis 5B. *Hospital operational efficiency has a significant positive correlation with hospital debt level.*

2.1.5 Working capital efficiency and hospital efficiency

We propose that working capital may also play a key role in influencing U.S. hospitals' operational efficiency by affecting cost savings and the availability of financial resources. In particular, efficient management of cash, receivables, and payables (for example, limiting patient credit and reducing compensated care) ensures timely resources for boosting productivity and service quality. Ferrier et al. (2006) estimated that eliminating working capital inefficiencies, such as burdens of uncompensated care, could increase hospital operational output by about 7%, underscoring how a hospital's liquidity constraints hinder its capacity. Similarly, Rauscher and Wheeler (2012) report that hospitals with better working capital efficiency, by imposing shorter collection periods and timelier payment of obligations, achieved higher profitability, enabling reinvestment into quality improvement and expanded access. These findings imply that efficient revenue cycle and payables management can strengthen financial performance and, in turn, operational efficiency. Moreover, in crisis conditions, Jalilian et al. (2023) documented that Iranian hospitals' service volumes plunged alongside a 90% collapse in cash ratios during the pandemic period in 2019 and 2020, showing that liquidity shortfalls directly undermine operations. Accordingly, we expect that efficient working capital management, measured by higher inventory turnover, shorter patient collection periods, and longer supplier payment periods, will be positively associated with hospital operational performance:

Hypothesis 6A. *Hospital operational efficiency has a significant positive correlation with hospital working capital efficiency.*

However, we also consider the possibility that overly aggressive liquidity optimization may impair service delivery. For example, strictly limiting patient credit or reducing uncompensated care in an effort to conserve cash could restrict access to care and undermine equity. Dalci and Ozyapici (2018) report that the profitability effect of working capital policy depends on leverage. They show that highly indebted hospitals benefited from shorter cycles, whereas low-leverage hospitals did not benefit from shorter cycles. Such a consideration encourages the test on an alternative hypothesis:

Hypothesis 6B. *Hospital operational efficiency has a significant negative correlation with hospital working capital efficiency.*

2.2 Moderating role of geographic location

The geographic distribution of hospitals has also been widely recognized as a factor influencing hospitals' operational and financial performance. Vitaliano (1988) offered a seminal assessment of the locational efficiency of hospital systems from an economic perspective. He argued that an efficient configuration of hospitals is one that minimizes the combined costs of hospital service provision and patient travel, essentially treating hospital location as an optimization problem in which total societal costs are minimized. This work made a key theoretical and methodological contribution by including a hospital's location and accessibility as a key measure of hospital efficiency. More recent studies offer substantial empirical evidence demonstrating that geographic location significantly influences hospital operational efficiency. Based on a large-scale study across 181 Chinese hospitals from different geographic regions, Zhao et al. (2015) reveal the uneven distribution of medical resources across regions, which translated into uneven hospital performance. In particular, hospitals located in wealthier eastern regions tended to be more efficient, whereas those in less developed regions lagged. Burkey et al. (2012) analyzed the hospitals in four southeastern states in the U.S. by using the geographic information systems. They find that the actual distribution of hospitals was nearly optimal in providing geographic access to care. This suggests that, at least in those regions, geographic location has been considered in an efficient manner with respect to patient access, which is a key measure of hospital operational efficiency. Krzeczewski et al. (2018) provided strong evidence of an agglomeration effect in urban hospitals in Poland. Their research confirmed that hospitals in large cities benefited from economies of scale, higher patient volumes, access to specialized labor, and opportunities for outsourcing, factors that collectively enhanced operational efficiency. Tsagaankhuu et al. (2018) found that, in

Mongolia, urban hospitals adopted hospital information systems at significantly higher rates than rural hospitals, resulting in greater operational efficiency and reductions in mortality rates. This finding aligns with the broader theme of technological diffusion being closely tied to location-based resource availability. These studies strongly support the notion that urban hospitals tend to be more efficient than rural ones due to their advantageous positioning in resource-rich environments. This urban–rural divide is a critical consideration for policymakers aiming to ensure both effective and equitable healthcare delivery.

A growing body of research has also explored the relationship between hospital location and financial performance, suggesting that urban settings not only enhance operational outcomes but also bolster financial sustainability. A report from the United States General Accounting Office (2003) shows that specialty hospitals, which are usually concentrated in urban areas, often have lower investment in emergency services and underserved populations compared to general hospitals. However, these specialty hospitals outperformed general hospitals in terms of care quality and profitability. The study raised questions about how location-specific regulatory environments shape hospital financial outcomes. Younis (2003) explores the impact of geographic setting on U.S. hospitals' financial and economic performance using comprehensive post-PPS data. The study finds that small rural hospitals face inherent disadvantages compared to urban hospitals, such as lacking certain subsidy payments and suffering limited economies of scale due to smaller size and patient mix, which hinder their financial efficiency. Jervis et al. (2012) examines the tension between community need and financial incentive in hospital location decisions. They document that hospitals were closed in poorer, high-minority urban neighborhoods while new facilities opened in affluent suburbs, indicating financial considerations often outweighed equity concerns. The healthcare system justified these relocations as efforts to meet community needs at lower cost, but ultimately the moves proved financially advantageous for the hospital network. This argument highlights how geographic location can dramatically influence financial outcomes and raises ethical questions about equity in access. Krzeczewski et al. (2018) confirm that hospitals' location matters, that is, hospitals in big cities show significantly better financial condition than those in less urbanized areas. More recently, Park and Lee (2024) find that greater investment in medical facilities and buildings increases medical profit but can reduce other income measures, an effect offset by higher investment in transportation assets. Notably, they report that expanding vehicle and transport equipment is especially beneficial for hospitals in the Seoul metropolitan area, highlighting the moderating role of geographic location on profitability. Through these studies, we observe consistent evidence that location plays a pivotal role in shaping hospital financial performance. Urban hospitals benefit from greater demand, better payer mixes, and more favorable infrastructure conditions, all of which translate into superior financial health compared to rural hospitals.

Given that urban versus rural location plays a pivotal role in shaping hospital operational and financial efficiency, we propose that the relationship between financial performance and operational efficiency might depend on geographic location. Financial health may translate into efficiency gains more readily for hospitals in urban areas, which can leverage resources for process improvements and technology adoption, than for hospitals in rural areas, which may be constrained by smaller scale and workforce shortages. To examine this potential moderating effect, we test the above hypotheses separately for urban and rural hospital subgroups.

