

Measuring Efficiency of Health Systems in the Eastern Mediterranean Region During COVID-19 Using Data Envelopment Analysis Method (DEA)

قياس كفاءة الأنظمة الصحية في منطقة شرق البحر الأبيض المتوسط خلال جائحة كوفيد-19
باستخدام أسلوب تحليل مغلف البيانات (DEA)

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Abstract

This study aims at measuring the efficiency of health systems in the Eastern Mediterranean countries in facing the rapid spread of the COVID-19 during the first year of its expansion in the region using data envelopment analysis (DEA) approach. We have adopted a set of variables that express inputs and outputs of the model (Health Expenditure per Capita, Physicians per 10 000 population, Nurses and midwives per 10 000 population, Hospital beds per 10 000 population) as input variables, (Recovery Rate) as output variables. The study concludes that the studied Eastern Mediterranean countries achieved different levels of efficiency from one country to another, in that the efficiency is not always linked to high income and increased supply, but rather to optimal utilization of resources.

Keywords: efficiency, health systems, covid-19, Eastern Mediterranean countries, data envelopment analysis model.

ملخص:

تهدف هذه الدراسة إلى قياس كفاءة الأنظمة الصحية في بلدان شرق البحر الأبيض المتوسط في مواجهة الانتشار السريع لكوفيد-19 خلال السنة الأولى من توسعه في المنطقة باستخدام نموذج تحليل مغلف البيانات (DEA)، وقد اعتمدنا مجموعة من المتغيرات التي تعبر عن المدخلات والمخرجات للنموذج (نصيب الفرد من نفقات الصحة، والأطباء لكل 10000 نسمة، والممرضات لكل 10000 نسمة وأسرة المستشفيات لكل 10000 نسمة) كمدخلات، (معدل الاستشفاء) كمتغير الإخراج.

خلصت الدراسة إلى أن بلدان شرق البحر الأبيض المتوسط المدروسة حققت مستويات مختلفة من الكفاءة من بلد إلى آخر، حيث أن الكفاءة لا ترتبط دائماً بارتفاع الدخل، وإنما بالاستخدام الأمثل للموارد المتاحة.

الكلمات المفتاحية: كفاءة، الأنظمة الصحية، كوفيد-19، بلدان شرق البحر الأبيض المتوسط، نموذج تحليل مغلف البيانات.

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1. INTRODUCTION

As of 30 January 2020, the Director General of the World Health Organization (WHO), declared the outbreak of Corona virus disease (COVID-19), a public health emergency of international concern (Araban, et al., 2022) which has spread all over the world very quickly, it became a pandemic (global epidemic) declared by the WHO on March 2020 (Sultanoglu, et al., 2020).

The outbreaks of COVID-19 have caused a serious burden on human health, making health systems around the globe face a financial and operational demand caused by the dramatic conditions created by the pandemic of COVID-19 (Milionis, et al., 2021).

Countries in the Eastern Mediterranean Region (EMR), which is the focus of this study, are among many countries in which the pandemic started by few daily cases, where on February, 20, 2020, eight cases were reported from the United Arab Emirates (UAE), of which six cases belong to two families and one case was reported from Egypt (Mandhari, et al. 2020), but most of these countries witnessed escalation with time, as at the end of the year 2020, a total was reported 4 670 421 cases, which represent about 6.3% of the global count, with 115 650 associated deaths (WHO EMRO, 2020).

In December 2021, a total of 17 203 559 COVID-19 cases were reported from the countries of the (EMR), with 316 176 related deaths (WHO, 2021). As of 25 June 2022, the (EMR) countries have reported a total of 21 957 162 cases, with 343 509 associated deaths (WHO EMRO, 2022).

It is recently noticed that the pace of deaths decreased due to the introduction of vaccination programs, in contrast to what was the case in the first year of the spread of COVID-19 in the countries of the region, where the health systems found themselves in direct confrontation with the rapid spread of the COVID-19, which was not prepared for them in the absence of an effective vaccine. The accelerated height of the number of injuries created significant pressure on the health structures of the countries. Furthermore, various EMR countries have limited testing facilities, weak health system infrastructure and response, and inadequate vital registration and documentation (Saad, et al., 2022). In this regard, the main purpose of this study is to obtain answers to the following question: *How efficient are health systems in the Eastern Mediterranean Region during COVID-19 ?*

Therefore, this study aims to measure the efficiency of health systems in the (EMR) countries in facing the rapid spread of the COVID-19 during the first year of its expansion in the region. And for the purpose of achieving the goal of the study and answer the presented problematic, we relied the quantitative standard method by using data envelopment analysis DEA model, we also relied on the analytical approach in the Discuss the results of the applied aspect to study.

