Application of Data Envelopment Analysis to Evaluate Health Regions Efficiency in Saudi Arabia

Walid Abdelfattah
Department of Mathematics, College of Arts and Science, Northern Border University, Rafha, Saudi Arabia
walid.abdelfattah@nbu.edu.sa (corresponding author)

Bader S. Alanazi
Department of Mathematics, College of Arts and Science, Northern Border University, Rafha, Saudi Arabia
bader.alenezi@nbu.edu.sa

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ABSTRACT

Efficient healthcare systems must provide quality care, ensuring equitable access and sustaining financial viability. This study employs Data Envelopment Analysis (DEA) to evaluate the efficiency of healthcare regions in Saudi Arabia over a five-year period (2017-2021). Departing from traditional hospital-centric assessments, the study takes a regional approach, offering a holistic view of the entire healthcare system. Inputs such as number of beds, physicians, and nurses, along with outputs like outpatients and inpatients, were considered. The study not only provides efficiency scores but also identifies reference health regions, benchmarks, and tangible targets for improvement. Notably, the impact of the COVID-19 pandemic on healthcare efficiency is analyzed, providing insights into adaptive strategies during crises. The findings contribute to the understanding of regional healthcare dynamics, offering actionable insights for policymakers, facilitating evidence-based resource allocation, and informing strategies for continuous improvement. Future research directions include a global benchmarking analysis and a qualitative exploration of policy implications. This study bridges the gap between academic research and practical policy considerations, emphasizing the importance of adaptability and resilience in healthcare systems.

Keywords-data envelopment analysis; efficiency evaluation; efficiency improvement; regional healtcare

I. INTRODUCTION

Healthcare systems globally face significant challenges in balancing quality care, equitable access, and financial sustainability. This necessitates continuous evaluation and optimization of efficiency to ensure optimal utilization of resources and maximize positive health outcomes for the population. Evaluating efficiency within healthcare is particularly complex due to its multifaceted nature, encompassing diverse inputs (e.g. healthcare personnel, infrastructure, and financial resources) and outputs (e.g. patient outcomes, health service accessibility, and disease prevention). Healthcare efficiency has been assessed using methods like Cost-Benefit Analysis (CBA) [1], and Stochastic Frontier Analysis (SFA) [2]. However, these methods have limitations. For instance, CBA often struggles to account for intangible benefits in healthcare, while SFA and DFA require assumptions about the underlying data distribution, which may not always hold true for healthcare data. Data Envelopment Analysis (DEA) offers an alternative approach that overcomes these limitations due to its unique advantages: (1) Non-parametric nature: Unlike SFA, DEA requires no prior assumptions about the underlying production function, making it suitable for complex healthcare settings where relationships between inputs and outputs are not fully understood. (2) Multiple inputs and outputs: DEA can efficiently handle situations with multiple inputs and outputs, a crucial feature for comprehensive healthcare assessments. (3) Identification of best practices: DEA benchmarks each unit against the most efficient performers, enabling identification of best practices and potential areas for improvement. (4) Decomposition of inefficiency: DEA allows for decomposing inefficiency into technical and scale inefficiencies, providing valuable insights into the sources of inefficiency within each unit.

Since the mid-eighties, DEA has been increasingly used to measure the performance of health care services. Studies have examined various healthcare entities, including hospitals, clinics, healthcare systems, and primary care centers [3–7]. These studies have yielded valuable insights into performance variations, best practices, and potential areas for improvement within specific healthcare contexts. Several studies have demonstrated the effectiveness of DEA in healthcare efficiency evaluation. For instance, authors in [5] reviewed numerous DEA applications in healthcare, highlighting its potential to inform policy decisions and resource allocation. Furthermore, the research examining healthcare efficiency categorizes studies based on their unit of analysis: countries, regions, hospitals, or specific units. These investigations aim to understand how well these entities utilize limited resources to deliver efficient and high-quality healthcare services. National studies, such as [8, 9], compare the efficiency of treatment approaches across different countries. Regional studies, like [10], examine efficiency in various geographical areas within a single nation. Hospital studies, such as [11, 12], investigate the efficiency of individual hospitals, often considering various hospital characteristics. Additionally, some studies explore integrating DEA with other methodologies to gain a more comprehensive understanding of healthcare efficiency.

