Decomposition of Health Technical Efficiency

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Abstract: - Health efficiency is an important metric in any health delivery system since it guarantees that healthcare systems utilize the fewest resources feasible while delivering the highest quality of treatment and health outcomes. The study examined the technical efficiency of the health systems in the SADC region for the period 2010-2022. In order to identify the causes of the technical inefficiencies in the SADC countries' health systems, the study broke down technical efficiency into pure technical and scale efficiency using the data envelopment analysis methodology. The study revealed that the average technical efficiency score was 55 percent, the average scale efficiency score was 81 percent, and the average pure technical score was 64 percent. This means that the region's health system technical inefficiency stems mostly from management inefficiency. The conclusion is that, despite operating at the proper scale, most countries are being choked by inadequate resource management. This suggests that enhancing administrative skills and resource use are key to increasing health efficiency.

Key-Words: - Technical efficiency, Scale efficiency, Pure technical efficiency, Data Envelopment Analysis, Health, Southern African Development Community

Received: April 26, 2025. Revised: July 27, 2025. Accepted: September 3, 2025. Published: April 9, 2026.

1 Introduction

Efficiency is one of the indicators of the effectiveness of a health system. Policymakers are particularly interested in it because it aims to evaluate the important results of a health system in relation to the resources that are given up in attaining those results. Health system efficiency is now at the center of policy conversations due to rising health care expenditures and growing worries about budgetary sustainability. While many middle- and low-income nations are aiming to grow their health systems while guaranteeing value for money, most high-income countries are looking for ways to provide the same health outcomes for less [1].

Policymakers around the world aim to prioritize health system efficiency as nations strive for universal health coverage and also deal with the added challenge of an aging population [2]. African health policy makers have also emphasized the importance of making effective use of the limited resources available to the health sector [3]. An increasing number of African nations have conducted health facility efficiency studies to direct the creation of solutions to lessen the waste of limited resources in the health system. One of the primary objectives of health systems is acknowledged to be increased efficiency [4], [5], [6]. According to WHO estimates, between 20 percent and 40 percent of all healthcare expenditures are lost annually among its member nations as a result of inefficiencies [7]. Additionally, low and middle-income nations have greater rates [8] of inefficiency. [9] found that 115 out of 180 nations, including South Africa, have technically inefficient healthcare systems.

Evaluating the efficiency of healthcare systems is a challenging procedure since assessments frequently run into methodological issues, especially because it requires appropriate and reliable outcome indicators. Efficiency may be quantified at both the macro and micro levels, notwithstanding the empirical challenges associated with applying efficiency concepts to health systems. In order to comprehend health system performance worldwide and take the necessary steps to reduce inefficiency, it is especially crucial to measure health system efficiency at a global level [10], [11]. In the health sector, technical efficiency is the process of achieving the greatest potential health outcomes (outputs) with the least amount of resources (inputs). It entails evaluating how well a health system or facility transforms inputs like personnel, funding, and beds into outputs like treatments, life expectancy, and newborn mortality rates. Systems that are inefficient squander resources, which means fewer resources may be used to accomplish the same outputs, or the same resources may be used to achieve better results.

Ranking the regions based on the efficiency of their health systems encourages transparency in policy making and serves as a significant motivator for the creation and execution of targeted initiatives meant to raise the standard of healthcare services in the nation [12]. An analysis of the efficiency of the health systems helps to draw comparisons between nations. The purpose of this article is to evaluate the technical efficiency of the health systems in the Southern African Development Community (SADC) region. The study further decomposes the technical efficiency of the different countries into pure technical efficiency and scale efficiency. Pure technical efficiency and scale efficiency are combined to create overall technical efficiency. Pure technical efficiency, which involves optimizing input/output consumption given present technology, and scale efficiency, which refers to operating at the optimal size/scale, are the two components of technical efficiency, which assesses how successfully inputs are transformed to outputs. While scale efficiency deals with whether a company's size is ideal, pure technical efficiency concentrates on how a company uses its resources. Based on these definitions, the study seeks to assess whether the health systems in SADC are operating at the correct scale and to what extent the countries are optimising their resource use.

