

# Assessing ICT Adoption and Human Development in Sub-Saharan Africa: Evidence from Malmquist Index-Based Efficiency Analysis of Life Expectancy and Literacy Rates

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## Abstract

**Background:** Information Communication Technologies have played a key role in human development; however, literature findings highlight there exists challenges in promoting life expectancy and literacy in Sub-Saharan African countries.

**Objective:** The aim of the research paper is to examine whether Information communication Technologies are associated with advancing life expectancy and literacy rates in forty-nine (49) Sub-Saharan African countries. The key aspects of the UTAUTmodel are explored in this paper to make recommendations to create policies viable for ICT usage to enhance literacy rates and lifespan in Sub-Saharan African countries.

**Methods:** The research study investigates the relationship between information and communication technologies (ICTs) and human development factors in Sub-Saharan African countries from the period of 2010-2022 in years. The independent and dependent variables are mobile subscriptions, internet penetration, literacy rate and life expectancy. The study applied non-parametric methods Data Envelopment Analysis (DEA) and the Malmquist Index (MI) to assess efficiency and productivity and utilized a Random Forest algorithm for predictive modelling.

**Results:** ICT penetration variables show positive associations with life expectancy and literacy in Sub-Saharan African countries. Random Forest analysis indicates that internet access has a stronger influence on life expectancy and literacy rates in Sub-Saharan African countries compared to mobile subscription accessibility.

**Conclusions:** The research findings suggest that ICT investments united with adoption-facilitating contexts which entail infrastructure reliability, affordability, skills and trust are associated with human development improvements. A conceptual framework was developed to inform policy makers in Sub-Saharan African governments and development partners on how to adopt ICTs to improve literacy and life expectancy rates.

**Keywords** – *Information and Communication Technology (ICT), Internet Access, Life Expectancy, Literacy Rate, Sub-Saharan Africa, Data Envelopment Analysis (DEA), Malmquist Index (MI), Malmquist Summary Index (MSI), Random Forest, Sustainability, Policy Making.*

## I. INTRODUCTION

Information communication Technologies are key to the development of both developed and developing countries in this digital era. “The degree of positive responsiveness of inclusive development to ICT varies across fundamental characteristics of human development and ICT dynamics” (Asongu& Le Roux, 2016, pp. 1-2). Ensuring sustainable human development requires equitable access to ICTs across all Sub-Saharan African countries. Asongu& Le Roux (2016, p. 1) mentioned that increasing information and communication technology (ICT) adoption affects inclusive human development in Sub-Saharan Africa. The research study focuses on the influence ICTs on Human development factors, for example: income levels, literacy rates, legal opinions, life expectancy, resource wealth, political stability.

Policy makers often make assumptions and create plans based on straightforward benefits, but actual research findings suggest that Sub-Saharan African countries vary in terms of ICT adoption, and their life expectancy and literary rates are not the same. Asongu& Le Roux, 2016, p. 1) further states that “the adoption and/or penetration rate of ICTs can be influenced by policy to achieve inclusive development outcomes”. The policies in African regions need to align with the needs, resources and technological availability of that specific country. It is therefore imperative to have an ICT adoption model in place that aligns with the needs of each specific Sub-Saharan African country.

Policy discussions often assume straightforward benefits, but actual evidence varies across different contexts in Sub-Saharan African countries. The research study assesses how ICT penetration relates to life expectancy and adult literacy in Sub-Saharan African countries. The study aims to identify whether ICTs have a positive or negative influence on the education and lifespan of the population in Sub-Saharan African countries.

Kim and Crowston (2011, pp.1-10) mentioned that there are various theories and models in studying individuals’ ICT adoption and post-adoption behaviours such as TRA, TAM, TPB, TAM2, IDT, SCT, and UTAUT. Oliveira and Martins (2011 pp.110-121) further stated that the most adopted theories in field of technology adoption are TAM, TPB, UTAUT, DOI Theory and TOE.

For this research study, we discuss one of the technology adoption frameworks which is the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al., 2003, p. 451). This will assist in explaining key factors such as perceived usefulness, ease of use, social influence, facilitating conditions, task-technology fit, attitudes, intentions, satisfaction, and norms that shape how ICT access translates into human development.

