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Health expenditure, health outcomes and productivity in sub-Saharan Africa: Sustainable thresholds, moderation and forecasting

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DECLARATION

I, Yetunde Oluranti Adegoke, declare that:

1. The research documented in this thesis, except where otherwise stated, is my original work.
2. This thesis has not been submitted for any degree or examination at another University.
3. This thesis does not contain another person or institution's data, pictures, graphs, tables or other information unless it is purposely acknowledged as being sourced from the person or institution.
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DECLARATION: PUBLICATIONS

The following publications (published, accepted and under review) have been derived from the thesis:

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ABSTRACT

SSA is known to be confronting distinctive health problems and growth challenges, thereby, inadequate health expenditure, poor health outcomes and their implications for productivity require investigation. This situation persists despite evidence-related policy produced in the past, suggesting the need to investigate further the nature of the relationship between interrelated variables. This study aims to investigate the nonlinear effect of PHE on health outcomes and the moderating role of education on health outcomes, forecast the performance of different PHE scenarios in achieving the 2030 Sustainable Development Goals (SDGs), examine the effect of PHE and health outcomes on TFP and assess the moderating role of education in the relationship between PHE and TFP.

The study utilizes various techniques including Panel spatial correlation consistent-ordinary least squares (PSCC-OLS and PSCC-FE) for Objective One, Feasible quasi-generalized least squares (FQGLS) for Objective Two. Fixed and random models, panel two-stage least squares (P2SLS), and panel threshold regression for Objective Three. System panel generalized method of moments (GMM) for Objective four.

This study concludes a nonlinear relationship between PHE and health outcomes exists. Furthermore, the interaction of PHE and education would improve health outcomes. Second, an overall increase in PHE by 30% would achieve the SDG target of 70 maternal deaths in only Botswana, Namibia and South Africa. In addition, about 60% of the countries in SSA might be able to achieve the SDG target for child mortality by the year 2030. Third, including PHE and health outcomes into the TFP framework would guarantee a further increase in TFP growth in SSA, and a threshold level of PHE above 3.5% of the GNP could achieve better health outcomes and a further increase in TFP growth in SSA. Fourth, the interactive impact of PHE and education might cause an improvement in TFP in SSA.

The study pioneers the investigation of nonlinear, threshold, moderating, forecasting and collaborative effect of PHE, the information is essential for optimizing, redistributing and utilization of resources, specifically, a minimum of 38 dollars per person will achieve better health and productivity in SSA.

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ABBREVIATIONS AND ACRONYMS

AIDS	Acquired immune deficiency syndrome
ASEAN	Association of Southeast Asian Nations
CSD	Cross-sectional dependence
CHE	Current PHE
CMH	Commission on Macro-Economics and Health
CMR	Child mortality rate
DALYS	Disability-adjusted life years
ECO	Economic Cooperation Organisation
ECM	Error correction model
EDU	Education
FDI	Foreign Direct Investment
GGHE-D	Domestic general government health spending
GDP	Gross Domestic Product
GNP	Gross National Product
GMM	Generalized method of moments
HIV	Human immunodeficiency virus
HIV/TB	Co-infection of HIV and tuberculosis in patient
HIC	High-income country
ICT	Information and communication technology
ICRG	International Country Risk Guide
LEB	Life expectancy at birth
LIV	Low-income country
MDGs	Millennium Development Goals

MMR	Maternal mortality rate
NEET	Not in employment, education or training
NHIS	National Health Insurance Scheme
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary least squares
OOPS	Out-of-pocket spending
PHE	Public health expenditure
PPP	Purchasing power parity
PSCC	Panel spatial correlation is consistent
PSCC-OLS	Panel spatial correlation consistent-ordinary least squares
PSCC-FE	Panel spatial correlation consistent-fixed effect
P2SLS	Panel two-stage least squares
PVT-D	Domestic private health spending
QARDL	Quartile auto-regression distributive lag
SAARC	South Asian Association for Regional Cooperation
SDGs	Sustainable Development Goals
SGMM	System generalized method of moments
SSA	Sub-Saharan Africa
TB	Tuberculosis
TFP	Total factor productivity
UHC	Universal health coverage
UNDP	United Nations Development Programme
VECM	Vector error correction model
WDI	World Development Indicators

WHO	World Health Organisation
WLS	Weighted least squares

THESIS AT A GLANCE

There has been on-going debate on inadequate health financing and poor health outcomes in SSA alongside low productivity in the region. The discussions suggest limited understanding and the need to further investigate this nexus. Table A below sets out the study's objectives in relation to the prevailing situation.

Table A: Objectives - Health financing and outcomes in SSA

Serial number	Objectives	Methodology	Results	Recommendation	Chapter
	Objective 1 To investigate the nonlinear effect of PHE and the moderating role of education.				**3**
1i	Reaffirm PHE and education as critical determinants of health outcomes.	Panel spatial correlation consistent (PSCC) approach	A percentage change in PHE significantly reduced maternal and child mortality. Moreover, a percentage change in education caused a decline in maternal and child mortality but improved life expectancy.	Increased PHE and education levels are essential for better health outcomes in SSA.	3
Iii	Confirm the linear and nonlinear (quadratic) effects of PHE on health outcomes.	Panel spatial correlation consistent (PSCC) approach	The quadratic results support a nonlinear relationship between PHE and the health outcome indices.	Given confirmation of the nonlinear relationship between PHE and health outcomes, the minimum threshold points of PHE should be applied for better health outcomes.	3
1iii	Determine the PHE threshold points on health outcomes.	Panel spatial correlation consistent (PSCC) approach	Sustainable PHE thresholds that could achieve better health outcomes were 3.16 for maternal mortality, 2.73 for child mortality and 3.65 for life expectancy.	PHE should be increased above the minimum thresholds for better health outcomes in SSA.	3
1iv	Analyse the moderation effect of education in the relationship between PHE and health outcomes.	Panel spatial correlation consistent (PSCC) approach, pooled ordinary least squares (PSCC-OLS), panel spatial correlation consistent fixed effect (PSCC-FE) models	The interactions between PHE and education reduced infant and maternal mortality while enhancing life expectancy.	Education and PHE should be taken as complementary variables for better health outcomes.	3

1v	Estimate the minimum thresholds of education required to sustain PHE in influencing health outcomes.	Panel spatial correlation consistent (PSCC) approach, pooled ordinary least squares (PSCC-OLS), panel spatial correlation consistent fixed effect (PSCC-FE) models	The threshold points from the interaction effects indicated that enhancing education beyond the critical thresholds of 1.51 and 1.49 could induce a drop in maternal and child mortality. In contrast, a point beyond 1.84 resulted in improved life expectancy.	Education levels should be increased beyond 1.84% for better health outcomes.	3
2	**Objective 2** To forecast the performance of PHE scenarios towards achieving the 2030 SDGs.				**4**
2i	Predict the performance of maternal and child mortality in relation to the SDGs' targets (70 deaths per 100,000 births for maternal mortality and 25 deaths per 1,000 live births for child mortality) by 2030, based on a certain percentage (10, 20 and 30%) level of improvement in PHE.	Feasible quasi-generalized least squares (QGLS)	Individual countries in SSA should finance health according to the stipulated projection.	Health financing should be increased to achieve the SDGs' targets by 2030.	4
3	**Objective 3** To investigate the role of health and its proxies in TFP				**5**
3i	Investigate the role of health and its proxies as a determinant of TFP in SSA.	Fixed and random model (primary model), panel two-stage least squares (robustness model)	PHE had a positive and significant relationship with TFP in both models.	PHE should be increased for TFP growth in SSA.	5
3ii	Reaffirm the effect of non-health factors on TFP in SSA.	Fixed and random model (primary model), panel two-stage least squares (robustness model)	Education, ICT and control of corruption all had a significant and positive relationship with TFP.	These non-health variables should be considered alongside health factors in achieving sustainable TFP growth in SSA.	5
3iii	Confirm the existence of a threshold relationship between PHE and TFP in SSA.	Panel threshold regression model	A threshold relationship was confirmed between PHE and TFP at 3.5% of GNP.	Stakeholders and governments should increase PHE beyond the standard estimated in the study for better TFP growth.	5
3iv	Confirm the existence of a threshold relationship between the non-health factors and TFP in SSA.	Panel threshold regression model	A nonlinear relationship existed between TFP and non-health variables like education and ICT at 2.56% and 21%, respectively.	Stakeholders and governments should increase education and ICT beyond the standard estimated in the study for better TFP growth.	5
4	**Objective 4** To assess the moderating role of education in the PHE effect on TFP.				

4i	Investigate the interactive impact of PHE and education on TFP in SSA.	System generalized method of moments (SGMM)	The interaction of education and PHE had a significant and positive relationship with TFP.	An increase in education will enhance the impact of PHE on TFP.	6
4ii	Examine the collaborative impact of PHE and other sectors like education, agriculture and manufacturing on TFP in SSA.	System generalized method of moments (SGMM)	Manufacturing, agriculture, and education had a significant and positive relationship with TFP, but PHE had a negative and significant relationship with TFP.	PHE is a significant determinant of TFP. Therefore, PHE should be increased to achieve the expected collaborative impact on TFP. Moreover, manufacturing, agriculture and education should be increased for sustainable TFP growth.	6

CHAPTER 1

INTRODUCTION

1.1. Introduction

This chapter presents an overview of the thesis. Section 1.2 provides a background to the problem. Section 1.3 examines the relationship between health outcomes, PHE, and productivity levels. Section 1.4 presents the problem statement, and the research objectives and hypotheses are outlined in Section 1.5. Section 1.6 highlights the study's contributions and significance. Section 1.7 describes the study's scope and the methodology adopted, while Section 1.8 presents an outline of the thesis. A summary of Chapter 1 is provided in Section 1.9.

1.2 Background

Sub-Saharan Africa is characterised by inadequate health spending and poor health outcomes (Arthur & Oaikhenan, 2017). Global discussions on health issues and challenges have centred on the need for increased funding for healthcare in low- and middle-income countries. This results from the growing international focus on the need for adequate domestic government spending on social services, especially in SSA, where public expenditure on healthcare services is inadequate. Health expenditure is a critical determinant of health sector performance in relation to equity, efficiency, and health outcomes (Ibukun, 2021).

Likewise, education is vital in delivering better health outcomes (Xue, 2020) and sustainable productivity growth. Despite inadequate levels of health spending and education, a marginal improvement in health has been observed in SSA (Raghupathi & Raghupathi, 2020). While Lucas (1988) noted that improved levels of human capital (health and education) are essential to achieve sustainable growth, productivity has been declining in SSA (Akinola, 2017).

Sub-Saharan Africa has experienced numerous changes in the health sector that are likely to spill over to other sectors. Lucas (1988) linked improved human capital (health or education) to higher production capacity. Therefore, higher PHE could translate to more productive sectors because a healthier labour force would be more efficient in delivering services. For example, governments in SSA have increased their spending in the health sector to influence health outcomes and ensure growth in the region (WHO, 2020). However, despite decades of increased government PHE, SSA countries have witnessed marginal improvement in the maternal mortality rate (MMR), the child mortality rate (CMR) and life expectancy at birth (LEB) (Ibukun, 2021). In addition, sustainability poses a threat because of insufficient PHE. The graphical relationship between PHE, education and health outcomes supports this assertion.

Figure 1.1 below presents scatterplots showing the intrinsic relationships between PHE, education and health outcomes in SSA. It indicates a negative relationship between maternal/child mortality and PHE/education but a positive relationship with life expectancy. These outcomes are unsurprising and are documented in the literature (Arthur & Oaikhenan, 2017; Raghupathi & Raghupathi, 2020; Ibukun, 2021).

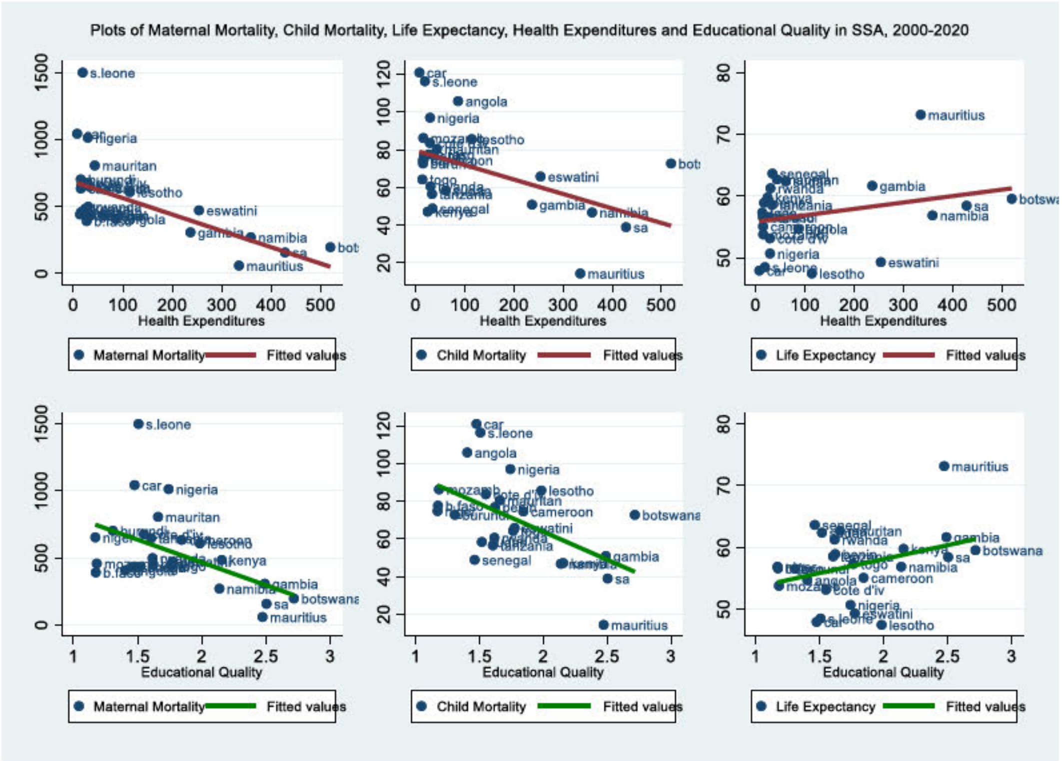


Figure 1.1: Relationship between maternal and child mortality/LEB and PHE/education in selected African countries (2000-2020)

Source: WHO (2021a)

The testing of the hypothesis that sustainable thresholds for PHE and education exist was motivated by the relatively poor performance of health outcomes and TFP growth in Africa and the apparent gap in the existing literature on this topic. Nevertheless, the literature agrees that improving PHE would enhance health outcomes and overall economic output (Arthur & Oaikhenan, 2017). Moreover, there has been on-going debate on improving other economic sectors such as the productive sector. The literature identifies various factors that could be utilised to enhance TFP. However, despite adopting these factors, such as education and ICT, TFP in SSA has remained very low (UN, 2012; Akinola, 2017).

To clarify the problems discussed in the literature, the current study first investigated the nonlinear effect of per capita PHE and the moderating role of education on health outcomes. Specifically, it examined whether per capita PHE and education were crucial determinants of health outcomes and whether there were linear and nonlinear (quadratic) effects of per capita PHE on health outcomes, considering the poor state of health, inadequate government commitment to health spending and low TFP growth in SSA. In addition, the study aimed to identify the threshold points of the effect of PHE on health outcomes, analyse the moderation effect of education in the relationship between PHE and health outcomes and estimate the minimum thresholds of education required to sustain the influence of PHE on health outcomes. It is important to consider the nonlinear impact of PHE on health outcomes because this offers a better understanding of the complex relationship between PHE and health outcomes in the broader context in which they exist. Positive and negative changes in a causal relationship can affect the health outcome differently. Moreover, exploring nonlinear relationships and threshold effects revealed points or levels at which investment in PHE had the most significant impact on health outcomes.

Secondly, the study forecast the performance of maternal and child mortality in terms of the SDGs' targets (70 deaths per 100,000 births for maternal mortality and 25 deaths per 1,000 live births for child mortality by the year 2030) based on different levels of improvement (10%, 20%, and 30%) in per capita PHE.

Thirdly, the study investigated the role of health and its proxies and non-health factors as determinants of TFP in SSA. This analysis confirmed the existence of a threshold relationship between PHE as well as non-health factors and TFP in SSA.

Lastly, the study examined the interactive impact of PHE and education on TFP in SSA and the collaborative impact of health sector performance and other sectors such as education, agriculture, and manufacturing on TFP in this region. This was motivated by the fact that, while numerous studies have been conducted on health and productivity, the persistently low performance of these variables and relevant factors could be attributed to policymakers' limited understanding of the complex relationships among these variables.

1.3 *Rationale behind a nonlinear relationship*

A nonlinear relationship can occur between variables when there is no direct relationship between the independent and dependent variables. Nonlinear simply means that initially, marginal returns may increase but later decrease. A nonlinear relationship can translate to both positive and negative relationships and a non-linear model can be parametric or non-parametric (Vaidya, 2023; Kamberi, Alimi & Orhani, 2022).

Law of diminishing marginal returns

The law of diminishing marginal product or diminishing marginal returns aligns with economic theories developed by Anne Robert Jacques Turgot (1914). The law of diminishing marginal product is most suitable to explain the mechanisms behind a nonlinear relationship (Ren, Stavrova & Loh, 2021) between public health spending and health outcomes in sub-Saharan African settings. In SSA, in the initial stage of PHE, the pre-threshold stage, the effect will result in a reduction (health benefits will increase) in the mortality rate. A continued increase in PHE will likely result in smaller effect sizes on health outcomes until the threshold point where additional spending will not have any effect. Therefore, beyond the threshold, additional PHE will cause reductions in the health benefits. This could result from misallocation of resources (resources being directed to a low disease prevalence area rather than a high disease prevalence area), or from inadequate PHE or corruption, which are prevalent in SSA countries.

Misallocation of funds or resources: Misallocation of funds or resources, with resources directed to a low disease prevalence area rather than a high disease prevalence one, can result in diminished health outcomes, which could cause overall health to decline. Some studies (see Hsiao, Vogt, & Quentin, 2019) have confirmed the existence of such misallocation in the health system in SSA. This is a variant of inequality. Should the government increase health expenditure to achieve reduced mortalities, such intention may not be realistic if a particular segment of the population (with low disease prevalence) is favoured at the expense of the other (high disease prevalence), thereby leading to an increase in mortalities despite the increase in health expenditure.

1.3.1 Inadequate Health Outcomes, PHE and TFP in SSA

Health outcomes in SSA are generally poor, and LEB is low compared to other regions. The LEB in SSA averaged 62 years in 2019, while it was 64 in low-income countries, 72 in middle-income countries, and 81 in high-income countries (World Bank, 2020). The World Health Organisation (WHO) has highlighted that increased PHE leads to healthier lives, employment creation, and political and social stability and contributes to economic growth and productivity (WHO, 2015). Furthermore, the WHO (2015) found that a 10% increase in LEB corresponds to a 0.35% increase in annual economic growth.

Over the years, countries in SSA have made significant efforts to increase PHE to improve health outcomes and facilitate economic growth. However, health outcomes have only improved marginally (Arthur & Oaikhenan, 2017). This can be attributed to the gap between the amount required to achieve improved health outcomes and the actual amount spent (UNECA, 2019). Furthermore, there is no consensus on the level of PHE required to achieve improved health outcomes in SSA (UNECA, 2019; WHO, 2001). The literature has, however, highlighted that progress towards universal health coverage (UHC) and the SDGs cannot be achieved without adequate resources (Funfkirchen, Lindelow, & Yoo, 2018).

Regarding economic growth, TFP, which represents productivity growth, is crucial in preventing diminishing marginal returns in an economy. Continuous growth without attention to technological frontiers can lead to diminishing returns and a stagnant economy (Solow, 1956). Moreover, inadequate health financing, poor health outcomes, and other economic challenges can hinder productivity growth. To achieve sustainable growth, governments and institutions should allocate resources to the health and education sectors and create an enabling environment by addressing issues like corruption, inflation and other economic problems (Adegoke, Mbonigaba, & George, 2022).

Figure 1.2 below, adapted from the Penn World Table 10.0, illustrates the rate of change in TFP in SSA over time.

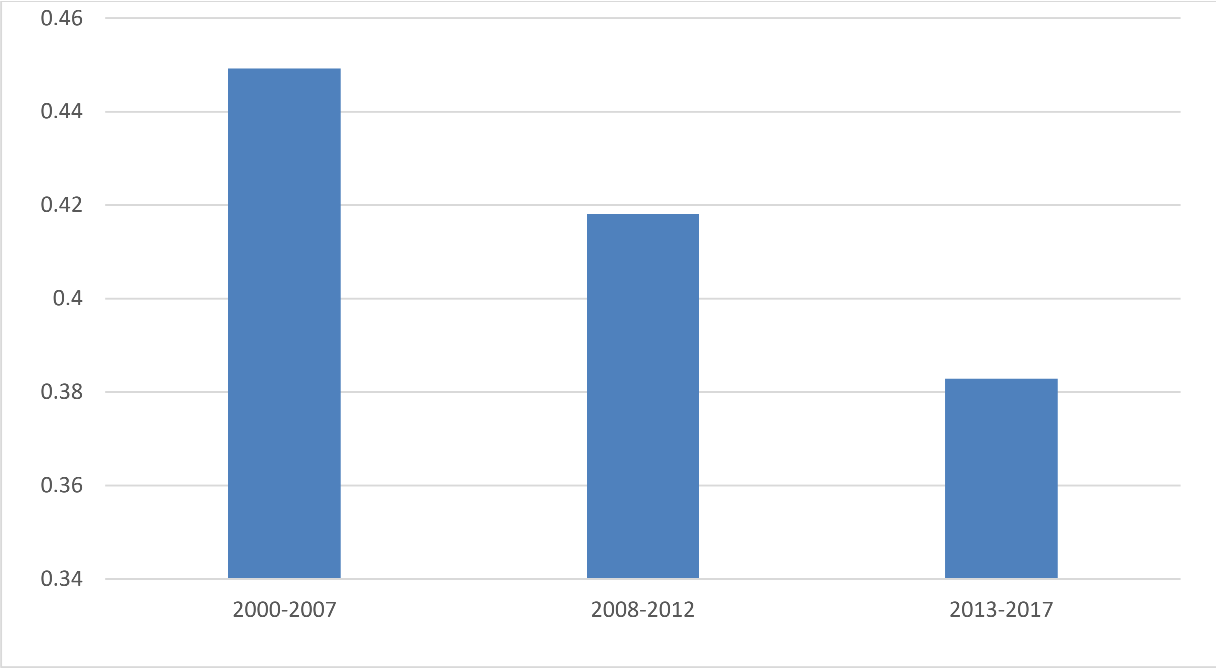


Figure 1.2: Rate of change in TFP in SSA between 2000 and 2017
Source: Author's compilation

In 2001, leaders in SSA pledged to allocate 15% of their budgets towards PHE (WHO, 2010). In the same year, the Commission on Macroeconomics and Health recommended that 12% of GNP should be dedicated to health (WHO, 2010). Mcintyre, Meheus, and Rottingen (2017) proposed that 5% of GNP should be designated for health. Despite these different recommendations, health financing remains a challenge in SSA, hindering potential improvements in health outcomes and TFP growth. It is worth noting that the 15% commitment by SSA leaders resulted from a political meeting rather than being a scientifically informed decision. Furthermore, the Commission on Macroeconomics and Health's recommendation of 12% has faced criticism in the literature due to several shortcomings (WHO, 2001; Waitzkin, 2003).

First, critics have raised concerns about the commission's use of disability-adjusted life years (DALYs) as a measure (Banerji, 2002). Secondly, the commission focused on targeting specific diseases for eradication rather than advocating for the development of an integrated healthcare system (Waitzkin, 2003). This study aimed to address these shortcomings by focusing on the critical indices of health outcomes: maternal mortality, child mortality and LEB. While not specific to data on SSA, Mcintyre, Meheus, and Rottingen's (2017) recommendation of 5% may not be sufficient to achieve UHC in this region.

Sub-Saharan Africa is known to confront distinctive health challenges, including high rates of maternal and child mortality. As a result, the applicability of evidence and recommendations regarding health financing from other low- and middle-income countries may not directly translate to the SSA context when striving to achieve the SDGs. Factors such as limited access to quality healthcare services, inadequate infrastructure, low numbers of healthcare workers and prevailing social and cultural norms can contribute to the persistent health challenges in the region.

Because research from other regions does not necessarily apply to SSA, the study examined the quadratic relationship between per capita PHE and health outcomes in this context. It also investigated the moderating effect of education and identified the threshold level of PHE and education required to attain improved health outcomes. In addition, the study projected the per capita PHE required to reach the SDG targets by 2030. It analysed the association between PHE and TFP growth, identifying the threshold level of PHE that could enhance TFP growth. Lastly, the study explored the interactive impact of PHE and education on TFP.

Information on the nonlinear threshold, moderating and forecasting effect is essential to optimise utilisation of resources in the health sector. Such information is scarce in the literature despite the many studies in this field (see Abbasi, 2022; Raghupathi & Raghupathi, 2020; Xue, 2020; Ibukun, 2021). In addition, it is important to understand the nonlinear threshold and moderating effect of PHE on TFP because adequate information on the relationship between PHE and TFP would reveal the role of health in achieving increases in TFP. In contrast, given the lack of studies in this regard, information on the moderating impact of PHE and education on TFP would help to assess the joint influence of the variables on TFP (see the studies by Jajri, 2007; Loko & Diouf, 2009; Sukazi, 2010; Filip, 2016; Akinlo & Adejumo, 2016; Fadiran & Akanbi, 2017; Timuno, 2017; Olomola & Osinubi, 2018 that did not consider the joint influence of education and PHE on TFP).

1.4 Problem statement

Insufficient expenditure, poor health outcomes and low productivity in SSA are of great concern. This situation persists despite ongoing debate and recommendations that do not seem to work. Despite the number of studies on the relationship between PHE, health outcomes (see Raghupathi & Raghupathi, 2020; Xue, 2020; Ibukun, 2021) and TFP (see Akinlo & Adejumo, 2016; Fadiran & Akanbi, 2017; Timuno, 2017; Olomola & Osinubi, 2018) in SSA, no study has considered PHE and health outcomes as determinants of TFP in this region. An unexplored approach to address these problems is to investigate the linkages using nonlinear and threshold analysis rather than linear relationships to explore whether there is a different relationship from that identified by most previous studies. Threshold analysis was expected to address the wastage and inefficiency that hinder the expected impact on health outcomes and resultant TFP growth.

First, it is important to examine whether the impact of per capita PHE and education on health outcomes aligns with the findings in the existing literature on countries in SSA (see Raghupathi & Raghupathi, 2020; Xue, 2020; Ibukun, 2021). This analysis is crucial because the PHE level in SSA is inadequate to achieve maximum reductions in mortalities. Therefore, establishing baseline results that justify nonlinear and threshold analysis is instructive. Specifically, it is necessary to determine whether the effect of PHE on health outcomes is directly proportional or if it has a more pronounced impact at certain funding levels. In addition, it is important to explore whether there is a threshold level beyond which the effect of public expenditure on health differs significantly and to investigate how education moderates the effect of PHE on health outcomes. Identifying the minimum threshold points at which the moderation impact of education and PHE influence health outcomes is also essential.

Second, an assessment is required to determine if a particular magnitude of increase in per capita PHE can effectively meet the targets set by the SDGs. This will provide valuable insights into the relationship between PHE and the desired outcomes outlined by the SDGs, shedding light on the effectiveness of investing in healthcare to address mortality rates in SSA.

Third, the role of PHE and health outcomes as determinants of TFP in SSA needs to be confirmed. Furthermore, there is a need to reaffirm the influence of non-health factors on TFP in the region and examine whether there is a threshold beyond which PHE becomes effective in improving productivity through its impact on health outcomes. In addition, it is necessary to investigate the existence of a threshold relationship between non-health factors and TFP in SSA.

Fourth, it is appropriate to examine the moderation effect of education on the impact of PHE on TFP and to explore the collective influence of PHE and other sectors, including manufacturing, agriculture and education on TFP. This analysis provides a comprehensive understanding of how education acts as a moderating factor in the relationship between PHE and TFP, as well as the combined effect of PHE and various sectors on overall productivity in SSA.

By addressing these aspects, governments could gain valuable insights into improving health financing, enhancing health outcomes and ultimately increasing productivity in SSA.

1.5 Research objectives and hypotheses

Despite the number of studies on the relationship between PHE, health outcomes (see Raghupathi & Raghupathi, 2020; Xue, 2020; Ibukun, 2021) and TFP (see Jajri, 2007; Loko & Diouf, 2009; Sukazi, 2010; Filip, 2016; Akinlo & Adejumo, 2016; Fadiran & Akanbi, 2017; Timuno, 2017; Olomola & Osinubi, 2018) in SSA, no study has considered PHE and health outcomes as determinants of TFP in this region. Therefore, the following research objectives and hypotheses were formulated.

1.5.1 Research objectives

The study aimed to explore the relationships between PHE, health outcomes and TFP in SSA, focusing on sustainable thresholds, moderation effects, and forecasting. In a broader sense, it is important to consider the nonlinear impact of PHE on health outcomes because this offers a better understanding of the complex relationship between these factors in the broader context in which they exist. Changes in a causal relationship can affect the health outcome differently. Moreover, exploring nonlinear relationship threshold effects and forecasting the health outcomes in relation to PHE revealed points or levels at which investment in PHE had the most significant impact on health outcomes and TFP, which are most relevant in preparing SSA countries to achieve the SDG 2030 targets.

The study's objectives were as follows:

1 **Investigate the nonlinear effect of PHE and the moderating role of education on health outcomes. This was necessary to ascertain whether a nonlinear or a linear relationship exists, while the moderation analysis will enhance understanding of the moderation impact of education on health outcomes.**

1i Reaffirm the crucial role of PHE and education as critical determinants of health outcomes. This analysis established baseline results to provide a foundation to justify nonlinear and threshold analysis.

1ii Confirm the nonlinear (quadratic) effects of PHE on health outcomes.

1iii Determine the specific threshold points of PHE that significantly impact health outcomes.

1 iv Analyse the moderation effect of education in the relationship between PHE and health outcomes.

1v Estimate the minimum thresholds of education required to sustain the influence of PHE on health outcomes.

2 **Forecast PHE scenarios towards achieving Goal 3 of the 2030 SDGs** because the PHE level in SSA is inadequate in achieving optimal reductions (in relation to the SDG targets) in mortalities.

2. i Forecast maternal and child mortality by the year 2030 based on a 10% increase in the current levels of PHE in SSA.

2. ii Forecast maternal and child mortality by the year 2030 based on a 20% increase in the current levels of PHE in SSA.

2. iii Forecast maternal and child mortality by the year 2030 based on a 30% increase in the current levels of PHE in SSA.

3 **Investigate the role of PHE and health outcomes as determinants of TFP in SSA because health is expected to enhance TFP growth.**

3. i Re-affirm the impact of non-health factors on TFP in SSA.

3. ii Confirm the existence of a threshold relationship between PHE and TFP in SSA.

3. iii Confirm the existence of a threshold relationship between non-health factors and TFP in SSA.

4 **Assess the moderating role of education in PHE's effect on TFP as an alternative human capital variant.**

4. i Examine the collaborative impact of PHE and other sectors such as education, agriculture, and manufacturing on TFP in SSA.

1.5.2 Hypotheses

The study tested the following hypotheses and sub-hypotheses:

Hypothesis 1: PHE does not have a nonlinear effect on health outcomes, and the interactive effect of PHE and education on health outcomes is insignificant.

- Sub-hypothesis 1i: PHE and education are not critical determinants of health outcomes, as measured by maternal and child mortality and LEB.
- Sub-hypothesis 1ii: PHE does not have a nonlinear effect on health outcomes, as measured by maternal and child mortality and LEB.
- Sub-hypothesis 1iii: There are no threshold points of PHE on health outcomes, specifically maternal mortality, infant mortality and LEB.
- Sub-hypothesis 1iv: Education and PHE do not moderate health outcomes, as measured by maternal and infant mortality and LEB.
- Sub-hypothesis 1v: No threshold level of education can sustain the influence of PHE on health outcomes, as measured by maternal and infant mortality and LEB.

Hypothesis 2: The forecast PHE scenarios of a 10%, 20% and 30% increase cannot achieve Goal 3 of the 2030 SDGs.

Hypothesis 3: PHE and health outcomes do not play a role as determinants of TFP in SSA.

- Sub-hypothesis 3i: Non-health factors do not significantly impact TFP in SSA.
- Sub-hypothesis 3ii: No threshold relationship exists between PHE and TFP in SSA.
- Sub-hypothesis 3iii: No threshold relationship exists between non-health factors and TFP in SSA.

Hypothesis 4: Education and PHE do not have a moderating effect on TFP in SSA.

- Sub-hypothesis 4i: PHE and the output of other sectors such as education, agriculture, and manufacturing do not significantly impact TFP in SSA.

1.6 Contributions to knowledge and significance of the study

1.6.1 Contributions to knowledge

The study makes several contributions to knowledge on the PHE-TFP nexus in SSA. The existing literature primarily focuses on the effect of PHE on health outcomes and determinants of health outcomes. It does not consider the moderating effect of education on the relationship between PHE and health outcomes or determine the threshold levels of PHE and education necessary for improved health outcomes in SSA, which the current study did. Specifically, it is necessary to determine whether the effect of PHE on health outcomes is directly proportional or if it has a more pronounced impact at certain funding levels.

The study also provides in- and out-of-sample forecasts for maternal and child mortality in SSA regarding the SDG 2030 targets. In addition, by considering scenarios of percentage increases to current levels of PHE, it determined the percentage of PHE necessary to achieve the targets of the health SDGs by 2030. To the best of the researcher's knowledge, these analyses have not been conducted specifically for SSA.

The existing literature on TFP primarily focuses on macroeconomic and institutional variables, with limited emphasis on the effect of PHE and health outcomes on TFP. The current study filled this gap by investigating the impact of PHE and health outcomes on TFP in SSA. Furthermore, it examined collaboration between PHE and other sectors (manufacturing, agriculture and education) and their collective impact on TFP. This analysis provided insights into the inclusion of health in the productivity framework and its potential effect on other sectors in relation to TFP.

1.6.2 Significance of the study

According to Hsiao, Vogt, and Quentin (2019), the health sector in SSA suffers from inefficiency and wastage, which hinder optimal utilisation of health investment. To address this issue and achieve the SDGs in SSA, it is crucial to determine the threshold level of PHE required to alleviate the high burden of mortality in the region. The study thus empirically investigated the relationship among healthcare financing, health outcomes and productivity, considering the significance of PHE in improving health outcomes and its implications for productivity.

A thorough threshold analysis was conducted to estimate the specific level of PHE necessary to achieve sustainable TFP growth. This could guide governments in SSA to invest appropriately in healthcare and thus not only improve health outcomes but also enhance TFP. Currently, PHE on healthcare services in SSA is insufficient, negatively impacting TFP. This situation is exacerbated by conflicting recommendations by various sources.

Healthcare financing plays a vital role in reducing the burden of preventable diseases, lowering mortality rates and enhancing the population's overall well-being. When individuals have access to quality healthcare services and preventive measures, they are less likely to suffer health-related issues that could hinder their productivity and economic potential. Therefore, by underscoring the importance of healthcare financing in promoting sustainable development and economic growth, the study recognised that investment in healthcare goes beyond immediate health outcomes and contributes to the broader socio-economic advancement of a nation.

By determining the threshold level of PHE, the study aimed to address the wastage and inefficiency that hinder the expected impact on health outcomes and resultant TFP growth. In other words, calculating the threshold level of PHE necessary to maximise the return on investment in terms of improved health outcomes and enhanced TFP growth sheds light on the point at which the benefits of healthcare financing could surpass the wastage and inefficiency inherent in the system.

