Data Envelopment Analysis of Public Health Facilities in Province Punjab of Pakistan

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Abstract

The performance analysis in the health care system plays an important role to measure efficiency of the emerging needs of the healthcare system. Thus it is inevitable to implement health system reforms and devising assessments. This study focuses on finding the current level of technical efficiency with and without quality factors of public health facilities of all districts in Punjab of Pakistan through the most widely accepted Data Envelopment Analysis (DEA), a method which incorporates the combination of multiple inputs with multiple outputs. The input variables for this study are taken as the number of beds, number of doctors, and number of nurses and percent of stock medicine. The quantitative output variables are number of OPD visits per day and OPD per capita birth, whereas quality output variables are number of ANC-1 visits, mortality rate and number of pregnant women with obstetric complications treated in a public health facility. Practically all the public health facilities in Punjab have deficient or low-quality framework. The derivation from this review might be useful for strategy creators to detail and execute arrangements which help the clinics of the local Punjab to perform better through working on their proficiency.

Keywords: Provide four to five key words. Avoiding plural and multiple concepts. Should be in alphabetical orders.

Introduction

Improvement in health conditions can influence the pace of economic growth through their effects on labor's productivity, labor market participation, fertility and investments in human capital (Bloom, Canning and Graham 2003; Easterlin 1999). Healthy individuals can contribute not only in the economic growth of the society but also it has a wider impact on national gross domestic product. Good health depends on the strong infrastructure of the healthcare System. The awareness of health quality in common people is increasing day by day which leads to higher demand for more efficient and quality health care services in hospitals. Literature has shown that different countries are inefficiently utilizing natural resources and as a result half of the World's scarce resources are being wasted; the problem is more severe in less developed economies. In addition to this, government expenditure is spent on ineffective and unsuitable services (Collins 1994). Schieber (1995) has empirically shown that in order to make health reforms successful, there should be a limit to unnecessary expenses and there should be a further examination of existing health policies. Islam and Salam (2022) conducted an empirical study on public sector hospitals of Province Punjab of Pakistan to evaluate total quality management performance, in recent decades, ineffectiveness of health care is a major concern of health experts and policy makers. In order to achieve efficiency, many economies are involved in revamping their healthcare system. However, in order to enhance the quality and effectiveness of healthcare services, policy makers need to identify loopholes through assessment of healthcare services present in the

country. This will ensure balance between resource allocation and output and accomplishment of objectives of the healthcare system.

Literature Review

Health Structure of Pakistan

The health mechanism of Pakistan comprises both public and private sectors. According to the constitution of Pakistan, the health Ministry of Pakistan is responsible to provide health plans for the people of all areas of Pakistan. The Health Secretary at provincial level determines the health policy, uses the budget and has full control over the hospitals and medical institutes in the province. Public health delivery system operates as a unified health complex which is handled at a district level. The state caters healthcare through a three tiered healthcare delivery method and a range of public health interventions. It includes Basic health units (BHU), and Rural Health Centers (RHCs) composing the core of primary healthcare structure. On the other hand secondary health care including first and second referral facilities providing minor, peripatetic and inpatient care is provided through Tehsil Headquarter Hospitals (THQs), and District Headquarter Hospital (DHQs) which are backed by tertiary care from teaching hospitals. Mental and children health centers (MCHCs) are also part of a unified health system, but the number of MCHC remains limited. The country's ample network of healthcare facilities include 919 hospitals, 5334 BHUs and Sub- Health Centers, 560 RHCs, 4712 Dispensaries, 905 MCH Centers and 288 TB centers. The health system is described by insufficient expenditure, low quality service and poor access and utilization of services. Many of the surveys show that utilization of Government health care services in Pakistan is poor. Three most popular reasons for that are unavailable facilities, non-availability of medicines and low skilled staff.

