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MEASURING HEALTHCARE EFFICIENCY IN KAZAKHSTAN: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

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ABSTRACT

The study aims to evaluate the efficiency of the Republic of Kazakhstan's healthcare sector over the period 2014-2021 using the non-parametric method of data envelope analysis. The analysis was carried out based on quantitative indicators of the medical statistics of the Republic of Kazakhstan. The study's results prove that efficiency tends to change over the medium term. Simultaneously, implementing digital technologies based on the computerisation and digitalisation of the healthcare sector in the short term is revealed to reduce overall efficiency, but that efficiency increases in the long term. The events of the COVID-19 pandemic did not reduce the overall efficiency of the healthcare sector in the Republic of Kazakhstan.

Keywords: healthcare; efficiency; data envelopment analysis; medical reform

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INTRODUCTION

Ensuring the effectiveness of healthcare activities substantially impacts the nation's health. The society receives feedback thanks to accomplishments and achievements in the healthcare system, as well as successful reform and professionalisation. Hence, institutionally guaranteeing research and innovation funding to establish the norms and content of professional training is crucial at the state and regional levels. This approach simultaneously creates specific difficulties, and the appropriateness of the reforms affects the adequate and accurate assessment of the efficiency of the healthcare system.

The modern paradigm of public healthcare requires developing and implementing qualitatively new principles and requirements for reforming the medical industry since crisis conditions, such as pandemics, can raise questions about the survival of humanity.

The healthcare systems of developing countries have several significant features that affect the efficiency, methods, and effectiveness of reforms (Amagoh, 2017). Examples of such countries are those of Central Asia in general and the Republic of Kazakhstan in particular. According to WHO estimates, public spending on health care in these countries is low, and the population faces difficulties in accessing medical services (Eriksen et al., 2022).

The study aims to evaluate the change in the efficiency of the healthcare sector of the Republic of Kazakhstan during the 2014-2021 period using the non-parametric method of Data Envelopment Analysis (DEA) – an application that empirically measures the productive efficiency of Decision-Making Units (DMU) (Charnes et al., 1978). DEA is one of the methods for assessing socioeconomic trends (Cooper et al., 2011). The main feature of DEA analysis is that the efficiency level of the analysed phenomenon or process is equated to the so-called "ideal" state. At the same time, the "ideal state" is one in which the most optimal level of development of the analysed sphere is observed for a particular year. Thus, DEA analysis makes evaluating the dynamics of changes in the efficiency of the healthcare sector by the considered years possible. Scientists use DEA as a preferred tool to analyse the efficiency of the healthcare system (Kohl et al., 2019; Afonso & Aubyn, 2011; Samut & Cafri, 2016; Stefko et al., 2018). At the same time, considering the peculiarities of the country's healthcare system under study, the choice of indicators, input, and output parameters for building a model remains an open question. In this case, it allows for the consideration of the specifics of the management of medical facilities in the Republic of Kazakhstan, where influential DMUs, which use mostly state levers (Pannier, 2015), lead not to the creation of a new product, but to the formation of positive practice boundaries (Sickles & Zelenyuk, 2019). Based on the study's aim, the following hypotheses are provided:

- The efficiency of the healthcare sector depends on indicators reflecting the potential for treatment and indicators reflecting the mortality rate.
- The efficiency of healthcare depends on the duration of the reforms implemented with state support.

LITERATURE REVIEW

Questions related to healthcare efficiency evaluation are especially acute in a crisis like the COVID-19 pandemic (Pecoraro et al., 2021). The shocking wave of the coronavirus has shown how helpless the healthcare system can be in the face of such challenges. Therefore, it is essential to know how efficiently the resources invested in the healthcare system are used, the effectiveness of medical services, and their impact on the country's population health (Wynia, 2020).

Scientists note (Institute of Medicine, 1993; Domecq et al., 2014) that in the healthcare industry, traditional market regulation mechanisms need to be revised, unlike other sectors of the economy. The lack of fundamental reforms leads to a decrease in the quality or volume of medical care while maintaining high service prices. Consequently, to improve the healthcare level, there is an urgent need for more reliable tools for assessing its effectiveness (Bernet et al., 2011).