Being aware of the threshold could assist governments and healthcare stakeholders to make informed decisions concerning the necessary PHE level to achieve desired health outcomes and promote TFP growth. There is a lack of comprehensive research on this aspect, further emphasising the significance of this study's contributions.

1.7 Methodology and scope

1.7.1 Methodology

Various econometric models and techniques were employed to achieve the study's objectives.

Panel spatial correlation consistent pooled ordinary least squares (PSCC-OLS) and panel spatial correlation consistent fixed effects (PSCC-FE) models were used for Objective 1. These models consider spatial correlation amongst the observations and provide robust estimates for the relationships between variables.

The feasible generalized least squares (FGLS) method was employed for Objective 2. This approach was suitable to address heteroscedasticity and autocorrelation in data analysis, allowing for efficient parameter estimation, especially in linear models.

Objective 3 involved using fixed and random panel models, panel two-stage least squares (P2SLS), panel threshold regression and dynamic panel threshold regression. These models enabled an examination of threshold effects and nonlinear relationships between variables, accounting for potential endogeneity issues.

The generalized method of moments (GMM) was employed as the estimating technique for Objective 4. This versatile method addresses endogeneity concerns by utilising moment conditions derived from the model's assumptions.

Detailed information on the specific models and techniques used in the study is provided in the analytical chapters (Chapters 3-6) that comprehensively explain the methodologies employed, ensuring transparency and clarity in the analytical process.

1.7.2 Scope of the study

Based on data availability, the study covered the period 1995 to 2020. Achievement of Objectives 1, 3 and 4 involved analysing data from 2000 to 2020 while realising Objective 2 entailed data from 1995 to 2020 to improve the outcome of the projection analysis. Data scarcity, particularly for PHE, limited the study's scope. Most countries in SSA lacked data on PHE before 1995, and thus, the study used the latest available data from sources such as the WHO, the World Bank and the Penn World Table 10.0.

Different variants of PHE were incorporated into the study. Attaining Objectives 1 and 2 entailed using data on PHE per capita, while satisfying Objective 3 involved using data on both

PHE and PHE per capita. In the main analysis, PHE (the total amount of public funding as a percentage of Gross Domestic Product (GDP)) was used, with PHE per capita (average amount of funding allocated per individual) for robustness checks. The realisation of Objective 4 entailed using only PHE to enhance the robustness of the results in terms of the study's focus on public health financing.

Forty-six countries in SSA were initially considered based on data from the WHO and the World Bank. However, the number was reduced to 25, as data on TFP was only available for these countries.

A similar study by Fadiran and Akanbi (2017) focused on institutional and other determinants of TFP in SSA using a panel of 26 countries from 1990 to 2011. Despite the limitation relating to country coverage, their study generated reliable and consistent results applicable to policy formulation, which influenced the decision to conduct this study in only 25 countries.

The selected period of 1995 to 2020 coincided with the United Nations Millennium Development Goals (UN MDGs) for 2015, which were formulated in 2000. Several of the MDGs were dedicated to improving health. The selected period also encompassed the meeting held in Abuja, Nigeria, in 2001, when African countries resolved to invest at least 15% of their GNP in PHE (WHO, 2001). In addition, this period aligns with the Commission on Macroeconomics and Health’s (WHO, 2001) recommendation to increase healthcare spending in SSA. It overlaps with the initiation in 2015 of the SDGs for 2030. It also covers the period of the economic downturn or meltdown, which affected most world economies. In 2008, all economic activities were affected throughout the globe. The scope of this study covers this period to determine whether health outcomes change with changes in economic activities.

1.8 Thesis outline

This thesis is structured into seven chapters to accomplish the study’s objectives. Chapter 1 provides the study’s background, problem statement, objectives and hypotheses, contributions, and the thesis outline. It presents the contextual background of SSA as relevant to the study's findings.

Chapter 2 offers a brief overview of the health status of SSA, PHE, macroeconomic conditions, and TFP.

Chapter 3 focuses on the first objective, examining the linear and quadratic relationship between PHE and health outcomes such as maternal mortality, infant mortality, and LEB. It also explores the interactive and moderating effects of education and PHE on these health outcomes.

Chapter 4 addresses the second objective, providing forecasts for the level of PHE required to achieve the targets of maternal mortality (70 deaths per 100,000 births) and infant mortality (25 deaths per 1,000 births).

Chapter 5 centres on the third objective, investigating the linear and nonlinear relationship between PHE and TFP.

Chapter 6 focuses on the fourth objective, examining the interactive impact of PHE and education on TFP. It also analyses the collaborative impact of PHE and the manufacturing/agricultural sectors on TFP.

Chapter 7 summarises the study and offers recommendations based on the results.

It should be noted that Chapters 3, 4, 5 and 6 are self-contained and encompass the relevant literature, methodological approaches, results and discussions.

1.9 Chapter summary

Chapter 1 set the stage for the study. It began by providing the necessary background information and contextualising the research within the broader field of study. This included discussing the relevant literature and identifying the existing gaps the study aimed to address. By reviewing the current state of knowledge, the chapter established the significance and relevance of the research.

The chapter also set out the aim and objectives that guided the study, ensuring it remained focused and aligned with its intended outcomes. The problem statement was also presented, clearly articulating the issue that the study sought to investigate. This helped to establish the rationale for the research and highlighted its importance within the academic and practical realms.

One of the aspects covered in Chapter 1 was the study's contributions to the existing literature. This section highlighted the originality of the research and how it extends current knowledge in the field. By identifying the gaps in the literature and explaining how the study fills those gaps, the chapter underscored the value and potential impact of the research.

Lastly, Chapter 1 provided an overview of the structure of the thesis to provide a roadmap for readers, giving them a clear understanding of how the subsequent chapters are organised and what they aim to accomplish.

CHAPTER 2

THE SUB-SAHARAN AFRICAN CONTEXT

2.1 Introduction

This chapter presents a comprehensive overview of the sub-Saharan African context regarding PHE, health outcomes and TFP. Furthermore, it provides the necessary contextual background for the study, establishing the interconnectedness of the variables under investigation. The chapter is structured to facilitate a systematic understanding of the context. Section 2.2 presents a profile of sub-Saharan African countries, offering a comprehensive overview of the region's characteristics and contextual background. Section 2.3 delves into PHE in SSA, providing a detailed discussion on its key aspects and dynamics. Building on this, Section 2.4 presents an overview of SSA health outcomes, exploring various factors that influence health outcomes within the region.

Section 2.5 provides an insightful overview of TFP in SSA, shedding light on its implications for economic development. Section 2.6 examines education in SSA, highlighting its role as a determinant of health outcomes and TFP. This section provides valuable insights into the educational landscape of the region. Section 2.7 delves into the determinants of PHE, exploring the factors that shape the allocation and utilisation of financial resources in the health sector. This analysis facilitates an understanding of the complexities of PHE in SSA. Section 2.8 establishes the relationships between PHE, health outcomes and TFP in SSA, highlighting their reciprocal impact.

The chapter concludes with a summary in Section 2.9, which encapsulates the main points discussed throughout the chapter, providing a concise overview of the SSA context in relation to PHE, health outcomes and TFP. This summary serves as a transition to the subsequent chapters, ensuring smooth progression of the research report.

2.2 Contextual background

Despite being home to only 13% of the global population in 2019, SSA shoulders the largest burden of maternal and infant mortality. The region accounted for a staggering 66% of maternal deaths worldwide, with an MMR of 546 deaths per 100,000 births. In comparison, Latin America/the Caribbean, South/East Asia, the Pacific region, the Middle East/North Africa and

Europe/Central Asia reported 534, 74, 163, 69 and 57 maternal deaths per 100,000 births, respectively. Sub-Saharan Africa also has the highest adult lifetime risk of maternal mortality, with 1 in 36 women at risk. In contrast, the global average is 1 in 180 women, with 1 in 210 women in Southern Asia, 1 in 380 in Eastern Asia, and 1 in 4,900 in developed countries. Infant mortality rates in SSA are also among the highest in the world (WHO, 2015; UN, 2017b).

Table 2.1 below provides insights into the characteristics of the selected SSA countries included in this study by presenting the health outcomes variables and key economic indicators for these countries in 2017. The table offers a comprehensive overview of the selected countries, facilitating a comparative analysis of their health outcomes and critical economic indicators.

Table 2.1: Health outcomes and key macroeconomic variables for 25 countries in SSA

Country	**PHE (2017)**	**LEB (2017)**	**MMR (2017)**	**CMR (2017)**	**Inflation Rate (2017)**	**GNP Growth Rate**	**TFP Growth Rate (2017)**
Angola	1.29	60	241	81	29.8	-0.1	0.33
Benin	0.81	61	397	98	0.36	5.7	0.22
Botswana	4.64	68	144	37	3.3	2.9	0.57
Burkina Faso	2.99	60	320	81	0.4	6.2	0.27
Burundi	1.86	60	548	62	16.6	0.5	0.21
Cameroon	0.62	58	529	84	0.68	3.5	
Central African Republic	0.73	52	829	121	4.1	4,5	0.23
Côte d'Ivoire	1.27	57	617	61	0.68	7.4	0.68
Democratic Republic of the Congo	1.20	60	567	78	41.5	3.7	0.42
Kenya	2.06	65	342	45	8.0	3.5	0.33
Lesotho	5.4	52	544	85	5.3	-1.3	0.22
Mauritius	2.4	74	61	13	3.7	3.8	0.81
Mauritania	1.7	64	766	79	2.3	3.5	0.28
Madagascar	2.32	66	183	38	8.5	3.9	0.25
Mozambique	1.4	59	273	55	15	3.7	0.36
Namibia	3.85	63	241	29	6.14	-0.30	0.64
Niger	2.5	61	226	49	2.4	5.0	0.19
Nigeria	0.53	53	917	100	16	0.8	0.52
Rwanda	2.2	68	248	37	4.8	4.0	0.23
Senegal	0.86	67	315	45	1.3	7.4	0.47
Sierra Leone	1.84	53	1120	110	18	4.2	0.23
South Africa	4.35	63	119	37	5.3	1.4	0.53
Tanzania	1.58	64	524	54	5.3	2.37	0.25
Togo	0.92	60	396	72	-0.7	4.4	0.17

Source: World Bank (2018)

2.2.1 *Profile of 25 countries in SSA*

The following sub-sections present a profile of each country selected for the study. Most of the data were sourced from the Penn World Table 10.0, the World Bank (2018) and the WHO (2020). A detailed discussion of each country is provided, examining its specific context and the relevant factors influencing the variables under investigation.

2.2.1.1 Angola

Angola's economy mainly relies on oil exports, and the decline in oil prices has kept the economy in recession since 2015. The crisis was escalated by the effect of the COVID-19 pandemic in 2020. The GNP growth rate was 2.0% in 2018, with an inflation rate of 29.8% in 2017, which fell to 17.5% in 2019, and the productivity growth rate was 0.33% in 2017. In 2017, 1.29% of GNP was allotted to health because, between 2000 and 2016, less had been expended on this sector, resulting in 241 maternal and 81 child deaths in Angola, with LEB of 60.

Information provided by the World Bank (2018) shows that the health indices have been improving but are still inadequate. The country needs to increase its PHE beyond the mere 1.07% allotted to health in 2018 for better health outcomes and technological improvement, which could achieve a sustainable TFP growth rate.

2.2.1.2 Benin

The country mainly depends on agriculture, with a special focus on cotton. The GNP growth rate was 5.8% in 2017, and the TFP growth rate was 0.22%, with a very low inflation rate of 0.36%. The country committed to increasing public spending from 21% of GNP in 2016 to 29.6% in 2019. In addition, it recorded average PHE of 0.95% between 2000 and 2016, while in 2018 and 2017, the government only spent 0.81 and 0.49% of GNP on health, respectively, despite the MMR of 397 deaths per 100,000 births and child mortality of 98 deaths per 1,000 children recorded in 2017 while the LEB was 61 years. Benin would have had a better health outcome if a larger proportion of GNP had been allotted to health, and in turn, improved health outcomes could enhance TFP growth in the country (Novignon *et al.*, 2012).

2.2.1.3 Botswana

Botswana, an emerging economy with a GNP growth rate of 4.5% in 2018, specialises in diamond mining. In 2017, the inflation rate was 3.3%, and the TFP growth rate was 0.57%.

The LEB was 68, and the MMR was as low as 144 deaths per 100,000 births (World Bank, 2018). The CMR was also low at 37 deaths per 1,000 children, but the rate was above the 25 deaths per 1,000 stipulated in the SDG target. The improvement in health outcomes can be linked to the increase in PHE. In 2017, the country spent only 4.64% of GNP on health, rising to about 5.53% in 2018. The government's commitment to health had a corresponding effect on productivity growth. Despite improved health outcomes, Botswana was bedevilled by a high HIV-prevalence rate of 20.7% in 2019.

2.2.1.4 Burkina Faso

Burkina Faso is a low-income country with a large percentage of youth (1 out of 10 people is less than 30 years old) and a total population of more than 20 million. Business and trade activities were severely affected by the COVID-19 pandemic, resulting in a contraction of 0.2% in GNP in 2020. The GNP growth rate in 2017 was 6.2%, while in 2018, it was 6.7%. The inflation rate in 2017 was 1.4%, which increased to 3.2% but returned to 1.4% in 2020. The TFP growth rate was 0.27% in 2017. In 2018, the country invested 2.39% of GNP in healthcare, the LEB was 60, the MMR was 320 deaths per 100,000 births, and the CMR was 81 per 1,000 births. Burkina Faso's health outcome indicators are still far from the SDG targets, with resultant low productivity growth.

2.4.1.5 Burundi

Burundi is a low-income country, and farming is the mainstay of the economy. In 2019 estimates, more than 50% of its inhabitants were women. The GNP growth rate was 1.8% in 2019 and 0.5% in 2017, while the inflation rate was 16.6%, and the productivity growth rate was 0.21% in 2017. LEB was 60 years in 2017, the MMR was 548 per 100,000 births, and the CMR was 61 per 1,000 births. Average PHE between 2000 and 2016 was 2.0% of GNP; however, in 2017 and 2018 the government spent 1.86% and 1.90% of GNP on health. Although the percentage of the GNP allotted to health has increased, more needs to be committed to improve health outcome indicators and increase productivity.

2.2.1.6 Cameroon

Cameroon's GNP grew by 3.5% in 2017, with an inflation rate of 0.68%, while LEB was 58, the MMR was 529 deaths per 100,000 births, and the CMR was 84 deaths per 1,000 births. The country invested only 0.62% of its GNP in health in 2017; therefore, poor health outcomes can be traced to poor investment in health despite the GNP growth rate increasing from 3.5% in

2017 to 4.1% in 2018. Future poor health outcomes may pose a threat to the growth thus far recorded if proper attention is not paid to health funding.

2.2.1.7 Central African Republic

The major source of income is agriculture, which accounts for about half the country's domestic product. The GNP growth rate was 3.8% in 2018, increasing to 4.8% in 2019. The inflation rate was 6.44% in 2017 and 3.2% in 2019, while the productivity growth rate was only 0.23%. This can be linked to poor health outcomes because a healthier population is more productive than an unhealthy one. The country had a life expectancy of 52 years in 2017, maternal mortality of 829 deaths per 100,000 births and child mortality of 121 deaths per 1,000 births. Despite the poor health outcomes, the government reduced PHE from 0.73% in 2017 to 0.69% in 2018. Therefore, it needs to reschedule its public spending with a special focus on health.

2.2.1.8 Côte d'Ivoire

The economy of Côte d'Ivoire greatly depends on agriculture. The GNP growth rate in 2017 was 7.7% and fell to 6.5% in 2019; while the productivity growth rate was 0.68% in 2017, and despite the favourable macroeconomic indices, the inflation rate was 0.68%. The LEB was very low from 1986 to 2000. In 2016, it increased to 53, while in 2017, it was 57. The CMR was 61 per 1,000 births, and the MMR was 617 per 100,000 births. The country invested 1.21% of GNP in health in 2018, which was not much given its health challenges. Côte d'Ivoire's citizens suffer poor health, as reflected in the LEB and other health outcome indices like HIV prevalence.

2.2.1.9 Eswatini

The country is popularly known as Swaziland, but Eswatini is its new name. The GNP growth rate was 1.9% in 2017 and 2.2 in 2019. However, it contracted by 3.3% in 2020. The inflation rate was 6.2% in 2017 but fell to 4.3% and 2.6% in 2018 and 2019, respectively. The inflation rate later increased to 4% in 2020 due to the COVID-19 pandemic's impact on the economy. Eswatini is bedevilled by high levels of poverty; more than 60% of the population is poor. More than a quarter of the population is living with HIV and AIDS, the highest prevalence rate in the world. The productivity growth rate was 0.71 % in 2017. LEB was 58 in 2017, while the MMR and CMR were 437 per 100,000 births and 62 per 1,000 births, respectively, in the same year. The government invested 3.51% and 2.15% of GNP in health in 2017 and 2018, respectively.

2.2.1.10 Gambia

Gambia's GNP growth rate was 0.8% in 2017, but it increased to 2.9% in 2019, with a decline of 21% in 2020 due to the drop in oil production on which the country mainly depends. Gambia is one of the countries that slipped into a recession in 2020 owing to the combined effect of a fall in oil prices and COVID-19. The inflation rate was 2.7% in 2017, the productivity growth rate was 0.55 %, and the LEB was 66. In 2017, Gambia recorded an MMR and CMR of 252 per 100,000 births and 45 per 1,000 births, respectively. Average PHE between 2000 and 2016 was 1.4% of GNP, while in 2017 and 2018, the government invested 1.76% and 1.61% of GNP in health.

2.2.1.11 Kenya

Kenya had a GNP growth rate of 6.3% in 2018 and was regarded as one of the fastest-growing economies in the world, with a productivity growth rate of 0.33% in 2017 and an inflation rate of 8% in 2018. Kenya's PHE was 2.06% and 2.18% of GNP in 2017 and 2018, respectively. The LEB was 65, maternal mortality was 342 deaths per 100,100 women, and child mortality was 45 deaths per 1,000 births in 2017. Despite the increase in PHE, the health outcomes (maternal and child mortality) remained poor, probably because such investment was insufficient.

2.2.1.12 Lesotho

The GNP growth rate in Lesotho was 0.4% and 1.5% in 2017 and 2018, respectively. The country was affected by economic crises in other countries like South Africa because it depends on workers' remittances from these countries. Income distribution disparities remain rampant, with 54% of the population living under the poverty threshold. In 2017, the LEB was 52, maternal mortality was 544 deaths per 100,000 births, and child mortality was 85 deaths per 1,000 births. The poor health outcomes led to investment of 5.5% of GNP in health in 2018, a small increase of 5.43% between 2000 and 2016. In addition, the HIV prevalence rate in this country is 22.8%, one of the highest in the world.

2.2.1.13 Mauritius

The economy of this sub-Saharan African island mainly depends on its service sector, which contributes about 76% of GNP. It is thus an upper middle-income country with a productivity growth rate of 0.81% in 2017, the highest in SSA. The GNP growth rate was 3.7% in 2018, with a moderate inflation rate of 3.6% in 2017. Between 2000 and 2016, the government invested an average of 1.89% of the country's GNP in health, which increased to 2.4% in 2017, although this is not high compared with other countries that were able to improve health outcomes. Moreover, because macroeconomic indices like the inflation rate were favourable, investment in health improved the MMR to 61 per 100,000, the lowest in SSA countries in 2017. The CMR was 13 per 1,000 births, which was also low, Mauritius recorded an LEB of 74 in 2017.

2.2.1.14 Mauritania

Mauritania's GNP growth rate was 3.0% in 2017, with productivity growth of 0.28%, and inflation at 2.2%. The GNP growth rate was estimated at 3.6% in 2018, which resulted in an investment of 1.64% of GNP in health in that year. However, the poor health outcomes of 2017, when the country's maternal mortality was 76 deaths per 100,000 births, and child mortality was 79 deaths per 1,000 did not improve. Although the LEB was 64 years in 2017, which was not too low, the high maternal and child mortality rates threaten the country's realisation of SDG Targets 3.1 and 3.2 by 2030.

2.2.1.15 Mozambique

Mozambique's GNP growth rate was 3.7%, 3.4% and 2.2% in 2017, 2018 and 2019, respectively. While the economy is dominated by agriculture, the country relies on workers' remittances from South Africa. The economy experienced a contraction of 0.5% in GNP due to the COVID-19 pandemic. In 2017, the inflation and productivity growth rates were 15.3% and 0.36%, respectively. Moreover, the MMR was 289 per 100,000 births, the CMR was 72 per 1,000 births, and life expectancy was 59 in 2017, one of the lowest in SSA. In the same year, although the government allotted 1.4% of the country's GNP to health, misspending brought about poor health outcomes.

2.2.1.16 Namibia

The Namibian economy is dominated by mining, while agriculture and government services contribute to income and employment (Humavindu & Stage, 2013). The economy recorded a GNP growth rate of 0.3% in 2017 after the 2016 recession. However, in 2018, there was a 12.2% decline in mining, which affected Namibia's weak economy and increased poverty, inequality and unemployment. The GNP growth rate was 0.26 in 2017, 0.7% in 2018 and -0.95% in 2019. The productivity growth rate was 0.64% in 2017, with an inflation rate of 6.1%.

PHE was 3.85 in 2017, and the LEB was 63 years. PHE had a resultant effect on the MMR of 195 deaths per 100,000 births and the CMR of 29 deaths per 1,000 births in 2017. From 2000 to 2016, the country invested an average of 5.64% of GNP in PHE, the highest among the SSA countries.

The maternal and child mortality rates fell drastically in 2017, but the country is still far from attaining the SDG target of 70 deaths per 100,000 women for maternal mortality. However, it is close to reaching 25 deaths per 1,000 births by 2030. The performance recorded in relation to health indicators can be linked to the high productivity growth of 0.64 in 2017 and 2018; as noted by Grossman's (1972) theory, improvements in output cannot be divorced from the quality of human capital.

2.2.1.17 Niger

Niger's GNP growth rate averaged 5.6% from 2016 to 2018. Specifically, in 2017, the GNP growth rate was 4.9%, and the productivity growth rate was 0.19%, one of the lowest in SSA countries, with an inflation rate of 2.7%. Nevertheless, poor health outcomes increased PHE from an average of 1.8% between 2000 and 2016 to 2.43% in 2018. This was expected to improve health outcomes and enhance productivity growth.

2.2.1.18 Nigeria

Nigeria is regarded as the largest economy in Africa, followed by South Africa, but it has not performed in line with its citizens' expectations, especially regarding health financing and outcomes. Between 2000 and 2016, the government spent only 0.58% of GNP on health, which is low given the size of its population. While PHE remained at 0.58% of GNP in 2018, maternal deaths in 2017 were 917 deaths per 100,000 women, while child mortality was 100 deaths per 1,000 births, and life expectancy was 53, the lowest in SSA.

The productivity growth rate was 0.52%, with an inflation rate of 16% in 2017, which was quite high, although the GNP growth rate was only 1.92% in 2018. Nigeria has vast material and human resources, but has been unable to translate them to productivity growth, possibly because insufficient attention is paid to health. The country has invested a high proportion of its income in overseas healthcare while local health facilities are outdated and inadequate, and there are incessant strikes by doctors due to poor remuneration (Omoleke & Taleat, 2017; Oyekale & Oyelake, 2017). In addition, high inflation rates might impact this country's health outcomes and productivity growth.

2.2.1.19 Rwanda

Economic development in Rwanda has been impressive because of the assistance of development partners like the World Bank. However, the country mainly relies on agriculture and the returns from this sector have not been sufficient to feed the growing population, which has led to increased food imports. The country had a GNP growth rate of 2.37% in 2017, which increased to 8.6% in 2018, and the productivity growth rate was 0.23% with an inflation rate of 8.2% in 2017. An average 1.8% of GNP was expended on health from 2000 to 2016, while the LEB was 68 years, and maternal mortality and child mortality were 248 and 37 deaths per 100,000 and 1,000 births, respectively, in 2017. In 2018, the government allocated 2.37% of the country's GNP to health. Therefore, an increase in health financing is required to improve health outcomes and productivity growth.

2.2.1.20 Senegal

GNP growth in Senegal was rated as one of the most impressive in Africa between 2014 and 2018. It stood at 7.1% in 2017 and 6.8% in 2018, which improved the average GNP by 4% between 2000 and 2012. Moreover, the productivity growth rate was 0.47% in 2017, with a low inflation rate of 1.3%. The mainstay of the economy is mining and agriculture, which contribute about 50% of GNP. The government spent 1.73% of the country's GNP on health from 2000 to 2016. However, since 2018, only 0.95% of GNP has been invested in health, which has not improved health outcomes. The LEB was 67 in 2017, and maternal and child mortality rates were 315 and 45 deaths per 100,000 and 1,000 births, respectively. Thus, health outcomes in terms of MMR and CMR have yet to reach the standard stipulated for meeting SDG Targets 3.1 and 3.2, and more commitment from the government to health financing may improve health outcomes and productivity growth in Senegal.

2.2.1.21 Sierra Leone

Sierra Leone's economy has been severely affected by the devastating effect of the Ebola virus, which has impacted the GNP, inflation rate and health outcomes. The GNP growth rate was 3.8% in 2017, dropping to 3.5% in 2018, and the inflation rate was 18% in 2017, rising to 24.8% in 2019, which is high. Moreover, the high inflation rate negatively impacted healthcare costs in the country. As Jackson, Tamuke and Jabbie (2019) maintain, the government's inadequate implementation of policies to improve health facilities increased the cost of medical services in Sierra Leone.

Between 2000 and 2016, the country spent an average of 1.5% of GNP on health. This had serious long-term implications for the sector, and the LEB was 53 in 2017, with 1,120 maternal deaths per 100,000 women, one of the highest in the world. Moreover, the CMR was 110 per 1,000 children in 2017. In 2018, the government increased its commitment to health by spending 1.56% of the country's GNP on health. Nevertheless, due to the previous high levels of maternal and child mortality, it should increase its expenditure on health to improve health outcomes and, ultimately, productivity growth.

2.2.1.22 South Africa

The South African economy is regarded as the second largest in Africa after Nigeria. The country had a GNP growth rate of 0.8% in 2018 and 0.2% in 2019, with a contraction of 8.2% in real GNP due to the COVID-19 pandemic in 2020. South Africa suffered a 32% contraction in its domestic investment despite the Reserve Bank of South Africa reducing the interest rate from 6.5% to 3.5%. The inflation rate was 5.1% in 2017, declining to 3.4% in 2020, the lowest since 2004 when it stood at 1.4%, and the second lowest since 1969, when it was 3.0%. Moreover, the productivity growth rate was only 0.53% in 2017.

In 2017, the country's LEB was 63 years, with an MMR of 119 deaths per 100,000 women and a CMR of 37 deaths per 1,000 births. Between 2000 and 2016, average PHE was 3.43%. The government was expected to invest more in the health system in 2021 for improved health outcomes for the 83% of the population that depends solely on government hospitals (National Department of Health, 2020) and to address HIV-TB and HIV prevalence rates, which were 17% and 19%, respectively of the global total in 2019.

2.2.1.23 Sudan

The growth in GNP in Sudan between 1999 and 2011 can be attributed to gains from oil production. The interruption of oil production meant that the country mainly depends on agriculture, which contributes about 30% of GNP and 80% of employment opportunities. The Sudanese economy confronted a number of issues, such as debt crises and a high inflation rate before the onset of the COVID-19 pandemic in 2020. In 2019, GNP contracted by 2.5%, followed by a triple-fold contraction in 2020. In 2017, the inflation rate was 32.4%, rising to 82.4% and 124% in 2019 and 2020, respectively. The productivity growth rate was 0.42% in 2017. In 2017, LEB was 65, the MMR was 295 deaths per 100,000 births, and the CMR was 62 per 1,000 births. The GNP growth rate was 0.8% in 2017, resulting in investment of 1.14% of GNP in health, but health spending was reduced to 1.03% in 2018.

2.2.1.24 Tanzania

Tanzania achieved a GNP growth rate of 2.37% in 2017, which rose to 5.4% in 2018. However, the productivity growth rate was 0.25%, with an inflation rate of 5.3% in 2017. PHE was at an average rate of 1.55% between 2000 and 2016, reflecting inadequate health financing, while in 2018, the country increased its PHE to 1.56% of GNP. The LEB was 64 years in 2017, with 524 maternal deaths per 100,000 births and a CMR of 54 per 1,000 births. Despite improved real GNP, the proportion allotted to PHE was low, translating into poor health outcomes and productivity growth in the country.

2.2.1.25 Togo

The Togolese economy was not spared the ravaging effect of the global COVID-19 pandemic, which caused a decline in the country's GNP. While this is not an oil-producing country, the Togo Triangle is an offshore illegal market for stolen oil off the coast of Nigeria and Togo near the Niger Delta. Togo mainly depends on agriculture, which contributes about 42% to the GNP, which grew by 4.4% in 2017, rising to 4.9% in 2019. The inflation rate has been persistently low and in 2017, it dropped to -0.22% from 0.86% in 2016, while the productivity growth rate was 0.17% in 2017. However, in 2018, the inflation rate rose to 0.93%.

The LEB was 60, the MMR was 396 per 100,000 births, and the CMR was 72 deaths per 1,000 births in 2017. Although average PHE was 0.9% of GNP between 2000 and 2016, it increased to 6.17% in 2018. Thus, health infrastructure and facilities are adequate, but the health system still suffers from inadequate staffing and is based on a 'pay-or-die' approach.

2.3 Health financing

Health financing plays a crucial role in ensuring the effective and efficient performance of the health sector. It is recognised as a fundamental human need (Oribabor, 2004), and adequate PHE is essential to improve the volume and quality of healthcare services (WHO, 2004). Health financing is required to cover overall health system costs, including health services, consumables, nutrition activities, diagnostics and pharmaceuticals. It is a key determinant of health sector performance in relation to equity, efficiency, and health outcomes (Amponsah, 2008). Equity and efficiency are important qualities emphasised in the SDGs. Adequate resources, such as PHE, are necessary to address escalating healthcare costs, thereby promoting efficiency and equity in healthcare delivery (Amponsah, 2008).

National governments are responsible for overall public health funding policy and strategic planning for healthcare services (Adebayo & Oladeji, 2004). Health financing is a critical component of the health system, as it provides the necessary resources to cover PHE (Raghupathi & Raghupathi, 2020). Various methods are employed for healthcare financing, including national health insurance systems (NHIS), general revenue, private insurance, community-based insurance, external financing, and out-of-pocket (OOP) payments. While it is important to note that the classification of these methods may vary among different countries in SSA, general revenue in the form of PHE provided by governments was the basis of the current study.

2.3.1 Health expenditure

Health financing in the form of health expenditure by private or public entities is widely recognised as a prerequisite for improving health outcomes (Raghupathi & Raghupathi, 2020) and fostering economic growth. It encompasses private and public funding covering various expenses related to health, such as prevention, pharmaceutical costs, diagnostic costs and health-related programmes. These programmes can include training, research, awareness campaigns and development initiatives to enhance the overall health system.

2.3.2 PHE in SSA

Government (public) health financing in SSA is inadequate, and simply increasing PHE may not necessarily lead to improved health outcomes (Kunze, 2014). This situation has negative implications for TFP and economic growth in the region (Akinci *et al.*, 2014).

According to WHO (2012) research, low- and middle-income countries would require an additional USD371 billion to meet the health-related SDGs targets. This would involve increasing health spending as a percentage of GNP from the current average of 5.6% to 7.5%. Moreover, there are significant financing gaps, particularly in low-income countries (LICs). However, it should be noted that this estimate cannot be generalised for SSA's MMR as some countries in the region have already exceeded the recommended 7.5% share of GNP for healthcare. Nonetheless, as shown in Table 2.2 below, these countries still face challenges regarding high MMRs and CMRs.

Table 2.2: Countries in SSA with high PHE, MMR and CMR (2017)

Country	PHE (% of GNP)	MMR	CMR
Burundi	7.52	548	62
Lesotho	8.95	544	85
Liberia	8.16	661	120
Malawi	9.64	349	90
Mozambique	8.14	289	55
Namibia	8.29	195	29
Niger	7.66	509	121
Rwanda	7.54	248	37
Sierra Leone	16.62	1120	110
South Africa	8.11	119	37
South Sudan	8.37	1150	95

Source: World Bank (2018)

As seen in Table 2.2, Sierra Leone and South Sudan have the world's highest MMRs. The failure of these countries to achieve UHC despite investing more than 7.5% of their GNP in health, could be attributed to wastage and inefficiency in using PHE. While some countries may have surpassed the 7.5% threshold for PHE as a share of GNP, the MMR and CMR remain high.

Table 2.2 above reveals a notable discrepancy between substantial investment in PHE and the persistently high mortality rates observed in certain countries. This inconsistency calls for further investigation to understand the underlying factors. To initiate this analysis, Table 2.3 below presents data on the ratios of PHE to GNP for various SSA countries in 2010, 2015, 2017, and 2018, including countries that were not the study's focus. The remarks column indicates whether PHE increased, decreased, or remained stable.

Table 2.3: PHE in SSA countries in 2010, 2015, 2017 and 2018

Country	PHE (2010) % of GNP	PHE (2015) % of GNP	Remarks	PHE (2017) % of GNP	PHE (2018) % GNP	Remarks
Angola	1.67	1.23	Decline	1.29	1.07	Decline
Benin	0.72	0.59	Decline	0.81	0.49	Decline
Botswana	3.56	3.88	Increase	4.64	4.53	Decline
Burkina Faso	1.47	1.65	Increase	2.99	2.39	Decline
Burundi	1.99	2.50	Increase	1.86	1.90	Increase
Cabo Verde	2.83	3.17	Increase	3.28	3.22	Decline
Cameroon	0.8	0.67	Decline	0.62	0.57	Decline
CAR	0.57	0.46	Decline	0.73	0.69	Decline
Comoros	0.47	0.74	Increase	0.51	0.42	Decline
DR Congo	0.40	0.66	Increase	0.41	0.50	Increase
Congo	0.89	1.56	Increase	1.20	0.79	Decline
Côte d'Ivoire	0.81	1.08	Increase	1.27	1.21	Decline
Equatorial Guinea	0.45	0.55	Increase	0.59	0.58	Decline
Eritrea	1.10	0.74	Decline	0.79	0.64	Decline
Eswatini	4.23	2.94	Decline	3.51	2.15	Decline
Ethiopia	0.94	0.97	Increase	0.87	0.77	Decline
Gabon	1.57	1.57	Stable	1.76	1.61	Decline
Gambia	0.89	1.00	Increase	1.06	0.95	Decline
Ghana	2.38	1.62	Decline	1.09	1.38	Increase
Guinea	0.36	0.43	Increase	0.71	0.65	Decline
Guinea Bissau	1.22	0.66	Decline	0.59	0.64	Increase
Kenya	1.77	2.11	Decline	2.06	2.18	Increase
Lesotho	4.4	5.4	Increase	5.5	5.3	Decline
Liberia	1.70	1.38	Increase	1.10	1.70	Decline
Madagascar	2.0	2.58	Increase	2.32	0.79	Decline
Malawi	1.59	2.67	Increase	2.96	2.70	Decline
Mali	0.67	0.92	Decline	1.24	1.10	Decline
Mauritania	0.95	1.82	Increase	1.70	1.64	Decline
Mauritius	2.02	2.37	Increase	2.4	2.51	Increase
Mozambique	0.67	1.64	Increase	1.4	1.73	Increase
Namibia	3.99	4.10	Increase	3.85	3.66	Decline
Niger	1.7	1.4	Decline	2.5	2.43	Decline
Nigeria	0.44	0.58	Increase	0.53	0.58	Increase
Rwanda	2.1	2.1	Stable	2.2	2.37	Increase
Sao Tome	2.05	1.69	Decline	2.97	2.75	Decline
Senegal	1.00	1.0	Stable	0.86	0.85	Decline
Seychelles	3.11	3.25	Increase	3.64	3.81	Increase
Sierra Leone	1.2	1.64	Increase	1.84	1.56	Increase
South Africa	3.91	4.39	Increase	4.35	4.46	Increase
Sudan	1.64	2.2	Increase	1.14	1.03	Decline
Tanzania	1.45	1.26	Decline	1.58	1.56	Decline
Togo	1.55	1.27	Increase	0.92	1.05	Decline
Uganda	1.43	1.02	Decline	0.97	1.03	Increase
Zambia	0.84	2.09	Increase	1.77	1.93	Increase
Zimbabwe	2.75	1.55	Decline	1.70	1.32	Decline

Source: World Bank (2018)

Table 2.3 above shows that the PHE of each country varied over time, with some countries experiencing increasing trends while others exhibit declining trends. The table thus provides a snapshot of PHE as a percentage of GNP for these countries and can be used to analyse trends and patterns in PHE in the sub-Saharan African region.

