Communication in Physical Sciences 2020, 6(2): 845-851

On the Efficiency of Health Systems in West Africa: A Data Envelopment Analysis Approach

Micheal Nnamdi Nwakobi

Received 24 July 2020/Accepted 29 December 2020/Published online: 30 December 2020

Abstract: *Data Envelopment Analysis was used to determine the efficiency of health systems of 16 countries in West Africa. We attempt to provide explanations on the inefficiencies of health systems in West Africa. This method allows us to evaluate the ability of each country to transform its sanitary "inputs" into health "outputs". Our results show that, on the average, the health systems of these countries have an efficiency score between 32% and 96% of their maximum level.*

Key Words: *Technical Efficiency, Data Envelopment Analysis, Health System, Health performance, health indicators*

Micheal Nnamdi Nwakobi
Department of Statistics
University of Nigeria, Nsukka
Enugu State, Nigeria.
Email: nwakobi.nnamdi@gmail.com
Oricid id:

1.0 Introduction

Health is now seen as a component of human capital in the same way as education and nutritional status (Grossman, 2007; Alsan *et al*., 2007). These authors maintained that everyone has an initial health stock that depreciates with age but can be maintained or even appreciated by combining individual health care, education and the time available. Health care expenditures in most developing countries have grown dramatically in recent decades. It is widely believed that the inefficiency of health care institutions has, at least in part, contributed to this phenomenon. Less efficiency means a waste of resources which could have been used elsewhere where inputs were missing. Inadequate supply of health services can lead to early death. There is also a growing concern among policy makers and planners that health services are not being delivered with utmost efficiency.

According to a study by the World Bank in 1993, at least four reasons support the assertion that a healthy individual is more productive and contribute more to economic growth.

(i) Health limits the loss of production because of the impact of disease on labour
(ii) It allows exploiting the natural resources that were largely inaccessible because they are located in infested areas
(iii) It increases the rate of school attendance and allows children to assimilate better the lessons learned
(iv) Health frees for other purposes, resources that would have served otherwise to provide care to the sick

In 2002, government in about 65% of the 46 countries in the WHO Africa Region spent less than US$ 10 per capita per year. Evidence from the Africa Region indicates that the problem of scarcity of resources is also compounded with technical inefficiency that leads to wastage of the available meager resources (Kirigia *et al*., 2006). In 2006, cognizant of the technical inefficiency plaguing the African health systems, Ministers of Health of the African Union Member States undertook to institutionalize efficiency monitoring within the national health information systems (Kirigia *et al*., 2007). Coupled with this recognition, there is a realization among policy makers that increased funding alone will not and cannot solve the problem. From a strict sustainability perspective, it can be argued that most African countries are approaching or have already reached their upper limit in terms of increasing real financial resources allocated to the health sector. Given the escalating disease burden and the limited ability of governments, private and donor funds to meet this burden, the issue of health system sustainability has gained prominence in policy debates about finding a solution. These concerns are legitimate due to the magnitude of expenditure on health services, which account for as much as 5% of GDP and between 5% to 10% of government expenditures in developing countries, though this falls below the Abuja target of 15% of government expenditure allocated to the health sector (World Bank, 2004). The WHO has estimated that due to inefficiency about 20%–40%, total

healthcare resources are being wasted per year among its member countries. Furthermore, this rate is higher in low-income and middle-income countries (Chisholm &and Evans, 2010). West African countries are not homogeneous in terms of area, population and economic conditions; however, they have public health functions and a number of their health system outcomes are in common. Many of the countries share similar health systems problems, including a high burden of diseases due to the geographical contiguity, disease patterns and social conditions and inadequate resources for healthcare. Understanding health systems efficiency in different West African countries could promote shared learning and highlight key areas of best practice, as well as areas where improvement is needed. Furthermore, given geographical proximity and many strong relationships experienced with nearby countries, there is likely to be relative ease in the ability to practically understand, learn and apply nuance about healthcare systems from one country to another.