Efficiency Measurement of Hospitals

The term efficiency is extensively used in management study. It is defined as how efficiently resources are allocated to produce optimal levels of output over a period of time (Vitaliano and Toren 1996). In many economies, health centers demand relatively large proportions of financial budget, human resource and capital resource pertaining to health. The World Bank has published a report in (2004) which states that despite sufficient allocation of financial resources to health sectors, in many countries health systems perform below the set targets and as a result raising concerns on their efficiency. In most less developed countries, existing health sector reforms place great significance to health centers as they are the first contact with the formal health care system. In order to enhance the effectiveness and efficiency of the public health system, policy makers need to develop methods to tackle the problems of ”accessibility, quality of healthcare, community ownership, acceptability, intensity of use and compliance with medical instructions and recurrent costs ”(Jacobs 2001). To develop this, researchers and policy makers need to have prior knowledge of the efficiency levels in the health centers. One of the most important methods to measure the efficiency of the healthcare system is the proportion of health sector outcomes to resources consumed by it. The importance of the indicator can be understood by the fact that it helps to figure out how the outcomes of the health sector are in comparison with the available resources (both monetary and physical) in the economy (WHO 2000).

Methodology

Data Envelopment Analysis (DEA)

Chilingerian and Sherman (1997) are among the most prominent advocates in measuring physician's performance by using Data Envelopment Analysis. They argued that by using DEA,"best practice primary care physicians" can easily be identified. Potential savings were also calculated in the study in case of adaptation of best practice patterns. Bowlin et al (1985) has used"a hypothetical data set for hospitals with known inefficiencies and efficiencies". They tested DEA against ratio and least squares regression analysis. Their results show that the DEA outperformed both methods in identifying sources of inefficiencies. Banker, Conrad and Strauss (1986) has conducted an empirical study on a sample from a hospital in North Carolina to compare efficiency characterizations obtained from Data Envelopment Analysis to the trans-log model. A study conducted by Ozcan and Luke (1993) used Data Envelopment Analysis to analyze efficiency of physicians involved in primary care. He has also examined the impact of inefficient practice patterns on treatment cost in the study. Data Envelopment Analysis study can also be used for comparative analysis. A study conducted by DeCos and Moral-Benito (2014) analyzed determinants of efficiency of public health care systems using DEA in twenty nine industrialized countries in the year 2009. Haddad et al. (2013) conducted a study which has used DEA to measure efficiency of the healthcare systems of OECD countries. A study has been conducted by Tlotlego et al. (2010) in the Republic of Botswana over a period of three years from (2006 to 2008) to analyze the efficiency of a sample of twenty-one non-teaching hospitals. The DEA method was used. A study conducted by Ozcan and Luke in 1993 applied DEA technique to conduct a national study of the efficiency of hospitals in urban markets. Following variables were analyzed in this study: hospital size, membership in multihospital system, ownership and payer mix. In 1998 Linna investigated the development of hospital cost efficiency and productivity in Finland by comparing both parametric and non-parametric panel models. Another study is by Stanford's (2004) examination of the performance by using DEA of 107 Alabama hospitals in the treatment of acute myocardial infarction patients because it too examined clinical efficiency and quality of care. Cross efficiencies were used to improve the efficiency discrimination between hospitals. Preethy and Yasar (2008) conducted DEA analysis to evaluate the technical efficiency scores and quality efficiency scores of Virginia hospitals. They compared the results using DEA models with and without quality outputs. Irfan et al. (2011, 2011a) emphasized that private hospitals are providing better quality of healthcare services as opposed to public sector hospitals. Rasool et al. (2014) computed efficiency scores of hospitals of non-profit private organization (Layton Rehmatullah Benevolent Trust) through DEA in Pakistan. Farooq et al (2021) analyzed 261 public sector Rural Health Centers (RHC's) in Pakistan through application of Data Envelopment Analysis (DEA). Asghar et al. (2018) used DEA to study the efficiency of hospitals in Punjab. In particular, utilized output oriented bootstrap with four inputs and two outputs models for measuring hospitals efficiency. The obtained results indicated that not a single district appears to be fully efficient when bias corrected efficiency technique is used.

The significance of the healthcare study can easily be witnessed due the extensive work which already had been carried out in the major North American countries such as USA, Canada, etc as well as in the most prominent European countries such as Germany, Austria, Switzerland, Czech Republic, Norway, Finland, England, Sweden etc. Some of the asian

countries like Japan, China, India, Iran, Saudi Arab and nepal etc have recognized the significance and the same studies were executed.