The Saudi Arabian healthcare system has undergone significant development in the recent years. However, concerns regarding efficiency and resource utilization persist. Several studies have employed DEA to analyze the efficiency of specific healthcare entities within the Kingdom, such as public hospitals [13–15]. These studies have provided valuable insights into individual hospital performance but lack a comprehensive picture of the healthcare system at the regional level. This study aims to address this gap by applying DEA to evaluate the efficiency of Saudi Arabia's healthcare system at the regional level. This macro-level approach offers several advantages: (1) Holistic perspective: By analyzing regional performance, we gain a broader understanding of the overall healthcare system's efficiency, capturing inter-regional variations and potential disparities. (2) Policy-relevant insights: Evaluating regional efficiency provides valuable insights for policymakers to formulate targeted interventions and resource allocation strategies for specific regions. (3) Addressing equity concerns: A regional focus allows for identifying potential inequities in healthcare access and resource distribution across different regions.

By utilizing DEA, this study will identify efficient and inefficient health regions. In fact, benchmarking regional performance against the best practices will reveal areas excelling in efficiency and those requiring improvement. In addition, the decomposing inefficiency within each region will pinpoint areas needing targeted interventions, such as resource allocation, operational improvements, or capacity building. Furthermore, the findings will provide valuable evidence to inform policymakers in formulating strategies for enhancing regional healthcare efficiency and ensuring equitable access to quality care across the country.

II. METHODOLOGY

A. *Data Envelopment Analysis*

DEA is a non-parametric method for evaluating performance and to determine the relative efficiency of a group of comparable Decision-Making Units (DMUs) [16]. The DEA utilizes linear programming methods to analyze observed inputs and outputs by constructing an efficient production frontier derived from optimal practices. Each DMU's efficiency is assessed in comparison to this frontier. In mathematical terms, let x_{ij} and y_{rj} denote the inputs and outputs of a DMU j, respectively, with m inputs, s outputs, and n DMUs. The output-oriented DEA model measuring the efficiency of a given DMU k is:

$$Min\, E_k = \sum_{i=1}^{m} v_i x_{ik} \,/\, \sum_{r=1}^{s} u_r y_{rk} \tag{1}$$

subject to:

$$\frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}} \geq 1;\ j = 1, 2, \dots, n;\ u_r, v_i \geq 0\ \ \forall\, r, i$$

where u_r indicates the weight assigned to the output r, and v_i is the weight assigned to the input i.

Model (1) is a fractional programming model converted into linear programming, as follows:

$$Min\, E_k = \sum_{i=1}^{m} v_i x_{ik} \tag{2}$$

subject to:

$$\sum_{r=1}^{s} u_r y_{rk} = 1; \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0;$$

$$j = 1, 2, \dots, n;\ u_r, v_i \geq 0\ \forall\, r, i$$

B. *Data*

This study examines the efficiency of hospital management in all health regions of Saudi Arabia. The DEA method is utilized to assess the efficiency of resource utilization in delivering high-quality healthcare. DEA has been utilized in numerous studies to assess efficiency [17].

Saudi Arabia prioritizes providing strong healthcare services to its population. According to the most recent World Bank statistics [18], Saudi Arabia's healthcare sector contributed 5.5% of its GDP in 2018. Saudi Arabia's healthcare system is distinctive in its structure, with 20 healthcare regions separate from the 13 administrative regions. The regions are carefully defined according to population demographics, healthcare demands, and geographic characteristics to address the unique healthcare needs of each region. Public health facilities are distributed among three sectors: the Ministry of Health, other governmental sectors, and the private sector. Ministry of Health facilities are categorized based on their mission, equipment, technical level, and territorial competence. They include primary health care centers, hospitals, specialized units (such as cardiology, oncology, diabetes, and endocrinology), central and regional laboratories, and clinics (such as smoking cessation). In this study, all 20 health regions are considered DMUs for the efficiency of DEA measurements.

