

Data Envelopment Analysis for estimating Health Care Efficiency in the Southwest Teaching Hospitals in Nigeria

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Abstract

Health care services in Nigerian teaching hospitals have been considered as less desirable. In the same vein, studies on the proper application of model in explicating the factors that influence the efficiency of health care delivery are limited. This study therefore deployed Data Envelopment Analysis in estimating health care efficiency in six public teaching hospitals located in southwest Nigeria. To do this, the study gathered secondary data from annual statistical returns of six public teaching hospitals in southwest, Nigeria, spanned five years (2010 - 2014). The data collected were analysed using descriptive and inferential statistical tools. The Inferential statistical tools used included Data Envelopment Analysis (DEA) with the aid of DEAP software version 2.1, Tobit model with the aid of STATA version 12.0. The results revealed that the teaching hospitals in Southwest Nigeria were not fully efficient. The average scale inefficiency was estimated to be approximately 18%. Result from the Tobit estimates showed that insufficient number of

professional health workers, especially doctors, pharmacist and laboratory technicians engineers and beds space for patient use were responsible for the observed inefficiency in health care delivery, in southwest Nigeria. This study has implication for decisions on effective monitoring of the entire health system towards enhancing quality health care service delivery which would enhance health system efficiency.

Keywords: Data Envelopment Analysis, Healthcare efficiency, TOBIT model, technical efficiency

Introduction

The quality of health care is a global issue which requires rapid transformation in order to meet the increasing needs and demands of the population of patients in any nation. Increase in demand for health care resources is essential to the need to improve efficiency in the health sector. Nigeria's ageing population, increased personal use of health care, and increased treatment options associated with medical advances contribute to the rising demand for health care. Due to the large size and rapid growth of health care expenditure, even small size increases in efficiency can lead to considerable savings of resources or expansion of services for the community.

In almost all the non-profit health institutions in Nigeria, especially public hospitals, it is not unusual to find long queues of patients waiting for several hours to be attended to with health resources that are very scarce in supply. Stakeholders in the Nigerian health care sector are regularly under intense pressure to find more beds, hire more doctors and nurses, provide more drugs, and other health care resources that will ensure efficient delivery of health care services. Lack of proper application of these health care inputs may lead to adverse or negative effects in the lives of patients'. In the same vein, doctors and nurses may become helpless as their patients' health care statuses are affected because basic health care materials are not readily available in the right proportions. In some cases, the quality of health care is hampered by instances such as damaged beds, insufficient or unavailability of drugs, too many administrative staff members, and few qualified medical personnel. In other cases, particularly where patients rely heavily on the expertise provided by tertiary health institutions such as teaching

hospitals, the inefficiency of healthcare systems may result in loss of lives owing to low quality of treatment from the health care service providers.

In order to proffer solutions to the challenges which face health care delivery, studies such as Iyang (2008) have identified the need to evaluate efficiency of health institutions, especially the non-profit ones, due to the high rate of poverty among ordinary individuals who are mainly in need of the most basic health care services. But the suggestions proffered by these studies have not been given enough or sustained empirical base. Moreover, in Nigeria, there is dearth of literature which deals with the evaluation of efficiency of health care system. The existing limited study in the Nigerian health care system such as Ityavyar (1988) provided mixed conclusions and inconsistencies associated with the concept of efficiency. Furthermore, Ibiwoye and Managi (2009) identified the problems facing the health sector as underfunding and the procedure for allocating resources being faulty. These problems were examined from the perspective of efficient use of resources; the absence of which may seriously jeopardize the effectiveness of any expenditure on health, irrespective of the size of budget. The extant literature has identified input-related issues as constraints to efficient delivery of health care services, which equally implies efficiency estimates from a technical point of view. For profit-oriented hospitals, such as private ones, evaluation of efficiency would be more appropriate from the allocative point of view, which requires the consideration of budgetary allocation and cost of operation. However, available evidence such as Asuzu (2004), Polsa, Spens, Soneye and Antai (2011) has shown that the low income earners in Nigeria, who constitute the majority, always seek to patronize non-profit health institutions. Hence, there is need for input-output-oriented approach to the study of efficiency which has not been given any concrete focus in the existing literature.

