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Evaluating the Financial Efficiency of the Healthcare System: A Three-Stage DEA Model Analysis

Relevance. Public health effectiveness is crucial for population health, especially in the face of global challenges like the COVID-19 pandemic. The study applies the Data Envelopment Analysis (DEA) model to measure the efficiency of operating costs in the health care system across various regions of Kazakhstan from 2017 to 2021. Existing methods for assessing healthcare effectiveness often overlook the system's complexity, which turns DEA into a valuable tool to identify inequalities in healthcare availability and quality.
Research objective. This study aims to employ the DEA model to measure the efficiency of operating costs in the health care system across regions of Kazakhstan in 2017–2021.
Data and methods. The DEA model was chosen for its ability to analyze the efficiency of operating costs. Data were collected from the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.
Results. Our findings indicate the need for increased healthcare financing in specific regions, emphasizing the importance of transparent spending. The study concludes that the DEA model can regularly assess health financing, ensuring resources are directed where most needed. The novelty lies in establishing a link between financing and health outcomes.
Conclusions. The study's results and methodology can be used by public health authorities in assessing operating costs' effectiveness, allocating resources judiciously, and making informed decisions to enhance the healthcare system.

KEYWORDS
Healthcare system, efficiency analysis, regions, regional economy, Data Envelopment Analysis, Kazakhstan.

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Оценка финансовой эффективности системы здравоохранения на основе трехступенчатой модели DEA

Актуальность. Эффективность здравоохранения важна для здоровья населения. Пандемия COVID-19 подчеркнула важность готовности здравоохранения к глобальным вызовам. Правильное использование ресурсов, развитие инфраструктуры и обучение медицинского персонала для более эффективного реагирования на будущие угрозы являются актуальными задачами. Существующие методы оценки эффективности здравоохранения не всегда учитывают сложность и многообразие системы здравоохранения. Оценка эффективности здравоохранения с помощью модели Анализа Свертки Данных (DEA) позволяет выявить неравенство в доступности и качестве медицинской помощи в разных регионах Казахстана.

КЛЮЧЕВЫЕ СЛОВА
Система здравоохранения, анализ эффективности, регионы, региональная экономика, Анализ Свертки Данных (DEA), Казахстан.

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Цель исследования. Целью настоящего исследования является применение модели DEA для оценки эффективности операционных расходов системы здравоохранения в регионах Республики Казахстан в период 2017–2021 гг.
Данные и методы. В качестве метода анализа для измерения эффективности операционных затрат была выбрана модель DEA. Данные для исследования были получены из Агентства по стратегическому планированию и реформам Казахстана.
Результаты. В статье проведена оценка эффективности финансирования здравоохранения в регионах Казахстана на основе анализа различных количественных показателей. Оценка показала необходимость увеличения финансирования здравоохранения в определенных регионах страны, но с соблюдением открытости и прозрачности в расходовании средств. Результаты позволяют сделать вывод, что модель DEA может использоваться для регулярной оценки финансирования здравоохранения по регионам, более точного учета потребностей каждого региона и направления средства в регионы, где они наиболее необходимы. Также, следует подчеркнуть новизну исследования, которая заключается в выявлении связи между финансированием и индикаторами здоровья населения в области здравоохранения.
Выводы. Результаты и методика исследования могут быть использованы государственными органами управления здравоохранением для оценки эффективности операционных затрат, ресурсов и принятия более обоснованных решений в разработке политик и программ по улучшению системы здравоохранения.

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评估医疗系统的财务效率：基于 三阶段DEA模型

现实性：医疗保健效率对于人口健康非常重要。 新冠疫情凸显了医疗保健应对全球挑战的重要性。 正确利用资源、发展基础设施和培训医务人员以更好地应对未来的威胁是当务之急。现有的医疗保健效率评估方法并不总能考虑到医疗保健系统的复杂性和多样性。使用数据包络分析(DEA) 模型评估医疗保健的有效性使我们能够识别哈萨克斯坦不同地区医疗保健的可用性和质量的不平等现象。
研究目标：本研究的目的是应用 DEA 模型评估 2017-2021 年期间哈萨克斯坦共和国各地区医疗保健系统运营成本的效率。
数据与方法：选择 DEA 模型作为衡量运营成本效率的分析方法。研究数据来自哈萨克斯坦战略规划和改革署。
研究结果：本文通过对各种量化指标的分析，评估了哈萨克斯坦各地区医疗融资的有效性。评估结果表明，有必要增加国内某些地区的医疗保健资金，但必须遵守支出的公开性和透明度。结果表明，DEA模型可分地区定期评估医疗筹资情况，更准确地反映各地区的需求，将资金引导到最需要的地区。此外，还应强调本研究的新颖之处，即确定了卫生部门筹资与卫生指标之间的联系。
结论：政府卫生当局可以利用该研究的结果和方法来评估运营成本、资源的有效性，并在制定改善医疗保健系统的政策和计划时做出更明智的决策。

关键词：
医疗保健系统、效率分析、区域、区域经济、数据包络分析(DEA)、哈萨克斯坦

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Introduction

In times of crises such as the COVID-19 pandemic, the assessment of healthcare efficiency gains heightened significance. The pandemic has exposed the vulnerabilities of healthcare systems when confronted with extraordinary challenges, which brought to the fore such questions as the optimal utilization of healthcare resources, the effectiveness of medical services, and their overall impact on public health. Pecoraro et al. (2021)

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and Wynia (2020) have offered valuable insights into this critical concern.