The Republic of Kazakhstan has undergone a long period of reforming its entire social and economic system, including the healthcare system (Ertz, 2005). The reformation process took about thirty years. Still, this reform's most challenging period occurred from 1991-2014 (Amagoh, 2021). This period relates to the reorientation of the state management system and the implementation of new technological solutions. For the healthcare system, this meant a complete shift from the Soviet system, including medical facilities, modern technological equipment and hardware, and the transition to a fundamentally new regulatory system (Eriksen et al., 2022). Since 2012, this transition included information and digital technologies related to computerisation and digitalisation in the public healthcare administration system and patient treatment technology. As such, the period until 2014 was a time of rapid changes in the Republic of Kazakhstan, which allowed for the stabilisation of the healthcare sphere. The reform processes are currently being implemented, focusing on digitalisation and globalisation.

Since 2014, the Republic of Kazakhstan has been a time of active reforms (UNECE, 2018), preceded by periods of stagnation or decline. Regarding healthcare, mortality rates in the Republic of Kazakhstan have always been lower than in other Central Asian republics (Freedom House, n.d.), although higher than in European countries (Dutta et al., 2021). Chronic illnesses, including those caused by environmental problems, prevail as diseases that cause mortality among the population (Grantham et al., 2020). The mortality rate from parasitic and infectious diseases is low due to the high number of primary healthcare facilities working with the population (UNECE, 2018). Kazakhstan's leadership has been building policies oriented to the nation's traditions while administratively implementing reforms (Freedom House, n.d.), including those that concern healthcare institutions. Approximately 5.5% of the GDP is allocated to healthcare facilities (Mukhitdinova, 2015).

The study of healthcare systems has certain barriers related to the specifics of analytical studies. Nevertheless, many scientific works evaluate the effectiveness of healthcare in a particular country (Ancarani et al., 2016; Stefko et al., 2018; Li et al., 2022; Marino & Quattrone, 2019) or region (Pecoraro et al., 2021; Lee, 2016; Samut & Cafri, 2016).

DEA analysis is applicable in healthcare efficiency research because it allows for forming a set of input and output parameters, through which the state of the healthcare sector and its efficiency are determined by the years of the specified period (Kohl et al., 2019; Afonso & Aubyn, 2011; Samut & Cafri, 2016; Stefko et al., 2018).

The number of medical facilities reflects the country's general level of healthcare development. Modern researchers such as Giancotti et al. (2017), Wu et al. (2018), and Li et al. (2022) use this indicator. At the same time, the number of medical facilities is adjusted for the number of beds. The number of beds is one of the most frequently used indicators for comparing hospitals in a country. Such authors as Lotfi et al. (2014), Giancotti et al. (2017), Ravaghi et al. (2020), Pecoraro et al. (2021), and Wynia (2020) defined beds as an input indicator. In our study, the indicator of the number of beds was further classified into adult and children's beds. The bed fund indicator (the percentage of use of the total number of beds for a specific period) is more accurate in evaluating the efficiency of medical institutions than the number of beds. Dy et al. (2015) cite that this indicator directly reflects the use of available resources in the hospital. In the national statistics of most states, this indicator needs to be more generalised, although it is considered in the studies of Ranjbar et al. (2021), Ravaghi et al. (2020), and Marino and Quattrone (2019).

Pourmohammadi et al. (2018), Botje et al. (2016), and Carini et al. (2020) argue that the number of hospital staff is a crucial indicator for evaluating hospital performance and efficiency. Lee (2016) points out that the number of doctors is the most valuable resource in the healthcare system. This research considers two crucial indicators: the number of doctors and the number of secondary medical staff.

Since the medical field is focused on preserving the nation's health, the determining indicators of the effectiveness of the country's medicine will be indicators that display minimal mortality, primarily of children and mothers. Our reasoning is supported by the approaches in the publications of Saturno-Hernández et al. (2019), Robbers et al. (2019), and Smith-Greenaway et al. (2021). They prove that mortality rates are decisive in evaluating the efficiency of a country's healthcare. In addition, our study considered mortality from infectious and parasitic diseases per 100,000 for the population of Kazakhstan. This indicator is hardly used in the global analysis of the healthcare sector in developed countries because of their healthcare systems and the fact that outbreaks of infectious diseases are not reflected in statistical reports. Nonetheless, the mortality rate from infectious and parasitic diseases for countries with transition economies and in developing countries is significant – it reflects the operational efficiency of the country's medicine and the general social situation and welfare of the population.