C. *Input and Output Selection*

While holding immense potential, big data in healthcare faces challenges like security, privacy, and integrating diverse data sources effectively. Authors in [19] review the use and effectiveness of data analytics in healthcare, examining secondary data sources such as books, journals, and other reputable publications between 2000 and 2020. The main challenge when using DEA to evaluate hospital efficiency, as in other real-world scenarios, is the careful selection of appropriate inputs and outputs. This topic is still commonly debated. In a recent preprint [20], a systematic review of 89 articles on DEA application in hospitals, specifically examining input and output selection methods, was conducted. The review categorizes hospital efficiency inputs into three groups:

capacity-related, cost-related, and staff-related, and outputs into two groups: production-related and quality-related.

This study focuses on the number of beds (Bs), physicians (Ps), and nurses (Ns) as key factors in healthcare provision. Beds represent physical space for patient care, physicians are medical doctors providing care, diagnosis, and treatment, and nurses include registered nurses and other professionals offering direct patient care. These variables make up the largest percentage of usage in their specific categories. Cost-related inputs were omitted because they are not available. The outputs chosen for this study were the total number of outpatients (Os) and the total number of inpatients (Is). These outputs represent the count of individuals receiving medical services at a hospital without being admitted and those admitted for treatment or surgical procedures requiring an overnight stay, respectively. According to [20], these outputs are commonly used to measure hospital efficiency. The data related to the corresponding regions' inputs and outputs during the 5 years from 2017 to 2021 were collected from statistical yearbooks downloaded from the official website of the Saudi Ministry of Health [21]. The data collection process was challenging due to the need to gather information from multiple files for each year of study. Therefore, careful selection, arrangement, and organization were required to create a consolidated, grouped file.

III. RESULTS

Between 2017 and 2021, the efficiency of the 20 health regions in Saudi Arabia was evaluated about the performance of their respective hospitals. MaxDEA software was used. The efficiency scores and their relative means are presented in Table I.

TABLE I. OBTAINED EFFICIENY SCORES

nº	DMU / H.Rg.	2017	2018	2019	2020	2021	Mean
1	Riyadh	0.637	0.695	0.681	0.746	0.762	0.7041
2	The Holy Capital	0.940	0.935	0.846	0.868	0.786	0.8752
3	Jeddah	0.566	0.549	0.527	0.724	0.847	0.6424
4	Ta'if	0.593	0.660	0.654	0.688	0.692	0.6574
5	Medinah	0.761	0.720	0.597	0.698	0.760	0.7073
6	Qaseem	0.996	1	1	1	1	0.9992
7	Eastern	0.910	1	0.741	0.731	0.867	0.8497
8	Al-Ahsa	0.705	0.634	0.659	0.693	0.686	0.6754
9	Hafr Al-Baten	0.640	0.759	0.752	0.670	0.957	0.7557
10	Aseer	1	0.988	1	1	1	0.9975
11	Bishah	1	1	0.808	0.826	0.734	0.8737
12	Tabouk	0.660	0.535	0.564	0.659	0.565	0.5966
13	Ha'il	0.816	0.614	0.569	0.653	0.648	0.6601
14	Northern	0.682	0.628	0.596	0.559	0.788	0.6508
15	Jazan	0.805	1	1	0.754	0.851	0.8820
16	Najran	0.742	0.905	0.910	0.896	0.926	0.8756
17	Al- Bahah	0.925	1	0.944	0.954	0.940	0.9526
18	Al- Jouf	0.898	0.880	0.899	0.633	0.820	0.8261
19	Qurayyat	1	1	1	1	1	**1**
20	Qunfudah	0.963	0.995	1	0.806	0.817	0.9162

The scores ranged from 0.527 to 1, with a higher score indicating greater efficiency. The average DEA efficiency score for all health regions is 0.8049. The health region of Qurayyat demonstrated exceptional efficiency in providing hospital services, achieving a perfect score of 1 on the DEA scale. This achievement is remarkable considering the region's limited healthcare resources, including a low number of physicians, beds, and nurses. The region has the lowest average number of physicians (372) and the second lowest average number of beds and nurses (490 and 1054, respectively). Another interesting finding refers to the health region of Riyadh, the capital of Saudi Arabia. This region ranks 14th out of 20 over the five years of study, with an efficiency mean of 0.7041, despite having the highest amounts of inputs and outputs compared to other regions.

