

TECHNICAL EFFICIENCY OF HEALTHCARE RESOURCES IN DEVELOPING COUNTRIES: A NON-PARAMETRIC APPROACH

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ABSTRACT

The world has witnessed an all-inclusive approach towards solving global health problems for the past two and half decades. Despite these commitments through increased human and material resources for health, larger proportion of developing countries has poor health outcomes. Many studies were carried out on the role of health expenditures on the health outcomes but very few have considered how best health resources are used. The focus was on how much rather than how best health resources are utilized. To fill in the gap, health system technical efficiency of 91 developing countries has been computed from 2005-2012 using input oriented data envelopment analysis (DEA). The central finding of this study is that most developing countries were below the efficiency frontier line- meaning they are technically inefficient in using their health resources. This means their present level of health outputs can be achieved with less health inputs. The results also show that the efficiency scores are inelastic to the quantum of physical and financial health resources because Burkina Faso and Myanmar with the least hospital beds & per capita health expenditures are technically efficient. Based on these conclusions, we highly recommend further studies to explore determinants of health efficiency via second stage technical efficiency. In that process quality of institutions should be centrally focused on. Moreover, national and international health policy makers should also re-examine health systems based on how well health resources are used not how much is spent on health.

Key words: Technical efficiency, Non-parametric and Data Envelopment Analysis.

1. INTRODUCTION

Recently, there is remarkable proliferation of investigations regarding health care system performances from both developed and developing countries. This may not be unconnected with the continuous pooling-in of more resources for health care over the years (figure 1).

The continuous increase in the global financial commitment on health vis-à-vis poor health outcomes has attracted the attention of national and international policy makers, governments, non-governmental organizations, as well as donors and humanitarian agencies over the years. Statistics has shown that about US\$ 6.9 trillion was expended on health care across the world in 2011 alone and out of which about 20% - 40% of the amount ended up misused inefficiently. Consequently, many people were left to suffer (Global Health Expenditure Atlas, 2014)

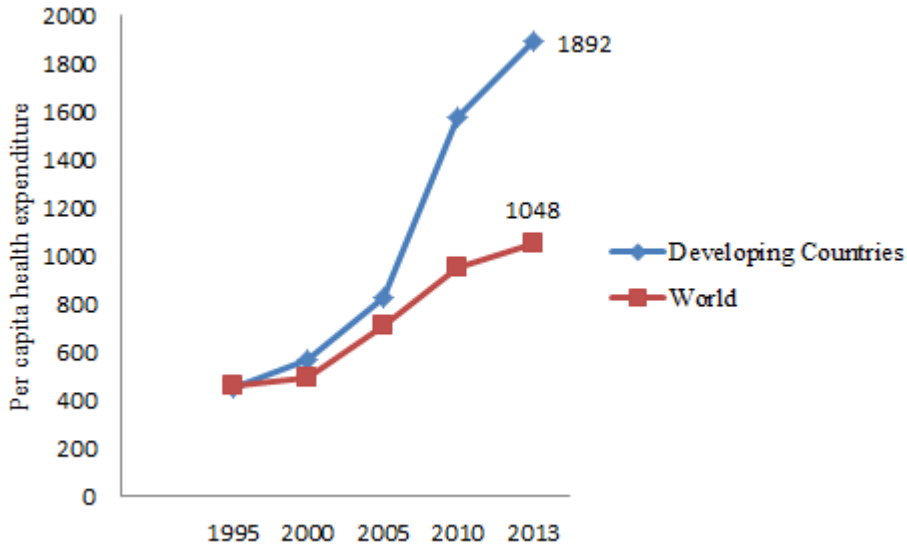
Health is central to human existence because it is one of the vital and basic requirements for human welfare (Bankauskaite & Dargent, 2007). Moreover, investigations also reveal that resources are enormously wasted as a result of inefficient utilization. Collins and Green (1994) opined that huge funds are being misused inefficiently on worthless projects and services in most developing countries.