3 Methodology and data

3.1 Conceptual model

Fig. 1 illustrates the conceptual model of our study. The framework is based on the six key financial characteristics identified by Zeller et al. (1996), including profitability (X1_PRO), liquidity (X2_LIQ), FAE (X3_FAE), capital structure (X4_CS), debt coverage (X5_DC), working capital efficiency (X6_WCE), and FAA (X7_FAA).[1] These variables are independent variables in our analysis. We hypothesize that these variables have an impact on hospital operational efficiency, which is the dependent variable in our analysis (as Y in Fig. 1). We measure hospital efficiency using DEA and benchmark hospitals against the "best practice" frontier.[2] In our model, hospital location (urban vs. rural) is included as a moderator that allows us to examine how the environmental

[1] Several previous studies have adopted frameworks similar to Zeller et al. (1996) when examining hospital financial performance and efficiency. The literature includes Pink et al. (2006), Lin et al. (2011), Chang et al. (2014), Matos et al. (2021).

[2] DEA is a special application of linear programming based on the frontier methodology of Farrell (1957). Building on Farrell's work, significant advancements in DEA were made by Charnes et al. (1978) and Banker et al. (1984). DEA provides a robust framework for evaluating the relative efficiency of comparable organizations or entities, referred to as decision-making units. By identifying the most efficient decision-making units within a given set, DEA serves as a valuable tool for comparative performance assessment and benchmarking (Mhatre et al., 2014).

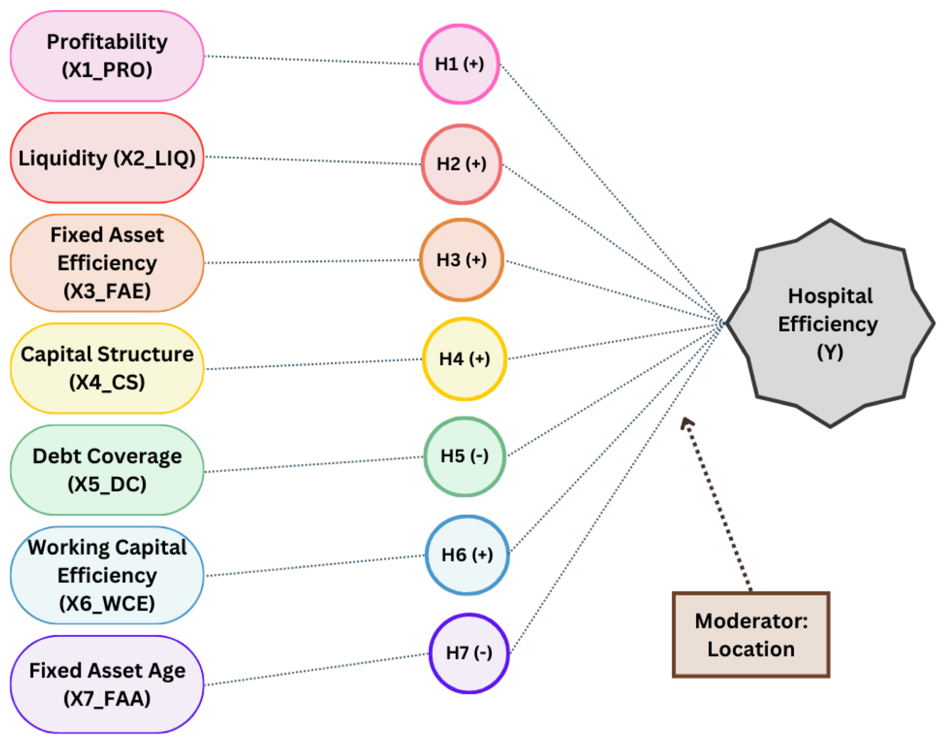

Fig. 1. Conceptual model.

context influences the effect of financial performance on hospital operational efficiency.

3.2 *Measure of hospital operational efficiency*

The dependent variable in this study is hospital operational efficiency, measured via DEA. In our case, each hospital is a decision-making unit (DMU). Consistent with Zeller et al. (1996), we use three input measures, which are resources used, and three output measures, which are services provided, to calculate efficiency. Specifically, the input variables are number of beds, number of staff, and total operating expense. The output variables are inpatient days, number of outpatients, and total patient revenue. These inputs and outputs capture the scale of resources employed and the volume of services delivered by a hospital.

DEA constructs an efficient frontier from the best-performing hospitals in the sample, and each hospital's efficiency score is calculated as its distance from this frontier. An efficiency score of 1 indicates a hospital lies on the frontier, defined as efficient relative to peers, while a score below 1 indicates relative inefficiency. Formally, for a given hospital (base unit 0), we solve the problem:

$$\text{Maximize} \quad E_0 = \frac{\{\sum_{r=1}^{R} u_{r0} y_{r0}\}}{\{\sum_{i=1}^{I} v_{i0} x_{i0}\}} \tag{1}$$

$$\text{subject to} \quad \frac{\{\sum_{r=1}^{R} u_{r0} y_{rk}\}}{\{\sum_{i=1}^{I} v_{i0} x_{ik}\}} \leq 1 \text{ for all DMU } k \tag{2}$$

$$u_{r0}, v_{i0} \geq d \text{ for all } r, i \tag{3}$$

where y_{rk} and x_{ik} are the observed outputs and inputs for hospital k, and u_{r0} and v_{i0}, which are determined by the model, are the weights that DMU 0 places on each output r and input i to maximize its efficiency score E_0. d is a very small positive constant to enforce positivity. The constraint (2) ensures that no hospital's weighted output–input ratio exceeds 1 under the weight set of DMU 0, thereby defining the efficient frontier.

This fractional program can be transformed into a linear programming (LP) model. The DEA model by Charnes, Cooper, and Rhodes (CCR) assumes constant returns to scale (CRS), implying that input–output combinations can be proportionally scaled without changing efficiency (Charnes et al., 1978). Banker, Charnes, and Cooper (BCC) later extend the model to allow variable returns to scale (VRS), which relaxes the proportionality assumption and accommodates increasing or decreasing returns (Banker et al., 1984). Tone (2001) introduces the slack-based model (SBM) for efficiency measurement. SBM is a nonradial DEA model that directly incorporates input excesses and output shortfalls into the efficiency score, addressing limitations of the traditional CCR and BCC models.

