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Research Article

THE TECHNICAL EFFICIENCY OF AFRICAN COUNTRIES: A DEA METHODOLOGY

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The primary objective of this study is to investigate the economic efficiency performance of African nations. Economic efficiency plays a crucial role in the economic growth of nations. By employing resources in a more efficient manner, nations are able to produce more output with the same or less inputs, which contributes to more sustainable economic growth. In assessing the economic efficiency of Africa nations, this study first employed Data Envelopment Analysis methodology in order to estimate the technical efficiency, scale efficiency and pure technical efficiency of the aforementioned countries for the period 1990 to 2023. The empirical results revealed that, with regard to the African context, there is scope for African countries to improve their efficiency by adopting new and innovative technology to produce more output more efficiently in their respective economies. Second, this study estimated the Malmquist Productivity Indexes, efficiency changes, and technology changes for a select list of African countries in order to assess the productivity changes of the aforementioned countries. Empirical results revealed, on average, a slight increase in productivity for African countries during the period 1990 to 2023. Lastly, this study evaluated the rate of efficiency convergence in a list of selected African countries during the period 1990 to 2023. The empirical results revealed that inefficient African countries were able to catch up with more efficient countries during the period assessed.

Keywords: Data Envelopment Analysis; Productivity; Factor Productivity; Efficiency; Technological Change; Africa

JEL Classification codes: O00, O11, O47

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1. INTRODUCTION

The primary objective of this study is to assess the economic efficiency performance of African countries. Economic efficiency refers to elements of both allocative efficiency and technical efficiency. Allocative efficiency is related to the ability to combine both inputs and outputs in optimal proportions. However, technical efficiency refers to the ability not to waste by producing as much output as possible using the available technology and inputs or by using as little inputs as required by available technology and output production.

Economic efficiency plays a crucial role in the economic growth of nations. By employing resources in a more efficient manner, nations are able to produce more output with the same or less inputs, which contributes to more sustainable economic growth. Therefore, measuring the efficiency performance of a nation is important in the pursuit of sustainable economic growth. Sustainable economic growth can be understood as economic development that meets the needs of the current generation without harming the ability of future generations to meet their own needs. Among others, sustainable economic growth places an emphasis on efficient resource use and minimizing wastage (Armeanu et al., 2018).

A vast majority of African countries still have the status of being underdeveloped or still developing even after many years of achieving independence (Itumo, 2017). African countries are faced with political, economic and socioeconomic challenges. Africa's main challenges relate to mass poverty, unsustainable population growth rates, the inability to feed its people, mass unemployment, and the lack of domestic savings. Further, on average, African countries suffer from rapidly increasing populations and a shortage of resources. Given this, it becomes imperative for African countries to use their limited available resources in a more efficient manner. Classical growth theory postulates that even when faced with limited resources, countries can achieve growth by increasing technical efficiency (Amare et al, 2025). Effective resource usage is understood as critical in attaining sustainable economic growth for African countries.

Amare et al. (2025) finds that Africa's real GDP growth rate on average has declined from 4.1% in 2022 to 3.1% in 2023. The contributing factors to this decline are listed as being: (i) weakened global demand which has impacted export performance; (ii) a change in climate variables which affect agricultural productivity; and (iii) political unrest and conflict. Therefore, given that technical efficiency relates to a nation's ability to achieve more output from a given set of inputs or to utilize the fewest inputs necessary to achieve a given level of output, the study of the technical efficiency of African nations is crucial for the achievement of sustainable economic growth and development given the challenges of limited resources faced by a majority of African countries.

To this end, one method of measuring and evaluating a nation's efficiency performance is by investigating whether a nation is employing its resources in an efficient manner. This can be achieved by assessing whether a nation uses its available minimum inputs, such as labour, physical capital and land to achieve maximum outputs such as gross domestic product and/or income per capita (Wu et al., 2014). One approach that can be used to measure the efficiency performance of nations is through employing the Data Envelopment Analysis model. This approach measures economic efficiency by employing a nonparametric frontier by considering the maximal or frontier output that can be produced by each amount of input (Fried & Schmidt, 2008).