Assessing the efficiency of healthcare systems is a difficult process as analyses often encounter methodological problems, particularly due to the need for appropriate and valid outcome indicators. Despite the empirical difficulties in applying efficiency concepts to health systems, efficiency can be measured on both micro and macro levels (Medeiros and Schwierz, 2015). Measuring health system efficiency at a macro level is particularly important in order to understand health system performance across the globe and take required action to minimize inefficiency (Smith, 2002). The impact of health on the well-being and overall health of a country probably justifies the huge investments of the states in this area. Indeed, in 1990, global spending on health was evaluated at $1 700 million with more than 1000 billion from states; representing 60% of the total expenditure. In developing countries (Africa, Asia, Latin, America), these costs were estimated at $170 billion, 50% funded by the states (World Bank, 1993).

Because of the increased financial pressure on public health systems and the availability of more appropriate databases, efficiency analyses were conducted in industrialized countries quite early as means to help reduce costs. By contrast, there are only a few applications of DEA in sub-Saharan Africa so far. As a consequence of insufficient data information systems not much is known about the efficiency of health care facilities. Most of the published studies about this topic focus on the hospital level, comparing the relative performance of facilities at the same health care level. In Africa, the application of DEA in the health sector has been quite limited. So far, the approach has been applied to health facilities in only few countries, i.e. a study of 155 primary health care clinics in Kwazulu-Natal province in South Africa found 70% of them to be technically inefficient (Kirigia *et al*., 2001). A similar study of 32 public health centres in Kenya revealed that 56% of them were technically inefficient (Kirigia *et al*., 2004). Kirigia *et al*. (2002) also assessed the technical efficiency of 54 public hospitals (which are higher level of health care) using the DEA application in Kenya and found that 26% (14) of the hospitals were technically inefficient. The study singled out the inefficient hospitals and provided the magnitudes of specific input reductions or output needed to attain technical efficiency. An assessment of technical efficiency of 30 district hospitals in Namibia was carried out in 2006 using DEA and the findings were similar to that of public hospitals in Kenya (Kirigia *et al*., 2002). The average technical efficiency was less than 75% (Zere *et al*., 2006). Another study in Sierra Leone revealed that 59% of the 37 peripheral health units in Pujehun district were technically inefficient (Renner *et al*., 2005). A recent technical efficiency study using DEA in Zambia of 20 hospitals revealed average efficiency of 64% implying that the 17 inefficient hospitals could lower their cost by 36% and still achieve their current levels of output (Masiye, 2007). A pilot study of 21 public health centers and 21 hospitals was carried out five years ago in Ghana (Osei *et al*., 2005) and the results shows that 18% of the health centers were technically inefficient. According to the paper, the sample of the health centers was too small (3.7%) that the results could not be generalized for the whole country and so suggested further studies on the technical and allocative efficiency of health centers. The issues that remain to investigate are, among other things, why some health systems can be considered more effective than others, and what explain the differences in countries' health systems. The purpose of this paper is to shed some more light on this issue that, to our knowledge, has received little attention in the literature. In this paper, we

compare and attempt to provide an explanation on the inefficiencies of health systems of 16 countries in West Africa. Our comparative analysis of health systems is based on the concept of efficiency obtained through Data Envelopment Analysis (DEA). This concept is related to the production function that shall be defined as the technical interrelationship which results in the maximum output for a combination of production factors and a given technology. This is somehow the ability of each country to transform its sanitary inputs in health outputs (Bosman and Fecher, 1992). Beyond this definition, this function is also conceived as a frontier or a standard of comparison for assessing efficiency. In other words, the health system of a country will be considered efficient when the combination of outputs and inputs is located on the frontier. An important rationale for using DEA in the health sector is its applicability to the multiple input-output nature of health care provision and the simplicity of the assumptions underlying the method. Note that the DEA method was applied in health sector by many other authors, including (Banker *et al*., 1986; Grosskopf and Valdmanis, 1987; Fare *et al*., 1989). However, in these applications, the analysis is usually at the micro level, that is to say, at the hospital level. The objective is then to evaluate the performance of a hospital in comparison to others (Banker *et al*., 1986). We consider all hospitals for each country as a single production unit. We aim to provide information on the efficiency measurement of health care facilities in developing countries and then build an international production frontier in the health sector.