Using these three models in sequence, we first calculate efficiency scores under CCR and BCC to identify efficient hospitals and to distinguish scale efficiency from pure technical efficiency. Next, we apply SBM to capture any nonradial properties that CCR and BCC might overlook. Following the approach in Mhatre et al. (2014), we contrast the results of the three models to identify the sources of inefficiency for each hospital. Prior studies classify DMUs as efficient versus inefficient or high-efficiency versus low-efficiency based on a threshold and then use logistic regression to identify characteristics of the two groups. In our later regression analysis, we will define a binary variable (for example, top quartile efficient hospitals = 1, others = 0) or use another binary classification for hospital operational efficiency. The classification of the binary variable in logistic terms will be clarified in Section 4 based on the distribution of DEA scores.

3.3 Measure of financial performance

We examine seven independent variables, each representing a financial ratio factor derived from Zeller et al.'s (1996) framework. Each factor is a composite concept measured by one or more specific financial ratios from hospitals' financial statements. Below we define each factor and its key ratio components:

1. *Profitability (X1_PRO):* Profitability reflects a hospital's ability to generate earnings from its assets and operations. Higher profitability generally indicates better financial performance. In this study, profitability is evaluated using the operating margin (OMAR):

$$OMAR = \frac{Total\ Revenue - Total\ Expenses}{Total\ Revenue\ +\ Net\ Nonoperating\ Gains}$$

   Our pick of OMAR is also motivated by Watkins (2000), who highlights it as a consistent and essential measure capturing the percentage of revenue remaining after operating expenses and taxes.
2. *Liquidity (X2_LIQ):* Liquidity indicates the hospital's ability to meet short-term obligations using its most liquid assets. It reflects financial flexibility and the risk of cash shortfalls. High liquidity means the hospital has sufficient cash or easily convertible assets to pay bills and handle emergencies, which can indirectly support efficient operations by avoiding disruptions due to cash flow problems. In this study, liquidity is evaluated using the days cash on hand (DCH):

$$DCH = \frac{Cash + Marketable\ Securities}{(Total\ Expenses - Depreciation)\ /365}$$

   This computes how many days the hospital can continue to operate using only its cash and liquid investments, assuming no new cash inflow. A higher DCH is desirable, signaling a strong liquidity buffer.
3. *FAE (X3_FAE):* FAE reflects how effectively a hospital utilizes its fixed assets (plant, property, and equipment) to generate revenue. Essentially, it is about the productivity of the hospital's physical capital. In this study, liquidity is evaluated using total asset turnover (TATO):

$$TATO = \frac{Total\ Revenue + Net\ Nonoperating\ Gains}{Total\ Assets}$$

   Our study broadens the scope of all assets. This is because hospitals' assets are indeed dominated by fixed assets, especially when looking at long-term investments in facilities and equipment. Current assets and intangibles typically make up a small portion.
4. *Capital Structure (X4_CS):* Capital structure measures how a hospital finances its assets, which is the mix of equity (or fund balance for nonprofits) and debt. In this study, capital structure is evaluated using long-term debt to equity (LTDE):

$$LTDE = \frac{Long\text{-}Term\ Liabilities}{Net\ Fixed\ Assets}$$

   Prior literature often finds that a higher debt level is associated with higher financial distress and inefficiency (Chang et al., 2014; Lin et al., 2011; Pink et al., 2006).
5. *Debt Coverage (X5_DC):* Debt coverage measures the hospital's ability to service its debt, essentially, how easily it can cover interest and principal payments from its earnings. In this study, debt coverage is evaluated using times interest earned (TIE):

$$TIE = \frac{EBIT}{Interest\ Expense}$$

   TIE focuses on interest coverage alone. A higher TIE means the hospital's operating earnings are many times its interest expense, indicating low risk of default on interest payments. Overall, debt coverage is crucial in financial analysis, as it helps stakeholders assess the financial sustainability and risk exposure of any hospital.
6. *Working Capital Efficiency (X6_WCE):* Working capital efficiency reflects how well the hospital manages its short-term assets and liabilities. In

Table 1. Descriptive statistics and correlation analysis.

	Mean	*SD*	*n*	Y1	$X1_{PRO}$	$X2_{LIQ}$	$X3_{FAE}$	$X4_{CS}$	$X5_{DC}$	$X6_{WCE}$	$X7_{FAA}$
***Y*1**	0.50	0.50	1526	1							
$X1_{PRO}$	−5.52	37.56	3051	.44***	1						
$X2_{LIQ}$	52.05	61.95	3051	−.17***	−.20***	1					
$X3_{FAE}$	1.12	0.54	3051	.09***	.08***	−.35***	1				
$X4_{CS}$	0.28	0.44	3051	−.13***	−.23***	.33***	−.20**	1			
$X5_{DC}$	12.98	21.75	3051	.09**	.24***	−.05**	.06**	−.15**	1		
$X6_{WCE}$	1.54	1.01	3051	.02	.06***	.38***	−.25**	.19**	.02*	1	
$X7_{FAA}$	11.87	6.62	3051	−.05*	−.09***	.22***	−.07**	.11**	.02*	.15	1

*$p < .05$. **$p < .01$. ***$p < .001$.

this study, working capital efficiency is evaluated using the current ratio (CR):

$$CR = \frac{Current\ Assets}{Current\ Liabilities}$$

Working capital efficiency essentially combines elements of liquidity and asset turnover on the current side of the balance sheet. A hospital that efficiently manages its working capital will avoid excessive idle current assets and will minimize short-term liabilities costs.

7. *FAA (X7_FAA):* FAA relates to the age and depreciation of the hospital's physical assets. This factor gives insight into how up to date the hospital's infrastructure is, which can affect efficiency. In this study, FAA is evaluated using the average age of plant (AAP):

$$AAP = \frac{Accumulated\ Depreciation}{Annual\ Depreciation\ Expense}$$

Table 1 presents the descriptive statistics and Spearman correlation coefficients for the key variables used in the study. The mean value of $Y1$ is 0.50, indicating an even split between efficient and inefficient hospitals in the sample.

Among the financial ratios, the mean and standard deviation values suggest substantial variability, particularly for operating margin ($X1_{PRO}$) and debt coverage ($X2_{LIQ}$). The correlation matrix reveals statistically significant relationships among the variables. For example, $Y1$ is positively associated with profit margin ($X1_{PRO}$, $r = .44$, $p < .001$), TATO ($X3_{FAE}$), and TIE ($X5_{DC}$), and negatively associated with debt coverage ($X2_{LIQ}$) and LTDE ($X4_{CS}$). Notably, several independent variables are moderately correlated with one another, such as the negative correlation between $X2_{LIQ}$ and $X3_{FAE}$ ($r = -.35$, $p < .001$) and the positive correlation between $X2_{LIQ}$ and CR ($X6_{WCE}$, $r = .38$, $p < .001$).