In Nigeria, there are limited studies on the efficiency of health facilities that have been conducted using Data Envelopment Analysis technique (DEA). This study will therefore be significant in estimating efficiency level of the teaching hospitals in Southwest Nigeria, using more robust techniques and generate information that will be useful for policy implementation, to improve the efficiency of the healthcare delivery.

The reminder of the study is organized as follows: Section two reviews the relevant empirical literature on measuring efficiency of hospitals using DEA techniques. Section three illustrates data and methodology. Section four describes and discusses the empirical results. Section five contains conclusion and recommendations.

Literature Review

Data Envelopment Analysis (DEA) is a non-parametric method used in measuring productive efficiency of the decision making units (DMU). The non parametric way of measuring efficiency was first introduced by Farrell (1957). Charnes, Cooper and Rhodes (1978) proposed a general methodology of DEA (named CCR), a model based on the assumption of Constant Return to Scale (CRS), implying that any proportional change in inputs usage results in the same proportional change in outputs, in order to measure and evaluate the performance of any decision-making unit (DMU). It was further extended by Banker, Charnes and Cooper (1984) (named BCC), a model based on the assumption of Variable Return to Scale.

Al-Shayea (2011) worked on measuring hospital units' efficiency using the DEA approach. This technique was applied by him to study the performance and efficiency of King Khalid University Hospital departments in Saudi Arabia. The results showed that only two, out of nine departments, have 100% efficiencies throughout the 12 months period.

Park, Fowler and Giebel (2011) discussed the measurement of hospital operating efficiencies for strategic decision, with a view to measuring and benchmarking the operational efficiency of a regionally-based hospital in Colorado, by using the Data Envelopment Analysis (DEA) for a period of two years (September 2007-August 2009), in order to fully understand the relationship among variables that affect hospital performance. Their findings indicated that revenue will need to increase for the future, because reducing operating expenses will only result in short-term improvement. They concentrated on revenue and efficiency measures, and laid more emphasis for further research which includes other performance measures such as patient waiting time, patients' satisfaction, service quality, as well as other financial measures.

Kundurzhiev and Salchev (2011) focused on technical efficiency in psychiatric hospital care in Bulgaria. In doing so, they assessed the

technical efficiency of psychiatric treatment facilities on the basis of input resources and output product, go ahead to compare groups of treatment facilities in relation to their efficiency. The Data Envelopment Analysis (DEA) model was used; it finds increasing application in many spheres of public life, including health care. During the process, treatment facilities for hospital psychiatric care were subdivided into three groups according to hospital type: State psychiatric hospitals (SPH) – 12; Regional dispensaries for psychic diseases with inpatient wards (RDPDI) – 12; Psychiatric clinics and wards in multi-profile hospitals for active treatment (PCW-MHAT) – 17. In all, these studies comprised all psychiatric treatment facilities in the public sector. The technical efficiency of the treatment facilities studied for hospital psychiatric care was assessed in accordance with the DEA model previously stated. In calculating efficiency, they used software developed by the scholars, based on the module for solving optimization problems “Solver” in MS Excel and a programming code of Visual Basic for Applications (VBA). They also presented a possible assessment method, which provides an opportunity for improving efficiency in the sector.

Ancarnai, Di Mauro and Giammanco (2009) pointed out that hospital efficiency has been largely underexplored. Therefore, their study examined the relationships between decision making processes of a hospital ward and technical efficiency using Data Envelopment Analysis (DEA). The results indicate that both decisions internal to the hospital and exogenous re-organizations affect the hospital’s efficiency.

Akazili, Adjuik, Jehu-Appiah and Zere (2009) used DEA method to calculate the technical efficiency of 89 randomly sampled health centers in Ghana, to determine the degree of efficiency of health center and recommend performance targets for inefficient facilities. The result revealed that 65% of the health centers were technically inefficient and were using resources that they did not actually need. It showed that there is inefficiency in the health care delivery system of public health centers and that significant amount of resources could be saved if measures were put in place to curb the waste.

Coyne, Richards, Short, Shultz and Singh (2009) measured efficiency and cost indicators in relationship to hospital size and ownership. What their research revealed is that small and large not-for-profit hospitals appear to achieve higher efficiency levels than

government-owned hospitals, but that larger hospitals of both ownership types report greater efficiency than that achieved by small hospitals.

