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Original Article

An Evaluation of the Efficiency Rankings of the Schools of Shiraz University of Medical Sciences Using an Integrated Approach of Data Envelopment Analysis and Goal Programming

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Abstract

Introduction: Performance appraisal and efficiency evaluation of schools and universities have had remarkable growth over the past two decades. The present study evaluated the performance of the schools of Shiraz University of Medical Sciences.

Methods: This is a cross-sectional study, conducted in 2017 on 10 schools of Shiraz University of Medical Sciences using data of the year 2016 related to 5 inputs and 12 outputs. In order to determine the weights of the inputs and outputs, fuzzy weighting was performed based on the experts' views. Then, by utilizing an integrated approach of data envelopment analysis (DEA) and goal programming (GP), the efficiency of the schools was determined using model Minimax. The final rankings were made by employing the super-efficiency ranking method (Anderson-Peterson). The results were exported using TORA software after producing the relevant linear models for each school. The software uses the notation and procedures developed in Taha Hamdi, Operation Research: an introduction, 5/e, Macmillan1992 ,.

Results: Results from the Minimax model, which presented the best answer, showed that the Schools of Dentistry, Pharmacy, Nutrition and Food Sciences, Paramedical Sciences, and Health were efficient with respect to the 5 inputs and 12 outputs. By employing the super-efficiency ranking method of Anderson-Peterson, the highest ranks and points were related to the Schools of Nutrition and Food Sciences, Paramedical Sciences, and Dentistry. The average efficiency score of the schools was 0.89

Conclusion: According to the results some schools must enhance their outputs. The continuous evaluations and publication of research results leads to awareness of the relative status and ranks, and ultimately causes increased competition and efforts to improve the efficiency of the schools.

Keywords: Data Envelopment Analysis, Goal Programming, Efficiency, Fuzzy-Weighting

Introduction

One of the important roles of managers is to ensure the success and long-term survival of their organizations, and in order to play this role effectively, they must be able to evaluate the performance of their organizations (1). In this regard, given the increase in the enrollment of students at state-run universities as trustees of producing and creating knowledge in countries and considering capital constraints, it is necessary for these institutions to operate effectively and always have their efficiency and productivity evaluated, especially in terms of the production, development, and application of knowledge (2). Measuring efficiency is widely used in a wide range of activities, including the performance of universities. One of the tools used in this area is data envelopment analysis such that in recent years, many studies have utilized this tool to measure the efficiency of universities in various countries, including England, Australia, Malaysia, Thailand and China (3-5). Also, the Emroozinezhad's study, which reviewed the literature on the discussion regarding data envelopment analysis up to 2008 reported that over 4000 studies published in different books and journals have implemented this method (6).

Data envelopment analysis (DEA) is one of the linear programming techniques which measures the relative efficiency of homogeneous units in terms of inputs and outputs, but its lack of distinction between the units under investigation and its unrealistic

weights of inputs and outputs have been recognized as some of its weaknesses. That is, if the weights of inputs and outputs have heterogeneous dispersion, then an efficiency of 1 is reported for most units. However, the use of the goal programming (GP) model creates homogeneity and rational distribution of weights (7, 8). This model also considers the value of the judgments of decision-makers in the process of evaluating efficiency (9).

Evaluating the performance of the units can create a sense of competition and ultimately improve the quantity and quality of learning and research in the university as a whole (10). Therefore, the purpose of the present study is to determine the criteria for assessing the efficiency of the schools of Shiraz University of Medical Sciences and evaluate the efficiency of these units by using a suitable model. To this end, an integration of data envelopment analysis and goal programming was used because such an integrated approach allows for some of the weaknesses in the data envelopment analysis method to be annulled.