A very little effort has been made in the body of knowledge targeting Pakistan. This initiated the motivation that this problem should be addressed and contributed with more details in Pakistan. The aim of this paper is to investigate the current level of technical efficiency with and without quality factors of public health facilities of all districts in province Punjab of Pakistan through the most widely accepted data envelopment analysis (DEA), a method which incorporates the combination of multiple inputs with multiple outputs.

For the review, data was obtained from the Director General of Health Services' District Health Information System (Punjab, Pakistan) for the year 2020. For the study, a total of 8300 public medical facilities across 36 districts of Pakistan's Punjab including all THQS, DHQ, THQ, RHC, BHU, MCH and dispensaries classes are considered. As the available information for the output and input data used in DEA model is district-wise, therefore we consider collectively all health facilities in a district as one DMU. Of the districts reporting quality measures only three of the measures including attendance of ANC1, mortality rate and obstetric complications had non-missing data so these three for quality measures are taken as outputs in the DEA models.

DEA Model Specification

DEA, a non-parametric technique based on linear programming, is used to estimate the relative efficiency of district wise health facilities. The DMUs (districts) having optimal performance are assumed as technically efficient and these obtain an efficiency score of 1. On the other hand DMUs having efficiency performance score less than 1 are assumed to be not efficient. Through slack analysis in DEA the shortage of outputs or excessive inputs for inefficient hospitals can also be identified. Thus in order to become efficient, these inefficient DMUs have to escalate their output slacks or decrease their input slacks. In fact DEA is a very valuable procedure for health administrators pursuing to recognize loop holes to enhance the efficiency performance in health facilities.

Selection of Orientation

The input direction for the DEA model is being implemented keeping in view the economic budget of the health ministry. The input direction is more suited for concentrating on medical services foundations of Punjab.. The specialized proficiency scores obtained under input direction reveal how much of a reduction in the selected inputs is possible given the current degrees of outcomes. The approach given by Avkiran (2001) for deciding on an option with regards to returns to scale suspicion for DEA models was used in this research. The DEA model was performed using constant return to scale (CRS).

Input/ Output Measures

In this study, collectively all hospitals of a district were supposed to yield basically three types of outputs: (1) Average new cases per day OPD visit during 2020 (2) OPD per capita percentage in 2020 (3) Survival rate. These are consistent with the DEA literature.

The input measures are: (1) hospital size—the total number of staffed beds during 2020; (2) the total number of doctors (3) total number of nurses (4) percentage of medicine stock. These input measures are consistent with the DEA literature.

Quality measures

The quality measures used as outputs in the DEA models are: (1) percent of women utilizing antenatal care during pregnancy; (2) percent of normal deliveries conducted during 2020(3) percent of women having obstetric complications treated in public hospitals district wise.

Data Analysis strategy

The DEA is carried out in two steps. In first step, we formulate DEA model 1 without quality outputs i.e. Model 1 contains three outputs/ four input using input-oriented CRS for technical efficiency of n=36 DMUs. The technical inputs used in this model are bed size, the number of doctors, and number of nurses and percent of available medicine stock. The technical outputs being used are average new cases per day OPD visit during 2020, OPD per capita percentage in 2020 (3) Survival rate.

On the other hand, in the second step we formulate model 2 having three technical outputs and three quality outputs/ four input models of technical efficiency with quality factor for 36 DMUs. The technical inputs and outputs are same as used in model 1, whereas quality outputs being used in model 2 are : percent of women utilizing antenatal care during pregnancy; percent of normal deliveries conducted during 2020 and percent of women having obstetric complications

Analysis

Analysis of Model 1

Using a four input/two output constant returns to scale DEA model, it is found that out of 36 DMUs(collectively all health facilities in one district) that had non-missing data for all of the quality outputs and technical inputs, 10 DMUs ware efficient (efficiency score=1) and 26 DMUs (efficiency score <1) were inefficient. The average efficiency score of the inefficient DMUs is 0.87, whereas, overall average efficiency score of all DMus is 0.93 (Table 1).