The healthcare sector plays a crucial role in shaping the overall health of a nation as it strives for effectiveness. Progress in the healthcare system serves as an indicator of social development, reflecting successful reforms and a higher level of professionalism. At both the state and local levels, it becomes imperative to ensure consistent funding for research, innovation and adherence to professional education standards. Nevertheless, this approach comes with challenges, and the accuracy of reforms directly affects the comprehensive and precise evaluation of healthcare system efficiency.

Since gaining independence in 1991, Kazakhstan's healthcare system has undergone significant transformations, driven by proactive governmental reforms to enhance access, quality, and affordability of healthcare for its citizens[1]. Post-independence, Kazakhstan's healthcare system witnessed decentralization measures, maintaining a balance between regional autonomy and central government control (Amagoh, 2021). The Ministry of Health shapes national health policies, while regional health departments manage healthcare services within their respective areas. These regional entities oversee state-owned hospitals and polyclinics, whereas national clinics and research centers are under the supervision of the Ministry of Health (Health Systems in Action: Kazakhstan, 2022).

In this research the lowest inefficiency score is observed in 2017. The Healthcare Minister of Kazakhstan associated the ineffectiveness of the healthcare system with corrupt practices, highlighting that in 2017, the healthcare sector ranked among the top five most corrupt sectors within the country's economy[2]. Widespread corruption can potentially influence the well-being of societies. Nations characterized by elevated corruption levels allocate a smaller proportion of their gross domestic product towards healthcare expenditures was proved by Glynn (2022). Moreover, President Kassym-Jomart Tokayev stated that special focus ought to be given to combatting corruption in customs, construction, education, and healthcare. The relevant government ministries are tasked with creating a comprehensive strategy for systematically eliminating corruption in these domains[3]. Therefore, the Ministry of Healthcare of the Republic of Kazakhstan together with the Anti-Corruption Agency has developed a roadmap to prevent corruption risks in the healthcare sector[4].

To enhance the efficiency of the national healthcare system, substantial efforts were made in legislation in 2018, aligning with the "Densaulyk 2016–2019" national healthcare advancement initiative. This resulted in a notable improvement in the healthcare system, as reported by the official information source of the Prime Minister of the Republic of Kazakhstan in 2019[5]. Meanwhile, a significant improvement is already demonstrated in Figure 1. The State Program for the Development of Healthcare of the Republic of Kazakhstan, "Densaulyk," for 2020–2025 was established with the objective of ensuring quality and affordable healthcare. Despite the anticipation of significant improvements in the healthcare system, the advent of COVID-19 in Kazakhstan in March 2020 disrupted these expectations, leading to adverse repercussions[6]. The COVID-19 crisis exposed the vulnerability of emerging economies, which were less able to withstand the economic shock than developed countries (Voskanyan, 2020).

Kazakhstan employs a mixed healthcare model, blending public and private elements. The government primarily provides healthcare through

[1] OECD Reviews of Health Systems: Kazakhstan (2018). Retrieved from: https://www.oecd-ilibrary.org/social-issues-migration-health/oecd-reviews-of-health-systems-kazakhstan-2018_9789264289062-en (Accessed: 31.06.2023).

[2] Minister: corruption in Kazakhstan's health care system is flourishing (2017). Retrieved from: https://ru.sputnik.kz/20170407/ministr-korrupciya-v-sisteme-zdravoohraneniya-kazahstana-procvetaet-1954450.html (Accessed: 10.07.2023).

[3] The head of state held a meeting on combating corruption (2022). Retrieved from: Official website of the President of the Republic of Kazakhstan. Retrieved from: https://www.akorda.kz/ru/glava-gosudarstva-provel-soveshchanie-po-voprosam-protivodeystviya-korrupcii-1128 (Accessed: 10.07.2023).

[4] The Ministry of Health of the RK jointly with the Anti-Corruption Agency Discussed The Issues of Minimizing Corruption Risks (2023). Retrieved from: Ministry of Health of the Republic of Kazakhstan. Retrieved from: https://www.gov.kz/memleket/entities/dsm/press/news/details/505996?lang=ru (Accessed: 11.07.2023).

[5] Densaulyk State Health Development Program: key indicators for 2018 (2018). Retrieved from: Official information resource Prime Minister of the Republic of Kazakhstan. Retrieved from: https://primeminister.kz/ru/news/zdravoohranenie/gosprogramma-razvitiya-zdravoohraneniya-densaulik-kluchevie-pokazateli-za-2018-god-17654 (Accessed: 11.07.2023).