In assessing the efficiency performance of African countries, this study first assessed the efficiency and scale economies of African countries using the Data Envelopment Analysis model. Second, this study estimated the Malmquist indexes, efficiency changes, and technology changes for a select list of African countries in order to examine the productivity changes of the aforementioned countries. Lastly, the study assessed the rate of efficiency convergence in the aforementioned countries using the growth concepts proposed by Barro & Sala-I-Martin (1991).

The rest of this study is organised as follows: Section 1 provides an introduction to the study and its objective. Section 2 presents the existing literature. Section 3 details the empirical strategy chosen. Section 4 discusses the empirical findings of the study. Finally, Section 5 concludes the study.

2. LITERATURE REVIEW

Over the years, a number of studies have evaluated the efficiency performance of countries and/or specific sectors within countries. These studies measured efficiencies in various economic sectors, territorial areas and economic cooperation areas. However, in the African context, there have been limited studies that have assessed the efficiency performance of African countries which reveals an empirical gap. According to Amare et al. (2025) existing studies that have assessed the efficiency performance of African countries have focussed on specific sectors such as manufacturing, agriculture and financial institutions. Further, the existing literature focuses largely on other territorial areas such as Asia, Europe and Latin America with limited research focus on the African context.

On study that focused on the Asian perspective is the work of Wu (1995) which assessed the growth of the total factor productivity, technological progress, and the change in technical efficiency in post-reform China. The author estimated production functions for three sectors, that being, the state industry, rural industry and agriculture using panel data from 1985 to 1991. The empirical results revealed that the production in all three sectors approached approximately 50-60% of best practice output, suggesting that there was scope for improvement. The author also found that technological progress dominated the change in technical efficiency as the main source of total factor productivity growth in all three sectors of the Chinese economy.

Another study that assessed efficiency from the Asian perspective is the work of Kim & Park (2006) which aimed to determine the dominant factor in Korean productivity growth and also assess why there were differences among other empirical studies. Additionally, the authors aimed to determine the effect of domestic and foreign research-and-development ("R&D") stocks on productivity using R&D spillover models. To do so, the authors constructed an industry data set for Korean manufacturing from various sources and estimated the Malmquist Productivity Index and its two components. The empirical results revealed that the productivity gains in Korean manufacturing during the years 1970 to 1996 were mainly due to efficiency improvements rather than technical progress.

Further, Chang & Hu (2010) employed a total factor energy productivity change index to evaluate the energy productivity change of regions in China. The authors decomposed the total factor energy productivity change index in changes into energy efficiency and a change in the energy use of technology. The empirical results revealed that China's energy productivity was decreasing by approximately 1.4% per year between 2000 to 2004. Furthermore, the empirical results revealed that the average energy efficiency improved by approximately 0.6% per year, while the technical change declined progressively by approximately 2% per year.

One study that assessed the European perspective is the work of Jurickova et al. (2019) which measured the technical efficiency of the National Innovation System across a sample of European Union countries using a Data Envelopment Analysis methodology. The authors employed an output-orientated constant returns-to-scale model in order to estimate the efficiency of the units represented by European Union nations for the period 2005 to 2016. The empirical results revealed that the only efficient countries were Cyprus, Luxembourg, Malta, and Romania. Furthermore, the empirical results revealed that the number of efficient nations decreased from six (6) nations in 2005 from among the eight (8) estimated in the years of the economic crisis to four (4) in 2015.

Another European study is the work of Radovanov et al. (2020) which attempted to find an adequate inclusion of sustainable factors in tourism development efficiency results by detection and the estimation of potential sources of efficiency. The authors conducted an efficiency benchmarking of tourism services on the level of countries as destinations using data collected from twenty-seven (27) European Union countries and five (5) Western Balkan countries over the years 2011 to 2017. The authors employed an output-oriented Data Envelopment Analysis methodology in order to estimate the efficiency scores for each nation and a panel data Tobit regression model in order to determine the significance of each individual tourism development indicator. The empirical results revealed relatively high efficiency scores for fifteen (15) European Union nations and room for improvement for other nations. The empirical results revealed positive and significant effects on the relative efficiency of tourism.