METHODOLOGY

The analysed period for the DEA of Kazakhstan's healthcare is chosen as 2014 to

2021 because the efficiency of the healthcare sector in the Republic is analysed by considering the period of industry reform and the changes that occurred due to globalisation challenges and digitalisation. For the dynamic assessment of Kazakhstan's healthcare system efficiency, a calendar year is chosen. The annual efficiency index is an abstract analogy of the leading economic indicators provided by the statistical reporting of the country's socioeconomic development. Nevertheless, the difference is only in the quantitative assessment; the annual efficiency index is calculated as a comparative model with absolute efficiency. The calculation is based on mathematical programming to obtain the optimal result. At the same time, a single year is considered as a Decision-Making Unit (DMU). The mathematical model for evaluating the efficiency of the healthcare system is regarded as an equation:

$$\mathrm{E}_{max} = \frac{k_1y_1+k_2y_2+\cdots+k_yy_{y0}}{n_1x_1+n_2x_2+\cdots+n_mx_{m0}} = \frac{\sum_{r=1}^{s} k_yy_{y0}}{\sum_{i=1}^{m} n_ix_{i0}}, \quad (1)$$

where E - efficiency evaluation, which was determined using DEA;

j - the number of years that are justified for analysis;

y_{rj} - the volume of the indicator r, which was adopted in a specific year j;

x_{ij} - the volume of result i, which was 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 the results 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 E for a particular year under study is less than one, this indicates its inefficiency. The priority objectives interpret all the calculation results, showing the consequences that will have certain levels of efficiency.

In the model, restrictions are introduced for the coefficients k and n so that the calculated efficiency is not greater than 100%:

$$j = \frac{k_1y_{1j}+k_2y_{2j}+\cdots+k_yy_{rj}}{n_1x_{1j}+n_2x_{2j}+\cdots+n_mx_{mj}} = \frac{\sum_{r=1}^{s} k_yy_{rj}}{\sum_{i=1}^{m} n_ix_{ij}} \leq 1, \quad (2)$$

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:

$$Max\ \mathrm{E} = k_1y_1 + k_2y_2 + \cdots + k_ry_{r0} = (\textstyle\sum_{r=1}^{s} k_ry_{r0}). \quad (3)$$

According to the constraints:

$$n_1x_{1\,0} + n_2x_{2\,0} + \cdots + n_mx_{m0} = \textstyle\sum_{i=0}^{m} n_i\,x_{io} = 0, \quad (4)$$

$$k_1x_{1j} + k_2y_{2j} + \cdots + k_ry_{rj} \leq n_1x_{1j} + n_2x_{2j} + \cdots + n_mx_{mj}. \quad (5)$$

With the above expression transformed into a standard mathematical form:

$$\textstyle\sum_{r=1}^{s} k_ry_{rj} \leq \sum_{i=1}^{m} n_ix_{ij}. \quad (6)$$

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

$$\textstyle\sum_{j=1}^{s} \lambda_jx_{ij} \leq Ex_{i0} \quad i = 1,2,\ldots,m, \quad (6.1)$$

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

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

The mathematical calculation reduces the equations to linear through the slack variable. The binary efficiency model minimises the value of E, subject to the constraints (6.1) so 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) and the weighted sum of outputs by year is greater 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 the λ indicator are effective. Those years for which the value of the E efficiency indicator is equal to one are at the efficiency limit. Years in which the E efficiency indicator is less than one indicates inefficiency.

The efficiency of the healthcare system in the Republic of Kazakhstan is assessed on the AtoZmath web platform. In practice, it was proposed to carry out calculations by converting the formula of the objective function to an expression when the denominator is equal to one, and the numerator is maximised. Since the dimension of such an optimisation issue will be equal to the sum of input and output data, it is necessary to select the data amount that best characterises the industry's management processes. The coverage of the study's boundaries is chosen empirically. In this case, determining the minimum required number of DMUs to obtain a standard discriminatory feature of the analysis under the conditions of sample homogeneity is required. The minimum sufficient number of DMUs can be calculated on the segment between the double sum of inputs and outputs and their double product. This calculation approach allows for the determination of the efficiency of the healthcare sector in the Republic of Kazakhstan by year in the studied period (2014-2021).

