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Technical Efficiency of Health Systems in African Least Developed Countries

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Abstract
Background: Motivated by the fact that between 20-40% of health expenditure around the world is wasted due to inefficiencies the magnitude of these efficiencies/inefficiencies is unknown for African least developed countries (African LDCs). The objective of this study is to estimate the technical efficiency of the health systems in 29 African Least Developed Countries for the 2008-2018 period.
Method: Using the output-oriented Data Envelopment Analysis based on the Variable Returns to Scale assumption, panel data on the input variables including domestic general government health expenditure, domestic private health expenditure, external health expenditure and out-of-pocket expenditure, as well as the output variables including life expectancy at birth, maternal mortality ratio, under-five mortality rate, and infant mortality rate, were taken from the World Health Organization and World Bank.
Results: Findings of the study showed that between 2008 and 2018, 16 African LDCs were technically efficient, while 13 were not. The highest benchmarks for technically inefficient countries were Madagascar (12 peers), Senegal (7 peers), Eritrea and Ethiopia (7 peers), and Rwanda (1 peer).
Conclusion: The practices of nations with technically efficient health systems can serve as benchmarks for nations with technically inefficient health systems. African LDCs also needed to increase their domestic general government health expenditure, domestic private health expenditure, external health expenditure and out-of-pocket health expenditure to increase their infant survival rate.

Keywords
Technical Efficiency; Data Envelopment Analysis; Health Systems; African LDCs.

Background

According to Behr and Theune (2017), the assessment of technical efficiency is becoming a significant area of ongoing interest in health economics literature. This is because on a global scale, more demands have been placed on countries to use their health resources efficiently and avoid wastages in the era of low levels of health financing and financial hardships (Novignon, 2015). Most least developed countries, especially those in Africa are struggling with providing health services to their populations because of the increasing budgetary restrictions (Hsu, 2014; Mirmirani & Lippmann, 2004). The lack of adequate health financing has negatively affected health outcomes in African LDCs because of their excessive reliance on external health funding, private health funding, and out-of-pocket payments (Tindimwebwa et al., 2018).

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Mohamadi et al. (2020) and Hsu (2014) suggest that increasing health expenditure is the only way countries can improve their health outcomes and achieve health-related sustainable development goals. Novignon (2015) disagrees and argues that since most of the health policy debates in several African LDCs focus on cutting or generating more funds for the health sector, raising health expenditures in African LDCs alone may not significantly improve health outcomes if the efficient use of these funds is low. Thus the efficient use of health expenditure has been singled out as one of the ways to expand fiscal space for health while containing rapidly escalating costs for health which is a key policy challenge for African LDCs (Masri & Asbu, 2018).

Studies have assessed the technical efficiency of health systems of countries from several groupings like the group of 12 countries (Mirmirani & Lippmann, 2004), the Organization for Economic Cooperation and Development countries (OECD) (Behr & Theune, 2017; Seddighi et al., 2020), European countries (Asandului et al., 2014; Storto & Ginčiaruk, 2017), African countries (Gupta & Verhoeven, 2001), World Health Organization (WHO) countries (Kumbhakar, 2010) and Commonwealth independent states (Mirzosaid, 2011). The theoretical literature for these studies is based on the theory of production which is also adopted for this study (Førsund, 2018; Yawe, 2006). According to the theory of production a country's health system "produces" outputs by combining inputs while the connection between inputs and outputs is demonstrated by the production function (Wagstaff, 1986). In the analysis of the technical efficiency of health systems following Koku (2015), the concept of Pareto efficiency is adopted where a given production technology dominates another if the former production is better with respect to at least one input or one output and is not worse for any input or output. This is because, in the estimation of the technical efficiency of health systems, we are not interested in the feasible productions but rather the "best efficient" frontiers (Kleine, 2004). Wagstaff (1986) also suggests that similar to the case of consumption activities, it is better to consider a "bundle of health inputs comprising of various forms of health expenditure and a bundle of outputs" rather than looking at a single input.