The rest of this article is organized as follows: Section 2 is devoted to the presentation of the DEA method. In Section 3, we present our results of the evaluation of the technical efficiency of the health systems of 16 countries of West Africa. Thus evaluated, the efficiency depends on the specific environment of each country. To provide explanatory elements of the efficiency scores of the different countries, we establish a relationship between the level of efficiency and certain strategic or environmental variables. Section 4 provides our concluding remarks.

2.0 Methodology

2.1 The DEA method

DEA is a non-parametric approach based on linear programming method initially developed by (Charnes *et al*., 1978) to evaluate the relative efficiency of the decision-making units (DMU) of non-profit institutions or of the public sector which use a group of similar inputs to produce a group of outputs. The DEA method measures the efficiency of a DMU "o" compared with the set of "*n*" DMUs in a given sample. The aim is to establish a level of relative efficiency θ ($0 \leq \theta \leq 1$) for each DMU by comparing its input and output quantities with those of other DMUs. The efficiency in DEA can be characterized in two ways: the input orientation which supposes a minimization of inputs for a given level of outputs and the output orientation which assumes a maximization of the outputs for a given level of inputs. It's also possible to consider constant or variable returns to scale. Our analysis is based on the input minimization model with the assumption of variable returns to scale. Indeed, minimizing inputs seems appropriate because:
1) In the case of public services, the services provided by the state to citizens are exogeneous
2) Resource utilization by the countries studied is generally carried out in a difficult budgetary situation.

The model we have estimated is expressed as follows with all notation adopted from Zhu (2002) and Sedzro *et al*. (2009).

$$\text{Min}_{\theta,\lambda}\ \lambda \quad (1)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j X_{ij} \leq \theta X_{io} \quad , \quad i = 1, 2, \ldots, m \quad , \quad (2)$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{ro}, \quad = 1, 2, \ldots, s \quad , \quad (3)$$

$$\sum_{j=1}^{n} \lambda_j = 1, \quad (4)$$

$$\lambda_j \geq 0, \quad (5)$$

where DMU "o" represents one of the "*n*" DMUs under evaluation. x_{io} and y_{ro} are respectively the i^{th} input and the r^{th} output of the DMU_o. *s* = the number of outputs produced by the DMU; *m* = number of inputs. θ^* (min θ) is a scalar which represents the score of the technical efficiency allotted to the unit under evaluation and is interpreted as the coefficient of the production level attained by the latter. λ is a weight allotted to DMUs which helps to determine the envelope formed by efficient DMUs (θ = 1).

2.2 Data and the variables

Data used in this work come from World Bank database and World development Index. It covers

the period from 1960 to 2015 and involves 16 West African countries. We chose as inputs: Number of Doctors per 1000 inhabitants, Hospital beds per 1000 inhabitants and International migrant Stock and as outputs we chose: Life expectancy at birth, infant mortality per thousand births and mortality rate for children under five. These are also some of the outputs generally considered to calculate composite indices measuring the performance of health systems like that of the world Health Organization (WHO, 2000) or of the UNDP (HDI, HPI).

3.0 Results and Discussion

We present the efficiency scores of the DEA specification. Furthermore, like Hoff (2007), Sueyoshi et al. (2010) and Samuel (2015), we use Tobit regression to analyze the impact of some exogeneous factors on the DEA efficiency scores.