The health regions of Qaseem, Aseer, Al-Bahah, and Qunfudah achieved an efficiency score of 1 at least once over the five year study period, with an overall efficiency mean exceeding 0.9. Jeddah, Taif, and Tabouk consistently showed low DEA efficiency scores, whereas Al-Ahsa and Hafr Al-Baten had fluctuating DEA efficiency scores over the study period. It is crucial to mention that DEA efficiency scores are comparative, not definitive. A score of 1 indicates that a health region is the most efficient among those included in the study, not necessarily perfectly efficient. Figure 1 shows the distribution of obtained efficiency means by health region.

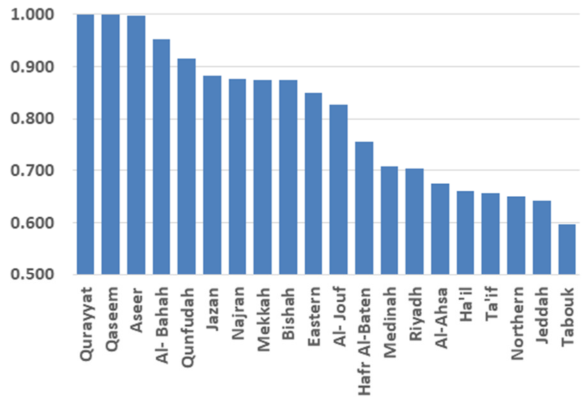

Fig. 1. Efficiency means by health regions

At this point, it is important to investigate the possible correlation between the number of hospitals and the efficiency scores in each health region. Increasing the number of hospitals could have advantages such as enhanced accessibility and specialization. However, it may also result in greater complexity in management and challenges in distributing resources. By computing the coefficient of correlation, a value of (- 0.1600) is obtained, indicating that there is no significant relationship between these two variables. This outcome also suggests the possibility that additional external factors, such as the size of the hospital, the distribution of specializations, and the density of the regional population, may have an impact on the obtained efficiency scores. Regrettably, the unavailability of relevant data prevents us from accomplishing this task in the current study.

IV. ANALYSIS AND DISCUSSION

From Table I, the efficiency mean for each year of the study could be deduced (Figure 2). Between 2017 and 2021, Saudi Arabia's hospitals' mean efficiency scores showed a dynamic trajectory. Following a peak in 2017, the score somewhat increased in 2018 before declining in 2019 and 2020. Interestingly, 2021 saw a notable resurgence to 0.8222.

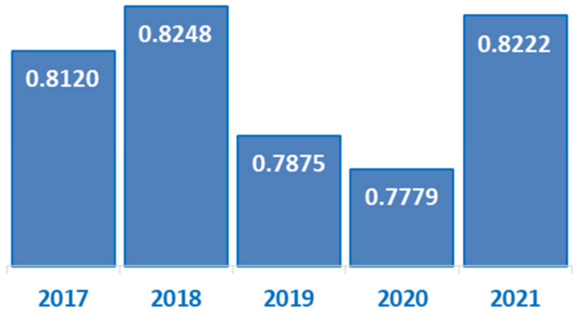

Fig. 2. Efficiency means for each year of the study.

However, the effect of the COVID-19 pandemic on healthcare services may account for a portion of the observed fluctuations. The pandemic probably put a strain on systems, changed how resources were allocated, and required modifications to protocols, which may have an impact on the variations in efficiency scores from year to year. The deviation of the efficiency score averages can be better understood by examining changes in the input and output amounts. Figure 3 demonstrates that there was not much variation in the quantities of inputs and outputs over the first two years of 2017–2019.

