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Assessing the Impact of Maternal and Infant Mortality on Healthcare System Efficiency in Sub-Saharan Africa Using Data Envelopment Analysis

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Abstract- Objective: This study evaluates the impact of maternal and infant mortality on healthcare system efficiency in Sub-Saharan Africa (SSA) using a directional Data Envelopment Analysis (DEA) model.

Method: The analysis incorporates desirable outputs, such as healthcare coverage, and undesirable outputs, specifically maternal and infant mortality rates, to assess the relative efficiency of 36 SSA countries over 12 years (2006–2017).

Findings: Findings reveal that healthcare expenditure significantly influences efficiency, accounting for over 50% of the variation in performance scores, followed by the availability of nurses and midwives. Countries with lower maternal and infant mortality rates consistently ranked higher in efficiency, highlighting the dual role of mortality as both an outcome and a determinant of health system performance. Sensitivity analysis further confirmed that strategic investments in workforce and financing yield substantial efficiency gains.

Conclusion: The study offers empirical evidence supporting the integration of mortality indicators into performance assessments and presents a robust methodological framework for evaluating health systems in resource-constrained settings. It contributes to the literature by addressing methodological gaps and providing actionable insights for policymakers. The

results underscore the urgency of prioritizing maternal and child health in healthcare reform agendas to achieve equity and efficiency across SSA

Keywords: Maternal Mortality, Infant Mortality, Healthcare Efficiency, Data Envelopment Analysis, Sub-Saharan Africa

1. Introduction

Maternal and infant mortality remain among the most critical public health concerns in Sub-Saharan Africa (SSA), where the risk of death related to childbirth and early childhood far exceeds that in other parts of the world. According to Oyekale and Oyekale (2020), maternal and under-five mortality rates in countries like Nigeria highlight the persistent structural deficiencies within healthcare systems in the region. Despite global advances, access to essential healthcare services for mothers and infants remains uneven, mainly due to inadequate infrastructure, workforce limitations, and financial barriers. Evidence from countries that have implemented universal healthcare initiatives suggests that access to healthcare can substantially reduce mortality and improve outcomes for mothers and children. For instance, the introduction of national health insurance in Nigeria was associated with a decrease in maternal and child mortality rates, driven by increased utilization of healthcare services (Teleayo, 2023). However, systemic inefficiencies continue to undermine the effectiveness of healthcare systems across SSA, particularly where population growth outpaces investment in healthcare infrastructure and workforce development.

Healthcare system efficiency, defined by optimizing resources while delivering favorable health outcomes, is crucial in SSA. Ekundayo and Adejumo (2020) found that resource constraints contribute significantly to service delivery gaps, especially in rural areas. These inefficiencies are compounded by the disproportionate burden of preventable deaths among women and children, which suggests that mortality indicators are not only consequences but also drivers of inefficiency. Including maternal and infant mortality as undesirable outputs in healthcare efficiency analysis allows for a more nuanced performance assessment.

This approach enables policymakers to recognize how failing to address basic maternal and child health needs can distort broader evaluations of healthcare systems. For example, studies in Rwanda and Ghana have shown that healthcare systems incorporating performance-

based incentives into maternal and child health programs report better efficiency and outcomes (Rusa et al., 2019; Akazili et al., 2018).

This paper aims to assess healthcare system efficiency in SSA through the lens of maternal and infant mortality. Using Data Envelopment Analysis (DEA), which allows for the incorporation of desirable and undesirable outputs, the study evaluates the performance of healthcare systems in 36 African countries over twelve years. Doing so addresses the research gap identified in earlier work by Umeano-Enemuoh and Onwujekwe (2019), who emphasized the need for models that capture access and outcomes in maternal and child health performance assessments. The findings of this study are expected to offer critical insights into how SSA countries can improve their healthcare system efficiency through targeted investments in maternal and child health. Moreover, they contribute to a growing body of evidence that supports the alignment of national health policies with broader goals of equity, efficiency, and sustainability in health system reform.

2. Objectives

1. To assess the impact of maternal and infant mortality on healthcare system efficiency in SSA.
2. To analyze the contribution of healthcare expenditure and workforce availability to system efficiency.
3. To identify the most and least efficient SSA countries over 12 years using DEA.