Further, Silva et al. (2022) aimed to investigate whether and to what extent socioeconomic conditions influenced eighteen (18) European countries grouped into subregions, that being, North, South, East and West during the years 2008 to 2018. To do so, the authors employed a two-stage Data Envelopment Analysis model. The empirical results revealed technical efficiency scores that indicated inefficiency in Northern Europe for Finland, Ireland, and Sweden whereas Belgium, Germany, France, and Luxembourg were deemed to be inefficient nations in Western Europe. Lastly, Spain and Italy were considered inefficient countries in southern Europe.

In regard to Latin America, Mata et al. (2024) examined the energy efficiency of eighteen (18) middle-income Latin American countries for the years 2008 to 2019 using two super-efficient Data Envelopment Analysis radial models. To do so, the authors obtained the production function, technical efficiency, total energy efficiency factor, and their respective correlation versus the per capita income of each country. The empirical results revealed that Costa Rica and Argentina had the highest energy efficiency within Q1 and Q2, whereas Paraguay and Chile obtained the lowest energy efficiency within Q5 and Q3. In addition, the empirical results revealed that for the eighteen (18) countries, a higher level of income was not significantly related to a higher level of energy efficiency.

In terms of the African perspective, Amare et al. (2025) examined the technical efficiency of African economic growth and its determinants for forty-seven (47) African countries for the period 2005 to 2025. To do so, the authors used the Cobb-Douglas functional form and a time-varying stochastic panel frontier model. The authors applied the generalized true fixed effects model and found that African countries had a mean of overall, transient and persistent technical efficiency scores of 90.4%, 91.15% and 99.18% respectively.

Other studies assessed and compared the efficiency scores of nations within economic cooperation areas. One such study is the work of Fare et al. (1994) in which the authors assessed the productivity growth of 17 Organisation for Economic Cooperation and Development (“OECD”) countries over the years 1979 to 1988. To do so, the authors employed a nonparametric programming methodology in order to estimate Malmquist productivity indexes. In addition, the authors decomposed the Malmquist productivity indexes into two component measures, that is, technical change and efficiency change. Empirical results revealed that the productivity growth in the United States of America was slightly higher than the average, which was a result of technical change. Furthermore, the authors found that Japan's productivity growth was the highest in the sample period.

Similarly, Prieto & Zofio (2007) employed a network efficiency analysis within an input and output model to assess the potential technical efficiency gains through comparing technologies corresponding to different economies within OECD countries. The authors introduced a number of models that allowed them to estimate the potential demand increases coming from domestic, free-trade, and technical efficiency gains. The empirical results revealed that efficiency gains were a result of the better use of national endowments of capital and labour, as well as efficiency gains that are a result of the employment of best-practice technologies.

Wu et al. (2014) employed four different Data Envelopment Analysis models in order to evaluate the performance efficiency of 21 OECD countries as well as determine whether the undesirable outputs were over produced relative to desirable outputs. The empirical results revealed that knowledge capital could improve the efficiency scores of a nation. Furthermore, the empirical results revealed that endogenous growth theory was supported in the OECD countries.

One study that focused on OECD countries as well as the Asian perspective is Guo et al. (2017) which employed a dynamic Data Envelopment Analysis model in order to assess inter-temporal efficiency for executive efficiency based on fossil-fuel CO2 emissions in OECD countries and China. In addition, the authors investigated output and input inefficiency indicators to determine the potential sources of operational inefficiency. Empirical results revealed average overall efficiency scores for the years 2000 to 2010. The empirical results also found that the sample countries should increase the number of energy stocks to improve their efficiencies.

Furthermore, Campoli et al. (2024) investigated the performance of G20 nations with respect to efficiency and productivity as a result of the seventh Sustainable Development Goal of providing affordable and clean energy between 2010 and 2019. To do so, the authors employed an output-orientated data envelope analysis methodology in order to estimate efficiency and the Malmquist Productivity Index to measure productivity. The empirical results revealed that the efficiency and productivity of developed and emerging nations towards the seventh Sustainable Development Goal targets were heterogeneous throughout the analysis. The empirical results revealed that among the G20 countries that ranked as efficient were emerging countries such as South Africa, Brazil, India, and China.