Using a variety of inputs like health expenditure, number of physicians, number of midwives, number of hospital beds, number of magnetic resonance imaging machines, level of education, and the non-immunized rate (Behr & Theune, 2017; Cetin & Bahce, 2016; Seddighi et al., 2020; Storto & Gončiaruk, 2017) and outputs like life expectancy, infant survival rate, adult survival rate, and healthy life years at birth (Cetin & Bahce, 2016; Popescu et al., 2014; Storto & Gončiaruk, 2017). Using several estimation techniques like DEA (Asandului et al., 2014; Kim & Kang, 2014; Popescu et al., 2014), free disposable hull (Afonso & Aubyn, 2005), value efficiency analysis (González et al., 2010) and regression analysis (Evans et al., 2001), these studies have established variations in the technical efficiencies of health systems. The majority of these studies simply consider the inputs and outputs as a "given" yet Madhanagopal and Chandrasekaran (2014) state that this is not good because some inputs and outputs included in the analysis may reduce the efficiency power resulting in biased results. The value addition and originality of the study are based on the choice of the best input and output combinations before the adoption of the DEA methodology (Wagner & Shimshak, 2007). It is on the basis of this using data from the World Bank (2021) and WHO (2019), that this study seeks to investigate the technical efficiency of health systems in African LDCs from 2008 to 2018.

Methods

Unit of analysis and variables

The unit of analysis or Decision Making Unit (DMU) is an African LDCs with focus on its health system (Kirigia et al., 2007). The WHO (2000) defines a health system as "a combination of activities whose primary objective is to promote, restore, or sustain health." According to Papanicolas et al. (2013) the

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majority of duties of health ministries are very similar to this broad definition which encompasses planning health services as well as promoting health and preventing disease.

Table 1: Input and Output variables used in the study

No	Variable	Definition
Inputs		
1	Domestic General Government Health Expenditure	This is the public expenditure on health from domestic sources per capita expressed in current USD.
2	Out-of-pocket health Expenditure	This is health expenditure through out-of-pocket payments per capita in USD. Out-of-pocket payments are spending on health directly out of pocket by households in each country.
3	Domestic Private Health Expenditure	This is the current private expenditures on health per capita expressed in current USD. Domestic private sources include funds from households, corporations and non-profit organizations. Such expenditures can be either prepaid to voluntary health insurance or paid directly to healthcare providers.
4	External Health Expenditure	This is the current external expenditure on health per capita expressed in current USD. External sources are composed of direct foreign transfers and foreign transfers distributed by the government encompassing all financial inflows into the national health system from outside the country.
Outputs		
1	Life Expectancy at Birth	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.
2	Maternal Mortality Ratio	The maternal mortality ratio is defined as the number of maternal deaths during a given time period per 100,000 live births during the same time period. It depicts the risk of maternal death relative to the number of live births and essentially captures the risk of death in a single pregnancy or a single live birth.
3	Under five Mortality Rate	The probability of a child born in a specific year or period dying before reaching the age of five, if subject to age-specific mortality rates of that period
4	Infant Mortality Rate	Infant mortality rate is the probability of a child born in a specific year or period dying before reaching the age of one, if subject to age-specific mortality rates of that period.

Source: Authors compilation based on World Bank (2021) and WHO (2019)

Twenty-nine African LDCs including: Burkina Faso, Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone, Togo, Burundi, Djibouti, Eritrea, Ethiopia, Madagascar, Malawi, Mozambique, Rwanda, Uganda, Sudan, Lesotho, Tanzania, and Zambia, are considered for this study based on the United Nations Conference on Trade and Development (2020) and the availability of data.

Following Hadad et al. (2013); Çelik et al. (2017); Ibrahim et al. (2019); Masri and Asbu (2018); Behr and Theune (2017); Retzlaff-Roberts et al. (2004) and Mohamadi et al. (2020), four inputs are outputs are considered for this study. Because the production of health at a macro level is difficult the health outcomes are used as health outputs (Çelik et al., 2017; Ng, 2008; Peacock et al., 2001). Table 1 shows the input, and output data and their definitions that are taken from the World Bank (2021) and WHO (2019). According to Zhou et al. (2020) and Ibrahim et al. (2019) to conform to isotonicity and devise variables that capture good health outcomes in infants, mothers and children under five years, the Infant Mortality Rate (IMR); Maternal Mortality Ratio (MMR) and under-five mortality rate (U5MR) values are converted to infant survival rate (ISR) ($ISR = (1000 - IMR) \ / \ IMR$), maternal survival ratio (MSR) ($MSR = (1000 - MMR)/MMR$) and under five survival rate (U5SR) ($U5SR = 1/U5MR$).