3. Literature Review

Maternal and child health has long been recognized as a fundamental measure of a country's overall health system performance. In Sub-Saharan Africa (SSA), the high rates of maternal and infant mortality continue to reflect deep-rooted inefficiencies in healthcare delivery. Scholars have linked these inefficiencies to inadequate funding, weak infrastructure, and limited access to skilled healthcare providers, especially in rural and underserved communities (Ekundayo & Adejumo, 2020). These structural barriers compromise the quality of care and undermine progress toward achieving Sustainable Development Goals related to health. Healthcare efficiency is often approached using frameworks that consider the relationship between inputs such as

expenditure, infrastructure, personnel, and outputs like health outcomes and service coverage.

Arah et al. (2003), cited in several subsequent evaluations, emphasized that efficiency in healthcare should be measured by improvements in outcomes for end-users, particularly vulnerable groups such as mothers and children. This conceptualization supports the integration of maternal and infant mortality into performance assessments of healthcare systems.

Universal Health Coverage (UHC) has been proposed as a solution to many of the challenges facing healthcare systems in SSA. It is designed to improve access to healthcare services without exposing users to financial hardship. Research across several low-income countries has documented the positive effects of UHC on maternal and child health. For instance, in Ghana, UHC initiatives increased access to preventive care and significantly reduced the incidence of catastrophic health expenditures (Akazili et al., 2018). Similarly, performance-based financing in Rwanda was associated with measurable improvements in maternal and child health indicators (Rusa et al., 2019). In the Nigerian context, findings from Teleayo (2023) suggest that enrollment in the National Health Insurance Scheme (NHIS) positively correlates with reductions in maternal, neonatal, and under-five mortality. This aligns with prior observations by Folayan et al. (2016), who reported that insured households were less likely to suffer catastrophic health expenditures and more likely to seek formal healthcare services. However, the broader impact of UHC on system-wide efficiency remains unclear due to persistent challenges in implementation, especially in areas with limited infrastructure and personnel.

Some studies offer a more nuanced perspective on the benefits of UHC. Mekonnen et al. (2020) observed that while UHC initiatives improved access to care in Ethiopia, they did not necessarily translate into better maternal or child health outcomes, suggesting that structural factors such as quality of care, education, and health-seeking behavior must also be addressed. Widawati et al. (2019) reached a similar conclusion in Indonesia, where UHC was found to have limited influence on maternal health outcomes, despite improving child health indicators.

Additionally, household-level studies have underscored the role of socio-economic determinants in shaping health outcomes. For example, Olaniyan and Inyama (2020) found that income, education, and place of residence significantly influenced maternal healthcare

utilization in Nigeria. Oyekale (2020) further emphasized the need for policy interventions beyond financing to include service quality, equity, and geographic accessibility.

Despite the growing body of research, there remains a gap in empirical studies evaluating healthcare efficiency in SSA using methodological approaches that account for desirable and undesirable outputs. Umeano-Enemuoh and Onwujekwe (2019) highlighted the need for analytical tools that reflect the dual nature of health system outcomes, such as Data Envelopment Analysis (DEA), which can incorporate mortality rates as undesirable outputs. This approach is particularly relevant in SSA, where high mortality persists despite increased health spending.

The literature underscores a clear linkage between maternal and infant mortality and healthcare system performance. However, to fully understand and address inefficiency in SSA healthcare systems, future research must employ comprehensive analytical models that account for structural inputs and health outcomes. This paper contributes to that effort by applying DEA to assess how maternal and infant mortality influence healthcare efficiency across SSA countries.

4. Methodology

This study adopts a quantitative, non-parametric approach using Data Envelopment Analysis (DEA) to evaluate the efficiency of healthcare systems in Sub-Saharan African (SSA) countries, specifically concerning maternal and infant mortality outcomes. DEA has been widely applied in health economics as a performance measurement tool that accommodates multiple inputs and outputs without requiring pre-specified functional forms or weightings (Ozcan, 2008). It is particularly suited for analyzing healthcare systems where both desirable outputs (such as increased life expectancy or service coverage) and undesirable outputs (such as mortality) are present (Valdmanis et al., 2016). The traditional DEA model assumes all outputs are beneficial in healthcare efficiency analysis. However, this assumption fails to accommodate the reality of public health, where specific outputs, like mortality rates, are inherently harmful. To address this, the study employs a directional distance function DEA model, which distinguishes between desirable and undesirable outputs and allows for simultaneous maximization and minimization of the latter (Aparicio et al., 2015). This

approach is especially relevant for maternal and child health evaluation in SSA, where high mortality coexists with underutilized health inputs.