[6] Covid-19 in Kazakhstan: the scope of the problem, assessment of services, health and social protection (2021). Retrieved from: 21_05_COVID_2_.indd (soros.kz) (Accessed: 12.07.2023).

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state-owned facilities like hospitals, clinics, and polyclinics. The establishment of the Social Health Insurance Fund in 2016 aimed to become the main buyer of publicly funded healthcare services. The fund collects insurance premiums from employees and employers and began reimbursing services in 2020[7] (Hejduková & Kureková, 2016).

This study aims to assess the effectiveness of healthcare financing across the regions of Kazakhstan from 2017 to 2021. Using a non-parametric technique, we intend to assess changes in the efficiency of healthcare financing in Kazakhstan's regions from 2017 to 2021 through Data Envelopment Analysis (DEA). DEA is selected for its suitability in measuring productive efficiency, considering the distinctive management characteristics of medical establishments and financing expenditures in the regions of Kazakhstan. We are going to identify the level of efficiency by using various indicators, such as operating costs, the number of medical facilities, beds, and other health metrics.

The above-described purpose of the study has determined the following goals:

– identify indicators for the DEA model and analyze financial data in the healthcare system of the Republic of Kazakhstan using the DEA method;

– examine changes in healthcare financing efficiency in different periods, encompassing periods before and after the COVID-19 pandemic;

– devise recommendations for enhancing the healthcare financing system in Kazakhstan, propose healthcare and financing solutions, and outline avenues for further research in this domain.

Theoretical novelty in this study lies in the first-time application of the DEA method to study the healthcare sector of the country. With multiple inputs and outputs, this application contributes fresh insights by showcasing the method's adaptability to a new context.

The non-parametric DEA method, in comparison to existing approaches, effectively gauged performance levels. The authors enhanced and adjusted the methodology by expanding input and output indicators to evaluate the financial efficiency of the healthcare system at the regional level.

Furthermore, the practical significance of the research extends to potential use by government healthcare agencies for assessing the system's effectiveness, informing sector development, and shaping policies. However, a limitation of the study is the absence of detailed official data on healthcare fund allocation, hindering an in-depth regional analysis for the case of Kazakhstan.

This article will begin by presenting an overview of the methodology, followed by the selection of relevant indicators that will be applied to the study of various regions of Kazakhstan. Subsequently, we will assess the efficiency of healthcare financing across the regions and discuss the resulting efficiency scores, ultimately determining the levels of efficiency.

Finally, it is worth noting that there is a lack of studies evaluating healthcare financing systems at the regional level. The evaluation is necessary, however, since it enhances data comparability across diverse regions, enabling researchers to identify the most successful financing and management practices. Therefore, our aim is to bridge this gap and provide a more nuanced consideration of specific regional characteristics, facilitating the adaptation of financing strategies to meet local needs. Our findings can be of interest to local authorities and healthcare organizations, seeking to make well-informed decisions regarding the financing and management of their regional healthcare systems.

Literature Review

The effectiveness of healthcare financing was evaluated in many countries. For instance, Ivankova et al. (2020) assess the effectiveness of health care financing in OECD countries by applying regression analysis with the use of indicator limits. Their methodology, however, was unable to provide a complete picture of the efficiency of health care financing: the relationship between the indicators was investigated, but the efficiency of financing itself was not identified.

Onwujekwe (2019) assesses the effectiveness of health financing in Nigeria using in-depth interview where inefficiency in health financing was identified. But the methodology failed to fully uncover and determine the extent of inefficiency.

It should be noted that we have found very few works devoted to analyzing the financial efficiency of the health care system and the methodologies used in the works could not reveal the level of efficiency.

[7] World Health Organization annual report 2019 (2019). Retrieved from: https://apps.who.int/iris/handle/10665/333249 (Accessed: 13.07.2023).

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Nevertheless, there are several works employing Data Envelopment Analysis (DEA) to identify the effectiveness of certain financial and medical resources. However, the application of DEA in healthcare cost-benefit analysis is still relatively limited.

Liu et al. (2021) conducted the analysis of health system cost-benefit and provided several key insights. They showed that the provision of pediatric services in China exhibits significant geographical heterogeneity, evident resource redundancy, and a limited role for financial capital. To enhance the efficiency of public pediatric services, they suggested that improvements in economic, technological, and professional environments, coupled with investments in urbanization, education, and an increase in the birth rate, can contribute positively.

Furthermore, Gong & Kang (2023) employed the DEA model and Difference-in-Differences (DID) analysis to optimize the allocation of medical and healthcare financial resources. Their objective was to enhance employee health within the corporate sector.

Additionally, Wu (2023) emphasized the importance of reducing medical costs to enhance financial efficiency in hospitals. This research, however, focused exclusively on the level of individual hospitals.

Measuring a country's development often revolves around the status of its health systems, which serve as crucial indicators (Alexander, 2003). A shared priority for nations is ensuring citizens' access to sufficient medical prevention, protection, and care. The World Health Organization (WHO) underscores the significance of a well-functioning health system that provides quality services promptly and appropriately to all individuals.