Overall, there is limited efficiency studies that focus on the African context, and more specifically, the efficiency performance of African countries in relation to maximizing output given their inputs. As a result, this study aims at contributing to the existing literature which will aid African countries by offering a point of reference in terms of effective resource use.

3. EMPIRICAL STRATEGY

Estimating efficiency scores

The primary objective of this study is to investigate the efficiency performance of African countries. Due to data limitations, the selected African countries included in the study were Algeria, Benin, Botswana, Burkina Faso, Cameroon, Comoros, the Republic of Congo, Egypt, Gabon, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, and Uganda. This study employed the methodology advocated by Farrel (1957) and Charnes et al. (1978) in estimating country-level efficiency scores. Farrel (1957) and Charnes et al. (1978) proposed the use of a technique called Data Envelopment Analysis ("DEA"). The DEA approach is a linear programming technique used to estimate efficiency scores for each decision-making unit relative to the best-practice decision-making units on the frontier. The DEA technique can take the form of being an input-orientated model or an output-orientated model. For an input-orientated model, the efficiency measure is referred to as the maximum radial reduction of all inputs, which is feasible given the existing technology and output (Fried et al., 2008). In the output-orientated model, the efficiency measure is referred to as the maximum radial expansion in outputs which are feasible given the existing technology and inputs (Fried et al., 2008). However, assuming constant scale returns, the estimated efficiency scores will not differ whether an input-or-output orientated model is employed (Hugenin, 2012).

This study employed an output-oriented model whereby it assessed the maximum output in terms of gross domestic product ("GDP") that is feasible to African countries given the existing technology and inputs. When deciding on whether to employ either an input-oriented or an output-oriented approach, consideration is given to the specific context and priorities. An input-oriented approach is more suitable if the priority is to reduce resource consumption while also maintaining current output. An output-oriented approach is more suitable if the priority is increasing output without necessarily increasing the available inputs (Hugenin, 2012). Given the existing challenges of African countries, i.e., declining GDP growth rates on average, rapidly increasing populations and a shortage of resources, the priority for Africa countries is the achievement of sustainable economic growth using the available limited inputs. Therefore, this study employed the output-oriented model.

To this end, this study considered "n" number of countries with "m" number of different outputs "y" produced from "k" number of different inputs "x". The study employed a country specific output-oriented technical efficiency, assuming constant returns to scale modelled into linear programming which was solved "n" for each country in the sample as illustrated below:

$$\hat{\theta}_i = \max\left\{\theta_i > 0 | \hat{\theta}_i y_i \leq \sum_{i=1}^{n} y_i\lambda;\ x_i \geq \sum_{i=1}^{n} x_i\lambda;\ \lambda \geq 0\right\},\quad i = 1, \dots, n \tag{1}$$

Whereby y_i and x_i represent vectors of output and inputs respectively, λ represents a non-negative vector of constants which specifies the optimal weights of inputs and outputs. $\hat{\theta}_i$ represents the efficiency score for the ith country. To this end, technically efficient ("TE") countries are believed to have $\hat{\theta}_i = 1$ while those with efficiency scores $\hat{\theta}_i < 1$ operate below the efficient frontier and are deemed inefficient. Additionally, to estimate scale efficiency, pure technical efficiency ("PTE") under variable scale returns, this study imposed the following constraint: $\sum_{i=1}^{N} \lambda_i = 1$. The aforementioned constraint helps to ensure that countries of similar size are compared to each other in order to generate efficiency scores greater than or equal to the TE scores. In addition, the differences between TE and PTE reflect scale inefficiency. Scale efficiency scores were estimated as illustrated below.

$$SE(x, y) = \frac{TE(x, y)}{PTE(x, y)} \tag{2}$$

Furthermore, for non-increasing returns to scale ('NIRS'), the PTE constraint was adjusted to $\sum_{i=1}^{N} \lambda_i \leq 1$. As a result, of TE, PTE and NIRS, this study used three returns to scale categories for each country. Due to this, the study employed the procedure advocated by Aly et al. (1990) and Cummins and Xie (2013) to reflect the scale economies of countries as follows.

