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RESEARCH ARTICLE

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The economic efficiency of clinical laboratories in public hospitals: A case study in Iran

Mina Alinejhad[1] | Siamak Aghlmand[2] | Sadegh Feizollahzadeh[3] | Hasan Yusefzadeh[2]

[1]Health Economic, Health Management and Economics Department, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran

[2]Health Management and Economics Department, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran

[3]Laboratory Sciences Department, School of Allied Medical Sciences, Urmia University of Medical Sciences, Urmia, Iran

Correspondence
Hasan Yusefzadeh, Health Management and Economics Department, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran.
Email: hyusefzade2010@gmail.com

Abstract

Introduction: Clinical laboratories are identified as one of the most important and expensive units of the health system. Therefore, it is essential to pay attention to these units' cost efficiency. This study purpose was to evaluate the economic efficiency of hospitals' laboratory units affiliated to Urmia University of Medical Sciences (UMSU), in order to assess their performance.

Methods: This research was a descriptive-analytic study that was accomplished in 2017. The statistical population of the study included all of the hospitals' clinical laboratories affiliated to UMSU. Moreover, DEA method and $Deap_{2.1}$ software were used to analyze data. In this study, technical and allocative efficiencies of the studied laboratory units were also calculated in addition to the determination of the economic efficiency of the laboratories.

Results: The average economic efficiency of clinical laboratories calculated by DEA in 2017 was 0.676. This value was lower than the allocative and technical efficiency scores, which indicates that these units could attain full efficiency by reducing their costs without having any effect on output values. Moreover, about 14 percent of the clinical laboratory units were economically efficient. In addition, it is noteworthy to state that, from total of university hospital laboratories, only three hospitals had no economic excess or deficiency values of inputs.

Conclusion: Considering that 76% of laboratory units have not been economically efficient, it is necessary for the laboratory managers to consider optimum allocating of resources, with respect to the cost of laboratory equipment and inputs in order to increase their units' economic efficiency.

KEYWORDS

clinical laboratory, data envelopment analysis, economic efficiency, hospital

1 | INTRODUCTION

It can be stated that between 50 and 80 percent of public health resources are consumed by hospitals in developing countries with respect to the World Bank study about public hospitals.[1] The size of the hospital's operating costs and lack of sufficient efficiency of healthcare system raise questions on the way of resources consuming by the hospital.[2] When issues related to capital and labor force

supply are compounded by the lack of full utilization of existing tools and equipment that is caused by working practices in undeveloped and developing countries, the efficiency rate decreases and it creates a kind of capital and labor force waste in times of scarcity.[3] Therefore, health promotion is an economic and social subject as well as ethical duty, and any type of health service planning should be considered as a part of the health policy approach.[4]

Laboratory is one of the important and vital parts of hospital. Nowadays, one of the quick ways for treating diseases and get informed about body health is referring to the medical diagnostic laboratories and performing various tests; this is while managing and treating many diseases without laboratories is not possible. In terms of the global standards, 70% of medical decisions are made based on the diagnostic test results, and those decisions that are irrelevant to these results are not considered acceptable.[5] Consequently, laboratories play an important role in patients' treatment along with prevention of disease, and a community's health is significantly dependent on appropriate functioning of the medical diagnostic laboratories. On the other hand, although, the role of hospital laboratories is very important, but they possess an expensive nature as a specialized technical unit. Therefore, in order to prevent their repetition that has a goal of performance improving, the optimal use of laboratory tests and also reducing the human and systemic errors are important.[6]

On the other hand, laboratory units include an important and vital part of the activities of many hospitals, so their performance plays a crucial role in the healthcare quality and efficiency, and presenting methods for evaluating and improving their performance have attracted attentions from the world's scientific and professional communities from past up to now.[7,8] The reason for selecting the laboratory unit in this study was the excessive growth of costs in this unit after the exchange rate fluctuations and Iranian subsidy reform plan in recent years; so that, most of the equipment and consumables of laboratory units are imported from other countries; hence, it has more dependency on the currency resources.