Table 1: Technical efficiency scores

DMU No.	*DMU Name*	*Input-Oriented VRS Efficiency*
1	Benin	1.00000
2	Burkina Faso	1.00000
3	Cote d'Ivoire	1.00000
4	Cabo Verde	1.00000
5	Ghana	0.87904
6	Guinea	0.96613
7	Gambia, The	0.89989
8	Guinea-Bissau	1.00000
9	Liberia	1.00000
10	Mauritania	1.00000
11	Niger	1.00000
12	Nigeria	0.32174
13	Mali	0.83141
14	Senegal	1.00000
15	Sierra Leone	1.00000
16	Togo	0.93544

The efficiency scores shown in Table 1 were computed using DEAP software. An efficiency score of 1 represents a proportional reduction in input level without any possible change to the output level. Importantly, a country with 85% efficiency score can reduce her health inputs by 15% while maintaining the same health output. The DEA model specification shows a reasonable efficiency score because out of 16 countries in the target population, only six were found to be inefficient. These countries with declared efficient health systems will serve as a reference point for other countries' health system. In the light of this, we attempt to examine of the causes of inefficiencies in health systems by establishing a relationship between efficiency scores and some variables peculiar to each country. It should also be noted that the location of these countries makes them critically important in the ongoing efforts to scale up pro-poor cost-effective public health interventions geared w achieving the health-related Millennium Development Goals (MDGs) (UNDP, 2005) and New Partnership for Africa's Development (NEPAD) health targets (NEPAD, 2001).

The works of Brunet-Jailly (1990), Brunet-Jailly (1998), Duret (1999), Flegg (1982), Flegg (1983) and Brun & Mathonat (1997) specified factors that could cause inefficiency in the health system of a country. Based on the availability of data, we estimated the following Tobit regression model:

$\text{Ln}\ (1/\text{EFF}_i) = \alpha_0 + \alpha_1 INMS_i + \alpha_2 HPI_i + \alpha_3 WATER_i + \alpha_4 GINI_i + \alpha_5 LITER_i + \alpha_6 DENS_i + \varepsilon_i$

where, for each country *i*, EFF = DEA efficiency scores, HPI = the Human Poverty Index, GINI = Gini Index, LITER = Literacy rate, WATER = Percentage of the population without access to safe water supply, INMS = International migrant stock and DENS = density of the population.

The Tobit regression was computed using the R software and the results obtained is presented in Table 2.