Table 1: Average Efficiency Scores of Model 1

District	Number	Percentage	Avg. Efficiency Score
Efficient	10	42	-
Inefficient	26	58	0.87
All	36		0.93

The average inputs for the efficient health facilities in a district using Model 1 are 1161.9 beds, 304.4 doctors, 323.6 nurses and 92.4 % availability of medicine stock. The average outputs produced by the efficient hospitals are 10090 OPD visits per day and 1.18 OPD per capita. Whereas, the average inputs for the inefficient health facilities in a district using Model 1 are 1547.73 beds, 403.08 doctors, 508.35 nurses and 95.46% availability of medicine stock. The average outputs produced by the efficient hospitals are 7988.46 OPD visits per day and 1.1 OPD per capita (Table 2).

Table 2: Average Input/ Output for Efficient/Inefficient DMUs in Model 1

	OPD visit per day	OPD per capita	No. of beds	No. of doctors	No. of Nurses	Percent of stock medicine
All DMUS mean	8572.22	1.12	1440.56	375.67	457.03	94.61

All DMUs SD	2881.23	0.21	2001.99	380.01	716.86	4.9
Efficient DUSs Mean	10090	1.18	1161.9	304.4	323.6	92.4
Efficient DMUs SD	4427.80	0.23	1110.33	309.02	456.64	5.25
Inefficient DMUs Mean	7988.46	1.10	1547.73	403.08	508.35	95.46
Inefficient DMUs Mean	1813.36	0.19	2263.69	406.18	796.57	0.047

Analysis of Model 2:

Using a four technical input/2 output and three quality outputs(total 5 outputs) constant returns to scale DEA model, it was found that out of 36 DMUs that had non-missing data for all of the quality outputs and technical inputs, 19 DMUs were efficient (efficiency score=1) and remaining 17 DMUs (efficiency score <1) were inefficient. The average efficiency score of the inefficient DMUs is 0.922529, whereas, overall average efficiency score of all DMUs is 0.96 (Table 3).

Table 3: Average Efficiency Scores of Model 2

District	Number	Percentage	Avg. Efficiency Score
Efficient	19	53	-
Inefficient	17	47	0.922529
All	36		0.922529

The average inputs for the efficient hospitals in the model 2 are 1753.42 beds, 442.63 doctors, 579.79 nurses and 92 % availability of medicine stock. The average outputs produced by the efficient hospitals are 9273.68 OPD visits per day, 1.15 OPD per capita, 85% ANC-1 attendance, 74% survival rate of patients and 5.54% pregnant women having obstetric complication are treated. Whereas, the average inputs for the efficient hospitals in the model 2 are 1090.88 beds, 300.82doctors, 319.82 nurses and 97 % availability of medicine stock. The average outputs produced by the efficient hospitals are 7788.23 OPD visits per day, 1.09 OPD per capita, 87% ANC-1 attendance, 76% survival rate of patients and 3.98 % of pregnant women having obstetric complication are treated (Table 4).

Table 4: Average Input/ Output for Efficient/Inefficient DMUs in Model 2

	OPD visit per day	OPD per capita	Quality1-percent of ANC-1	Quality 2-Survival rate	Quality 3-Obstetric Complication	No. of beds	No, of doctors	No. of Nurses	Percent of stock medicine
All DMUs mean	8572.22	1.125	86	75	4.80	1440.56	375.67	457.03	95
All DMUs SD	2881.23	0.20	12	14	5.45	2001.99	380.01	716.86	5
Efficient DUSs Mean	9273.68	1.15	85	74	5.54	1753.42	442.63	579.79	92
Efficient DMUs SD	3669.82	0.22	13	16	7.16	2661.72	514.63	969.91	6
Inefficient DMUs Mean	7788.23	1.09	87	76	3.98	1090.88	300.82	319.82	97
Inefficient DMUs Mean	1330.83	0.178	9	13	2.46	742.23	81.65	167.14	0.03

It is found that nine DMUs which are declared inefficient in model 1 become efficient in model 2. This shows that the corresponding districts include Nankana Sahib, Lahore, pakpattan , Lodharan, Multan, Okara, D. G. Khan, Jhelum and Bahawalpur are not maximizing technical efficiency in terms of quantitative outputs but are maximizing their efficiency in terms of quality outcomes. The projected input values for the health facilities of these nine districts using slack analysis of DEA model 1 are obtained. These are given in Table 5. The scores of technical efficiency(Model 1) and technical efficiency with quality(Model 2) are given in Table 6.