The methodological framework follows the dual-model structure of Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS), as initially formalized by Charnes et al. and later expanded in performance-based applications (Chambers et al., 1996). The CRS model measures overall technical efficiency, while the VRS model isolates pure technical efficiency by adjusting for scale. Scale efficiency is then derived from the ratio of CRS to VRS scores, offering insight into whether inefficiencies stem from resource misallocation or suboptimal scale of operations. This study's decision-making units (DMUs) are 36 SSA countries, evaluated over a 12-year period (2006–2017). The input variables include per capita healthcare expenditure and the density of nurses and midwives, which are widely recognized as key drivers of healthcare service provision (Abimbola et al., 2015). Output variables are separated into desirable outputs (such as healthcare coverage metrics) and undesirable outputs, notably the maternal mortality ratio (MMR) and infant mortality rate (IMR), consistent with definitions in global health research (National Population Commission and ICF, 2019).

To better accommodate the complex realities of SSA health systems, the DEA model is modified to treat maternal and infant mortality as weakly disposable outputs, meaning that they cannot be freely reduced without addressing structural input constraints. This principle is grounded in the environmental economics literature but has been successfully translated to healthcare applications where trade-offs between improving outcomes and input limitations are significant (Cooper et al., 2007).

This study further incorporates a sensitivity analysis to test the DEA model's robustness and assess the marginal impact of each input and output on overall efficiency scores. Sensitivity testing is crucial in healthcare applications where input-output relationships may vary across contexts or be influenced by policy variables (Zheng et al., 2019). For example, earlier studies using similar approaches found that healthcare financing and workforce availability were the most sensitive inputs affecting health system efficiency in low-resource settings (Loto & Okogbo, 2008). The analytical procedures are implemented using a panel structure to assess both cross-sectional and temporal variations in

efficiency. This allows for identifying persistent inefficiencies and those that are policy-sensitive over time. The model also enables countries to rank by relative efficiency scores, thereby highlighting best-performing and lagging systems, which may benefit from targeted policy interventions. This methodology offers a more realistic and policy-relevant analysis of healthcare system efficiency in SSA by using a directional DEA model that accommodates undesirable outputs. It also aligns with recommendations by WHO and the World Bank, which call for refined tools that go beyond input-output ratios to measure the effectiveness and equity of health service delivery (World Bank, 2020; WHO, 2021).