Table 2: Determinants of the efficiency scores for countries' health system

```
Pearson residuals:
                Min      1Q  Median      3Q   Max
mu          -1.5153 -0.6605 -0.1786 0.4160 2.113
loglink(sd) -0.7014 -0.6515 -0.4011 0.2043 2.450
```

```
Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept):1  1.294e+00  1.668e-01   7.759 8.55e-15 ***
(Intercept):2 -2.410e+00  1.890e-01 -12.751  < 2e-16 ***
DENSITY       -2.855e-05  9.358e-06  -3.051 0.002284 **
LITERACY      -2.131e-03  4.692e-04  -4.542 5.57e-06 ***
GINI          -2.402e-03  4.577e-04  -5.248 1.54e-07 ***
WATER          7.722e-04  2.135e-04   3.617 0.000298 ***
HPI            1.043e-01  2.146e-02   4.861 1.17e-06 ***
INMS          -6.747e-02  1.972e-02  -3.422 0.000622 ***

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

From the output recorded in Table 2, the health related variable (water) is significant and has a positive sign. It shows that if a higher percentage of the population do not have access to clean water then inefficiency will be high. The literacy rate indicated a negative relationship with inefficiency. It means that when there is an increase in educational level of the respective countries, there will be a drop in inefficiency. This result is also significant. The relationship between the human poverty index (HPI) and inefficiency is also positive and significant showing that an increase in HPI will cause inefficiency to increase. Surprisingly, the inequality in income proxied by Gini index has a significant negative relationship with inefficiency.

Finally, Density has a negative relationship with inefficiency. It implies that an increase in density causes a reduction in inefficiency.

4.0 Conclusion

This paper examined the health system efficiency of 16 West African countries using the data envelopment analysis technique and we found out that six countries have an inefficient health system. It was also discovered that factors like HPI and water were mainly responsible for inefficiencies in the health system of the sampled countries. This was due to their marginal effect compared to other significant factors.

Suffice to say that with good panel data, further research can be carried out to estimate DEA-based Malmquist productivity index (MPI) in order to observe the changes in efficiency and those changes in productivity that are accounted for by technological change. It will be proper also to examine allocative efficiency of health systems in West Africa. A comparison can be made as well regarding regional efficiency of health systems in Africa.

5.0 References

Alsan, M., Bloom, D. E., Canning, D. & Jamison, D. (2007). *The Consequences of Population Health for Economic Performance*. In: Mills, S., Gibson, L. and Mills, A., Eds., *Health, Economic Development and Household Poverty*, Routledge, Oxford, 21-39. http://dx.doi.org/10.4324/9780203023570.ch2

Banker, R. D., Conrad, R. & Strauss, R. (1986). A Comparative Application of Data Envelopment Analysis and Translog Methods: An Illustrative Study of Hospital Production. *Management Science*, 32, pp. 30-44. http://dx.doi.org/10.1287/mnsc.32.1.30

Bosman, N. & Fecher, F. (1992). *Une Étude Comparative de l'Efficacité Technique du Secteur de la Santé au Seindes Pays de l'OCDE. Université de Liège, Liège*, CIRIEC, Working Paper 92/08.

Brun, J. F. & Mathonat, J. (1997). Les Effets du Financement Extérieur sur le Niveau des Dépenses Publiques d'Education et de Santé dans les Pays en Voie de Développement. Une Analyse Econométrique sur Données de Panel. CERDI, Etudes et documents E.97.15.

Brun, J. F. & Mathonat, J. (1997.) *Les Effets du Financement Extérieur sur le Niveau des Dépenses Publiques d'Education et de Santé dans les Pays en Voie de Développement. Une Analyse Econométrique sur Données de Panel*. CERDI, Etudes et documents E.97.15.

Brunet-Jailly, J. (1990). L*a Pharmacie Populaire du Mali dans le Contexte de l'Initiative de Bamako*. Institut national derecherche en santé publique, Bamako.

Brunet-Jailly, J. (1998). Innover dans les Systèmes de Santé: Expériences d'Afrique de l'Ouest. Edition Karthala, Paris, 435.

Charnes, A., Cooper, W. W. & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2, pp. 429-444. http://dx.doi.org/10.1016/0377-2217(78)90138-8.

Chisholm, D. & Evans, D. B. (2010). *Improving health system efficiency as a means of moving towards universal coverage*. Geneva: World Health Organization.