Choice of the best input and output combinations

To select the best input and output combinations, correlation analysis recommended by Cetin and Bahce (2016); Yawe (2006) and Kizza (2012) is used. Following Cetin and Bahce (2016) input and output combinations that are highly correlated and significant are redundant and dropped from further analysis of the technical efficiency of health systems. In contrast, the input/output combinations that provide the highest average technical efficiency are chosen for the final DEA model (Kizza, 2012; Yawe, 2006).

Test for endogeneity for the most preferred model

Endogeneity according to Santín and Sicilia (2017) and Cordero et al. (2013), occurs when the technical efficiency scores are strongly correlated with any one input. According to Dhaoui (2019), correlation analysis is used to test for potential endogeneity in the context of the technical efficiency of health systems (Orme & Smith, 1996).

Theoretical Model

The theoretical model for the technical efficiency of health systems in African LDCs is based on the best practice frontier from the theory of production (Alexander et al., 2003; Lionel, 2015; Lovell et al., 1994). The "best-practice" frontier, according to Alexander et al. (2003), is a piece-wise linear envelopment of the health inputs and health output data that serves as a benchmark for comparison and identifying African LDCs with most efficient health systems. African LDCs operating on the frontier have technically efficient health systems, where as those operating of the frontier have technically inefficient health systems. Following Lionel (2015), s^t is the technology that transforms inputs into outputs. This technology can be modelled by the output possibility set in equation (1):

$$P^t(x^t) = \{y^t : (x^t,\ y^t) \epsilon S^t\}\ t = 1, \dots, T \quad (1)$$

Where $P^t(x^t)$ is the collection of health output vectors that consume no more than the bundle of resources indicated by the resource vector x^t, during period t. The best practice frontier is estimated as the upper bound of the output possibility set $P^t(x^t)$. $P^t(x^t)$ is estimated by assuming that the sample set is made up of $j = 1, \dots, J$ countries' health systems, each using $n = 1, \dots, N$ resources, X^t_{jn}, during period t, to generate $m = 1, \dots, M$ health outputs, Y^t_{jm}, , in period t. The piece-wise linear envelopment of the input possibility set is:

$$P^t(x^t) = \Big\{ y^t : X^t_n \le \sum_{j=1}^{j} Z_j x^t_{jn}\ , \quad n = 1 \dots N$$

$$\sum_{j=1}^{j} z_j y^t_{jm} \ \ m = 1 \dots M$$

$$\sum_{j=1}^{j} z_j = 1$$

$$z_j \ \ge 0,\ j = 1 \dots j \Big\} \quad (2)$$

Where z_j indicates the weighting of each of the health systems. The output-based efficiency score for each country's health system for period t can be derived as

$$F^t_0(x^t_j, y^t_i) = max\{\theta \ such \ that \ \theta y^t \ \in \ p^t\ (x^t)\} \text{ Where } F^t_0(x^t_j, y^t_i) \ \ge 1 \quad (3)$$

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This suggests that a county's health output vector, y^t, is located on the best practice frontier or technically efficient frontier when equation (3) has a value of one. However, if equation (3) has a value less than one, the health system must be classified as technically efficient relative to best-observed practice.

Empirical Model
The DEA model a linear programming tool, is used to estimate the technical efficiency of health systems in Africa LDCs (Novignon, 2015). According to Hadad et al. (2013) and Dhaoui (2019), DEA is preferred because it can incorporate multiple inputs and outputs and is not constrained by a particular production function or error distribution. Following Anton (2013), DEA represents a linear non-parametric method used to estimate the technical efficiency of a homogenous set of DMUs. Assuming that there are n DMUs, each with m inputs and r outputs, the relative technical efficiency score of a test DMU q is obtained by solving equation (4).

$$E_q = \frac{\sum_{i=1}^{r} u_i y_{iq}}{\sum_{j=1}^{m} v_i x_{jq}} \rightarrow max$$

$$E_q = \frac{\sum_{i=1}^{r} u_i y_{iq}}{\sum_{j=1}^{m} v_i x_{jq}} \leq 1, q = 1,2, \cdots n \qquad (4)$$

The most widely used DEA models are Charnes, Cooper and Rhodes (CCR) model by Charnes et al. (1978) and Banker, Charnes and Cooper (BCC) model by Banker et al. (1984). The CCR model has an input orientation and assumes that production follows a constant return to scale (CRS) while the BCC model has an output orientation and assumes that production follows a variable return to scale (VRS). According to Farrell (1957) both the CCR and BCC models are carried on and are expanded on the concept of "technical efficiency". A DMU is considered to be technically efficient if it lies on the efficient frontier. DMUs below the frontier are considered to be technically inefficient.