In contrast to the data on PHE in SSA presented in Table 2.3 above, Organisation for Economic Co-operation and Development (OECD) countries, which are medium- to high-income countries for the most part, recorded a significantly high percentage of public PHE as a proportion of total health expenditure (private and public) in 2017. Figure 2.2 presents each OECD country's contribution to PHE as a percentage of total health expenditure in that year. It is important to note that this figure presents the proportion of PHE relative to overall health expenditure. In contrast, the previous table discussed PHE as a percentage of GNP in SSA. Nevertheless, it is worth noting that this high proportion of PHE in overall health expenditure signifies significant investment in public health by these countries.

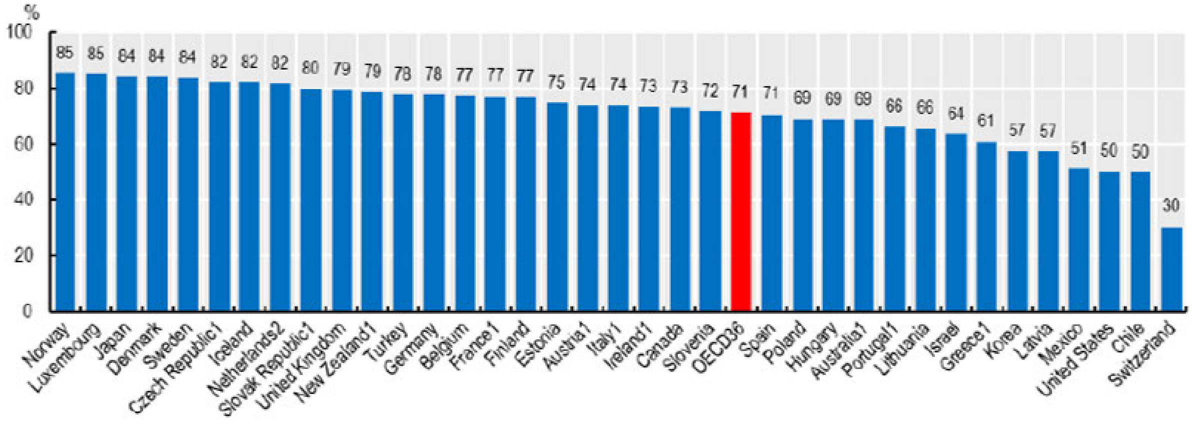


Figure 2.1: PHE as a percentage of total health expenditure in OECD countries (2017)

Source: OECD (2019)

Figure 2.1 above demonstrates that in 2017 OECD countries' PHE accounted for a significant proportion of total health expenditure, with an average of around 71%. This indicates higher reliance on public healthcare funding than in SSA. Traditionally, the primary source of health financing and expenditure is expected to be the national government (Adebayo & Oladeji, 2004); however, the situation in SSA differs. Figure 2.2 below presents health expenditure across income groups from 2000 to 2015.

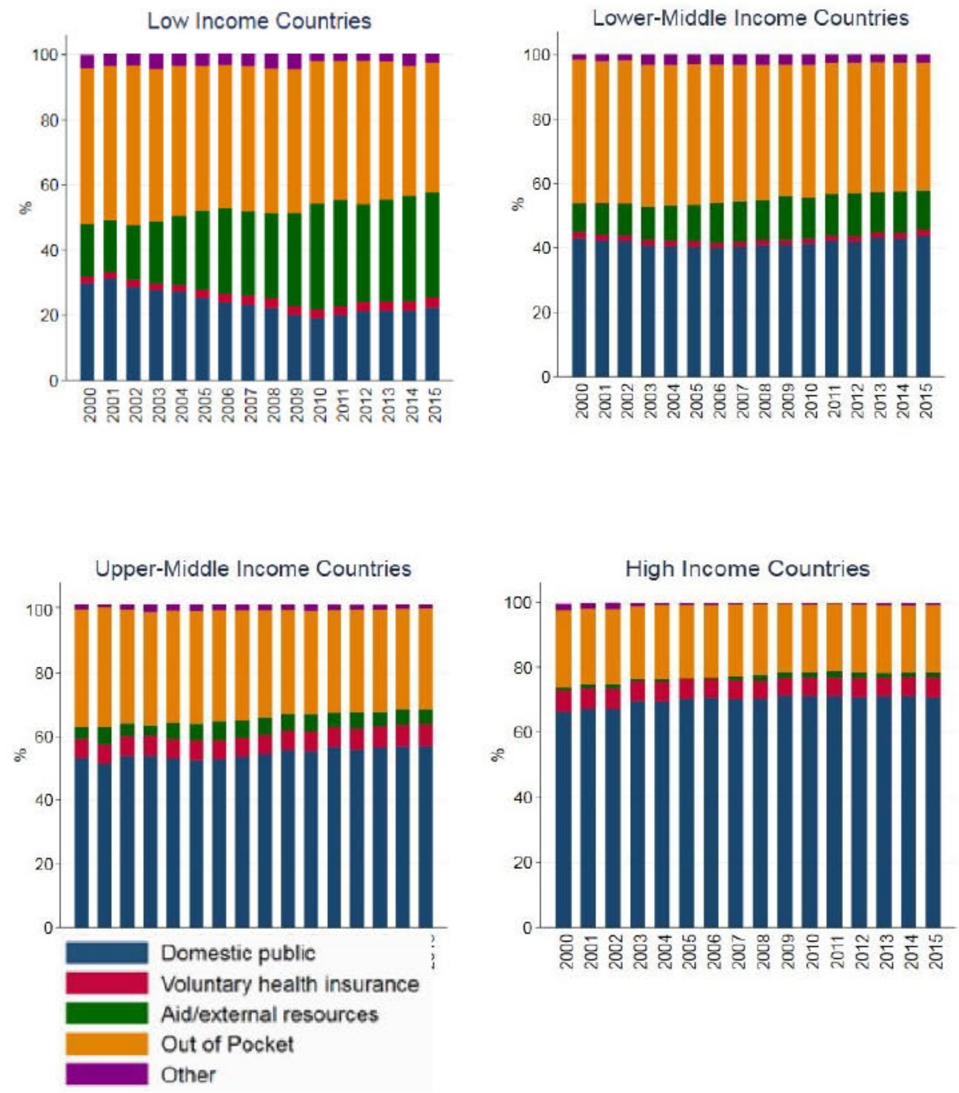


Figure 2.2: Health expenditure across income groups from 2000 to 2015

Source: World Bank (2018)

The above figure shows that in 2015, PHE in higher-income countries accounted for approximately 60% of total health expenditure, while in low-income countries, government investment constituted slightly above 30%. Private expenditure held the largest share, averaging more than 60%, while external resources accounted for around 10%. Public funding in high-income countries increased from 66% in 2000 to 70% in 2015, and in middle-income countries it increased from 48% in 2010 to 51% in 2015. These figures provide a clear picture of national governments' involvement in total health expenditure in countries across the world.

2.3.3 Health financing system

The health financing system plays a crucial role in determining the availability and distribution, and access to healthcare services within a country. According to McIntyre and Kutzuin (2012), the literature recognises three main functions of a health financing system: resource mobilisation, resource pooling, and purchasing.

Resource Mobilisation: This function focuses on how healthcare units generate and receive revenue to meet the population's health needs. There are three major aspects:

i. Sources of funding: These include internal and external sources. Internal sources involve funds from citizens and businesses within the country, while external sources encompass donor funding, such as grants.
ii. Fund access methods: Healthcare funds can be generated through various means, including government tax collection, government-provided NHISs, private insurance health schemes, and OOP payments.
iii. Fund collection: Government officials responsible for health revenue collection typically handle the collection of healthcare funds. Private insurance schemes also collect funds through their respective mechanisms.

Resource Pooling: Resource pooling involves gathering health resources in a specific domain to facilitate easier access, predictability and accountability. This approach aligns with the principles of equity and efficiency, as funds can be reallocated from wealthier individuals to subsidise healthcare costs for the less privileged.

Purchasing: The purchasing function involves acquiring health resources through social security agencies or NHIS providers, whether public or private. The provider may partially or fully cover the purchased health package based on the arrangement with the beneficiary. Two common payment models are service fees, which involve payment based on the quality and quantity of healthcare services rendered, and capitation, which entails prepayment to cover projected patient volumes or population size.

By understanding and effectively implementing these functions, a country can establish a robust health financing system that supports equitable and efficient healthcare provision.

2.4 Overview of health outcomes in SSA

The impact of PHE on TFP growth cannot be fully understood without considering its influence on health outcomes, which are the consequences of the healthcare system's structure, processes and reforms and reflect population health and well-being. Furthermore, the UN MDGs from 2000 to 2015 and the subsequent SDGs from 2015 to 2030 emphasise the significance of good health for economic development.

Moshiri, Alijunid and Amin (2010) suggest that health outcomes can be measured in terms of intermediate outputs such as the number of patients treated and waiting times, or broader indicators such as lower mortality rates and improved life expectancy. In this study on SSA, health outcomes encompass the MMR, the CMR and LEB, which tend to be poorer in comparison with other regions. Furthermore, in the case of SSA, the region's performance in terms of PHE has been relatively low compared to other regions. However, while the performance of most African countries, particularly those in SSA, fell significantly below the desired targets set by the MDGs, introducing these goals underscored the importance of healthcare expenditure and financing in the region.

Three of the eight MDGs were dedicated to improving people's health, specifically focusing on reducing child mortality, improving maternal health and combating diseases like HIV and AIDS and malaria. Similarly, Goal 3 of the SDGs promotes good health and well-being by ensuring healthy lives and well-being for all age groups. This goal encompasses increasing life expectancy, reducing common causes of child and maternal mortality, improving access to clean water and sanitation, and combating diseases such as malaria, tuberculosis (TB), polio, and HIV and AIDS.

The literature uses various measurements to assess health outcomes. As noted previously, this study focused on the MMR and CMR, which are high, and LEB, which is low in SSA. By examining these specific health outcomes, it provides insights into the impact of PHE on the well-being of the population in the region.

2.4.1 Maternal mortality rate

The MMR is measured by the number of pregnancy-related deaths per 100,000 women in a population, occurring during pregnancy, childbirth, or within six weeks of delivery. Developing or less developed countries bear a greater maternal mortality burden than developed countries because of factors such as better healthcare, increased availability of health personnel, stronger health systems and advanced technology. For instance, in the United States (US), only 17 maternal deaths per 100,000 live births were recorded in 2015 (World Bank, 2018)

Although there has been progress in reducing maternal deaths in SSA, the region continues to face a high burden of maternal mortality. Approximately 20 countries in SSA are included on the list of countries with the highest MMR in the world, accounting for about 62% of global maternal deaths (World Bank, 2018). Despite the target set by the SDGs to reduce the global MMR to less than 70 per 100,000 live births by 2030 (SDG 3.1), SSA is far from reaching this target.

In terms of the specific target for the MMR, countries experiencing 432 or more deaths per 100,000 live births in 2015 need to achieve an annual rate of reduction of 7.5% to reach the target of 70 per 100,000 live births by 2030 (World Bank, 2018). However, in 2015, SSA had an MMR of 547, higher than 432, indicating that the reduction rate in MMR needed to be greater than 7.5% to reach the desired target within the next nine years.

Maternal deaths can be attributed to both direct and indirect factors. Direct factors refer to medical factors that directly impact a pregnant woman's survival, including bleeding, high blood pressure, infection, age-related risks, complications from abortion, blood clots, unavailability of skilled health personnel and parity (the number of times a woman has given birth). Indirect factors encompass socioeconomic determinants and macroeconomic factors that indirectly influence maternal health outcomes.

Understanding these determinants of maternal deaths would ensure the development of effective strategies and interventions, such as increased PHE that is not wasted, to improve maternal health outcomes and reduce the MMR. Addressing both the direct and indirect factors would require efforts to enhance healthcare systems and access to skilled health personnel, and improve socioeconomic conditions, ultimately leading to better maternal health outcomes in SSA.

2.4.2 Child mortality rate

The CMR is a measure of the number of child deaths per 1,000 live births. Globally, it has shown improvement over the years, declining from 93 deaths per 1,000 live births in 1990 to 39 deaths per 1,000 live births in 2017. However, SSA still has a high CMR compared with other regions. In 2017, the CMR in SSA was 76 deaths per 1,000 live births. In addition, in 2009, SSA had the highest under-five mortality rate, with 130 deaths per 1,000 live births, compared with the global average of 61. Low-income countries had an average of 118 deaths per 1,000 live births, high-income countries had an average of 7, and Middle East and North African countries had an average of 33 per 1,000 live births in the same year (World Bank, 2017).

The SDGs set a target to reduce under-five mortality to 25 deaths per 1,000 live births by 2030. According to the World Bank (2018), if a country maintained a 3.9% reduction rate from 1990 to 2015, it would have a chance of achieving the SDG target. However, in 2015, the CMR in SSA was 81.4 per 1,000 live births, which was far off target. The World Bank (2018) also estimated that SSA may not meet the target by 2030, projecting an under-five mortality rate of 54 in the region by that time, which is far above target.

2.4.3 Life expectancy at birth

According to the World Bank (2018), in 2015, the global average LEB was 71.4 years, while in SSA, it was 59.9 years. However, over the past few decades, a significant increase in global life expectancy in developing countries has been crucial in reducing global inequalities. Several factors have contributed to this positive trend, with improved healthcare systems and access to healthcare services playing a pivotal role. Many developing countries have invested in strengthening their healthcare infrastructure, expanding primary healthcare services and enhancing disease prevention and control programmes. This has led to better management of infectious diseases, improved maternal and child healthcare, and increased access to essential medicines and treatment.

Furthermore, advances in medical technology and pharmaceutical innovations have made significant contributions. Breakthroughs in vaccinations, treatments for common illnesses and access to life-saving medication have been instrumental in prolonging lives and reducing mortality rates. These have been made possible through international collaboration, research and development efforts, and the dissemination of medical knowledge.

Socioeconomic development and improvements in living conditions have also had a positive impact on life expectancy. Increased access to education, better nutrition, improved sanitation facilities and enhanced socioeconomic opportunities have contributed to overall improvements in population health. However, despite these advances, challenges persist in SSA regarding life expectancy. Factors such as a high disease burden, limited healthcare resources, inadequate infrastructure, and socioeconomic disparities continue to pose significant obstacles to improving life expectancy in the region (Ortiz-Ospina & Roser, 2019). Addressing these challenges requires sustained efforts to strengthen healthcare systems, increase investment in public health, promote equitable access to healthcare services and address the social determinants of health.

2.4.4 Health outcomes and macroeconomic determinants

Before the global financial crisis of 2008, SSA encountered various macroeconomic challenges. Between 1980 and 2000, the region experienced a decline in trade, high interest rates and external shocks stemming from oil price increases (IMF, 2016). These economic factors impacted the health outcome indicators, which exhibited slow improvement rates during this period and the subsequent economic downturn from 2007 to 2010. The poor health outcomes observed in 1980-2000 and 2007-2010 can be attributed to the influence of shocks arising from macroeconomic variables. To better understand this relationship, Figure 2.4 below illustrates the association between health variables (MMR, CMR and LEB) and macroeconomic indicators (GDP and inflation) in SSA from 2000 to 2017.

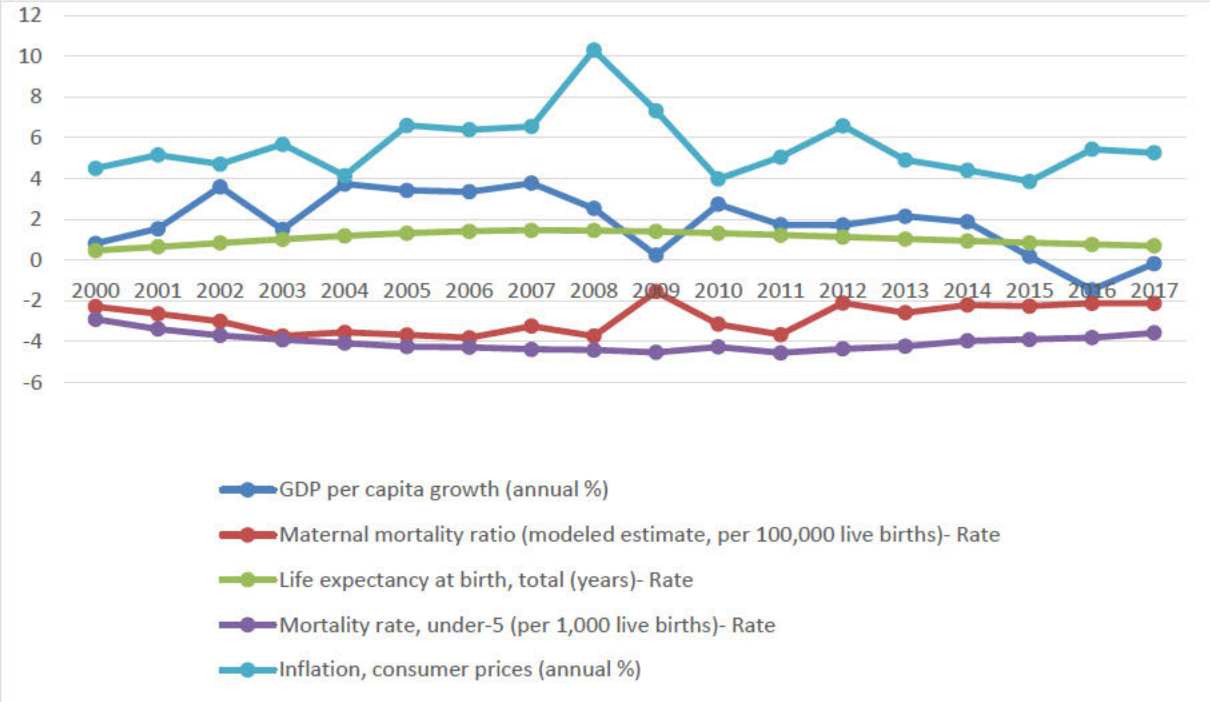


Figure 2.4: Health and selected macro-economic determinants

Source: World Bank (2018)

It is evident in Figure 2.4 above that countries in SSA experienced a significant increase in consumer prices from 2007 to 2009, with a peak in 2008 resulting in a 10% inflation rate in the region (World Bank, 2017). GDP per capita was exceptionally low in 2009 and 2016. This macroeconomic variable had a corresponding negative impact on health outcomes from 2008 to 2010 (World Bank, 2017). In 2009, the MMR was exceptionally high, which suggests that the persistent challenges faced by SSA in addressing poor health funding and improving health outcomes can be partially attributed to the influence of the macroeconomic variables GDP and inflation. Studies by Chen and Vujic (2016) and Ramasamy and Abar (2015) identified interest rates, exchange rates, inflation rates and money supply as macroeconomic shocks affecting SSA. Schwandt (2018) and Chen and Vujic (2016) also reported that macroeconomic determinants can impact health outcomes.

Enhancing health outcomes through increased PHE is also expected to promote economic growth, including TFP (Bloom, Canning & Jamison, 2007; Hartwig & Sturm, 2017; Riman *et al.*, 2010), particularly when considering the effect of the macroeconomic determinants of health outcomes. In terms of morbidity and mortality, poor health leads to a loss of productive years and imposes an economic burden on the formal health sector. Informal caregivers also experience the impact, resulting in lower TFP and slower economic growth (Baker, 1998). Inadequate PHE and limited improvements in health outcomes in SSA are of serious concern for the well-being of citizens and have potential consequences for TFP growth in the region (Baldacci, Clements & Gupta, 2015; Gong, Li & Wang, 2012). In SSA, insufficient health funding and poor health outcomes may have negatively impacted TFP.

2.4.5 Health-related developmental goals and targets

This section discusses various health-related programmes and targets within the scope of the study.

2.4.5.1 Millennium Development Goals (MDGs)

The MDGs were international development targets established after the UN's Millennium Summit in the year 2000 (UN, 2000). Among the eight goals from 2000 to 2015, three related to health: reducing the CMR by three-quarters, reducing the MMR by two-thirds and combating HIV and AIDS, malaria, and other major diseases.

2.4.5.2 Abuja Target

In 2001, African leaders convened in Abuja, Nigeria. Due to the significant burden of diseases like HIV on the continent, they committed to allocate 15% of their budgets and 0.7% of GNP from donor assistance to healthcare (UN, n.d.[b]). However, nearly all countries in SSA have failed to meet this target, except for Sierra Leone, which allocated 16.06% of its GNP to current PHE in 2017 and 2018 (see Table 2.2). The Abuja Target was thus a political statement without scientific or empirical justification, lacking consideration of the unique characteristics of each country's epidemiological profile.

2.4.5.2 Commission on Macroeconomics and Health

The Commission on Macroeconomics and Health sponsored by the WHO examined the relationship between health and economic growth in 2001. It recommended that low- and middle-income countries increase their PHE by 1% of GNP in 2007 and 2% in 2015. High-income countries were encouraged to contribute 0.1% of GNP as donor financing, amounting to $27 billion annually in 2007 and $38 billion annually in 2015. The Commission on Macroeconomics and Health also recommended specific healthcare spending targets for different income groups and emphasised the need for investment in integrated healthcare systems. However, based on 2017 government health spending, none of the SSA countries met the recommended targets for least developed and low-income countries, while approximately 16 met the target of $38 per person in 2017. The Commission on Macroeconomics and Health's recommendations did not adequately consider each country's population spatial characteristics and specific needs (WHO, 2001).

2.4.5.3 Sustainable Development Goals

The SDGs were introduced in 2015 as global targets to be achieved by 2030. All countries worldwide committed to achieving the 169 targets derived from a list of 17 SDGs (UN, n.d.[a]). However, SSA countries are still far from reaching these goals, and the region may face challenges in achieving the targets due to the reduced percentage of GNP allocated to health, particularly when maternal and child mortality rates remain high (WHO, 2020).

2.5 Overview of total factor productivity growth in SSA

Total factor productivity measures productive efficiency by measuring how much output can be produced from a certain number of inputs (Mankiw, Romer & Weil, 1992). It is the ratio of input to output to derive overall production efficiency within a system. Although the meaning of TFP depends on the context, it is regarded as a determinant of a firm's profitability, competitiveness and growth. Moreover, there is increasing interest in the literature on factors affecting TFP (Choudhry, 2009; Fallahi, Sojoodi & Nassim, 2010).

Solow's (1956) model identifies technological progress or improvement in TFP as the main determinant of economic growth in the long run. Technological progress can be described as the invention and application of new technology (Solow, 1956). Without the invention of new technology, extra capital accumulation would have to be distributed amongst the same set of existing inputs, diminishing returns would set in, and financial growth would stagnate.

As the Penn World Table 10.0 indicates, TFP growth has been low in SSA from 1980 to date. The TFP level at current purchasing power parity (PPP) for Botswana (relative to the US, which equals 1) was 0.77 in 1980 and 0.57 in 2014; for Côte d'Ivoire, it was 0.76 and 0.46; for Egypt, it was 1.11 and 1.08; for Nigeria, it was 1.44 and 0.65 and for South Africa, it was 0.97 and 0.53 (Feenstra, Inklaar & Timmer, 2015). Figure 2.5 below shows the average TFP in SSA countries from 1980 to 2017, with Mauritius having the highest TFP average of 0.95, while Niger had the lowest of 0.2.

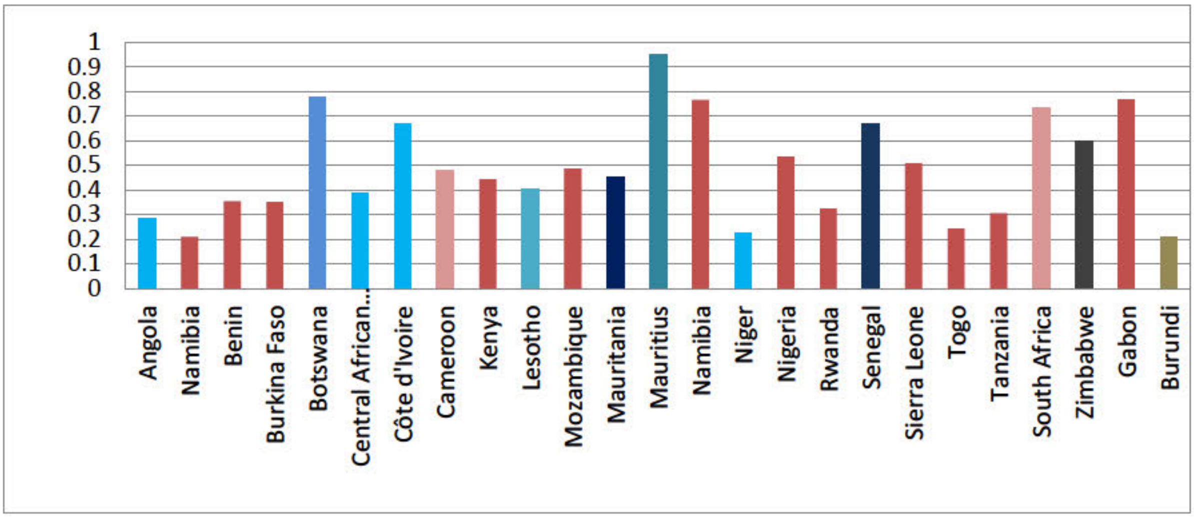


Figure 2.5: Average rate of change in TFP in SSA countries from 1980-2017

Source: Penn World Table 10.0

Figures 2.6(a and b), 2.7(a and b) and 2.8(a and b) below reflect TFP growth trends in SSA countries in 2000 and 2015, 2005 and 2018, and 2006 and 2019, respectively. The figures show that although TFP growth improved for a few countries over the years, many revealed a downward trend.