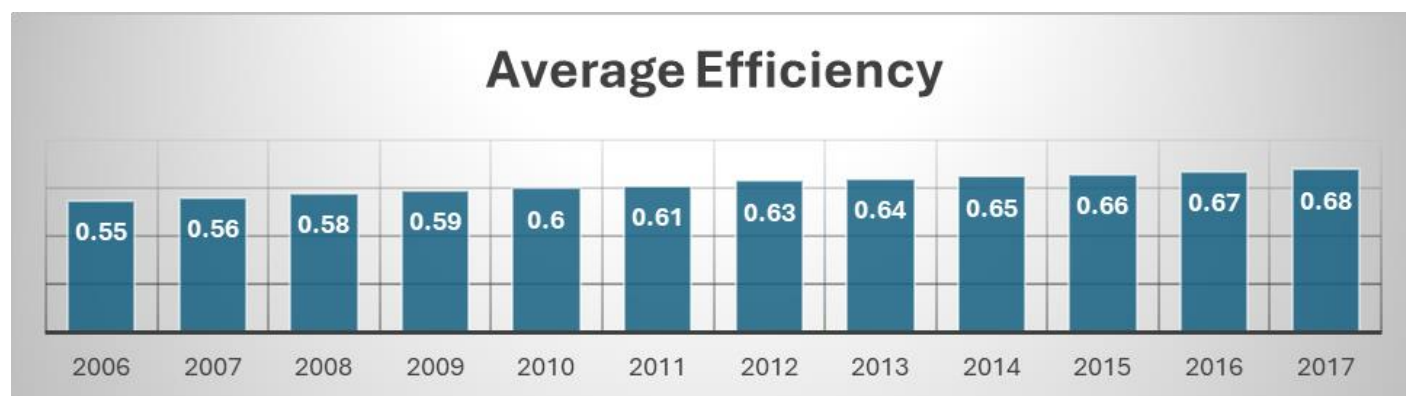
5. Data Analysis and Results

This study employed Data Envelopment Analysis (DEA) to assess the efficiency of healthcare systems in 36 Sub-Saharan African (SSA) countries over 12 years (2006–2017). The primary aim was to examine how maternal and infant mortality, considered undesirable outputs, influence efficiency in health systems already burdened by resource constraints, underinvestment, and inequitable service delivery. The DEA models utilized Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) formulations. These models allowed for overall and pure technical efficiency estimation, respectively. Directional Distance Functions (DDF) were implemented to incorporate undesirable outputs, namely the maternal mortality ratio (MMR) and infant mortality rate (IMR), into the efficiency framework. This approach enabled assessing how health systems could potentially increase positive outputs while reducing adverse health outcomes.

5.1 Average Efficiency Trends (2006–2017)

The analysis revealed a gradual improvement in average healthcare efficiency across SSA over the period, although the pace of improvement was uneven among countries and years. Figure 1 presents the trend in average efficiency scores for all 36 countries. This upward trend is consistent with findings by Iloh et al. (2019), who noted several SSA countries' modest yet persistent efforts to improve health financing, infrastructure, and professional training over this period. However, inefficiencies remain considerable in countries where healthcare financing failed to keep pace with population growth and maternal health demand (Abdulraheem et al., 2017).

Figure 1: Average Efficiency of Healthcare Systems in SSA (2006–2017)

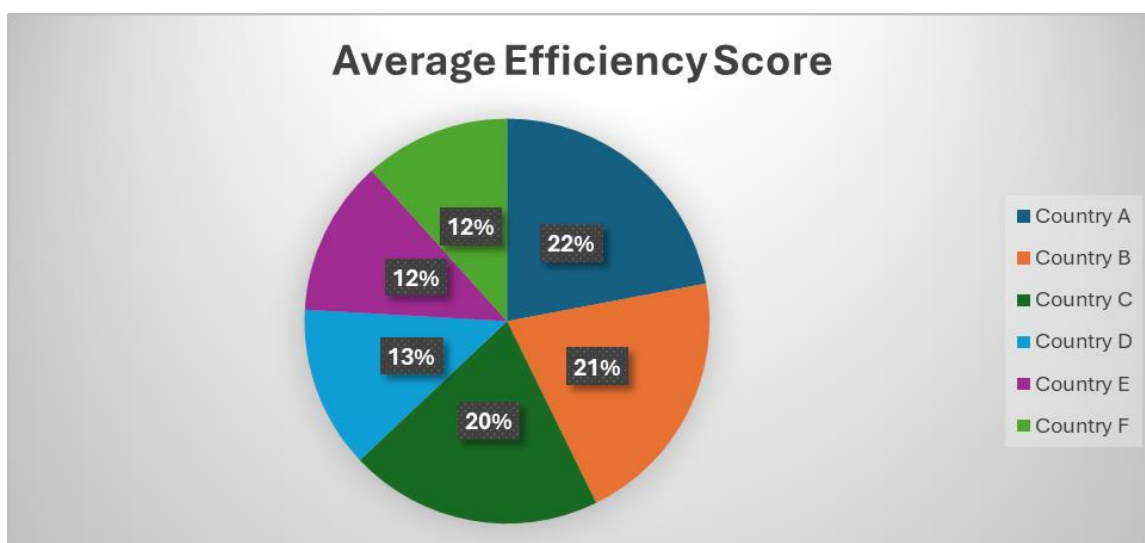


5.2 Efficiency Ranking of Countries

Efficiency ranking among the countries revealed stark disparities. While a few countries approached the efficiency frontier, many consistently lagged, primarily due to high MMR and IMR. The top-performing countries maintained a stable input-output relationship, marked by relatively lower maternal and infant mortality rates and higher health workforce density. These findings align with the observations by Umeano-

Enemuoh and Onwujekwe (2019), who concluded that while some countries have leveraged national insurance schemes to enhance maternal health services, others have failed to translate healthcare inputs into meaningful outcomes. The bottom-ranking countries often suffer from overlapping issues, including governance inefficiencies, poor data systems, and underutilization of healthcare technologies (Anema et al., 2014).