This study is divided into six major sections. Following the introduction, section 2 presents the literature review, section 3 explains the methodology; the results in Section 4, and discussion are interpreted in Section 5. Finally, section 6 concludes the study.

2. Literature review

One of the most important topics of interest to researchers during the pandemic is the efficiency of health systems. So, there've been significant numbers of studies on the subject of health systems efficiency during COVID-19. The following is a review of the most important previous studies, by way of example but not limited to:

(Milionis, et al., 2021) in a study entitled "Maintaining fair and efficient health care during the COVID-19 pandemic: Theoretical context and practical implications", the study covered theoretical context and practical implications for maintaining fair and efficient health care during the COVID-19 pandemic, it mentioned that The simultaneous protection of both universal health coverage and health care efficiency is a difficult task due to conflicting challenges of these two goals. Key actions need to be decided and, so that health care continues to perform its mission in a sustainable manner.

(Shirouyehzad, et al., 2020) in their paper tagged with "Fight Against COVID-19: A Global Efficiency Evaluation based on Contagion Control and Medical Treatment", using data envelopment analysis, the performance of most seriously affected countries regarding contagion control and medical treatment of COVID-19 is evaluated. The results show the performance of the countries regarding the contagion control and medical treatment.

Also (Martínez-Córdoba, et al., 2021) examined political and territorial factors of efficiency in the governance of the Covid-19 pandemic using data envelopment analysis method, in results they found significant differences according to the geographical location of the country, with European and American countries being less efficient than Asian and African countries.

While another research paper for (Seddighi, et al., 2020) concerned Health systems efficiency in Eastern Mediterranean Region in 2018 so before the spread of COVID-19, input-oriented Data Envelopment Analysis (DEA) models have been applied to estimate efficiency scores, this study showed increasing health expenditure and healthcare facilities will not guarantee better performance in healthcare.

What distinguishes our study from previous studies is measuring efficiency of health systems in the Eastern Mediterranean Region during the first year of the spread of COVID-19 and highlight the most efficient countries and the factors affecting it.

3. Methods

The study sample

The study targeted the countries of the WHO's Eastern Mediterranean Region, which reach 22 countries (WHO, 2022). It should be noted that four countries (Libya, Yemen, Syria and Somalia) were dispensed because the most important data around them are not available. Therefore the efficiency of health systems of 18 countries was measured during the first year of the prevalence of the Covid-19 in these countries, that is, in 2020, using data envelopment analysis DEA model.

Study model

Data Envelopment Analysis is a reliable non-parametric technique to evaluate the efficiency of decision-making units (Shirouyehzad, et al., 2020). One type of DEA method, (CCR) model

developed by (Charnes, et al., 1978), assumes that production has constant returns to scale (CRS). Another model (BCC) introduced by (Banker, et al., 1984), assumes that production has variable returns to scale (VRS). The latter is very useful for this study since it aims to measure the efficiency related to organizational units (i.e., the health systems of different countries), which depend on various resources to produce multiple outputs and accommodate a more flexible assumption of VRS. This is more realistic and reflective of changes in the real world (Ahmed Hasan, et al., 2019).

DEA model can be either input-oriented or output-oriented. Under input direction, the efficiency degrees correspond to the largest feasible proportional reduction in inputs for given outputs; Under output direction, the efficiency degrees correspond to the largest feasible proportional expansion in outputs for given inputs (Chai.P, et al., 2019).

In this study, the output-orientation appears more consistent, because efficiency in health systems is more important to the output and always seeks to achieve a better level of health results within the available resources. The output-oriented linear programming of VRS (BCC) model is shown below (Yitbarek, et al., 2019):

$$Eff = \max \sum_r U_r Y_{rj_0} + U_o$$

Subject to

$$\sum_r U_r Y_{rj} - \sum_r V_i X_{ij} + U_o \leq 0; \forall_j$$

$$\sum_i V_i X_{ij_0} = 1$$

$$U_r, V_i \geq 0; \forall_r, \forall_i$$

where Y_{rj} = the amount of output r produced health system j , X_{ij} = the amount of input I used by health system j , U_r = the weight given to output r ($r = 1, \dots, t$ and t is the number of outputs), V_i = the weight given to input I ($I = 1, \dots, m$ and m is the number of inputs), and j_0 = health system under assessment.