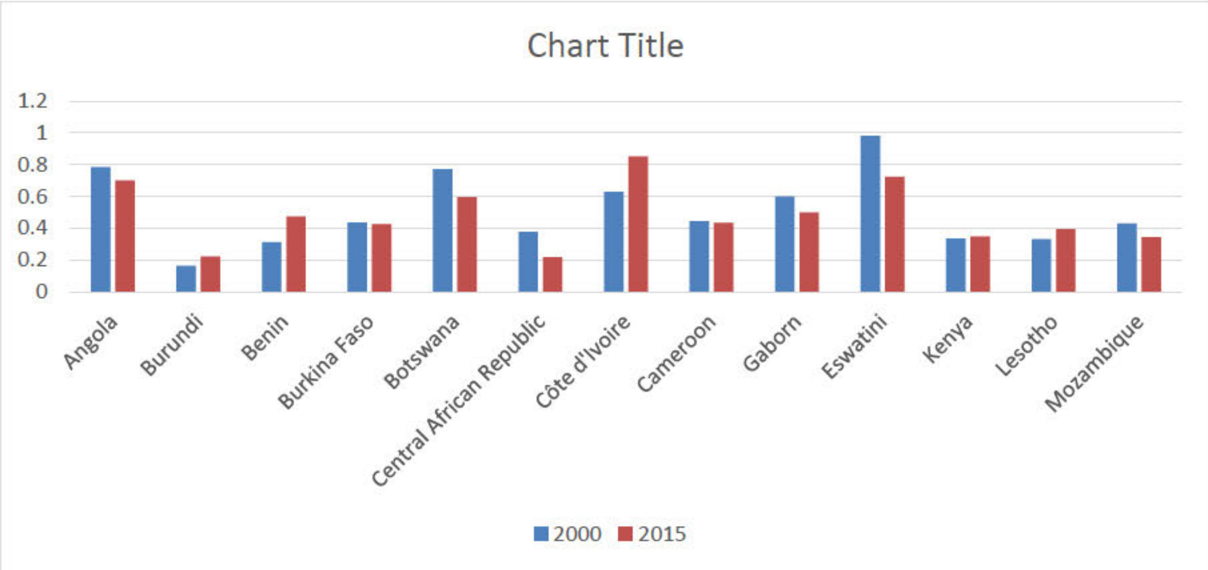


Figure 2.6(a): TFP growth in SSA countries in 2000 and 2015

Source: Penn World Table 10.0

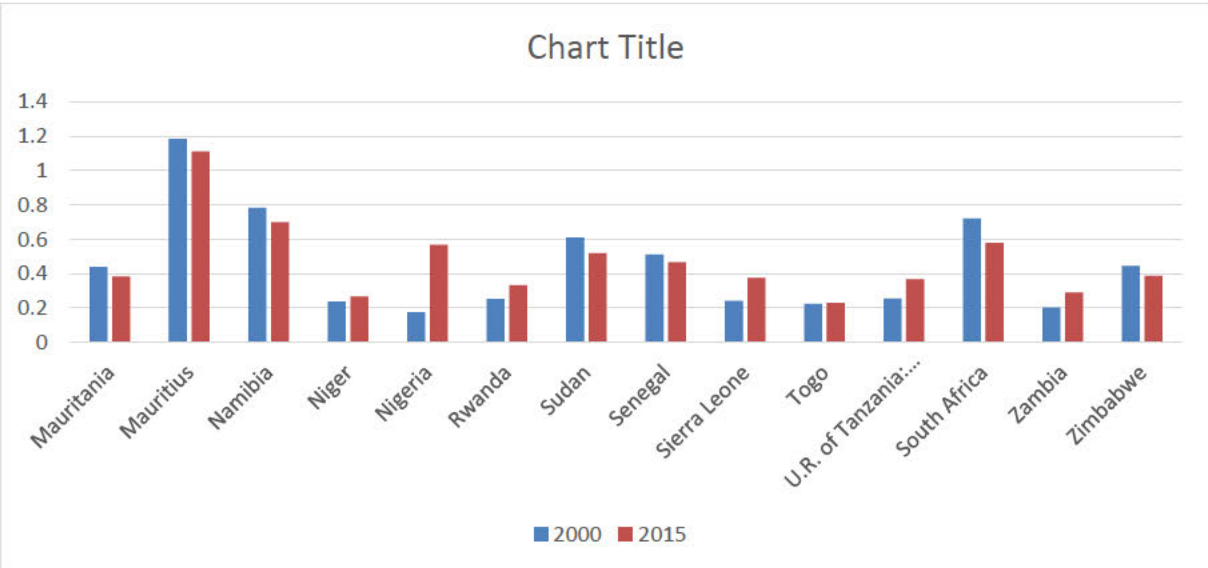


Figure 2.6(b): TFP growth in SSA countries in 2000 and 2015

Source: Penn World Table 10.0

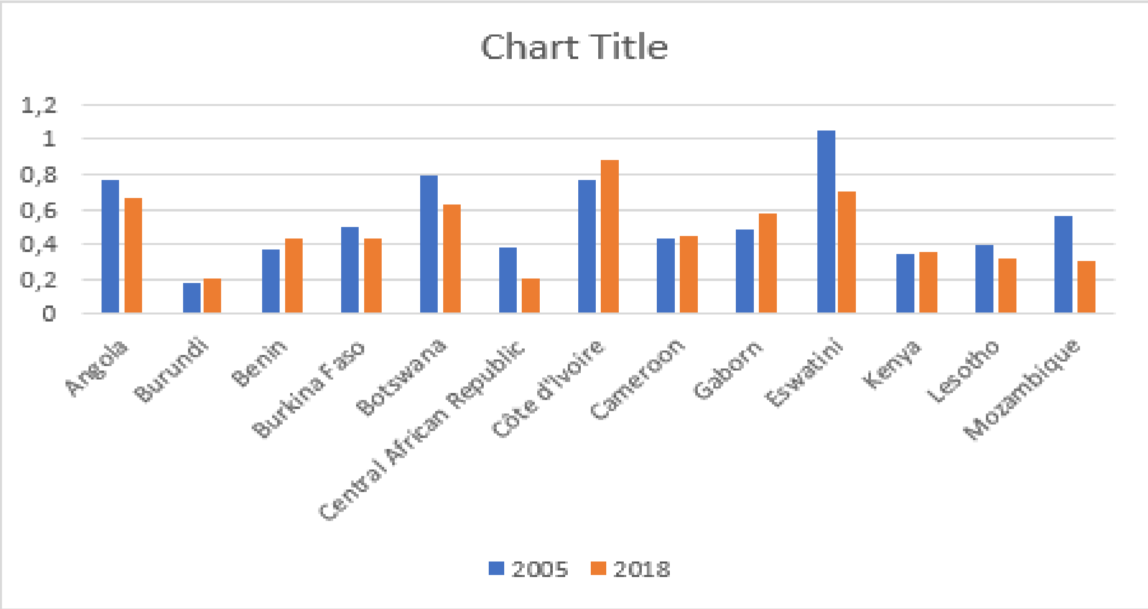


Figure 2.7(a): TFP growth in SSA countries in 2005 and 2018

Source: Penn World Table 10.0

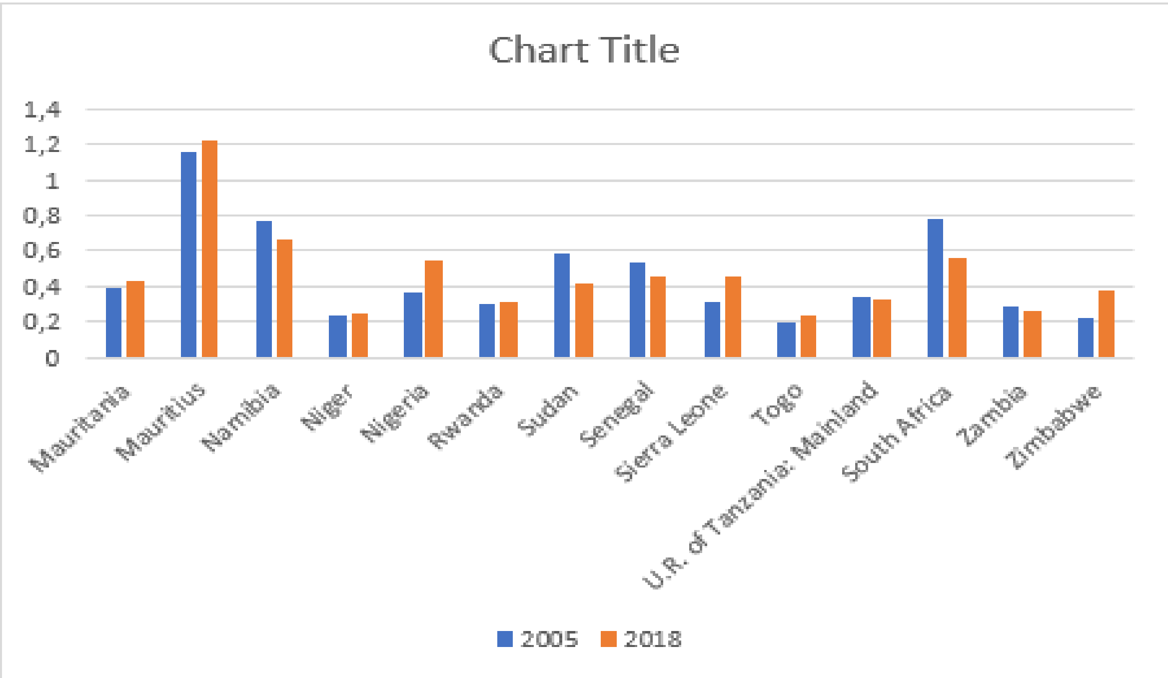


Figure 2.7(b): TFP growth in SSA countries in 2005 and 2018

Source: Penn World Table 10.0

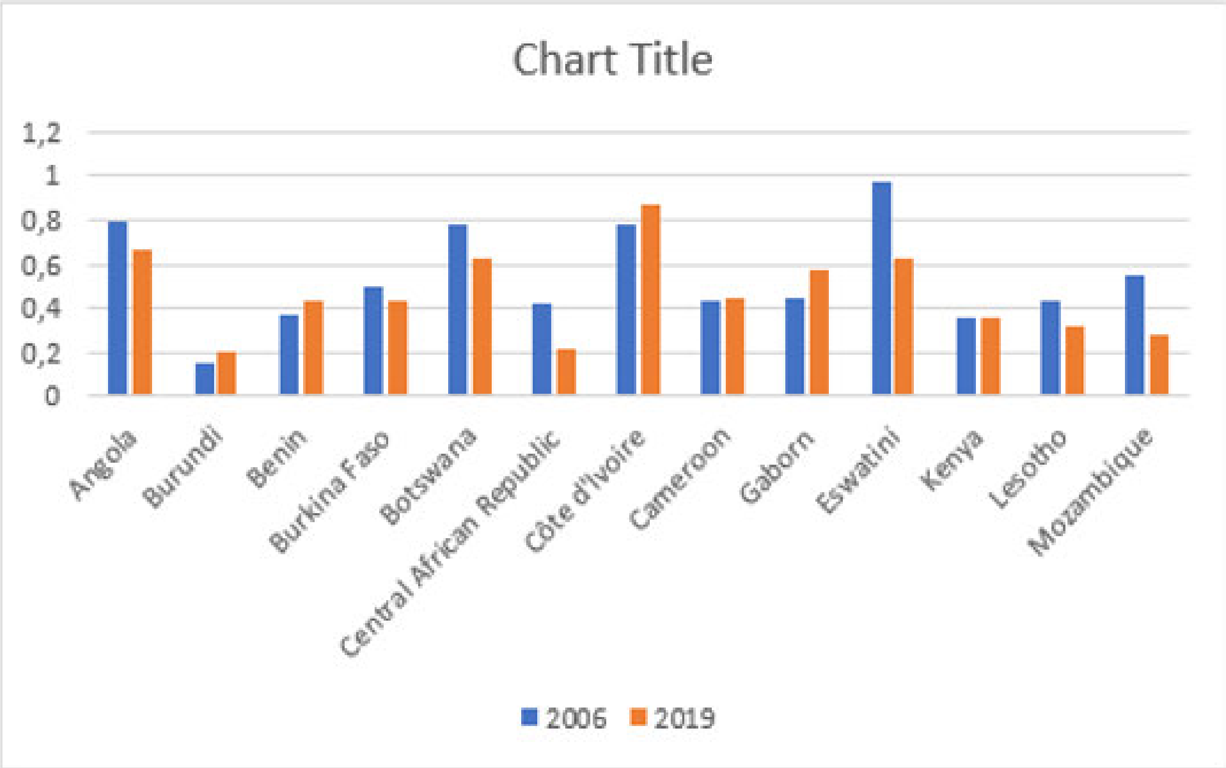


Figure 2.8(a): TFP growth in SSA countries in 2006 and 2019

Source: Penn World Table 10.0

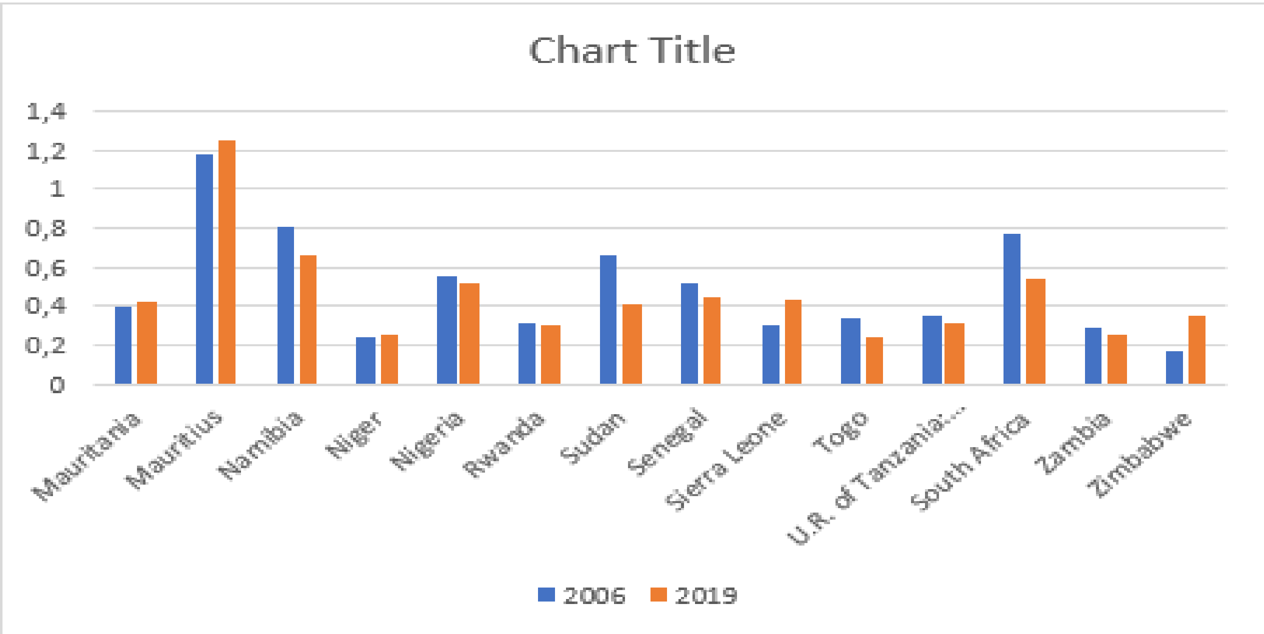


Figure 2.8(b): TFP growth in SSA countries in 2006 and 2019

Source: Penn World Table 10.0

The above figures depict a concerning downward trend in TFP growth in the sub-Saharan African countries under review. This suggests that the link between PHE, health outcomes and human productivity needs to be strengthened and prioritised in these countries. Efforts to increase PHE and improve health outcomes can substantially impact TFP growth by reducing morbidity, mortality and the economic burden of poor health. By investing in healthcare infrastructure, disease prevention, and healthcare services, countries can create a healthier workforce, leading to increased productivity and overall economic growth, healthcare infrastructure development, and the implementation of effective healthcare policies. Prioritising these factors and ensuring adequate funding for health would enable countries in SSA to work towards reversing the declining trend in TFP growth and fostering sustainable economic development.

2.6 Relationship between PHE and TFP

The literature confirms that increased public and private health expenditure improves health outcomes and economic growth (Novignon & Lawson, 2018). Novignon *et al*. (2018) investigated the effect of PHE on child health outcomes in 45 countries in SSA between 1995 and 2011, with neonatal, infant and under-five mortality rates used as indices. The research results revealed that PHE significantly affects child health outcomes in SSA.

Other studies have also found a relationship between government PHE and economic growth at both country-specific and cross-country levels (Bloom, Canning & Malaney, 2000; Bhargava *et al.*, 2001; Bloom, Canning & Sevilla, 2004; Baltagi & Moscone, 2010; Wang, 2011; Bakare & Olubokun, 2011; Amiri & Ventelou, 2012; Edeme, Emecheta & Omeje, 2017; Eboh, Abba & Fatoye, 2018; Ogunjimi & Adebayo, 2019). Moreover, using GMM, Aboubacar and Xu (2017) established a positive relationship between PHE and economic growth in SSA.

Given that TFP measures the residual growth in the total output of a firm or industry, which depends on inputs of labour, capital and technology in production, Aigner, Lovell and Schmidt (1977) and Meeusen and Den Broeck (1977) developed a stochastic frontier production model that measured TFP. Thus, TFP refers to the efficiency and effectiveness with which inputs such as labour and capital are transformed into outputs in an economy. It represents an economy's overall productivity and technological progress, capturing the ability to generate more output from a given set of inputs. The link between PHE and TFP suggests that public health investment can impact the economy's productivity and efficiency. Access to adequate healthcare services, including preventive care, treatment, and health promotion, can improve health outcomes and overall well-being. Figure 2.9 below shows a close and steady alignment between PHE and TFP and suggests a positive relationship between the two variables.

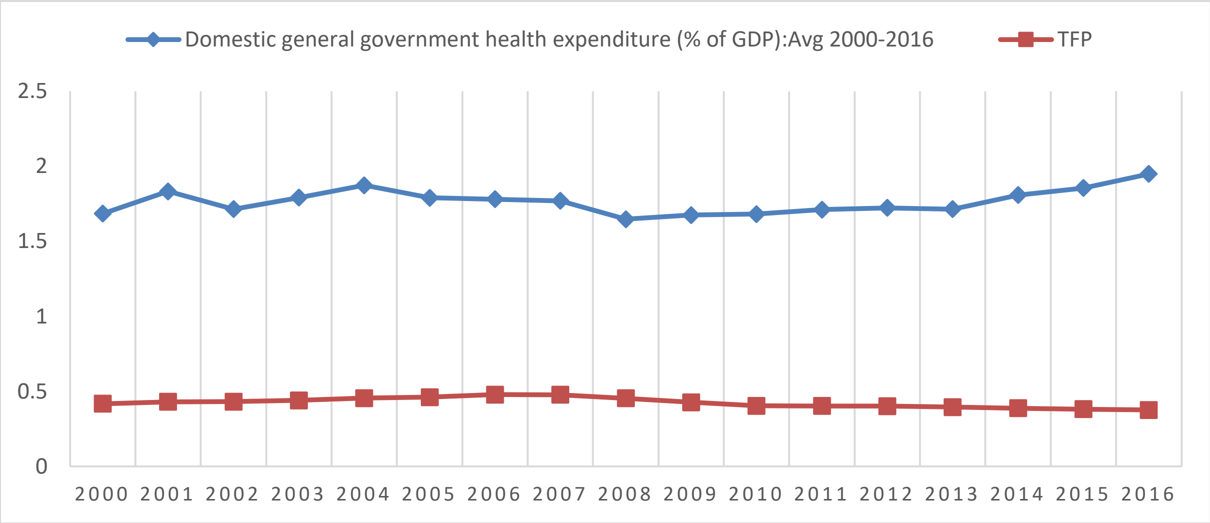


Figure 2.9: Trend of PHE and TFP growth in SSA from 2000-2016

Source: World Bank (2018) and Penn World Table, 10.0

Figure 2.9 above shows a generally consistent and parallel trend between PHE and TFP, which can be interpreted in the following ways (WHO, 2017):

- Health as a driver of productivity: Increased investment in public health such as healthcare infrastructure, preventive measures, and access to quality healthcare services can lead to improved health outcomes for the population. A healthier workforce is generally more productive, enhancing overall productivity and economic growth.
- Productivity gains from health interventions: Public health expenditure may target interventions that directly contribute to improving productivity. For example, programmes focusing on occupational health and safety, disease prevention, and health promotion can reduce absenteeism and work-related injuries, and increase worker productivity.
- Feedback loop: Higher TFP can also generate increased resources for PHE. As the economy becomes more productive, it generates greater income and tax revenue, providing governments with more financial capacity to invest in PHE

It's important to note that while Figure 2.9 shows a close relationship between PHE and TFP, further analysis is needed to understand the specific mechanisms and causal relationships driving this correlation. Factors such as healthcare system efficiency, human capital development, technological advancements and overall socioeconomic conditions can also influence PHE and TFP (World Bank, 2017).

2.7 Relationship between PHE, health outcomes and TFP

In light of the literature, which reflects a relationship between PHE, health outcomes and TFP, the researcher developed a framework for these interconnected variables, which were also explained in this chapter. Figure 2.10 below presents the framework and explains the relationships between these variables and other factors.

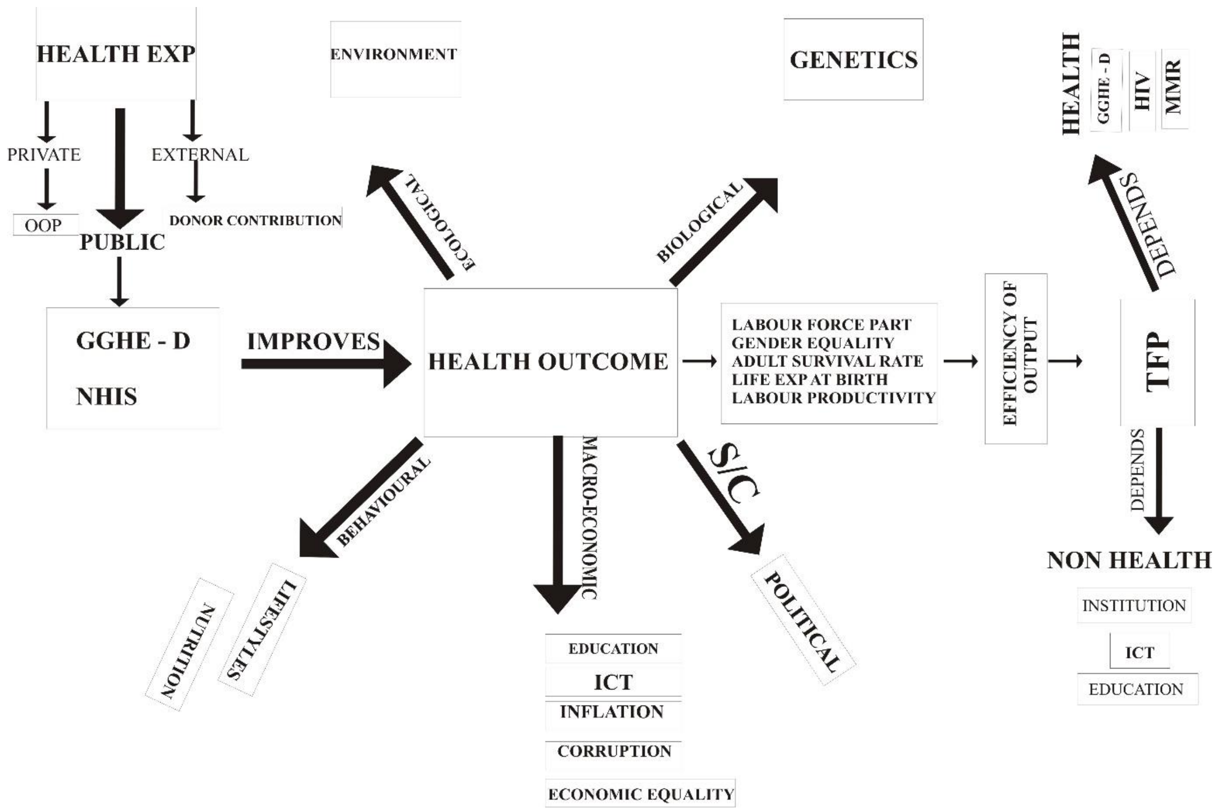


Figure 2.10: Conceptual framework for PHE, health outcomes and TFP

Figure 2.10 above presents the study's conceptual framework and the interconnectivity of the research objectives. Firstly, the framework identifies the three sources of total health financing: private, public and external:

- Private health expenditure includes OOP spending and private health insurance.
- Public health financing, termed PHE throughout this thesis, comprises domestic general government health expenditure and the government's contribution to national health insurance schemes. It is expected to improve health outcomes, i.e., child and maternal mortality. Gupta, Verhoeven and Tigosen (2002) provide evidence from 70 countries that public spending on health is important for the health of people experiencing poverty in countries in SSA. In these countries, PHE is often low compared with OECD countries, where it is higher than private funding.
- External funding refers to the financial contributions provided by donors to support health initiatives in SSA. This study represents external funding as a donor's contribution (DC). It encompasses financial support and resources provided by international organisations, foreign governments and non-governmental organisations to supplement domestic health expenditure in SSA countries. These external funds play a significant role in improving healthcare infrastructure, expanding access to essential services, and addressing health challenges in the region.

The framework also explains the concept of health outcomes. According to the literature (Mosley & Chen, 1984), numerous factors can influence health outcomes. Amongst them are behavioural (lifestyles, nutrition), biological (genetics), ecological (environment), socio-cultural (political) and macroeconomic factors. The latter were the focus of this study, which considered the effect of education, ICT, inflation, control of corruption and economic equality on health outcomes represented by maternal and child mortality.

The figure suggests that improving health outcomes would increase labour force participation because women who would otherwise die due to maternal complications will be absorbed into the general labour force, thereby increasing labour productivity. Furthermore, children constitute about 27.1% of the labour force in SSA. Therefore, a child's survival would increase labour force participation and productivity.

Reducing maternal deaths would also enhance gender equality because the economy of SSA would have more women to compete with men, especially in male-dominated professions. In addition, reducing maternal and child mortality would increase the survival rate of the population and LEB.

An improvement in human capital would enhance the efficiency of output, which would, in turn, increase TFP. However, TFP growth would be determined by improved health outcomes and non-health factors. The extant literature has established the non-health determinants of TFP as trade, foreign direct investment (FDI), and education (Akinlo & Adejumo, 2016; Olomola & Oshinubi, 2018; Fadiran & Akanbi, 2017). The conceptual framework in Figure 2.10 above shows that the study investigated the effect of the non-health factors of ICT and control of corruption on TFP in SSA. This was in addition to establishing the health-productivity nexus in the region by investigating the effect of PHE, maternal/child mortality and HIV/TB on TFP.

2.8 Overview of education in SSA

Education is widely recognised as a tool to develop human capital. Moreover, it is considered a universal human right and a public good. However, in SSA, many children face barriers that prevent them from accessing education, resulting in high dropout rates. Furthermore, the region has the highest rate of education exclusion globally (WHO, 2018). Approximately 60% of SSA youths aged 15-17 are out of school, with girls accounting for 68% of those excluded (Alexander, 2008).

The region has, however, witnessed significant progress in primary school enrolment, mainly driven by population growth and the Education for All (EFA) movement. However, this has generated corresponding demand for secondary education in SSA. Common challenges, especially with regard to secondary education, persist across countries in the region, including inadequate funding; a shortage of qualified teachers; insufficient infrastructure in both rural and urban areas; high student-teacher ratios, limited management and evaluation systems; a lack of teacher motivation; and inadequate support for students with special needs (Hartgen & Klasen, 2009). These challenges contribute to unsatisfactory secondary education and lower enrolment rates in higher education for which learners are unprepared.

The challenges faced by the education system in SSA, especially at the secondary level, have had a detrimental effect on students' upward educational mobility, impeding their progression to higher levels of education. This situation highlights the urgent need to address these challenges and prioritise the enhancement of secondary education in SSA. Addressing the barriers and improving the quality and accessibility of secondary education will increase the number of young individuals pursuing tertiary education and raise the overall level of education in the region.

A well-functioning secondary education system is a stepping stone towards higher education opportunities. It equips students with the necessary knowledge and skills and provides a solid foundation for further academic pursuits. By addressing the inadequate funding, shortage of qualified teachers, lack of infrastructure and other challenges in secondary education, an environment conducive to learning would be established, thereby fostering a pipeline for students to advance to tertiary institutions, with far-reaching positive impacts on the social and economic development of both individuals in SSA and the region itself.

2.9 Determinants of PHE

2.9.1 Age of population

Various factors influence PHE, including the composition of a country's dependent population. The presence of individuals below the age of 15 and over 65 has implications for healthcare needs and adequate funding. For example, an ageing population often faces health challenges such as strokes, high blood pressure, diabetes and cancer. Thus, private and public health funding must be adequate to address the healthcare demands of this segment of the population. As the prevalence of non-communicable diseases, especially among the elderly, continues to rise, the need for expanded medical services becomes even more pronounced. This holds even in well-performing markets like Brazil, Russia, India, China and South Africa (BRICS) (Jankovic, 2016).

The presence of individuals below the age of 15 in the dependent population is significant for several reasons. Children have distinct healthcare needs, including routine check-ups, vaccinations, preventive care and treatment of common childhood illnesses. Therefore, adequate investment in PHE ensures children's well-being and proper development.

Investing in the health of individuals below the age of 15 also has long-term benefits. Early interventions and access to healthcare services during childhood significantly impact long-term health outcomes. Addressing health issues and providing appropriate healthcare for children offers a greater chance of preventing or managing health conditions effectively. This, in turn, reduces future healthcare costs and improves overall population health. Moreover, children represent the future workforce and contributors to the economy. Investing in their health and well-being is crucial for the development of human capital and the long-term economic growth of a country. Healthy and well-nurtured children are more likely to reach their full potential, pursue higher education, and become productive members of society.

Investing in the health of the ageing population and individuals below the age of 15 is vital to ensure a healthy and prosperous future for individuals and societies. It requires a comprehensive approach that includes adequate PHE, healthcare interventions, and long-term strategies to promote population health and well-being. Consequently, private and public health expenditure must be increased to meet the ageing population's needs. Non-communicable diseases are the primary drivers of increasing demand for medical services, even in top-performing markets like BRICS countries (Jankovic, 2016).

2.9.2 Technological progress

Technological progress is also a crucial factor influencing PHE. The adoption of new technologies such as advanced medical devices and equipment has resulted in higher demand for healthcare services, leading to increased PHE. Similarly, the availability of new technologies has increased the supply of healthcare services by enabling advanced medical procedures, expanding access through telemedicine and digital health, enhancing data management and analysis and empowering individuals to actively manage their health. Thus, technological progress has improved healthcare delivery and promoted better health outcomes, but requires more PHE (Bodenheimer, 2005; Rankovic *et al.*, 2013; Jakovijevic *et al.*, 2015).

2.9.3 GNP per capita

The proportion of GNP per capita allocated to health funding is a determinant of PHE and an indicator of a country's commitment to prioritising health and well-being. When a significant portion of GNP is dedicated to healthcare, this demonstrates strong commitment by the government and society to invest in the health sector. Such commitment often leads to robust healthcare infrastructure and improved access to medical services and, ultimately, better health outcomes for the population.

Commitment to healthcare services in OECD countries is indicated by a high percentage of GNP allocated to PHE (Newhouse, 2015; Banmol & Blinder, 2015). However, SSA countries often allocate less to health expenditure (Okunade, 2005; Khan, Razali & Shafie, 2016).

Low levels of PHE are of concern in developed, developing and underdeveloped countries (Nesrin, Sonmez & Yitmaz, 2017). It is believed that countries should formulate their PHE based on the epidemiological profile of their populations because the higher the prevalence of epidemics, chronic/non-communicable diseases (not caused by infectious agents or transmission) and mortality rates in a country or region, the higher the level of PHE should be.

In sub-Saharan African countries, where mortality and morbidity rates are relatively high, the proportion of governmental income allocated to PHE is often insufficient. This highlights the challenge of limited government commitment to health spending in these countries. In comparison, OECD countries that have shown strong dedication to higher health expenditure have achieved better health outcomes for their citizens. Furthermore, in SSA, PHE is often inadequate for healthcare infrastructure, services and resources, which hinders the region's ability to combat diseases and improve overall health outcomes. However, OECD countries have prioritised health expenditure to enhance healthcare accessibility, quality and outcomes. Therefore, to achieve sustainable long-run growth, sub-Saharan African governments must allocate more resources to health, guaranteeing better health outcomes.

2.9.4 Unemployment

Unemployment can impact PHE and the level of government commitment to spending on health in several ways:

Reduced tax revenue: Unemployment often decreases tax revenue as fewer people earn taxable income. With lower tax revenues, governments may face budget constraints and find it challenging to allocate sufficient funds to various sectors, including healthcare. The reduced income from employed individuals directly affects the government's capacity to invest in PHE.

Increased demand for public health services: Unemployment can result in higher demand for public health services, especially among individuals who have lost employer-sponsored health insurance or cannot afford private health insurance. As more people rely on publicly funded healthcare services, governments may need to allocate additional funds to meet increased demand and ensure adequate access to healthcare for unemployed individuals.

Social welfare programmes: Unemployment often requires that social welfare programmes be implemented or expanded to support those without income or employment. Such programmes, such as unemployment benefits or welfare assistance, require government funding. Allocation of funds to social welfare programmes can indirectly affect the amount available for PHE, as resources are redirected to support unemployed individuals.

An economic downturn and prioritisation of spending: High unemployment rates can indicate an economic downturn. During such periods, governments may prioritise spending on economic recovery measures, job creation and other critical areas. This may result in limited funds being allocated to PHE as the government focuses on stabilising the economy and reducing unemployment rates.

The impact of unemployment on PHE is particularly notable in SSA, where high unemployment rates can adversely affect public and private health expenditure.

2.10 Chapter summary

This chapter provided a comprehensive overview of PHE and the variables associated with it. It presented clear explanations and graphical and tabular representations to enhance understanding of PHE.

The chapter compared the allocation of PHE in SSA countries with that of OECD countries. It highlighted the disparities in PHE between these regions, emphasising the need for increased commitment to health spending in SSA. Furthermore, the chapter explored the determinants of PHE, recognising factors such as income per capita, the composition of the dependent population, availability of new technologies, and the influence of unemployment. These determinants play a crucial role in shaping the level of PHE and have implications for health outcomes.

The chapter also delved into specific health outcomes, particularly regarding SSA countries' maternal and child mortality rates. It emphasised the importance of addressing these health challenges and highlighted the role of the SDGs, the MDGs, the Abuja Target, and the Commission on Macroeconomics and Health.

Detailed explanations and graphical representations of TFP growth in SSA were presented. By examining TFP growth, the chapter enhances understanding of the broader economic context in which PHE operates. In addition, it addressed the role of education and other non-health variables in shaping public health outcomes. By acknowledging the significance of these variables, the chapter highlighted the multidimensional nature of public health. It emphasised the need for a comprehensive understanding to inform policies and interventions to improve public health outcomes and achieve sustainable development.

Lastly, this chapter presented a conceptual framework that elucidates the interconnectedness between the variables included in the study. This framework depicts the complex relationships and interdependencies between PHE, health outcomes, health and non-health variables and TFP growth.

In summary, this chapter serves as a valuable resource to comprehend the dynamics of PHE and its interconnectedness with the other variables in the study in the context of selected sub-Saharan African countries. It underscores the importance of effective health spending, targeted interventions and collaborative efforts to improve health outcomes and achieve sustainable development in this region.

CHAPTER 3

PUBLIC HEALTH EXPENDITURE AND HEALTH OUTCOMES IN SUB-SAHARAN AFRICA: QUADRATIC, MODERATION AND THRESHOLD EFFECT

3.1 Introduction

This chapter explores the intricate relationship between PHE, health outcomes, and TFP in SSA. It commences with a background discussion in Section 3.2, providing context to the study. Section 3.3 outlines the overall aim of the chapter and delineates the specific objectives and hypotheses. Section 3.4 provides a comprehensive review of relevant literature and highlights the current study's contributions to the existing body of knowledge. The methodology employed in the study is discussed in Section 3.5, elucidating the research design and analytical techniques employed. Section 3.6 presents the results obtained from the analysis and Section 3.7 engages in a thorough discussion, addressing the research hypotheses and providing conclusive insights. The chapter concludes with a summary in Section 3.8, encapsulating the key findings and implications of the study.

By adhering to this framework, the chapter contributes to enhanced understanding of the complex relationship between PHE, health outcomes, and TFP in SSA, shedding light on the importance of optimal PHE and the influence of education on the other variables.

3.2 Background

In SSA, the level of PHE is relatively low, which has been identified as one of the reasons for poor health outcomes in the region (Arthur & Oaikhenan, 2017; Amposah, 2019). Despite global improvements in health services, countries in SSA lag behind, as reflected in the marginal performance of health outcomes, particularly LEB (Fayissa & Gutema, 2005; Arthur & Oaikhenan, 2017). In 2019, the average LEB in SSA was 62 years, while it was 64 years in other low-income countries outside Africa. Middle-income countries had an average LEB of 72 years, and high-income countries an average LEB of 81 years. As at 2020, the LEB in SSA remained at 62, while other regions with countries of varying income levels such as South Asia, the Middle East and North Africa, recorded higher LEB of 70, 64, and 74, respectively.

In 2017, 20 countries in SSA accounted for 62% of global maternal mortality, indicating adverse health outcomes in the region (WHO, 2022). Moreover, the suboptimal levels of PHE in SSA are considered to contribute to the poor health outcomes observed in the region. However, there is a need to verify the connection between PHE and health outcomes. Thus, the data were analysed to establish initial results to lay the foundation for further exploration of nonlinear relationships and threshold effects between PHE and health outcomes. This initial analysis enabled an understanding of the general patterns and associations between the variables.

The initial results were obtained by examining potential non-linearities or thresholds in the relationship between PHE and health outcomes. Nonlinear relationships refer to situations where the effect of one variable on another is not constant but varies based on the levels or interactions of the variables involved. Conversely, a threshold refers to specific points at which the level of the variable starts to influence the other variables in ways that are different from the ways in which lower levels do.

Exploring nonlinear relationships and threshold effects revealed points or levels at which investment in PHE had the most significant impact on health outcomes. Ultimately, the analysis and further exploration of nonlinear relationships and threshold effects provides policymakers, researchers, and stakeholders with valuable insights and evidence-based guidance to design and implement effective interventions and policies to improve health outcomes in SSA.

While the existing literature acknowledges the role of PHE as a determinant of health outcomes (Novigon & Lawson, 2018), an increase in PHE has not translated into significant improvements in health outcomes in SSA (Amposah, 2019). It is therefore essential to determine the threshold level of PHE that would significantly impact health outcomes in this region. Recent studies have suggested the existence of non-linearities in the relationship between PHE and health outcomes, including LEB (Kelley & Schmidt, 1995; De la Croix & Licandro, 1999; Boucekkine, De la Croix & Licandro, 2002; An & Jeon, 2006; Kunze, 2014). These studies revealed that increasing PHE may be of more benefit to health outcomes when starting from low levels of health than from high levels. There is thus a need to understand the nonlinear relationship and identify the threshold level of PHE required for improved health outcomes in SSA.

Previous studies in this field of research differ in many ways from the analysis in this study because of the emphasis on the nonlinear, threshold and moderation analysis with a focus on SSA. For example, McIntyre, Meheus, and Rottingen (2017) examined the level of PHE that would promote progress towards UHC in low-income countries but did not specifically focus on SSA. Other studies, such as those by McIntyre and Ataguba (2012) and Mathauer *et al.* (2007, 2008), focused on PHE in individual countries in southern Africa, particularly South Africa, Lesotho, and Swaziland. Building on these studies, the current study provides a comprehensive analysis of PHE and health outcomes across multiple countries in SSA to identify common patterns, trends and potential thresholds that are specific to the region, thus contributing to a deeper understanding of the factors influencing health outcomes in this particular context.

In the Abuja 2001 Declaration (WHO, 2001), members of the African Union committed to allocating 15% of their budget to health. However, since 2001, only a few countries have been able to meet this requirement, highlighting the challenge of obtaining sufficient funding for healthcare. Moreover, there is considerable diversity among countries in terms of health allocations, with some dedicating more than 5% of their GNP to health while others allocate only 3%. This discrepancy in funding levels further compounds the disparities in healthcare provision across SSA.

The Commission on Macroeconomics and Health (2001) recommended that healthcare spending in SSA increase from US$34 per person per year in 2007 to US$38 by 2015, equivalent to roughly 12% of GNP (WHO, 2001). However, 22 years after the Abuja Declaration and the Commission's recommendation, many SSA countries still fall short of this target, with a significant number spending less than 5% of their GNP on health.

The growing international focus on the need for increased government funding for healthcare has been driven by discussions on UHC, which might largely depend on PHE. However, as documented by Amposah (2019), in SSA, PHE is consistently insufficient to ensure effective and efficient performance of the health sector, impacting equity in health outcomes (Rahman *et al.*, 2018).

The current study expanded the existing literature by exploring the interplay between PHE, health outcomes and education. Previous studies mainly focused on linear relationships between these variables, ignoring the possibility of nonlinear relationships. By analysing the interactions between PHE, education and health outcomes, the study provides a holistic understanding of how investment in PHE and raising the level of education could contribute to improved health outcomes in SSA.

Given the limited impact of PHE on its own in bringing about substantial improvements in health outcomes, the study explored the interaction between education and PHE to do so.

Understanding whether a combination of education and PHE yields different results from either factor in isolation could inform policies and interventions to, for example, lower the MMR and CMR and raise LEB in SSA. It is thus necessary to identify specific thresholds for the education level and the optimal mix of PHE and education that could lead to improved health outcomes.

Increasing the level of education can have a positive impact on health outcomes through various mechanisms (WHO, 2014), including:

- Health knowledge and awareness: Education teaches individuals about healthy behaviour, disease prevention, and healthcare resources. With higher levels of education, people are more likely to be aware of health risks, understand the importance of preventive measures, and make informed decisions regarding their health.
- Health literacy: Education enhances individuals' ability to understand and interpret health information, including medical instructions, health guidelines, and healthcare policies. Improved health literacy enables individuals to navigate the healthcare system effectively, understand health-related information, and make informed decisions about their health and that of their families.
- Access to healthcare: Education can improve individuals' access to healthcare services. People with higher education levels are more likely to have higher incomes and better job opportunities, which can provide access to health insurance coverage and financial resources to afford healthcare services. In addition, education can empower individuals to navigate complex healthcare systems, advocate for their health needs, and overcome barriers to accessing healthcare.
- Health behaviour: Education has been linked to healthier lifestyle choices. Individuals with higher levels of education are more likely to engage in behaviour that promotes good health, such as regular exercise, a balanced diet, and avoiding harmful substances like tobacco and alcohol. Education can also influence reproductive health decisions, leading to improved family planning and safer sexual practices.
- Socioeconomic factors: Education is closely tied to socioeconomic status, and higher socioeconomic status is associated with better health outcomes. Education can lead to improved job prospects, higher income levels, and greater social mobility, all of which contribute to better access to healthcare, safer living environments, and improved overall well-being.
- Empowerment and agency: Education empowers individuals to take control of their health and advocate for their rights. It can enhance critical thinking skills, problem-

solving abilities, and decision-making capabilities, enabling individuals to actively participate in healthcare and engage in health-promoting behaviour.

Like PHE, education has been recognised as a significant factor in improving health outcomes (Xue, 2020). Lucas' (1988) theory acknowledges that investing in education leads to better health outcomes, human capital, and economic growth.

Figure 3.1 presents scatterplots that demonstrate the inherent relationships amongst PHE, education, and the three health outcomes: MMR, CMR, and LEB. It was anticipated that MMR and CMR would exhibit a negative association with PHE and education while a positive association would be observed with LEB. This would align with the existing literature on the subject.