If SE < 1 and PTE ≠ NIRS, a country will be deemed to be operating with increasing returns to scale ("IRS"). However, if SE < 1 and PTE = NIRS, a country will be deemed to operate with decreasing scale returns ("DRS"). IRS symbolises inefficiencies from under-utilisation of resources, whereby DRS symbolises inefficiencies that result from over-use of a country. Furthermore, countries that are found to have SE = 1 are believed to operate with constant scale returns ("CRS"), as this represents the optimal scale of production of a country.

Productivity Changes

In addition to the above, this study employed a similar approach to the works of Malhberg and Url (2003), Luhnen (2009) and Cummins and Xie (2013) in estimating country-specific productivity change. The use of a Malmquist Productivity Index ("MPI") was used to estimate the changes in output that are caused by changes in input over time. In addition, Fare et al. (1991) suggest that the MPI between period t-1, the base technology period, and period t+1, the referenced technology period, can be illustrated by the following equation:

$$MPI(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \quad (3)$$

In addition, under the assumptions of constant returns to scale, output-orientated total productivity changes can be illustrated by the following equation:

$$MPI(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \times \frac{d^t(x^{t+1}, y^{t+1})}{d^{t+1}(x^t, y^t)}\right]^{1/2} \quad (4)$$

Whereby x^t and y^t both illustrate the input and output vectors respectively, $d^t(x^t, y^t)$ illustrates the distance between t and t+1. Consequently, if the MPI value is greater than 1, TFP >1, then it is believed that a positive change in total factor productivity occurred between periods t and t+1. However, if MPI < 1, then it is believed that there was a decrease in productivity between periods. Additionally, the MPI can be decomposed into productivity growth arising from efficiency changes (EFFCH) and (TECHCH), as illustrated below:

$$MPI(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \left[\frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} \times \frac{d^t(x^{t+1}, y^{t+1})}{d^{t+1}(x^t, y^t)}\right]^{1/2} \quad (5)$$

The ratio in the squared brackets measures shifts in frontier technology (TECHCH). To this end, frontier shifts arise from innovation in production techniques. The ratio outside the square brackets is understood to represent (EFFCH), which measures changes in efficiency between the base period t and the reference period t+1, which is termed the catch-up effect.

Estimating Efficiency Convergence

Furthermore, this study employed a methodology similar to the work of Barro and Sala-i-Martin (1991) to measure the rate of efficiency convergence. Convergence in efficiency is the tendency of countries to achieve an equal level of efficiency over time. There are two common forms of convergence, that being, β-convergence and α-convergence. β-convergence is the ability of inefficient countries to catch up with more efficient countries and thus becomes more efficient over time. If it is found that inefficient countries can improve their efficiency levels more rapidly than efficient countries, β-convergence is believed to have occurred. β-convergence is assessed by estimating regressions of initial efficiency levels on the growth rate in efficiency scores. To this end, Casu and Giarandone (2010) proposed the following equation to measure β-convergence :

$$\Delta y_{i,t} = \alpha + \delta \Delta y_{i,t-1} + \beta ln y_{i,t-1} + \varepsilon_{i,t} \qquad (6)$$

Whereby $y_{i,t}$ illustrates the bias corrected efficiency score for country i at time t, $y_{i,t-1}$ is the bias corrected efficiency score for country i at time $t-1$. $\Delta y_{i,t} = ln y_{i,t} - ln y_{i,t-1,}$ β illustrates the coefficient that measures the rate of efficiency convergence. α represents the constant term and finally δ is the coefficient of the lagged dependent variable. A negative value for β indicates convergence of technically inefficient countries while a higher absolute β suggests a faster rate of efficiency convergence. Sala-i-Martin (1996) indicate that evidence of β-convergence is a necessary but not sufficient for α-convergence which is the reduction in the dispersion of efficiency over the period. The model for α-convergence is illustrated as follows:

$$\Delta E_{i,t} = \alpha + \varphi \Delta E_{i,t-1} + \sigma E_{i,t-1} + \varepsilon_{i,t} \qquad (7)$$

Where $E_{i,t} = \ln(y_{i,t}) - \ln(\bar{y}_t)$; $E_{i,t-1} = \ln(y_{i,t-1}) - \ln(\bar{y}_{t-1})$; $y_{i,t}$ and $\Delta E_{i,t} = E_{i,t} - E_{i,t-1}$.