Regular measuring and evaluating the performance and efficiency of hospitals' laboratory units will make the optimal utilization of the resources and facilities available in these units, will prevent the unbalanced increase in the costs, and also will improve the quality and quantity of the services of these units.[9,10] Accordingly, economic efficiency means allocation of production resources with respect to their price with the aim of achieving maximum production. Indeed, this efficiency indicates that, due to the specific price of inputs, whether the inputs were used in order to minimize the production costs for every level of the production or not.[11,12]

Similar investigations were accomplished in this field that included the study of Abedi et al[13] entitled "the investigation of the economic efficiency of the intensive care units of the hospitals affiliated to Shahid Sadoughi University of Medical Sciences in Yazd"; the study of Zahavi et al entitled "the investigation of the economic efficiency of the CCU sector of the hospitals of Tehran University of Medical Sciences using Stochastic Frontier Analysis (SFA) and DEA methods",[14] and the study of Keshtkaran et al[15] entitled "the investigation of the evaluation of economic efficiency of radiology units of public hospitals affiliated to Shiraz University of Medical Sciences using the DEA method"; and all of them have emphasized on the efficiency evaluation by the use of the Data Envelopment Analysis method.

Considering the necessity and importance of knowledge about the performance of hospitals' laboratory units, this study purpose was to measure the performance of clinical laboratories of hospitals affiliated to Urmia University of Medical Sciences (UMSU) by calculating their economic efficiency. Undoubtedly, the information about the efficiency of these units and efforts to improve it can help the managers of hospitals to improve the performance of the laboratory units of hospitals and prevent the waste of valuable resources of these units in the current situation, which has increased the demand for the health services by implementing the health reform plan.[16] Therefore, an examination of the economic efficiency improvement of clinical laboratories in hospitals is immediately required, and according to these investigations, no study has been conducted on the economic efficiency of clinical laboratories in Iran. Accordingly, this study investigated the economic performance of the medical diagnostic laboratories of the UMSU hospitals in 2017 by the use of the DEA method for the first time.

2 | METHODOLOGY

In this cross-sectional descriptive-analytic study, the economic efficiency of the hospitals' clinical laboratories affiliated to UMSU in 2017 was calculated using the DEA method that is a linear programming technique by including 22 laboratories. Data collection was accomplished through a checklist containing the characteristics of clinical laboratories and required variables for the analysis (inputs include number of specialists, experts, technicians, tools, and equipment [such as microscope, ELISA, cell counter, auto-analyzer, centrifuge, and incubator], used materials and solutions [such as kits, culture medium, isotone solutions, and lubricating solutions], wages of specialists, experts and technicians, materials and solution prices, tools, and equipment prices, and output include the number of patients who were admitted). After that, the researchers proceeded to complete the checklist by referring to the hospitals' clinical laboratories and the treatment deputy. Moreover, laboratory experts and professors confirmed the content of the designed checklist for data collection. After collecting the data and entering them into the Excel software, using the $Deap_{2.1}$ software, the analysis and calculation of economic, allocation, and technical efficiency types were accomplished by the assumptions of minimizing production factors (input-oriented) and variable returns to scale. In the DEA method, the most efficient laboratory unit economically would be scored as number one and the rest would be scored under one.[17-19]

In the process of calculating the tools and equipment cost, taking into account their depreciation, a straight-line method was used because different devices were used in the laboratory units of the hospitals affiliated to UMSU, and some devices have more or less

than 10 years old in terms of their useful life. In the straight-line method, the fixed percentage of the initial value of the capital was depreciated over the useful life of the capital. For those devices and equipment whose useful life had been expired, only their maintenance cost was considered.[20] In addition to the maintenance cost, the depreciation cost was also calculated for those equipments that worked in the laboratory units <10 years.

Also, since it was possible that the output data may be higher than the average of these data and consequently represent the greater efficiency of these units, all output data were standardized using the following formula and were also multiplied by 100 after inverting, and after that, they were entered into $Deap_{2.1}$ software.

$$Z_i = \frac{X_i - \mu}{\delta}$$

Moreover, in the DEA method, the economic excess or deficiency values of inputs were obtained for the purpose of minimizing the cost of the laboratory units in the hospitals with economic efficiency less than one.

In order to observe ethical considerations, the results were indicated with relevant numbers.