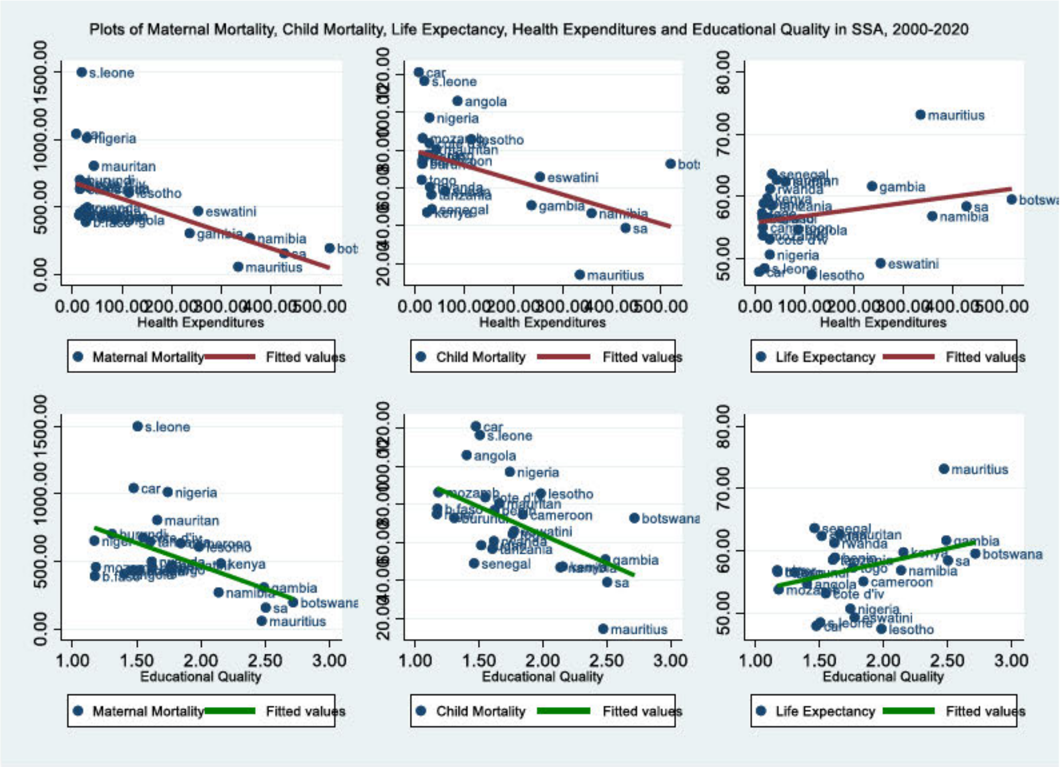


Figure 3.1: Maternal/child mortality, LEB, PHE, and education in SSA (2000-2020)

Building on the insights provided by Figure 3.1 above, the study directed its attention to the crucial relationships between PHE, education, and sustainable thresholds to provide insights into the factors that influence health outcomes in SSA. By examining the interplay between PHE, education, and sustainable thresholds, it uncovered key determinants and effective strategies that can contribute to improved health outcomes in the region.

The study investigated whether increasing PHE, improving education levels, and adhering to sustainable thresholds can contribute to better health outcomes in the context of the SDGs and MDGs. It fills a significant gap in the existing literature by exploring the interplay between PHE, education, and the establishment of sustainable thresholds to improve the region's health outcomes.

3.2 Research aim, objectives, and hypotheses

The main objective of the part of the study described in this chapter was to investigate the nonlinear effect of PHE on health outcomes and the moderating role of education and PHE in selected sub-Saharan African countries. The specific objectives were as follows:

- To re-affirm the importance of PHE and education as key determinants of health outcomes, justifying an examination of their nonlinear effect
- To investigate the nonlinear (quadratic) relationship between PHE and health outcomes
- To determine the threshold points of PHE that significantly impacted health outcomes in the countries under study
- To analyse the moderating effect of education on the relationship between PHE and health outcomes
- To estimate the minimum education thresholds required to sustain the influence of PHE on health outcomes

The main hypothesis of this chapter was that PHE did not have a nonlinear effect on health outcomes and education and did not play a moderating role in determining health outcomes in the countries under study. The sub-hypotheses were as follows:

- PHE and education did not significantly determine health outcomes, as measured by maternal mortality, child mortality and life expectancy in the studied countries.
- PHE did not exhibit a nonlinear effect on health outcomes, as measured by maternal mortality, child mortality and life expectancy in the studied countries.

- There was no identifiable threshold point at which PHE significantly affected changes in health outcomes, as measured by maternal mortality, child mortality and life expectancy in the studied countries.
- Education and PHE did not moderate health outcomes, as measured by maternal mortality, child mortality and life expectancy in the studied countries.
- There was no identifiable threshold point at which education significantly affected changes in health outcomes, as measured by maternal mortality, child mortality and life expectancy in the studied countries.

3.4 Literature review

The following sections review the theoretical and empirical literature.

3.4.1 Theoretical literature

3.4.1.1 Grossman's (1972) model of health demand

Grossman's (1972) model posits that demand for medical care is based on the interaction of a demand function and a production function for health. Health is seen as a capital good/stock, which people initially have, although it depreciates over time because people's health deteriorates as they age. Nevertheless, health can be increased through investment but will also depreciate if the necessary inputs (investment) are lacking. Thus, the model recognises health as both a consumption and investment good. Investment in health involves a sacrifice on the part of the consumer who must be willing to devote time and resources to have a reasonable health outcome (output). Compared with its output, the health input will determine the optimal level of health investment.

3.4.1.2 Mosley and Chen's (1984) framework for child survival

The current study, which used infant mortality as one of the proxies for health outcomes, adopted Mosley and Chen's (1984) framework for child survival in developing countries. According to this framework, socioeconomic determinants acting through biological mechanisms influence mortality. In other words, underlying socioeconomic factors determine proneness to disease and death, which is relevant to the study's focus on factors that affect the impact of PHE on health outcomes. Thus, people's health status largely depends on their genetics, behaviour, environment, and socioeconomic status.

3.4.1.3 Fayissa and Gutema's (2005) theory

Fayissa and Gutema's theory extends Grossman's (1972) model from the micro to the macro level. Fayissa and Gutema (2005) investigated the determinants of health status in SSA. Three core determinants were established. The first is economic determinants, represented by the ratio of PHE to GDP and food availability per capita. The second is social, represented by the illiteracy rate and alcohol consumption. The third is environmental, indicated by the urbanisation rate and carbon dioxide emissions per capita. One-way and two-way panel data analyses were carried out, and the results revealed that a decrease in the illiteracy rate and an increase in food availability increased LEB.

3.4.1.4 Life Course Perspective (LCP)

Lu and Halfon (2003) provide a lens through which to analyse maternal/child mortality. Moreover, the life course perspective theory was created due to maternal challenges that result in birth outcome discrepancies (Lu & Halfon, 2003). It borrows conceptually from early programming (Barker, 1990) and cumulative pathways to demonstrate how the environment influences growth (McEwen, 1998). Early programming and cumulative route processes were derived from a large British birth cohort research study during the 1930s (Lu & Halfon, 2003).

The early programming mechanism arose from the Barker hypothesis, which states that human development is susceptible to prenatal and early childhood experiences (Hogan *et al.,* 2012). It goes on to state that these early experiences have long-term health effects, such as the development of diabetes and cardiovascular disease (Barker, 1990). In contrast, the cumulative path mechanism investigates the effects of accumulation and adaptation to persistent social and physical stressors, sometimes referred to in the literature as "wear and tear", on human development and health (Lu & Halfon, 2003; McEwen, 1998; Pies, Parthasarathy & Posner, 2012). These may include homelessness, prejudice, infectious diseases, and health-related activities (e.g., smoking) (Lu & Halfon, 2003).

The LCP proposes that women who experience chronic stress such as recurrent experiences of racism, discrimination, displacement, and intergenerational poverty are at increased risk of adverse health outcomes, particularly when these experiences occur during critical developmental periods such as prenatal development, adolescence and pregnancy (Lu & Halfon, 2003; Pies *et al.*, 2012). Thus, this model determines health outcomes based on the belief that environmental stressors impact a person's health status, which aligns with the current study**.**

3.4.1.5 *Historical trauma theory*

The historical trauma (HT) theory provides an alternative lens to comprehend socioeconomic determinants by identifying the effect of traumatic experiences on the health outcomes of marginalised groups as a result of targeted oppression. It emerged from a study of Jewish Holocaust survivors, which found that survivors' offspring were more likely than the general population to suffer from mental health conditions such as post-traumatic stress disorder despite not having directly experienced the Holocaust (Brave Heart & DeBruyn, 1998). This generated the belief that future generations biologically, socially, and culturally inherent mental and physical health disorders (Sotero, 2006). Recent research has applied HT to Mexican Americans (Estrada, 2009), and it was relevant in the current study to identify the socioeconomic determinants of health.

3.4.2 Empirical literature

This section reviews the empirical literature in line with the relationships of interest in the study.

3.4.2.1 *Health expenditure and health outcomes*

Numerous studies have been conducted on the relationship between PHE and health outcomes. Hlafa, Sibanda, and Hompashe’s (2019) research revealed that PHE is a prerequisite for better health outcomes and sustainable development. It examined the South African economy's inability to achieve the health-related MDGs despite achievement of this goal by other middle-income countries and, therefore, investigated the impact of PHE on health outcomes in South Africa across its nine provinces.

The study employed fixed and random effect panel data to control for time effects, individual provincial heterogeneity, and seemingly unrelated regression and least squares dummy variables to analyse data from 2002 to 2016. The results revealed that PHE had a varying effect across the nine provinces. Specifically, it was documented as a significant determinant of LEB and child mortality. While the influence of the ratio of physicians remained insignificant on LEB and child mortality, HIV and AIDS reduced LEB. Most of the variables employed in Hlafa, Sibanda, and Hompashe’s (2019) research were adopted in the current study.

Njoroge’s (2020) study assessed Eastern and Southern African countries’ efforts to achieve the SDGs by capturing the impact of PHE on health outcomes in 18 of these countries with an emphasis on the role of governance. The study period spanned from 2001 to 2017, and GMM was the estimating technique. The results revealed that PHE (total, public, and private) had a significant negative relationship with health outcomes (under-five and maternal mortality). In contrast, a positive relationship was documented between PHE and LEB. In addition, the study revealed that PHE had a higher impact on health outcomes than private health expenditure because of the largely poor population that depends solely on the government for healthcare in Africa. For instance, in South Africa, 82.6% of the population depends on PHE, making only 17 in 100 South Africans able to access private health insurance schemes (World Bank, 2017). Moreover, the WHO (2018) contends that OOP funding does not contribute to equitable progress in achieving UHC.

Shilongo (2019) investigated the impact of government PHE on health outcomes in 10 countries in SSA from 2000 to 2016: Angola, Botswana, Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania and Zambia. Fixed effects regression was employed for the analysis, which revealed that PHE had a significant impact on child/maternal mortality outcomes but an insignificant effect on LEB. This study differed from that conducted by Njoroge (2020) described above, where PHE (total, public, and private) was not found to impact maternal/child mortality. However, it had a positive relationship with LEB. Furthermore, Shilongo's (2019) study revealed improved maternal/child mortality only after controlling for corruption, which, along with other studies, suggests the need to include this variable in frameworks to determine health outcomes.

Amposah (2019) examined the impact of PHE and other macroeconomic determinants on health outcomes in SSA using data from 2000 to 2015. The results revealed that GDP per capita, one physician per 1,000 people, the proportion of the population older than 65 and under-five mortality are determinants of health outcomes. In addition, PHE had a significant negative impact on maternal and infant mortality but a positive significant impact on LEB. The study also showed that PHE does not exhibit income elasticity in countries with higher income levels.

Bein *et al.* (2017) assessed PHE's impact on health outcomes proxied by infant mortality and LEB in 10 Eastern countries. Fixed effects regression analysis was employed and the results revealed a positive relationship between PHE and LEB. However, a negative relationship was recorded between PHE and health outcomes proxied by neonatal, infant, and under-five mortality.

Novignon *et al*. (2018) investigated the effect of PHE on child health outcomes in 45 sub-Saharan African countries between 1995 and 2011 using neonatal, infant and under-five mortality ratios as indices for child outcomes. The research showed a significant, negative relationship between PHE and child health outcomes. Boachie and Ramu (2015) employed standard ordinary least squares (OLS) to examine the relationship between PHE and health status in Ghana for the period 1990-2002. The study found that the declining infant mortality rate in Ghana was influenced by public health spending. It thus concluded that PHE is associated with improved health status through reduced infant mortality.

In most economies in SSA, the effect of PHE on child health outcomes is more significant than maternal health outcomes because maternal deaths are still very common in this region. Thus, SSA is closer to achieving the SDG target for child mortality than maternal mortality. Shetty and Shetty (2014) studied the correlation between health spending and infant mortality in 34 Asian countries. They found that countries with higher per capita government GDP spending on health had a lower infant mortality rate. The analysis showed that Singapore and South Korea, with a higher level of PHE, had the lowest infant mortality rate, while Afghanistan, with the least per capita health spending had the highest. Due to on-going health challenges, Iraq spent a moderately high proportion of its GDP. The authors thus concluded that there was a need for greater allocation of funds to rebuild health resources.

Novignon *et al.*'s (2012) study investigated the effects of public and private healthcare expenditure on health status in SSA from 1995-2010, covering 44 countries. Fixed and random effects panel data regression models were fitted. The research results revealed that healthcare expenditure significantly influenced health status by improving LEB and reducing maternal mortality rates. In addition, public and private healthcare spending showed a strong positive association with health status, although public healthcare spending had a relatively higher impact.

Odhiambo (2005) investigated the impact of PHE on health outcome indicators like LEB and under-five mortality in Kenya between 1975 and 2004 using OLS. The results revealed that PHE had a significant positive relationship with LEB and a negative relationship with under-five mortality.

Ogbuagu and Olunkwa (2020) adopted the autoregressive distributed lag to study the relationship between capital PHE and infant/maternal mortality. The study produced mixed results, with the relationship positive in the short run, and negative in the long run.

Ogunjimi and Adebayo (2019) examined the relationship between PHE, health outcomes, and economic growth in Nigeria from 1981 to 2017. This study adopted the Toda-Yamamoto causality framework, and found unidirectional causality running from PHE to infant mortality, no causality from real GDP to infant mortality, unidirectional causality from PHE and real GDP to life expectancy and maternal mortality, and unidirectional causality from real GDP to PHE. The study also adopted the autoregressive distributed lag (ARDL), which was used to investigate if a long-run relationship exists among the macroeconomic variables used, and the result was in the affirmative.

Eboh *et al.* (2018) investigated the impact of PHE on the infant mortality rate in Nigeria. The study used an ex-post facto research design and time series data spanning 24 years (1994-2017) sourced from the Central Bank of Nigeria Statistical Bulletin 2016 and the World Bank Report. The data analysis generated descriptive statistics, while OLS were used to estimate the model. The results revealed that recurrent PHE and the Nigerian government's capital expenditure on health significantly affected the infant mortality rate during the period under review. Moreover, recurrent PHE had a more significant negative effect on infant mortality than health capital expenditure.

Aronu and Bilesanmi (2018) examined the impact of the Federal Government of Nigeria's expenditure on health on infant and maternal mortality rate using unit root tests, Granger causality tests, and least squares regression analysis. The results revealed that the government's expenditure on health had a significant, negative impact on infant and maternal mortality in Nigeria, which suggested that an increase in funding might decrease such mortality.

Edeme *et al.* (2017) investigated the effect of PHE on health outcomes in Nigeria, which were proxied by LEB and infant mortality, using the OLS technique. The research revealed that PHE and health outcomes had a long-run equilibrium relationship and that a rise in PHE improved life expectancy and reduced infant mortality. In addition, the results showed that the size of the urban population and the HIV prevalence rate significantly affected health outcomes. At the same time, per capita income exhibited no effect on health outcomes in Nigeria. These results suggest that PHE remains a necessary component in improving health outcomes in this country.

Onofrei *et al.* (2020) analysed the relationship between PHE and health outcomes in European Union countries via regression and factor analysis. The study concluded that PHE can improve LEB and reduce infant mortality. Rahman *et al.* (2018) examined the healthcare expenditure and health outcomes nexus in South Asian Association for Regional Cooperation-Association of Southeast Asian Nations (SAARC-ASEAN). Private, public, and total PHE were incorporated and three main health status outcomes were used: LEB, the crude death rate (number of deaths per 1,000 midyear population) and the infant mortality rate. The study involved data on 15 countries from 1995 to 2014, which were analysed using the fixed and random effects model. It reported that total PHE and private PHE significantly reduced infant mortality rates. However, the extent of the effect of private PHE was higher than that of total PHE, which reduced crude death rates.

Kilanko (2019) investigated the impact of PHE on the infant and under-five mortality rate in West African countries from 2000 to 2018. Fixed and random effect models were employed to analyse the data, and the results revealed a significant negative relationship between PHE and both variables. Danladi's (2021) research on PHE's impact on LEB in Nigeria from 1979 to 2019 employed the dynamic OLS method. The results revealed an insignificant positive relationship between PHE and LEB. Munteh and Fonching (2020) also used OLS regression to assess PHE's impact on under-five mortality in Cameroon. The results showed that PHE had a negative but insignificant effect on under-five mortality.

3.4.2.2 Moderation impact of governance and PHE on health outcomes

Yaqub, Ojapinwa, and Yusuuf (2012) studied the impact of PHE on health outcomes due to governance in the Nigerian economy. The study aimed to determine why health financing did not translate to improved health outcomes despite the government's budgetary outlay. The data on PHE and governance, ranked according to the corruption perception index, were regressed on infant and under-five mortality and LEB. The study employed OLS and two-stage least squares for the analysis.

The results revealed that PHE significantly negatively impacted infant and under-five mortality, especially when the corruption perception index of governance was included. However, the study was conducted to prepare the country to achieve the MDGs. Therefore, the complementary impact of governance on health outcomes was included in the analysis without the interaction of the governance indicator with the PHE variable. This analysis, therefore, only captured the linear impact of all the variables without accounting for their joint variation (Yaqub *et al.*, 2012).

Ibukun (2021) accounted for the joint effect of PHE and governance on health outcomes by examining the mediating role of governance in the PHE-health outcomes nexus for a panel of 15 West African countries from 2000 to 2018. Using the two-stage least-squares estimating technique, the study aimed to determine whether PHE's impact can be altered through interaction with another influencing variable. Ibukun (2021) adopted three indices of health outcomes and six governance indices. The results revealed that all types of PHE significantly affected the health outcomes of infant mortality, under-five mortality, and LEB. This study justified the present study that investigated whether the moderating impact of other variables can improve the impact of PHE.

3.4.2.3 Impact of education on health outcomes

The nexus between education and health has also been considered in the literature. For example, Xue (2020) conducted a meta-analysis of 105 studies with 4,671 estimates to explain the education-health outcomes nexus and found that education is a significant determinant of health outcomes. While the education-health nexus was established in most of the studies Xue (2020) considered, those that did not control for endogeneity were prone to exaggerate the estimated effect. However, the effect became weaker in more recent studies.

Raghupathi and Raghupathi’s (2020) study aimed to understand the impact of education on health in order to improve national health administration and policy. The study drew on World Bank health data on 26 OECD countries from 1995 to 2015 The variables were education proxied by enrolment rates at various educational levels, the not-in-employment, education or training (NEET) rate, and school life expectancy. The health indicators were proxied by infant mortality, child vaccination rates, deaths from cancer, LEB, potential years lost, and smoking rates.

The data were analysed using Tableau for data visualisation and SAS Visual Analytics for correlations and descriptive statistics. The results revealed that adults with a high education level enjoy better health and a longer life span than their less-educated peers. In addition, the study found that tertiary education influences the infant mortality, life expectancy, and child vaccination. Raghupathi and Raghupathi’s (2020) study concluded that health disparities exist across countries and recommended that governments design educational interventions to reduce inequality and improve health.

Monheit and Grafova (2018) investigated the association between parental education and family health. They controlled for family income and health insurance status using data from a medical expenditure panel survey from 2004 to 2012. The study found that parental education beyond 12 years of schooling is associated with increased family healthcare spending and a reduced likelihood of adverse health conditions. Nevertheless, despite this and other studies on the nexus between education and health outcomes, the modifying effect of education combined with PHE on health outcomes is not covered in the literature. The current study thus established the minimum thresholds of PHE and education necessary for better health outcomes.

3.4.2.4 PHE/education thresholds for improved health outcomes

Some studies have examined the threshold of PHE required to achieve a specific target. For example, Abbasi *et al*. (2022) investigated the impact and threshold of healthcare expenditure on morbidity and life expectancy rates in Southeast Asian countries via a dynamic panel threshold model. The results show that healthcare expenditure increases LEB and lowers the death rate as proxied by infant and maternal mortality rates. In addition, the cost-effective level of the country's healthcare expenditure was documented at 6%. Meheus and McIntyre (2017) focused on the level of domestic government PHE required to achieve UHC in low-income countries. Using data from the International Monetary Fund (IMF) and the WHO on various countries, the study concluded that 5% of a country's GDP should be committed to health to fulfil this objective. In a similar study, McIntyre and Ataguba (2012) recommended that PHE rise to 6.4% of GDP for UHC in South Africa. In Tanzania, Borghi, Mtei, and Ally (2012) estimated that PHE should be 4.4% of GDP by 2025 for UHC.

3.4.2.5 Gap in the literature

Notwithstanding the increasing number of studies on the nexus between health expenditure and health outcomes in SSA and the world at large, no study has examined the moderating impact of education in the relationship between health expenditure and health outcomes and the threshold of PHE required in SSA as a whole to achieve improved health outcomes proxied by maternal mortality, child mortality and LEB. However, studies have been conducted on single countries to establish the minimum thresholds (see Meheus & McIntyre, 2017; McIntyre & Ataguba, 2012; Borghi, Mtei, & Ally, 2012).

Nonlinearities could exist in the relationship between PHE and health outcomes such as life expectancy and infant mortality. In other words, the relationship between the variables may not be direct (Kelley & Schmidt, 1995; De la Croix & Licandro, 1999; Boucekkine *et al.*, 2002; An & Jeon, 2006; Kunze, 2014). Therefore, there is a need to determine the threshold of PHE required to improve health outcomes. Increasing PHE may be beneficial when starting from a low level with an increasing trend but ineffective when starting from a high level with a decreasing trend.

3.5 Research methodology

The research methodology adopted to achieve the objectives of this part of the overall study was grounded in the theoretical framework based on Grossman's (1972) model of health theory, which is explained below. Other aspects of the research methodology described below are the study variables, the a priori expectation, the estimating technique, and model specification.

3.5.1 Theoretical framework

The study's theoretical framework was based on Grossman's (1972) model of health demand, where health is not only infirmity or a lack of disease but also physical, mental, and social wellness and, thus, a durable good. A person could be healthy throughout his/her lifetime if good care is taken of the stock of health capital provided at birth. This requires financial and other types of investment, especially when health as a capital good depreciates due to age, disease, and various macroeconomic factors. Moreover, demand for health providers triggers a supply of health, thereby making it a derived demand. Furthermore, demand and supply render health a production function.

Therefore, in light of Grossman's (1972) theory, the health production function can be specified as follows:

$$H = f(x) \qquad (1)$$

Where;

H measures individual health output, and X is a vector of individual inputs in the health production function. The vector elements include PHE (PHE) and education (EDU). The control variables are ICT, household consumption (HCON), individuals living with HIV, people with TB, and TFP.

This theoretical model was designed to analyse health production at the micro level. The interest here, however, is to analyse the production system at the macro level. Therefore, to switch from micro to macro analysis without losing the theoretical foundation, the elements of the vector X were represented by per capita variables and regrouped into the sub-sectoral vectors of health, social, and economic factors as follows:

$H = f(w, y, z)$ (2)

Where;

H is a measure of individual health output, W is a vector of per capita health variables, Y is a vector of per capita social variables, and Z is a vector of per capita economic variables. In its scalar form, Equation 2 above can be rewritten as follows:

$H = f(w_1, w_2 \ldots w_n, y_1, y_2 \ldots y_{n,}, z_1, z_{2\ldots} z_n)$ (3)

Where;

h is an individual's health status proxied by LEB, maternal mortality, and child mortality. In addition, (w_1, $w_2 \ldots$ w_n)=W (vector of per capita health variables), (y_1, $y_2 \ldots$ y_n)=Y (vector of per capita social variables), (z_1, $z_{2\ldots}$ z_n) =Z (vector of per capita economic variables), and n, m, and l are the number of variables in each sub-group. However, using calculus, Equation 3 above can be transformed into an explicit form as follows:

h= $\Omega \Pi y_i$ αi $\Pi sj\beta j$ $\Pi yi\gamma\kappa$ (4)

Where;

αi, βj and $\gamma\kappa$ are elasticities

Equation 4 shows that Ω estimates the initial health stock pointed out by Grossman (1972), which measures health status that has neither depreciated nor improved due to changes in socioeconomic and environmental factors introduced into the production system. However, ($\Pi y_i \alpha i$ $\Pi sj\beta j$ $\Pi yi\gamma\kappa$-1) x 100% would estimate the percentage change in health status due to socioeconomic and health factors.

For the empirical analysis, the variables representing health factors were limited to PHE (w_1), HIV (w_2), and TB (w_3). The variables representing social factors were limited to ICT (y_1) and education (y_2), and those representing economic factors were TFP (z_1) and household consumption (z_2). Moreover, taking the logarithm of Equation 4 above and rearranging it, the following equation was formulated:

$Lnh= ln\Omega + \Sigma\alpha_i (lny_i) + \Sigma\beta_j(lns_j) + \Sigma\gamma\kappa (lnv_\kappa)$ (5)

Where;

i=1, 2, 3; j=1, 2, 3, k=1, 2, and Ω is an estimate of the initial health stock.

The following sections explain the construction of the empirical model to obtain econometric estimates of the parameters given in Equation 5 above. The results determined the relative importance and significance of the factors used in the health production function.

The study's theoretical framework explained health outcomes (maternal mortality, infant mortality, and LEB) regarding PHE, education, and other regressors. As noted previously, education is a component of human capital development and health. In addition, the framework comprised other variables, such as the role of ICT, TFP, and household consumption. The model specification was based on these variables, explained in the next section.

3.5.2 Data definition

This section captures the definition of variables and rationale for including variables. The study used a total of ten variables to achieve the research objectives. The three dependent variables of health outcomes were proxied by the variables of maternal mortality (MAT), child mortality (CHD), and LEB (LEX). The explanatory variable was PHE per capita (HEXPC), the moderating variable was the human capital index as the proxy for education (EDU), and the control variables were Internet usage (ICT), household consumption (HCON), individuals living with HIV, people with TB, and TFP. The data on the health variables which were derived from the literature and covered the period from 2000 to 2020 were sourced from the WHO (WHO, 2021), while the data on non-health variables were sourced from the Penn World Table 10.0.

3.5.2.1 Dependent variables

The health variable was proxied by the maternal/child mortality and LEB variables.

a) Maternal mortality

The maternal mortality variable is labelled MAT in the tables below. It referred to pregnancy-related deaths per 100,000 women during and six weeks after delivery. This variable is one of the critical indices that can be adapted to proxy health outcomes. In this study, it was considered important because of the high level of maternal mortality recorded in SSA (WHO, 2022).

b) Child mortality

The child mortality variable labelled CHD in the tables below referred to the number of deaths per 1,000 live births of children under five (WHO, 2022).

c) Life expectancy at birth

Life expectancy at birth labelled LEX in the tables below, was the number of years a new born is expected to live if exposed to prevailing conditions at the time of birth. Life expectancy in SSA is low compared to other regions and the global average (WHO, 2022).

3.5.2.2 Independent variables

a) Explanatory variable

In the study, the explanatory variable, PHE per capita (HEXPC), referred to as PHE in the tables below, is the capital outlay on health provided by a country's government, including the NHIS. The study measured PHE as a percentage of GNP per person as domestic government PHE. The variable adopted as the most important determinant of health and the impact of PHE on health outcomes is well-established in the literature (see Njoroge, 2020; Shilongo, 2019).

b) Moderating variable

In the study, the moderating variable, education (EDU in the tables below), was proxied by the human capital index, which quantifies the economic and professional potential of a country's citizens. Education is the process of acquiring knowledge and information, which refines an individual's capabilities, proficiency, ability to interact, state of mind, and values. This variable was adopted because it is an alternative variant of human capital (Xue, 2020; Monheit & Grafova, 2018). A combination of PHE and education could have a positive impact on the health outcomes of a country.

c) Control variables

*Human immunodeficiency virus

In the study, the human immunodeficiency virus (HIV) variable referred to this disease, which can increase maternal/child mortality and reduce LEB, thereby impacting health outcomes (Vigezzi *et al*., 2022).

*Tuberculosis

In the study, the TB variable referred to this disease, which can increase maternal/child mortality and reduce LEB, thereby impacting health outcomes.

*Total factor productivity

In the study, the TFP variable referred to the measure of a country's productive efficiency in terms of the output produced from a particular amount of input. Health outcomes can determine the TFP of a country, which means that people need to be healthy and live long to ensure productivity and economic growth. Good health outcomes and longevity are characteristics of developed countries with strong economic growth, which is not the case in SSA. This variable was adopted because it represents productivity growth and prevents diminishing economic marginal returns. Continuous growth without attention to technological frontiers can lead to diminishing returns and a stagnant economy (Solow, 1956).

*Household consumption

The study's household consumption (HCOM) variable referred to the value of goods and services purchased by families or individuals using constant prices across countries. This variable was adopted to indicate the standard of living. It was expected that it would determine health status.

*Information and communication technology

In the study, the information communication technology (ICT) variable referred to the percentage of the population using the Internet, which would provide health information, thereby promoting it. This variable was adopted because an individual might find information about an ailment, which would prompt them to arrange an appointment with a doctor and, in some cases, lead to early diagnosis and survival (Jing *et al.*., 2022).

3.5.3 A priori expectations

A negative relationship between HEXPC and CHD/MAT was expected in the study; in other words, higher PHE per capita would reduce mortality and improve health outcomes (Anyanwu & Erhijakpor, 2009; Alvi & Ahmed, 2014; Rahman *et al.,* 2018; Ibukun, 2021). In addition, a negative relationship was expected between CHD/MAT and ICT/HCOM/TFP, meaning that increased Internet access, an improved standard of living (Majeed & Khan, 2018), and better TFP would reduce maternal/child mortality (Kammerlander & Schulze, 2023). However, a positive relationship was expected between CHD/MAT and HIV/TB; in other words, these diseases would promote maternal/child mortality and poor health outcomes (Moran & Moodley, 2012). Moreover, LEX and HEXPC were expected to be positively related; in other words, increasing PHE per capita would increase life expectancy (Onofrei *et al.*, 2020).

Nevertheless, a positive relationship was expected between EDU and LEX/ICT/TFP/HCOM, which meant that education would improve life expectancy, competence in accessing digital information, TFP, and the standard of living.

3.5.4 Estimating techniques (Justification for parametric model)

PSCC-OLS was used for the analysis, while the pooled OLS (PSCC-FE) method was employed for the robustness check and to control for fixed effects. These techniques were suitable as there might have been cross-sectional dependence in the data, and they were also used in various panel data studies (Adeleye & Eboagu, 2019; Adusei, Adeleye & Okafor, 2020). The PSCC estimator uses the Driscoll and Kraay (1998) robust standard errors technique and corrects the standard errors of the coefficient estimates for possible dependence (Cameron & Trivedi, 2005; Hoechle, 2006). It also considers spatial correlation amongst the observations and provides robust estimates for the relationships between variables. It has a special ability to capture the nonlinear relationship as it summarises the variability of mortality across countries over time in an economical manner (using a minimal number of assumptions, steps, or conjectures as seen in a non-parametric model) without imposing any specific structure OR assumptions on the model specification as assumed.

The underlying algorithm routines the OLS/WLS (ordinary least squares/weighted least squares) and fixed effects (within) regression and computes spatial correlation consistent standard errors for linear panel models. Contextually, cross-sectional dependence (CSD) can be defined as “some correlation structure in the error term between [cross-sectional] units” (Burdisso & Sangiácomo, 2016, pg. 15). Hence, it is necessary to “test whether the residuals are correlated across entities” (Burdisso & Sangiácomo, 2016). The study's null hypothesis was that “there is no correlation of the residual”. There might be CSD in the data if, for instance, a Nigerian migrant who lives in South Africa has access to maternal and child care. If she relocates back to her country, the same maternal and child care would be inaccessible, which may be a health challenge.

Reverse causality might also be a concern. For instance, PHE is likely to be larger in countries with greater health issues and, therefore, higher mortality. To control for this, the models were estimated for the 25 countries in SSA[1] using a one-period lag of each regressor, thereby mitigating the problem of reverse causality.

The researcher was confident that the results were unbiased and somewhat precise for inferences. Next, the study deployed the fixed effects approach (PSCC-FE), which served as robustness checks and accounted for heterogeneities across the panel. For additional robustness checks, the study used (1) people living with TB in place of those living with HIV to observe if the results were consistent and (2) five-year averages for both the HIV and TB models to determine whether the initial results were sustained.

3.5.5 Model specification

To establish linear effects for baseline results, each health outcome was expressed as a linear function of PHE, education, and a set of control variables to address the first objective. That is

$$\ln HO_{it} = \varphi_0 + \varphi_1 \ln HEXPC_{it} + \varphi_2 \ln EDU_{it} + \beta' \boldsymbol{X}_{it} + \delta_t + \varepsilon_{it} \quad [3.1]$$

where ln is a natural logarithm; HO represents each health outcome (maternal mortality, child mortality, and LEB); $HEXPC$ is PHE per capita; EDU is education; $\boldsymbol{X}$ is a vector of the control variables (ICT, HCON, HIV, TFP); δ_t represents year dummies; φ_i and β' are parameters to be estimated, and ε is the idiosyncratic error term assumed to be white noise. All variables were transformed into their natural logarithms to control for outliers, establish an elasticity relationship, and reduce “noise” in the data. To address the second objective of determining the PHE thresholds, a quadratic specification was included in Equation 3.1, and the model became

$$\ln HO_{it} = \eta_0 + \eta_1 \ln HEXPC_{it} + \eta_2 \ln HEXPC_{it}^2 + \eta_3 \ln EDU_{it} + \theta' \boldsymbol{Z}_{it} + \phi_t + v_{it} \quad [3.2]$$

To determine the PHE threshold, Equation 3.2 assumed homogeneity for the parameters. η_1 and η_2, which depended neither on a specific country nor on the period. It was assumed that all countries would take on the same shape of the functional relation of the health outcomes-expenditure paradox. More importantly, Equation 3.2 allowed the various forms of the relationships with (i) $\eta_1 < 0, \eta_2 > 0$ to be tested, revealing a U-shaped relationship; with (ii) $\eta_1 > 0, \eta_2 < 0$ revealing an inverse U-shaped relationship. Moreover, the PHE turning point of this curve was computed by $\hat{\tau} = \exp\left(0.5 \hat{\eta}_1 / \hat{\eta}_2\right)$; (iii) $\eta_1 > 0,\ \eta_2 > 0,$ revealing a

[1]Angola, Burkina Faso, Benin Republic, Botswana, Burundi, Cameroon, Central African Republic, Côte D'Ivoire, Eswatini, Gambia, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania, and Togo.

monotonically increasing linear relationship; (vi) $\eta_1 < 0, \eta_2 < 0$ pointing to a monotonically decreasing linear relationship; and (vii) $\eta_1 = 0,\ \eta_2 = 0$ revealing a level relationship. In general, the turning point was when the first derivative of Equation 3.2 concerning health outcomes was equated to zero.