According to Anton (2013) technical efficiency can be evaluated from the perspective of either the input orientation or output orientation. In an input-oriented model, the goal is to minimize the use of inputs in order to maintain the current level of outputs constant while in the output-oriented model, the aim is to maximize the outputs with the given level of inputs. In line with Ahmed et al. (2019) and Retzlaff-Roberts et al. (2004), the output-oriented model is used in this study because it emphasizes increasing output without altering the quantity of inputs used. The objective of the output oriented DEA model is to maximize the efficiency score E_q in equation (4). The output-oriented DEA model according to Ahmed et al. (2019) is specified as follows:

$$Max\ E_q = \sum u_i y_{iq} + \mu \qquad (5)$$

Subject to constraints

$$\sum_{i=1}^{m} v_i + y_{iq} = 1 \qquad (6)$$

$$\sum_{r=1}^{j} u_i + y_{iq} - \sum v_j x_{jq} + \mu \leq 0,\ q = 1, \ldots, n \qquad (7)$$

$$u_i, v_j \geq \varepsilon > 0$$

$$\mu > 0, \mu = 0,\ \mu < 0,$$

Where;
E_q = efficiency of the $q - th$ DMU,
y_{iq} = output i produced by DMU q
x_{jq} = input j produced by DMU q
u_i = weight given to output i
v_j = weight given to input j
ε is a constant which makes all weight of inputs and outputs positive.

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For every DMU the model determines the input weight (v_j) and output weight (u_i) that maximize its efficiency scores (E_q). μ >0 defines Increasing Returns to Scale (IRS), μ=0 defines Constant Returns to Scale (CRS), and μ<0 defines Decreasing Returns to Scale (DRS). In general, a DMU is technically efficient if it obtains a score of 1 from DEA model. Otherwise, the DMU is considered to be technically inefficient.

Data Analysis

The DEA model is estimated using DEAP version 2.1 a DEA Program developed by Coelli (1996). The STATA version 15 by StataCorp (2015) is used for the pre-estimation techniques (choice of the best input/output combinations and checking for endogeneity issues regarding the technical efficiency of health systems).

Results

Descriptive Statistics

There is variation among the chosen inputs and outputs for various Africa LDCs (see Table 2).

Table 2: Descriptive statistics of the input and output variables (n=29) from 2008–2018

Variable	Observations	Mean	Std. Dev.	Min	Max
Inputs					
Domestic General Government Health Expenditure	319	14.273	16.633	0.927	89.079
Domestic Private Health Expenditure	319	20.959	17.611	2.182	147.569
External Health Expenditure	319	11.774	9.137	1.121	74.705
Out of Pocket Health Expenditure	319	18.098	16.253	1.825	139.601
Outputs					
Under Five Survival Rate	319	0.013	0.007	0.005	0.046
Maternal Survival Ratio	319	1.438	1.587	-0.405	8.259
Life Expectancy at Birth	319	59.056	4.901	43.384	68.7
Infant Survival Rate	319	17.453	5.422	7.734	35.63

Source: Author

The minimum and maximum amounts for domestic general government health spending were 0.927 and 89.097 million US dollars, respectively, while the minimum and maximum amounts for external health spending were 1.121 and 74.705 million US dollars. The difference between domestic private health spending and out-of-pocket medical expenses is even greater, with minimum and maximum values of 2.182 and 1.825 million US dollars and 139.601 and 147.569 million US dollars, respectively. For the health outputs, the average life expectancy at birth is 59.056 years, with a range of 43.384 to 68.7 years. With minimum values of 0.005, -0.405, and 7.734 and maximum values of 0.046, 8.259, and 35.63, respectively, the average under-five survival rate, maternal survival ratio, and infant survival rate are 0.013, 1.438, and 17.453, respectively.

Choice of Input and Output Combinations

To determine the interrelationships between various input and output variables, the Pearson's correlation matrix for the input and output variables in Table 3 is calculated.

DEA Model Specifications

Several input/output combinations for three (3) DEA model specifications based on the output orientation and VRS assumption are presented in Table 4 in light of the results of the Pearson's correlation matrix in Table 3. Only two outputs and all inputs are included in the DEA Model 1. Under

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five survival rate and maternal survival rate are dropped from DEA Model 1 as outputs because they have a strong significant positive correlation ($r = 0.837 > 0.5,\ p < 0.001$).