Table 5: Projected Input of inefficient districts of Model 1 but efficient districts of Model 2

	Beds		Doctors		Nurses		Percent of Stock Medicine	
	Actual	Projected	Actual	Projected	Actual	Projected	Actual	Projected
Nankana Sahib	578	430.93	248	165.47	187	139.42	90	67
Lahore	11921	721.838	2239	217.937	4159	212.661	85	57
Pakpatan	365	352.953	181	175.026	189	91.657	93	87

Lodharan	391	320.399	258	160.051	117	88.063	94	77
Multan	2984	2254.53	799	630.217	1441	842.716	81	68
Okara	864	856.423	317	305.667	358	280.852	99	98
D.G.Khan	1431	748.854	284	191.482	300	217.379	100	73
Jhelum	602	570	229	191.057	206	129.484	96	91
Bahawalpur	2560	1863.15	811	539.201	823	631.386	96	95.6

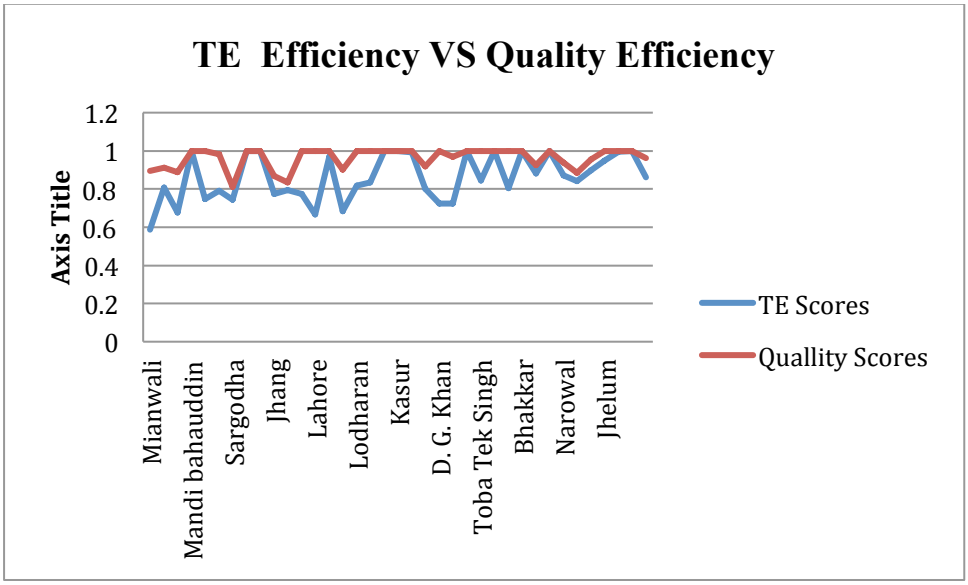
The Spearman rank correlation coefficient between the efficiency scores for each district calculated in Model 1 based only on technical efficiency without quality factor and using Model 2 based on both technical and quality efficiency and quality model is computed. It is found to be 0.608. The graph between technical efficiency (Model 1) and combined technical efficiency with quality factors for each district (DMU) is exhibited in Figure 1.

Table 6: TE scores and TE with quality scores

No.	Districts	TE Scores	TE &Quality Scores
1.	Mianwali	0.587	0.894
2.	Bahawalnagar	0.808	0.913
3.	Rajanpur	0.676	0.888
4.	Mandi bahauddin	1	1
5.	Nankana Sahib	0.746	1
6.	Khushab	0.79	0.983
7.	Sargodha	0.745	0.81
8.	Rahimyar Khan	1	1
9.	Muzaffargarh	1	1
10	Jhang	0.774	0.869
11.	Gujranwala	0.795	0.835
12.	Gujrat	0.774	0.999
13.	Lahore	0.666	1
14.	Pakpatan	0.967	1
15.	Attock	0.683	0.902
16.	Lodharan	0.819	1
17.	Multan	0.834	1
18.	Sialkot	1	1
19.	Kasur	1	1
20.	Okara	0.991	1
21.	Khanewal	0.802	0.917
22.	D. G. Khan	0.725	1
23.	Layyah	0.725	0.97
24.	Faisalabad	1	1
25.	Toba Tek Singh	0.843	0.999