Other researchers have examined the different ownership forms of hospitals and efficiency performance of Taiwanese hospitals (Hsu and Hu, 2007; Hu and Huang, 2004; Wei, 2006). Hu and Huang (2004) observed that public ownership significantly worsens a hospital's efficiency, while higher ward capacity utilization helps improve efficiency. Similarly, Huerta, Ford, Peterson and Brigham (2008) opined that profit institutions had a significant and negative impact on efficiency, supporting the notion that publicly-run and non-profit hospitals may be more efficient than those privately-owned. Harrison and Sexton (2006) noted that religious, not-for-profit hospitals are becoming more efficient in management of resources, and goes on to highlight the importance of the hospital's unique mission to the community, in order to ensure continuing support. Similarly, Friesner, Roseman and McPherson (2008) examined whether or not hospital efficiency is affected by seasonal inefficiency. What is indicated is that hospital efficiency does vary over time, but that the type of inefficiency depends on the specific efficiency being measured.

Zere, Mbeeli, Shangula, Mandlhate, Mutirua, Tjivambi and Kapenambili (2006) examined the technical efficiency of some hospitals in Namibia, with a view to quantifying the level of technical inefficiency in the country, so as to alert policy-makers of the potential resource gains to the health system, if the hospitals that absorb a lion's share of the available resources are technically efficient. All public sector hospitals (n = 30) were included in the study. Hospital capacity utilization ratios and the Data Envelopment Analysis (DEA) technique were also used to assess technical efficiency. The DEA model used three inputs and two outputs. Data for four financial years (1997/1998 to 2000/2001) were used for analysing the economic efficiency scores. The findings suggest the presence of substantial degree of pure technical and scale inefficiency. The average technical efficiency level during the given period was less than 75%. Less than half of the hospitals included in the study were located on the technically efficient frontier. Increasing returns to scale is observed to be the predominant form of scale inefficiency. Based on this, it was concluded that the existing level of pure technical and scale inefficiency of the district hospitals is considerably high and may negatively affect the government's initiatives to improve access to quality health care and scaling up of interventions

that are necessary to achieve the health-related Millennium Development Goals.

Hagen, Veenstra and Stavem (2005) analysed the effects of a reimbursement reform on somatic hospitals' efficiency and quality, measured as patient experiences in Norwegian hospital. By the reform, a capitation-based block grant system was replaced by an activity-based system. Data on efficiency and patient satisfaction from 213 hospital departments before (1996) and after the reform (1998, 2000 and 2003) were analysed using a mixed model approach. At the same time, the efficiency ratings were developed at the level of the hospital using Data Envelopment Analysis, while the patients' satisfaction scores were at department level data from recent patients' surveys. The result showed that both, technical efficiency and patients' satisfaction increase after the reform. They interpreted it by increasing technical efficiency as a direct effect of the reimbursement reform. In the same vein, higher patients' satisfaction is understood as an effect of lower waiting time, which in turn is an effect of the introduction of activity-based financing.

Kirigia, Lambo and Sambo (2000) investigated the technical efficiency of public hospitals in Kwazulu-Natal Province of South Africa. They employed the use of Data Envelopment Analysis methodology to identify and measure individual hospital's inefficiencies. The result revealed that forty percent of the hospitals had some degree of technical inefficiency and fifty-eight percent were scale inefficiency indicating that the following inputs such as doctors, nurses, paramedics, technician, administrative staff, labor provisioning staff, other staff & beds are currently wasted and not utilized in the production of hospital output in Kwazulu-Natal public hospitals. These specific input reductions are required to make inefficient hospitals become technically efficient. Based on this, it was concluded that DEA result constitute a strong guide to health care decision making, especially with regards to practical ways of increasing efficiency and rational use of health care resources.

Rutledge, Parson and Knaebel (1995) examined the model of DEA and its ability to determine the relative efficiency of each of the latest twenty- two (22) months of available data for a mid-sized non-profit hospital in Southeast, United States. The DEA was able to simultaneously consider multiple inputs and outputs (five each) which are classified in months, as efficient or inefficient. Accordingly, the specific inputs and outputs that caused the month to be considered

inefficient were identified, as well as the magnitude of the excess inputs and insufficient outputs. The results were discussed with the hospital management. They considered DEA as an efficient and effective tool, a potential device that will assist in reducing hospital costs.