Duret, E. (1999). Décentralisation, Dépenses Publiques et Mortalité Infantile. *Revue d'Economie du Développement*, 4, pp. 39-68.

Färe, R., Grosskopf, S. & Valdmanis, V. (1989). Capacity, Competition and Efficiency in Hospitals: A Nonparametric Approach. *Journal of Productivity Analysis*, 1, pp. 123-138. http://dx.doi.org/10.1007/BF00157792

Flegg, A.T. (1982). Inequality of Income, Illiteracy and Medical Care as Determinants of Infant Mortality in Underdeveloped Countries. *Population Studies*, 36, pp. 441-458. http://dx.doi.org/10.1080/00324728.1982.10405597

Flegg, A.T. (1983). On the Determinants of Infant Mortality in Underdeveloped Countries. *International Journal of Social Economics*, 10, pp. 38-51. http://dx.doi.org/10.1108/eb013943

Grosskopf, S. & Valdmanis, V. (1987). Measuring Hospital Performance: A Non-Parametric Approach. *Journal of Health Economics*, 6, pp. 89-107. http://dx.doi.org/10.1016/0167-6296(87)90001-4

Hoff, A. (2007). Second Stage DEA: Comparison of Approaches for Modelling the DEA Score. *European Journal of Operational Research*, 181, pp. 425-435. http://dx.doi.org/10.1016/j.ejor.2006.05.019

Kirigia, J. M, Sambo L. G, & Scheel H. (2001). Technical efficiency of public clinics in Kwazulu-Natal province of South Africa. *East* African Medical Journal, 78, 3, pp. S1-S13.

Kirigia, J. M. & Emrouznejad A., Sambo LG, Munguti N and Liambila W. (2004). Using Data Envelopment Analysis to measure the technical efficiency of public health centres in Kenya**.** *Journal of Medical Systems*, 28, 2, pp. 155-166.

Kirigia, J. M., Asbu, E. Z., Greene, W. & Emrouznejad A. (2007). Technical efficiency, efficiency change, technical progress and productivity growth in the national health systems of continental African Countries. *Eastern Africa Social Science Research Review*, XXIII, 2, pp. 19-40.

Kirigia, J. M., Emrouznejad A. and Sambo L, G (2002). Measurement of technical efficiency of public hospitals in Kenya: using data envelopment analysis**.** *Journal of Medical Systems*, 26, 1, pp. 39-45.

Kirigia, J. M., Preker, A., Carrin G., Mwikisa, C. & Diarra-Nama A. J. (2006). An overview of health financing patterns and the way forward in the WHO Africa Region**.** *East Africa Medical Journal*, 83, 9, pp. S1-S28.

Masiye, F. (2007). Investigating health system performance: an application of data envelopment analysis to Zambia hospitals**.** *BMC Health services research*, **7,**58, doi.org/10.1186/1472-6963-7-58

Medeiros, J. & Schwierz, C. (2015). *Efficiency estimates of health care systems in the EU*. 3187.

New Partnership for Africa's Development (NEPAD) (2001). Human Development Programme. *NEPAD Health Strategy Pretoria.*

Osei, D., D'Almeida, S., Melvill, O. G., Kirigia, J. M., Ayayi, O. M. & Kainyu, L. H. (2005). Technical efficiency of public district hospitals and health centres in Ghana: a pilot study. *Cost Effectiveness and Resource Allocation* 2005, **3:**9

Renner, A., Kirigia, J. M., Zere, E. A., Barry, S. P., Kirgia, D. G., Kamara, C. & Muthuri, L. H. K. (2005). Technical efficiency of peripheral health units in Pujehun district of Sierra Leone: a DEA application. *BMC Health Services Research,* 5, 77, doi.org/10.1186/1472-6963-5-77.

Sedzro, K. & Keita, M. (2009). Assessing the Efficiency of Microfinance Institutions Using Data Envelopment Analysis. *Journal of International Finance & Economics*, 9, pp. 54-67.

Smith, P. C. (2002). Measuring health system performance. *European Journal of Health Economics*. 3, pp. 145–8.

Sueyoshi, T., Goto, M. & Omi, Y. (2010). Corporate Governance and Firm Performance: Evidence from Japanese Manufacturing Industries after the Lost Decade. *European Journal of Operational Research*, 203, pp. 724-736. http://dx.doi.org/10.1016/j.ejor.2009..021

WHO (2000). *The World Health Report: Health System: Improving Performance*. Genève.

World Bank (1993). *World Development Report*: Investing in Health. The World Bank, Washington DC.

World Bank (2004). *The millennium development goals for health: rising to the Challenges***.** Washington DC, World Bank.

World Health Organization (2000). The World Health Report**.** *Improving performance of health systems. Geneva*.

Zere, E., Mbeeli, T., Shangula, K., Mandlhate, C., Mutirua, K., Tjivambi, B. & Kapenambili, W (2006). Technical efficiency of district hospitals: Evidence from Namibia using Data 09Envelopment Analysis**.** *Cost Effectiveness and Resource Allocation*, 4**:**5.

Conflict of Interest

The author declared no conflict of interest