By following the pragmatic approach, we use both qualitative and quantitative methods to gather information and insights to address the following research questions:

- Main-Research Question: How does information and communication technologies (ICTs) affect life expectancy and literacy rates in Southern African nations?
  - SRQ 1: Is there a significant relationship between life expectancy and ICTs in Southern African countries?
  - SRQ 2: Is there a significant relationship between literacy rates and ICTs in Southern African countries?
  - SRQ 3: How effective are ICTs in enhancing efficiency and productivity in Southern African countries?
  - SRQ 4: What are the challenges of ICTs adoption in Southern African countries?

## II. THEORETICAL BACKGROUND

### 2.1 Understanding ICT Dynamics within the African Region

#### **Information Communication Technologies impact on human development factors**

Bayar et al. (2024, p.1) highlighted that ICT penetration-specifically mobile usage, broadband connectivity, and internet adoption-significantly stimulates sustainable development, revealing multiple layers of causality between ICT indicators and development outcomes across African countries between 2000 and 2020. Bayar et al. (2024, p.1) revealed that the expansion of ICT access-particularly through mobile phone penetration, broadband availability, and increased internet use-substantially promotes sustainable development. The research findings suggest that there is a significant relation between ICT indicators and development outcomes across African regions.

Lwoga and Sangeda's (2019, p.1) extensive analysis of ICT4D scholarship reveals that, although ICT interventions foster advancements in education, health services, and economic participation, their long-term impact remains uneven owing to persistent infrastructural shortcomings, socio-technical limitations, and institutional fragilities. The challenges are a more distinct in Sub-Saharan African countries where ICT access varies across the regions. In addition to this, UNESCO (2023) has indicated that globally, 763 million adults and young people, approximately sixty-six percent of whom are women, still lacking basic literacy skills (UNESCO, 2023, p. 3). A significant portion of the female population continues to experience low literacy levels, with nearly half facing challenges in reading and writing (Aguboshim& Nwokedi, 2019, p.1). Across African countries, uneven ICT access has influenced human development factors such as life expectancy and literacy rates. Inadequate infrastructure that leads to limited internet connectivity might deviate digital learning environments, restricting potential for ICTs to consistently strengthen educational outcomes. Digital gaps in digital health systems may also be weakened hindering support for better health services, which could otherwise contribute to increased life expectancy across the region.

#### **Information Communication Technologies impact on Business and productivity**

In the context of business and productivity, ICTs have proven to be pivotal to the growth of developing countries and more particularly Sub-Saharan African countries. It serves a foundation to connect developing countries with developed countries at a global scale. It addresses the need for the African continent's need to integrate into worldwide digital ecosystem. However, challenges persist in preventing people from having access to ICTs, access to ICTs varies greatly across African regions. Lwoga and Sangeda's (2019, p.1) comprehensive review of ICT4D literature indicates that although ICT initiatives contribute to advancements in education, healthcare, and economic engagement, their long-term benefits remain inconsistent because of persistent infrastructural limitations, socio-technical challenges, and institutional weaknesses.

David (2024,p.223), drawing on PVAR and GMM estimations across 16 SADC nations, shows that the spread of ICT exerts a statistically significant and reciprocal effect on economic growth over the period 2000 to 2017. Asongu and Acha-Anyi (2020, pp. 831-832) show that while ICT has a positive effect on total factor productivity (TFP), the incremental gains taper off unless bolstered by sufficiently high levels of mobile penetration (around 100%) and a minimum internet penetration rate of approximately 15%.

Key benefits of ICTs towards on economic growth and productivity:

- ICT enhance economic performance.
- Improvements in economic conditions further stimulate ICT uptake.
- Improves firm-level productivity.
- Creating a cyclical growth-enhancing mechanism.

### III. METHODS

#### 3.1 Data Collection

The data collected for the research study entails a sample size of 500 participants from any of the Sub-Saharan African Countries. An online survey will be used to collect the data from all willing participants. Raw data used was collected from the United Nations data bank for the period of 2010-2022. Data from the United Nations data bank particularly for the 49 sub-Saharan African countries which are: Angola, Burundi, Benin, Burkina Faso, Botswana, Central African Republic, Cote d'Ivoire, Cameroon, Congo, Dem. Rep., Congo, Rep., Comoros, Cabo Verde, Djibouti, Eritrea, Ethiopia, Gabon, Ghana, Guinea, The Gambia, Guinea-Bissau, Equatorial Guinea, Kenya, Liberia, Lesotho, Madagascar, Mali, Mozambique, Mauritania, Mauritius, Malawi, Namibia, Niger, Nigeria, Rwanda, Sudan, Senegal, Sierra Leone, Somalia, South Sudan, Sao Tome and Principe, Eswatini, Seychelles, Chad, Togo, Tanzania, Uganda, South Africa, Zambia and Zimbabwe.