26.	Hafizabad	1	1
27.	Chakwal	0.805	0.999
28.	Bhakkar	1	1
29.	Sheikhupura	0.881	0.925
30.	Chiniot	1	1
31.	Narowal	0.872	0.939
32.	Rawalpindi	0.842	0.886
33.	Sahiwal	0.897	0.955
34.	Jhelum	0.948	1
35.	Bahawalpur	0.996	1
36.	Vehari	1	1

Figure 1: Technical Efficiency Vs Quality Efficiency



Discussion

One of the important outcomes of DEA analysis of this study is that district which is technically efficient i.e., the health facilities in that district proficiently generating quantitative outputs including OPD and OPD per capita are also declared as quality wise efficient with reference to quality factors including percent of antenatal care services(ANC-1), Survival rate and percent of admission of pregnant women having obstetric complication. The health facilities in ten districts including Mandi bahauddin, Rahimyar Khan, Muzaffargarh, Sialkot, Kasur, Faisalabad, Hafizabad, Bhakkar, Chiniot and Vehari in sample obtain score of 1 in both type of models i.e. these are technical efficient both with and without quality factors. The collective health facilities in these districts are declared best health facilities in maximizing both the quantitative outputs and quality outputs.

Among 36 districts, the health facilities in nine districts are found to be technically inefficient with respect to quantitative outputs but are efficient with respect to quality outcomes. The performance of health facilities in these districts can be improved by increasing their technical efficiency. This can be done either by reducing the level of inputs or increasing the level of outputs. Since our aim is to minimize the expense of inputs, the reduction in inputs is more appropriate. The amount of reduction in level of input so that technical efficiency increases can be obtained by projected values of inputs given in Table. For example, the

health facilities in Lahore are technically inefficient with respect to two outputs(OPT visit and OPD per capita) but its technical efficiency score with quality is 1. The technical efficiency of health facilities of Lahore can be improved if number of beds 11921, number of doctors 2239, number of nurses 4159 and medicine stock 85 are reduced to 721.838, 217.937, 212.661 and 57, respectively(Table). The health management can use these projected values of inputs to figure out extra staff or equipment in certain health facilities so that the extra staff or equipment or medicines can be transferred to other needy places. This study helps to find the appropriate level of inputs which is required for an efficient health facility. As a culmination, a conclusion can be drawn that efficient distribution of health resources, subsequent facilities followed by their effective utilization is vital.

The health facilities in the remaining 17 districts are inefficient (bad performer) with respect to both types of outcomes. It is important to note that collective health facilities in none of the 36 districts are found to be technically efficient but inefficient with respect to quality outcomes. Thus this study is evident that quality is not compromised in technically efficient health facilities, i.e., the health facilities maximizing quantitative outcomes are highly probable to maximize quality outcomes.

Another important finding of the study is that there is a moderate degree of correlation (0.5<Spearman's rho>0.7) between the efficiency scores obtained in both models. Thus, this authenticates the addition of quality factors as outputs in DEA models for collective efficiency of health facilities in districts. This indicates that including quality factors as outputs in efficiency measures of an organization can be used as a better benchmarking tool. It is recommended that further research by incorporating authorized quality outcome measures on bigger samples is conducted to see if these basic findings are consistently found.

Conclusion

This study significantly contributes to the literature. Although the DEA model is extensively used by the number of researchers to compute efficiency measures in healthcare systems throughout the world, so far very few attempts have been made to find technical efficiency along with quality factors. The reason behind this is unavailability of such a measure which incorporates both technical efficiency and all measures of quality and makes comparison possible. As far as the Pakistani perspective is concerned, the literature gap on this issue needs to be immediately attended to. The study concluded that the technically efficient health facilities of a district are also efficient with respect to quality factors. Whereas, the inefficient health facilities of few districts are found to be efficient with respect to quality. The findings of study can be used to benchmark the performance of health facilities with respect to both quantitative output measures and quality output measures. The study indicates that health facilities may increase their efficiency by improving the quality factors. But at the same time it also indicates that if a health facility is technically efficient then it must be efficient with respect to quality, i.e., technical efficiency implies quality efficiency. Further, the results obtained will become the guidelines for health policy makers in Pakistan for better planning and improvements.

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