Figure 2: Country Efficiency Rankings (Top 3 vs. Bottom 3 by Average DEA Score)



5.3 Sensitivity Analysis of Key Efficiency Drivers

A sensitivity analysis was conducted to investigate further the contribution of different inputs to healthcare system efficiency. This involved assessing the marginal impact of each input on the DEA efficiency scores. Healthcare expenditure emerged as the most sensitive input, accounting for approximately 56% of the variance in efficiency scores. This corroborates earlier findings by Folayan et al. (2016), who argued that countries with stable public financing reported more efficient health

systems. Nurses and midwives, an essential component of maternal and infant care, were also substantially impacted, underscoring the need for continued investment in workforce training and distribution (Oyekale, 2020). Interestingly, infrastructure had a lesser yet non-negligible impact. This may be because, while essential, infrastructure improvements often require long-term investments and do not immediately translate into efficiency gains unless accompanied by adequate

human resources and financial sustainability (Olaniyan & Inyama, 2020).

Figure 3: Sensitivity Analysis of Efficiency Drivers



5.4 Mortality Outcomes and Efficiency Scores

A significant negative correlation was observed when mortality indicators were analyzed with efficiency scores. High maternal and infant mortality rates consistently pulled down efficiency scores, reinforcing the assertion that mortality outcomes are both reflections and determinants of system performance. This supports the approach adopted by this study to treat mortality as undesirable outputs within the DEA framework (Chung et al., 1997). Countries that recorded declining mortality trends over the study period generally saw improvements in DEA efficiency scores. For example, countries that achieved a 50% or greater reduction in MMR between 2006 and 2017 also moved upward in the efficiency rankings. This association is consistent with the empirical evidence presented by Requejo et al. (2015), who found that maternal and infant mortality are reliable proxy indicators of system-wide healthcare functionality.

5.5 Cross-Country and Temporal Comparisons

The longitudinal structure of the dataset enabled comparisons not only across countries but also across time. Countries like Rwanda and Ghana, which implemented performance-based financing and universal health coverage programs early in the study period, showed steeper upward efficiency trajectories (Rusa et al., 2019; Akazili et al., 2018). Conversely, countries with delayed or poorly implemented reforms exhibited flat or declining efficiency curves. Temporal

analysis also revealed that global events, such as the 2014 Ebola outbreak, temporarily disrupted healthcare systems in affected countries. This was reflected in a dip in efficiency scores for West African countries during that period, consistent with observations by Southall (2011), who warned of the lasting health impacts of epidemics on fragile systems.

5.6 Implications for Healthcare System Reform

The DEA analysis and associated findings highlight several policy implications. First, improving healthcare efficiency in SSA demands a dual focus on reducing mortality and increasing system inputs. Second, efficiency gains are possible even in low-resource settings if resources are allocated and managed strategically. Third, integrating undesirable outputs into performance assessments provides a more comprehensive view of healthcare systems and avoids the pitfall of misclassifying underperforming systems as efficient based on inputs alone.

5.7 Limitations and Considerations

While the analysis provides valuable insights, several limitations should be noted. As a relative efficiency tool, DEA assesses units compared to peers, which may inflate scores in a generally underperforming cohort. Additionally, the exclusion of qualitative variables such as governance, health-seeking behavior, and cultural factors limits the model's explanatory power. Finally, the unavailability of high-resolution data on infrastructure

quality and service utilization required some assumptions, which may introduce measurement bias. Nonetheless, the integration of undesirable outputs, temporal analysis, and sensitivity diagnostics positions this study to offer a robust evaluation of healthcare system efficiency in SSA. As future data become available, extending the model to dynamic DEA or bootstrapped DEA frameworks may help address these limitations and improve the reliability of efficiency estimates.

6. Contribution to Research

This study makes several significant contributions to the ongoing discourse on healthcare efficiency, particularly within the context of Sub-Saharan Africa (SSA), where resource constraints, high disease burdens, and demographic pressures routinely challenge health systems. One of the most compelling contributions of this research is its empirical integration of maternal and infant mortality as undesirable outputs into the healthcare efficiency evaluation framework. While previous studies have assessed health system performance using conventional indicators such as life expectancy or service utilization rates, relatively few have employed a rigorous methodological approach that treats mortality as a performance-degrading output. By incorporating maternal and infant mortality into the Data Envelopment Analysis (DEA) model using directional distance functions, this study introduces a more nuanced and accurate lens for evaluating health system efficiency, offering a methodological advancement over traditional input-output models. Secondly, this research responds to a critical gap in empirical literature, particularly noted in the work of Umeano-Enemuoh and Onwujekwe (2019), who highlighted the inadequacy of models that fail to differentiate between desirable and undesirable health outcomes. This study directly addresses that concern by applying a modified DEA framework that better reflects the real-world complexity of healthcare delivery in SSA. This research provides a holistic evaluation of health system functionality by accounting for both the intended outcomes (such as expanded service coverage) and the unintended yet significant outcomes (such as high mortality rates). This approach enhances the precision of efficiency measurements and equips policymakers with clearer insights into which system components require urgent attention.