The ICT indicators used for this research are Mobile cellular subscribers (per 100 inhabitants) and Internet users (per 100 inhabitants). The human development indicators are Life expectancy (per 100 inhabitants) and Literacy rates (per 100 inhabitants).

#### 3.2 Analysis & UTAUT Model

The UTAUT Model (Venkatesh et al., 2003, p. 451) provide insights of how ICTs can contribute to improving life expectancy and literacy rates across the regions of African countries.

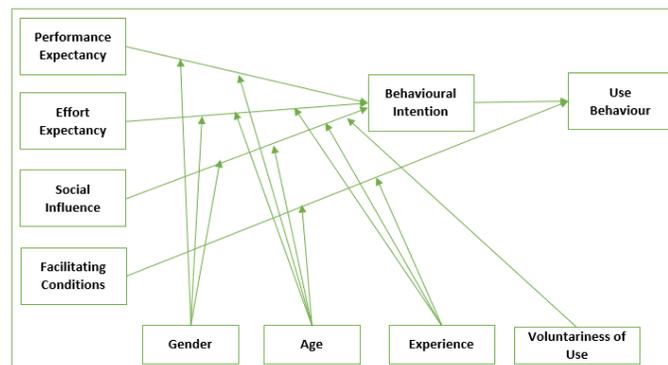


Figure 1. The UTAUT Model (Venkatesh et al., 2003, p. 451).

The UTAUT Model (Venkatesh et al., 2003, p. 451) model integrates elements from eight technology acceptance theories to provide a unified view of user acceptance. The application and the impact of the UTAUT model in respect to the research study which is on Life Expectancy and Literacy in Sub-Saharan Africa entails the following:

- The UTAUT model explains that communities adopt technology when they have belief in the performance of the technology. In for example, in the health care sector, AI-based diagnostics and health systems can be used for better health services and help increase life expectancy. In education sector, digital platforms can be used to improve literacy and make learning a lot more engaging.
- The people using the technology should find it easy to use and this speaks to effort expectancy. For instance, mobile health apps should make accessing healthcare simple and in the education sector where user-friendly educational tools allow people who cannot attend school to learn online.
- Easy access to information systems encourages people to use the technologies because accessible learning platforms empower people to gain knowledge and advance their education.

- Information Communication Technologies benefit the communities which they serve; there needs to be reliable internet and mobile networks to support the information demand for those communities. There needs to be ICT policies, investments and sustainable plans that will ensure that there is infrastructure to sustain communities at the current moment and the future.
- The culture of technology usage also needs to be driven by community leaders and healthcare professionals to ensure that people see the value of ICTs. When healthcare professionals and community leaders promote ICT and AI, people are more likely to accept and use them

IV. RESULTS

4.1 SRQ 1: Is there a significant relationship between life expectancy and ICTs in Southern African countries?

Random Forest Tree Results: Life Expectancy and ICTs

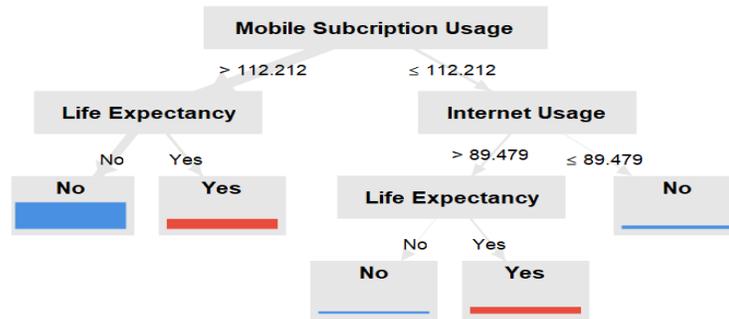


Figure 2. Random Forest Tree for Life Expectancy.

The above tree diagram indicates Random Forest Tree results in evaluating whether mobile subscription and internet usage has a positive relationship or are contributors to Life expectancy in the African countries. The results indicate the average of the following:

- Mobile subscription is not a significant contributor to Life expectancy.
- Internet Usage has more weight of about 89% compared to mobile subscriptions in contributing to Life expectancy.