Table 3: Pearson Correlation Matrix of Inputs and Output Variables (n=29), 2008 – 2018

	Under Five Survival Rate	Maternal Survival Ratio	Life Expectancy at Birth	Infant Survival Rate	Domestic General Government Health Expenditure	Domestic Private Health Expenditure	External Health Expenditure	Out of Pocket Health Expenditure
Under Five Survival Rate	1							
Maternal Survival Ratio	0.837^{***}	1						
Life Expectancy at Birth	0.0660	0.118^{*}	1					
Infant Survival Rate	0.0771	0.0760	0.775^{***}	1				
Domestic General Government Health Expenditure	-0.0820	0.117^{*}	-0.0772	-0.0474	1			
Domestic Private Health Expenditure	0.187^{***}	0.190^{***}	0.0602	-0.0832	0.357^{***}	1		
External Health Expenditure	0.404^{***}	0.442^{***}	-0.113^{*}	0.0689	0.0658	-0.0780	1	
Out of Pocket Health Expenditure	0.168^{**}	0.122^{*}	0.0411	-0.104	0.282^{***}	0.980^{***}	-0.0911	1

Note: * ***p < 0.05,*** ** ***p < 0.01,*** *** ***p < 0.001 indicates 5%. 1% and 0.1% significance level***
Source: Author

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Table 4: DEA Model Specifications for different input/output combinations

Variables / Model	1	2	3
Inputs			
Domestic general government health expenditure	X	X	X
Domestic private health expenditure	X	X	
External health expenditure	X	X	X
Out of pocket health expenditure	X	X	
Outputs			
Under five survival rate		X	X
Maternal survival ratio		X	X
Life expectancy at birth	X		X
Infant survival rate	X		X

Source: Author

DEA model 2 has two outputs and all inputs. DEA model 2's outputs life expectancy at birth and infant survival rate are dropped due to their strong significant positive correlation ($r = 0.775 > 0.5,\ p < 0.001$). DEA Model 3 only has two inputs and four outputs. Due to their significant positive correlation ($r = 0.980 > 0.5,\ p < 0.001$), domestic private health expenditure and out-of-pocket health expenditure inputs were dropped for DEA Model 3.

Three (3) DEA models are estimated in Table 5 showing technical scores based on the VRS technical efficiency scores and differ depending on the model specification. DEA Model 1 was the most preferred model because it had a mean technical efficiency score of 0.944 with a total of 16/29 countries on the production frontier. DEA Models 2 and 3 came next, with mean technical efficiency scores of 0.741 and 0.935, respectively, and 14/29 and 12/29 countries on the production frontier.

Table 5: Technical efficiency for three (3) selected DEA models

	Model 1	Model 2	Model 3
Country/DMU	**vrste**	**vrste**	**vrste**
Angola	0.847	0.702	0.867
Benin	0.947	0.421	0.951
Burkina Faso	0.89	0.539	0.894
Burundi	1	1	0.938
Central African Republic	1	1	0.801
Chad	1	1	1
Democratic Republic of Congo	1	1	1
Djibouti	0.943	0.81	0.968
Eritrea	1	0.717	1
Ethiopia	1	1	1
Gambia	0.958	0.444	0.954
Guinea	1	1	1
Guinea-Bissau	0.856	0.505	0.871
Lesotho	0.692	0.35	0.7
Liberia	0.94	0.472	0.96
Madagascar	1	1	1
Malawi	1	0.454	0.838
Mali	0.885	0.339	0.885

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Mauritania	1	1	1
Mozambique	1	1	0.857
Niger	1	1	0.964
Rwanda	1	1	1
Senegal	1	0.465	1
Sierra Leone	0.791	1	1
Sudan	1	1	1
Togo	1	1	1
Uganda	0.878	0.331	0.887
Tanzania	0.912	0.577	0.926
Zambia	0.845	0.365	0.854
Mean	**0.944**	**0.741**	**0.935**
Number on Frontier	**16**	**14**	**12**

Note: vrste = technical efficiency from VRS DEA: Source: Author

Test for endogeneity for the most preferred model: DEA Model 1

Table 6 presents pearsons correlation results between the inputs and technical efficiency scores of model 1.

Table 6: Pearson correlation between inputs and Technical efficiency scores of Model (1) for Africa LDCs(n=29) from 2008 to 2018

Inputs	**Technical efficiency scores**
Domestic general government health expenditure	-0.30447
Domestic private health expenditure	-0.12302
External health expenditure	-0.30551
Out of pocket health expenditure	-0.13614

Source: Author

Table 6's findings show that there isn't a strong correlation between technical efficiency scores and input variables. As a result, DEA Model 1 is suitable for further analysis because it does not have an endogeneity issue. Table 7 presents the findings of the most preferred model.

