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Modelling technical efficiency of health systems in SADC

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Abstract

Efficiency is the application of resources in a way that maximizes intended results. Policymakers around the world are prioritising health system efficiency as nations strive for universal health coverage. The study used the data envelopment analysis and the Tobit regression approach, the current study evaluated the technical efficiency of the health care system and its determinants. The study established that the average efficiency of the SADC countries is 78 percent signifying high levels of inefficiencies. Further the study found that the most efficient countries were Angola, Botswana, Eswatini, Mauritius, Mozambique, and Malawi. The number of practitioners i.e. physicians and nurses, primary school graduation rates, and national income all have a beneficial impact on the efficiency of the health system. The use of nitrous oxide in agriculture and vulnerable employment have a negative impact on technical efficiency. The study recommends that SADC countries should improve on resource use to improve on technical efficiency, train more doctors, nurses, and other medical professionals. Additionally, nations should implement pro-growth policies to boost revenue to capacitate their health systems with beds and other requisite equipment.

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1. Introduction

Globally the health care sector continues to face significant obstacles that must be addressed, despite the numerous efforts made to improve its efficiency and organisation as well as to guarantee equitable access to healthcare services. These obstacles include the high prevalence of non-communicable diseases, rising health care demand, a lack of funding for healthcare expenses, rising costs of healthcare services, and fragmentation of health care systems (Nassar, Sakr, Ezzat, & Fikry, 2020). Increasing health spending is an investment that guarantees access to better health care because health is a growing global concern (Zhou et al., 2020). According to Hadad, Hadad, and Simon-Tuval (2013) health investments are essential to the effective operation of health systems in both developed and least developed nations. The high cost of healthcare makes it difficult for people in least developed nations to access it. Since countries have limited resources for healthcare, efficient use of those resources is essential to ensuring that people have access to quality, reasonably priced healthcare (El Husseiny, 2023).

Policymakers have been worried about the performance of health systems in recent decades. Many countries have changed their health systems because of subpar operation. However, enhancing the scope of healthcare services necessitates a thorough evaluation of the effectiveness and efficiency of the health systems. Health care systems that are efficient guarantee that resources are being used to optimise health outcomes. They also boost taxpayers' confidence by providing assurance that their financial contributions are being used to meet their medical needs in the most appropriate manner. Enhancements in efficiency will also result in cost savings and make it easier to expand health care services, provide more services and cover more people (Cylus, Papanicolas, Smith, & Organization, 2016). Serious issues that could impair social cohesion, the process of producing the health system, and the overall social surplus are brought on by the inefficient use of resources in the health

system. Better use of the hospital's resources will therefore make it possible to serve more patients and allow for the redistribution of available resources to guarantee improvements in accessibility, equity, and health outcomes as well as the provision of long-lasting, high-quality care (Al Subhi, 2022).

Healthcare systems are estimated by the World Health Organization (WHO) to be underusing between 20 and 40 percent of the resources that are spent on healthcare (World Health Organization, 2010). While rates vary by nation, certain nations can offer better value for their money than others, as evidenced by greater coverage levels and improved health outcomes. The main causes of inefficiencies in the health care system are inadequate procurement, ineffective management and allocation of human and technical resources, disjointed funding and organisation, inadequate governance, and inappropriate medication use (World Health Organization, 2010; Zhou et al., 2020).

The Southern African Development Community (SADC) is composed of 16 countries. With 16 member nations, the block is one of the AU's largest regional economic communities. Nonetheless, the main issues that all SADC member states deal with are inadequate funding for public healthcare and typically inadequate access to healthcare. Considering this alarming situation, governments in the SADC area have pledged to enhance the health and welfare of their constituents by supporting international programs like the United Nations Sustainable Development Goals (SDGs) and the 2001 Abuja Declaration. The Abuja declaration requires all signatory nations to prioritise investing in public health care. The rising realisation that the health of the continent's population is a key factor in determining its political, economic, and human progress led to the accord. The declaration includes a legally enforceable commitment to devote at least 15 percent of a nation's yearly budget to enhancing the health sector. Most of the countries have not been able to meet this commitment due to limited fiscal space.