Since the DEA model is determined by the ratio of input and output parameters, the main forming parameters for the medical field are defined. Their specification and general characteristics are presented in Table 1.

Table 1: DEA model variables

	Variable	Definition
	Input variables	
x_1	Number of medical facilities	Total number of medical facilities in the country
x_2	Number of beds	Total number of beds in the medical facility
x_3	Number of beds for sick children	Total number of beds for children in a medical facility
x_4	Number of doctors	The total number of doctors in the medical facility
x_5	Number of secondary medical staff	Total number of secondary medical staff
	Output variables	
y_1	Child mortality rate	Children under the age of 5 per 1 thousand births are considered
y_2	Maternal mortality rate	The number of women's deaths during childbirth per 100,000 live births is considered
y_3	Mortality rate of the population from infectious and parasitic diseases	The mortality rate from infectious and parasitic diseases per 100,000 population is considered

Source: Created by authors.

The adopted input and output parameters reflect the primary factors that indicate the overall efficiency of Kazakhstan's healthcare system. In this case, only quantitative indicators without an economic component are considered. This makes it possible to calculate without considering inflationary processes and the impact of short-term government policy changes in Kazakhstan's healthcare field.

The analysis was based on publicly available statistical data from the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics (2021).

RESULTS

Input and output criteria for analysing the healthcare efficiency in the Republic of Kazakhstan for the period under study are revealed in Table 2.

Table 2: Initial data for the analysis of the healthcare efficiency in the Republic of Kazakhstan according to the DEA mode

Years	Input parameters					Output parameters		
	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3
	Number of medical facilities	Number of beds	Number of beds for children	Number of doctors	Number of secondary medical staff	Child mortality rate	Maternal mortality rate	Mortality rate of the population from infectious and parasitic diseases
2014	911	105219	18621	68864	160061	12.35	15.7	9.1
2015	901	102489	18571	69722	163937	12.04	15.8	8.7
2016	877	100079	18559	74611	170819	10.79	15.7	7.5
2017	853	99465	18237	72134	175246	10.24	14.8	7.8
2018	788	98371	18613	72877	175705	10.11	13.9	7.3
2019	749	96286	19355	74046	179837	10.69	13.7	7.4
2020	773	127464	20899	76443	185757	9.41	36.5	15.3
2021	773	125034	22428	78227	188800	8.37	44.7	7.2

Source: Created by authors based on the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan Bureau of National Statistics (2021).

The measures made it possible to calculate the linear equations of the target efficiency function by year. The resulting calculations are displayed in Tables 3-4.

Table 3: Calculation of weighted indicators of healthcare efficiency in the Republic of Kazakhstan

Years	2014	2015	2016	2017	2018	2019	2020	2021
Score	1.0	1.0	0.9	0.9	0.9	1.0	1.0	1.0
Rank	1	1	6	8	7	1	1	1
(x_1)	0.0006	0	0	0.0004	0.001	0.0007	0	0
(x_2)	0.00000385	0.00000976	0.00000999	0.00000621	0	0.00000525	0	0
(x_3)	0.00001193	0	0	0	0.0000122	0	0.00004785	0
(x_4)	0	0	0	0	0	0	0	0
(x_5)	-0.00000086	0	0	0	0	0	0	0.0000053
(y_1)	0.067	0.0622	0.0163	0.0676	0.0825	0.0788	0	0
(y_2)	0.0103	0.0159	0.0163	0.012	0.0065	0.0115	0.0226	0.0227
(y_3)	0	0	0	0.0042	0	0	0.0116	0
$x_1^*(x_1)$	0.486	0	0	0.4124	0.7728	0.4944	0	0
$x_2^*(x_2)$	0.5348	1	1	0.5876	0	0.5056	0	0
$x_3^*(x_3)$	-0.0208	0	0	0	0.2272	0	1	0
$x_4(x_4)$	0	0	0	0	0	0	0	0
$x_5^*(x_5)$	0	0	0	0	0	0	0	1
$y_1^*(y_1)$	0.8272	0.7541	0.6921	0.7305	0.834	0.8452	0.452	0
$y_2^*(y_2)$	0.18	0.2459	0.2503	0.1706	0.0902	0.1548	0.548	0
$y_3^*(y_3)$	0.0072	0	0	0	0	0	0	1
$\sum x_i^*(x_i)$	1	1	1	1	1	1	1	1

Source: Calculated by authors.