The study's variables and sources

To measure the efficiency of the health systems of the sample, we have adopted a set of variables that express inputs and outputs of the model. So as for the results of the measurement to be reliable, it is necessary to depend on the variables data of quality and credibility. Therefore, the data published on (WHO EMRO) and (WHO) has been relied upon. The inputs and outputs of the model were identified in table 1:

Table 1. Input and output variables used in DEA model:

	Explanatory variable	Description	Data source
Inputs	Health Expenditure	Current Health Expenditure per Capita in US\$	WHO
	Physicians	Physicians (per 10 000 population)	Eastern
	Nurses	Nurses and midwifery (per 10 000 population)	Mediterranean
	Hospital beds	Hospital beds (Per 10 000 population)	(2020)
outputs	Recovery Rate	Number of recovered/Confirmed Cases	WHO (2020)

Source: Prepared by authors

Health expenditure is an essential input to cover the health needs of the people, individually and collectively, in the health system. The last three inputs express the ability to provide health services and access to them; in other words, health coverage in a country. The output expresses the percentage of people who are not deceased by the Covid-19 and evaluates the real health situation of the ability of health systems to fight the epidemic

4. Results

Descriptive statistics

Table 2. Descriptive statistics of the input and output variables:

	variable	Units	Mean	Standard Deviation (SD)	Min	Max
Inputs	Health Expenditure	Per capita US\$	639.89	613.624	12	1827
	Physicians	per 10 000 population	16.7944	9.91039	2.20	31.20
	Nurses	per 10 000 population	33.0556	22.44903	3.60	81.00
	Hospital beds	per 10 000 population	14.7667	5.93633	4.00	27.30
Inputs	Recovery Rate	Percentage	0.97861	0.018809	0.939	0.998

Source: Authors' computation using SPSS program outputs

The descriptive statistics of the input and output variables used in this study are presented in Table 2. The health expenditure per capita ranges from a minimum of US\$12 (Afghanistan) to a maximum of US\$1827 (Qatar) with a mean, and SD of 639.89, 613.624 respectively. The physicians number per 10 000 population ranges from a minimum of 2.20 at Djibouti to a maximum of 31.20 at Lebanon. As for the number of nurses per 10 000 population is the smallest in Afghanistan 3.60 and the highest in Qatar 81.00. Regarding the Hospital beds per 10 000 population Record the smallest

in Afghanistan and highest in Lebanon of 4.00 and 27.30 respectively. The average recovery rate of the studied countries is 97 % as Sudan recorded the lowest of 93% and the highest in Qatar 99%.

Efficiency estimates

The efficiency during the COVID-19 pandemic results were obtained using DEAP.EXE software and are presented in Table 3, according to the VRS model that differentiates between technical efficiency and scale efficiency and according to output-oriented for 18 countries based on data for 2020:

Table3. Efficiency scores (2020)

Country	Efficiency	Technical efficiency	Scale efficiency	Returns To scale
United Arab Emirates	0.262	1.000	0.262	drs
Morocco	0.489	1.000	0.489	drs
Tunisia	0.247	0.975	0.254	drs
Jordan	0.294	0.996	0.296	drs
Lebanon	0.152	0.997	0.152	drs
Oman	0.279	0.995	0.280	drs
Egypt	0.389	0.950	0.409	drs
Kuwait	0.215	0.998	0.216	drs
Qatar	0.372	1.000	0.372	drs
Bahrain	0.234	1.000	0.234	drs
Saudi Arabia	0.182	0.987	0.185	drs
Iraq	0.374	0.992	0.377	drs
Djibouti	1.000	1.000	1.000	-
Sudan	1.000	1.000	1.000	-
Afghanistan	1.000	1.000	1.000	-
Pakistan	0.751	1.000	0.751	drs
Iran	0.246	0.963	0.256	drs
Palestine	0.320	0.998	0.321	drs
Mean	0.434	0.992	0.436	

$$\text{efficiency} = \text{Technical efficiency} * \text{Scale efficiency}$$

Source: Authors' computation using DEA program outputs

From table 3, it seems that the countries had a low efficiency score (0.434) indicating that the countries could produce, on average, 56.6% higher output with the same level of inputs. 83.33% of the countries are inefficient and in order to increase their efficiencies, the outputs for those countries must be increased.