It is obvious that previous studies has tried to measure the technical efficiency of hospitals in developed and developing countries using DEA, but there is rarity of studies that has tried to measure the technical efficiency of public teaching hospitals in Nigeria, particularly in Southwest Nigeria. This reflects the significance of the current study that attempt to measure the technical efficiency of public teaching hospitals in Southwest Nigeria.

Objectives of the study

The aim of this paper is to use Data Envelopment Analysis to estimate the health care efficiency level in selected teaching hospitals in southwestern Nigeria, while the specific objectives are to:

- (i) determine the applicability of DEA in modeling health care efficiency in the teaching hospitals selected for this study;
- (ii) determine the operational efficiency of facilities in the teaching hospitals selected for this study;

Research Questions

- (i) How can DEA model be applied in health care efficiency in teaching hospitals selected for the study in Nigeria?
- (ii) How operationally efficient are the facilities in the teaching hospitals selected for this study?

Methodology

The study covers six public teaching hospitals in Southwest Nigeria. The data were obtained from the annual statistical returns of the teaching hospitals for the period of five years (2010- 2014). Descriptive and inferential statistics were used. The inferential statistics include Data Envelopment Analysis (DEA) with the aid of DEAP software version 2.1; Tobit model with the aid of STATA version 12.0.

The Data Envelopment Analysis Methodology

Efficiency in DEA is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs (Hollingsworth and Parkin, 1998;

Smith, 1998). Given p outputs and m inputs, efficiency (h_0) for hospital 0 is defined in the following way:

$$\text{Maximize: } h_0 = \frac{\sum_{r=1}^p u_r \times y_{r0}}{\sum_{i=1}^m v_i \times x_{ij}}$$

Subject to:

$$\frac{\sum_{r=1}^p u_r \times y_{r0}}{\sum_{i=1}^m v_i \times x_{ij}} \leq 1$$

where:

y_{r0} = quantity of output r for hospital 0

u_r = weight attached to output r , $u_r > 0$, $r = 1, \dots, p$

x_{i0} = quantity of input i for hospital 0

v_i = weight attached to input i , $v_i > 0$, $i = 1, \dots, m$

The weights are specific to each unit so that $0 \leq h_0 \leq 1$ and a value of unity imply complete technical efficiency relative to the sample of units under scrutiny. Since the weights are not known *a priori*, they are calculated from the efficiency frontier provided by DEA framework.

The DEA model

The Data Envelopment Analysis input oriented dual formulation for hospital j or decision- making unit (DMU) j :

X_{ij} = the number of health resources (input) used in health hospital j in a year

X_{1j} = the number of beds available in health hospital j in a year

X_{2j} = the number of doctors available in hospital j in a year

X_{3j} = the number of nurses available in hospital j in a year

X_{4j} = the number of pharmacist available in hospital j in a year

X_{5j} = the number of technician available in hospital j in a year

X_{6j} = the number of administrative staff available in hospital j in a year

X_{7j} = the number of engineers available in hospital j in a year

X_{8j} = the number of other support staff available in hospital j in a year

While:

Y_{ij} = the number of patients categories attended to in hospital j in a year

Y_{1j} = number of outpatient visit attended to in hospital j in a year

Y_{2j} = number of inpatient surgeries attended to in hospital j in a year

Y_{3j} = number of inpatient visits attended to in hospital j in a year

Y_{4j} = number of emergency cases attended to in hospital j in a year

Y_{5j} = number of maternal and child health cases.

j = teaching hospitals considered in the study while J ranges from 1 to 6.
 1 denotes LUTH; 2 denotes OOUTH; 3 denotes UCH; 4 denotes LAUTH; 5 denotes OAUTH and 6 denote EKSUTH.

Θ = Relative efficiency of the hospital

λ_j = weight attached to the inputs used and outputs in each hospital j

Generally it is not expected that teaching hospitals would be found prospecting for more patients in order to increase output, rather cost minimization might be the objective.