The SADC region is composed of sixteen countries. The region is experiencing insufficient investment in public health and poor access to health care [13]. Facing mounting challenges in the health sector, each member country of the bloc committed to enhancing the health and wellbeing of its citizens. These members are committed to global and regional initiatives, including the United Nations Sustainable Development Goals and the Abuja declaration. In SADC, governments continue to face acute resource constraints, weak governance, and institutional limitations, which frequently undermine the effective translation of health expenditure into outcomes [14], [15]. The study contributes to the body of knowledge in several ways. Most studies that have been on health system efficiency have been at the country level [16], [17], [18], [19], [20], [21], while the current study will look at efficiency from a regional block perspective. Secondly, there are limited studies that have tried to decompose efficiency into scale efficiency and pure technical efficiency [22], [23], with the majority looking at technical efficiency alone [24], [25], [26], [27]. Thirdly, there is a dearth of studies on health efficiency for the SADC region as a block. This study contributes to the policy discourse by identifying the sources of health inefficiency in the SADC region.

2 Study Hypothesis

In order to identify the causes of the technical inefficiencies in the SADC countries' health systems, the study broke down technical efficiency into pure technical and scale efficiency using the data envelopment analysis method. The main thrust of the study is to understand the distribution of the two components of technical efficiency into pure technical efficiency and scale efficiency; hence, the hypothesis to be tested are:

H_1: The health system in the SADC region is efficient

H_2: Pure technical efficiency is superior to scale efficiency

3 Methodology

One of the most popular techniques for gauging efficiency is data envelopment analysis (DEA). The technique was first presented by [28] to gauge relative efficiency. It is based on the idea of Pareto efficiency. The technique uses input and output data from a few Decision Making Units (DMUs) to evaluate efficiency. The technique finds DMUs that are comparatively efficient and serve as benchmarks. The efficiency frontier and the inefficiency of other DMUs that fall below it are then determined using the relative efficient points [29], [30]. Only in comparison to other DMUs in the sample are the efficient DMUs efficient.

The model is based on linear programming techniques that allow calculating the relative efficiency of DMU [31]. [32] proposed the use of relative efficiency, which involves multiple inputs and outputs, though not necessarily in equal proportion. The major goal of the relative efficiency technique is to develop a frontier of the most efficient DMUs and then ascertain the distance of the less efficient units from the frontier [33].

The current study seeks to decompose the technical efficiency (T) into pure technical efficiency (PT) and scale efficiency (S). The model for measuring the technical efficiency is shown in equation (1)

$$\theta^* = \min \theta$$

Subject to

$$\sum_{j=1}^{m} \lambda_j x_{ij} \leq \theta x_{i0} \quad i = 1,2,3 \ldots \ldots m$$

$$\sum_{j=1}^{m} \lambda_j y_{rj} \leq y_{ro} \quad j = 1,2,3 \ldots \ldots m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 1 \qquad (1)$$

The model has n DMUs being investigated. x and y represent the i_{th} input and then r_{th} output for the DMU_0, respectively. λ are unknown weights and j = 1, 2, .. m represents the number of DMUs. The optimal value of θ* shows the distance of the country from the efficient frontiers. This means that the most technically efficient country has θ* = 1 and the inefficient countries will have θ*<1.

The empirical model for this study becomes:

$$\theta^* = \min \theta$$

Subject to

$$\lambda_1 NOD_j + \lambda_2 NOB_j + \lambda_3 NON_j \leq \theta x_{i0}$$
$$j = 1,2,3 \ldots \ldots n$$
$$\lambda_1 LIFE_j + \lambda_2 MORT_j \leq y_{ro}$$
$$j = 1,2,3 \ldots \ldots m$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 1 \qquad (2)$$

Where, NOD is the number of doctors, NOB is the number of beds, NON is the number of nurses, LIFE is the life expectancy, and MORT is the under-five infant mortality rate.