Frogner (2008) argue strongly that the proportion of expenditures on health sector in developed countries is high and on the increase at the expense of the other sectors whereas Novignon, Olakojo and Nonvignon (2012); Grigoli and Kapsoli (2013) argued that health expenditures in developing countries is low and need to be increase. Although on the surface the problem of the developed and developing countries in this regards seems different but they are same. As the former advocates for cutting down health budgets while maintaining their health outcomes, the latter is devising means of improving health outcomes given their limited budget. This is typically an input and output oriented technical efficiency issue. Meanwhile, despite the united nation's aim of reducing development gaps among nations through common development targets like sustainable development goals (SDGs), investigations on how developing countries use health resources vis-a-vis their outcomes are few and still new. Worth noting is the reason why most developing countries could not meet their millennium development goals (MDGs) health target despite increasing trend of total resource for health over the years.

Therefore this study is focused on health system performances by examining technical efficiency of health care systems based on a non-parametric technical efficiency methodology. This is because one of the unique and imperative yardstick

that can be used to evaluate the health systems performance is the proportion of health system outputs to the human and material resources committed in the entire process (World Health Report, 2000).

Figure 1 Developing countries' per capita Health expenditure (current US\$)



Source :World Development Indicators

Figure 1 reveals that since 1995 when data on health expenditures became available in the World Bank data bases, per capita health expenditure in developing countries parted way upward above world average. As at 2013, per head health expenditure in developing countries was \$1892 as against \$1048 world average. Hence, this aspect of the research is determined to test the hypothesis that most health systems in developing countries operate below the performance frontier line.

Country	Health expenditure [(per capita) 2013]	Health outcomes (2013)		
		Infant mortality	Under5 mortality	Life expectancy
Bangladesh*	31.63443	33	41	71
Bhutan**	89.74884	30	36	68
Algeria***	313.5202	22	25	71
Angola***	267.2243	102	167	52
Botswana* **	397.3183	36	47	47
El Salvador**	265.7711	14	16	72
Ethiopia*	24.51865	44	64	64
Ghana**	99.52847	52	78	61
Tanzania*	49.32111	36	52	61
Nigeria**	114.9669	74	117	52

Table 1 Paradox of health expenditure and health outcomes in developing countries

Source: WDI World Bank database, 2015. *, **, & *** represent lower income, lower middle & upper middle income countries

Table1 shows health expenditure and health outcomes randomly picked from low, lower middle and upper middle income countries. It has been established that countries with larger per capita health expenditure record poor health outcomes with a wide margin. For example Bangladesh and Bhutan comparably spent less on health but they have better health outcomes to Angola and Botswana. El Salvador's health expenditure per capita is far below what is obtainable in Algeria yet it has better health outcomes. Similarly, Nigeria spent more but has worse outcome to Tanzania and Ethiopia. Paradoxically, this scenario happen in several countries across the income levels but time and space cannot allow us to show them all.

The conceivable reasons why the concept of efficiency and health systems performances measurement gain acceptance in health economics and public health research are not farfetched: i) the global financial predicaments and budget constraints forced central governments to enhance monitoring and evaluation of the health care operations for cognisant decision in their health systems planning, financing, policies and implementation programmes; ii) health donor countries and non-governmental agencies equally want the performance records for assessment and accurate balance between health assistance and outcomes for future priority settings on their health targets.

The concept of technical efficiency is not new in the academic literature owing to the fact that long ago Farrell (1957) advanced an encompassing characterization in his definition of technical efficiency as the production of maximum output with a given input or production of given output with a minimum input. Within this entity, a firm is said to be technically efficient when it operates on its production frontier. Whereas allocative efficiency is a situation where inputs are combined with a minimised cost given the inputs prices or an output combination that maximises revenue given the output prices. The two make up the overall efficiency. Efficiency has also been extensively used in economics as best use of resources in production (Shone,1981).