3 | RESULTS

The lowest and highest scores of personnel, equipment and materials, and solution costs belonged to the 2nd laboratory and the 14th laboratory.

As shown in Table 1, the economic, allocative, and technical efficiencies of the hospitals' laboratory units have been calculated using the $Deap_{2.1}$ software in 2017.

According to the achieved results, it can be observed that by applying DEA method, the technical, allocative, and economic efficiencies of the clinical diagnostic laboratories of the hospitals affiliated to the UMSU were different, so that the range of technical, allocative, and economic efficiencies of these units were 0.760-1, 0.373-1, and 0.373-1, respectively.

In this study, all units had relatively high technical efficiency, but they had low allocative and economic efficiencies. In addition, units 6, 14, and 19 were efficient in terms of technical and allocative efficiencies and finally at economic (cost) efficiency. Meanwhile, the lowest technical efficiency was associated with the laboratory of hospital No. 11 with a value of 0.760 and the lowest allocative and economic efficiencies were related to the laboratory of hospital No. 20 with a value of 0.373. With respect to the results of the above Table, the mean economic efficiency of the investigated laboratory units was 0.676 (with the standard deviation of 0.21). The mean technical efficiency was 0.983 (with the standard deviation of 0.05), and the mean allocative efficiency was 0.686 (with the standard deviation of 0.2). Also, the difference in the mean of the technical efficiency and the allocative efficiency was 0.297. Moreover, laboratory units 6, 14, and 19 had the higher economic efficiency (with index 1) and could be a peer for other laboratory units of the province in terms of performance and profitability.

TABLE 1 Efficiency results of laboratory units of UMSU hospitals via DEA model in 2017

Laboratory of hospital	Technical efficiency (TE)	Allocative efficiency (AE)	Economic efficiency (CE)
1	1	0.553	0.553
2	1	0.739	0.739
3	1	0.434	0.434
4	0.940	0.507	0.476
5	1	0.646	0.646
6	1	1	1
7	1	0.491	0.491
8	1	0.812	0.812
9	1	0.713	0.713
10	1	0.888	0.888
11	0.760	0.594	0.452
12	1	0.853	0.853
13	1	0.745	0.745
14	1	1	1
15	0.920	0.551	0.507
16	1	0.425	0.425
17	1	0.743	0.743
18	1	0.512	0.512
19	1	1	1
20	1	0.373	0.373
21	1	0.891	0.891
22	1	0.613	0.613
Mean	0.983	0.686	0.676

The values of inputs to minimize the laboratory unit cost in those investigated hospitals proposed by the software are presented in Table 2. According to the following Table results, for example, the laboratory unit in the hospital No. 20 had deficiency in inputs of expert inputs (one person), incubator (one number), centrifuge (two numbers), lubricating solutions (42 bottles) and isotone (314 bottles), hormonal kits (60 numbers), and biochemical kits (23 numbers) and had excess in inputs of auto-analyzer (two numbers), cell counter (one number), and also microscope (three numbers). For example, in order to achieve maximum economic efficiency, the unit must reduce its microscope input from 5 to 2 and eliminate three microscopes, which do not play a significant role in its production for cost reduction.

4 | DISCUSSION

This study purpose was to examine the economic efficiency of diagnostic laboratories of Urmia's public hospital using the DEA technique in order to achieve their efficiency rate and performance status. In this research, the assumptions of input minimization and

TABLE 2 The economic excess (+) or deficiency (−) value of inputs in laboratories of the studied hospitals to minimize their costs