Efficiency can be calculated using either the Variable Returns to Scale (VRS) or Constant Returns to Scale CRS model. The envelopment surface's shape and, consequently, the quantity of effective DMUs are impacted by the decision between CRS and VRS. If every input results in a proportionate rise in output, CRS achieves a proportional increase. CCR (Charnes, Cooper, and Rhodes) models are those that use the CRS. The Farrell's efficiency measurement idea is expanded from multiple inputs and one output to multiple inputs and multiple outputs by the CCR model. This paradigm [28] converts various inputs and outputs into a single virtual input and output using a linear combination. Assuming a constant output, the efficiency barrier for measuring relative efficiency will be estimated as the ratio of these virtual combinations of outputs to inputs.

Compared to the alternative VRS, the CRS model is more restrictive, produces fewer efficient units, and has poorer efficiency scores. VRS may be rising or falling. The opposite is true for decreasing returns to scale, where a proportionate decrease in factor inputs results in a less-than-proportional decrease in output. Increasing returns to scale require a proportionate increase in all production factor inputs, which leads to a more proportionate increase in output. The [34] model is a model that uses the VRS. 34 model posits a variable output about the scale, as opposed to the CRS model's constant yield. According to [35], a company that is efficient under VRS is regarded as technologically efficient; the VRS score represents PT. In contrast, a company that is efficient under CRS is both technologically efficient and employs the most efficient scale of operation. The metrics of technical efficiency, T and PT, are used to calculate scale efficiency (S).

$$S = \frac{PT}{T}$$

Or

$$S = \frac{CRS}{VRS} \qquad (3)$$

Where $0 \leq S \leq 1$ because $CR \leq VR$. If the value of S equals 1, the firm is scale efficient, and all values less than 1 reflect scale inefficiency. The analysis considers three inputs: number of doctors (NOD), number of beds (NOB), and number of nurses (NON). The two outputs considered for the study are life expectancy (LIFE) and under-five infant mortality rate (MORT).

4 Results Presentation and Analysis

The average efficiency score for SADC health systems from 2010 to 2022 was 54.99 percent. The results indicate that the health system is suffering from technical inefficiency. This finding suggests that the average national health system experienced a level of technical inefficiency of 45.01 percent. This shows that there is a lot of wastage in the SADC health systems. In other words, if the health systems had functioned at the same degree of efficiency as the most efficient nation in the sample, there would have been more opportunity for them to boost output. The findings indicate that during the study period, there was a higher degree of technical inefficiency dispersion among the nations.

Table 1: Technical, Pure Technical, and Scale Efficiency

Year	T	PT	S
2010	0.5842	0.6275	0.8538
2011	0.5538	0.6054	0.8442
2012	0.5441	0.6026	0.8418
2013	0.5415	0.5954	0.8462
2014	0.5627	0.6146	0.8491
2015	0.5595	0.6111	0.8483
2016	0.5605	0.6097	0.8444
2017	0.5429	0.6066	0.8374
2018	0.5079	0.6185	0.7847
2019	0.5095	0.6248	0.7828
2020	0.5187	0.6159	0.8021
2021	0.5809	0.8067	0.6720
2022	0.5833	0.7956	0.6779
Average	0.5499	0.6411	0.8065

Source: Created by authors.

Table 1 shows the decomposed technical efficiency for the SADC region. The results show that technical efficiency ranged between 50.79 percent and 58.42 percent between the period 2015 – 2022. This shows that throughout the period, there has not been an improvement in the technical efficiency of the health systems in the SADC region. The level of wastage ranged between 41.58 percent and 49.21 percent, which is considered high. According to the World Health Organisation, the level of health inefficiency lies between 20 percent and 40 percent. Further, the results compare to [36], who established that the average efficiency for Sub-Saharan Africa was pegged at 85%, and 60%, with the majority of the countries evaluated performing below-average efficiency. The results lend credibility to a study that established that 49 African countries' National Health Services(NHSs) were run inefficiently in 1999 and 2000; 94.3 percent, 90.6 percent, and 88.7 percent operated inefficiently in 2001, 2002, and 2003, respectively [37].