Methods

This is a cross-sectional study, conducted in 2017 on the schools of Shiraz University of Medical Sciences. The study was conducted on 10 schools which were the Schools of Medicine, Dentistry, Pharmacy, Health, Nutrition and Food Sciences, Nursing and Midwifery, Management and Medical Informatics, Advanced Medical Sciences and Technologies, Rehabilitation, and Paramedical Sciences. In this research, the time range considered was the data up to the year 2016 which was in the hands of the researchers in an accumulated form. In order to collect the data, first an index of key indicators for the evaluation of the performance and measurement of the efficiency of schools was compiled by reviewing the literature on this subject. To determine the weights of the inputs and outputs, fuzzy weighting was used based upon the opinions of 10 experts which included the academic assistants and/or faculty members of the schools, so that the importance of each indicator was expressed using verbal variables and then converted into quantitative values based on the research of Chen et al. (2011) (11), and their weights were calculated. Input indicators in this study included: the number of classrooms, the number of laboratories, the number of undergraduate students, the number of postgraduate students and the number of faculty members. Output indicators included the number of graduate students, number of postgraduate graduates, number of published books, number of

published articles, h-index of the professors, ratio of ISI articles to all articles as a percentage, proportion of PUBMED articles compared to all articles as a percentage, proportion of SCOPUS articles compared to all articles in percentage, number of ISI articles, number of PUBMED articles, number of SCOPUS articles, and per capita production of articles. Then, using the integrated model of data envelopment analysis and goal programming, the efficiency of the schools was calculated, and the final rankings were made by employing the super-efficiency ranking method (Anderson-Peterson).

Fuzzy Weighting Method

In order to determine the weights and importance of indicators, the opinions of experts were used and triangular fuzzy numbers were applied, allowing for the indicators to be ranked. Based on the described verbal values, the fuzzy weight of each criterion was determined based on triangular fuzzy numbers. Thus, each of the verbal variables was converted into quantitative values according to Table 1, which was based on the work of Chen et al. (2011) (11). Then, using the Best Non-Fuzzy Performance (BNP) relationship, definitive values were standardized and fuzzy numbers were converted into a definitive state.

In the BNP relationship, a, b and c represent the lower bound, the middle value and upper bounds of the triangular fuzzy numbers, respectively.

$$BNP = a + \frac{(c-a) + (b+a)}{3}$$

Table 1: Spectrum of Verbal Variables

Degree of Importance	Fuzzy weights
Very High	0.83,1,1
High	0.67,0.83,1
Fairly High	0.50 ,0.67, 0.83
Medium	0.33,0.50,0.67
Fairly Low	0.17,0.33,0.50
Low	0,0.17,0.33
Very Low	0,0,0.17

*Fuzzy Weight of Verbal Variables Based on Chen Research

Accordingly, the weights of the indicators are presented in Table 2, where the results of applying fuzzy weighting showed that the number of academic faculty members was the most important input and the number of postgraduate graduates was the most important output.

Data Envelopment Analysis

The method of data envelopment analysis was used in various fields such as health care, finance,

Table 2: Indicator Weighting Values (Inputs-Outputs)

Inputs	Weighting Values
Number of classes	0.0508
Number of laboratories	0.0567
Number of undergraduate students	0.0498
Number of postgraduate students	0.0637
Number of academic faculty members	0.0649
Outputs	
Number of undergraduate graduates	0.0484
Number of postgraduate graduates	0.0656
Proportion of books published to professors	0.0581
Number of books published	0.0520
H-index of professors	0.0650
Proportion of ISI articles to all articles (%)	0.0641
Proportion of PUBMED articles to all articles (%)	0.0641
Proportion of SCOPUS articles to all articles (%)	0.0614
Number of ISI articles	0.0552
Number of PUBMED articles	0.0581
Number of SCOPUS articles	0.0581
Articles produced per capita	0.0637

education, and was cited appropriately in the literature of economics and research operations (12). There are two general orientations in data envelopment analysis which are focusing on inputs in the input-centered model and focusing on outputs in the output-centered model (13). CCR input-centered model is classified as the basis of the formation and integration with goal programming in this research.

An Integrated Model of Goal programming and Data Envelopment Analysis

The data envelopment analysis model which has been developed based on goal programming is divided into several categories:

Model 1: Data envelopment analysis model with the aim of minimizing the deviation variable of the unit under investigation

In this model, d_0 is the deviation variable for the unit under investigation, and d_j is the deviation variable of unit j which appears in the jth limit. Ur is output weight r, Vi is input weight i, Xij is Input i is related to unit j, Yrj is output r is related to unit j. In this model, the unit under investigation is efficient when $Z_0=1$, or in other words $d_0=0$. If the unit is not efficient, the efficiency score is $Z_0=1-d_0$.