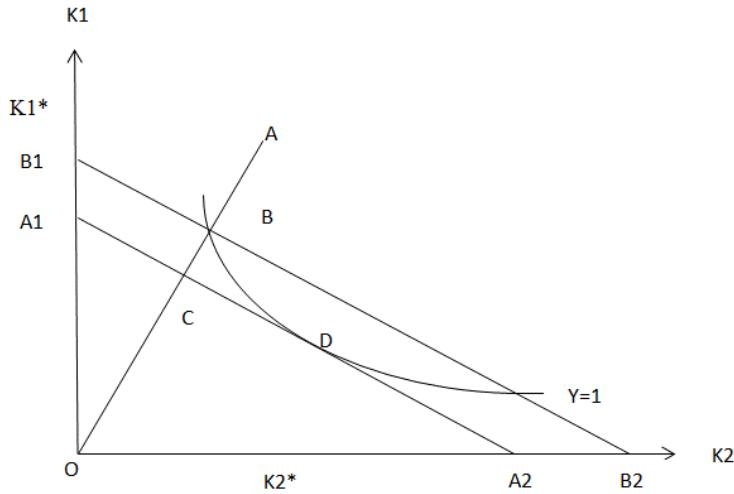
In the context of health care , Folland , Goodman, & Stano (1997) argued that technical efficiency can be describe as the sustained health output realized from technical mixture of human and material health resources (e.g physicians; other health workers; hospitals; health post; hospital beds etc). In other words, it means a physical association amongst health allocated resources in the form of labor, capital,

apparatus and health outcomes such as mortality rates and life expectancy (Palmer & Torgerson, 1999).

Based on Farrell's theoretical formation, the concept of efficiency can be demonstrated geometrically using simple combination of two inputs, k_1 and k_2 in producing single good y .

Assuming the function $y = f(k_1, k_2)$ is linear homogeneous under constant returns to scale $1 = f(k_1/y, k_2/y)$ where increasing and decreasing returns to scale are also not ruled out. Figure 1 shows input combination that is considered technically efficient in producing unit of output by the isoquant $y=1$. Supposing the real practical input-output mix rest on point A, through input combination (K_1^*, K_2^*) to produce output $y=1$. Production at point A is technically inefficient since output $y=1$ can be produce using same input combination but by the input quantities at point B on the isoquant. Technical efficiency at point A is $OB/OA=TE$ ($0 < TE \leq 1$). A health system is said to technically efficient and operates on the isoquant if $TE=1$ and technically inefficient if $TE < 1$. On the other hand, allocative efficiency can be explain using the iso-cost lines A_1A_2 AND B_1B_2 respectively. Given the relative factor prices represented by iso-cost line A_1A_2 , the cost minimising combination for producing $y=1$ is at D. Assuming point A is technically efficient, i.e. operating at B, its cost is denoted by the iso-cost line B_1B_2 , which is above minimum cost A_1A_2 . Therefore at its practical input combination, unit A needs to use input quantities corresponding to point C to produce at minimum cost. Thus allocative (price) efficiency is $AE = OC/OB$ ($0 < AE \leq 1$). The total cost of production at D in relation to A is the amount of total (productive) or economic efficiency. The economic efficiency (EE) in this case, $EE = OC/OA = TE * AE = OB/OA * OCOB$ ($0 < EE \leq 1$) respectively.

Figure 2 Graphical illustration of Efficiency



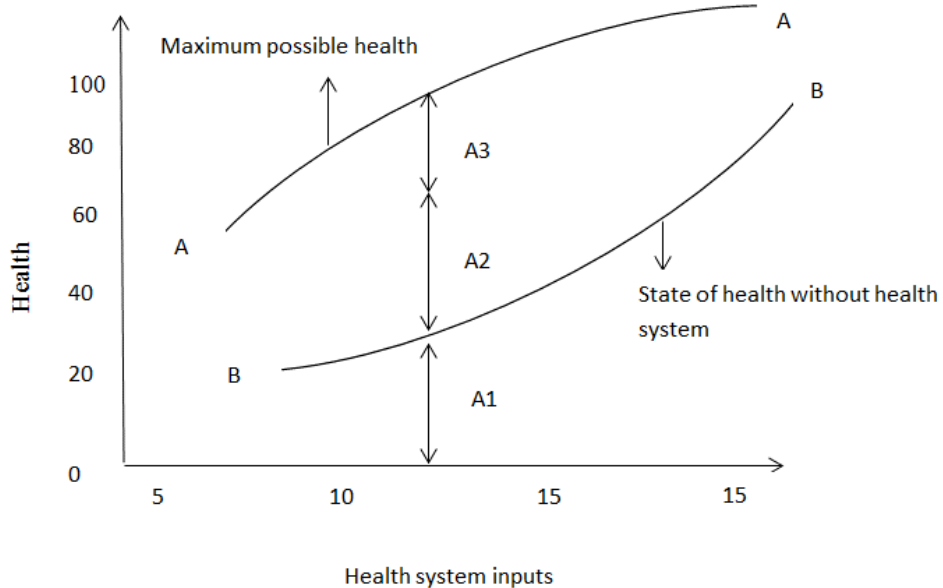
Source: Hollingsworth, Dawson, & Maniadakis (1999)

The diagrammatical illustration of efficiency in a health care system can be easily comprehended as elucidated below.