The results show that the average pure technical efficiency during the period 2015-2022 was 64.11 percent. The pure technical efficiency ranged between 59.54 percent and 80.67 percent. Since pure technical inefficiency refers to the failure of health systems to produce the maximum possible outputs from a given set of inputs, the source of this inefficiency is poor management. It specifically relates to internal managerial and operational shortcomings. The results imply that, on average, 35 percent of the wastages are a result of poor management decisions. This can be resolved by improving the managerial acumen in the health system.

The average scale inefficiency for the period 2010-2022 is 80.65 percent. Scale efficiency in the health sector assesses whether a health system is operating at the optimal size to maximize output from its inputs, measured by comparing its current size to the most productive scale size. This shows that the majority of the countries operate at the correct scale with inefficiency levels of 19.35 percent. The scale efficiency ranged between 67.79 percent and 85.38 percent. This means the levels of inefficiency ranged from 14.62 percent to 32.21 percent. Operating at the correct scale is important for health systems to ensure there is increased efficiency.

A comparison between the pure technical efficiency and scale efficiency shows that the average scale efficiency was higher than pure technical efficiency. This means that the main source of technical inefficiency is pure technical efficiency, rather than scale inefficiency, and managerial inefficiency dominates scale inefficiency. Scale inefficiency was higher in SADC for the period 2010-2020. The trend changed in 2021 and 2022 when pure technical efficiency increased and surpassed scale inefficiency. This means the scale of operation declined for SADC as a result of the COVID period. The overwhelming demand for health services during the pandemic meant that the health facilities became constrained, hence the scale inefficiencies for 2021 and 2022.

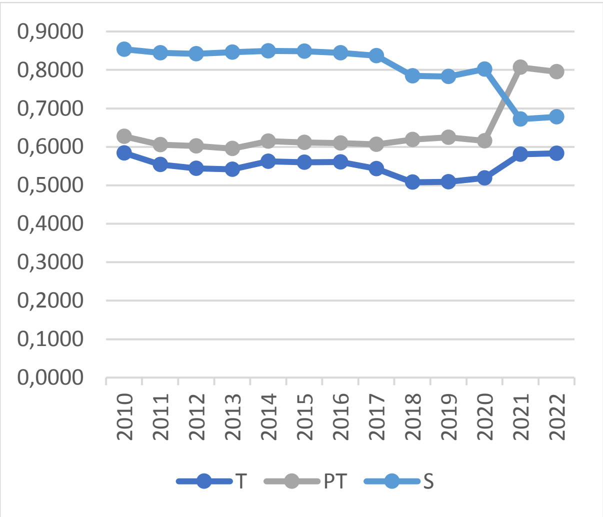

Fig. 1: Decomposed Technical Efficiency
Source: Created by authors.

Figure 1 shows the trend in the technical, pure technical, and scale efficiency for the period 2010–2022. The figure reveals that the scale efficiency was higher than the pure technical efficiency, giving credence to the fact that the main source of the technical inefficiency during the whole period was pure technical inefficiency rather than scale inefficiency. Since pure technical efficiency measures the ability to get the most output from inputs without considering the scale of operations, reflecting operational management and technological proficiency. There are several reasons behind the SADC region's pure technical inefficiency. Most of these flaws were exposed during the COVID-19 pandemic, including staff shortages, an unsuitable doctor-to-total-staff ratio, ineffective performance reviews, ineffective administrative procedures, a lack of competition that lessens the incentive to improve quality and efficiency, and the lack of systems to monitor and enhance the effectiveness of public facilities.