Model 1:

$$\text{Min } d_0$$

St:

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

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

$$u_r, v_i, d_j \geq 0$$

Model 2: Data envelopment analysis model with the aim of minimizing the sum of deviation variables

This model is called MinSum and the efficiency of the investigated unit can be calculated as $1 - d_j$.

Model 2:

$$\text{Min } \sum_{j=1}^{n} d_j$$

St:

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

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

$$u_r, v_i, d_j \geq 0$$

Model 3: Data envelopment analysis model with the aim of minimizing the maximum deviation

If the maximum deviation value is specified by M, the following limitations will be added to the problem: $d_j \leq M \quad \text{for} \quad j = 1,2,...,n$

If the value of M reaches its minimum, it means that the value of deviation variables will be less than

ideal.

Model 3:

$$\text{Min } M$$

St:

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

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

$$M - d_j \geq 0$$

$$u_r, v_i, d_j \geq 0$$

If the models do not have the power to make distinctions between the units for the evaluation of efficiency, then the multi-objective linear programming model with the target function of the three models above can be used. This means that all three target functions of minimizing the deviation variables of the unit under investigation, minimizing the sum of its deviation variables and minimizing its maximum deviation value are used simultaneously (11).

Result

The results of the present study showed that by taking into account the model structure and considering 17 input and output indicators and 10 schools in Shiraz University of Medical Sciences, an ideal linear programming model was created which included 17 main variables (decision) and 11 limitations. Therefore, in order to measure the efficiency of the schools, a model is constructed, so that the differences between these models are in their target functions and first limitations. Three goal programming models were written for each school of Shiraz University of Medical Sciences so that for a total of 10 schools, 30 models were devised. In this study, descriptive statistics of the schools' inputs and outputs are presented in Table 3.

The results of calculations obtained from TORA software are presented in Table 4. The MinMax function had the highest power of distinction. As shown in the output Table, units become efficient in goal programming through minimizing the deviation, but the Minmax target function can provide a suitable and acceptable distinction between different schools. Taking into account that the Schools of Dentistry, Pharmacy, Nutrition and Food Sciences, Paramedical Sciences, and Health have an efficiency score of 1, their rankings can be made using the super-efficiency ranking method of Anderson-Peterson. The

method of Anderson-Peterson is used for ranking efficient units. In data envelopment analysis, units which are efficient have an efficiency value of 1 and those which are not efficient have values below 1. The efficiency values of non-efficient units are considered as the criteria for their ranking, whereas the super-efficiency ranking method of Anderson-Peterson is used in order to rank efficient units, so that the limit related to the efficient unit is removed from the model for this unit, and the model is again devised. In this situation, the score for efficiency will be greater than 1. Based on this, the super-efficiency ranking method was employed for the Schools of Dentistry, Pharmacy, Nutrition and Food Sciences, Paramedical Sciences, and Health, where the Schools of Nutrition and Food Sciences, Paramedical Sciences and Dentistry had the highest scores.

Discussion

By measuring the level of efficiency, organizations can evaluate and control the performance of their units and take steps towards improvement (14). In the present study, 5 inputs and 12 outputs were used to evaluate 10 schools, and by utilizing an integrated approach of goal programming and data envelopment analysis, the performance evaluation and ranking of the schools of Shiraz University of Medical Sciences were addressed. DEA is a method which is widely used to evaluate the relative efficiency of a complex which consumes several inputs and produces multiple outputs (15). Furthermore, GP is a tool for achieving multiple goals simultaneously (15), and various studies have suggested its use for addressing the problems associated with DEA (16-19)

The findings of the present study showed that according to the results of applying fuzzy weighting, the number of faculty members is the most important input and the number of postgraduate graduates is the most important output. The results also revealed that some schools had high efficiency, including the Schools of Dentistry, Pharmacy, Nutrition and Food Sciences, Paramedical Sciences, and Health, all having an efficiency score of 1. Thus, using Anderson-Patterson's super-efficiency ranking method, the aforementioned schools were ranked. In general, according to the findings of this research, the Schools of Nutrition and Food Sciences, Paramedical Sciences and Dentistry had the highest scores of efficiency compared to other schools.