Due to a lack of funding and personnel, the SADC area faces significant obstacles in delivering health services. As a result, access to quality, reasonably priced healthcare is frequently inadequate, especially in public and rural settings. Many factors, including living conditions, the burden of sickness, financial hurdles to accessing healthcare services, and the frequently severe financial implications of healthcare events, compound these issues for the low-income population (Ranchod et al., 2016). African nations allocate a sizeable portion of their Gross Domestic Product (GDP) to the provision of health care via opaque, costly, and inefficient systems (Mlambo, Sibanda, Ntshangase, & Mvuyana, 2022). The SADC region has the worst health system in the world, and diseases like malaria, Tuberculosis (TB), Human Immunodeficiency Virus (HIV), and other conditions that are easily treatable kill both adults and children. The discussion above demonstrates how the healthcare systems in the SADC countries are still lagging those in other areas (Achoki et al., 2022). This study uses the data envelopment analysis and Tobit panel data regression approach to analyse the technical efficiency and its determinants in the health systems among SADC countries.

2. Literature Review

There has been a proliferation of studies on health system efficiency since the COVID pandemic (Gavurova, Kocisova, & Sopko, 2021; Ibrahim, 2023; Lupu & Tiganasu, 2022; Musoke, Yawe, & Sentamu, 2023; Seddighi, Nosrati Nejad, & Basakha, 2020). The current review looks at studies on technical efficiency that were carried out at regional level. Ibrahim (2023) investigated the effectiveness and productivity of maternity and newborn healthcare services in Sub-Saharan African (SSA) nations. Efficiency was assessed using data envelopment analysis, and productivity was assessed using Malmquist-Luenberger's (ML) productivity estimation. The findings point to inefficiencies in the SSA's newborn and maternal healthcare programs. The estimated average efficiency is 85%. Musoke et al. (2023) evaluated the factors that determine the technical efficacy of health systems in the least developed countries (LDCs) of Africa. The study evaluated the technical efficacy of health systems using the panel Tobit model and two-stage data envelopment analysis approach. The study established that there was positive relationship between efficiency and gross domestic product. The research also established that efficiency was negatively related to HIV prevalence, external health expenditure and political stability.

Allel et al. (2022) determined the technical efficiency of 78 nations in providing acquired immune deficiency syndrome (AIDS) services between 2010 and 2018 using data envelopment analysis (DEA) and a truncated regression analysis. They employed national HIV/AIDS spending as the DEA input and antiretroviral therapy (ART) and prevention of mother to child transmission (PMTCT) as the outputs. Between 2010 and 2018, the technical efficiency average was 66.9 percent. This indicated that for the same amount of money, 33.1 percent more outputs could have been produced in comparison to what was being produced. The study further established that the human development index, the rule of law, the prevalence of HIV, out-of-pocket expenses, and the gross national income all had a significant correlation with efficiency scores. Lupu and Tiganasu (2022) used Data Envelopment Analysis (DEA) and Tobit regression analysis to examine how well the health systems of 31 European nations treated COVID-19. The study's inputs included hospital beds, doctors, nurses, and health expenses. The outputs for the study were the number of COVID-19 deaths. The findings demonstrate that the health systems' level of inefficiency was relatively high. The Tobit regression results show that comorbidities, population density, and age of the population were significant determinants of efficiency during the first wave of the pandemic. Government effectiveness and power distance had a major impact on the relaxation period while population density and education were significant during the second wave.

The efficiency of Organisation for Economic Co-operation and Development (OECD) health systems was modeled by Gavurova et al. (2021) employing the Dynamic Network Data Envelopment Analysis (DNDEA). The study established that the overall average efficiency of health systems during the period was 0.8693 using input-oriented model with constant returns to scale. The efficiency of the OECD countries improved over time.

The effectiveness of the health systems in the eastern Mediterranean region was evaluated by Seddighi et al. (2020). The study used input-oriented data envelopment analysis techniques to determine efficiency ratings. The findings indicated that the factors influencing efficiency were life expectancy and the newborn survival rate. Top, Konca, and Sapaz (2020) examined the effectiveness of healthcare systems across several African countries, comparing the degrees of efficiency across different countries using the data envelopment analysis method. The findings showed that 21 of Africa's 36 healthcare systems were efficient. The results of the study demonstrated a statistically significant relationship between the efficiency of national healthcare systems and both economic disparity and the supply of nurses.