Technical Efficiency of health systems of Africa LDCs

The results in Table 7 show that between 2008 and 2018, sixteen African LDCs (Burundi, Central African Republic, Chad, Democratic Republic of the Congo, Eritrea, Ethiopia, Guinea, Madagascar, Malawi, Mauritania, Mozambique, Niger, Rwanda, Senegal, Sudan, and Togo) had technically efficient health systems, while thirteen (Angola, Benin, Burkina Faso, Burkina Faso, Djibouti, Gambia, Guinea Bissau, Lesotho, Liberia, Mali, Sierra Leone, Uganda, Tanzania, and Zambia) had technically inefficient health systems.

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Table 7 Technical efficiency scores of Africa LDCs(n=29) for model 1 from 2008 to 2018

Country/DMU	crste	vrste	Returns to Scale
Angola	0.716	0.847	Decreasing Returns to Scale
Benin	0.628	0.947	Decreasing Returns to Scale
Burkina Faso	0.532	0.890	Decreasing Returns to Scale
Burundi	0.970	1	Increasing Returns to Scale
Central African Republic	0.855	1	Increasing Returns to Scale
Chad	1	1	-
Democratic Republic of Congo	1	1	-
Djibouti	0.696	0.943	Decreasing Returns to Scale
Eritrea	1	1	-
Ethiopia	1	1	-
Gambia	0.753	0.958	Decreasing Returns to Scale
Guinea	1	1	-
Guinea-Bissau	0.454	0.856	Decreasing Returns to Scale
Lesotho	0.321	0.692	Decreasing Returns to Scale
Liberia	0.595	0.940	Decreasing Returns to Scale
Madagascar	1	1	-
Malawi	1	1	-
Mali	0.587	0.885	Decreasing Returns to Scale
Mauritania	1	1	-
Mozambique	1	1	-
Niger	1	1	-
Rwanda	0.849	1	Decreasing Returns to Scale
Senegal	1	1	-
Sierra Leone	0.586	0.791	Decreasing Returns to Scale
Sudan	1	1	-
Togo	1	1	-
Uganda	0.404	0.878	Decreasing Returns to Scale
Tanzania	0.604	0.912	Decreasing Returns to Scale
Zambia	0.278	0.845	Decreasing Returns to Scale
Mean	0.787	0.944	

Note: vrste = technical efficiency from VRS DEA, crste = technical efficiency from CRSDE, Source: Author

Peer Count, Peers, Peer Weights for Africa LDCs

To further understand the technical efficiency scores for the preferred Model 1 in Table 7, Table 8 presents the peer counts, peers and peer weights. According to Kizza (2012) African LDCs forming the efficiency reference set are known as peer groups for the inefficient African LDCs. This means that the efficiency reference set comprises of African LDCs that are relatively efficient and act as models to the inefficient African LDCs (Kizza, 2012). Angola should 100% benchmark the policies of Senegal. Benin should bench mark 80.5% of the policies of Madagascar and 19.5% of the policies from Ethiopia.

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Table 8: Results of the Peer Count, Peers and Peer Weights

Country/DMU	Peer count:	Peers			Peer weights		
Angola	0	Senegal			1		
Benin	0	Madagascar	Ethiopia		0.805	0.195	
Burkina Faso	0	Eritrea	Madagascar		0.026	0.974	
Burundi	0	Burundi			1		
Central African Republic	0	Central African Republic			1		
Chad	0	Chad			1		
Democratic Republic of Congo	0	Democratic Republic of the Congo			1		
Djibouti	0	Senegal	Madagascar		0.437	0.563	
Eritrea	4	Eritrea			1		
Ethiopia	4	Ethiopia			1		
Gambia	0	Eritrea	Madagascar	Rwanda	0.42	0.454	0.126
Guinea	0	Guinea			1		
Guinea-Bissau	0	Senegal	Madagascar		0.422	0.578	
Lesotho	0	Senegal	Madagascar		0.475	0.525	
Liberia	0	Madagascar	Ethiopia		0.809	0.191	
Madagascar	12	Madagascar			1		
Malawi	0	Malawi			1		
Mali	0	Madagascar	Ethiopia		0.571	0.429	
Mauritania	0	Mauritania			1		
Mozambique	0	Mozambique			1		
Niger	0	Niger			1		
Rwanda	1	Rwanda			1		
Senegal	7	Senegal			1		
Sierra Leone	0	Madagascar	Ethiopia		0.165	0.835	
Sudan	0	Sudan			1		
Togo	0	Togo			1		
Uganda	0	Senegal	Madagascar		0.406	0.594	
Tanzania	0	Eritrea	Senegal	Madagascar	0.227	0.186	0.588
Zambia	0	Senegal	Eritrea	Madagascar	0.099	0.19	0.712