Table 4: The table of the slack variable calculation of the healthcare efficiency in the Republic of Kazakhstan by the DEA method

Years	2014	2015	2016	2017	2018	2019	2020	2021
Score	1	1	0.9428	0.9028	0.9243	1	1	1
Rank	1	1	6	8	7	1	1	1
Slack x_1	0	0	12.566	0	0	0	0	0
Slack x_2	0	0	0	0	158.86	0	0	0
Slack x_3	0	0	411.06	316.84	0	0	0	0
Slack x_4	0	0	6474	4697.3	2483.1	0	0	0
Slack x_5	0	0	10646	15913	7249.8	0	0	0
Slack y_1	0	0	0	0	0	0	0	0
Slack y_2	0	0	0	0	0	0	0	0
Slack y_3	0	0	0.3412	0	0.2383	0	0	0

Source: Calculated by authors.

Table 5: Summary table of the calculation of the healthcare efficiency in the Republic of Kazakhstan, 2014-2021

Years	2014	2015	2016	2017	2018	2019	2020	2021
Score	1	1	0.9428	0.9028	0.9243	1	1	1
Rank	1	1	6	8	7	1	1	1
x_1	911	901	877	853	788	749	773	773
Projection = x_1*Score	911	901	826.87	770.06	728.31	749	773	773
Diff (%) = (Projection - x_1)/x_1*100	0	0	-5.72	-9.72	-7.57	0	0	0
x_2	105219	102489	100079	99465	98371	96286	127464	125034
Projection = x_2*Score	105219	102489	94306	89631	90920	96286	127464	125034
Diff (%) = (Projection - x_2)/x_2*100	0	0	-5.72	-9.72	-7.57	0	0	0
x_3	18621	18571	18559	18237	18613	19355	20899	22428
Projection = x_3*Score	18621	18571	17498	16464	17203	19355	20899	22428
Diff (%) = (Projection - x_3)/x_3*100	0	0	-5.72	-9.72	-7.57	0	0	0
x_4	68864	69722	74611	72134	72877	74046	76443	78227
Projection = x_4*Score	68864	69722	70345.8	65120.15	67357.01	74046	76443	78227
Diff (%) = (Projection - x_4)/x_4*100	0	0	-5.72	-9.72	-7.57	0	0	0
x_5	160061	163937	170819	175246	175705	179837	185757	188800
Projection = x_5*Score	160061	163937	161054	158206	162396	179837	185757	188800
Diff (%) = (Projection - x_5)/x_5*100	0	0	-5.72	-9.72	-7.57	0	0	0
y_1	12.35	12.04	10.79	10.24	10.11	10.69	9.41	8.37
Projection = y_1 * $\sum xi \cdot (xi)$	12.35	12.04	10.79	10.24	10.11	10.69	9.41	8.37

Table 5: Continued

Diff (%) = (Projection - y_1)/y_1 * 100	0	0	0	0	0	0	0	0
y_2	15.7	15.8	15.7	14.8	13.9	13.7	36.5	44.7
Projection = y_2 * $\sum xi\cdot(xi)$	15.7	15.8	15.7	14.8	13.9	13.7	36.5	44.7
Diff (%) = (Projection - y_2)/y_2 * 100	0	0	0	0	0	0	0	0
y_3	9.1	8.7	7.5	7.8	7.3	7.4	15.3	7.2
Projection = y_3 * $\sum xi\cdot(xi)$	9.1	8.7	7.5	7.8	7.3	7.4	15.3	7.2
Diff (%) = (Projection - y_3)/y_3*100	0	0	0	0	0	0	0	0

Source: Calculated by authors.

The analysis made it possible to determine the main periods of Kazakhstan's healthcare sector efficiency development. The years 2014-2015 and 2019-2021 are marked as efficient years since the indicator of maximum efficiency of this period is equal to the highest value (Figure 1). In 2016-2018, healthcare efficiency does not correspond to the “ideal” model.