The above studies have applied the data envelopment analysis to assess the technical efficiency (Ibrahim, 2023; Lupu & Tiganasu, 2022). Most of these studies used life expectancy at birth, maternal mortality ratio, under-five mortality rate, and infant mortality rate as the outputs (Musoke et al., 2023; Seddighi et al., 2020; Top et al., 2020). The inputs that have been used include the number of doctors, nurses, and hospital beds per 1000 people, The number of healthcare facilities, public and private county health expenditures (Barasa et al., 2021; Lupu & Tiganasu, 2022; Top et al., 2020). These studies established that efficiency was determined among other factors by the Gini coefficient and the number of nurses per 1000 persons, Human Development Index, the rule of law, the prevalence of HIV, out-of-pocket expenses, and the gross national income (Ibrahim, 2023; Lupu & Tiganasu, 2022; Seddighi et al., 2020).

The results reveal that the concept of technical efficiency has not been comprehensively studied given the contradicting results of the levels of efficiency, determinants and the contexts of the studies. This study hence seeks to cover the gap using the SADC region as the case study.

3. Methodology

The research used a two-step approach to fulfill the study objectives. Firstly, the study uses the data envelopment analysis (DEA) technique to evaluate the health technical efficiency for each country. The efficiency scores are estimated using the linear programming techniques.

The flexibility of the DEA method to handle a variety of inputs and outputs led to its selection, the method can also account for the problem of returns to scale, and it is the method of choice for determining efficiency with small sample sizes (averages (Kirigia, 2013)).

The technical efficiency, represented by the ratio of the weighted sum of outputs to the weighted sum of inputs, can be computed using the mathematical programming technique. The Decision Making Unit(DMU) performance variances are the focus of the DEA approach. The efficient frontier serves as the standard by which the relative performance of various firms is evaluated when utilising the DEA. Every DMU should be able to function at the highest possible level of efficiency, which is established by the most efficient DMU in the sample, given a specific sample of firms.

The efficiency frontier is established by these productive DMU, which are commonly referred to as "peer firms." The DMU that makes up the efficient frontier uses the fewest possible inputs to generate an equal number of outputs. Efficiency is quantified by the distance to the efficiency frontier.

3.1. Output-Oriented Model

The study adopted the output-oriented DEA model. The objective of the output-oriented model is maximising output at the same level of inputs. The study follows prior studies (Ahmed et al., 2019; Tigga & Mishra, 2015). The score for country j_0, which is the reciprocal of the inefficiency, θ is obtained by solving the linear programming problem.

$$\max \quad \theta$$

Subject to

$$\sum_{j=1}^{n} \gamma_j x_{ij} \leq x_{ij_o} \; \forall_i = 1,2$$

$$\sum_{j=1}^{n} \gamma_j y_{rj} \geq \theta_{rj_o} \; \forall_r = 1,2$$

$$\sum \gamma_j = 1$$

$$\gamma \geq 0; j = 1,2, \dots, \dots, j$$

Presented with notations, state j uses x_{ij} inputs and y_{rj} outputs. Let x_{ij} = input i for country j, where i = 1, 2 and j = 1, 2, 3, …,n and y_{rj} = level of output r for state j, where r = 1, 2 and j = 1, 2, 3, …, n.

The efficiency scores ranges from zero to one. A score of one shows the most efficient system while zero indicates the least efficient. Country efficient scores are computed in comparison to the most efficient among the group. Once the efficient country is determined all other scores are then ranked in comparison to that country.

Table 1 presents the inputs and outputs used to compute the efficiency scores.

Table 1. Input and outputs for DEA.

Variable	Definition and justification
External health expenditure per capita	External health expenditure per capita (EHE) expressed in US dollars. All funding entering the national health system from outside the country is referred to as external sources. This includes direct foreign transfers as well as those channelled through the government.
Out of pocket health expenditure	Out-of-pocket health expenditure per individual (OPE) measured in US dollars refers to the money that each person pays out-of-pocket for healthcare, expressed in US dollars. Any direct payment made by households to healthcare providers, suppliers of drugs, medical equipment, and other goods and services whose primary objective is to enhance or restore an individual's or a population's health status—including gratuities and in-kind payments—is regarded as an out-of-pocket expense.
Public health expenditure	The level of general government health expenditure expressed as a percentage of total population is known as public health expenditure per capita, or PHE (US dollars). This statistic is related to the resources that government agencies collect and aggregate, which includes all types of revenue.
Outputs	
Maternal mortality rate	The number of maternal deaths in a certain period of time divided by the number of live births during that same period is known as the maternal mortality ratio. It basically captures the risk of dying in a single pregnancy or giving birth to a single live child and shows the risk of maternal death in relation to the number of live births.
Life expectancy at birth	The life expectancy at birth represents the number of years that a newborn would live if the mortality rates that were in place at the time of the infant's birth remained constant.
Under 5 mortality	The likelihood that a kid born in a certain year or period will pass away before turning five, assuming that era's age-specific mortality rates apply.