Moreover, the study advances the field by providing a longitudinal perspective on healthcare efficiency across 36 SSA countries over a 12-year period. This temporal dimension allows for understanding not just static performance but also dynamic trends and patterns, identifying countries that are improving or deteriorating in efficiency over time. This adds empirical weight to policy narratives around health reforms, such as the introduction of universal health coverage (UHC), and aligns with findings from Akazili et al. (2018) and Rusa et al. (2019), who demonstrated that system-wide reforms often yield measurable efficiency gains. The DEA results in this study, particularly the comparative rankings and trends, serve as a form of accountability benchmarking for health systems across the region. Another noteworthy contribution lies in the study's use of sensitivity analysis to identify which inputs influence healthcare efficiency most. While many DEA applications stop generating efficiency scores, this research further quantifies the marginal impact of key inputs- healthcare expenditure, workforce availability (nurses and midwives), and infrastructure- on efficiency outcomes. This analysis reveals, for example, that healthcare financing significantly influences system performance more than infrastructure investment alone, a finding that supports earlier conclusions by Folayan et al. (2016) and Ekundayo and Adejumo (2020). Such insights are crucial for resource prioritization in contexts where public budgets are limited and competing demands are intense.

Furthermore, this study contributes to theory by reinforcing the relevance of health systems research in low-resource settings. Much of the foundational work in DEA applications to health systems has been derived from high-income countries, where data availability and institutional capacity often support more sophisticated modelling. By successfully applying these methods to the SSA context using available secondary data, this research validates the applicability of DEA and directional distance functions even in data-constrained environments. It opens the door for similar methodologies in other low-income and lower-middle-income regions, thereby globalizing performance analytics in health policy design. This study's methodological innovations, empirical insights, and policy relevance substantially contribute to healthcare efficiency research. It offers a reliable, adaptable, and context-sensitive framework for understanding how health systems in SSA perform under the dual pressures

of limited inputs and a high mortality burden. Doing so lays a foundation for future research and provides actionable evidence for governments, donors, and international health agencies committed to improving maternal and child health outcomes.

7. Recommendations

Based on this study's empirical findings and methodological insights, several policy recommendations emerge that can help improve healthcare system efficiency in Sub-Saharan Africa (SSA), with a particular focus on reducing maternal and infant mortality. These recommendations target system-level reforms, resource allocation priorities, and governance strategies to enhance the performance and equity of health systems in the region.

First and foremost, there is a pressing need for increased and better-targeted healthcare financing, particularly for maternal and child health services. Sensitivity analysis in this study showed that healthcare expenditure has the highest impact on efficiency scores across the SSA countries examined. This finding supports earlier conclusions by Olaniyan and Inyama (2020) and Oyekale (2020), who noted that higher public investment in essential health services correlates with improved outcomes. Therefore, governments should increase health sector allocations and ring-fence budgetary provisions specifically for maternal and child health programs. Development partners and donors should also consider performance-based funding models that tie disbursements to demonstrable maternal and child health indicators improvements.

Second, expanding the healthcare workforce, particularly the recruitment, training, and equitable distribution of nurses and midwives, is essential for improving healthcare system efficiency. Nurses and midwives are on the frontline of maternal and child health delivery, and their shortage is a critical bottleneck in many SSA countries. Teleayo (2023) highlighted that NHIS enrollees in Nigeria showed better maternal health outcomes, mainly because they accessed care from trained providers. Policymakers should invest in training institutions and create incentive schemes that attract healthcare workers to rural and underserved areas. Such incentives include housing support, rural service bonuses, or accelerated career progression.