Murray and Frenk (1999) stressed on the importance of the health system performance in their definition and diagrammatical illustration on figure 3. To understand the concept well, vertical axis represents the goal of the health system label as health whereas the horizontal axis represents the health system inputs. Line AA denotes the maximum possible level of health the health system wishes to accomplish or is called the frontier line. Unlike in other production settings such as agriculture where zero input means zero output, health will never be zero in the absence of health input because zero health means everybody is dead. Therefore, line BB denotes the level of health without health system.

Assuming a country have accomplished $(A1+A2)$ level of health. Murray and Frenk defined health system performance by $A2/(A2+A3)$. This shows the health system achievement compared to its potential. Conversely, the health system efficiency is defined by $(A1+A2)/ (A1+A2+A3)$ should the horizontal axis measured only single input.

Figure 3 Health System Efficiency.



Source: Hollingsworth, Dawson, & Maniadakis

2. LITERATURE REVIEW

It is admissible as reported in the productivity commission (2013) that health care efficiency measurement is apprehensive owing to its complexities. One of the difficulties involved is how to measure the health outcomes that can truly represent health system outputs. The report outlined factors that hinders improvement in Australia's health system efficiency as; absents of political will, dismal resourcing and poor policy and implementation. Heller and Hauner (2006) argued that the pressure on public finances can only be relief through increase in the efficiency of their expenditures.

Gupta and Verhoeven (2001) in their efficiency study concluded that the link between public spending and the efficiency scores is negative. This rationalises the argument that the rise in health spending is not an optimal solution to health systems efficiency. They also argued that health systems in Africa are inefficient compared to Asia and Latin America. Using data envelopment analysis (DEA), Alexander, Busch and Stringer (2003) study about health system efficiency in 51 developing countries and reported that countries with higher GDP and those with low level of health spending are more efficient. They concluded that Africa took a lead on the countries with inefficient health systems. Afonso and Aubyn (2005) compared health system efficiency of 24 OECD countries using DEA and free disposable hull (FDH). Their result showed that 11 out of the 24 countries are efficient under FDH methods as only 8 was efficient under DEA.

Jayasuriya and Wodon (2003) efficiency study in 76 developing countries between 1990-1998 reveals that education has strong influence over life expectancy but health expenditure increase is not an answer to the question of health system efficiency predicaments. Evans et al (2001) uses panel data to construct a efficiency index for all world health organization (WHO) member countries and concluded that large number countries health systems are inefficiency regardless of their regions or income level. Number of Physicians, nurse and other health workforces is an essential component of a health system because it determines the effective and efficient operation of the healthcare system (WHO, 2006).

About 80% of frontier efficiency published studies down to the middle of 2006 used nonparametric techniques; the key application is DEA (Hollingsworth, 2008). The acceptance of DEA is accentuated by its suitable qualities.

3. METHODOLOGY

The application of data envelopment analysis (DEA) in evaluating health system efficiency has been in use for more than three decades. Estimating efficiency and output, we need information about the production or the cost frontier. In reality, the frontier is made by the most efficient amongst sample of decision making units (DMUs) or firms. The frontier is defined relative to the DMU that uses the minimum input to produce a given output or otherwise produces the maximum output for a fixed input. The efficiency of other DMUs in the sample is defined in relation to the best performers. Moreover, the efficiency of these top performers in a period relative to the top performers in a different period is used to describe the frontier movements (technological change). There exist two key features that differentiate alternative practical methods for developing the frontier in calculating efficiency and productivity methods: a) They are either parametric or non-parametric b) they are either stochastic or deterministic.