Whereby $y_{i,t-1}$ illustrates the bias corrected efficient score for country i at time $t-1$, $\bar{y}_t$ illustrates the mean efficiency score for the nations in period t. $\bar{y}_{t-1}$ illustrates the mean efficiency score for the nations in period $t-1$. $E_{i,t}$ represents the time-varying error term. α represents the constant term and φ represents the coefficient of the dynamic term. σ captures the rate of convergence from $y_{i,t}$ to $\bar{y}_t$. Furthermore, this study estimated equations 6 and 7 using Ordinary Least Squares ("OLS"), Fixed Effects, and the System Generalised Method of Moments ("GMM") of Arellano and Bover (1995) with forward orthogonal.

Input and Output Variables

According to standard economic theory, the main production factors used by a country to produce output are labour, physical capital, land, and entrepreneurship. As a result of this, the input variables used in this study were labour and capital inputs. These inputs were as follows: (i) as a proxy for labour, this study used the total labour force employed within a country which comprises of individuals aged fifteen (15) and older who supply labour for the production of goods and services during a specified period. This includes individuals who are currently employed and people who are unemployed but are seeking employment. Data extracted from the World Development Indicators Database was used as a proxy for the labour input in this study's labour input; and (ii) as a proxy for capital, this study used the gross fixed capital formation of a nation that includes land improvements, plant machinery and equipment purchases; and the construction of roads and railways and the like. This data was also extracted from the World Development Indicators.

In regard to the output variable, this study used GDP which represents a nation's total value of all the goods and services produced within a country's borders for a specified period. GDP data was extracted from the World Development Indicators database.

4. RESULTS AND DISCUSSION

Table 1 reflects the average efficiency results for a select list of African countries for the period 1990 to 2023. It appears that Comoros, Gabon, Mauritius, and Botswana are the most efficient in terms of technical efficiency, whereas countries such as Tanzania, Madagascar, Uganda, and Niger are ranked the least efficient. In regard to scale efficiency, countries such as Mauritania, Togo, Lesotho, and Namibia are ranked as the most efficient, whereas countries such as South Africa, Egypt, Algeria, and Morocco are ranked as the least efficient. Moreover, in terms of Pure Technical Efficiency, countries such as South Africa, Gabon, Comoros, and Algeria are ranked as the most efficient, whereas countries such as Niger, Madagascar, Burkina Faso, and Rwanda are ranked as the least efficient.

Overall, the empirical results found in Table 1 below reveal lower Pure Technical Efficiency scores than Scale Efficiency scores. This suggests that technical inefficiency is the result of pure technical inefficiency. Pure technical efficiency is the ability of countries to fully employ state-of-the-art technology in attempts to operate on the efficient frontier. Given the empirical results, there is scope for Africa's countries to improve their efficiency scores by adopting new and innovative technologies to produce production within their countries.

DEA Efficiency Scores

Table 1: Average country DEA Efficiency Results for the Period 1990 to 2023

Country Name	Technical Efficiency Measure under CRS	Scale Efficiency	Pure Technical Efficiency
Algeria	0,91387	0,92955	0,98326
Benin	0,90040	0,98935	0,91010
Botswana	0,96414	0,99251	0,97141
Burkina Faso	0,88307	0,98857	0,89340
Cameroon	0,89581	0,96644	0,92695
Comoros	0,98008	0,99425	0,98577
Congo, Rep.	0,91827	0,99500	0,92287
Egypt, Arab Rep.	0,90546	0,92469	0,97928
Gabon	0,97859	0,99225	0,98618
Kenya	0,89233	0,94976	0,93953
Lesotho	0,91292	0,99698	0,91568
Madagascar	0,86997	0,98306	0,88493
Mali	0,88833	0,98604	0,90098
Mauritania	0,93376	0,99892	0,93477
Mauritius	0,96750	0,99600	0,97144
Morocco	0,90423	0,94612	0,95577
Namibia	0,95892	0,99643	0,96235
Niger	0,87529	0,99192	0,88243
Rwanda	0,89311	0,99403	0,89850