Source: Author

Burkina Faso should benchmark 2.6 % of Eritrea's policies and 97.4 % of Madagascar's policies. Djibouti is eligible for 43.7% of Senegal's policies and 56.3% of Madagascar's policies. The Gambia can use and bench mark 42% of Eritrea's policies, 45.4% of Madagascar's policies and 12.6% of Rwanda's policies. Senegal's policies are appropriate and should act as benchmarks for both Guinea-Bissau and Lesotho at 42.2% and 47.5%, respectively, while Madagascar's policies are appropriate and should act as benchmarks for both countries at 57.8% and 52.5%. In comparison, 19.1%, 42.9%, and 83.5% of Ethiopia's

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policies are appropriate benchmarks for Liberia, Mali, and Sierra Leone, respectively, while 80.9%, 57.1%, and 16.5% of Madagascar's policies should act as benchmarks for Liberia, Mali and Sierra Leone. Tanzania and Zambia should each benchmark 58.8% and 71.2% of Madagascar's policies, respectively, as well as 22.7% and 19% of Eritrea's policies as well as 18.6% and 9.9% of Senegal's policies. Uganda, should benchmark 40.6% of Senegal's policies and 59.4% of Madagascar's policies.
The countries that provided highest bench marks for inefficient countries to consider were Madagascar (had highest peer count of 12), Senegal (peer count of 7), Eritrea and Ethiopia (peer counts of 7) and Rwanda (peer count of 1).

Input and Output Slacks needed to make inefficient countries Efficient

According to Tindimwebwa et al. (2018), African LDCs that where 100 percent efficient (see Table 7) neither needed to reduce their inputs or increase their outputs thus had zero input and output slacks while inefficient African LDCs had input and output slacks as seen in Table 9. As per the requirement to increase health financing in accordance with SDG 3 (United Nations, 2017).

Results from Table 9 indicate that for Angola, Benin, Burkina Faso, Djibouti, Guinea Bissau, Lesotho, Liberia, Mali, Sierra Leone, and Uganda to increase their infant survival rate by 7.981, 5.036, 4.898, 4.739, 6.109, 2.838, 5.759, 4.817, 6.5, and 0.135 per 1000 live births the following input increments are necessary. Increases in domestic general government spending of 67.883, 1.322, 18.291, 0.034, 2.574, 25.828 and 5.981 million USD are required in Angola, Burkina Faso, Djibouti, Gambia, Guinea Bissau, Lesotho, and Tanzania, respectively while a total of 18.501, 6.793, 0.876, 12.259, 14.593, 24.255, 18.141, and 13.261 million USD should be added to the domestic private health expenditures of Angola, Benin, Gambia, Liberia, Mali, Sierra Leone, Uganda, and Zambia, respectively.

It is necessary for Angola, Benin, Burkina Faso, Djibouti, Gambia, Guinea Bissau, Lesotho, Liberia, Mali, Sierra Leone, Uganda, Tanzania, and Zambia to increase their external health expenditure in by 0.186, 3.015, 6.336, 1.74, 18.685, 5.617, 7.857, 2.842, 1.986, 1.182, 7.811, 4.376, and 18.371 million USD, respectively. While out-of-pocket expenditures for Angola, Benin, Burkina Faso, Djibouti, Guinea Bissau, Lesotho, Liberia, Mali, Sierra Leone, Uganda, Tanzania, and Zambia all need to increase by 8.95, 6.694, 0.992, 3.478, 1.95, 1.282, 12.698, 15.193, 24.78, 9.988, 1.903, and 10.485 million USD, respectively.