Key constituents of public healthcare systems encompass funding, resources, effective leadership, and governance[8]. Resources include medical personnel, healthcare facilities, equipment, and medications (Jovanovic, 2013). Human resources stand as the linchpin of any health system, requiring ongoing development (Kuhlmann et al., 2018). The availability and equitable distribution of resources are essential prerequisites for an efficient healthcare system, necessitating efficient funding mechanisms.

Healthcare policies are tailored to a country's economic capacities, resulting in distinct health systems with varied funding models (Greer et al., 2017b).

Generally, health systems can be categorized into four models (Wallace, 2013):

1) The Beveridge model relies on taxation for financing, providing universal healthcare through state-owned institutions (Hejduková & Kureková, 2016);

2) The Bismarck model relies on mandatory health insurance contributions, covering the entire population with a non-profit orientation (Wranik, 2011);

3) The National Health Insurance (NHI) model combines elements of the Bismarck and Beveridge models, with predominantly private institutions and state-paid services[9];

4) The out-of-pocket model is prevalent in underdeveloped countries, where individuals bear full healthcare costs, often limiting access to the wealthier population.

Funding models shape healthcare access and affordability, and different models may coexist within countries. For example, the United States has elements from all four models, often classified as having an out-of-pocket model due to high per capita health insurance expenditure (Squires, D. & Anderson, C., 2015).

Efficiency is a goal for healthcare systems, aiming for resource optimization and adequate services (Cylus & Pearson, 2016). Thus, assessing healthcare system efficiency is vital, enabling accurate resource allocation and identifying improvement areas (Varabyova & Müller, 2016).

Efficiency assessment in healthcare remains a topic of interest. Radojicic et al. (2019) used Data Envelopment Analysis to assess healthcare efficiency in 22 countries. Most literature focuses on hospital efficiency, with limited studies evaluating national health system efficiency (Hollingsworth, 2008). Interest grew after the World Health Organization's 2000 report evaluated health system effectiveness across 191 countries (Evans et al., 2001).

As for Kazakhstan, there are very few works analyzing the financial efficiency of the health-

[8] World health statistics (2010). Retrieved from: https://www.who.int/publications/i/item/9789241563987 (Accessed: 15.07.2023).

[9] World Health Organization annual report 2019 (2019). Retrieved from: https://www.modernacupuncture.com/docs/2019-WHO-Report.pdf (Accessed: 16.07.2023).

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care system, but in the article "SWOT Analysis and Expert Assessment of the Effectiveness of the Introduction of Healthcare Information Systems in Polyclinics in Aktobe, Kazakhstan", the authors noted the inefficient use of financial resources in one of the regions of the Republic of Kazakhstan (Yermukhanova et al., 2022).

Furthermore, Doskeyeva et al. (2018) examined the outcomes of healthcare financing system reforms and identified persistent challenges. Notably, the management and organization of financial resources emerged as a prominent issue.

However, there have been no studies regarding Efficiency assessment in healthcare in the regions of the Republic of Kazakhstan using Data Envelopment Analysis.

Methods and Data

The evaluation of healthcare financing efficiency in Kazakhstan relies on Data Envelopment Analysis (DEA), a method commonly employed for assessing socioeconomic trends (Cooper et al., 2011). The DEA methodology enables us to compare the efficiency level to an 'ideal' state, representing the most optimal development level of the analyzed sphere for a specific year. This approach allows us to assess how the efficiency of the healthcare sector changes over the years under consideration.

DEA analysis proves suitable for researching healthcare efficiency, facilitating the establishment of input and output parameters to assess the healthcare sector's condition and efficiency over the specified period (Stefko et al., 2018). For our study, we chose a calendar year to dynamically evaluate the efficiency of Kazakhstan's healthcare system. The annual efficiency index serves as an abstract analogy to the primary economic indicators found in the statistical reports of the country's socio-economic development. However, the distinction lies only in the quantitative evaluation, as the annual efficiency index is calculated using a comparative model with absolute efficiency.

The DEA approach encompasses two fundamental models: CCR (Charnes, Cooper, Rhodes) and BCC (Banker, Charnes, Cooper). Both can be applied in input-oriented, output-oriented, and non-oriented models. In this research, an input-oriented model based on the variable returns to scale (VRS model) was employed. The VRS model is more relevant for the healthcare system in the regions of Kazakhstan due to its complexity with numerous inputs and outputs, likely exhibiting some degree of increasing or decreasing returns to scale. Additionally, it is more flexible than the CRS model and widely used in evaluating the efficiency of hospitals, health systems, and government agencies. This model was chosen for its practical relevance in assessing technical efficiency (Jia and Yuan, 2017).