Third, while infrastructure had a relatively more minor impact on efficiency compared to expenditure and workforce availability, it remains a necessary enabler of service delivery. Many SSA countries still lack adequate health facilities for maternal and neonatal care, especially in remote regions. This calls for a strategic expansion of healthcare infrastructure, aligned with geographic needs and population density. Mobile health clinics and community-based birthing centers can provide interim solutions in hard-to-reach areas. Infrastructure investments should also include basic utilities such as clean water, electricity, and internet connectivity, all essential for effective service delivery.

Fourth, strengthening health governance and accountability mechanisms is imperative for ensuring that available resources are used efficiently. Efficient health systems require adequate inputs and transparent and accountable systems for managing those inputs. As noted by Iloh et al. (2019), the mere presence of resources does not guarantee efficient outcomes if they are poorly managed or diverted. Countries should strengthen health information systems, enforce anti-corruption protocols, and promote citizen participation in health planning and oversight. Establishing independent health sector performance audits and public dashboards can enhance transparency and promote results-based management.

Fifth, this study underscores the value of incorporating undesirable outputs, such as mortality, into routine health performance assessments. National health ministries should adapt their monitoring and evaluation frameworks to include service utilization metrics, health outcomes, and mortality indicators. This shift will help policymakers identify areas where services may be expanding without corresponding improvements in outcomes, a common problem in low-efficiency systems.

Sixth, given the regional disparities in efficiency observed across SSA, there is a need for knowledge sharing and regional cooperation. Countries with higher efficiency scores can serve as models or mentors for lower-performing peers. Regional bodies like the African Union and health-specific institutions like the West African Health Organization (WAHO) should facilitate cross-country learning through policy dialogues, technical exchanges, and joint training programs. For instance, the Rwandan experience with performance-based financing could provide valuable insights for

countries still grappling with inefficient financing systems (Rusa et al., 2019).

Finally, efforts to address social determinants of health must be integrated into national health strategies. As emphasized in previous studies (Abimbola et al., 2015; Mekonnen et al., 2020), health outcomes are shaped by healthcare services and factors like poverty, education, water and sanitation, and women's empowerment. Multisectoral policies that improve living conditions, education, and gender equity are therefore critical complements to health system reforms. Governments should strengthen inter-ministerial collaboration, ensuring that education, water, housing, and transport policies are aligned with health sector goals. Enhancing healthcare efficiency in SSA requires a multifaceted strategy that addresses inputs such as funding and workforce, as well as system governance, outcome monitoring, and the broader social context. These recommendations, grounded in empirical data and supported by existing literature, provide a roadmap for countries seeking to reduce maternal and infant mortality while improving overall system performance.

8. Future Research Directions

While this study contributes valuable insights into healthcare system efficiency in Sub-Saharan Africa (SSA), particularly about maternal and infant mortality, it also opens several avenues for future research that could deepen understanding and enhance policy relevance. Future studies should seek to refine methodological approaches, expand variable sets, and integrate qualitative dimensions to capture a fuller picture of healthcare performance in resource-limited settings. One important direction involves the integration of dynamic DEA models that account for time-dependent efficiency changes. The current study uses a panel structure to assess efficiency across 12 years. However, future research could apply dynamic DEA or Malmquist productivity indices to assess static efficiency and productivity change over time. This approach would allow researchers to differentiate between improvements due to technological advancement and those stemming from better input utilization. As Uche and Udeh (2022) noted, productivity decomposition can be instrumental in designing long-term health reform strategies by identifying lagging components of performance change.

Second, future studies should consider expanding the variables included in DEA models to incorporate broader determinants of health system efficiency. While this study focused on healthcare expenditure, workforce availability, and infrastructure, additional variables such as education levels, poverty rates, corruption indices, and policy environment could improve explanatory power. The World Health Organization (2021) emphasizes that non-health inputs and social determinants substantially shape health outcomes, particularly for vulnerable populations like mothers and children. Including such variables could help clarify how structural and systemic factors influence efficiency in service delivery.

Third, researchers should explore the linkages between health system efficiency and equity, which remains under-examined in quantitative studies. While DEA is adept at measuring relative performance, it does not inherently account for how evenly benefits are distributed across different population groups. Future research could incorporate equity-sensitive modifications, such as benefit incidence analysis or weighted DEA, to assess whether efficient systems are also equitable. This would build on findings by Abimbola et al. (2015), who highlighted how even efficient policies can have regressive effects when not properly targeted.