It can also be observed that most countries in the sample have achieved an average high technical efficiency score (0.992). It can be seen that 08 countries (44.44%) of the sample have the value of 1 (Pakistan, Afghanistan, Sudan, Djibouti, Bahrain, Qatar, Morocco, United Arab Emirates) were technically efficient in combating the pandemic implying that these countries created the best practice frontier based on their output and input combinations; while the remaining 10 (55.55%) of all countries were technically inefficient (Palestine, Iran, Iraq, Saudi Arabia, Kuwait, Egypt, Oman, Lebanon, Jordan, Tunisia), but they had high technical efficiency scores fluctuate between 0.950 and 0.998.

The results either show that most countries in the sample have achieved an average low scale efficiency score (0.436). Only three countries (16.66%) of the sample have the value of 1

(Afghanistan, Sudan, Djibouti), which means that these countries were operating at a proportionate input size, which achieved maximum output. while most of countries of the sample had a low scale efficiency score ranging from 0.152 to 0.489 (Bahrain, Qatar, Morocco, United Arab Emirates, Palestine, Iran, Iraq, Saudi Arabia, Kuwait, Egypt, Oman, Lebanon, Jordan, Tunisia) and a country (Pakistan) had an average scale efficiency score 0.751. All the inefficient countries were operating at a decreasing return to scale (DRS) and what it means that an increase in the input will result a lower output. So, a gain in efficiency can only be achieved by scaling down operational size.

Sensitivity analysis

In this part, the sensitivity of efficiency indicators for each input of the health system is studied by excluding each time an input and observing its impact on recorded efficiency levels, and the greater change in efficiency levels means higher importance for the excluded variable. The results are shown in table 4:

Table 4. Sensitivity of the efficiency scores

	Efficiency (main model)	Excluding Health expenditure	Excluding Physicians And Nurses	Excluding Hospital beds
United Arab Emirates	0.262	0.262	0.262	0.103
Morocco	0.489	0.489	0.410	0.477
Tunisia	0.247	0.247	0.168	0.219
Jordan	0.294	0.294	0.294	0.127
Lebanon	0.152	0.152	0.152	0.111
Oman	0.279	0.279	0.279	0.133
Egypt	0.389	0.389	0.275	0.337
Kuwait	0.215	0.215	0.215	0.098
Qatar	0.372	0.372	0.372	0.086
Bahrain	0.234	0.234	0.234	0.126
Saudi Arabia	0.182	0.182	0.182	0.100
Iraq	0.374	0.374	0.341	0.298
Djibouti	1.000	1.000	0.295	1.000
Sudan	1.000	1.000	0.594	0.745
Afghanistan	1.000	1.000	1.000	1.000
Pakistan	0.751	0.751	0.454	0.751
Iran	0.246	0.246	0.246	0.206
Palestine	0.320	0.320	0.320	0.148
Mean	0.434	0.434	0.339	0.337
Variation of average efficiency scores		0	- 0.095	-0.097
Number of countries whose efficiency score has changed		0	7	15

Source: Authors' computation using DEA program outputs

The previous results show that in all of these cases, the average of the efficiency scores varied from 0.337 to 0.434. The sensitive combination was found while excluding hospital beds variable from input. The average efficiency score decreased by 0.097, the efficiency of 15 countries has also changed, followed by the impact of physicians and nurses with decreasing average efficiency by 0.095 and changing efficiency score for 7 countries. But the impact of health expenditure variable was non-existent, as there has been no change in efficiency scores.

5. Discussion

Efficiency of 18 health systems of the countries in Eastern Mediterranean Region during covid-19 was measured. According to the descriptive statistics, it seems that health systems' resources vary from one country to another, apparently between minimum value and maximum value. This is attributable to disparity in these countries' economic level while the range of the recovery rate is very low. This is due to the impact of life expectancy as a human nature as well as countries' efforts to control the spread of the pandemic.