The computation relies on mathematical programming to achieve the best possible outcome. In this context, each individual year is treated as a Decision-Making Unit (DMU). The mathematical model used to assess the healthcare system's efficiency is expressed as an equation:

$$E_{\max} = \frac{k_1 y_1 + k_2 y_2 + \ldots + k_y y_{y0}}{n_1 x_1 + n_2 x_2 + \ldots + n_m x_{m0}} = \frac{\sum_{r=1}^{s} k_y y_{y0}}{\sum_{i=1}^{m} n_i x_{i0}} \quad (1)$$

where E — efficiency evaluation, determined using DEA; j — the number of years considered for analysis; y_{rj} — the volume of indicator r, adopted in a specific year j; x_{ij} — the volume of result i, adopted in a specific year j; i — the number of indicators used in the country's healthcare sector; r — the number of resulting indicators of the country's healthcare sector; k_r — resource weight coefficient r assigned by DEA; n_r — weighting coefficient of result i assigned by DEA.

The data required for DEA estimation are the outputs y_{rj} and inputs x_{ij} over a finite period in a given year in a definite set of indicators. Thus, x_{ij} shows the volume of input parameter i that applies year j, and y_{rj} is the volume of parameter r at the output for year j.

If the calculated efficiency (E) for a specific year is below one, it signifies inefficiency for that period. The prioritized goals interpret the entirety of the computed results, providing insights into the implications of different efficiency levels.

In the model, constraints are applied to coefficients k and n to ensure that the calculated efficiency does not exceed 100%:

$$j = \frac{k_1 y_{1j} + k_2 y_{2j} + \ldots + k_y y_{rj}}{n_1 x_{1j} + n_2 x_{2j} + \ldots + n_m x_{mj}} = \frac{\sum_{r=1}^{s} k_y y_{rj}}{\sum_{i=1}^{m} n_i x_{ij}} \leq 1 \quad (2)$$

where $k_1, \ldots, k_n > 0$ and $n_1, \ldots, n_m \geq 0$.

To apply DEA in a standard linear programming package, the objective function should be transformed as follows:

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$$\text{Max}E = k_1 y_1 + k_2 y_2 + \ldots + k_r y_{r0} = \left(\sum_{r=1}^{s} k_r y_{r0} \right) \quad (3)$$

According to the constraints:

$$n_1 x_{10} + n_2 x_{20} + \ldots + n_m x_{m0} = \sum_{i=0}^{m} n_i x_{io} = 0 \quad (4)$$

$$k_1 x_{1j} + k_2 y_{2j} + \ldots + k_r y_{rj} \leq$$
$$\leq n_1 x_{1j} + n_2 x_{2j} + \ldots + n_m x_{mj} \quad (5)$$

We will transform the above expression into a standard mathematical form:

$$\sum_{r=1}^{s} k_r y_{rj} \leq \sum_{i=1}^{m} n_i x_{ij} \quad (6)$$

Weighting coefficients are determined using a "coverage model". The dual linear programming model will be used at $E \rightarrow$ min under the following prerequisites:

$$\sum_{j=1}^{s} \lambda_j x_{ij} \leq E x_{i0} \quad i = 1, 2, \ldots, m \quad (6.1)$$

$$\sum_{j=1}^{s} \lambda_j y_{ij} \leq y_{r0} \quad r = 1, 2, \ldots, s \quad (6.2)$$

$$\lambda_j \geq 0 \quad q = 1, 2, \ldots, z \quad (6.3)$$

The mathematical calculation reduces the equations to linear through the slack variable. The binary efficiency model minimizes the value of E, subject to the constraints (6.1) that the sum of weighted inputs by year is less than or equal to the input of the year for which the estimate is made, (6.2) the weighted sum of outputs by year is grander than or equal to the output of the year being evaluated. λ is the value of the weighting coefficient. All years with a non-zero value of λ indicator are effective.

Years for which the E efficiency indicator equals one represent the efficiency limit, while years with an E efficiency indicator less than one indicate inefficiency. The assessment of the healthcare system efficiency in Kazakhstan is conducted using the Python (pyDea) software platform

This approach in calculation allows us to determine the efficiency of the healthcare sector in regions of Kazakhstan by year in the given period (2017–2021). This time interval was chosen because the last study on the healthcare financing system in Kazakhstan was conducted in 2016 (Ahmed et al, 2019). However, the methodology for assessing the efficiency of this system at the regional level in the country has not been applied and used.

In this research, we analyze Kazakhstan's healthcare financing system. We have developed Decision Making Units (DMU) at the regional level, consisting of 17 regions in 2021 and 16 regions in 2017. In the first step, DEA window analysis is performed with 6 inputs and 4 outputs (Table 1). DEA window analysis calculates healthcare

Table 1

DEA model variables

Ind.	Variable	Definition
Input variables		
X1	Operating Expenses	Total number of operating costs for maintaining the health care system, producing products and providing services
X2	Number of medical facilities	Total number of medical facilities in the country
X3	Number of beds	Total number of beds in the medical facility
X4	Number of beds for sick children	Total number of beds for children in a medical facility
X5	Number of doctors	The total number of doctors of the medical facility
X6	Number of secondary medical staff	Total number of secondary medical staff
Output variables		
Y1	Child mortality rate	Children under the age of 5 per 1 thousand births are considered
Y2	Maternal mortality rate	Number of women's deaths during childbirth per 100,000 live births is considered
Y3	Mortality rate of the population from infectious and parasitic diseases	Mortality rate from infectious and parasitic diseases per 100,000 population is considered
Y4	Life expectancy	Average number of years that a person could expect to live

Source: compiled by the authors

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facilities and operating expenses, which are significant financial statements. The selection of inputs and outputs in the DEA method is informed by a literature review, as illustrated and determined by Worthington (2004)

As the DEA model is established based on the ratio of input and output parameters, we identify the key determining parameters for the medical field. The specifications and general characteristics of these parameters are outlined in Table 1.