4.2 SRQ 2: Is there a significant relationship between literacy rates and ICTs in Southern African countries?

Random Forest Tree Results: Literacy rate and ICTs

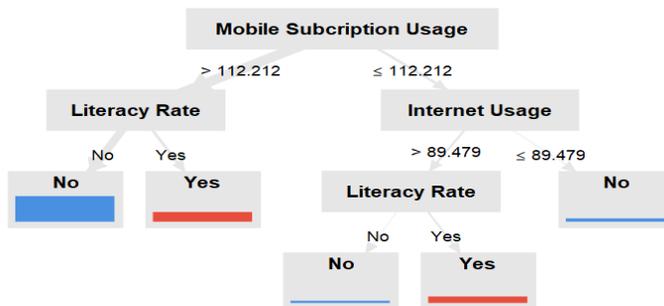


Figure 3. Random Forest Tree for Literacy Rate.

The above tree is related to predicting Literacy rate based on mobile subscription and internet usage statistics. It illustrates that internet usage has more weight of about 89% compared to mobile subscriptions in contributing to literacy rates in Sub-Saharan African countries.

#### 4.3 SRQ 3: How effective are ICTs in enhancing efficiency and productivity in Southern African countries?

DEA Malmquist Summary Index Results for the 49 Sub-Saharan African Countries.  
Kindly note the following definitions:

Kindly note the Interpretation:

- An MSI greater than 1 indicates productivity improvement (positive change).
- An MSI less than 1 indicates productivity decline (negative change).
- An MSI equal to 1 implies there is no change in productivity.

Year	effch	techch	pech	sech	tfpch
2	0.962	1.636	0.965	0.997	1.574
3	1.000	1.364	1.000	1.000	1.364
4	1.000	1.250	1.000	1.000	1.250
5	1.000	1.190	1.000	1.000	1.190
6	1.027	1.146	1.024	1.003	1.177
7	0.974	1.133	0.976	0.997	1.103
8	1.000	1.111	1.000	1.000	1.111
9	1.000	1.097	1.000	1.000	1.097
10	1.068	1.015	1.065	1.003	1.084
11	0.937	1.153	0.939	0.997	1.080
12	1.000	1.071	1.000	1.000	1.071
13	1.000	1.065	1.000	1.000	1.065
mean	0.997	1.176	0.997	1.000	1.172

Table 1. Results for MI Summary of Annual Means.

The above table highlights that the overall average total factor productivity change was 17.2%. The overall average total factor productivity change was 17.2% from the time on the year 2010-2022. The increase is a result of the overall increase in the efficiency change to the extent of 99%. The results indicate the overall technical efficiency change has increased to the extent of 17.6%, pure efficiency to the extent of 99.7% whilst scale efficient remains stagnant. This percentages are from the period of the year 2010 up until the year 2022.

#### 4.4. SRQ 4: What are the challenges of ICTs adoption in Southern African countries?

The participants of the online survey were asked to respond to open-ended questions. This is the opportunity for the respondents to provide insight and clarity of the views about Information Communication Technologies and its challenges in the African continent.

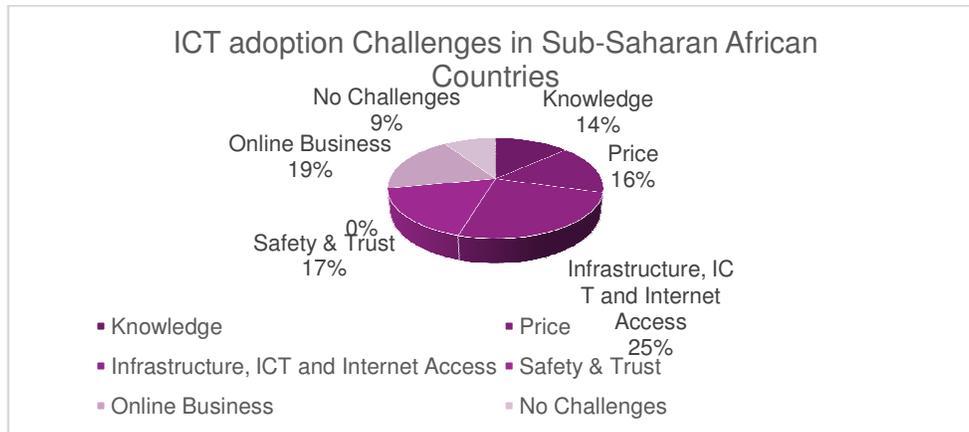


Chart 1. Challenges Identified in Information Communication Technologies Adoption.