To establish the determinants of efficiency, the study uses the Tobit regression method. The method is appropriate because the efficiency scores are censored since they range between zero and one. The OLS is not appropriate since it assumes a normal and homoscedastic distribution of the disturbance and the dependent variable, estimating the regression using this method results in biased parameter estimates (Maddala, 1983).

The Tobit regression model is specified as below:

$$EFF = \beta_0 + \beta_1 GDPP_{it} + \beta_2 OXIDE_{it} + \beta_3 PRI_{it} + \beta_4 VUL_{it} + \beta_5 NOB_{it} + \beta_6 NOD_{it} + \beta_7 NON_{it} \quad (3)$$

Where:

A basic indication of the value of output per person, GDP per capita (GDPP) is an indirect measure of per capita income. One can consider GDP growth and GDP per capita growth to be broad measures of economic expansion. It is anticipated that as GDPP advances, the health system's technological efficiency would rise as well. Workers who are considered vulnerable (VUL) are individuals who, because of their work type, lack of expertise, hesitation to ask questions, and communication hurdles, are more likely than most to be hurt or ill. These vulnerable people are more likely to make the health system less technically efficient. The Primary Completion Rate (PRI) measures the number of pupils who successfully complete their final year of primary school, or graduate from it, each year, divided by the total number of children in the population who are officially of graduation age. The technical efficiency increases with the completion rate. Most of the SADC countries are agricultural dependent which uses Agricultural nitrogenous oxide emissions (OXIDE). This then causes the stratospheric ozone layer to be destroyed, they increase UV radiation, which in turn increases the risk of skin cancer. This has an indirect health effect. This then strains a country's health and affects its technical efficiency.

Number of hospital beds per 1000 (NOB) measures the resources hospitals have at their disposal to offer care to inpatients by counting the number of beds that are staffed, maintained, and ready for use right away per 1000 population. This then enhances the health outcomes and efficiency as the number of beds increases. Number of doctors per 1000 (NOD) show the number practising doctors providing direct care to patients per 1000 population. The greater the number of the practicing doctors improves the health outcomes which translates to improved efficiency. Number of nurses per 1000 (NON) measures the practising nurses providing direct health

services to patients, including self-employed nurses. The greater the number of nurses the more efficient the health delivery system.

3.2. Data Sources

The study utilises the country level data sets on health and macroeconomic variables of the 16 SADC countries. The data for the study was obtained from the World Bank, WHO database and International Monetary fund. The period of the study is 2010-2020. The period was based on the availability of the data.

3.3. Presentation of Results

This section presents the results of the study. The movements in regional health efficiency are displayed in Figure 1. The region's average health efficiency stands at 78.4 percent. This indicates SADC that countries are experiencing a 22 percent degree of resource waste in health system. The obtained results mean that given the current resources the countries could have produced 21.6 percent more outputs. The study confirms that the current health status in the SADC region has the potential to improve using the current level of resources by simply replicating what the most efficient countries in the region are doing.

The results of the study show that the overall maximum efficient score was 85 percent recorded in 2020 and the lowest was recorded in 2013 being 68 percent. Overall, the efficient scores improved during the period showing that SADC countries have been improving resource use over the years from 75 percent in 2010 to 85 percent in 2020 (Figure 1).

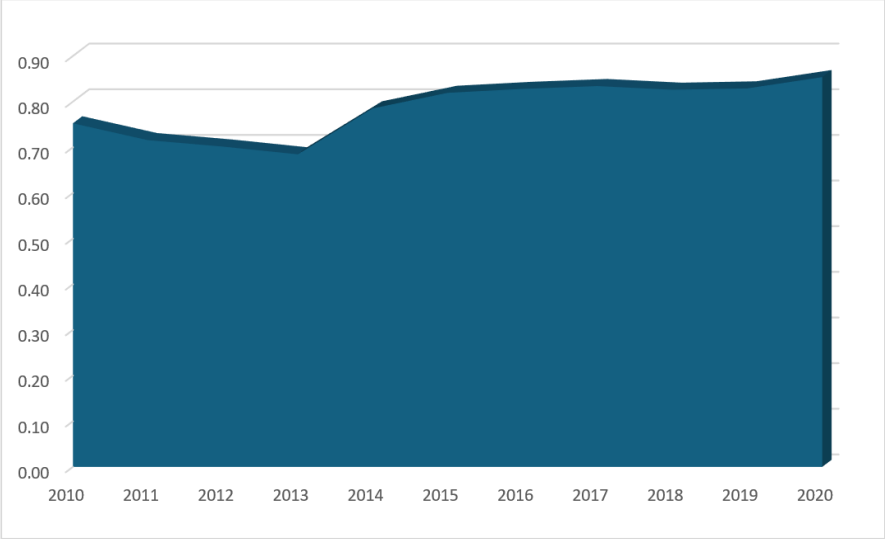

Figure 1. Overall average efficiency scores.