Results and Discussion

Healthcare expenditure worldwide experienced significant growth in the last twenty years, increasing by over twofold in real terms. In 2019, the total expenditure amounted to US$ 8.5 trillion, equivalent to 9.8 % of the global GDP. However, the distribution of these funds was highly unequal, with approximately 80% attributed to high-income countries.[10] The distribution of global health expenditure across income groups reveals significant disparities. High-income countries allocate a substantial portion, ranging from 17% to 37 % (with the USA spending 42 %), while upper-middle income countries spend between 2.8 % and 16 % (Kazakhstan spending 3,79 %) (Global Health Expenditure Database). In contrast, low-income countries allocated a mere 0.24 % of their GDP towards healthcare in 2019. This stark contrast underscores the substantial inequality in the allocation of global health spending across different income groups.[11]

The report produced by the European Observatory on Health Systems and Policies "Health Systems in Action Insight (2022)" highlighted Kazakhstan's economic prosperity. The report also noted that healthcare expenditure is relatively modest and comparatively low considering the country's national wealth. In 2019, individual health spending in Kazakhstan reached US$ 765 when adjusted for purchasing power. Although surpassing the Central Asian average of US$ 552, it fell short of the averages for upper-middle-income nations within the WHO European Region (US$ 1,338) and the region as a whole (US$ 3,226).[12]

This research aims to assess the financial efficiency of expenses in the regions of Kazakhstan, thus the DEA approach was applied to the regions of Kazakhstan in the period of 2017–2021 using data that were gathered from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

Efficient regions are those with DEA efficiency scores equal to 1, operating at the efficiency frontier. They fully utilize inputs to produce outputs and perform optimally given the considered inputs and outputs. Close-to-efficient regions have scores very close to 1, indicating high efficiency with minor areas for improvement. Inefficient regions, with scores significantly less than 1, suggest suboptimal use of inputs for outputs. Identifying inefficient regions is crucial because it signals areas that can be improved to enhance overall performance and efficiency.

The results that were calculated by applying DEA methodology are shown in Table 2.

The regions of Atyrau, West Kazakhstan, North Kazakhstan, and Mangistau displayed notably high efficiency scores. In contrast, Akmola, Aktobe, Almaty, Kostanay, Kyzylorda, Pavlodar, Turkestan, Nur-Sultan city, and Shymkent city showcased scores that were closely aligned with those of the efficient regions. Zhambyl and Almaty city delivered performances that fell within the average range, while Karaganda and East Kazakhstan demonstrated significantly lower levels of efficiency.

This disparity in resource use and operational expenditures across different regions in Kazakhstan highlights variations in efficiency regarding resource allocation and financial management. These differences underscore the need for tailored evaluations and governance strategies in healthcare and other public sector domains. The insights gained from these findings provide a valuable foundation for future investigations and the development of strategies to improve performance in regions with lower efficiency levels.

[10] Report of the Health Systems Governance and Financing UHL. Global expenditure on health: Public spending on the rise? (2021). Retrieved from: https://www.who.int/publications/i/item/9789240041219 (Accessed: 20.07.2023).

[11] Official site of the World health organization. Global Health Expenditure Database (2022). Retrieved from: https://apps.who.int/nha/database/PHC_Country_profile/Index/en (Accessed: 20.07.2023).

[12] European Observatory on Health Systems and Policies, WHO Europe. Health systems in action: Kazakhstan (2022). ISBN: 978 92 890 5914 5. Retrieved from: https://eurohealthobservatory.who.int/publications/i/health-systems-in-action-kazakhstan-2022(Accessed: 22.07.2023).

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Table 2

Results of the DEA (input orientation, VRS) analysis

Regions/DMUs	2017	2018	2019	2020	2021	growth rate to the basic year, %	Average efficient score
Akmola	0,80	1,00	1,00	1,00	1,00	25	0,96
Aktobe	0,77	0,86	0,84	1,00	1,00	29	0,89
Almaty	0,43	1,00	0,77	1,00	0,79	83	0,80
Atyrau	1,00	1,00	1,00	1,00	1,00	0	1,00
West Kazakhstan	1,00	1,00	1,00	1,00	0,99	–1	1,00
Zhambyl	0,61	0,71	0,67	0,70	0,72	18	0,68
Karaganda	0,42	0,46	0,46	0,47	0,43	9,53	0,45
Kostanay	0,75	0,79	0,83	1,00	0,85	5,43	0,85
Kyzylorda	0,73	0,75	0,75	1,00	1,00	3,80	0,85
Mangistau	1,00	1,00	1,00	1,00	1,00	0,00	1,00
Pavlodar	0,78	1,00	1,00	1,00	0,90	15,4	0,94
North Kazakhstan	1,00	1,00	1,00	1,00	1,00	0	1,00
Turkestan	0,89	0,69	0,69	1,00	1,00	12	0,86
East Kazakhstan	0,42	0,48	0,46	1,00	0,48	14,28	0,57
Nur-Sultan city	1,00	1,00	1,00	1,00	1,00	0	1,00
Almaty city	0,89	0,79	0,61	1,00	0,57	0,64	0,77
Shymkent city	-	1,00	0,87	1,00	1,00	0	0,97