Laboratory of hospital	Input												
	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7	Input 8	Input 9	Input 10	Input 11	Input 12	Input 13
1	−0.521	−0.125	1.958	0.979	−0.042	−1.021	−0.062	−0.042	−394.4	−505.8	−132.8	−263.8	−14.48
2	−5	0	1	0	0	0	−1	0	−17	−254	−234	−231	4
3	−1.056	0.849	2	0	0	−1	−1	−0.151	−109.4	−234.4	28.309	−55.71	−2.865
4	−5.695	−0.167	1.944	0.972	0.944	−0.028	−1.083	0.944	−632.5	−741.1	35.88	74.863	−12.64
5	−12.98	0.525	1.842	0.921	0.842	−0.079	−0.238	−0.158	−650.6	−1260	−304.9	−1112	−14.82
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2.077	0.778	1.926	0.963	−0.074	2.963	0.889	1.926	−598	−798.1	199.52	−364.3	−2.849
8	−2.64	−0.634	1.789	−0.106	−0.211	−0.106	−1.317	−0.211	−636.5	−1140	−458	−878.9	−0.429
9	−1.377	0.43	1.81	−0.095	−0.19	−1.095	0.715	0.81	−504.3	−812.3	−280.8	−941	−15.19
10	−2.118	−1.468	1.511	−0.245	0.511	0.755	−2.734	−0.489	−53.93	−676	−601.1	−1252	−10.63
11	1.738	−0.303	1.899	0.95	0.899	2.95	0.849	1.899	−561.4	−898.4	234.91	415.48	−15.16
12	−7.087	−1.461	1.513	−0.243	0.513	−0.243	2.27	1.513	−570.3	−1225	−486.6	−1292	−23.6
13	7.286	−2.091	2.303	−0.349	0.303	0.651	0.954	3.303	−525.9	−1205	−452.3	−1568	0.983
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	−5.382	−0.092	1.969	0.985	0.969	0.985	−0.046	−0.031	−515.9	−934.6	−232.4	−116.2	−8.351
16	1.983	0.569	2	0	1	1	0	1.569	−241.1	−421.9	−194	−377.7	−5.19
17	2.124	−0.65	2.45	−0.275	0.45	−0.275	0.175	−0.55	−345.7	−399	−653.2	−1343	−3.326
18	−8	0	2	0	1	−1	−1	0	−568	−982	−213	−569.1	−13
19	0	0	0	0	0	0	0	0	0	0	0	0	0
20	−1	0	2	0	1	−1	−2	3	−42	−314	−60	−23	0
21	6.435	−2.256	1.915	−0.543	0.915	3.457	3.372	4.915	−213.5	547.63	−1137	−2274	33.52
22	−5.388	0.373	1	0	1	−1	−1	0.373	−411.5	−853.3	−106	−344.7	−11.91

variable returns to scale have been used for estimating the values of the efficiency types through the data envelopment analysis method.

Except the laboratories of the 6th, 14th, and 19th hospitals, technical, allocative, and economic efficiency scores of the rest of laboratories were less than one and consequently did not reach optimum performance.

The mean technical efficiency calculated using DEA method in this study was 0.983 indicated that the existing hospitals' laboratory units had a partial excess capacity and capacity improvement of technical efficiency of the clinical laboratories in those investigated hospitals was possible using the same level of inputs without costs increasing (up to 1.7%). In other word, current output level of these units was accomplished with 98.3% of inputs.

Moreover, the mean allocative efficiency calculated by the DEA method was 0.686; that is, the resource and input distribution between the outputs of the existing laboratory units was inappropriate, except for units 6, 14, and 19. Therefore, in the allocative efficiency, consideration of the effective factors like taking into account the relative prices of inputs in determining their composition, the correct use of the equipment, and improving the management of laboratory units could significantly increase the allocative efficiency of hospitals' clinical laboratories.

In the DEA method, the range of economic efficiency or the difference between the highest and lowest economic efficiency in the laboratory units was high (0.373-1) and its mean was 0.676, which indicated that these units could attain full efficiency along with reducing their costs by 32% without affecting the output values. In other words, laboratory units at university hospitals have high potentials to increase their economic efficiency through increased profits. With respect to the DEA method results, 27% of the units had economic efficiency less than 50%, which was a low value for the unit's performance. Therefore, those units with the lowest economic efficiency must reduce their expenses in order to approach the profitability efficiency frontier.