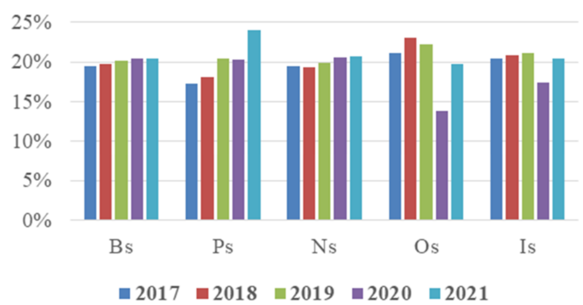

Fig. 3. Variation between 2017 and 2021 in the input and output (normalized averages).

Nonetheless, it is evident from the same figure that 2019–2020 saw a significant decline in output, particularly in terms of the overall number of outpatients. The fact that the COVID-19 pandemic peaked in this particular year may explain this. Actually, unexpected disruptions in the health-care systems brought on by the pandemic, which affected almost every nation on the globe, not just Saudi Arabia, may directly affect the way that patients register as both inpatients and outpatients. The impact of the COVID-19 pandemic on health decisions in hospitals was discussed in [22].

Saudi Arabian authorities, specifically the Ministry of Health, have taken many preventative measures to safeguard public health, in response to the COVID-19 pandemic. This included postponing non-urgent surgeries to shield vulnerable patients from potential infections, prioritizing critical cases in hospitals while directing others to healthcare centers, and introducing a mobile application allowing residents to book appointments, review healthcare providers, and obtain prescriptions remotely. These measures aimed to curb the spread of the virus and prioritize the well-being of the citizens. The 2021 recovery could be seen as the hospitals' adaptive efficiency in response to the crisis. This year, the total number of outpatients and inpatients almost reached the levels seen before the pandemic. Between 2020 and 2021, there was a slight rise in the number of physicians.

Since the main objective is to find a way to improve efficiency among inefficient DMUs, measuring efficiency is more of a means than a goal. One of the advantages of the DEA is that it illustrates the extent to which an inefficient DMU can outperform other DMUs by decreasing the quantity of its inputs and/or increasing the quantity of its outputs. One approach to this is through the use of a dual model. Using the dual of model (2), this study ascertains potential improvements that inefficient health regions can achieve. The explicit dual model is described below:

$$Max\ \phi \tag{3}$$

subject to:

$$\phi y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} \leq 0;\ r = 1, 2, \dots, s;$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} - x_{ik} \leq 0;\ i = 1, 2, \dots, m;\ \lambda_j \geq 0,$$

$$j = 1, 2, \dots, n$$

In this model, ϕ is scalar, such that ϕ^{-1} represents the proportional increase that will be simultaneously applied to all outputs of the k^{th} region to make it efficient. Thus, the value of ϕ^{-1} obtained from resolving this model defines the efficiency score of the k^{th} region. If $(\phi = 1)$, this DMU is considered efficient and inefficient if $(\phi > 1)$; $\phi^{-1} \in [0, 1]$.

The previous section measured the efficiency scores of the 20 health regions. Only three regions, represented by DMUs 6, 10, and 19, were found to be efficient in 2021, such that while maintaining their current input and output values, these regions can be considered as references for the other inefficient regions. Table II lists the target values of inputs and outputs for the 17 inefficient regions. In other words, this table provides the possible input and output adjustments that these can apply to achieve perfect efficiency. As an example, let us consider the region of Medinah, denoted by DMU 5. Its efficiency score for 2021 was 0.760, as shown in Table I. To enhance efficiency in this region, the following objectives need to be met: 2368 beds instead of 3118, 2377 physicians instead of 3216, and 4815 nurses instead of 6408. This region might maintain consistent output levels. Forcing individuals to visit a specific hospital in a particular region to ensure its efficiency is unreasonable. Alternatively, decision-makers in an inefficient health region with given resources can be encouraged to make efforts to take more patients.