There are several nations in the region with effective health systems despite the inefficiencies already mentioned. Figure 2 show that Angola, Botswana, Eswatini, Mauritius, Mozambique, and Malawi had the most efficient health systems. These countries had an efficient score of one implying there is no resource wastage within these countries.

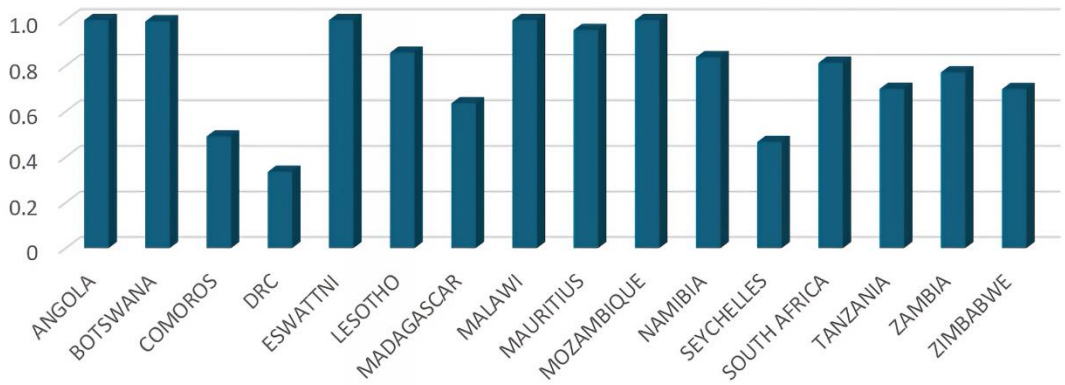

Figure 2. Average country efficiency scores.

The least efficient countries are DRC with a score of 30 percent, Comoros 50 percent, Seychelles 50 percent, and Madagascar 60 percent. These results imply that they could be able to perform significantly better and

generate greater results as compared to the efficient countries. These countries are depressing the regional average. To cut down on resource waste and enhance health outcomes, these nations must reconsider their procedures and take cues from the most productive nations.

The descriptive statistics for all the independent variables used for the regression analysis are presented in Table 2.

Table 2. Descriptive statistics of independent variables.

Statistic	GDPP	OXIDE	PRIM	VUL	NOD	NOB	NON
Mean	3674.60	6975.66	75.44	51.71	2.95	16.58	19.51
Median	1489.90	4673.92	79.82	59.30	1.60	16.50	9.35
Maximum	16851.10	22735.49	111.26	88.51	23.28	39.00	92.24
Minimum	324.80	2.6820	0.000	0.00	0.100	2.00	2.40
Observations	176	176	176	176	176	176	176

The descriptive statistics show the gross domestic product per capita (GDPP) ranges between US$325 and $16851 per capita within the SADC region reflecting the greater divergence between the countries. The average per capita GDP stands at US$3674. The mean number of doctors (NOD) and nurses are 2.95 and 19.51 per 1000 population which is low given the population of the whole SADC region. This explains the non-availability of doctors in some areas in the SADC region where patients must travel long distances to access doctors. The average number of beds per 1000 (NOB) stood at 16.58 per 1000 population. This variable ranges between 2 beds per 1000 to 39 beds per 1000 which shows some of the countries are worse than others in terms of providing for the sick. The number of pupils who successfully complete their final year of primary school each year, divided by the total number of children in the population who are officially graduation age, is known as the Primary Completion Rate, or PRIM. This ratio stands at the average of 75 percent. Enrolment of 75 percent in primary education plays a crucial role in shaping basic literacy levels, which in turn is likely to improve health uptake. The average vulnerable employment (VUL) stands at 52 percent of the total workforce. This implies that most of the workers are high risk employees given that they have greater exposure to injury and illness due to their lack of experience, reluctance to ask questions, communication barriers and type of work. The intensity of the agricultural practice in SADC is reflected using nitrous oxide (OXIDE) fertilisers to boost yields. The average nitrous oxide emission is 6975.66 showing the intensity of the emissions to the environment which directly impacts the populace.