Table 2: Average Country Efficiency Scores

	TE	PT	S
ANGOLA	0.7715	0.9491	0.8106
BOTSWANA	0.3067	0.3637	0.7700
COMOROS	0.3290	0.3764	0.8597
DRC	0.2702	0.5559	0.3989
ESWATTNI	0.7811	0.9193	0.8032
LESOTHO	0.4402	0.4488	0.9764
MADAGASCAR	0.7867	0.9281	0.8282
MALAWI	0.9209	1.0000	0.9209
MAURITIUS	0.8716	0.9844	0.8770
MOZAMBIQUE	0.8888	0.9849	0.8935
NAMIBIA	0.2948	0.3214	0.8649
SEYCHELLES	0.1924	0.2311	0.5776
SOUTH AFRICA	0.2289	0.2819	0.6689
TANZANIA	0.9310	1.0000	0.9310
ZAMBIA	0.3677	0.4121	0.8850
ZIMBABWE	0.4176	0.5005	0.8382

Source: Created by authors.

A comparative analysis of the efficiency of the countries shows that SADC countries are heterogenous with some more efficient than others. Table 2 shows that Malawi, Tanzania, Mauritius, and Madagascar have the most health technically efficient systems in SADC. The least efficient countries are Seychelles, the Democratic Republic of the Congo (DRC), and South Africa. The average health technical efficiency among the countries ranges from 92.09 percent in Malawi to 19.24 percent in Seychelles. This means that there are a great deal of disparities between the SADC countries in terms of health technical efficiency.

The results show that Angola, Eswatini, Madagascar, Malawi, Mauritius, Mozambique, and Tanzania have superiority in pure technical efficiency as compared to scale efficiency. This means that these countries are suffering more from scale inefficiency as compared to pure technical efficiency. This means these countries are prone to operating at the wrong level on their cost curves, leading to higher costs. Scale inefficiency in the health sector reveals that health systems are not operating at the optimal size to maximize output from their inputs, measured by comparing their current size to the most productive scale size. There is a need to review their scale of operations to enhance their technical efficiency.

Botswana, Comoros, DRC, Namibia, Lesotho, Seychelles, South Africa, Zambia, and Zimbabwe are suffering more from pure technical inefficiency as compared to scale inefficiency. This means that these countries are facing managerial problems in their health system. They are operating at the correct scales, but face challenges which could be attributable to a number of reasons, including corruption, mismanagement of resources, procurement processes challenges, all leading to managerial inefficiencies in the health system. The results confirm the challenges, including a lack of qualified staff, staff attrition, and unfilled vacancies, among others. This then leads to the inability to achieve maximum possible output from a given set of inputs, or to use the minimum possible inputs to produce a given output. Unqualified personnel become a cost because decisions are not made in an effective way. Further, the challenges could emanate from inadequate leadership, poor organizational structure, and failure to set and monitor performance targets. Procedural issues that cause delays, create bottlenecks, and lead to wasted resources were a common phenomenon during the Covid era. During the COVID period, health institutions experience serious bottlenecks as the procurement systems were not geared for such a pandemic, leading to delays in institutions getting equipment and medications

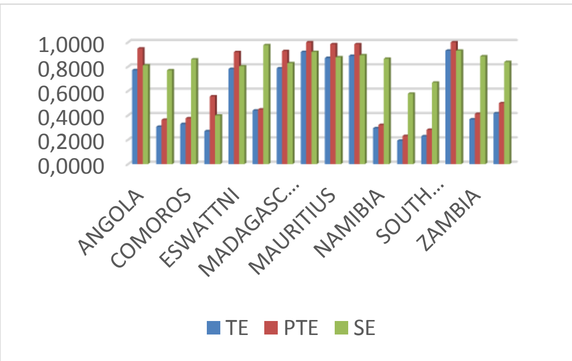

Fig. 2: Average Country Efficiency Scores
Source: Created by authors.