Therefore, the input minimizing model used for the teaching hospital is:

Minimize: $h_0 = \theta$

Subject to:

Input constraints

$\sum_{j=1}^6 \lambda_j X_{1j} \leq \theta X_j$	Bed constraints
$\sum_{j=1}^6 \lambda_j X_{2j} \leq \theta X_j$	Doctors' constraints
$\sum_{j=1}^6 \lambda_j X_{3j} \leq \theta X_j$	Nurses constraints
$\sum_{j=1}^6 \lambda_j X_{4j} \leq \theta X_j$	Pharmacist constraints
$\sum_{j=1}^6 \lambda_j X_{5j} \leq \theta X_j$	Technicians' constraints
$\sum_{j=1}^6 \lambda_j X_{6j} \leq \theta X_j$	Administrative staff constraints
$\sum_{j=1}^6 \lambda_j X_{7j} \leq \theta X_j$	Engineers' constraints
$\sum_{j=1}^6 \lambda_j X_{8j} \leq \theta X_j$	Other support staff constraints

Output constraints

$\sum_{j=1}^6 \lambda_j Y_{1j} \geq Y_j$	Outpatients visits constraints
$\sum_{j=1}^6 \lambda_j Y_{2j} \geq Y_j$	Inpatients surgeries constraints
$\sum_{j=1}^6 \lambda_j Y_{3j} \geq Y_j$	Inpatients visits constraints
$\sum_{j=1}^6 \lambda_j Y_{4j} \geq Y_j$	Emergency cases constraints
$\sum_{j=1}^6 \lambda_j Y_{5j} \geq Y_j$	Maternal and child health cases
$\sum_{j=1}^6 \lambda_j = 1$	Scale constraints

$\lambda_j \geq 0,$ (Non-Negativity Constraints)

where $j = 1, 2, 3, 4, 5$ and 6

The model above assumes that the objective is to minimise input use in the selected teaching hospitals for a given level of output. This

system of equation is to be formulated and solved for each of the hospital selected in this study, that is, six (6) runs.

DEA Inputs measures used for this study

Physical input data are proxy for the capital and labor factors. As proxy for capital, we used total number of beds (Beds) and the labor proxies were employees who are physicians (i) Doctors (number of medical doctors including residents and interns), (ii) Nurses (number of nurses), (iii) pharmacists, (iv) technicians, (v) number of administrative staffs, (vi) engineers, (vii) other support staff

DEA outputs measures used for this study

The output measures consist of outpatients' visits (total number of outpatients), inpatients' surgeries, inpatient visit, emergency cases, maternal and child health cases. There are usually a number of factors which determines efficiency in hospitals, in terms of both inputs and outputs.

Tobit regression model

Tobit regression model was used to predict the determinants of efficiency level of health care delivery in Nigeria. The Tobit equations are expressed as follows:

$$I = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_nX_n = f(X_i)$$

$$\text{and } y = g(I)$$

$$\text{Where; } y = 0 \text{ if } I < I^*$$

$$Y = I - I^* \text{ if } I \geq I^*$$

Specifically:

$$y = b_iX_i + e_i$$

Where:

y = efficiency scores obtained from DEA estimation,

b_i = parameters of I,

e_i = random error term,

X_i refers to independent variables ($i = 1, 2, 3 \dots 8$),

I = represent the equation of all the independent variables.

I^* = censored value

Results and Discussion

Table no. 1. DEA Technical Efficiency for teaching hospitals (2010 – 2014)

Year	TEV	TEC	TEI	SE
2010	0.734	0.767	0.812	0.721
2011	0.736	0.864	0.797	0.823
2012	0.689	0.745	0.766	0.904
2013	0.639	0.654	0.729	0.869
2014	0.742	0.894	0.804	0.763
Mean	0.708	0.785	0.782	0.816
Standard deviation	0.044	0.096	0.034	0.074
Minimum	0.639	0.654	0.729	0.723
Maximum	0.742	0.894	0.812	0.904

TEV, TEC and TEI are the average technical efficiency scores from Data Envelopment Analysis under Variable Returns to Scale, Constant Returns to Scale and Non-increasing Returns to Scale. SE represents scale efficiency of the sampled health institutions. Table no. 1 shows the efficiency score estimates for teaching hospitals over the sampled period of five years. Overall, the technical efficiency analysis indicates that there are inefficiencies in health care delivery in Nigeria. Average scale efficiency was 82%, suggesting that pure technical inefficiency is the main factor that hinders health sector to operate at optimal scale. The results indicate that scale efficiency was highest in the year 2012 across the sampled hospitals. Scale efficiency in the Nigerian health sector was at its lowest in 2010. The findings indicate a possibility of reaching the optimal level of health care efficiency, if the estimated inefficiency of 18.4% is addressed.