Source: Calculated by the authors based on the Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2023). Retrieved from: https://stat.gov.kz/ru/industries/social-statistics/stat-medicine/ (Accessed: 20.06.2023)

The wide gap in economic development between different regions of Kazakhstan is a major obstacle to national development (Kireyeva et al., 2022).

According to the results of the DEA analysis and its average score for 2017–2021, it is possible to divide the regions into the following groups:

1. Efficient regions (efficiency score equals 1.0): Atyrau, West Kazakhstan, North Kazakhstan, and Mangistau;

2. Highly efficient regions (from 0.8 to 1.0): Akmola, Aktobe Almaty, Kostanay, Kyzylorda, Pavlodar, Turkestan, Nur-Sultan city, Shymkent city;

3. Medium efficiency (from 0.6 to 0.8): Karaganda, Almaty city.

4. Inefficient regions (under 0.6): Karaganda, East Kazakhstan

The period from 2017 to 2021 saw varying growth rates among several regions. The region of Almaty led with the highest growth rate of 83%, while Aktobe, Akmola, Zhambyl, Pavlodar, East Kazakhstan, and Turkestan demonstrated moderate growth rates of 29%, 25%, 18%, 15.4%, 14.28%, and 12%, respectively.

Conversely, some regions experienced slower growth, such as Karaganda with a rate of 9.53%, Kostanay at 5.43%, and Kyzylorda at 3.80%. Notably, the growth rate in Almaty was only 0.64%. Additionally, West Kazakhstan showed a negative growth rate of –1%. Figure 1 shows the regions that lie on the efficiency frontier.

Every year the amount of money allocated to health care increases, for example, local budget expenditures on healthcare in Kazakhstan almost doubled from 2018 to 2022, reaching 0.3 billion tenge. Shymkent saw the most significant growth, with expenditures increasing from 0.1 billion tenge to 9.9 billion tenge over the same period. Almaty city had the largest share of local budget expenditures on healthcare, at an average of 14.0 % for 2018–2022. Turkestan region came in second, with an average of 9.9 %, followed by Almaty region (9.0 %), East Kazakhstan region (8.8%), and Astana city (7.2 %). The lowest share of local budget expenditures on healthcare was recorded in Mangistau region (2.3 %), West-Kazakhstan region (2.6 %), North-Kazakhstan region (3.2 %), Akmola region (3.3 %), Atyrau region (3.6 %), and Shymkent city (3.7 %).[13]

[13] How much money from the RK state budget is spent on healthcare (2023). Retrieved from: https://spik.kz/skolko-deneg-iz-gosbyudzheta-rk-tratitsya-na-zdravookhranenie?ysclid=lm9c85w3x8976138483 (Accessed: 27.07.2023).

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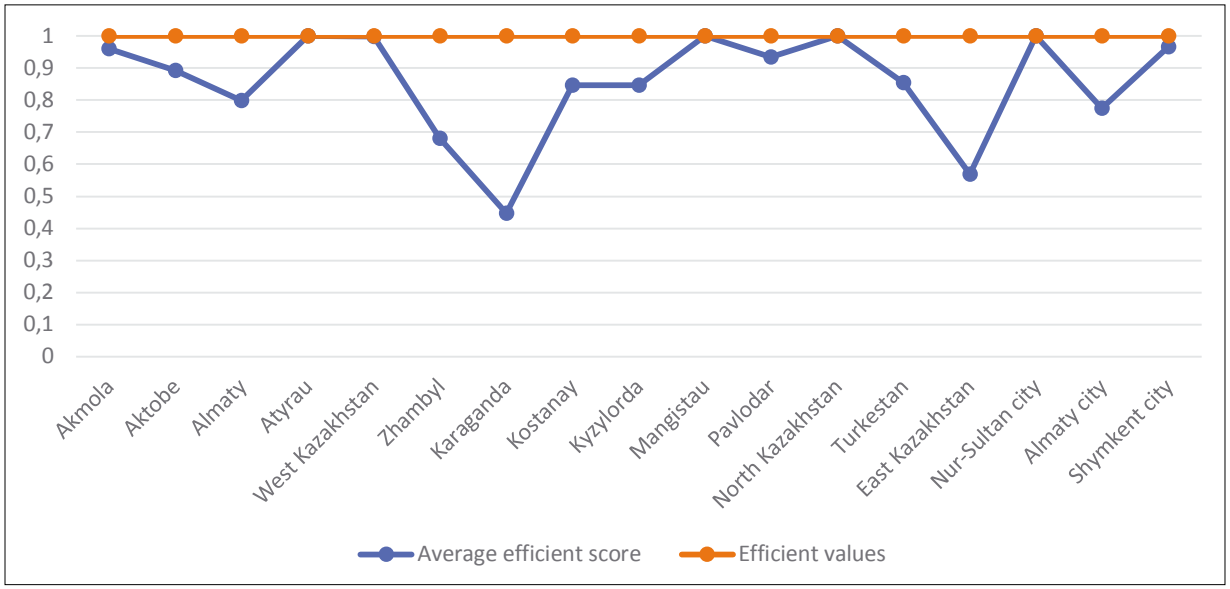