Table II also provides the reference health region that each inefficient region is compared with in calculating their efficiency scores, in addition to their respective possible benchmarks.

TABLE II. TARGET VALUES OF INPUTS AND OUTPUTS FOR INEFFICIENT REGIONS TO ACHIEVE PERFECT EFFICIENCY

no	DMU / Rg.	DMU(s) of reference	Benchmark	Target amounts				
				Bs	Ps	Ns	Os	Is
1	Riyadh	6; 10; 19	1.4118; 0.4436; 3.052	6636	6667	13584	2071765	280926
2	The Holy Capital	6; 19	0.4957; 1.3787	2118	2130	4544	660776	90104
3	Jeddah	6	0.8997	2617	2624	5208	911262	96585
4	Ta'if	6; 10; 19	0.2029; 0.2577; 0.713	1540	1547	3031	456429	68585
5	Medinah	6; 19	0.7421; 0.4277	2368	2377	4815	800895	91112
7	Eastern	6	1.0295	2995	3003	5959	1042727	110519
8	Al-Ahsa	6	0.4847	1410	1414	2806	490961	52037
9	Hafr Al-Baten	6; 19	0.1374; 0.6973	741	747	1642	219426	33407
11	Bishah	10; 19	0.2409; 0.1117	616	618	1062	170652	28901
12	Tabouk	6; 10; 19	0.0751; 0.2793; 0.2254	980	983	1782	284912	44131
13	Ha'il	6; 10; 19	0.2797; 0.0797; 0.0534	1025	1028	1990	341619	40024
14	Northern	6	0.3061	891	893	1772	310048	32862
15	Jazan	6; 19	0.6255; 0.172	1904	1910	3829	653301	71747
16	Najran	6; 19	0.3907; 0.1366	1203	1207	2427	411436	45597
17	Al- Bahah	6; 10	0.1666; 0.1727	887	889	1628	281806	36454
18	Al- Jouf	6; 19	0.1367; 1.0102	893	900	2019	254763	41707
20	Qunfudah	10; 19	0.0924; 0.2274	327	328	631	86693	16022

Let us focus on the health region of Medinah (DMU 5), which is compared to the reference regions of Qaseem (DMU 6) and Qurayyat (DMU 19), with benchmark values of 0.7421 and 0.4277, respectively. Therefore, using the number of beds as an example, the specified target number of beds shown in Table II is calculated as follows:

$$x^*_{Bs(5)} = 0.7421\, x_{Bs(6)} + 0.4277\, x_{Bs(19)} \; = 2368$$

where $x^*_{Bs(5)}$ denotes the target number of beds for DMU 5, $x_{Bs(6)}$ is the current number of beds of DMU 6, and $x_{Bs(19)}$ is the current number of beds of DMU 19 ($x_{Bs(6)}$ and $x_{Bs(19)}$ are extracted from Table III).

By doing so, decision-makers can find areas where they can increase or decrease inputs or outputs to increase efficiency by comparing the current performance to targets. The information gathered can also aid in better resource allocation. Decision-makers can give priority to the areas that are located farthest from the efficiency frontier in order to provide them with more resources and assistance.

Relevant studies applying DEA to assess the efficiency of the healthcare sector in Saudi Arabia have primarily focused on hospital efficiencies. For instance, [13] utilized 4 inputs and 5 outputs in their DEA analysis to evaluate the efficiency of 91 hospitals. Authors in [15] compared the efficiency scores of hospitals from 2006 to 2014. Authors in [14] focused on analyzing the efficiency of hospitals in the Riyadh Region. The unique features of the current study compared to prior research can be outlined as follows:

- Focusing on regional health efficiency instead of hospital efficiency suggests that using DEA at a regional level can be an effective way to evaluate the efficiency of Saudi Arabia's healthcare system and inform policy decision makers. By studying the practices and strategies of efficient regions, other regions can learn and adopt best practices to improve their own efficiency.
- The study's period frame is relatively recent, and its most significant feature is that it includes the COVID-19 pandemic period, which makes it possible to assess its impact on efficiency.
- Suggestions for improving efficiency are based on explicit results. Actually, one benefit of the DEA approach is taken advantage of, as evidenced by the identification of reference DMUs and the amounts of inputs that need to be reduced and outputs that need to be increased for the inefficient DMUs.