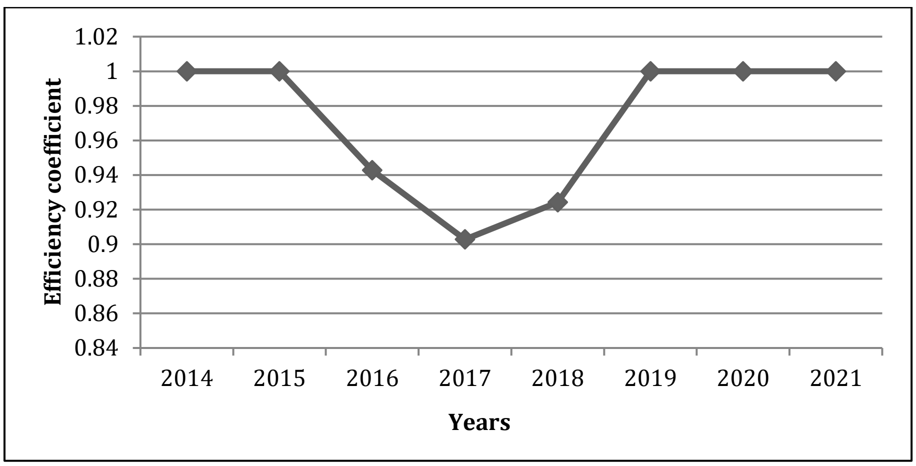

Figure 1: Dynamics of changes in healthcare efficiency in the Republic of Kazakhstan, 2014-2021.
Source: Created by authors based on Table 4.

The effectiveness of the 2014-2015 period is determined by the implementation of the State Program for the Development of Healthcare of the Republic of Kazakhstan, “Salamatty Kazakhstan”, which allowed for the setup and expansion of the primary healthcare (PHC) system. Consequently, the indicators based on the results of PHC implementation were analysed, and the performance of healthcare facilities was evaluated before and after the implementation of state reforms. A medical and sanitary model was initiated and created. This model used market mechanisms to consolidate the funds for “Guaranteed Volume of Free-of-Charge Medical Assistance” (GVFMA) at the single-payer level and equalise interregional tariffs for medical services. In addition, the “funds come with the patient” principle was implemented. For rural areas, financing for medicine was reoriented from the state budget. Service payment was carried out through outpatient departments according to a comprehensive per capita standard as a partial fund receipt. Inpatient medical care was carried out according to clinical cost groups. Several consolidating activities occurred, including:

- A national screening program for 11 diseases (6 oncology) was implemented.

- The equalisation of regional financing of PHC was implemented as an increase in the tariff from 180 to 486 tenge per inhabitant.
- The number of doctors increased by 30%.
- New medical staff positions (psychologists, second and third nurses) were introduced.
- Forty-nine mobile complexes were operated in rural areas, covering 871,000 people.

Since 2016, the government in the Republic of Kazakhstan has developed and implemented a "Strategy for Electronic Healthcare Development." By 2020, a new "State Program for the Development of Healthcare 2020-2025" will be implemented in the Republic of Kazakhstan. The country spends 2.3 trillion tenges annually on treating infectious diseases, 4.5% of the annual GDP in 2017 (Farrington et al., 2019).

The 2017-2018 period is characterised by a shortage of doctors, at 2,482 full-time staff units. In addition, Mandatory Social Health Insurance (MSHI) funds have accumulated since 2017. Moreover, the social and medical insurance fund has acted as a strategic medical care customer within the guaranteed volume of free-of-charge medical assistance since 2018 (Imanova et al., 2020).

During the 2016-2018 period, Kazakhstan's healthcare inefficiency was caused by the introduction of market relations in the medical field and the guarantee of minimum medical services for the population. This reflects the dynamics of the reduction of input indicators: the number of medical facilities, the overall number of beds, and beds for children (Table 2).

Therefore, the efficiency analysis revealed that 2017 was the most critical year. At the same time, the deviation from the ideal model was 9.7% (Table 5). In other years, this deviation is less significant (Figure 2).