The above chart highlights that 25% of the respondents do say that Infrastructure, ICTs an internet access is a challenge in their respective country. This percentage is the highest compared to other challenges that were highlighted as Safety and trust, knowledge, price, and online businesses.

## V. DISCUSSION

The research study investigated the role of Information Communication Technologies (ICTs) in providing a foundation for sustainable socio-economic outcomes in Sub-Saharan African countries. This study focuses on life expectancy, literacy rates, productivity and adoption of ICT challenges. The research study findings provide practical evidence that aligns with technology such as Unified Theory of Acceptance and Use of Technology (UTAUT) which emphasize the transformative potential of internet connectivity and technological progress.

The research findings are as follows:

### 1. SRQ 1: ICTs and Life Expectancy

The Random Forest Tree analysis suggests that internet usage has a positive relationship with life expectancy, accounting for approximately 89% of the predictive weight. Mobile subscriptions contribute less to life expectancy in Sub-Saharan African countries. The results suggest that internet connectivity is a lot more critical to the lives of people living in Sub-Saharan African countries. Digital connectivity has improved the lives of people because it has improved healthcare access, health information dissemination, and telemedicine adoption.

### 2. SRQ 2: ICTs and Literacy Rates

The research results suggests that internet connectivity is still the dominant factor to enhancing literacy rates in Sub-Saharan African countries. The results indicate that nearly internet connectivity contributes nearly 89% while mobile subscriptions remain lower in weight and insignificant. These findings highlight that internet connectivity plays a key role in providing a platform for facilitating educational access, e-learning, and knowledge sharing.

### 3. SRQ 3: ICTs and Productivity Growth

The Data Envelopment Analysis Malmquist Index was done for 49 Sub-Saharan African countries for this timeframe (2010-2020), and the following trends were noted:

- The Total Factor Productivity Change (tfpch): 1.172, indicating a 17.2% improvement in productivity across all 49 Sub-Saharan African countries.
- Efficiency Change (effch): ~0.997, suggesting near-constant efficiency levels.
- Technological Change (techch): 1.176, reflecting a 17.6% improvement, and serving as the primary driver of productivity growth.

- Pure Technical Efficiency (pech):  $\sim 0.997$  and Scale Efficiency (sech): 1.000, both stable.

#### 4. SRQ 4: Challenges in ICT Adoption

On online survey was conducted across 49 Sub-Saharan African countries. The research findings indicated that infrastructure and internet access (25%) as the most significant barriers to ICT adoption, followed by security concerns, knowledge gaps, high costs, and limited online business opportunities. Sub-Saharan African countries' government leaders and policy makers need to start addressing infrastructure deficits and start making sure that there is investment in towards ICTs adoption. Internet usage is the most influential ICT factor for improving life expectancy and literacy rates. What drives productivity growth across Sub-Saharan African countries is the technological advancements rather than efficiency or scale. The primary cause of challenges in ICT adoption is infrastructural limitations. In conclusion, between the year 2010 and 2022, productivity growth (17.2%) across the Sub-Saharan African countries was largely driven by technological change (17.6%), supporting that ICT adoption and innovation are the principal engines of socio-economic progress in Sub-Saharan Africa.

## VI. RECOMMENDATIONS

Information communication Technologies are not only technological processes, but they shape how human perceptions, social infrastructure and system quality. The successful adoption develops a continuous cycle that improves health and education outcomes in Sub-Saharan African countries thus further ensuring the growth of ICTs.