Senegal	0,91067	0,98110	0,92822
Sierra Leone	0,92986	0,99608	0,93353
South Africa	0,91474	0,92157	0,99262
Tanzania	0,86387	0,95967	0,90025
Togo	0,90444	0,99823	0,90604
Tunisia	0,92795	0,96366	0,96299
Uganda	0,87411	0,96966	0,90162

Table 2 below reflects the results of the average productivity analysis for a select list of African countries for the period 1990 to 2023. The table shows the Malmquist Total Factor productivity change (MPI), the Efficiency changes (EFFCH), and the Technology changes (TECHCH) for a select list of African countries. On average, there was a slight increase of 0,006%, 0.0008% and 0,0003% of the MPI, EFFCH and TECHCH, respectively, over the sample period. The results reveal, on average, a slight productivity increase in African countries suggesting that at any given level of input over the sample period of 1990 to 2023, African countries on average did maximise their outputs.

Productivity Analysis

Table 2: Average country productivity results for the period 1990 to 2023

Country Name	Malmquist Productivity Index	Efficiency Changes	Technology Changes	Malmquist Productivity Index change (%)	Efficiency Changes (%)	Technology Changes (%)
Algeria	1,000400	0,999900	1,000537	0,01658	0,00816	0,01768
Benin	1,001458	1,000679	1,000785	0,00631	0,00841	-0,00054
Botswana	1,000738	1,000131	1,000674	-0,00766	-0,00274	0,01003
Burkina Faso	0,999403	0,999032	1,000373	-0,00203	0,00059	-0,00228
Cameroon	1,000356	0,999594	1,000768	0,00184	0,00212	0,00081
Comoros	1,000511	0,999857	1,000707	-0,00243	0,00264	0,00769
Congo, Rep.	1,000873	1,000198	1,000663	0,02253	0,01387	0,00712
Egypt, Arab Rep.	0,999615	0,998987	1,000636	-0,03899	-0,03807	0,00066
Gabon	1,001549	1,000889	1,000742	0,04308	0,04896	0,01260
Kenya	1,001035	1,000201	1,000840	-0,00763	-0,00303	-0,00317
Lesotho	1,001514	1,000851	1,000675	0,00430	0,00367	0,00329
Madagascar	1,000800	1,000478	1,000322	0,00474	0,00486	-0,00014

Mali	1,000247	0,999714	1,000537	0,00111	0,00205	0,00013
Mauritania	1,000768	1,000327	1,000541	0,01114	0,03185	0,00719
Mauritius	0,999838	0,999206	1,000703	0,06014	0,06535	0,01030
Morocco	1,000177	0,999570	1,000630	-0,02811	-0,02293	0,00069
Namibia	1,001428	1,000838	1,000645	0,07312	0,07972	0,00800
Niger	1,000785	1,000256	1,000531	-0,06739	-0,06581	-0,00131
Rwanda	1,001088	1,000139	1,000949	0,01501	0,01543	-0,00014
Senegal	1,001186	1,000518	1,000684	0,00573	0,00701	0,00286
Sierra Leone	1,001085	1,000395	1,000693	0,04062	0,04394	-0,00268
South Africa	1,000183	0,999502	1,000698	0,00075	0,00281	0,00219
Tanzania	1,000466	1,000000	1,000466	-0,00322	-0,00229	-0,00080
Togo	1,000188	0,999479	1,000714	0,01393	0,01363	0,00157
Tunisia	0,999837	0,999179	1,000691	-0,01901	-0,01623	0,00486
Uganda	1,000517	0,999757	1,000764	0,00949	0,01079	-0,00064

Table 3 below reflects the efficiency convergence results for a select list of African countries. The results reveal that for all models, for the test of unconditional β-Convergence for both pure technical and technical efficiency, β is negative and statistically significant at 1%. This suggests the existence of unconditional β-Convergence in African countries, implying that inefficient African countries have been able to catch up with more efficient countries during the period evaluated. In regard to σ-convergence in African countries, it appears that σ appears to be positive and statistically significant for both pure technical and technical efficiency for all models. This suggests that there is no evidence of σ-convergence in African countries, as there is no reduction in the variability of efficiency and conversions toward a common level.