Some schools had a rather low level of efficiency, indicating that these units do not use their resources adequately. In this regard, Visbal-Cadavid et al. (2017) investigated the efficiency of using resources

Table 3: Descriptive statistics of schools' inputs and outputs

By the end of 2016	DMU	Number of academic faculty members	Number of postgraduate students	Number of undergraduate students	Number of laboratories	Number of classes	Articles produced per capita	Number of SCOPUS articles	Number of PUBMED articles	Number of ISI articles	Proportion of SCOPUS articles to all articles (%)	Proportion of PUBMED articles to all articles (%)	Proportion of ISI articles to all articles (%)	H-index of professors	Number of books published	Proportion of books published to professors	Number of postgraduate graduates	Number of undergraduate graduates
1	Management and Medical Informatics	15	107	182	0	8	3.79	4	26	23	8	49	43	3.26	0	0	16	52
2	Advanced Medical Sciences and Technologies	9	69	0	4	3	2	3	2	15	15	10	75	5.55	0	0	5	0
3	Dentistry	104	112	403	2	20	1.54	13	73	51	9	53	37	2.62	0	0	60	6
4	Pharmacy	48	84	449	25	8	4.28	23	24	124	13	14	73	9.1	0	0	9	54
5	Nutrition and Food Sciences	16	92	83	2	0	1.29	2	3	13	11	17	72	4.56	0	0	14	41
6	Rehabilitation	28	63	284	1	8	0.7	2	5	12	11	26	63	2.07	0	0	20	90
7	Paramedical Sciences	32	51	457	8	16	1.04	7	31	15	24	24	52	2.75	6	0.187	15	125
8	Nursing and Midwifery	56	189	863	5	20	1.59	8	0	34	11	42	47	1.92	1	0.017	40	277
9	Medicine	518	1911	1701	123	24	1.9	108	216	575	12	24	64	5.76	3	0.005	302	147
10	Health	36	228	384	12	15	3.91	24	29	72	19	23	58	6.33	2	0.055	36	115

Table 4: Results of Application of Models and Complete Rankings

Name of the school	Goal programming Min	Goal programming Minsum	Goal programming Minmax	AP	Complete rankings
Management and Medical Informatics	1	0.7645	0.7806		9
Advanced Medical Sciences and Technologies	1	0.5601	0.5434		10
Dentistry	1	1	1	2.7482	3
Pharmacy	1	1	1	1.8647	4
Nutrition and Food Sciences	1	1	1	M	1
Rehabilitation	1	0.8408	0.8848		7
Paramedical Sciences	1	1	1	15.2157	2
Nursing and Midwifery	1	0.7626	0.8172		8
Medicine	1	1	.09735		6
Health	1	1	1	1.8578	5

for general higher education in Colombia in relation to the two basic purposes of higher education institutions: education and research. The results showed that only 18 of the 32 institutions present in the study had no inefficiency (56.25%) and were generally efficient (20). In addition, the results of the study performed using DEA by Meskarpour Amiri (2016) on 16 health research centers of Iran University of Medical Sciences showed that half of the centers were below the level of complete efficiency (21). Therefore, according to the results, an efficient university must have real goals and be able to use minimum inputs to produce maximum outputs as inefficient units waste large amounts of resources (22). The existence of an effective and efficient evaluation system for the efficiency of any organization, such as a university, is highly important and significant, and such evaluations can help university administrators to allocate resources efficiently and identify the strengths and weaknesses (23).

Amongst the limitations of this research is that the efficiency scores obtained using the DEA tool are relative, and can be changed based on the inputs and outputs and the number of units under investigation. It is also necessary to evaluate the efficiency and compare the performance of the schools over a few years in order to determine the extent and direction of increase or decrease in the efficiency of the units. Future studies should be based on the reasons for the inefficiency or low efficiency of some schools as compared to others, as well as factors that affect the performance of schools.

Conclusion

The present study provided detailed and useful information about the relative efficiency of schools of Shiraz University of Medical Sciences, and its results can help contribute to improvements in schools and resource management. The results indicated that some units should improve their output. Continuous implementation of evaluations and publication of research results to portray the relative status and position of schools leads to increased competition and efforts to improve efficiency.

Informed consent
This study includes analysis of data rather than human; therefore, there was no need to obtain informed consent.

Conflict of Interest: None declared.

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