### 6.1 Integrated Technology Adoption Model for ICTs impacting on Literacy and Lifespan in Sub-Saharan African countries

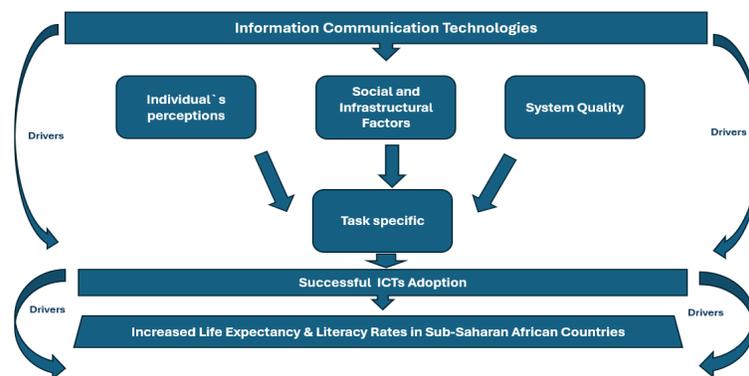


Figure 4. Integrated Technology Adoption Model for ICTs impacting on Literacy and Lifespan in Sub-Saharan African Countries

The above diagram illustrates the key drivers and relationships that influence successful adoption of Information Communication Technologies and its influence life expectancy and literacy rates in Sub-Saharan African countries. The key components are as follows:

**Information communication Technologies (ICTs)**-ICTs comprise of online technologies which may include the following: wireless or broadband Internet access, mobile devices (Phones, laptops, I-pads), mobile subscriptions.

**Influencing factors**-This may be individual's perceptions on how they perceive ICT usefulness and ease of use. The societal and infrastructural factors which include the readiness of people to use the new technology, the availability of infrastructure that supports accessibility to online services and applications. The culture norms of society also influence the way people perceive using new technologies and may affect their decision making to use or not use it. The system quality of the

technology informs us about the reliability and system performance of the system. The system's usability also informs us whether people can use the technological system or not.

**Task-specific configuration**-The technology needs to be tested on whether it fulfils the tasks that people are aiming to achieve when they use it. The ability of the system to fulfil key tasks that were manually done by people is key to its adoption by users.

**Successful ICT adoption**-User needs of the users need to be met for the successful adoption of the system.

**Impact**-The impact relates to how Information Communication Technologies have impacted society. If ICTs leads to increased life expectancy and literacy rates in Sub-Saharan African countries, then adoption of ICTs will increase. A positive feedback loop is created further advancing the development of ICTs in Sub-Saharan African countries.

**Drivers**- The arrows in the diagram illustrate the key drivers that suggest ICT adoption: ICTs technologies driving adoption. The adoption of ICTs that is driving the literary and health outcomes in Sub-Saharan African countries. The improvements in health and literacy rates further encourage people to use ICTs.

### *6.2 A proposed MSI & RF Framework for ICT adoption and Sustainability Policy Making in Sub-Saharan African Countries*

This study proposes a dual conceptual framework comprising the Malmquist Summary Index and a Random Forest Tree model to rigorously assess the efficiency and sustainability of ICT adoption. The benefits of having a dual conceptual framework are as follows:

- It provides a combines efficiency analysis which is done via Malmquist Summary Index with predictive modelling via Random Forest tree which enables comprehensive evaluation of ICT adoption.
- It allows researchers to bridge the gap between productivity measurement and forecasting techniques which are often treated separately in prior research.
- It improves accuracy because Random Forest enhances predictive reliability and Malmquist Index ensures benchmarking of productivity over time.
- It empowers policymakers and organizations to identify both performance trends and future adoption patterns.