Parametric approach adopts a definite functional procedure for the frontier while non-parametric approach does not. Deterministic technique assumes that the distance of a DMU from a frontier is a product of inefficiency while stochastic technique assumes that it is as a result of inefficiency plus random error. Parametric programming is founded on the application of quadratic or linear programming to build a smooth parametric frontier. One of its identified weaknesses is the imposition of a probably inappropriate edifice on the technology. Similarly as it is deterministic, the outcomes are sensitive to outliers. The statistical, parametric approach applies econometric methods to estimate either a stochastic or a deterministic frontier function. The latter has the shortcomings of both parametric and deterministic methods: the former has the benefit as it accounts for stochastic error that is not captured as part of the measure of efficiency but its shortcoming is the imposition of a parametric edifice on both efficiency distribution as well as production function (Silkman, 1986; Ganley & Cubbin, 1992).

Seventy (70) developing countries representing our target decision making units (DMUs) randomly selected based on data availability were classified under low, lower middle and upper middle income countries. Although the study focused on developing countries, yet twenty one (21) developed countries assumed to have better health systems than the developing ones were also included as controlled decision making units (DMUs). The rationale of the inclusion is that DEA is a non-parametric technical efficiency technique that compares DMUs with their best performers in a given sample.

Meanwhile we have two types of health outcomes; positive outcomes (life expectancy) and the negative ones (mortalities) and our study include both. The averaged data from 2005-2012 for this research were obtained from two major sources. Number of physicians, nurses and midwifery personnel and hospital beds were all from world health statistics, 2013. The selection was based on WHO (2006) submission that number of physicians and other health personnel are central to the performance of any health system and when they fall short of a certain threshold, the system cannot perform efficiently. Per capita health expenditure, infant and under-5 mortalities, life expectancy were all obtained from world development indicators, World Bank database.

DEA MODEL

In this study the technique used for measuring technical efficiency of developing countries' healthcare systems is input oriented DEA under the assumption of VRS suggested by Banker, Charnes and Cooper (1984) commonly known as BCC model. The choice of the orientation was because our decision making units (DMUs) do not have control over their output but the inputs. And the choice of the BCC model (VRS assumption) was to avoid the effects of scale efficiency.

The target of DEA is to create a non-parametric frontier where all observations are expected to fall on the frontier.

Assuming there are k DMU and each DMU_j , $j = 1, 2, \dots, k$ producing s quantity of outputs, y_{rj} ($r = 1, 2, \dots, s$), with m inputs, x_{ij} ($i = 1, 2, \dots, m$). The BCC input-oriented variable returns to scale model is as follows:

min θ

$$s. t \sum_{j=1}^k \lambda_j x_{ij} \leq \theta x_{i0} \quad i = 1, 2, \dots, m; \dots \dots \dots (1)$$

$$\sum_{j=1}^k \lambda_j y_{rj} \geq y_{r0} \quad r = 1, 2, \dots, s; \dots \dots (2)$$

$$\sum_{j=1}^k \lambda_j = 1 \dots \dots \dots (3)$$

$$\lambda_j \geq 0 \quad j = 1, 2, \dots, n \dots \dots \dots (4)$$

The BBC model above seeks to minimise the current level of inputs by maintaining the same factor outputs (assuming output is constant).

Let θ^* = the optimal solution (i.e. optimal value of θ). If $\theta^* = 1$ then the current level of input cannot be reduce without reducing quantity of output because the DMU in question is on the DEA frontier – meaning it is efficient, and on the other way;

If $\theta^* > 1$ then the DMU is inefficient- meaning less input can be used to achieve same level of output.

One of the major limitations of this study is the data envelopment analysis (DEA) method used. This technique is deterministic therefore its results will be contingent to the decision making units (countries)'s peculiarities and variables used. Since the method is also based on relative efficiency measurement, adding/removing a country (DMU) or any variable from the sample may give different result entirely. Furthermore, our sample of countries (DMUs) and data used were based on data availability since DEA necessitates availability of complete dataset.

4. RESULTS AND DISCUSSIONS

Table 2 gives the statistical summary of inputs used in this study. The number of physicians (PHY) per 10,000 population ranges from 0.20 in Malawi to 67.20 in Cuba. The sample mean of the physicians was 16.37. The minimum number of nurses and midwives staff (NMW) per 10,000 populations was 1.40 in Chile and the maximum was 319.30 in Norway. Burkina Faso has the least number of hospital beds (4 beds) per 10,000 populations where Japan recorded the maximum with 137 beds per 10,000 populations. On the average 32 beds serve 10,000 people in the sample. The country with minimum health expenditure per capita was Myanmar and the maximum was recorded in Kiribati.