These results provide preliminary support for the hypothesized relationships between financial indicators and hospital operational efficiency and help assess potential multicollinearity prior to regression analysis.

3.4 Control variables

In our regression analysis, we control for four hospital characteristics that could impact operational efficiency. The first is hospital size (C1_Size), measured by bed count. The second is hospital location (C2_LOC). This is a categorial variable based on the AHA classification of the hospital's community. The data include three categories: rural, microcity, and metro city. We recode this into rural and urban, where urban encompasses the micro- and metro city categories, and rural is the rural category. Location is of particular interest because we will test it as a moderator, that is, whether the relationship between financial ratios and operational efficiency differs between urban and rural hospitals. The third characteristic is ownership type (C3_OWN), a category variable including not-for-profit, for-profit, and government-owned.[3] The not-for-profit hospitals are those privately controlled by nonprofit organizations. They are typically tax-exempt and reinvest any surplus into their mission, community services, facility improvements, education, or charity but do not distribute profits to owners. For-profit hospitals are owned by individuals, corporations, or investors. Their goal is to generate profits that are distributed as dividends or equity growth. They have access to equity financing, and decision making may prioritize financially profitable services. Government-owned hospitals are owned and controlled by state or local governments; they are funded primarily through tax dollars. They often serve as safety-net providers, offering care to uninsured or underserved populations. The last variable is teaching status (C4_TCH). This variable is a

[3] Not-for-profit has the codes 21 and 23. For-profit has the codes 31, 32, and 33. Government-owned has the codes 12 to 16 and 41 to 48.

binary that indicates membership in the Council of Teaching Hospitals.[4] We define this binary as 1 for teaching hospitals, which have significant teaching programs, and 0 for nonteaching hospitals. Teaching hospitals often have higher costs due to medical education, research, and complex patient cases, which might impact hospital operational efficiency.

3.5 Analytical approach

To test the hypotheses listed above, we employed logistic regression analysis. Following prior work that applies logistic models to classify DEA-based performance states (e.g., Sohn, 2006; Ullah et al., 2023), we transformed continuous DEA technical efficiency scores into a binary dependent variable. Observations in the top quartile of DEA scores were labeled 1 (highly efficient), while those in the bottom quartile were labeled 0 (inefficient); observations in the interquartile range were excluded from the classification analysis to maximize separation. This prespecified quantile rule improves interpretability and mitigates distributional concerns associated with regressing bounded efficiency scores directly (Ramalho et al., 2010; Simar & Wilson, 2011). We then estimated multivariable logistic regression models to assess the association between explanatory factors and the odds of belonging to the highly efficient (top quartile) group.

Furthermore, two healthcare articles support quartile-based benchmarking when the goal is to reveal meaningful performance gaps rather than central tendencies (Brown et al., 2021; Dragan et al., 2022). Collectively, these findings justify analytic strategies that contrast top versus bottom quartiles (and sometimes exclude the middle 50%) to reveal material differences that can be muted by aggregate averages or undifferentiated stratifications.

We regress the measure of hospital operational efficiency (Y1) on hospital profitability ($X1_{PRO}$), liquidity ($X2_{LIQ}$), FAE ($X3_{FAE}$), capital structure ($X4_{CS}$), debt coverage ($X5_{DC}$), working capital efficiency ($X6_{WCE}$), and FAA ($X7_{FAA}$). Hospital location ($C2_{LOC}$) is included as a key control variable:

$$\begin{aligned} Logit\,(Y1) = \;& \beta_0 + \beta_1 X1_{PRO} + \beta_2 X2_{LIQ} + \beta_3 X3_{FAE} \\ & + \beta_4 X4_{CS} + \beta_5 X5_{DC} + \beta_6 X6_{WCE} + \beta_7 X7_{FAA} \\ & + \beta_8 C2_{LOC} + \varepsilon \end{aligned}$$

To explore whether the relationship between hospital financials and operational efficiency varies by hospital location, we further use hospital location (C2_LOC) as a moderator. We introduce interaction terms between location and the key financial predictors in extended models. Specifically, we include the terms $X1_{PRO} \times C2_{LOC}$, $X2_{LIQ} \times C2_{LOC}$, $X3_{FAE} \times C2_{LOC}$, $X4_{CS} \times C2_{LOC}$, $X5_{DC} \times C2_{LOC}$, $X6_{WCE} \times C2_{LOC}$, and $X7_{FAA} \times C2_{LOC}$. We include the interaction terms one at a time or all together. A significant coefficient for the interaction term implies the slope of profitability on efficiency changes based on location. We will report and interpret such findings accordingly. We also check standard diagnostics, including multicollinearity among predictors, goodness-of-fit, pseudo-R^2, and classification accuracy. Our sample size is large; thus, even modest effects could be statistically significant. Accordingly, we focus on both statistical significance and the economic magnitude, measured by odds ratios, to assess practical significance.

3.6 Data and sample

This study utilizes data from the 2020 AHA Annual Survey combined with hospital financial data from the Healthcare Cost Report Information System (HCRIS). Two primary data files were obtained for 2020. The first is the AHA Annual Survey Database (ASDB) file. ASDB contains hospital organizational characteristics, such as bed count, location type, ownership, teaching status. The AHA survey is sent to all U.S. hospitals annually. There are 6165 hospitals that responded to the AHA survey in 2020. The second file is the HCRIS financial file. HCRIS contains Medicare cost report data and derives financial metrics for hospitals. This file provides the raw figures for calculating the financial ratios, for example, the hospitals' profitability and liquidity. HCRIS contains data from 5988 hospitals. We merged these two databases based on hospital identifiers to create a comprehensive data set. We only retained the hospitals that appeared in both data sets. The merged data set initially included 5988 hospitals.

We then applied several data cleaning and filtering steps. First, hospitals missing any of the inputs or outputs for constructing the operational efficiency measure or any major financial ratio components were removed from the sample. Second, we examined the distribution of each variable and excluded extreme outliers that likely reflected data errors or atypical cases; for example, a hospital reporting an implausibly high number of beds or revenue given its type. Third, we conducted validity checks. Specialty hospitals or facilities not directly comparable

[4] We develop this binary based on the variable MAPP8 in the AHA database.

to general acute-care hospitals, such as stand-alone long-term care facilities and psychiatric hospitals, were considered for exclusion to maintain a homogeneous set of DMUs for the DEA analysis used to construct the measure of hospital operational efficiency.