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Table 9: Input and Output Slacks needed to make inefficient Africa LDCs Efficient. Country/DMU	**Inputs**				**Outputs**	
	Domestic General Government Health Expenditure	**Domestic Private Health Expenditure**	**External Health Expenditure**	**Out of Pocket Health Expenditure**	**Life Expectancy**	**Infant Survival Rate**
Angola	67.883	18.501	0.186	8.95	0	7.981
Benin	0	6.793	3.015	6.694	0	5.036
Burkina Faso	1.322	0	6.336	0.992	0	4.898
Burundi	0	0	0	0	0	0
Central African Republic	0	0	0	0	0	0
Chad	0	0	0	0	0	0
Democratic Republic of Congo	0	0	0	0	0	0
Djibouti	18.291	0	1.74	3.478	0	4.739
Eritrea	0	0	0	0	0	0
Ethiopia	0	0	0	0	0	0
Gambia	0.034	0.876	18.685	0	0	0
Guinea	0	0	0	0	0	0
Guinea-Bissau	2.574	0	5.617	1.95	0	6.019
Lesotho	25.828	0	7.857	1.282	0	2.838
Liberia	0	12.259	2.842	12.698	0	5.759
Madagascar	0	0	0	0	0	0
Malawi	0	0	0	0	0	0
Mali	0	14.593	1.986	15.193	0	4.817
Mauritania	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0
Niger	0	0	0	0	0	0
Rwanda	0	0	0	0	0	0
Senegal	0	0	0	0	0	0
Sierra Leone	0	24.255	1.182	24.78	0	6.5
Sudan	0	0	0	0	0	0
Togo	0	0	0	0	0	0
Uganda	0	18.141	7.811	9.988	0	0.135
Tanzania	5.981	0	4.376	1.903	0	0
Zambia	0	13.261	18.371	10.485	0	0
Mean	**4.204**	**3.748**	**2.759**	**3.393**	**0**	**1.68**

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Source: Author

For Africa LDCs to increase their infant survival rate by an average of 1.68 per 1000 live births they needed to increase their domestic general government health expenditure by 4.204 million USD, domestic private health expenditure by 3.748 million USD, external health expenditure by 2.759 million USD, and out-of-pocket health expenditure by 3.393 million USD.

Discussion

This study reports variations in the technical efficiency of health systems of African LDCs. African LDCs with technically efficient health systems like Eritrea, Ethiopia, Madagascar, Malawi, Senegal and Togo had good health outcomes while those like the Central African Republic, the Democratic Republic of Congo, Chad and Guinea had poor health outcomes despite having technically efficient health systems. Similar findings were reported by authors such as Çelik et al. (2017), Dhaoui (2019) and Retzlaff-Roberts et al. (2004), who established that efficiency results can be observed between countries with good health outcomes and those with poor health outcomes. Burundi, the Central African Republic, Chad, the DRC, Eritrea, and Guinea were among the Africa LDCs with technically efficient health systems despite having low levels of health spending, while Lesotho, Djibouti, Angola, and Zambia had technically inefficient health systems despite having high levels of health spending. This is in line with the findings of Behr and Theune (2017), Sinimole (2012) and Alexander et al. (2003), who noted high levels of inefficiencies among nations that spent a lot of money on health and efficiencies among nations that spent low amounts.

Countries like Madagascar, Senegal, Eritrea and Ethiopia with technically efficient health systems were benchmarks for countries with technically inefficient health systems. Those with good health outcomes in terms in infant survival rate and life expectancy (Madagascar, Senegal, Eritrea, Ethiopia and Rwanda) were reference countries for countries with poor health outcomes. This is in disagreement with the findings of Cetin and Bahce (2016) who established that that OECD countries which produced poor health services with fewer inputs such as Chile, Mexico and Turkey were found to be reference countries for other countries with much better health outcomes.

It was also established that African LDCs need to increase their domestic general government health expenditure, domestic private health expenditure and external health expenditure to realize increase in their infant survival rates. These results concur with those of Ahmed et al. (2019), who also suggested that increasing health expenditures particularly domestic general government health expenditure was associated with better health outcomes particularly a rise in the infant survival rate.

Conclusion

Health expenditure wastages exist/don't exist in some African LDCs. African LDCs with efficient health systems are benchmarks for African LDCs with inefficient health systems. Increments in domestic general government health expenditure, private health expenditure, external health expenditures and out of pocket health expenditures are associated in increase in infant survival rates. It is on the basis of the findings that the study calls for increased domestic general government and domestic private health expenditures health expenditures, this can be done through private public partnerships to promote universal access to health care. Inefficient Africa LDCs can also benchmark the practices of efficient Africa LDCs to improve the performance of their health systems.

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