Table 2: Summary of inputs used

	PHY	NMW	HBD	HEX
Minimum	0.20	1.40	4.00	2.00
Mean	16.37	45.93	32.23	6.01
Maximum	67.20	319.30	137.00	11.00

Source: Authors computation

Table 3 on the other hand gives the descriptive statistic of the health outputs used. Luxembourg has the minimum of 2.16 infant mortality (IFM) and 2.75 under-5 mortality (UFM) per 1000 live births as Central African Republic recorded the maximum infant mortality of 104 and 155 under-5 mortality per 1000 live births respectively. The least life expectancy (LEX) was 46.52 in Botswana and the maximum was 82.60 in Japan.

Table 3: Summary of outputs used

Description	IFM	UFM	LEX
Minimum	2.16	2.75	46.52
Mean	26.04	34.92	70.28
Maximum	104.06	155.29	82.60

Source: Authors computation

Table 4 contains the DEA input oriented technical efficiency scores under the assumption of variable returns to scale (vrs).

The input oriented technical efficiency results (table 4) indicate that 54 (77%) out of the 70 DMUs were technically inefficient. This implies that only 16 (23%) happened to be on the frontier line (technically efficient). This has also been spotted on figure 4 where only the efficient DMUs falls on the “1” but the rest (inefficient DMUs) are below it. The countries that operate their health system efficiently include: Bangladesh, Benin, Bhutan, Burkina Faso, Cabo Verde, Cambodia, Central Africa, Honduras, Indonesia, Lao PDR, Malawi, Togo, Ethiopia, Mozambique, Myanmar and Pakistan. None of these countries is from upper middle income but all from low

and lower middle income countries. Even though some countries are efficient but on the aggregate the entire health system in the sampled developing countries are technically inefficient since the TE mean score is 0.6921 (table 5). This implies that they can still attend to the present level of the health outcomes with fewer resources.

Worth noting from the results is the paradox of the inputs used because Burkina Faso has the least number of hospital beds yet it is comparably efficient than those with the higher quantity. Moreover, Myanmar has the least per capita health expenditure but was able to operate its health system on the frontier line.

Our result is robust because its difference with the biased corrected TE mean score (table 6) is not much, even though none of the DMUs was on the frontier line (figure 5).

Table 4: Input-oriented Technical Efficiency

Level of TE efficiency	Developing Countries			Developed	TOTAL
	Low income	Lower middle	Upper middle		
0.0000-0.2500	00	00	00	00	00
0.2501-0.5000	00	07	09	05	21
0.5001-0.7500	00	09	12	11	32
0.7501-0.9999	02	07	08	00	17
1.0000	08	08	00	05	21
TOTAL	10	31	29	21	91
% OF TE	80%	26%	0%	24%	23%

Source: Authors computation

Table 5: Summary of Input -oriented Technical Efficiency

Minimum	1 st Quota	Median	Mean	3 rd Quota	Maximum
0.3025	0.5108	0.6550	0.6921	0.9011	1.0000

Table 6: Summary of the Bias corrected Bootstrap Result

Minimum	1 st Quota	Median	Mean	3 rd Quota	Maximum
0.2672	0.4440	0.5690	0.5779	0.7483	0.8405

Figure 4: The deavrs plot.