These differences in inputs and outputs gave different efficiency results from country to country. The only efficient health systems are Afghanistan, Sudan, Djibouti and the most inefficient are Iran, Saudi Arabia, Kuwait, Oman, Lebanon, Jordan, Tunisia, Bahrain, United Arab Emirates while Seddighi et al in a study found that these health systems (except for Saudi Arabia, Kuwait and Jordan) were from the most efficient in the Eastern Mediterranean in 2018 (Seddighi, et al., 2020). This is because of the rapid spread of COVID-19 throughout the world. Within the Eastern Mediterranean Region, 1 521 033 cases and 39 213 deaths have been reported as of 29 July 2020 (WHO, 2020).

This spread in a short period has caused negative effects on the performance of health services and its efficiency because of that, health professionals have been under increased physical and psychological pressure due to the workload and the exposure to the pathogen (Milionis, et al., 2021). In Tunisia, as in other countries, the fast increasing numbers of confirmed cases and deaths resulted in both health care workers and the public experiencing psychological problems, including anxiety, depression, and stress (Zgueb, et al., 2020). Regarding Iran, 138 medical staff had died due to COVID-19 (23 July 2020), nursing staff constituted nearly 20%, another 20% were those working in other hospital services, as well as health technicians, however, nearly 60% of those who died were doctors (Lankarani, 2020).

While the reason for low efficiency in the other most inefficient countries (as Lebanon) is the highest levels for inputs compared to their outputs since the efficiency can be achieved by the ability of homogeneous units to produce the same level of output from the same level of inputs or that fewer inputs (Jayamaha & Mula, 2011) . And the reason is that the three countries mentioned above in this study achieved complete efficiency (as Afghanistan), it means that they have less relative inputs than other countries and approximately the same output.

It was observed that the mean of the efficiency scores decreased from the low-income to high-income countries; the highest mean efficiency was in low-income countries (mean efficiency=1), followed by middle-income (mean efficiency= 0.426), and high-income countries (mean efficiency= 0.257). Thus, the efficiency of health systems is not always linked to developed countries, especially when it comes to the sudden spread of the epidemic.

Health systems efficiency in the face of COVID-19 is also affected by health (as percentage of Population over 65) and social (as Population density) factors based on data of (The World Bank) of these two factors. It found that countries with a population density of less than 100 People per sq.km have achieved an average efficiency equal to 0.535 followed by population density confined

between 100 and 500 have achieved an average efficiency equal to 0.380 and population density more than 500 have achieved an average efficiency equal to 0.235. This can be explained by the fact that population density contributes to the high prevalence of the COVID-19 and the high incidence of infections among the population, which prevents all infected people from being covered.

As to percentage of Population over 65, it found that countries with less than 5 % Population ages 65 and above in the total population have achieved an average efficiency equal to 0.483, while countries with more than 5 % have achieved an average efficiency equal to 0.304.

This can be traced back to that older population (Population over 65) have needed more resources to deal with severe cases because of possible previous pathologies or a more deteriorated immune system, consequently, an increase in the median age implies a lower efficiency (Martínez-Córdoba, et al., 2021).

The study findings showed that among the studied Eastern Mediterranean countries, some have scale efficiency scores less than technical efficiency scores due to external factors not controlled by states, and can be structural or constructive factors related to the health sector. The results of sensitivity analysis showed that hospital beds variable is the most important to measure efficiency. Generally, the results were consistent which supports the findings from this study.

Finally, given the low level of scale efficiency in the region, it is necessary for health policy-makers to determine the optimum scale of operation of health systems and rationalize their resources, rather than indiscriminate increase for it.

With regard to combating COVID-19, it requires providing financial and human resources to ensure the continuity of the provision of health services and ensure that health care workers are adequately protected and work in safe environments (WHO, 2020).

6. Conclusion

This study examined the efficiency of 18 health systems of the WHO's Eastern Mediterranean region in facing COVID-19 with limited resources. It shows that the health systems had a low efficiency score, and 16.66 % of the countries which used less inputs than other countries and are from low and middle income countries achieved complete efficiency.

Thus, efficiency is not always linked to high income and increased supply, but rather to optimal utilization of resources. It should be noted that these results relative rather than absolute where it's very possible that efficient systems would become inefficient if compared to those of other countries.

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