Table 3. Tobit regression results.

Variable	Coefficient
GDPP	0.000355***
	(0.0011)
OXIDE	-0.000285
	(0.5379)
PRIM	0.003390***
	(0.0002)
VUL	-0.005641***
	(0.0000)
NOD	0.060173***
	(0.0000)
NOB	0.006510*
	(0.0937)
NON	0.007233***
	(0.0065)
Mean dependent variable	0.7880
Standard error pf regression	0.2835
Akaike information criterion	0.3699
Schwartz criterion	0.5243
Hannan- Quinn criterion	0.4326

Note: ***, **, * presents significance at 1%, 5% and 10% respectively.

The results as shown in Table 3 shows that the technical efficiency is positively impacted by gross domestic product per capita. Increases in GDPP that are proportionate to income increases provide the public more disposable money, which enables them to pay for health care. Increased income also enables economies to achieve better health outcomes, which leads to increased efficiency. This is corroborated by Kaya and Cafrı (2016) who discovered that across OECD nations, affluence significantly impacted the technical efficiency of the health system.

The study has established that that there is a positive relationship between primary school completion rate and technical efficiency. This means that the greater the number of people within the population who complete primary school, the greater the technical efficiency of the health system. Completion of the primary schooling entails people had acquired a certain level of literacy which can assist them to use the health facilities and understand some of the basic health issues.

The results show that the number of nurses is positively related to the technical efficiency. The increase in the number of nurses entails that the greater the number of nurses the more efficient the health system becomes. Nurses as the members of the patient care team who frequently have the closest patient interactions are essential in providing care, educating patients, standing up for the weak, and organising treatment. The results tallies with Top et al. (2020) who established that number of nurses had significant effect on health system efficiency.

The number of beds per 1000 has a positive effect on the technical efficiency of the health system. As the number of beds increase in the hospital, the efficiency of the health delivery system also improves. Hospital beds has an immediate impact on patient care, resource allocation, and overall hospital efficiency. Hospital bed usage is a crucial component of healthcare administration and is influenced by several variables, including different viewpoints and causes. The result corresponds to Ahmed et al. (2019) who established that the density of number of beds has positive association with technical efficiency.

The number of doctors have a positive effect on the technical efficiency of the health system of a country according to the results. Doctors play a critical role in the health care system hence improves the efficiency of the system. They aid patients and their families in navigating difficult medical circumstances by offering them comfort, support, and direction. To guarantee a complete approach to treatment, they work in conjunction with other experts, nurses, pharmacists, medical scientists and therapists.

The average vulnerable employment has a negative effect on the technical efficiency of the health system. As the number of vulnerable people increases, it dwindles the efficiency of the health care system given the fact that the vulnerable employees are at high risk with greater exposure to injury and illness due to their lack of experience, reluctance to ask questions, communication barriers and type of work. This then tends to put a strain on the health care system.

The study has established that the technical efficiency of the healthcare system is negatively impacted by the usage of nitrous oxide. This results from the fact that most of the SADC nations rely heavily on agriculture and increase crop yields by using fertilizers based on nitrogen. Among other adverse effects, they may result in transient disorientation, dissociation, dizziness, loss of balance, memory and cognitive impairment, and limb weakness. When intoxicated, accidents such as stumbling and falling might occur.

4. Conclusion

Efficient utilisation of resources is a fundamental concern for every country and institution. The scarcity of resources has been taunted as a major challenge towards achieving universal health coverage. This has forced countries to devise mechanisms of employing resources efficiently to free up scarce resources. The study investigated the technical efficiency of health care system in the SADC region. The study established average efficiency score of 78.4 percent. The results show that SADC countries are experiencing resources inefficiencies in their health systems. This indicates that the region could have done better with the resources that they have if they conformed to use resources like the most efficient countries, Angola, Botswana, Eswatini, Mauritius, Mozambique, and Malawi. The efficiency of the health system is positively influenced by number of practitioners i.e. doctors and nurses, primary school completion rates, and national income. The factors that negatively affects technical efficiency are usage of nitrous oxide and vulnerable employment. The policy implication of the study is that countries should continue investing in health care and education to increase the number of nurses, doctors and other health personnel. Countries are also supposed to institute pro-growth policies so that income increases which will also increase resources available for health-related acquisitions and investment.

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