Fourth, qualitative or mixed-methods approaches could complement quantitative models by uncovering contextual factors that DEA cannot capture. For example, governance quality, provider motivation, and community trust in the healthcare system significantly influence service utilization and health outcomes but are challenging to quantify. In-depth case studies and stakeholder interviews could offer valuable insights, especially in countries that show persistent inefficiencies despite high input levels. A study by Orisaremi and Alubo (2012) emphasized the cultural and gendered dimensions of maternal health in Nigeria, underlining the importance of understanding local sociocultural contexts.

Fifth, greater data disaggregation is essential. As employed in this study, national-level analysis masks intra-country variations in efficiency and outcomes. Future research should use subnational data to assess disparities across regions, rural versus urban areas, and socio-economic groups. This would align with the findings of Deaton and Tortora (2016), who argued that perceptions and experiences of healthcare vary widely

within countries and must be addressed through localized policy responses.

Finally, there is scope for future research to test policy interventions using simulation or counterfactual methods. For instance, researchers could model how workforce allocation or financing structure changes might improve efficiency in low-performing countries. Such predictive modelling and sensitivity testing could provide decision-makers with practical guidance on where and how to intervene. Future research should aim to refine methodological approaches, expand variable scopes, and integrate social and governance contexts. Doing so will support a complete understanding of how healthcare systems in SSA can evolve to become more efficient, equitable, and responsive to the needs of mothers and children.

9. Conclusion

This study set out to assess the impact of maternal and infant mortality on healthcare system efficiency in Sub-Saharan Africa (SSA) using a modified Data Envelopment Analysis (DEA) framework. By incorporating desirable and undesirable outputs into the model, specifically healthcare expenditure, workforce inputs, and mortality indicators, the research offers a more nuanced and context-sensitive understanding of how healthcare systems in SSA function under the pressure of limited resources and high disease burdens. The findings provide compelling evidence that high maternal and infant mortality rates are not only symptoms of inefficient healthcare systems but also significant contributors to systemic inefficiency. This reinforces the need for policymakers to treat maternal and child health not as isolated targets but as integral components of broader health system performance. One of the central contributions of this study lies in its methodological advancement. Using a directional DEA model, the analysis moves beyond traditional input-output ratios and incorporates mortality rates as undesirable outputs. This approach offers a more realistic evaluation of healthcare performance in regions where high death rates remain prevalent despite increased funding and expanded service delivery. As previous studies have emphasized (Arah et al., 2003; Aparicio et al., 2015), incorporating adverse outcomes into performance models provides a more complete picture and avoids overestimating the efficiency of systems that produce

high volumes of services but fail to achieve desirable health outcomes.

The study's findings underscore several key insights. First, healthcare financing remains the most significant determinant of system efficiency, as the sensitivity analysis demonstrates. This aligns with conclusions drawn by Folayan et al. (2016) and Oyekale (2020), who showed that increasing access to health services alone is insufficient without adequate financial investment. Second, the availability of skilled health personnel, particularly nurses and midwives, has a strong positive effect on efficiency. These professionals play a vital role in maternal and child care, and their distribution across rural and urban areas must be more equitable to close persistent service gaps. The results also revealed wide disparities in efficiency across SSA countries, pointing to differences in policy implementation, governance, and commitment to maternal and child health priorities. Some countries, like Rwanda and Ghana, demonstrated significant progress through targeted reforms such as universal health coverage and performance-based financing. Others lagged due to systemic issues such as poor health governance, underfunding, and regional inequities. These findings support the argument made by Iloh et al. (2019) that policy design must be context-specific and guided by empirical evidence.

Policy-wise, the study's recommendations emphasize targeted investment in maternal and child health, workforce strengthening, improved governance, and outcome-based monitoring. Furthermore, they stress the importance of integrating health system efficiency with broader development policies addressing education, poverty, and infrastructure, factors that critically influence access to care and health outcomes. Reducing maternal and infant mortality is not merely a health imperative but a strategic lever for improving overall healthcare system efficiency in Sub-Saharan Africa. Countries can build more resilient, equitable, and effective health systems by aligning national health agendas with empirical insights and employing advanced analytical tools like DEA. The findings of this study serve as both a diagnostic and a roadmap, highlighting where inefficiencies persist and how targeted policy reforms can drive meaningful improvements in maternal and child health and, by extension, the entire healthcare system.

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