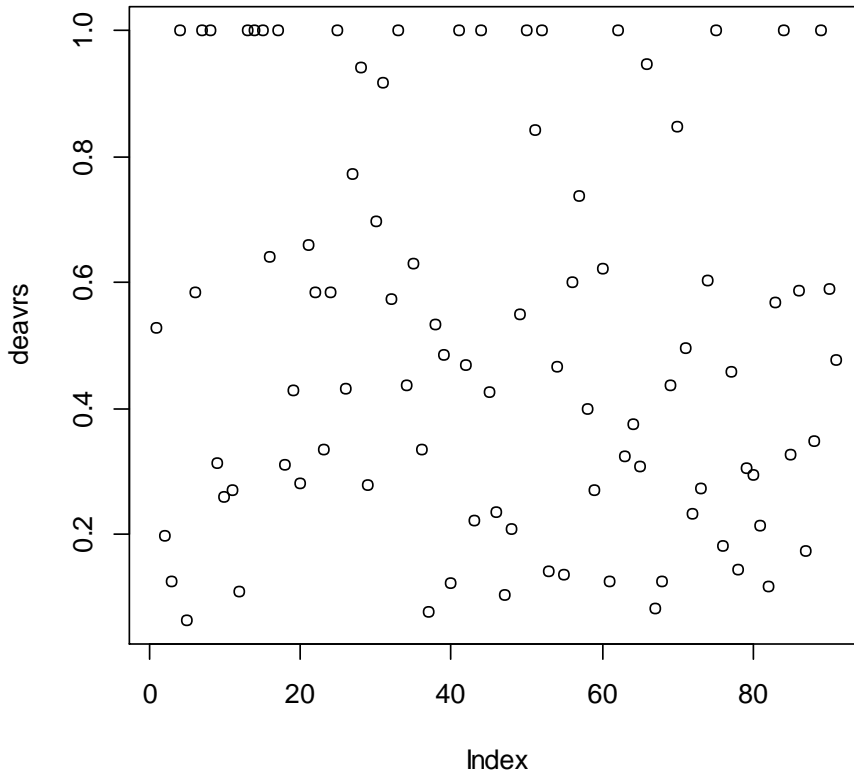
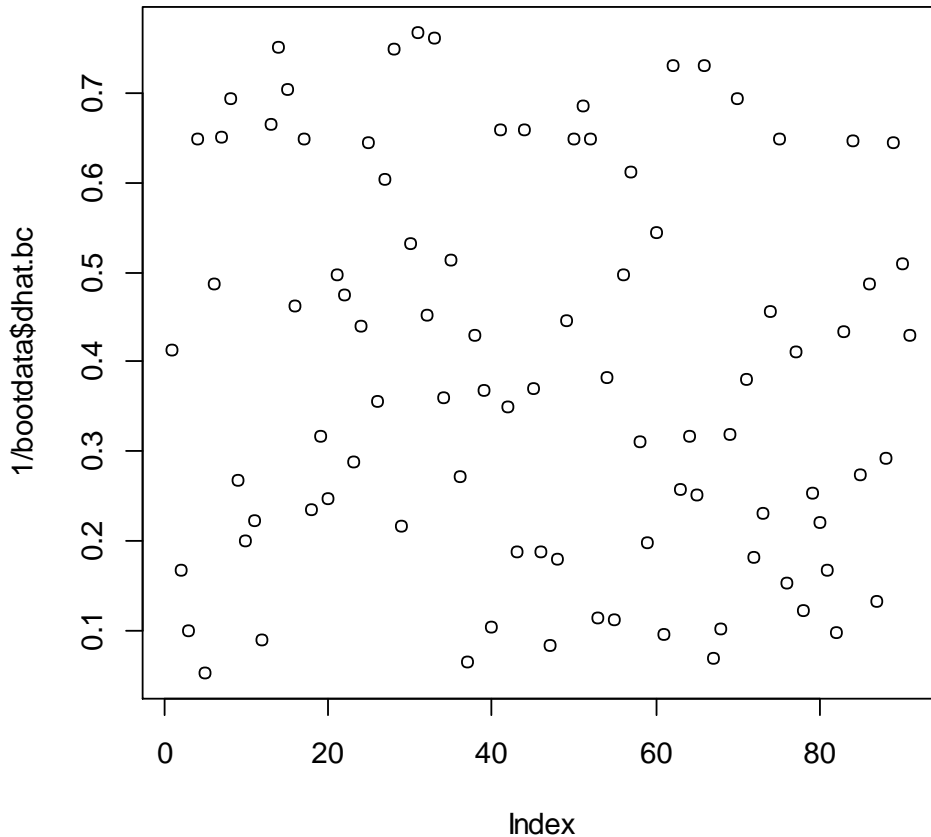


Figure 5: The bias corrected bootstrap plot.



5. CONCLUSIONS

The main finding of this study is that most DMUs (countries) are below the efficiency frontier line- meaning they are inefficient in using their health resources. This means their present level of health outputs can be achieved with less health inputs. The results also show that the efficiency scores are inelastic to the quantum of physical and financial health resources because Burkina Faso and Myanmar with the least hospital beds & per capita health expenditures are technically efficient. Based on these conclusions, we highly recommend further studies to explore determinants of health efficiency via second stage technical efficiency.

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