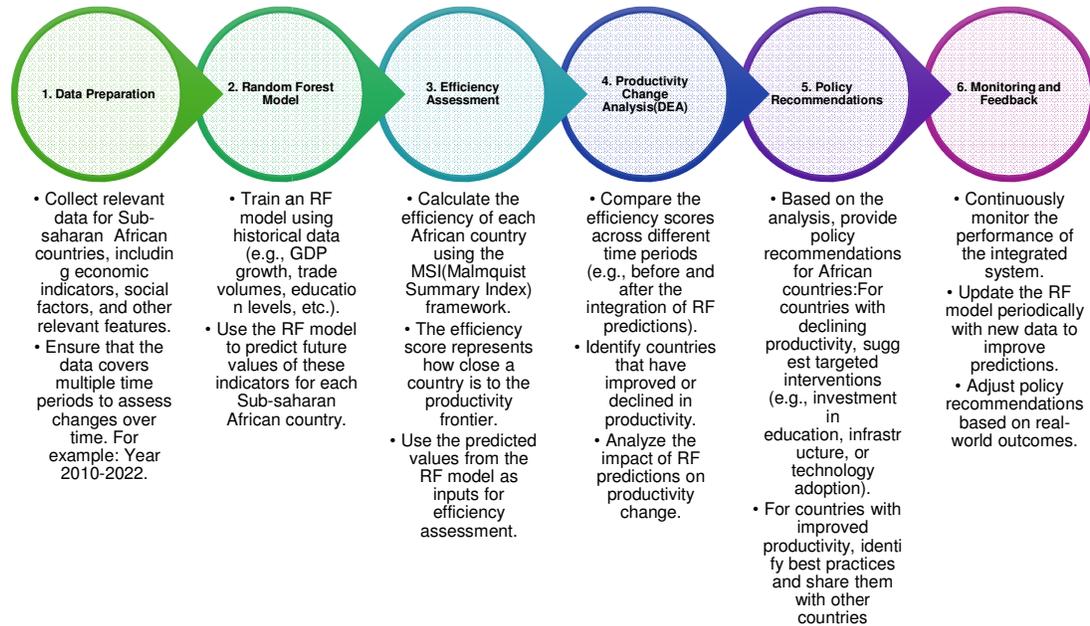


Figure 5. The MSI & RF Framework for ICT Adoption and Sustainability Policy Making in Sub-Saharan African Countries.

This integrated approach combines predictive modelling, efficiency benchmarking, and policy feedback, enabling a holistic, data-driven strategy for improving ICT adoption and its impact on life expectancy and literacy. The MSI & RF Framework for ICT Adoption and Sustainability Policy Making in Sub-Saharan African Countries consists of six steps that entail the following:

**Step 1: Data Preparation**

The researcher or scientist can collect data from a data bank or source which is multi-year. Multi-year data for example may comprise of data from the year 2016 up until 2021 for Sub-Saharan African countries. One may include economic indicators such as the following: education level, social factors or other contextual features. The data needs to span across multiple periods of time to ensure that trends and changes are noted.

**Step 2: Random Forest Tree Model**

The Random Forest Tree model needs to be trained by using historical data such as the following for example: educational levels, life expectancy rates, Mobile subscription GDP growth. The Random Forest Tree model can be used to predict future values for these mentioned indicators of each Sub-Saharan African country.

**Step 3: Efficiency Assessment**

The efficiency score of each Sub-Saharan African country can be calculated by using the MSI framework. The calculated efficiency score will show how close a Sub-Saharan African country is to the productivity benchmark. The Random Forest Tree predicted values will be used as inputs for this efficiency assessment.

**Step 4: Productivity Change Analyses (DEA)**

A comparison between efficiency scores across different periods will be done. The identification of improved or declined productivity is done across all the Sub-Saharan African countries. Make an analysis of the impact if Random Forest tree scores on productivity change.

**Step 5: Policy Recommendations**

Targeted Policy recommendations can be done based on the analysis: When the data results suggest that there are countries where productivity is declining then there needs to be interventions for example (education, CT adoption or improvement in infrastructure). By doing this comparison, one can identify which countries have improved in productivity and the best practices can be shared amongst them regionally.

**Step 6: Monitoring and feedback**

Ensure there is continuous monitoring to detect any changes to the productivity of each Sub-Saharan African country. Ensure that the Random Forest Tree model is updated with new data to make better predictions. Ensure that policies are adjusted based on the dynamic world outcomes and the productivity of each Sub-Saharan African country.

**VII. LIMITATIONS**

There were limitations to the study because not all African countries were included in the study, only 49 Sub-Saharan countries were included. Data was collected from the United Nations data bank from the years 2010 up until the year 2022. Some of the data pertaining to Sub-Saharan countries were missing, therefore, a mean average was taken to make up for the missing data.

**VIII. CONCLUSION**

The study evaluates the productivity change in 49 Sub-Saharan African countries during the years 2011-2022. The components that were assessed were technological change, efficiency change and scale efficiency. The benefits of machine learning and how Random Forest tree can be used to make accurate predictions for the performance of each African Sub-Saharan country. The results highlight that ICTs and internet accessibility have contributed at an average mean of 17% to life expectancy and literacy rates in African countries. The results indicate that the overall mean for TPF is 17.2%. Random forest tree provided aggregated results that are accurate and indicate that internet accessibility and mobile subscriptions do contribute to life expectancy and literacy rates. The overall study has allowed the research to come with a framework that will allow African governments to create policies and mandates associated with ICTs and internet accessibility to be aligned with their strategic goals. This will ensure that their respective countries are sustainable, and their population is literate with increased lifespan.

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