After data cleaning, the final analysis sample consists of 3051 U.S. hospitals. This reflects the usable observations with complete data for calculating DEA efficiency and all independent and control variables. The reduction from 5988 to 3051 hospitals results from the exclusion of incomplete or noncomparable cases. Although this process eliminates roughly half of the original sample, it enhances the reliability of the data set and ensures that the DEA analysis is conducted on a valid basis.

This large sample provides robust statistical power for the regression analysis and a comprehensive view of the relationships between financial management and operational efficiency in U.S. hospitals. The use of 2020 data (the latest available year in AHA and HCRIS at the time of study) also means our findings will reflect contemporary hospital performance, although we recognize that 2020 was a year affected by the COVID-19 pandemic—a point we will consider when interpreting results.

4 Empirical findings

4.1 Financial performance and operational efficiency

Table 2 shows the results of the logistic regression of hospital operational efficiency on seven financial ratios as follows:

$$\begin{aligned} Logit\ (Y1) = {} & \beta_0 + \beta_1 X1_{PRO} + \beta_2 X2_{LIQ} + \beta_3 X3_{FAE} \\ & + \beta_4 X4_{CS} + \beta_5 X5_{DC} + \beta_6 X6_{WCE} + \beta_7 X7_{FAA} \\ & + \beta_8 C2_{LOC} + \varepsilon \end{aligned}$$

Hospital operational efficiency is a binary variable ($Y1$), with low efficiency = 0 and high efficiency = 1. The seven financial ratios include: OMAR ($X1_{PRO}$), DCH ($X2_{LIQ}$), TATO ($X3_{FAE}$), LTDE ($X4_{CS}$), TIE ($X5_{DC}$), CR ($X6_{WCE}$), and AAP ($X7_{FAA}$). The regression model controls the geography context of the hospitals ($C2_{LOC}$, rural vs. urban). The table reports unstandardized coefficients (B), standard errors (SE), Wald statistics, p values, and odds ratios (OR).

As regards the quality of the regression, the omnibus test of model coefficients shows that the chi-square is 169.521 with $p < .001$, which indicates the model reliably distinguishes between high- and low-efficiency hospitals. The pseudo-R-square values (Cox & Snell = .105; Nagelkerke = .140) suggest the financial predictors explain about 10% to 14% of the

Table 2. Financial performance and operational efficiency—full sample analysis.

	B	*SE*	Wald	*p*	*OR*
$X1_{PRO}$	0.023	0.003	73.453	< .001***	1.024
$X2_{LIQ}$	−0.003	0.001	9.000	.003**	0.997
$X3_{FAE}$	0.09	0.108	0.701	.402	1.095
$X4_{CS}$	−0.317	0.131	5.824	.016*	0.729
$X5_{DC}$	0.005	0.002	3.848	.050#	1.005
$X6_{WCE}$	0.133	0.059	5.138	.023*	1.143
$X7_{FAA}$	−0.006	0.008	0.514	.474	0.994
Constant	0.077	0.204	0.142	.706	1.080

Omnibus test of model coefficients:
$\chi^2 = 169.521$, $p < .001$
-2 log likelihood = 1945.964
Cox & Snell $R^2 = .105$
Nagelkerke $R^2 = .140$
Accuracy = 67.2%

#$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

variance in hospital operational efficiency, which is reasonable for cross-sectional data. The model's classification accuracy (67.2%) is acceptable for practical prediction. Controlling for hospital location ($C2_{LOC}$), four of the seven financial factors show significant effects ($p < .050$) on the likelihood of being a high-efficiency hospital ($Y1$), and one is marginally significant. In particular, profitability ($X1_{PRO}$), liquidity ($X2_{LIQ}$), capital structure ($X4_{CS}$), and working capital efficiency ($X6_{WCE}$) emerged as significant impactors; debt coverage ($X5_{DC}$) is marginally significant with $p = .050$, whereas FAE ($X3_{FAE}$) and FAA ($X7_{FAA}$) did not exhibit significant associations with operational efficiency.

Specifically, higher profitability is associated with better operational efficiency outcomes. A hospital's OMAR ($X1_{PRO}$) has a positive coefficient ($B = 0.023$, $OR = 1.024$, $p < .001$) and the largest Wald statistic (73.45), which indicates that hospitals with stronger OMARs have significantly higher odds of being in the high-efficiency group. This finding aligns with Watkins's (2000) emphasis on OMAR as a key performance metric and with prior evidence that efficient hospitals tend to be more profitable.

The CR ($X6_{WCE}$) also shows a significant positive impact ($B = 0.133$, $OR = 1.143$, $p = .023$). All else equal, a one-unit increase in the CR, indicating better short-term financial health, raises the odds of high efficiency by about 14.3%. This suggests that hospitals adept at managing current assets and liabilities can avoid disruptive cash shortages, thereby supporting smoother, more efficient operations. A high CR signifies a strong ability to meet short-term obligations, which in turn appears to facilitate operational efficiency in our results.

By contrast, LTDE ($X4_{CS}$) has a significant negative effect on operational efficiency ($B = -0.317$,

$OR = 0.729$, $p = .016$). Heavily leveraged hospitals, those with high debt relative to equity, are substantially less likely to achieve high efficiency, which has about 27% lower odds per unit increase in LTDE. This supports the view that excessive debt can strain hospital resources and flexibility, leading to lower efficiency. It is consistent with prior studies noting that high debt levels often coincide with financial distress and inefficiency in hospitals (e.g., Lin et al., 2011; Pink et al., 2006).

In our model, working capital management ($X6_{WCE}$) has the largest positive effect size, while high debt ($X4_{CS}$) exhibits the strongest negative impact, which underscores the practical importance of prudent financial structure.

Debt coverage measured by TIE ($X5_{DC}$) shows a marginally positive effect ($B = 0.005$, $OR = 1.005$, $p = .050$), which suggests that a higher ability to cover interest expenses contributes slightly to efficiency. A better TIE ratio signifies lower risk of financial default and more earnings available for operations, which intuitively should support efficiency; however, in our data, once a basic threshold of debt service is met, further increases in TIE yielded only minimal efficiency gains, about an increase of 0.5% per unit.

The results for liquidity reveal more complex relationships. Liquidity measured by DCH ($X2_{LIQ}$) is statistically significant ($B = -0.003$, $p = .003$), but its effect is very small in magnitude ($OR = 0.997$). Interestingly, the negative coefficient implies that holding more days of cash on hand is associated with slightly lower odds of being a high-efficiency hospital. This counterintuitive result may indicate diminishing returns to liquidity; excess liquid reserves might reflect underutilized funds that could have been invested in improvements. In other words, excessive liquidity indicates that the hospital's available operating funds have not been properly used to enhance capacity or performance.