Efficiency Convergence

Table 3: Country Efficiency Convergence

	OLS				Fixed effects				GMM			
	PTE		TE		PTE		TE		PTE		TE	
	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z
Unconditional β-Convergence												
Constant	-0.00313***		-0.00172***		-0.0536***		-0.0342***		-0.0274**		-0.0211***	
	(0.000823)		(0.000600)		(0.00177)		(0.00130)		(0.0109)		(0.00745)	
$\delta(\Delta lny_{i,t-1})$	-0.0379		-0.0442		0.0213		0.00168		-0.0264*		-0.0303	
	(0.0329)		(0.0329)		(0.0233)		(0.0248)		(0.0157)		(0.0200)	
$\beta(lny_{i,t-1})$	-0.0335***		-0.0259***		-0.590***		-0.510***		-0.297***		-0.316***	
	(0.00843)		(0.00778)		(0.0193)		(0.0191)		(0.115)		(0.103)	
$m1\ p - value$												
$m2\ p - value$												
R^2	0.021		0.016		0.526		0.459					
	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z

	σ-convergence					
Constant	0.000648*	-0.000618*	0.00373***	-0.00256***	0.00160	-0.00220*
	(0.0329)	(0.000344)	(0.00102)	(0.000848)	(0.00102)	(0.00121)
$\varphi(\Delta E_{i,t-1})$	-0.0680**	-0.0706**	-0.0899***	-0.0913***	-0.0713*	-0.0758*
	(0.0329)	(0.0329)	(0.0332)	(0.0332)	(0.0378)	(0.0435)
$\sigma(E_{i,t-1})$	0.0299***	0.0278***	0.156***	0.112***	0.0842**	0.101***
	(0.00846)	(0.00777)	(0.0398)	(0.0347)	(0.0330)	(0.0364)
$m1\ p-value$						
$m2\ p-value$						
R^2	0.017	0.018	0.024	0.019		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. CONCLUSION

This study assessed the efficiency performance of twenty-six (26) African countries for the period 1990 to 2023. To do so, this study first employed a data envelopment analysis methodology in order to estimate the technical efficiency, scale efficiency and pure technical efficiency of the aforementioned countries for the period 1990 to 2023. Empirical results revealed that in regard to the context of Africa, there is scope for African countries to improve their efficiency by adopting new and innovative technology to produce more output more efficiently in their respective economies. Second, this study estimated the Malmquist Productivity Indexes, efficiency changes, and technology changes of a select list of African countries in order to assess the productivity changes of the aforementioned countries.

The empirical results revealed on average a slight increase in productivity for African countries during the period 1990 to 2023. Lastly, this study evaluated the rate of efficiency convergence in a list of selected African countries during the period 1990 to 2023. Empirical results revealed that inefficient African countries were able to catch up with more efficient countries during the period assessed. Given the empirical findings of this study, African leaders and African policy makers should attempt to create policies that promote and improve economic efficiency. This will ensure that African countries can achieve more sustainable economic growth. Specifically, countries with high technical inefficiencies such as Tanzania, Madagascar, Uganda, and Niger should focus on more efficient resource use in order to improve their technical efficiencies. These countries should learn from their more efficient counterparts such as Comoros, Gabon, Mauritius, and Botswana which have, on average, low technical inefficiencies. This will ensure economic growth without the need to significantly alter the amount inputs being currently used in the production of goods and services. Policymakers in countries with high technical inefficiencies should aim at developing targeted inventions that improve better resource usage in order to achieve better outcomes in terms of economic growth. These interventions could focus on improving productivity through: (i) investing in improving physical capital that could potentially increase productivity and lower the cost of producing goods and services; (ii) investing in improving the quality and accessibility of education and human capital which will yield a skilled workforce; (iii) fostering competitive markets that encourage innovation and efficiency gains; (iv) fostering good governance that leads to more transparent and accountable institutions which is important in efficient resource allocation; and (v) the adoption of new technologies that drive efficiency gains.

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