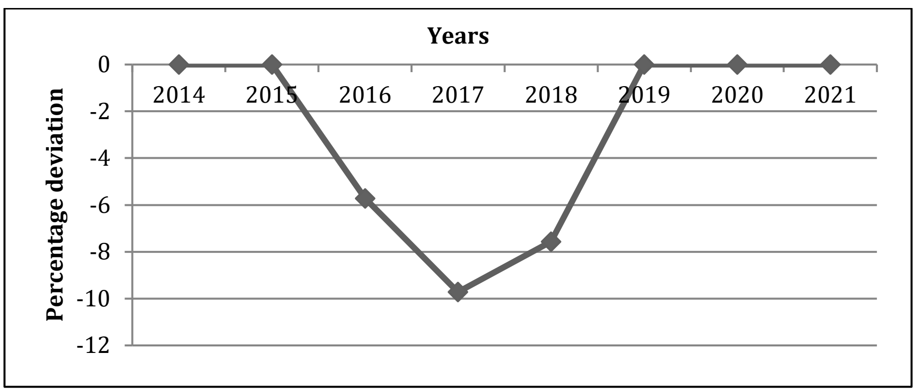

Figure 2. Deviation from the ideal healthcare efficiency model of Kazakhstan, 2014-2021.
Source: Created by authors based on Table 5.

Despite the global challenges of the coronavirus pandemic, Kazakhstan's healthcare sector has generally remained effective according to the analysed parameters.

DISCUSSION

The advantage of the DEA approach is that the sources of inefficiency can be analysed quantitatively for each unit being evaluated. The dual optimisation problem also determines how one DMU can be assessed compared to the others. This allows for the industry's efficiency to be characterised and individual units' weak points to be determined. The negative side of using DEA can be the boost in efficient DMUs when input and output variables increase. Based on the analysis of Figure 1, when the indicator is equal to one for several years, it may seem that precisely such a process occurred.

Nevertheless, the minimum required set of input and output variables was used in this case. The obtained high result proves the efficiency of DMU and considers Kazakhstan's peculiarity, where a paternalistic approach to management remains part of the national traditions. Therefore, each DMU tries to implement the tasks the state sets fully. The above is comprehensively detailed in Table 5 and proves the hypothesis about the time dependence of the reform under active state protectorate.

Regarding the fact that the DEA methodology allows for the determination of the efficiency of the healthcare sector based on the indicators characterising the treatment potential and the mortality rate, conclusions about such efficacy can be made based on the inputs and outputs of Table 2 and the final analysis of Table 5. The results obtained from the research confirm the results of previously published works. For example, Lopez-Valcarcel and Perez (1996) applied this method to compare the efficiency of Spanish hospitals. Samut and Cafri (2016) used DEA to compare the healthcare systems of 29 OECD countries. A broader study based on the DEA model is the analysis by Torabipour et al. (2014), who further applied the Malmquist index. The authors used SPSS.18 and DEAP.2 software, even though this is an adapted DEA method for evaluating changes in the efficiency of medical facilities. In the present research, its application is inappropriate because it requires consideration of numerous indicators that are not presented in the public statistical reporting of the country under study (e.g., high-tech diagnostic and treatment equipment: radiographs, mammograms, positron tomographs, electroencephalographs, tomographs, angiographs, monitoring devices, IR and UV radiation, emitters, dialysis monitors, gamma cameras, isotopic irradiators, electromyographs, MRI devices, etc.). An extensive study on the evaluation of the regional efficiency of healthcare facilities is provided by Stefko et al. (2018). Using data coverage analysis (DEA), the authors analyzed Slovakia's medical system. Nonetheless, this approach needs to consider assessing the general trend of changing the efficiency of medicine according to the implementation of specific government measures regarding its reformation. That is, there is a time lag that does not allow for the dynamics of changes in the efficiency of the healthcare sector to be determined.

A relatively large array of research on medical facilities is carried out using indicators characterising the general technical equipment of hospitals. This indicator includes many technological devices and expensive equipment. That is why this indicator is used in different ways in research. Grosskopf et al. (2004) extended the study of hospital equipment by using the indicator “input assets,” which refers all the existing buildings and structures of the hospital. Dy et al. (2015) use the indicator of change in “major objects.”