To achieve the third, fourth, and fifth objectives, an interaction term of PHEs and education, $(\ln HEXPC_{it} * \ln EDU_{it})$, was added to Equation 3.1, and the model became

$$\ln HO_{it} = \phi_0 + \phi_1 \ln HEXPC_{it} + \phi_2 \ln EDU_{it} + \phi_3(\ln HEXPC_{it} * \ln EDU_{it}) + \psi'\boldsymbol{K}_{it} + \omega_t + s_{it} \quad [3.3]$$

Adapting Brambor, Clarke, and Golder (2006) and Barua *et al.* (2022), the sign of the coefficient of the interaction term, ϕ_3 evaluated whether the interaction of EDU and HEXPC enhanced or distorted the impact of PHE on health outcomes. Since ϕ_1 was expected to be negative for mortality models and positive for life expectancy models, which was a "good effect", a positive (negative) ϕ_3 indicated that EDU distorted (improved) the "good effect" of PHE on maternal and child mortality. At the same time, it enhanced (reduced) the "good effect" of PHE on LEB. Therefore, the conditional effect of HEXPC on health outcomes was computed as follows:

$$\frac{\partial \ln HO}{\partial \ln HEXPC} = \phi_1 + \phi_3 \ln EDU \quad [3.4]$$

From Equation 3.4, the overall effect of HEXPC on health outcomes depended on the estimated signs of $\phi_1$andϕ_3, their respective statistical significance, and the magnitude of EDU. However, if either $\phi_1$and $\phi_3 = 0$, then the conditional effect could not be evaluated. The expectation was that increasing PHE would reduce MMR and CMR but increase LEB in countries with a high level of education. Therefore, $\phi_3 < 0$ was expected for the mortality model and $\phi_3 > 0$ for the life expectancy model. Thus, the minimum threshold of education required to sustain PHE in influencing health outcomes was derived as follows:

$$\text{Ln}EDU^* = -\frac{\phi_1}{\phi_3}$$

where, $\ln EDU^*$ denoted the education threshold beyond which PHE reduced MMR and CMR but increased LEB.

3.5 Presentation of results

3.5.1 Pre-estimation results

Table 3.1 below displays the correlation coefficients between the target variables (lnMAT, lnCHD, and lnLEX) and the regressor variables (lnHEXPC, lnEDUC, lnICT, lnHCON, lnHIV, lnTB, and lnTFP). The closer the correlation coefficient is to -1 or 1, the stronger the association (Gujarati, 2004). While the correlation matrix measures the direction and strength of the association between dependent and independent variables, it does not always indicate causality.

Table 3.1: Summary statistics, pairwise correlations, and cross-sectional dependence results

Variable	Summary Statistics					Pairwise Correlations			CD-Test
	Obs	Mean	Std. Dev.	Min	Max	lnMAT	lnCHD	lnLEX	
LnMAT	525	550.133	332.249	52	2480	1.000			64.870***
LnCHD	525	71.095	26.195	13.262	147.185	0.827***	1.000		37.693***
LnLEX	525	56.982	7.049	39.441	74.515	-0.677***	-0.744***	1.000	74.414***
LnHEXPC	525	110.342	161.28	3.395	844	-0.694***	-0.533***	0.322***	34.962***
LnEDU	525	1.753	0.449	1.069	2.939	-0.586***	-0.563***	0.343***	65.981***
LnICT	525	11.427	13.902	0.026	59.42	-0.602***	-0.566***	0.617***	75.210***
LnHCON	525	0.709	0.151	0.221	1.039	0.326***	0.076*	-0.191***	1.734*
LnHIV	525	6.459	7.939	0.2	28.9	-0.153***	0.021	-0.369***	17.337***
LnTB	525	363.395	325.685	11	1590	0.267***	0.381***	-0.567***	37.413***
LnTFP	525	0.472	0.227	0.142	1.25	-0.551***	-0.491***	0.223***	6.021***

Table 3.1 above shows that all the variables of interest were significant at a 1% level, as indicated by the estimated correlation coefficients. In most cases, the strength of the relationship was quite strong and had the expected signs. In addition, the cross-sectional dependence test showed no cross-sectional independence, as the coefficients were all significant.

Table 3.2 below shows the results of the PSCC-OLS, which was used for the analysis as explained in 3.5.2 above.

Table 3.2: PSCC-OLS results

Variables	Linear Models			Quadratic Models			Moderation Models		
	LnMAT	lnCHD	lnLEX	lnMAT	lnCHD	lnLEX	LnMAT	LnCHD	lnLEX
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
LnHEXPC	-0.181***	-0.0794***	0.00509	0.708***	0.175***	-0.0594**	0.306***	0.125***	-0.0613***
	(-4.550)	(-5.031)	(0.623)	(8.702)	(3.084)	(-2.312)	(8.017)	(8.206)	(-5.463)
LnEDU	-0.167***	-0.681***	0.135***	0.189**	-0.579***	0.109***	2.954***	0.635***	-0.268***
	(-4.072)	(-15.02)	(15.43)	(2.359)	(-12.86)	(7.275)	(17.82)	(6.087)	(-5.888)
LnICT	-0.226***	-0.143***	0.0318***	-0.298***	-0.164***	0.0371***	-0.361***	-0.201***	0.0457***
	(-6.296)	(-6.942)	(6.131)	(-10.92)	(-7.747)	(6.771)	(-9.994)	(-9.786)	(6.376)
LnHCON	0.108**	-0.421***	-0.0179**	0.0937**	-0.425***	-0.0169**	0.0167	-0.461***	-0.0126*
	(2.290)	(-13.03)	(-2.397)	(2.308)	(-12.78)	(-2.472)	(0.644)	(-13.65)	(-2.060)
LnHIV	0.0529***	0.118***	-0.0500***	0.0998***	0.131***	-0.0534***	0.0743***	0.127***	-0.0526***
	(8.303)	(23.36)	(-11.72)	(11.57)	(19.45)	(-10.95)	(7.385)	(20.25)	(-10.98)
LnTFP	-0.130*	-0.0575**	-0.00126	-0.0707	-0.0406	-0.00554			
	(-1.807)	(-2.649)	(-0.0897)	(-0.915)	(-1.632)	(-0.395)			
LnHEXPCSQ				-0.112***	-0.0321***	0.00814***			
				(-13.59)	(-5.304)	(3.198)			
lnHEXPC*lnEDU							-0.740***	-0.312***	0.0960***
							(-18.23)	(-18.87)	(8.777)

Threshold				**3.16**	**2.73**	**3.65**	**0.41**	**0.40**	**0.64**
Constant	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Year Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**
R-squared	**0.589**	**0.573**	**0.634**	**0.644**	**0.584**	**0.643**	**0.679**	**0.610**	**0.681**
Countries	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
F-Statistic	**6698**	**6758**	**1385**	**5201**	**10942**	**7154**	**760.8**	**1541**	**820.2**

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses; ln = natural logarithm; MAT = maternal mortality; CHD = child mortality; LEX = life expectancy at birth; HEXPC = PHE per capita; EDUC = education; ICT = Internet users; HCON = household consumption; HIV = people living with HIV; TFP = total factor productivity.

The linear results revealed that a percentage change in PHE significantly reduced maternal and child mortality by -0.181% and -0.079%, respectively. Similarly, a percentage change in education caused a decline in maternal and child mortality of -0.167% and -0.681%, respectively, but improved life expectancy by 0.135%. In addition, the results revealed that ICT had a significantly negative impact on health outcomes proxied by maternal mortality and child mortality in SSA. Nevertheless, the relationship between HIV and health outcomes was positive, which implied that an increase in HIV prevalence might result in increased child and maternal mortality.

For the quadratic models, the focus lay solely on the coefficients of HEXPC and HEXPCSQ to observe the shape of the curve. The relationship with PHE produced an inverted U-shape curve for maternal and child mortality. In other words, an initial increase in PHE caused a rise of 0.708% and 0.175%, respectively, in maternal and child mortality. However, a further increase in PHE resulted in a decline in mortality by -0.112% and -0.0321%, respectively, which supports the literature on the mortality-reducing effect of PHE.

The relationship between life expectancy and health was U-shaped. In other words, an initial increase in PHE caused a decline in life expectancy of -0.0594%, but an additional increase in PHE resulted in improved life expectancy of 3.198%.

The quadratic results revealed sustainable thresholds or turning points beyond which PHE significantly impacted health outcomes. Using Equation 2, the PHE turning point for maternal mortality was computed as $\widehat{HEXPC} = 0.5 * {}^{0.708}/_{0.112}$ = 3.16; for child mortality, it was computed as $0.5 * {}^{0.175}/_{0.0321}$ = 2.73; and for life expectancy, it was computed as $0.5 * {}^{0.0594}/_{0.00814}$ = 3.65.

Since these equations were computed using natural logarithms, it was essential to calculate the exponents to confirm whether the thresholds fell within the data range. Therefore, for each health outcome, the corresponding sustainable PHE thresholds in real terms were as follows: maternal mortality: $[\exp(3.16)] = 23.57$, child mortality: $[\exp(2.73)] = 15.33$, and life expectancy: $[\exp(3.65)] = 38.47$.

As indicated in Table 3.1 above, the range of values for PHE varied from 3.395 to 844. In addition, the shape of the parabola in the mortality models exhibited an inverted U-shape. This suggests that beyond the thresholds of 23.57 and 15.33, higher PHE would substantially reduce maternal and child mortality. Similarly, because of the U-shape relationship, it can be inferred that PHE per capita would significantly improve life expectancy beyond the threshold of 38.47. This relationship is visually depicted in Figure 3.2 below.

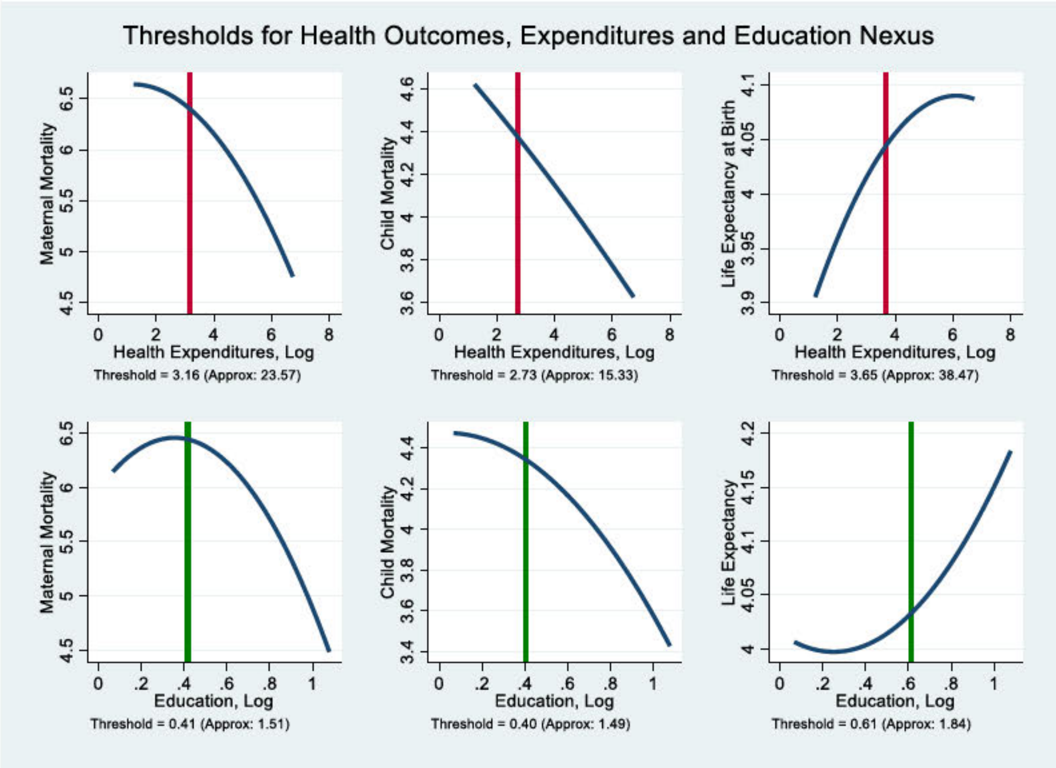


Figure 3.2: Sustainable thresholds of health expenditures and educational quality
Source: Authors' Computations

Having established the linear and quadratic effects, the study used the results of the moderation models to compute the minimum sustainable thresholds at which education could enhance the effect of PHE on each health outcome. These thresholds would have policy implications because, beyond the critical masses, the effect of PHE on each health outcome depends on the strength of education. Given these clarifications, only the significant coefficients of HEXPC and HEXPC*EDUC were used in computing the threshold points.

An inverted U-shaped curve was observed between PHE, education, and the mortality models, indicating that as these factors initially increased, mortality rates decreased until a certain point, after which further increases in these factors led to an increase in mortality rates. Conversely, a U-shaped curve was found between these factors and the life expectancy model, suggesting that as they initially increased, life expectancy also increased until a certain point, beyond which further increases in those factors led to a decrease in life expectancy.

Following Equation 4, the threshold points for $\ln EDU^{*}$ across each health outcome were as follows: maternal mortality: $-\frac{0.306}{-0.740} = 0.41$; child mortality: $-\frac{0125}{-0.312} = 0.40$; and life expectancy: $-\frac{-0.0613}{0.0960} = 0.64$. In these computations, 0.306, 0.125, and -0.0613 represented the absolute value of the unconditional effect of PHE on each health outcome. In contrast, -0.740, -0.312, and 0.096 represented the moderation/conditional effect between PHE and education on each health outcome, respectively. Hence, these computed thresholds revealed that thresholds beyond 0.41 and 0.40 induced a drop in maternal and child mortality, respectively, while a point beyond 0.64 improved life expectancy.

Similar to the quadratic thresholds, those computed from the moderation models used natural logarithms. Therefore, to ensure that those threshold points fell within the range of education, the exponents were calculated and employed to obtain the corresponding values, as follows: maternal mortality: $[\exp(0.41)] = 1.51$; child mortality: $[\exp(0.40)] = 1.49$; and life expectancy: $[\exp(0.64)] = 1.84$. As indicated in Table 3.1 above, the range of values for education varied from 1.069 to 2.939. In addition, the shape of the parabola in the mortality models exhibited an inverted U-shape. This suggests that beyond the thresholds of 1.51 and 1.49, education would substantially reduce maternal and child mortality, respectively. Similarly, because of the U-shape relationship, it can be inferred that education would significantly improve life expectancy beyond the threshold point of 1.84. This relationship is visually depicted in Figure 3.2

The PSCC-OLS did not recognise the individual heterogeneities or fixed effects across the countries in the panel. Therefore, the models were re-estimated using the fixed effects routine (PSCC-FE), and the results are shown in Table 3.3 below. These results were mostly consistent with those shown in Table 3.2. A significant negative linear relationship was found between PHE and child mortality. The linear relationship between education and each health outcome was statistically significant with the expected signs.

Contrary to expectations and the results in Table 3.2 (Columns 4-6), the quadratic models revealed a U-shaped relationship between PHE and maternal/child mortality. Moreover, an inverted U-shaped relationship with life expectancy indicated that allocating more funds to PHE beyond a certain threshold would worsen health outcomes. The calculated thresholds were 3.47%, 4.37%, and 3.85% for maternal/child mortality and life expectancy, respectively.

Analogous to the results shown in Table 3.2, the real values for the threshold points, which fell within the range of PHE (3.395 to 844), were determined to be 32.14, 79.04, and 46.99 for maternal/child mortality and life expectancy, respectively. The most plausible explanation for these contradictions could be that individual differences across the countries drove these anomalies. Table 3.3 below shows the PSCC-FE results.

Table 3.3: PSCC-FE results

Variables	Linear Models			Quadratic Models			Moderation Models		
	LnMAT	LnCHD	lnLEX	lnMAT	lnCHD	LnLEX	lnMAT	lnCHD	lnLEX
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
LnHEXPC	-0.0110	-0.0413*	0.00481	-0.280***	-0.172***	0.0350**	-0.154***	-0.0944**	0.000433
	(-0.729)	(-1.905)	(1.393)	(-6.173)	(-3.447)	(2.133)	(-5.039)	(-2.523)	(0.0297)
LnEDU	-0.493***	-0.857***	0.0602***	-0.463***	-0.842***	0.0569**	-1.700***	-1.323***	0.0194
	(-6.737)	(-11.54)	(2.968)	(-5.533)	(-10.28)	(2.631)	(-6.405)	(-5.683)	(0.145)
LnICT	-0.0844***	-0.0152*	0.0106***	-0.0702***	-0.00831	0.00898***	-0.0454***	-0.00435	0.0110**
	(-7.129)	(-1.900)	(3.919)	(-7.849)	(-0.956)	(3.234)	(-6.257)	(-0.378)	(2.690)
LnHCON	-0.00175	-0.0226	0.00625	-0.0220	-0.0324	0.00852	-0.0173	-0.0446*	0.00222
	(-0.0322)	(-0.780)	(0.629)	(-0.380)	(-1.122)	(0.785)	(-0.406)	(-1.736)	(0.148)
LnHIV	-0.0978***	0.0345**	0.0103	-0.166***	0.00154	0.0179	-0.167***	0.00720	0.00781
	(-2.992)	(2.607)	(0.543)	(-5.990)	(0.208)	(1.208)	(-5.884)	(1.245)	(0.640)
LnTFP	0.0196	-0.0350**	-0.00871	0.0579	-0.0165	-0.0130			
	(0.377)	(-2.479)	(-0.492)	(1.257)	(-1.113)	(-0.846)			
LnHEXPCSQ				0.0405***	0.0197***	-0.00455*			
				(6.207)	(3.643)	(-1.830)			
lnHEXPC*lnEDU							0.268***	0.0984**	0.00796
							(6.151)	(2.685)	(0.335)
Threshold				3.46	4.37	3.85	0.57	0.96	NA
Constant	0	0	0	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	525	525	525	525	525	525	525	525	525
Time	21	21	21	21	21	21	21	21	21
Countries	25	25	25	25	25	25	25	25	25
F-Statistic	67.60	195.6	35.28	784.2	1244	665.7	60.12	241.8	30.99

Lastly, the moderation models revealed a U-shaped curve between PHE, education, and the mortality models. At the same time, the relationship with life expectancy was not different from zero (that is, statistically not significant). The computation of the critical mass for sustainability resulted in 0.57 and 0.96 for maternal and child mortality, respectively. Converting to real terms, the threshold points, which lay within the range of values for education, were determined to be 1.77 and 2.61 for maternal and child mortality, respectively. Beyond these points, education negatively influenced the impact of PHE on maternal and child mortality.

3.5.2 Robustness Check results

To test the robustness of the results of the PSCC-OLS and PSCC-FEFE analyses shown above, a substitution was made by replacing people living with HIV with those living with TB. The results of this robustness test are presented in Tables 3.4 (PSCC-OLS) and 3.5 (PSCC-FE) below. As discussed by White and Lu (2010), the results are considered robust if they align with the main model's results or fall within a similar range. Robustness checks aim to identify changes when assumptions are altered.

In Table 3.4 below, the linear models indicate that an increase in PHE reduced maternal mortality and child mortality by 0.26% and 0.11%, respectively, while improving life expectancy by 0.12%. However, in the quadratic model, as reflected by the negative coefficient of the squared PHE, the relationship between PHE and child mortality and life expectancy initially showed improvement but later worsened. The relationship between PHE and maternal mortality and life expectancy followed a U-shaped pattern, whereas the relationship with child mortality exhibited an inverted U-shaped pattern. The thresholds for maternal and child mortality and life expectancy were 2.72, 2.85, and 6.67, respectively.

Table 3.4 below shows the PSCC-OLS robustness results.

Table 3.4: PSCC-OLS robustness results

Variables	Linear Models			Quadratic Models		
	lnMAT	lnCHD	lnLEX	lnMAT	lnCHD	lnLEX
	[1]	[2]	[3]	[4]	[5]	[6]
LnHEXPC	-0.255***	-0.113***	0.0121***	0.536***	-0.0468	0.0303***
	(-10.11)	(-12.12)	(3.228)	(7.740)	(-1.265)	(3.553)
LnEDU	-0.215***	-0.523***	0.0536***	0.198*	-0.489***	0.0631***
	(-3.800)	(-13.08)	(5.868)	(2.013)	(-11.66)	(5.650)
LnICT	-0.172***	-0.116***	0.0252***	-0.242***	-0.122***	0.0236***
	(-5.587)	(-7.357)	(7.748)	(-8.614)	(-6.810)	(7.115)
LnHCON	0.132***	-0.314***	-0.0665***	0.166***	-0.311***	-0.0657***
	(4.103)	(-24.32)	(-7.468)	(5.637)	(-22.59)	(-7.280)
LnTB	0.257***	0.205***	-0.0675***	0.266***	0.206***	-0.0673***
	(35.83)	(70.32)	(-20.43)	(35.29)	(62.44)	(-20.65)
LnTFP	-0.0488	-0.00703	-0.0157	-0.00152	-0.00310	-0.0146
	(-0.598)	(-0.264)	(-1.005)	(-0.0177)	(-0.104)	(-0.942)
LnHEXPCS				-0.0984***	-0.00820*	-0.00227*
				(-11.21)	(-1.806)	(-1.952)
lnHEXPC*lnEDU						
Threshold				2.72	2.85	6.67
Constant	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	525	525	525	525	525	525
R-squared	0.721	0.689	0.708	0.769	0.689	0.709
Countries	25	25	25	25	25	25
F-Statistic	4537	13888	1533	6992	5364	17567

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses; ln = natural logarithm; MAT = maternal mortality; CHD = child mortality; LEX = life expectancy at birth; HEXPC = PHE per capita; EDUC = education; ICT = Internet users; HCON = household consumption; TB = people living with tuberculosis; TFP = total factor productivity.

Other control variables demonstrated similar effects on the key variables to those observed in the main model. The fixed effects model in Table 3.5 below showed robustness results that are consistent with the main model. Health expenditure improved the performance of the key variables across all models, and TB had a similar effect to HIV in the main model. Therefore, the robustness results supported the findings of the main model.

Table 3.5 below shows the PSCC-FE robustness results.

Table 3.5: PSCC-FE robustness results

Variables	Linear Models			Quadratic Models		
	LnMAT	lnCHD	lnLEX	lnMAT	lnCHD	lnLEX
	[1]	[2]	[3]	[4]	[5]	[6]
LnHEXPC	-0.0144	-0.0397*	0.00464*	-0.209***	-0.171***	0.0262
	(-0.962)	(-1.861)	(1.845)	(-5.918)	(-3.615)	(1.365)
LnEDU	-0.484***	-0.868***	0.0697***	-0.462***	-0.853***	0.0672***
	(-7.569)	(-11.26)	(3.336)	(-6.615)	(-10.20)	(3.169)
LnICT	-0.0758***	-0.0194**	0.0113***	-0.0618***	-0.0100	0.00970***
	(-8.053)	(-2.380)	(4.626)	(-8.036)	(-1.055)	(3.428)
LnHCON	-0.0256	-0.0259	0.0241*	-0.0572	-0.0473*	0.0276**
	(-0.380)	(-0.933)	(1.725)	(-0.821)	(-1.770)	(2.100)
LnTB	-0.0473*	0.0666***	-0.0606***	-0.0487	0.0656***	-0.0605***
	(-1.755)	(8.216)	(-3.835)	(-1.649)	(5.640)	(-3.699)
LnTFP	0.0156	-0.0357**	-0.00557	0.0402	-0.0191	-0.00830
	(0.297)	(-2.636)	(-0.314)	(0.813)	(-1.446)	(-0.527)
LnHEXPCSQ				0.0292***	0.0197***	-0.00323
				(5.965)	(3.929)	(-1.131)
lnHEXPC*lnEDU						
Threshold				3.58	4.34	NA
Constant	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	525	525	525	525	525	525
Countries	25	25	25	25	25	25
F-Statistic	56.18	237.6	56.53	1282	1855	2118

The results obtained using five-year averages are displayed in Tables 3.6 and 3.7 below. The results from the PSCC-OLS in Table 3.4were similar to those displayed in Table 3.2. The inverted U-shaped relationship between PHE and maternal and child mortality was sustained, aligning with the main model. The threshold points for this relationship were determined to be 3.58 and 4.34, respectively. However, the relationship with life expectancy was inconclusive as it was statistically insignificant, although the coefficients had the expected signs.

The quadratic effect of the PSCC-FE results in Table 3.6 revealed a U-shaped nexus with maternal/child mortality and an inverted U-shaped relationship with life expectancy. The respective threshold points were 3.46, 4.27, and 4.04. Similarly, the moderation relationship depicted a U-shaped nexus with maternal mortality, with the threshold point at 0.60. However, the relationship between PHE and child mortality, as well as life expectancy, was insignificant. Thus, the results shown in Table 3.6 below resemble those shown in Table 3.2 above.

Table 3.6: Robustness check results – 5-year averages (HIV Models)

Variables	PSCC-OLS			PSCC-FE		
	Quadratic Models			Quadratic Models		
	LnMAT	lnCHD	lnLEX	lnMAT	LnCHD	lnLEX
	[1]	[2]	[3]	[7]	[8]	[9]
lnHEXPC	0.818***	0.209***	-0.0619	-0.306***	-0.164**	0.0314***
	(10.34)	(2.867)	(-1.225)	(-7.382)	(-2.619)	(6.134)
LnEDU	0.374***	-0.533***	0.0910***	-0.541***	-0.834***	0.0546**
	(4.325)	(-8.122)	(4.483)	(-4.865)	(-8.503)	(2.498)
lnHEXPCSQ	-0.127***	-0.0366***	0.00882*	0.0442***	0.0192***	-0.00389***
	(-23.07)	(-5.108)	(1.831)	(7.349)	(3.579)	(-5.440)
lnHEXPC*lnEDU						
LnICT	-0.374***	-0.197***	0.0418***	-0.0986***	-0.0129	0.0110***
	(-9.934)	(-8.269)	(3.861)	(-5.394)	(-1.381)	(3.474)
LnHCON	0.0615	-0.480***	-0.0163***	-0.176	-0.0576	0.0104
	(1.155)	(-10.64)	(-2.858)	(-1.409)	(-1.443)	(0.569)
LnHIV	0.101***	0.131***	-0.0498***	-0.190***	0.00868*	0.0267
	(11.67)	(13.77)	(-5.543)	(-7.997)	(1.755)	(1.564)
LnTFP	0.0400	0.00291	-0.0160	0.171**	-0.0101	-0.0262
	(0.259)	(0.115)	(-0.833)	(2.117)	(-0.529)	(-1.555)
Threshold	3.22	2.86	NA	3.46	4.27	4.04
Constant	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125	125	125	125	125	125
R-squared	0.652	0.583	0.651			
Countries	25	25	25	25	25	25
F-Statistic	156.8	98.33	669.8	1794	5678	1296

Note: *** p<0.01, ** p<0.05, * p<0.1; *t*-statistics in parentheses; ln = Natural logarithm; MAT = Maternal mortality; CHD = Child mortality; LEX = Life expectancy at birth; HEXPC = Health expenditures per capita; EDUC = Education; ICT = Internet users; HCON = Household consumption; HIV = People living with HIV; TFP = Total factor productivity. Source: Authors' Calculations

Table 3.7 below shows the results of further robustness checks, which were conducted by substituting people living with HIV with individuals living with TB. These robustness checks aimed to ensure the accuracy and transparency of the model.

The PSCC-OLS results showed an inverted U-shaped relationship between PHE and maternal mortality, with a threshold of 2.86. However, the relationships between child mortality and life expectancy were inconclusive. In the moderating relationships, an inverted U-shaped nexus was found with maternal mortality and a U-shaped nexus with life expectancy, while the relationship with child mortality remained inconclusive.

The PSCC-FE results revealed a U-shaped relationship between PHE and maternal and child mortality, while an inverted U-shaped nexus was found between PHE and life expectancy. The threshold points were 3.62, 4.16 and 4.29 for maternal/child mortality and life expectancy, respectively. These results suggested that the relationship between PHE and the three health outcomes was nonlinear.

Table 3.7: Robustness check results – 5-year averages (TB Models)

Variables	PSCC-OLS			PSCC-FE		
	Quadratic Models			Quadratic Models		
	LnMAT	lnCHD	lnLEX	LnMAT	lnCHD	LnLEX
	[1]	[2]	[3]	[7]	[8]	[9]
LnHEXPC	0.636***	-0.0184	0.0239*	-0.231***	-0.168**	0.0222***
	(9.937)	(-0.391)	(2.055)	(-10.44)	(-2.790)	(4.303)
LnEDU	0.381**	-0.460***	0.0566***	-0.543***	-0.849***	0.0690***
	(2.781)	(-9.203)	(4.163)	(-5.914)	(-8.600)	(4.346)
LnHEXPCSQ	-0.111***	-0.0112**	-0.00134	0.0319***	0.0202***	-0.00259***
	(-11.00)	(-2.315)	(-1.234)	(12.06)	(3.708)	(-2.946)
lnHEXPC*lnEDU						
LnICT	-0.316***	-0.149***	0.0262***	-0.0881***	-0.0175	0.0134***
	(-6.610)	(-36.03)	(6.725)	(-5.788)	(-1.492)	(3.167)
LnHCON	0.169***	-0.335***	-0.0721***	-0.251*	-0.0909***	0.0546*
	(5.751)	(-17.43)	(-7.633)	(-1.726)	(-3.326)	(1.762)
LnTB	0.261***	0.205***	-0.0645***	-0.0344	0.0805***	-0.0677***

	(25.54)	**(44.49)**	**(-11.10)**	**(-0.867)**	**(5.567)**	**(-3.245)**
LnTFP	**0.105**	**0.0314**	**-0.0211**	**0.158***	**-0.00702**	**-0.0266**
	(0.596)	**(0.881)**	**(-1.005)**	**(1.829)**	**(-0.489)**	**(-1.027)**
Threshold	**2.86**	**NA**	**NA**	**3.62**	**4.16**	**4.29**
Constant	**0**	**0**	**0**	**0**	**0**	**0**
Year Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	**125**	**125**	**125**	**125**	**125**	**125**
R-squared	**0.769**	**0.687**	**0.721**			
Countries	**25**	**25**	**25**	**25**	**25**	**25**
F-Statistic	**2492**	**7761**	**1472**	**1595**	**1179**	**12295**

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses; ln = natural logarithm; MAT = maternal mortality; CHD = child mortality; LEX = life expectancy at birth; HEXPC = PHE per capita; EDUC = education; ICT = Internet users; HCON = household consumption; TB = people living with TB; TFP = total factor productivity.

Two sensitivity checks were performed to test the robustness of the analysis, including education as a moderating variable. The first set involved replacing individuals with HIV with those living with TB. The second set used five-year averages of the sample data for both the HIV and TB models, applying them to both empirical techniques, the PSCC-OLS and the PSCC-FE.

The results of the robustness check applying PSCC-OLS and PSCC-FE are presented in Table 3.8 below, which shows that with education as the moderation variable, the PSSC-OLS results revealed that PHE had an inverted U-shaped relationship with maternal mortality and a U-shaped relationship with life expectancy. The PSSC-OLS results revealed conditional threshold points for the effect of PHE on maternal mortality and life expectancy of 0.25 and 0.37, respectively. The PSCC-FE results revealed a U-shaped nexus between PHE and maternal/child mortality, with conditional threshold points of 0.62 and 0.92.

Table 3.8: Robustness check results (TB Models) with education as moderating variable

Variables	PSCC-OLS			PSCC-FE		
	Moderation Models			Moderation Models		
	lnMAT	lnCHD	lnLEX	lnMAT	lnCHD	lnLEX
	[4]	[5]	[6]	[10]	[11]	[12]
LnHEXPC	0.143***	-0.0132	-0.0145***	-0.113***	-0.0982***	0.00251
	(5.652)	(-0.524)	(-3.600)	(-4.414)	(-2.945)	(0.212)
LnEDU	2.290***	0.101	-0.114***	-1.320***	-1.365***	0.0516
	(13.92)	(0.731)	(-3.476)	(-6.762)	(-6.728)	(0.485)
LnICT	-0.285***	-0.144***	0.0327***	-0.0492***	-0.00361	0.0118**
	(-8.962)	(-7.418)	(7.795)	(-5.848)	(-0.314)	(2.761)
LnHCON	0.0887***	-0.324***	-0.0636***	-0.0708	-0.0528*	0.0231**
	(4.196)	(-22.01)	(-7.553)	(-0.964)	(-1.816)	(2.189)
LnTB	0.233***	0.200***	-0.0659***	-0.0330	0.0751***	-0.0603***

	(48.53)	**(60.18)**	**(-20.94)**	**(-0.932)**	**(5.970)**	**(-4.290)**
LnTFP	**0.0269**	**0.0119**	**-0.0207**	**0.0358**	**-0.0237***	**-0.00513**
	(0.383)	**(0.407)**	**(-1.313)**	**(0.734)**	**(-1.929)**	**(-0.326)**
lnHEXPCSQ						
lnHEXPC*lnEDU	**-0.580*****	**-0.145*****	**0.0388*****	**0.181*****	**0.107*****	**0.00392**
	(-19.86)	**(-4.615)**	**(6.385)**	**(5.290)**	**(3.617)**	**(0.200)**
Threshold	**0.25**	**NA**	**0.37**	**0.62**	**0.92**	**NA**
Constant	**0**	**0**	**0**	**0**	**0**	**0**
Year Dummies	**Yes**	**Yes**	**Yes**			
Observations	**525**	**525**	**525**			
R-squared	**0.776**	**0.697**	**0.715**			
Countries	**25**	**25**	**25**			
F-Statistic	**1606**	**6760**	**1203**			

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses; ln = natural logarithm; MAT = maternal mortality; CHD = child mortality; LEX = life expectancy at birth; HEXPC = PHE per capita; EDUC = education; ICT = Internet users; HCON = household consumption; TB = people living with tuberculosis; TFP = total factor productivity.

The results obtained using five-year averages are presented in Tables 3.9 and 3.10 below, where the findings from the PSCC-OLS align closely with those displayed in Table 3.2, indicating that the moderating effect of education on the relationship remained consistent.

Table 3.9 below presents the results of a robustness check using different regression models to examine the relationship between various variables and HIV-related outcomes. The focus is on assessing the moderating effect of education on the relationship between the independent variables and the outcomes.

Overall, this table allows for a comparison of different regression models and their coefficients to assess the relationship between various variables and HIV-related outcomes, focusing on the moderating effect of education.

Specifically, there was an inverted U-shaped relationship between maternal and child mortality and a U-shaped relationship with life expectancy. The respective threshold points for the PSCC-OLS results were 0.44, 0.46, and 0.60, respectively. The PSCC-FE results revealed a U-shaped nexus between PHE and maternal mortality, with a threshold of 0.60. However, the relationships between PHE and child mortality and life expectancy were inconclusive and insignificant.

Table 3.9 below presents the robustness check results – five-year averages (HIV Models) with education as a moderating variable.