In this study, based on the output of $Deap_{2.1}$ software, the mean allocative efficiency and therefore the units' economic efficiency were less than the mean technical efficiency, which means that units obtain decent production by a certain input combination, but providers with this combination and also the cost and production that is made, could not maximize profits. In other words, the used inputs did not maximize profits, and the service provider with this amount of cost had a low profit, which would waste the laboratories resources. This issue in private hospitals can reduce the supplier incentives to provide services, and reducing service delivery will also have its own social issues. In addition, the difference between the minimum and maximum allocative efficiency (0.373-1) indicated that there was a great interval between the units that had the highest and the lowest efficiency, and these units did not have the proper knowledge about the input combination. Therefore, the hospitals' and clinical laboratories' chief and managers should minimize the gap between minimum efficiency and maximum efficiency and, on the other hand, must enhance the efficiency by promoting the modern method principles in laboratory diagnosis. Therefore, it can be concluded that the input inappropriate combination and distribution in the event of a lack of proper awareness results in an increase in costs.

In addition, increasing return to scale among the hospitals' laboratory units indicated low utilization of some laboratories, not allowing the optimal use of the full capacity of the laboratory units, which can be one of the factors of low economic efficiency in those laboratory units in the DEA method. Therefore, laboratories with increasing return to scale should increase the level of their services, because with the assumption of constant factors for production, the output increase would be higher in comparison with inputs. Therefore, the long-term marginal cost and, consequently, the long-term total cost will be reduced, and as a result, an increase in service delivery will have economic justification.

Furthermore, in this research, the optimal amount of inputs was determined in order to achieve the economic efficiency of one using excess or deficiency values of inputs. In fact, these values demonstrated that the output of each laboratory unit could be obtained at which levels of inputs, which itself indicated a reduction in inputs and costs.

No similar study was found in various databases searching, which examined the economic efficiency of clinical laboratories, consequently comparing the results of this study with other studies is impossible. This first and only study evaluated the allocative and economic efficiencies of laboratory units using the DEA method. Other studies have investigated technical efficiency using the abovementioned method.

Abedi et al in their study evaluated the economic efficiency of the intensive care units of the educational hospitals affiliated to Shahid Sadoughi University of Medical Sciences in Yazd using DEA method. They indicated that the average economic efficiency of these sectors was 0.834, and in this study, the economic inefficiency was more associated with technical efficiency instead of the allocative efficiency.[13] Despite the fact that in the present study, the economic inefficiency was more associated with the allocative efficiency instead of the technical efficiency.

In evaluating the economic efficiency of the radiology units of the public hospitals affiliated to Shiraz University of Medical Sciences, the average score of economic efficiency of radiology units was 0.749 using data envelopment analysis by Keshtkaran et al, and this score was less than the technical and allocative efficiencies. Due to most of the radiology units that were inefficient, the researchers concluded that units' managers should pay special attention to the cost of radiology equipments and inputs in optimally resources allocating.[15]

In the study accomplished by Zahavi et al,[14] the average economic efficiency of CCU in the hospitals affiliated to Tehran University of Medical Sciences using SFA and DEA was 0.59 and 0.95, respectively.

Taheri in his study entitled technical efficiency of clinical laboratories affiliated to Shiraz University of Medical Sciences by the use of the DEA method concluded that most of the laboratories had a high level of technical efficacy,[9] which confirmed this study obtained results.

The strengths and limitations of this study were calculating the exact costs of equipment by considering their depreciation and limiting the study to laboratory units of educational hospitals with respect to the lack of cooperation of private hospital laboratories, social security organization, and armed forces, respectively. Another limitation of this study was the lack of some information records, which was required for the study.

Due to the limited resources and facilities and the increasing demand for laboratory services, maximizing the usage of existing facilities is one of the most important solutions for reducing the gap between supply and demand. Therefore, investigating the performance of laboratory units has considerable importance. Accordingly, it is recommended that the factors affecting the demand for laboratory services be investigated, along with the calculation of the productivity and profits and losses of laboratories, using production and cost functions.

This study results indicated that laboratory units of hospitals in the province still have the potential for increasing their economic efficiency by profits increasing. Therefore, laboratory managers need to consider the devices and equipment prices as well as the costs associated with other factors of production used in this unit in optimal resources allocation.

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ORCID

Mina Alinejhad https://orcid.org/0000-0002-3047-1802
Siamak Aghlmand https://orcid.org/0000-0002-2775-3702
Sadegh Feizollahzadeh https://orcid.org/0000-0002-9942-0296
Hasan Yusefzadeh https://orcid.org/0000-0001-9919-0235

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