Figure 2 shows the decomposed technical efficiency of the different countries from the data presented in Table 2. As discussed above, the sources of technical inefficiency of the SADC countries are different. Angola, Eswatini, Madagascar, Malawi, Mauritius, Mozambique, and Tanzania are pure technically efficiency dominates scale efficiency. This implies these countries are operating at the wrong scale of operation. On the other hand, Botswana, Comoros, DRC, Namibia, Lesotho, Seychelles, South Africa, Zambia, and Zimbabwe are experiencing pure technical inefficiency and not scale inefficiency. This implies these countries are prone to managerial challenges.

Table 3: Tests for Equality Between Means of Scale Efficiency and Pure Technical Efficiency

Method	**Degree of freedom**	**Value**	**Prob**
t-test	4141	5.7009	0.0000
Satterthwaite-Welch t-test	356.9894	5.7009	0.0000
Anova F-test	(1, 414)	32.5009	0.0000
Welch F-test	(1, 356.989)	32.5009	0.0000

Source: Created by authors.

The results in Table 3 show that there is a significant difference between the mean of scale efficiency and pure technical efficiency. The t-test of Equality Between Means of Scale Efficiency and Pure Technical Efficiency shows that the p-value (0.0000) is less than the significance level (0.05), giving credence to the rejection of the null hypothesis that the means are equal. The results are further confirmed by the Satterthwaite-Welch t-test and the Welch F-test, which proves that the means of the scale efficiency and pure technical efficiency are not equal.

Table 4: Analysis of variance

Source of variation	Degree of freedom	Sum of squares	Mean Sum of Squares
Between	1	2.8451	2.8451
Within	414	36.2414	0.0875
Total	415	39.0865	0.0942

Source: Created by authors.

The results of the analysis of variance shown in both Table 3 and Table 4 further confirm the t-test results that the difference between the mean of technical efficiency and scale efficiency is different. A p-value of the (0.0000) F-test in Table 3 confirms that there is a significant difference in the means of scale and pure technical efficiency according to the Analysis of variance method.

5 Conclusion

There has been an increased call for increased health financing in the SADC region to improve the health delivery system. Despite the call, the countries are suffering from limited fiscal space, hence inability to increase funding to the health system. One of the mechanisms which has been proffered is to increase the efficiency of the resources usage in the different sectors including health, to cover the limited fiscal space. The study investigated the technical efficiency of the health systems in the SADC region spanning the period 2010–2022. The study entailed the decomposition of the technical efficiency into pure technical and scale efficiency to understand the sources of the technical inefficiency in the health system among SADC countries. The decomposition was meant to ascertain whether the inefficiencies among countries' health systems were a result of managerial inefficiencies or because of wrong choice of scale of operation. The study has shown that scale efficiency scores were higher than pure technical efficiency scores, implying that health systems suffers more from pure technical inefficiency as compared to operating at the wrong scale of operation. Since pure technical efficiency measures the ability to get the most output from inputs without considering the scale of operations, reflecting operational management and technological proficiency. There are several reasons behind the SADC region's pure technical inefficiency, including staff shortages, an unsuitable doctor-to-total-staff ratio, ineffective performance reviews, ineffective administrative procedures, a lack of competition that lessens the incentive to improve quality and efficiency, and the lack of systems to monitor and enhance the effectiveness of public facilities, which are all contributing factors. The study therefore recommends that SADC countries should resource their health systems adequately, enhance their monitoring and evaluation systems to ensure administrative challenges are resolved timeously, and ensure staff with adequate managerial skills are employed at the correct levels. This means, given the low technical efficiency of the health system, there is a general need for the reform of the health system for member states in the region. Health sector reforms are intentional adjustments meant to make a nation's healthcare system more effective, equitable, and efficient. Decentralizing services, enhancing infrastructure and human resources, and deploying digital health technology are just a few examples of the many efforts that SADC countries can implement to enhance technical efficiency.

Acknowledgement:
The authors acknowledge the three reviewers of the article for their thought-provoking comments.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.