Table 3.9: Robustness check results – 5-year averages (HIV Models) with education as moderating variable

Variables	PSCC-OLS			PSCC-FE		
	Moderation Models			Moderation Models		
	LnMAT	LnCHD	LnLEX	lnMAT	lnCHD	lnLEX
	(6.799)	(11.01)	(-2.610)	(-10.11)	(-1.502)	(-0.691)
LnEDU	3.312***	0.799***	-0.313***	-1.862***	-1.258***	-0.0415
	(59.39)	(15.06)	(-3.916)	(-12.30)	(-4.214)	(-0.463)
LnHEXPCSQ						
		-0.793***	-0.341***	0.278***	0.0886*	0.0212
	(-29.64)	(-44.48)	(4.793)	(14.18)	(1.915)	(1.372)
LnICT	-0.442***	-0.243***	0.0570***	-0.0740***	-0.00774	0.0168***
	(-9.084)	(-13.40)	(5.235)	(-4.956)	(-0.482)	(2.964)
LnHCON	-0.0290	-0.520***	-0.00419	-0.209*	-0.0638	0.00173
	(-0.411)	(-9.280)	(-1.001)	(-1.715)	(-1.549)	(0.0982)
LnHIV	0.0706***	0.125***	-0.0489***	-0.196***	0.0145**	0.0152
	(6.656)	(15.19)	(-5.971)	(-18.71)	(2.539)	(0.955)
LnTFP	0.0890	0.0345**	-0.0266*	0.167**	-0.0172	-0.0185
	(0.843)	(2.295)	(-1.876)	(2.215)	(-1.157)	(-1.146)
Threshold	0.44	0.46	0.60	0.60	NA	NA
Constant	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125	125	125	125	125	125
R-squared	0.685	0.614	0.692			
Countries	25	25	25	25	25	25
F-Statistic	12423	759.1	21.28	1827	486.1	93.16

Note: *** p<0.01, ** p<0.05, * p<0.1; *t*-statistics in parentheses; ln = Natural logarithm; MAT = Maternal mortality; CHD = Child mortality; LEX = Life expectancy at birth; HEXPC = Health expenditures per capita; EDUC = Education; ICT = Internet users; HCON = Household consumption; HIV = People living with HIV; TFP = Total factor productivity. Source: Author's Calculations

The substitution of HIV with TB was undertaken, and the outcomes are presented in Table 3.10 below. The PSCC-OLS results revealed a moderating inverted U-shaped and a U-shaped relationship with maternal mortality and life expectancy, respectively. The threshold points for these relationships were identified as 0.30 and 0.44, respectively. However, the relationship with child mortality yielded inconclusive findings. Furthermore, the PSCC-FE results revealed the presence of a U-shaped nexus between PHE and maternal and child mortality, as determined by the moderation models. The respective threshold points for these relationships were 0.66 and 0.84, respectively. These results partially supported the findings presented in Table 3.2 above. In addition, it can be argued that the relationship between PHE and the three health outcomes was nonlinear, as indicated in Table 3.10 below.

Table 3.10: Robustness check results – 5-year averages (TB Models) with education as moderating variable

Variables	PSCC-OLS			PSCC-FE		
	Moderation Models			Moderation Models		
	lnMAT	lnCHD	lnLEX	lnMAT	lnCHD	lnLEX
	[4]	[5]	[6]	[10]	[11]	[12]
lnHEXPC	0.190***	0.0187	-0.0199***	-0.110***	-0.0980**	-0.00499
	(7.134)	(0.377)	(-3.288)	(-10.72)	(-2.091)	(-0.955)
LnEDU	2.670***	0.271	-0.149***	-1.340***	-1.402***	-0.00379
	(15.05)	(1.560)	(-6.458)	(-18.71)	(-5.724)	(-0.0676)
lnHEXPCSQ						
lnHEXPC*lnEDU	-0.639***	-0.179***	0.0455***	0.166***	0.116***	0.0159*
	(-24.81)	(-3.566)	(12.24)	(8.657)	(3.317)	(1.751)
LnICT	-0.367***	-0.182***	0.0384***	-0.0776***	-0.00892	0.0181***
	(-7.564)	(-20.18)	(10.30)	(-4.717)	(-0.539)	(3.307)
LnHCON	0.0628***	-0.356***	-0.0686***	-0.270*	-0.108***	0.0424
	(4.357)	(-37.73)	(-9.477)	(-1.797)	(-5.449)	(1.617)
LnTB	0.227***	0.197***	-0.0627***	-0.0189	0.0917***	-0.0652***
	(54.45)	(47.27)	(-11.99)	(-0.364)	(5.949)	(-3.544)
LnTFP	0.135	0.0492	-0.0277	0.149*	-0.0107	-0.0210
	(0.975)	(1.530)	(-1.380)	(1.740)	(-1.479)	(-0.845)
Threshold	0.30	NA	0.44	0.66	0.84	NA
Constant	0	0	0	0	0	0
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125	125	125	125	125	125
R-squared	0.777	0.698	0.731			
Countries	25	25	25	25	25	25
F-Statistic	4543	2208	3791	1466	136.7	4260

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses; ln = natural logarithm; MAT = maternal mortality; CHD = child mortality; LEX = life expectancy at birth; HEXPC = PHE per capita; EDUC = education; ICT = Internet users; HCON = household consumption; TB = people living with TB; TFP = total factor productivity

3.6 Discussion of research results

3.6.1 Determinants of health outcomes

Poor health outcomes have been a persistent challenge in the health sector in SSA, calling for further analysis. In addition, the appropriate level of PHE to improve health outcomes remains an unresolved debate, with limited evidence on the impact of funding on maternal/child mortality and life expectancy, for example. To address these gaps, the study employed PSCC-OLS and PSCC-FE estimation techniques to investigate the determinants of health outcomes, such as PHE and education, the moderating effect of education on the relationship between PHE and health outcomes and non-linearity in SSA. In addition, the study aimed to identify the thresholds associated with these effects.

The objective of reaffirming PHE and education as determinants of health outcomes was to establish baseline results that support nonlinear and threshold analysis. Furthermore, the study aimed to verify the presence of a nonlinear relationship between PHE and health outcomes, identify the threshold effects of PHE on health outcomes, examine the moderating influence of education on the relationship between PHE and health outcomes, and determine any threshold effects of education on health outcomes. Despite the growing number of studies on the determinants of health outcomes and the impact of PHE, to the best of the author's knowledge, no study has investigated the interactive or modifying impact of education and PHE on health outcomes. Therefore, the study contributed valuable understanding of the topic.

3.6.2 Summary of research results

The research results revealed that a percentage increase in PHE significantly reduced maternal and child mortality by 0.181% and 0.079%, respectively. This aligned with a priori expectations and the neo-materialist theory of health. It is also supported by research conducted by Novingnon *et al.* (2012), Boachie and Ramu (2015), and Ibukun (2021), for example. The positive relationship between PHE and LEB has also been documented in the literature (Rahman *et al.*, 2018).

Similarly, a percentage increase in education led to a decline in maternal and child mortality of 0.167% and 0.681%, respectively, and improved LEB by 0.135%. These results aligned with a priori expectations and the literature, indicating that increased education of mothers and pregnant women reduces child and maternal mortality. (Raghupathi & Raghupathi, 2020; Ogunleye, 2014).

The analysis of the linearity of the effect of PHE on health outcomes revealed that it was more nonlinear than linear. The relationship between PHE and maternal and child mortality demonstrated an inverted U-shaped curve, which was nonlinear. Initially, an increase in PHE led to a rise in both maternal, and child mortality. However, further increases in PHE resulted in a decline in mortality, supporting the literature's stance on the mortality-reducing effect of PHE (Ibukun, 2021). Similarly, the relationship between PHE and LEB followed a U-shaped curve. The initial increase in PHE caused a decline in life expectancy, but additional increases improved life expectancy. This finding aligns with previous empirical literature (Onofrei, Vatamanu, Vintila & Cigu, 2020).

The results indicated that ICT significantly and negatively impacted maternal and child mortality in SSA. This result was in line with a priori expectations and previous research on the effect of ICT on health outcomes (Majeed & Khan, 2018). On the other hand, a positive relationship was found between ICT and LEB (Jing *et al.*., 2022). The relationship between HIV and maternal and child mortality in SSA was positive, suggesting that an increase in HIV prevalence would result in higher mortality rates. Similarly, the relationship between HIV and LEB was negative and significant, indicating that higher HIV prevalence would lead to a reduction in LEB (Vigezzi *et al.*, 2022).

In the quadratic models, the coefficients of HEXPC and HEXPCSQ were of specific interest because of the shape of the curve, which would allow for an examination of the relationships between variables. The nonlinear analysis was considered superior to the linear analysis because it introduced a threshold variable that divided the analysis into two separate compartments: one with negative and one with positive relationships. This division allowed for the identification and examination of both positive and negative relationships between the dependent and independent variables over time.

In other words, including the threshold variable in the analysis helped to distinguish between different phases or regimes in the relationship between the variables. This enabled the researcher to observe and understand how the direction and strength of the relationship changed as the independent variable crossed the threshold point. By recognising and studying these distinct compartments, the nonlinear analysis provided a more comprehensive and nuanced understanding of the relationship between the variables than the linear analysis.

The presence of positive and negative relationships indicated a nonlinear or quadratic relationship and the existence of a threshold point. Thus, the relationship between PHE and health outcomes in SSA was found to be nonlinear or quadratic, and there were threshold points. In simpler terms, positive and negative relationships between PHE and health outcomes suggested that the study did not point to a straightforward linear relationship, but a more complex pattern.

This finding has important implications for policymakers. Firstly, it indicates that simply increasing PHE may not always lead to proportional improvements in health outcomes. The relationship between expenditure and outcomes is more nuanced and involves specific threshold points that should be considered. Identifying these threshold points is crucial for policymakers. They represent the specific levels of PHE beyond which significant impacts on health outcomes are observed. By understanding these thresholds, policymakers can make more informed decisions about allocating resources and targeting interventions. They can aim to ensure that PHE reaches or surpasses these threshold points to achieve the desired improvements in health outcomes.

The threshold effect analysis revealed the sustainable thresholds or turning points beyond which PHE significantly impacted health outcomes. Using Equation 2, PHE's turning point for maternal mortality was computed as $\widehat{HEXPC} = 0.5 * {}^{0.708}/_{0.112}$ = 3.16; for child mortality: $0.5 * {}^{0.175}/_{0.0321}$ = 2.73, and for life expectancy: $0.5 * {}^{0.0594}/_{0.00814}$ = 3.65. Moreover, 3.65% was the highest benchmark threshold adopted in the study. This result differed from McIntyre, Filip, and John-Arne's (2017) study that recommended 5% of GDP as the benchmark level of PHE for achievement. The difference in results can be attributed to the fact that the 5% of GNP recommended by McIntyre *et al.* (2017) was not linked to specific health outcomes, whereas the results of this study were.

The parabola for the mortality models was an inverted U-shape, suggesting that PHE would significantly reduce maternal and child mortality beyond US$23.57 and US$15.33 (real terms, in dollars), respectively. Similarly, the U-shape relationship between PHE and life expectancy indicated improvement beyond the threshold point of US$38.47 (real terms in dollars), which aligns with the recommendation of the Commission on Macroeconomics and Health (WHO, 2001) that healthcare spending in SSA should rise to US$38 in 2015, representing roughly 12% of GNP.

The results of the interactive effect of PHE and education on health outcomes indicated an inverted U-shaped curve between PHE, education and the mortality models. In contrast, a U-shaped curve was observed for the life expectancy model. The threshold education point that would achieve better health outcomes was estimated by obtaining the corresponding values using exponents: $[\exp(0.41)] = 1.51$ for maternal mortality; $[\exp(0.40)] = 1.49$ for child mortality; and $[\exp(0.64)] = 1.84$ for life expectancy.

In summary, this study on SSA found the following:

- Education and PHE have the potential to determine health outcomes.
- A nonlinear relationship was detected between PHE and health outcomes, suggesting that the relationship might not be linear or proportional.
- A minimum threshold of 3.65% of GDP or US$38.47 was identified as potentially improving health outcomes.
- Education moderated the relationship between PHE and health outcomes, indicating that the education level might influence PHE's impact on outcomes.
- A threshold level of a 1.84% increase in the level of education was associated with improved health outcomes in SSA.

The study contributes to the existing literature by providing evidence that PHE and education were determinants of health outcomes in SSA. It also provided evidence that an optimal mix of PHE and education could significantly reduce maternal and child mortality rates and increase life expectancy. Moreover, the study provided information on the nonlinear relationship between PHE/education and health outcomes, whereby specific threshold points need to be considered. These results have important implications for policymakers when determining the optimal levels of investment in health and education.

The study's major limitation lay in not considering additional control variables in the model. Future studies could address this limitation by including variables such as GDP per capita, urbanisation, and development aid, which could alter the signs and statistical significance of the coefficients used to calculate the thresholds.

3.6.3 Implications of research results for SSA

The research results have significant implications, highlighting the urgent need for increased PHE and improved education levels in most countries across SSA. The study revealed that, except for Lesotho and Namibia, nearly all the countries examined in SSA (96%) fell short of meeting the computed minimum threshold of 3.65% of GDP or US$38.47 for PHE. The study identified this threshold as potentially crucial for enhancing health outcomes. Furthermore, the findings indicated that 68% of the countries in the region failed to meet the calculated minimum threshold of a 1.84% improvement in education levels, deemed necessary to improve health outcomes.

These results underscore the pressing need for action, highlighting insufficient allocation of resources to PHE and the inadequate education level across most SSA countries. According to Lucas, both variables are proxies of the human capital required to enhance growth. Policymakers and stakeholders should recognise the importance of increasing public health funding and investing in education to improve regional health outcomes.

The WHO (2016) used a scientifically proven method (DEA) to show that all countries (including those with very low levels of public spending on health) could achieve UHC with < US$40 per capita. In comparison, the Macroeconomic Commission on Health stated that countries should spend at least US$34 per capita to achieve UHC.

Based on the results of this study, we recommend that SSA countries increase their health spending to an optimum level of US$38 per capita for better health outcomes. The results of this analysis align with the previous recommendations by the WHO and the Macroeconomic Commission because they all fall within the same range of < US$40 per capita as recommended by the WHO, although not exactly as recommended by the Macroeconomic Commission. The commission recommended US$34 per capita, while our estimate is slightly higher. The difference could be linked to the high mortality and epidemics in the SSA region. This analysis is important because the SSA data was exclusively used based on appropriate scientifically proven methodology. Apart from the methodology employed, the amount recommended is linked to specific health outcomes (infant mortality, maternal mortality and LEB). The recommendations by the WHO and the Macroeconomic Commission lack this credibility.

Table 3.11 below presents the mean of PHE compared to the thresholds calculated in the study for countries in SSA. The data in this table provide valuable insights into the mean PHE concerning the thresholds calculated for countries in SSA. This analysis sheds light on the financial allocations made towards public health. It enables a comparison of the predetermined thresholds derived from the study and the extent to which countries have met or fallen short of the recommended thresholds, highlighting the areas where improvements are necessary.

Analysing this data could help policymakers to identify countries that have effectively allocated resources towards public health and those that require additional investment. Thus, Table 3.11 below could serve as a tool to assess the adequacy of PHE in countries across SSA by providing a clear picture of the current situation and helping policymakers make informed decisions in allocating resources and improving healthcare outcomes in the region.

Table 3.11: PHE in SSA versus recommended thresholds

Country	Mean of PHE per capita as a percentage of GDP	Threshold of PHE per capita as a percentage of GDP and in US$	Interpretation
Angola	3.4884	3.65 (US$38.47)	Below threshold
Burkina Faso	1.6466	3.65 (US$38.47)	Below threshold
Benin	0.7083	3.65 (US$38.47)	Below threshold
Botswana	3.5556	3.65 (US$38.47)	Below threshold
Burundi	2.0699	3.65 (US$38.47)	Below threshold
Cameroon	0.7313	3.65 (US$38.47)	Below threshold
Central African Republic	1.2228	3.65 (US$38.47)	Below threshold
Côte d'Ivoire	0.8921	3.65 (US$38.47)	Below threshold
Eswatini	3.3083	3.65 (US$38.47)	Below threshold
Gabon	1.4304	3.65 (US$38.47)	Below threshold
Kenya	1.6968	3.65 (US$38.47)	Below threshold
Lesotho	4.2560	3.65 (US$38.47)	Threshold met
Mauritania	1.1607	3.65 (US$38.47)	Below threshold
Mauritius	1.8724	3.65 (US$38.47)	Below threshold
Mozambique	1.9735	3.65 (US$38.47)	Below threshold
Namibia	4.3361	3.65 (US$38.47)	Threshold met
Niger	1.8266	3.65 (US$38.47)	Below threshold
Nigeria	0.6757	3.65 (US$38.47)	Below threshold
Rwanda	1.9087	3.65 (US$38.47)	Below threshold
Sierra Leone	1.5402	3.65 (US$38.47)	Below threshold
South Africa	3.4884	3.65 (US$38.47)	Below threshold
Senegal	1.3125	3.65 (US$38.47)	Below threshold
Sudan	1.5549	3.65 (US$38.47)	Below threshold
Tanzania	1.5488	3.65 (US$38.47)	Below threshold
Togo	0.9728	3.65 (US$38.47)	Below threshold

Table 3.12 below presents the mean of education proxied by the HCI and compares it with the thresholds calculated in the study for countries in SSA. It offers valuable insights into the average education levels and allows for a comparison with the predetermined thresholds derived from the study.

By examining the data in Table 3.12 below, policymakers might better understand the educational investment made in each country in SSA. The calculated thresholds could serve as benchmarks against which education levels can be evaluated.

This comparative analysis between the mean education levels and the recommended thresholds presented in the table provides a comprehensive assessment of how SSA countries perform in education. It reveals the extent to which they have met or fallen short of the recommended thresholds, highlighting areas that require improvement and enabling policymakers to prioritise resources and interventions where education levels are relatively low to meet the calculated thresholds.

Table 3.12: Education proxied by HCI in SSA versus recommended thresholds

Country	Mean of increase in the level of education proxied by HCI |as a percentage	Threshold of PHE per capita as a percentage of GDP and in US$	Interpretation
SSA	1.30	1.84	Below threshold
Angola	2.4411	1.84	Threshold met
Burkina Faso	1.1565	1.84	Below threshold
Benin	1.5755	1.84	Below threshold
Botswana	2.6824	1.84	Threshold met
Burundi	1.2898	1.84	Below threshold
Cameroon	1.8338	1.84	Below threshold
Central African Republic	1.4625	1.84	Below threshold
Côte d’Ivoire	1.5264	1.84	Below threshold
Eswatini	1.7179	1.84	Below threshold
Gabon	2.4302	1.84	Threshold met
Kenya	2.1251	1.84	Threshold met
Lesotho	2.0278	1.84	Threshold met
Mauritania	1.6332	1.84	Below threshold
Mauritius	2.4471	1.84	Threshold met
Mozambique	1.1746	1.84	Below threshold
Namibia	2.1189	1.84	Threshold met
Niger	1.1620	1.84	Below threshold
Nigeria	1.7045	1.84	Below threshold
Rwanda	1.5701	1.84	Below threshold
Sierra Leone	1.4849	1.84	Below threshold
South Africa	2.4411	1.84	Threshold met
Senegal	1.4375	1.84	Below threshold
Sudan	1.5025	1.84	Below threshold
Tanzania	1.5868	1.84	Below threshold
Togo	1.7568	1.84	Below threshold

3.7 Chapter Summary

Chapter 3 provided an overview of how the study determined the nonlinear effect of PHE and education on health outcomes in SSA, focusing specifically on maternal and child mortality and life expectancy. It emphasised the need to meet minimum thresholds and highlighted that simply increasing the levels of PHE and education would not guarantee improvements in health outcomes.

The chapter addressed the first secondary research objective of the study, which was to investigate the quadratic relationship between PHE and health outcomes. It also covered the second secondary research objective, which examined the moderating and threshold effect of education and PHE on health outcomes in selected countries in SSA.

The chapter began by providing background information on the specific part of the study covered in this chapter (Section 3.2). It then outlined this part of the study's aim, research objectives and hypotheses (Section 3.3). A literature review relevant to the topic was presented in Section 3.4, which highlighted the study's contribution to the existing body of knowledge. The methodology employed for this part of the study was discussed in Section 3.5, while the results were presented, interpreted, and discussed in Section 3.6. Finally, a summary of the chapter was provided in Section 3.7.

The study investigated the nonlinearity, threshold, and moderating effect of PHE on health outcomes, focusing specifically on maternal mortality, child mortality and LEB. Unlike previous studies that analysed the linear effect of PHE without considering these aspects, this chapter aimed to fill that gap by providing a comprehensive analysis. It established PHE and education as determinants of health outcomes using maternal mortality, child mortality and LEB as proxies.

The chapter validated the existence of a threshold relationship between PHE per capita and health outcomes, identifying a threshold level of 3.65%, which corresponds to PHE per capita of US$38 in real terms. In addition, the interactive impact of PHE and education on health outcomes was established, identifying a threshold relationship between education and health outcomes at 1.84%.

Based on the findings, the study recommends that a balanced combination of PHE per capita and education is crucial to significantly reduce maternal and child mortality rates and increase life expectancy. The policy implications derived from this chapter include the need for governments and stakeholders to implement strategies that enhance PHE and education. This is because improvements in these variables will substantially impact health outcomes. Furthermore, it is important to increase the levels of PHE and education to meet the minimum sustainable thresholds estimated in the study. In addition, education should be considered a complementary factor in health, given its modifying effect on the relationship between PHE and health outcomes.

The following chapter focuses on forecasting maternal and child mortality regarding the SDG targets, considering different PHE scenarios.

CHAPTER 4

FORECASTING MATERNAL AND CHILD MORTALITY PERFORMANCE WITH IMPROVED PUBLIC HEALTH EXPENDITURE IN TERMS OF SDG TARGETS

4.1 Introduction

This chapter explains how the study forecast maternal and child mortality in terms of SDG Targets 3.1 and 3.2 (70 deaths per 100,000 births for maternal mortality and 25 deaths per 1,000 live births for child mortality by 2030) based on PHE scenarios. Section 4.2 covers the background of this part of the study, and Section 4.2 spells out the overall aim, specific objectives, and hypothesis. Section 4.4 discusses the literature, Section 4.5 details the methodology, and Section 4.6 presents and discusses the results. Section 4.7 concludes the chapter.

4.2 Background

Sub-Saharan Africa has not been on track to achieve the health-related SDGs (Adegoke *et al.,* 2022). Specifically, the region has been bedevilled by a high, chronic MMR and CMR. It also had a low LEB of 62 years in 2020, below the world average of 73 years. In the same period, low-income countries in South Asia, the Middle East and North Africa recorded an LEB of 70, 64 and 74 years, respectively. Although the UN target for maternal mortality is 70 deaths per 100,000 births and 25 deaths per 1,000 live births for child mortality by 2030 (UN, 2015), countries in SSA have much higher rates. These health outcomes are due to limited PHE (Stenberg, Hanssen, Edejer & Bertram, 2017). The economic profile of these countries does not support the achievement of these targets because of the unfavourable macroeconomic environment in the region.

Average PHE in SSA was 1.9% of GNP from 1995 to 2019, while in 2020, it was 2.02% of GNP (WHO, 2022a), which was insufficient, with more required to achieve the SDG targets. Therefore, the study identified the need to forecast whether the countries under review could achieve the SDG targets based on various PHE scenarios. The scenario analysis represents a pre-assumed increase in PHE per capita to achieve the maternal and child mortality SDG targets by 2030. The region is known to have the highest maternal and child mortality across the globe as a result of various macroeconomic, social and biological factors. Inadequate government expenditure is recognised as the most prominent determinant of health outcomes. Over time, PHE in SSA has been reported as the lowest in the world. Despite various strides by governments in ensuring a sustainable increase in health spending, the region is overburdened with high maternal and infant mortality, raising concern that SDG 3 might not be achievable in SSA.

The results of this analysis could inform policymakers and stakeholders about the necessary resources and the PHE they need to commit to realise these targets. Although several studies exist on factors determining maternal and infant health outcomes in SSA, none have projected the required PHE levels.

4.3 Research aim, objectives and hypothesis

The overall aim of this chapter was to forecast whether the selected countries in SSA could achieve the maternal and child mortality SDG targets based on per capita PHE scenarios.

The specific research objectives were as follows:

- Forecast maternal and child mortality based on a 10% increase in per capita PHE
- Forecast maternal and child mortality based on a 20% increase in per capita PHE
- Forecast maternal and child mortality based on a 30% increase in per capita PHE

The following hypothesis was formulated:

The forecasts of a 10%, 20% and 30% increase in per capita PHE did not indicate achievement of SDG Targets 3.1 and 3.2.

4.4 Literature review

The following sections review the theoretical and empirical literature on forecasting. This section presents a critical review of forecasting models based on the duration and models adopted, which covers short-term, medium-term, and long-term forecasts. Classification is based on the models involved: the micro-simulation-based model, macro model, and machine learning (ML) techniques like TreeNet, stochastic gradient boosting, and multivariate adaptive regression splines (MARS).

4.4.1 Theoretical literature

The quest for health expenditure growth and long-term sustainability stimulated the introduction of health expenditure forecasting models. Hollembeck (1995) states that forecasts could be short-term, medium-term and long-term.

4.4.1.1 Short-, medium- and long-term forecasting models

The quest for a sustainable increase in health funding led to the adoption of loping vari short-term forecasting models, such as those used to predict the weather, which are appreciated for their predictive accuracy. However, medium- and long-term models, such as those used for future economic trends, are valued for enhancing policymaking. According to Besseling *et al*. (2011), health spending forecasting models can be divided into three types:

a) Micro-simulation models

These models focus on individuals as the unit of projection analysis, and individuals can be aggregated. They can provide solutions to challenging policy questions, relate to the entire population and address prevention, treatment and financing of healthcare with different characteristics that may be reflected in the model, such as gender, age group, disease, and health provider or the epidemiological transition of a population (Wolfson, 1994; Klevmarken, 2011).

b) Component-based model

This model involves cases or cohorts based on demographic factors, e.g., age groups. Moreover, it is an actuarial model because it involves calculating risks and making forecasts (Besseling *et al*., 2011).

c) Macro models

These models involve forecasting total PHE and time-series analysis. The forecasting techniques could also take the form of ML, which entails the study of computer algorithms that improve automatically through experience (Besseling *et al*., 2011). These are discussed below:

- ***TreeNet (stochastic gradient boosting)*** involves many small trees, each no larger than two to eight terminal nodes. The model relates a series expansion sum of factors that increasingly produce better results as the expansion series continues. Combining a series of simple tree models improves the decision tree models.

- ***Multivariate adaptive regression splines (MARS)*** is a linear statistical model with a forward stepwise algorithm to select model terms followed by a backward procedure to prune the model.

4.4.1.2 Health outcomes and determinant theories

The theories documented below are associated with health determinants such as genetics, social, behavioural and environmental/physical factors, and medical care.

a) Materialist theory of health

The materialist theory of health proposes that inadequate individual income levels lead to a lack of resources to cope with the stressors of life and thus produce ill health (Goldberg, Gerard & Peracchio, 2003; Frohlich *et al.*, 2001; Wilkinson, 2005). Moreover, the theory postulates that social comparison, humiliation and shame lead to poor health among those with lower social status as determined by income, education and type of employment compared with their richer counterparts. Thus, according to the materialist theory. poverty, income inequality, unemployment, underemployment, low wages and a lack of education due to various macroeconomic variables affect the health outcomes of low-income individuals.

b) Neo-materialist theory

This theory focuses on the distribution of resources, including GNP, amongst the population, which can vary from country to country (Lynch *et al.*, 2000). In addition, the theory directs attention to living conditions as a social determinant of health and how society distributes resources among citizens. Thus, like the materialist theory, this theory explains how a country's wealth plays a role in defining health status. In the current study, countries' spending on health was influenced by how wealthy they are because PHE is based on a percentage of GDP, and low-income countries do not have sufficient resources for this to be adequate.

c) Cultural-behavioural theory

This theory emphasises how an individual's culture influences their behaviour, which, in turn, determines their health. Thus, behavioural choices due to shared values such as smoking, alcohol consumption, diet and types of physical activity, for example, affect an individual's health and proneness to various diseases.

4.4.2 Empirical literature

The following analysis of the empirical literature aligns with the study's relationships of interest.

4.4.2.1 Forecasting PHE

Muremyi, Haughton and Niragire (2020) predicted OOP PHE in Rwanda using ML techniques to identify the best model for this type of health funding. In Rwanda, OOP PHE was 24.46% of health spending in 2000, increasing to 26% in 2015. Moreover, an integrated living condition survey was conducted during the analysis with about 14,580 households in Rwanda. In Muremyi *et al.*'s study, TreeNet was found to be accurate in predicting OOP PHE, which led to the recommendation that the government increase PHE because of the poor performance of OOP health spending. This recommendation supports the claim of inadequate PHE in SSA.

The OECD (2012) performed a comparative analysis of health forecasting methods to determine the main drivers of growth in health spending and forecast PHE for UHC. A component-based PHE model was employed to make future projections of public expenditure on healthcare in OECD countries and emerging economies with which the OECD worked, such as China, which was not a member. A cross-country framework allowed for consistent international comparisons using cost pressure and cost containment procedures.

Although China had already increased its health insurance in 2011, with 95% of citizens benefitting, the insured Chinese population was less than 50% in 2005. The projection was that China's PHE and long-term healthcare expenditure would rise from 3.0% of GDP in 2012 to 4.7% or 5.2%, thereby achieving SDG 3 by 2030. This would be about a 55% and 72% increase compared with the OECD average of 29% and 40% for PHE and long-term healthcare expenditure. In other major emerging economies, the change represented up to 46% and 63%, respectively, reflecting China's growing ageing population. In the OECD study, technology and prices were drivers of PHE health and long-term healthcare spending growth across all countries. However, the forecasting results for China indicated the need for policy changes to moderate costs while improving the extent and type of healthcare coverage.

Besseling and Shestolova (2015) forecast PHE in the Netherlands. The study used a forecasting methodology for medium-term PHE in the country from 2011 to 2015. Four factors were identified as the determinants of PHE growth: demographic, epidemiological, budgetary and residual factors.

The OECD (2019) made country-specific projections for health spending per capita from 2015 to 2030. Health spending per capita was projected to grow more than 4% per year in the Slovak Republic, Turkey and Korea, while in Belgium, Germany, Italy, Lithuania, Japan and Portugal, PHE was projected to grow less than 2% per year. In 20 out of 36 OECD countries, growth was projected to be 1% higher than between 2000 and 2015. Moreover, in Iceland, Hungary, Mexico, Israel, Portugal and Turkey, PHE growth was projected to be 1% more than what was observed from 2000 to 2015. In 20 of the 36 OECD countries, including Iceland, Hungary, Mexico, Israel, Portugal, and Turkey, it was 1% more than observed for 2000-2015.

Most countries studied by the OECD in 2019 experienced a slowdown in health spending growth following the global economic and financial crisis. However, in Lithuania, Korea, Chile, Latvia and Estonia, PHE growth rates were projected to be more than 2% lower than historical rates. These countries also reported some of the highest growth rates in health spending per capita from 2000 to 2015. Across the OECD, PHE as a share of GDP was projected to rise to 10.2% by 2030, compared to 8.8% in 2015. The only countries for which a slight decrease was expected were Latvia, Hungary and Lithuania, largely due to projected decreases in population size over the coming decades. Most countries studied by the OECD in 2019 were expected to experience moderate increases in PHE as a share of GDP, with only the US experiencing growth of more than 3%.

Adegoke, Mbonigaba and George (2022) investigated the macroeconomic determinants of health outcomes proxied by maternal and infant mortality in Nigeria. An ARDL model was employed as the baseline model. The results revealed a significant negative relationship between health outcomes proxied by maternal and child mortality, and household consumption, which was a proxy for the standard of living and poverty level of Nigerian citizens. In other words, the research results indicated that an increased standard of living would cause a reduction in maternal and infant deaths.

Adegoke *et al.*’s (2022) study also revealed a significant negative relationship between total PHE and health outcomes, whereby an increase in PHE caused reductions in maternal and infant deaths. In addition, a significant negative relationship was found between gross fixed capital and health outcomes, which suggested that an increase in domestic investment in Nigeria would lead to a reduction in maternal and infant deaths and that higher spending on enhancing health infrastructure would reduce the number of pregnancy-related and infant deaths. Adegoke *et al.*’s (2022) study found a positive but insignificant relationship between control of corruption and health outcomes, which implied that increased control of corruption would reduce maternal and infant deaths. However, the relationship was registered as insignificant because of inadequate control of the high level of corruption in the Nigerian health system. Lastly, Adegoke *et al.* (2022) found a positive relationship between health outcomes and unemployment. In other words, reducing unemployment would lead to reduced maternal and infant mortality.

The forecasting results of Adegoke *et al.*’s (2022) study revealed the need for PHE in Nigeria to increase to 987.21 (US$1.2 billion), 1,260.57 (US$1.5 billion) and 1,818.87 (US$2.2 billion) billion naira in 2025, 2027 and 2030, respectively. However, in 2019, the country’s PHE was only 474.24 billion naira (US$597 million), which means that a tremendous increase in PHE is needed to meet the SDG targets for maternal and infant health by 2030. Moreover, PHE must increase to 3.2% of GDP from its 2019 level, and corruption control must increase so that corruption can decrease by -4.2% for the country to meet the UN targets by 2030.

As the unemployment rate in the country was 8.5% in 2019, the study recommended a reduction to 1.84% before the UN targets could become a reality by 2030. Furthermore, as domestic investment in Nigeria was 24.62 (US$30 million) billion naira in 2019, which was far from the projected level required to meet the UN target by 2030, the study recommended that it should increase to 94.46 billion naira (US$117 million) to empower the country to realise SDG 3.

4.4.3 Gap to be filled in the literature

This part of the study was essential because although several studies exist on PHE forecasting for developed countries and emerging economies, including those by the World Bank and IMF, none have focused on SSA. Thus, this study sought to contribute to the existing literature on forecasting maternal/child mortality based on specific levels of improvement in PHE to empower the region to achieve the SDG targets of 70 maternal deaths per 100,000 women and 25 child deaths per 1,000 live births by 2030. To the best of the researcher's knowledge, this might be the first study to simultaneously predict maternal and child mortality based on specific levels of improvement in PHE to achieve SDG Targets 3.1 and 3.2.

4.5 Research methodology

The study's forecasting analysis was based on the macro projection model, whereby the investigation extends to aggregate PHE, especially when making short-term projections with unperturbed trends and without structural breaks (Bialowski, 2012). An economic regression analysis, the GMM, was used to fit time-series data.

4.5.1 Types of Projections

Projections can be made via pure extrapolation of the statistical models fitting the data, or they can work through projected values of the critical independent variable. The projection was done using projected values of the critical independent variable.

Examples of methods that use pure extrapolation are exponential smoothing, moving average, autoregressive integrated moving average (ARIMA) and computable general equilibrium (CGE) techniques, which are preferred due to their ability to use small data such as single time series.

Examples of methods that employ projected values of the critical independent variable are the straight-line technique, the moving average method, simple linear regression and multiple linear regression. These are explained below.

4.5.1.1 Straight-line technique

This is an uncomplicated forecasting method in which historical figures and trends predict future growth such as revenue growth and expenditure costs. The following are features of the technique:

- The growth rate is determined and used to estimate future costs or revenue.
- The growth rate is derived from historical performance.
- Growth is assumed to be constant in the future.

- The growth rate is calculated by subtracting the starting number from the final number, dividing the result by the starting number and multiplying by 100 for the percentage.

4.5.1.2 Simple and multiple linear regression

These forecasting methods are commonly used to analyse the relationship between variables to forecast future values. First, multiple linear regression establishes a linear relationship between the dependent variable and two or more independent variables. After establishing the linear relationships, the forecast value can be derived using the forecast function.

4.5.2 Data definition

The 1995 to 2020 annual data for the study variables derived from the literature that are explained below were sourced from the WHO (2021) to forecast maternal and child mortality based on specific levels of improvement in PHE necessary to achieve SDG Targets 3.1 and 3.2 in SSA. However, sufficient observation was required for a robust and reliable forecast. Therefore, the data on maternal and infant mortality variables representing health outcomes and PHE were selected based on particular features of various countries.

4.5.2.1 Dependent variables

The health variable was proxied by the maternal/child mortality and LEB variables.

a) Maternal mortality

The maternal mortality variable referred to pregnancy-related deaths per 100,000 women during and six weeks after delivery.

b) Child mortality

The child mortality variable in the study referred to the number of deaths per 1,000 live births of under-five children.

c) Life expectancy at birth

In this study, LEB referred to the number of years a new born is expected to live if exposed to prevailing conditions at the time of birth.

4.5.2.2 Independent variables

a) Explanatory variable

In the study, the explanatory variable, PHE per capita, or PHE, is the capital outlay on health provided by a country's government, including NHIS. It was measured as domestic government PHE as a percentage of GDP per person. The impact of PHE on health outcomes is well-established in the literature.