TABLE III. CURRENT VALUES OF INPUTS AND OUTPUTS FOR EFFICIENT REGIONS (DMUs OF REFERENCE)

no	DMU / Rg.	Current amounts				
		Bs	Ps	Ns	Os	Is
6	Qaseem	2909	2917	5788	1012830	107350
10	Aseer	2330	2334	3843	654931	107552
19	Qurayyat	490	496	1215	115128	26758

V. CONCLUSION

In conclusion, this study utilized DEA to evaluate the efficiency of healthcare regions in Saudi Arabia, adopting a unique focus on regional efficiency rather than focusing on individual hospitals. Spanning five years and considering inputs such as the number of beds, physicians, and nurses, and outputs including the total number of outpatients and inpatients, the efficiency scores ranged from 0.527 to 1, with an average efficiency score of 0.8049 for all health regions. Notably, the region of Qurayyat consistently demonstrated exceptional efficiency with a perfect score of 1, despite its limited healthcare resources. The fluctuating efficiency scores observed between 2017 and 2021 reflected the impact of external factors, particularly the COVID-19 pandemic. The pandemic induced changes in healthcare resource allocation, patient behavior, and operational protocols, influencing the efficiency of healthcare regions. Notwithstanding the challenges, the adaptive efficiency of healthcare regions was evident, with a notable recovery in 2021.

One primary contribution of this study is its departure from the conventional hospital-centric approach to efficiency evaluation. The study provides a holistic view of the entire healthcare system, enabling policymakers to identify overarching trends, regional variations, and formulate strategies for system-wide improvement. Additionally, this study uniquely captures the influence of the COVID-19 pandemic on healthcare efficiency. By including the pandemic period in the analysis, the research offers valuable insights into the adaptive capacity of the healthcare system during crises and informs strategies for enhancing resilience in the face of unforeseen challenges. Furthermore, explicit suggestions for improvements identify reference health regions and benchmarks, offering decision-makers tangible targets for improvement. This approach empowers regional authorities with actionable insights, facilitating more informed resource allocation and intervention strategies.

The study's five-year longitudinal analysis provides a dynamic perspective on healthcare efficiency, allowing for the identification of trends and patterns. This contributes to a nuanced understanding of the evolving healthcare landscape, facilitating targeted interventions and adaptive strategies over time. By highlighting these contributions, this study not only advances academic understanding but also provides actionable insights for healthcare policymakers and stakeholders in Saudi Arabia, aiding in the continuous improvement of the healthcare system.

While this study utilized a comprehensive data set, limitations related to hospital size, specialization distribution, and regional population density, along with other external factors of each health region that could have a significant impact on efficiency scores may be addressed in future research. The use of DEA in this study provided valuable insights, but alternative efficiency measurement techniques could be explored in future research to offer a more comprehensive perspective.

Considering other future research directions, it would be valuable to integrate findings from studies such as the exploration of machine learning applications in supporting occupational safety and health decisions within hospital workplaces [22]. Understanding how machine learning can contribute to optimizing healthcare processes and resource allocation could enhance the overall efficiency of healthcare regions in Saudi Arabia. Additionally, the dynamic adaptive bio-inspired multi-agent system proposed in [23] for healthcare task deployment presents an intriguing avenue for investigation. Future research could delve into the practical implementation of such innovative systems within the Saudi Arabian healthcare context, assessing their potential impact on efficiency and adaptive capacity. Combining insights from these studies with a focus on the long-term effects of specific interventions, the role of technological advancements, and predictive modeling for crisis resilience could offer a comprehensive framework for advancing the understanding and enhancement of the healthcare system in Saudi Arabia.

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