Finally, neither FAE measured by asset turnover ($X3_{FAE}$) nor FAA measured by average plant age ($X7_{FAA}$) had a significant impact on operational efficiency in the model. The insignificant effect of asset turnover ($X3_{FAE}$) implies that simply generating more revenue per unit of assets does not automatically translate to operational outcomes when other financial factors are accounted for. We propose three possible causes of the weak link between fixed-asset turnover and operating outcomes among U.S. hospitals. All three stem from institutional and systematic characteristics unique to U.S. hospitals. Frist, under the current Medicare or Medicare reimburse payment system, hospitals in the U.S. are typically reimbursed for the specific services they provide (surgeries, tests, or procedures), not for the use of fixed assets such as buildings or equipment. Because the payments are all tied to billing codes for the specific medical services rather than how well the hospital uses its capital resources, hospital administrators have less financial motivation to improve the operational efficiency through enhancing the efficiency of using fixed assets. Second, hospitals often invest in new facilities and equipment for competitive or prestige reasons, engaging in a "medical arms race" of duplicating specialized services and cutting-edge technology, which expands capacity without proportionally raising patient output (Devers et al., 2003). Finally, many U.S. hospitals, especially the ones carrying out research and teaching missions, tie up fixed assets without generating corresponding patient-care outcomes. In sum, the unique reimburse payment system, the competitive and prestige capital spending, and non-patient caring missions could be the possible factors contributing to the weak correlation between fixed-asset turnover and hospitals' operational efficiency.

Likewise, the insignificant coefficient on average plant age ($X7_{FAA}$) suggests that newer (or older) facilities do not necessarily guarantee better operational efficiency. This finding echoes recent research which found no significant difference in efficiency performance between hospitals with newer and hospitals with older physical plants (Beauvais et al., 2021; Koundakjian et al., 2023). It appears that hospitals can maintain high operational efficiency even with aging assets but through maintenance or process improvements, and conversely, while capital investments in modern facilities alone may help, this it is not the primary factor of boosting operational efficiency.

In summary, our empirical results highlight profitability as a primary driver of hospital operational efficiency, followed by effective working capital management, while excessive leverage and, to a lesser extent, extreme liquidity positions can hinder efficiency. These findings carry useful implications: financially healthy hospitals that generate solid OMARs and manage liquidity and debt wisely are better positioned to achieve high operational efficiency. This aligns with theoretical expectations from resource-based and financial management perspectives, that is, robust finances provide the slack resources and stability needed to invest in staff, technology, and process innovations that improve efficiency. In contrast, hospitals carrying heavy debt or holding idle cash may face constraints in optimizing operations. The discussion that follows will explore these relationships further, including how hospital location (urban vs. rural location) might moderate the impact of financial metrics on operational efficiency.

Table 3. Financial performance and operational efficiency—rural vs. urban.

	Rural ($n = 149$)				Urban ($n = 1377$)			
	B	*SE*	Wald	*OR*	*B*	*SE*	Wald	*OR*
$X1_{PRO}$	0.060*	0.024	6.502	1.062	0.020***	0.003	55.267	1.020
$X2_{LIQ}$	−0.011*	0.005	5.261	0.989	−0.002#	0.001	2.937	0.998
$X3_{FAE}$	−0.411	0.564	0.532	0.663	0.177	0.112	2.465	1.193
$X4_{CS}$	0.414	0.750	0.305	1.513	−0.360**	0.136	7.040	0.698
$X5_{DC}$	−0.002	0.015	0.010	0.998	0.005*	0.003	4.034	1.005
$X6_{WCE}$	0.325	0.282	1.334	1.385	0.117#	0.061	3.659	1.125
$X7_{FAA}$	0.041	0.037	1.188	1.041	−0.005	0.008	0.310	0.995
Constant	−0.937	1.117	0.703	0.392	0.036	0.213	0.029	1.037
	Omnibus test of model coefficients: $\chi^2 = 18.697^{**}$, $p < .01$ −2 log likelihood = 106.050 Cox & Snell $R^2 = .118$ Nagelkerke $R^2 = .208$ Accuracy = 85.9%				Omnibus test of model coefficients: $\chi^2 = 126.227^{***}$, $p < .001$ −2 log likelihood = 1774.686 Cox & Snell $R^2 = .088$ Nagelkerke $R^2 = .117$ Accuracy = 66.1%			

#$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

4.2 Rural versus urban hospitals

In this section, we examine whether the relation between financial performance and operational efficiency is sensitive to hospital location. As shown in Table 3, our logistic regression results reveal notable differences between rural and urban hospitals in how financial performance relates to operational efficiency. We estimate the logistic regression of hospital operational efficiency on seven financial ratios as in Table 2, but separately for rural and urban hospital subsamples. The table reports unstandardized coefficients (*B*), standard errors (*SE*), Wald statistics, and odds ratios (*OR*).

Profitability ($X1_{PRO}$) is a strong positive predictor of efficiency in both the rural and urban groups, which confirms that more profitable hospitals are more likely to achieve better operational performance. This effect appears especially pronounced in rural hospitals ($OR = 1.062$ for rural and $OR = 1.020$ for urban), implying that even modest improvements in OMAR substantially raise the odds of being efficient for rural facilities. This finding aligns with prior studies showing that efficient hospitals tend to be more profitable and vice versa, and it reinforces the idea that strong profits give hospitals a buffer to invest in process improvements and quality initiatives.

In contrast, liquidity ($X2_{LIQ}$) exhibited a significant negative association with efficiency among rural hospitals, while its effect in urban hospitals was weak but marginally significant ($OR = 0.998$, $p = .09$). This result suggests that rural hospitals with very high cash reserves are less likely to be efficient in operation. One interpretation is that excessive liquidity might signal idle resources or overly cautious management rather than reinvestment into efficient operations. In resource-constrained rural settings, there may be a trade-off between banking cash and pursuing efficiency, as it is very difficult for rural hospitals to simultaneously maintain high margins and large cash cushions. Given that, a high level of liquid assets in a rural hospital is more likely driven by underinvestment in operational improvements and thus will lead to low operational efficiency. Urban hospitals did not exhibit this strong liquidity–efficiency trade-off. It is likely because they have greater access to capital and economies of scale, which reduces the need to hoard cash for emergencies.

Turning to other financial predictors, we find that FAE ($X3_{FAE}$) did not significantly impact operational efficiency in either rural or urban hospitals ($p > .10$). Our results suggest that asset utilization alone is not a decisive factor in whether a hospital is efficient, regardless of the geography of hospitals.