Figure 1. *Efficiency target points*

Source: Calculated by the authors based on the Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2023). Retrieved from URL: https://stat.gov.kz/ru/industries/social-statistics/stat-medicine/ (Accessed: 25.06.2023).

Since 2018, East Kazakhstan has had the highest level of expenditures on healthcare relative to income, with an average excess of 0.7 %. In 2019, the excess was 1.1 %. The largest excess of expenditure over income occurred in 2020, when there was a global crisis and high incidence of disease, at 4.3 %. In 2021, revenues lagged expenditures by 0.2%. In summary, local budget expenditures on healthcare in Kazakhstan have increased significantly in recent years. Shymkent has seen the most growth, while East Kazakhstan has had the highest level of expenditures relative to income. The global crisis and high incidence of disease in 2020 led to a significant increase in expenditures in all regions.

In addition to current revenues and expenditures, healthcare in East Kazakhstan receives transfers for capital expenditures, which account for 27.2 % of the republican level. According to Figure 5, the main source of transfers for healthcare in Kazakhstan is the Social Health Insurance Fund (52.39 %). The second largest source is the republican budget (37.53 %). In Kazakhstan, 13 % of transfers for healthcare are spent on capital repairs, and 17.5 % are spent on the acquisition of fixed assets.

Atyrau, Mangistau, and North Kazakhstan exhibit efficient scores for several reasons. These regions have experienced substantial investments in healthcare, including the construction of new hospitals and clinics, the purchase of modern medical equipment, and the training of healthcare professionals. In 2021 alone, notable investments included $1 billion from the Kazakh government for a new cancer center in Atyrau, $500 million for the acquisition of medical equipment in Mangistau, and the training of 1,000 new doctors and nurses in North Kazakhstan.

Despite increased funding, regional disparities in healthcare performance remain a challenge. Transparency issues hinder effective financing and contribute to corruption. A roadmap to prevent corruption risks in healthcare has been developed. Legislative efforts and the “Densaulyk 2016-2019” initiative improved the healthcare system, but COVID-19 disrupted these gains[14].

Conclusion

This paper investigates the use of Data Envelopment Analysis (DEA) to assess the operational efficiency of healthcare financing in Kazakhstan. Our findings confirm the hypotheses and show the significance of efficient health financing for enhancing healthcare quality and population

[14] Healthcare in Kazakhstan: problems and solutions (2020). Retrieved from: https://borgenproject.org/healthcare-in-kazakhstan/ (Accessed: 28.07.2023).

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health. Additionally, the study highlights DEA's unique applicability in analyzing healthcare funding across Asian nations with similar traditions and a tendency for paternalistic management across diverse sectors.

Our analysis relied on publicly accessible statistical data, focusing on quantitative indicators like operational expenditures (the main financial marker), medical facility counts, beds, pediatric beds, medical personnel, child mortality rate, maternal mortality rate, general population mortality rate, and life expectancy. The primary focus of this efficiency analysis is the reduction of both mortality and morbidity. In order to enhance the management of healthcare financing in Kazakhstan, increased attention and improvements are necessary.

The lowest healthcare efficiency in Kazakhstan was recorded in 2017 and the peak efficiency in 2020, which was largely attributed to increased funding during the COVID-19 crisis.

During the COVID-19 pandemic, the operational framework of healthcare financing in Kazakhstan demonstrated noteworthy efficiency in the sector, aligning closely with the conceptual "ideal" model. However, while life expectancy increased, certain health indicators remained problematic. The government is dedicated to improving the health and overall welfare of the population through comprehensive national initiatives, including expanding primary healthcare services, enhancing care quality, and increasing healthcare funding.

The study recommends to increase the financing of the healthcare system, particularly focusing on salaries and the procurement of medical equipment. Emphasizing transparency in healthcare spending is crucial to prevent unreliable practices and corruption. The application of the DEA model enables regular assessments of healthcare financing results by region, considering service quality, accessibility, and population health indicators more accurately. This approach implies that funds should be directed to regions where they are most needed.

For further in-depth analysis it is planned to apply the methodology to assess the efficiency of financing in the context of private and public hospitals and compare the results.

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