Evidence from the results of Tobit model which analyzed the optimal gap in health care efficiency is presented in Table no. 2. Parameter estimates from the Tobit model indicates that insufficient number of professional health workers (doctors, pharmacist and laboratory technicians), engineers and beds space for patient use are responsible for the observed inefficiency in health care delivery, in the studied hospitals in Southwestern part of Nigeria.

Table no. 2. Analysis of Determinants of Scale Efficiency

Variables	Coeff	Z value
number of beds	-0.07	2.43**
number of doctors	-0.672	3.10**
number of nurses	0.04	1.65*
number of non medical staff	0.324	1.62
number of pharmacist	-0.231	1.73*
number of technician	0.001	2.90**
number of administrative staff	0.242	1.54
number of engineers	-0.15	2.32**
Constant	1.04	
LR chi2	214.1661	
Prob > chi2	0.000	

Table no. 3 shows the descriptive statistics of the inputs and outputs of the teaching hospitals. The results show that the average number of outpatient visit in the selected hospitals for the entire sampled period is approximately 106,780. The hospital with the least number of outpatient visit recorded 12,480, while the highest reported in the selected teaching hospitals was 305,097 number of outpatient visit. The average number of inpatient surgeries in the selected teaching hospitals for the sampled period stood at 12,021; the average number of inpatient visits in the selected teaching hospitals for the sampled period was 48,083. The average number of emergency cases was 9,170. The average number of beds available in the sampled teaching hospitals was 510, an indication of insufficient facilities in the hospitals relative to the number of patients in need of such facilities. Descriptive statistics showed that the average number of doctors and nurses in the teaching hospitals were 394 and 595 respectively. The average number of nurses was found to be higher than that of the doctors. The highest number of doctors and nurses for the period were 909, and 1447 respectively.

Table no. 3. Descriptive statistics of input and output variables of study

Variables	Mean	Standard deviation	Minimum	Maximum
Number of outpatient visit	106,779.5	88,311.04	12,480	305,097
Number of inpatient surgeries	12020.8	9,264.382	2,420	38,787
Number of inpatient visit	48,083.2	16,843.73	31,240	71,205
Number of emergency cases	9,170.533	7,233.313	1,415	31,787
Number of maternal and child health cases.	1,890.733	1,248.323	290	4,343
Number of beds	510	299.0125	214	899
Number of doctors	394.9333	332.0952	143	909
Number of nurses	595.5333	483.8778	210	1,447

Conclusion

The DEA investigates the health care efficiency of the teaching hospitals in south west Nigeria for the period of five years (2010-2014). Overall, the technical efficiency analysis indicates that there are inefficiencies in health care in the teaching hospitals in Southwest, Nigeria. From the data analyses, average scale efficiency was approximately 82% and indicates that pure technical inefficiency is the main factor that causes the inability of the health sector to operate at optimal scale. The results also indicate that scale efficiency was highest in 2012, across the six selected teaching hospitals. Scale efficiency in the Nigerian health sector was at its lowest in 2010. The findings indicate a possibility of reaching the optimal level of health care efficiency, if the estimated inefficiencies of 18% are addressed. Parameter estimates from the Tobit model indicates that insufficient number of professional health workers (doctors, pharmacist and laboratory technicians), engineers and beds space for patient use are responsible for the observed inefficiency in health care delivery, in the studied hospitals in the Southwestern part of Nigeria.

There is need for the government to recruit more healthcare professionals especially doctors, pharmacist, laboratory technicians,

also engineers and also provide more funds for the teaching hospitals so as to increase the capacity of the facilities like the number of beds in the hospitals in order to reduce the technical inefficiency rate of the teaching hospitals in Nigeria. In addition, the managers of healthcare facilities at various hospitals should ensure optimal use of resources at their disposal for greater level of efficiency.

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