By contrast, capital structure ($X4_{CS}$) shows a significant contextual difference. In urban hospitals, a heavier debt load is significantly associated with lower operational efficiency (urban $OR = 0.700$, $p < .01$), which is consistent with the argument that high leverage and financial burden can undermine performance (Chang et al., 2014; Lin et al., 2011; Pink et al., 2006). Excessive debt may divert resources to interest payments and limit financial flexibility, thus hindering investments in improving hospital service quality. However, for rural hospitals, the debt ratio has no significant effect on operational efficiency ($p = .53$). This finding suggests that managing debt is particularly crucial for efficiency in larger urban institutions, whereas in rural hospitals debt levels have not had a key impact on operational efficiency. It is possible that many rural hospitals avoid heavy debt financing but rely more on grants or government support or that their debt is often at manageable levels due to smaller-scale capital projects, so its relationship with efficiency is nonsignificant.

The debt coverage ratio ($X5_{DC}$), measured by TIE, further underscores this pattern. In urban hospitals, a stronger ability to cover debt interest from earnings correlates with higher efficiency ($OR = 1.005$, $p < .05$), whereas in rural hospitals TIE has no significant effect on operational efficiency. Urban hospitals that comfortably cover their interest obligations are likely those with solid operating surpluses and with more access to financial resources, which in turn translates to better operational efficiency. In essence, an urban hospital that earns many times its interest expense can invest in efficiency initiatives, such as upgrading electronic health record systems, modernizing infrastructure for energy efficiency, expanding telehealth services, or adopting AI-based staffing tools. On the other hand, these hospitals are less pressured to delay equipment upgrades, reduce staffing levels, or limit service offerings to manage costs. For rural hospitals, many of which carry low debt to begin with, variation in interest coverage may be too small to impact operational outcomes, or other factors, such as external funding and cost control, dominate their efficiency profile.

We also observe a modest difference in working capital efficiency ($X6_{WCE}$), measured by CR, between the groups. In urban hospitals, a higher current ratio, which indicates strong short-term liquidity and prudent working capital management, has a marginally positive association with efficiency ($OR = 1.130$, $p = .056$). This suggests that maintaining a healthy balance of current assets to liabilities must help urban hospitals improve operation and avoid operational disruptions. Urban hospitals typically have complex operations and supply chains, so efficient working capital management, for example, avoiding overdue payables or stockouts of supplies, can contribute to smoother, more cost-effective care delivery. In rural hospitals, by contrast, CR was not a significant predictor of efficiency. Many rural hospitals operate on leaner budgets with less complex supply needs, so as long as minimum liquidity is met, having an extra-high CR does not necessarily improve their day-to-day efficiency.

Finally, FAA ($X7_{FAA}$) showed an insignificant relationship with efficiency in either setting. This indicates that newer facilities or equipment alone do not guarantee better operational efficiency, nor do older facilities contribute to a hospital's inefficiency. Operational efficiency appears to be associated more with how resources are managed than with the age of the physical plant. An older rural hospital can still be run efficiently through good management practices, and conversely, a modern urban hospital could still be inefficient if mismanaged.

In further analysis, we extend the model to include interaction terms between hospital location and each key financial factor (X_1 to X_7). All independent variables are mean-centered to mitigate multicollinearity, and interaction terms are constructed as the product of each centered variable with the location dummy (e.g., $X1_{PRO} \times C2_{LOC}$), where rural is set to 0 and urban is set to 1. We also include hospital size (measured by number of beds, $C1_{Size}$), ownership type dummies ($C3_{Own\_NFP}$), teaching status ($C4_{TCH}$), and for- and not-for-profit status ($C5_{NFT}$) as controls in this interaction model. The results are presented in Table 4.

We find that the interaction between location and liquidity ($X2_{LIQ}$) is statistically significant ($p = .012$), with a positive coefficient. This indicates that the impact of liquidity on the outcome varies by location: in rural hospitals, $X2_{LIQ}$ had a significant negative association with the outcome, consistent with the results in the rural-only model. However, in urban hospitals, this effect is substantially weaker and only marginally significant. Additionally, the interaction between working capital efficiency ($X6_{WCE}$) and location was marginally significant ($p = .078$). The positive main effect of $X6_{WCE}$ in rural hospitals becomes weak for urban hospitals, which suggests that strong working capital efficiency improves operations in rural settings more than in urban ones. No other interaction terms show statistical significance.

In sum, the location-specific analysis demonstrates that while profitability remains a universally crucial driver of hospital efficiency, the influence of other financial factors is highly context-dependent. This suggests that rural hospitals often rely on cost discipline to achieve viability, whereas urban hospitals must balance more complex financial structures. For example, Wang et al. (2001) find that rural hospitals in one state achieved better cost efficiency and productivity than urban hospitals, enabling higher profitability despite their smaller size. Our results similarly suggest that rural efficiency is closely tied to maintaining a solid profit margin and not accumulating excessive slack, whereas urban efficiency is tied to balanced financial structure with moderate debt and strong debt coverage. Our findings extend prior frameworks by showing the same financial ratio can have different performance implications depending on the hospital's geography.

These findings offer practical insights for hospital administrators and policymakers. First, hospital leaders should recognize which financial factors most strongly affect operational efficiency in their particular context. Rural hospital administrators may need to prioritize strategies that improve OMAR, for

Table 4. Financial performance and operational efficiency—with interaction and control variables.

	B	*SE*	Wald	*OR*
$X1_{PRO}$	0.055*	0.028	3.927	1.057
$X2_{LIQ}$	−0.015*	0.006	5.916	0.986
$X3_{FAE}$	−0.308	0.602	0.261	0.735
$X4_{CS}$	0.820	0.825	0.989	2.271
$X5_{DC}$	0.004	0.019	0.045	1.004
$X6_{WCE}$	0.613*	0.305	4.037	1.845
$X7_{FAA}$	0.061	0.041	2.219	1.063
$X1_{PRO} \times C2_{LOC}$	−0.038	0.028	1.868	0.963
$X2_{LIQ} \times C2_{LOC}$	0.015#	0.0060	6.297	1.015
$X3_{FAE} \times C2_{LOC}$	0.533	0.6150	0.751	1.704
$X4_{CS} \times C2_{LOC}$	−1.065	0.837	1.621	0.345
$X5_{DC} \times C2_{LOC}$	0.000	0.019	0.000	1.000
$X6_{WCE} \times C2_{LOC}$	−0.550#	0.312	3.100	0.577
$X7_{FAA} \times C2_{LOC}$	−0.061	0.042	2.100	0.941
$C1_{Size}$	0.003***	0.000	52.182	1.003
$C2_{LOC}$	1.037***	0.343	9.127	2.822
$C3_{Own\_NFP}$	−1.619***	0.246	43.236	0.198
$C4_{TCH}$	−0.485**	0.153	9.987	0.616
$C5_{NFT}$	−1.908***	0.428	19.911	0.148
Constant	−0.952**	0.353	7.260	0.386
	Omnibus test of model coefficients: $\chi^2 = 322.8$***, $p < .001$ −2 log likelihood = 1536.7 Cox & Snell $R^2 = .214$ Nagelkerke $R^2 = .285$ Accuracy = 72.0%			