Another approach was using technological solutions for treatment to determine their effectiveness. Tai et al. (2021) used the index of high-tech services, and Roberts et al. (2017) used technology accessibility. Park et al. (2019) tracked efficiency by implementing advanced medical technologies. A more qualitative and fundamental indicator for evaluating a hospital’s efficiency according to the technological approach is the use of relevant medical and information technologies presented in the research by Ancarani et al. (2016).

Scientific publications prove that the DEA technique is generally recognised and productive for evaluating the efficiency of healthcare facilities. The definition of a set of input parameters remains a controversial issue. Since this study focuses on quantitative assessment, the input and output parameters were determined according to the available government statistics of the Republic of Kazakhstan.

The primary research of leading social scientists focuses on evaluating the efficiency of healthcare facilities in countries and regions. At the same time, the problem of changing efficiency trends and periods associated with introducing information and digital technologies based on computerisation and digitalisation over the medium term in general throughout the industry needs to be addressed. Most authors emphasise such changes in terms of medical facilities and hospitals. In this study, the annual efficiency aspect is decisive for the dynamics of change in healthcare. The similar particularity of our research, considering The specifics of the DMU actions and the state impact on the implementation of changes in the industry, indicates the possibility of using the DEA approach to analyse the efficiency of healthcare facilities in many Asian countries (e.g., China, India, North Korea, Kyrgyzstan, Turkmenistan, and others). In this case, the DEA allows for the efficiency of each medical facility to be determined, defining the impact of reforms on the industry development. Based on the aforementioned approach, conducting a comparative analysis of the healthcare facilities' work in different countries of Asia is possible, which is especially relevant while the world is still suffering from the COVID-19 pandemic.

CONCLUSION

This article considers the non-parametric method of Data Envelopment Analysis to determine the efficiency of healthcare facilities in the Republic of Kazakhstan. The proposed hypotheses were proved and substantiated with relevant examples. A peculiarity regarding the application of DEA was revealed as a result: the method is effective for analysing healthcare facilities of several Asian countries that are similar in tradition in terms of their tendency towards paternalistic management in various economic sectors.

The evaluation of healthcare efficiency in the Republic of Kazakhstan was carried out according to open statistical data, considering the following quantitative parameters in particular: the number of medical facilities, the number of beds, the number of beds for sick children, the number of doctors, the number of secondary medical staff, the child mortality rate, the maternal mortality rate, and the mortality rate of the population from infectious and parasitic diseases. At the same time, the basis of efficiency remains to be the reduction of mortality and morbidity. As such, the maternal mortality rate has been increasing since 2019. Therefore, the management of medical institutions in the Republic of Kazakhstan needs to pay more attention to the treatment of meters to bring this indicator at least to the level of 2014.

The lowest efficiency level of the healthcare sector in the Republic of Kazakhstan occurred in 2017. Quantitatively, the deviation from the “ideal” model in 2017 was almost 10%.

The stress of the COVID-19 pandemic demonstrated that the operational activities of Kazakhstan’s healthcare facilities ensured high efficiency of the sphere itself as there was no deviation from the “ideal” model.

Generally, the research reveals a change in the efficiency of the Republic of Kazakhstan's healthcare sector during the transformation period. It is linked with the active implementation of reforms in the long term. The results also indicated that short-term reforms aimed at radical transformations led to decreased efficiency indicators. This allowed for considering the tendency towards the decreasing efficiency of the healthcare sector in the short-term period (2016-2018). Yet, while increasing during the implementation period, these same reforms raised the efficiency of healthcare facilities, as was evident from the period analysis (2019-2021).

The study obtained results when the effective model approached a specific limit, accepted as “ideal” within the research framework. For several years, the indicator equals one when using the minimum required input and output data set, allowing future research to expand and deviate from operating with indicators characterizing treatment potential and mortality rates. In further studies on the efficiency of the healthcare sector in the Republic of Kazakhstan, other parameters that would reflect the economical components (state budget expenditures on medicine, investments in equipment and hardware of medical facilities, state expenditures on training for improving the qualifications of medical staff, average annual expenditure of households on medical treatment) would be reasonable suggestions to implement. Such an approach will allow for a more detailed assessment of the economic component of the medical sector’s efficiency in the Republic of Kazakhstan and verify or prove its sustainability. Furthermore, a comparative cross-country analysis of Asian countries may be a potential channel for further research.

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