#$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

instance, tightening cost control, expanding profitable service lines, or negotiating better payer rates as even slight gains in profitability can markedly boost their efficiency outcomes. At the same time, they should ensure that cash reserves, while important for stability, are actively used for service enhancements or process improvements rather than sitting idle. A large cash buffer alone does not guarantee efficiency and might indicate missed opportunities to invest in modernizing operations. Urban hospital executives, on the other hand, should be attentive about capital structure and debt management. The negative impact of high leverage on urban hospital efficiency suggests that administrators must carefully evaluate the return on debt-financed investments. Keeping debt at sustainable levels by using phased capital projects or utilizing equity and maintaining healthy debt coverage ratios will help ensure that financial obligations do not deteriorate operational performance. Urban hospitals that manage to limit debt burdens and cover interest easily can channel more resources into efficient initiatives, such as new health IT systems or process innovation, but not necessarily jeopardize financial stability. For policymakers and regulators, the results highlight that the approach of improving hospital efficiency should not be uniform. Instead, tailored policies are needed. For rural hospitals, policies that aim to strengthen OMARs and financial stability can indirectly raise efficiency; for example, enhanced reimbursement for rural providers, grant programs for cost-saving technology, or support for collaborations that improve economies of scale. Such measures recognize that rural hospitals often operate on thin margins; however, if they do not generate enough revenue to cover costs, they will risk being unable to pay staff, maintain facilities, invest in new programs, or deliver high-quality healthcare services. For urban hospitals, policy oversight might focus on encouraging prudent financial practices; for example, monitoring hospitals' debt levels through transparency requirements or debt ratio caps for certain public funding eligibility. Meanwhile, these hospitals should also focus on incentivizing reinvestment of surpluses into quality and efficiency programs. Overall, our findings underscore that financial health and operational efficiency are tightly correlated. Hospital administrators should view financial metrics not just as accounting outcomes but as strategic tools that can enable or constrain efficiency. Likewise, policymakers aiming to improve the performance of the hospital sector must account for contextual differences, for example, strengthening profitability and cash flow in vulnerable rural hospitals, while ensuring larger urban hospitals maintain balanced finances, to create conditions for sustained operational efficiency and high-quality care.

5 Conclusion

This study examined the relationship between hospital financial health and operational efficiency and how a hospital's geographic location influences this relationship. We investigated whether being an urban or rural hospital alters the impact of key financial indicators on efficiency. To explore this, we considered seven key financial ratios covering profitability, liquidity, debt coverage, asset efficiency, capital structure, and FAA. Using data from AHA and applying DEA to measure efficiency, we tested our hypotheses with regression analysis. The results confirmed that several financial metrics are closely linked to hospital efficiency. In particular, higher profitability, stronger debt coverage, balanced capital structure, and efficient working capital management were all associated with better efficiency. Notably, liquidity had a negative relationship with efficiency. In contrast, neither fixed asset turnover nor asset age showed a significant effect on efficiency. Hospital location appeared to moderate these relationships: in urban hospitals, more of the financial ratios (such as profitability and debt coverage) were linked to efficiency, whereas in rural hospitals fewer of these factors proved relevant. This underscores the importance of financial management in driving hospital performance and suggests that improving specific financial ratios can lead to better operational outcomes.

While this study contributes important evidence to the literature, there are several directions for future research that could extend and refine these insights. First, future studies may expand beyond the framework of Zeller et al. (1996) by exploring different or additional financial ratios, as our findings suggest that not all of the traditional measures are equally relevant. Given that profitability consistently emerged as the strongest determinant of efficiency, a more focused analysis on profitability-related metrics, such as return on assets (ROA) or return on equity (ROE), would provide deeper understanding of how financial performance supports operational outcomes. In addition, simulation modeling and predictive analytics could allow for testing long-term impacts of financial strategies under different location scenarios and policy environments. Another promising direction is to investigate how hospital management practices and decision making influence operational efficiency. Emerging evidence indicates that effective managerial strategies can improve key performance outcomes by enhancing patient flow and optimizing resource allocation (Zehir & Zehir, 2023). For instance, reorganizing caring processes based on patient volume and complexity has been shown to significantly improve flow efficiency and productivity, and simulation models suggest that increased resource support, such as financial subsidies or staffing, improves efficiency, whereas resource cuts or surges in patient volume can undermine performance (Huang et al., 2025). Additionally, the adoption of comprehensive management approaches, such as total quality management, has been linked to higher hospital operational performance. Given that, future research could try to provide more holistic understanding of efficiency drivers beyond financial metrics. Another potential avenue is to streamline ratio analysis by concentrating on a select few metrics rather than a broad set, which may yield clearer insights into the financial levers most critical for efficiency. Finally, future research should incorporate a wider range of control variables, such as teaching status (part of medical school or not), to capture a more comprehensive picture of hospital efficiency determinants beyond location alone.

In summary, this research provides empirical evidence that improving specific aspects of financial performance can enhance hospital efficiency and that location (urban vs. rural) plays a role in this relationship. By recognizing which financial indicators matter most in their context, hospital administrators can make more informed and sophisticated strategic decisions to boost operational productivity based on the financial analysis.

Data availability statement

The sample data was gathered from the 2020 American Hospital Association (AHA) U.S. Hospital Survey data sets. The 2020 AHA data sets are available through *American Hospital Association (AHA) Data & Insights* (https://www.aha.org/data-insights/aha-data-solutions). C. Christopher Lee, a coauthor of this paper, purchased the data sets. The data sets are exclusively licensed to C. Christopher Lee. *AHA Data & Insights* has imposed limitations on the use of the data sets, restricting them solely to his research and prohibiting any sharing. Consequently, the data sets are not publicly accessible. However, the filtered final sample data utilized in this paper can be obtained from C. Christopher Lee upon reasonable request, provided that permission is granted by *AHA Data & Insights*.

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