4.5.3 A priori expectations

A negative relationship between PHE and maternal/child mortality was expected; in other words, higher PHE would reduce mortality and poor health outcomes (Anyanwu & Erhijakpor, 2009; Alvi & Ahmed, 2014; Rahman *et al.*, 2018; Ibukun, 2021). Thus, a negative relationship between PHE per capita and health outcomes could be expected.

4.5.4 Estimating technique

Generalized least squares are usually used to estimate the unknown parameters in linear regression. However, the feasible quasi-generalized least squares technique was used in the study because it would be consistent, asymptotically normal and robust to heteroskedasticity. It also enabled salient time series features of the data such as unit roots, which reveal a systematic, unpredictable pattern, persistence effects and endogeneity bias, to be taken care of.

4.5.5 Model specification

The respective models for the expected negative relationships between PHE per capita ($Health_t$) and maternal mortality ($Maternal_t$) and child mortality ($Child_t$) are as follows:

$$Maternal_t = \alpha + \beta Health_{t-1} + \varepsilon_t \quad (4.1)$$

$$Child_t = \alpha + \beta Health_{t-1} + \varepsilon_t \quad (4.2)$$

Based on the preceding specification, the feasible quasi-generalized least squares approach was adopted to address salient time series features of the data, including the unit root problem, persistence effect and possible endogeneity bias. The updated specifications with double-log forms are as follows:

$$\log(Maternal_t) = \alpha_1 + \beta_1 \log(Health_{t-1}) + \theta_1 \Delta \log(Health_t) + \gamma_1 \log(Maternal_{t-1}) + \varepsilon_{1t} \quad (4.3)$$

$$\log(Child_t) = \alpha_2 + \beta_2 \log(Health_{t-1}) + \theta_2 \Delta \log(Health_t) + \gamma_2 \log(Child_{t-1}) + \varepsilon_{2t} \quad (4.4)$$

Where;

the alphas (α_1 & α_2) are the constant terms, and the betas (β_1 & β_2) are the coefficients of interest that show the impact of PHE per capita on maternal and child mortality, respectively. In addition, θ and γ are the coefficients of the unit root and persistence accounted for in the models. $Health_t$ is PHE per capita at the present period, and $Health_{t-1}$ is PHE per capita in the previous period. $Child_{t-1}$ is child mortality in the previous period; $Maternal_{t-1}$ is maternal mortality in the previous period. The model is stated dynamically, thus providing an opportunity for the previous level of health outcomes to explain some variations in the present health outcomes.

In estimating the models for countries in SSA (1995-2020), the expected negative sign indicated by the theory in the relationship between PHE per capita and maternal/child mortality was sought. The estimated results were then utilised as the basis for in-sample and out-of-sample forecasting, with an analysis of an optimistic scenario that examined the likely impact of consistent growth in PHE per capita by approximately 10%. Consequently, during the out-of-sample forecasting analysis period (2021-2030), reductions in mortality were observed across the countries in SSA.

4.6 Research results

Table 4.1 below shows the analysis of the relationship between health outcomes (maternal and child mortality) and PHE for each selected country in SSA. This analysis aimed to determine whether a negative relationship existed with PHE, as hypothesised a priori, suggesting that increased PHE would lead to reductions in maternal and child mortality.

As indicated in Table 4.1 below, a negative relationship was observed between health outcomes and PHE amongst the countries in SSA included in the study. The analysis covered 24 countries, with Mauritius excluded due to its consistently low maternal and child mortality levels since 2016 (World Bank, 2020).

In Mauritius, child mortality has remained below 25 since 1995, and maternal mortality has been consistently below 70. The non-negative relationship between PHE and mortality in Cote D'Ivoire and Sierra Leone are highlighted in bold in the table. This non-negative relationship suggests that the country's health outcomes are already relatively favourable, and further increases in PHE may not yield significant improvements. In addition, other factors apart from PHE may be contributing to the current level of child mortality observed in the country.

The regression results in Table 4.1 below provide strong evidence to support the hypothesis that higher levels of PHE per capita would lead to better health outcomes in the selected countries in SSA. To further investigate the validity of this hypothesis, the researcher performed forecasting procedures to determine whether the observed relationship between higher PHE per capita and better health outcomes was likely to hold in the future. This would provide valuable insights for policymakers and stakeholders, enabling them to make informed decisions regarding resource allocation and prioritise investment in public health infrastructure and services to improve maternal and child health. These forecasting results are explained later in this chapter.

Table 4.1 below shows the regression results for the relationship between health outcomes and PHE per capita.

Table 4.1: Regression results (relationship between health outcomes and PHE per capita)

Country	Maternal mortality model		Child mortality model	
	Constant	Beta	Constant	Beta
Angola	0.3833** (0.1802)	-0.0487* (0.0253)	0.3417 (0.2855)	-0.0241 (0.0267)
Burkina Faso	0.2350* (0.1289)	-0.0211 (0.0173)	-0.4235** (0.1971)	-0.0345 (0.0318)
Benin	-0.1024 (0.2296)	-0.0073 (0.0086)	0.6212** (0.2238)	-0.00003 (0.0042)
Botswana	0.1998 (0.3042)	-0.0134 (0.0147)	0.3634* (0.1765)	-0.0176* (0.0098)
Burundi	0.3571** (0.1396)	-0.0444** (0.0223)	0.2629*** (0.0584)	-0.0611*** (0.0132)
Cameroon	-0.0474 (0.1526)	-0.0169 (0.0122)	-0.3046*** (0.0776)	-0.0288*** (0.0077)
CAR	0.8856 (0.6401)	-0.0057 (0.0182)	0.7619** (0.3513)	-0.0013** (0.0005)
Cote D'Ivoire	0.0470 (0.2947)	-0.0107** (0.0049)	**0.0828*** (0.0332)**	**0.0162*** (0.0032)**
Eswatini	1.3503*** (0.2642)	-0.0444*** (0.0084)	3.1321*** (0.8269)	-0.0625*** (0.0149)
Gambia	0.2151 (0.1953)	-0.0107 (0.0076)	0.4274*** (0.1272)	-0.0146** (0.0054)
Kenya	0.9180** (0.3985)	-0.0905 (0.0666)	0.2957*** (0.0680)	-0.0055*** (0.0010)
Lesotho	1.7660** (0.6734)	-0.0818*** (0.0288)	0.7056 (0.4219)	-0.0111 (0.0155)
Mauritania	0.3311 (0.2511)	-0.0074** (0.0029)	0.2069*** (0.0673)	-0.0094*** (0.0019)
Mozambique	5.0635	-0.0006	0.3215***	-0.0003

	(1.0313)	(0.0061)	(0.0708)	(0.0076)
Namibia	0.5101 (0.4279)	-0.0596 (0.0371)	0.3195 (0.3019)	-0.0966* (0.0475)
Niger	2.1183*** (0.6618)	-0.0117* (0.0062)	0.2292*** (0.0541)	-0.0133 (0.0136)
Nigeria	0.5917*** (0.0948)	-0.0380*** (0.0074)	0.1329* (0.0665)	-0.0328*** (0.0066)
Rwanda	1.2979** (0.4721)	-0.0357 (0.0449)	1.0869*** (0.3450)	-0.0075 (0.0286)
Sierra Leone	**0.3608*** (0.1152)**	**0.0343*** (0.0074)**	**0.0601 (0.0599)**	**0.0098*** (0.0032)**
South Africa	0.4511 (0.3919)	-0.0364* (0.0204)	1.1223*** (0.3392)	-0.0838*** (0.0233)
Senegal	-0.0670 (0.1615)	-0.0216 (0.0378)	-0.2318*** (0.0465)	-0.1414*** (0.0173)
Sudan	0.4719** (0.2007)	-0.0559*** (0.0184)	0.2571*** (0.0285)	-0.0159*** (0.0035)
Tanzania	2.3167** (0.6448)	-0.0068 (0.0076)	0.2109*** (0.0498)	-0.0270** (0.0118)
Togo	0.0974 (0.1718)	-0.0137* (0.0067)	0.7327*** (0.2506)	-0.0061* (0.0033)

Note: Mauritius is excluded from the analysis since maternal mortality in the country has been consistently below 70 since 2016. Similarly, child mortality in Mauritius has been constantly below 25 since 1995. Boldface indicates non-negative relationship between public health expenditure and mortality in the country in question, therefore, higher health expenditure does not reduce mortality. *,**, and * signify 1 percent, 5 percent, and 10 percent significance respectively.**

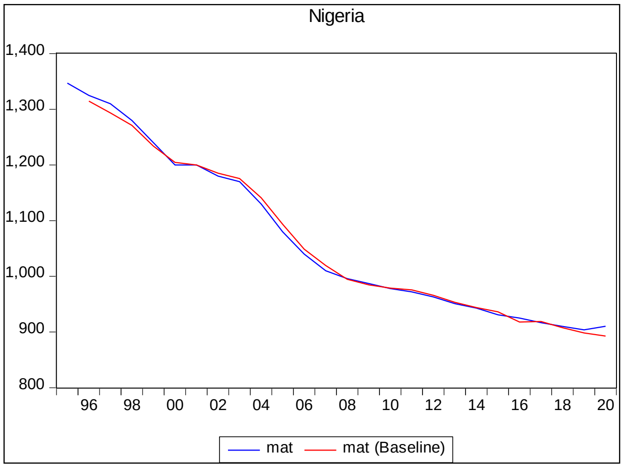
Figure 4.1 below reflects the in-sample forecast for maternal mortality. It demonstrates the movement path between maternal mortality and the forecast values within the given data period. Actual and forecast maternal mortality align closely with minor variations. The x-axis represents years, while the y-axis represents maternal mortality per 100,000 women. The red curve represents observed or actual maternal mortality, while the blue curve represents forecast maternal mortality. The close alignment between these curves indicates that the model used for the in-sample forecast reasonably captures the historical patterns and variations in maternal mortality.

The relationship depicted in Figure 4.1 below indicates a declining trend in maternal mortality over time amongst the countries in SSA. This suggests that MMRs decreased over the analysed period. The downward trend could suggest that efforts to address maternal mortality, including investment in PHE, had some positive impact on reducing MMRs. However, despite the decreasing trend, maternal mortality remained a significant burden in these countries. This suggests that additional interventions and strategies would be necessary to reduce MMRs and achieve the SDG targets.

While Figure 4.1 below does not explicitly indicate the causal relationship between PHE and maternal mortality, it does suggest that investment in healthcare infrastructure and services, reflected in the declining trend of maternal mortality, have played a role in improving maternal health outcomes. This implies that PHE has likely contributed to reducing MMRs in the analysed countries in SSA, although it may not be the sole determinant.

In-sample forecasting primarily assesses the model's ability to accurately predict outcomes based on available data. In this case, the in-sample forecast provided insights into the model's performance in estimating maternal mortality within the investigated period. Researchers can evaluate the model's accuracy and reliability by comparing actual and forecast values. This assessment helps to build confidence in the model's ability to make meaningful predictions and inform subsequent out-of-sample forecasting, which extends the predictions beyond the available data to estimate future outcomes.

Figure 4.1 below presents the in-sample forecast for maternal mortality in selected countries in SSA.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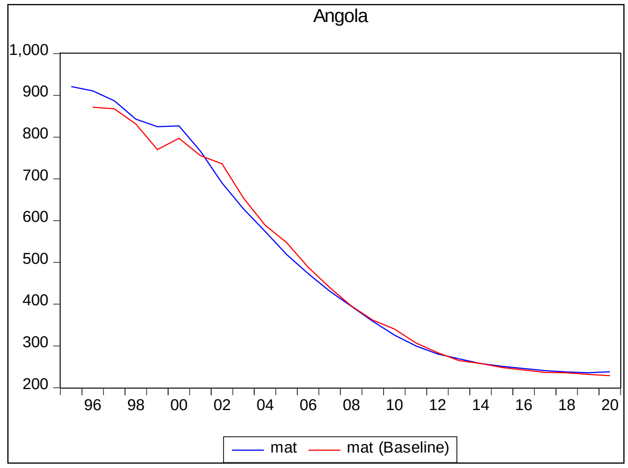
1,300
1,200
1,100
1,000
900
800
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)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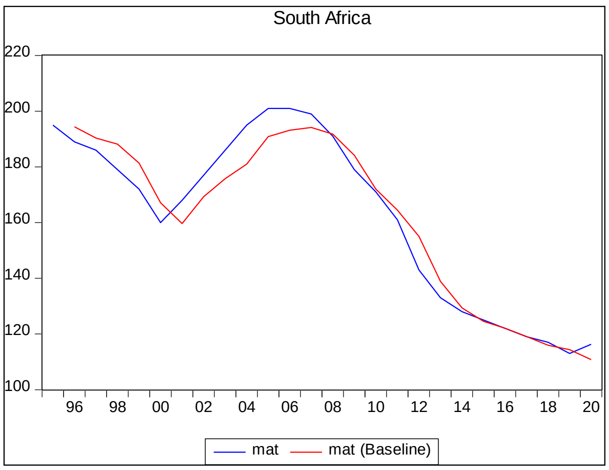
mat
mat (Baseline)


South Africa
220
200
180
160
140
120
100
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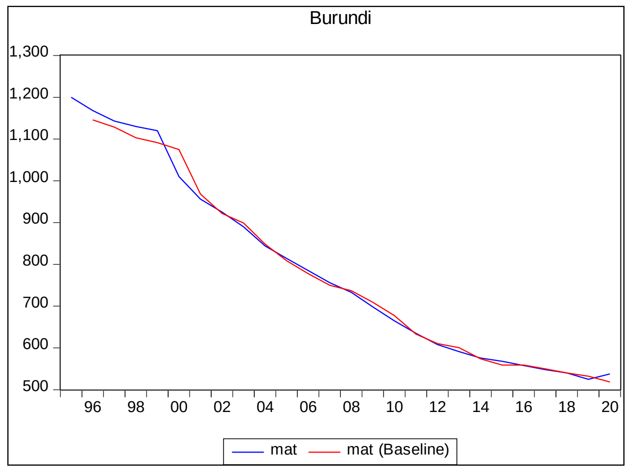
mat
mat (Baseline)


Burundi
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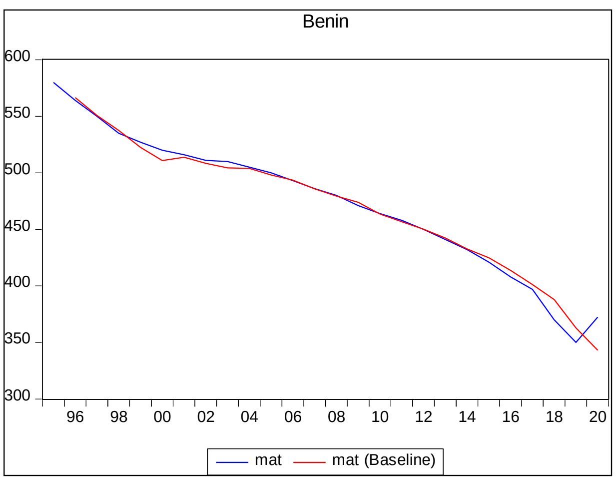
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500
450
400
350
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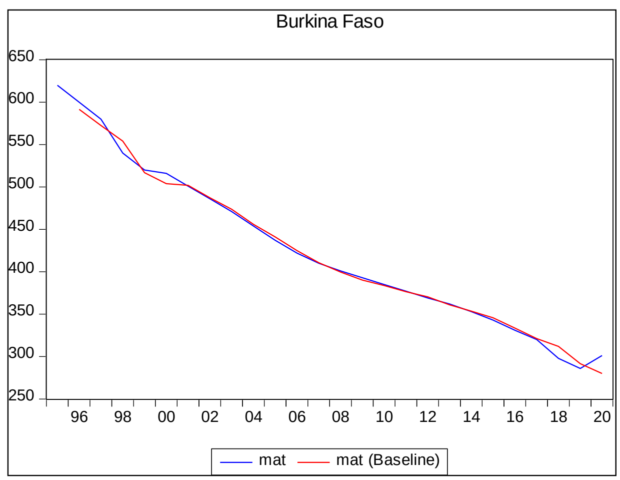
mat (Baseline)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250
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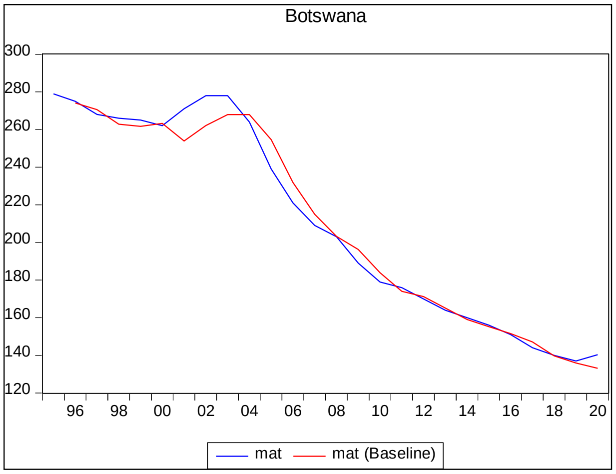
mat (Baseline)


Botswana
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260
240
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180
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140
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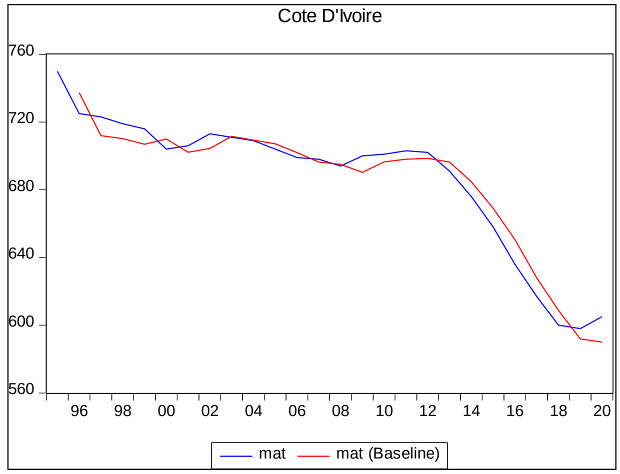
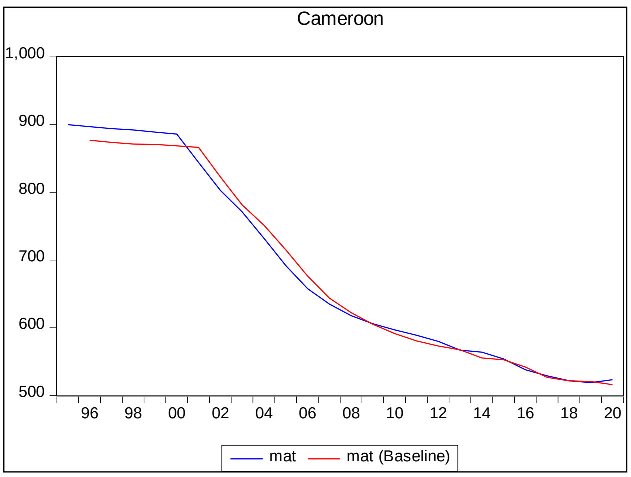

Cote D'Ivoire
760
720
680
640
600
560
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Cameroon
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900
800
700
600
500
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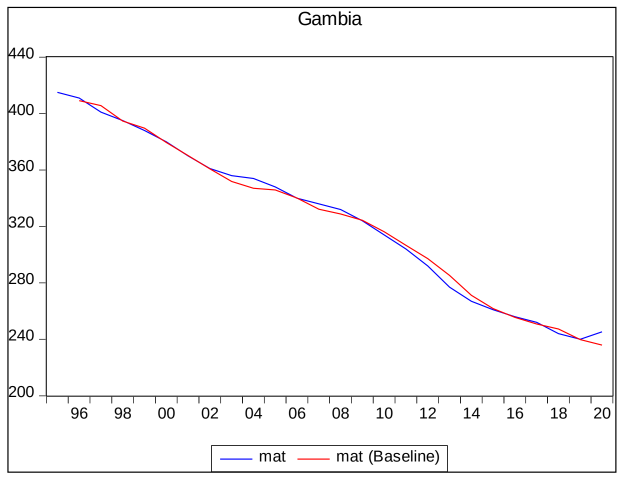
mat
mat (Baseline)


Gambia
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240
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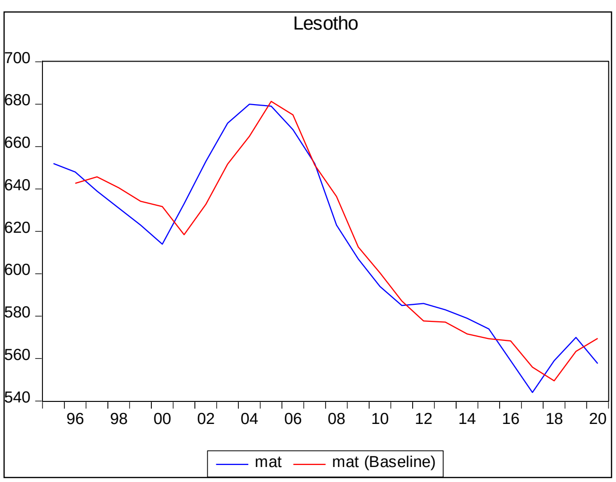
mat (Baseline)


Lesotho
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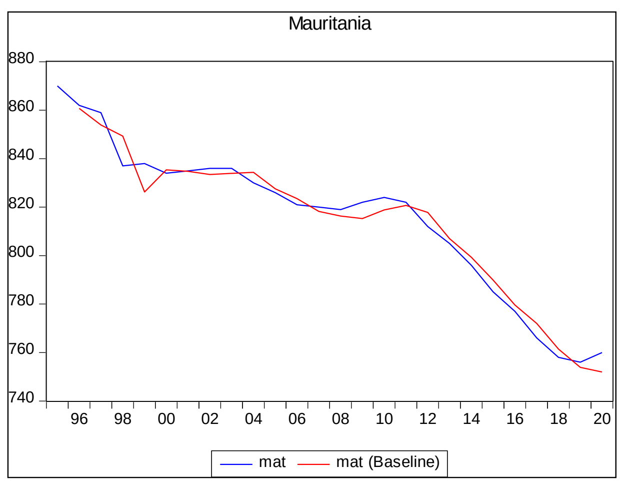
mat
mat (Baseline)


Mauritania
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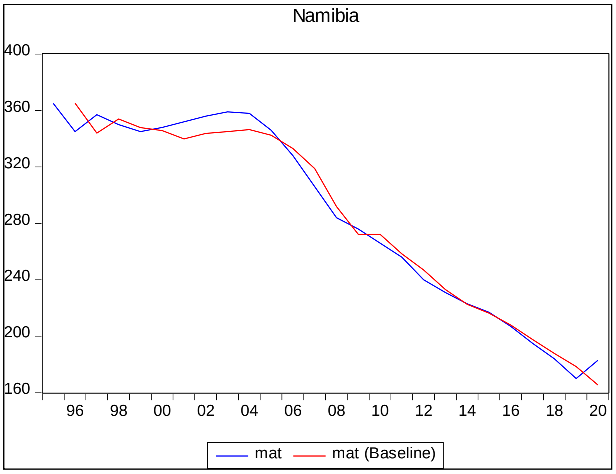
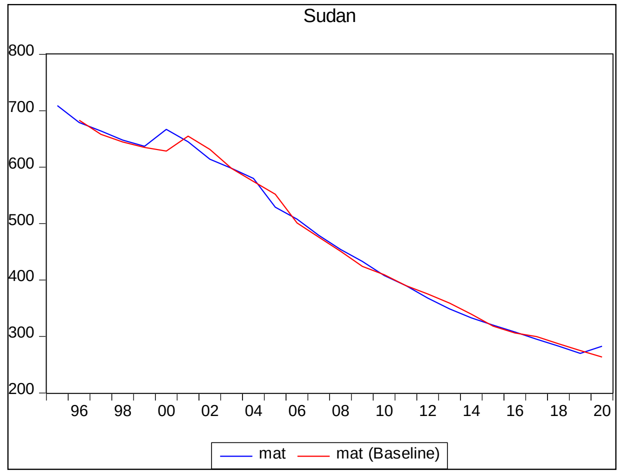
840
820
800
780
760
740
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Namibia
400
360
320
280
240
200
160
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Sudan
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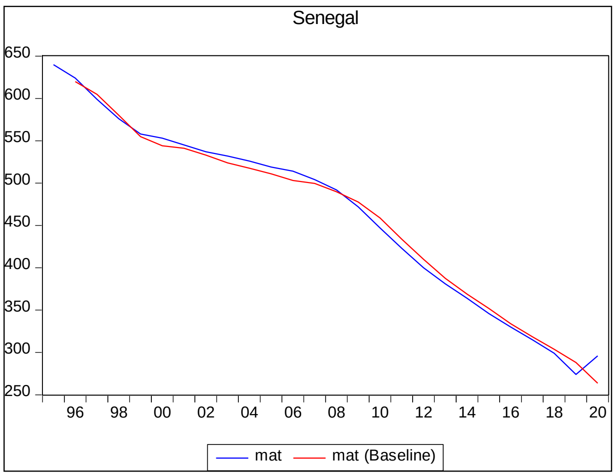
500
400
300
200
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Senegal
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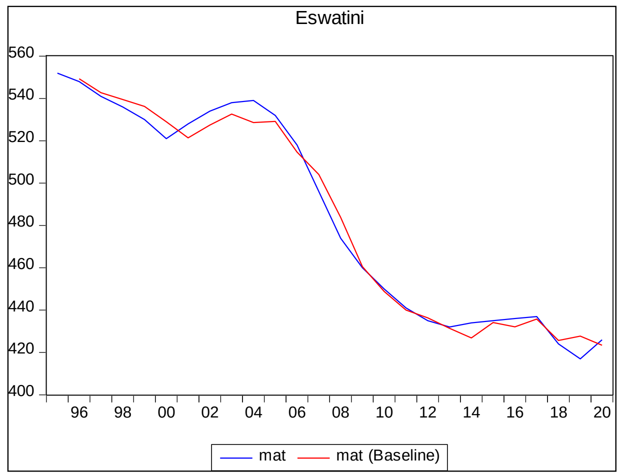
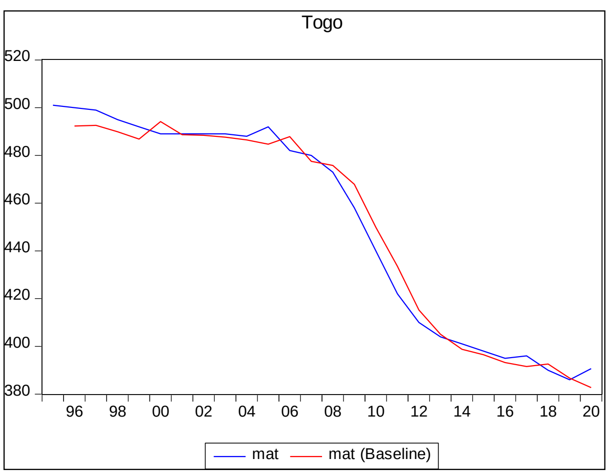
600
550
500
450
400
350
300
250
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Eswatini
560
540
520
500
480
460
440
420
400
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)


Togo
520
500
480
460
440
420
400
380
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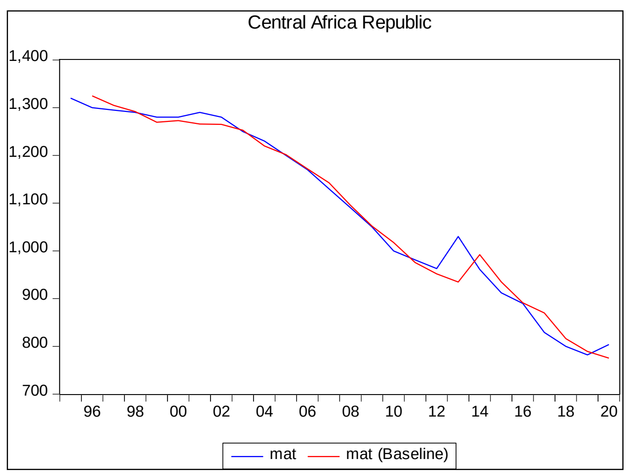
mat
mat (Baseline)


Central Africa Republic
1,400
1,300
1,200
1,100
1,000
900
800
700
96 98 00 02 04 06 08 10 12 14 16 18 20
mat
mat (Baseline)

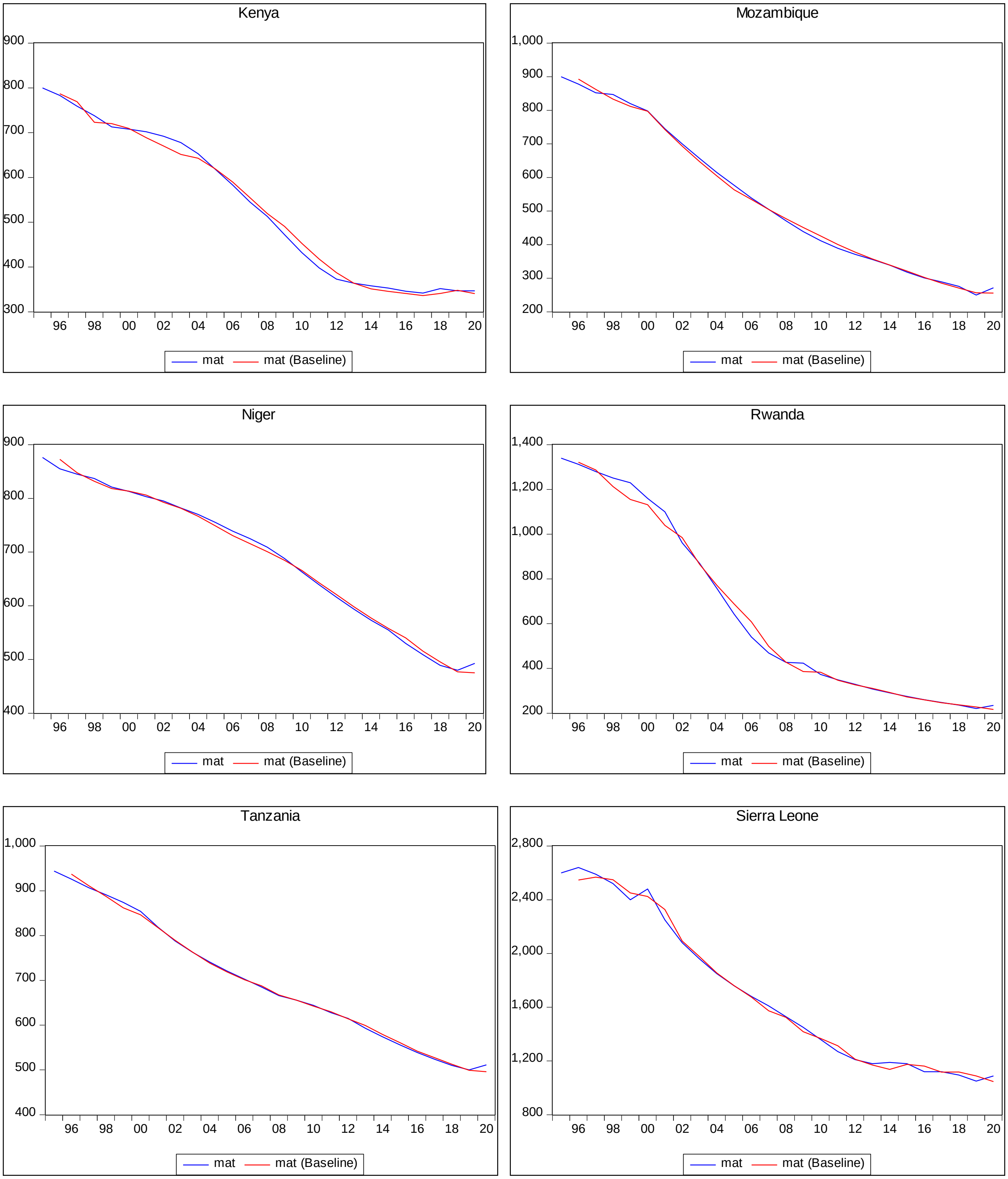


Figure 4.1: In-sample prediction of maternal mortality

Figure 4.1 above presents in-sample forecasting of maternal mortality in various SSA countries. The table below presents out-of-sample predictions of maternal mortality in a scenario of a 10% increase in their PHE.

Out-of-sample forecasting involves making predictions or projections for periods beyond the available data to build the forecasting model. It aims to estimate future outcomes based on the relationships and patterns observed in historical data. In the context of maternal mortality forecasting, the out-of-sample forecast provided insights into the potential trends and outcomes for maternal mortality beyond the analysed data period. It allowed the researcher to explore the expected impact of changes or interventions such as a 10% increase in PHE on MMRs. Using the forecasting model developed using in-sample data, the out-of-sample forecast estimated how maternal mortality may evolve when certain conditions or factors change. In this case, the focus was on the effects of increased PHE on MMRs.

The out-of-sample forecast in Table 4.2 below displays the projected maternal mortality outcomes for 2021, 2025 and 2030, assuming a 10% increase in PHE. The table indicates the potential trajectory of MMRs and offers insights into the progress countries may make towards achieving the SDG target for maternal mortality.

In cases where the relationship between PHE and maternal mortality is non-negative, indicated as "Nil" in the table, the implication is that higher PHE does not reduce maternal mortality. Therefore, the expected impact on reducing maternal mortality is limited, even with increased PHE.

Considering the specific periods shown in the table, it becomes evident that none of the countries analysed was able to achieve the SDG target of 70 maternal deaths by 2030 despite the in-sample forecast outcomes. This suggests that additional efforts beyond increasing PHE are required to address the complex factors influencing MMRs. Thus, the results underscore the need for comprehensive strategies and interventions beyond financial investment to combat maternal mortality and work towards achieving the SDG target.

Out-of-sample forecasts are, however, subject to inherent uncertainties and assumptions. The actual future outcomes may deviate from the projections due to various unforeseen factors and changes in the operating environment. Therefore, while out-of-sample forecasting provides valuable insights into potential future outcomes, it should be interpreted with caution, and policymakers should consider multiple factors and strategies beyond a single variable such as PHE to address maternal mortality and work towards achieving the SDG target.

Table 4.2 below presents the out-of-sample maternal mortality forecasting, which assumes an annual 10% increase in current PHE per capita (real terms).

Table 4.2: Out-of-sample maternal mortality forecast with a 10% annual increase in PHE

Country	2021 Numbers per 100,000	2025 Numbers per 100,000	2030 Numbers per 100,000
Angola	229	193	145
Burkina Faso	293	263	225
Benin	364	332	289
Botswana	136	120	103
Burundi	528	478	397
Cameroon	517	485	431
CAR	792	748	694
Côte d'Ivoire	596	558	502
Eswatini	426	414	380
Gambia	240	222	199
Kenya	337	284	211
Lesotho	556	521	456
Mauritania	755	734	703
Mozambique	253	193	138
Namibia	178	152	114
Niger	475	392	294
Nigeria	899	833	724
Rwanda	227	209	199
Sierra Leone	Nil	Nil	Nil
South Africa	112	98	79
Senegal	284	237	176
Sudan	274	236	181
Tanzania	498	442	373
Togo	386	367	335

Note: This table presents the forecasts for maternal mortality relative to a 10% increase in PHE in the out-of-sample period, 2021 to 2030. "Nil" indicates a non-negative relationship between PHE and maternal mortality in the country in question; therefore, higher PHE does not reduce maternal mortality.

Figure 4.2 below displays the in-sample predictions for child mortality. It illustrates the trajectory of actual child mortality and the corresponding forecast values within the available data period. The alignment between the observed and forecast child mortality was generally close, with minor variations.

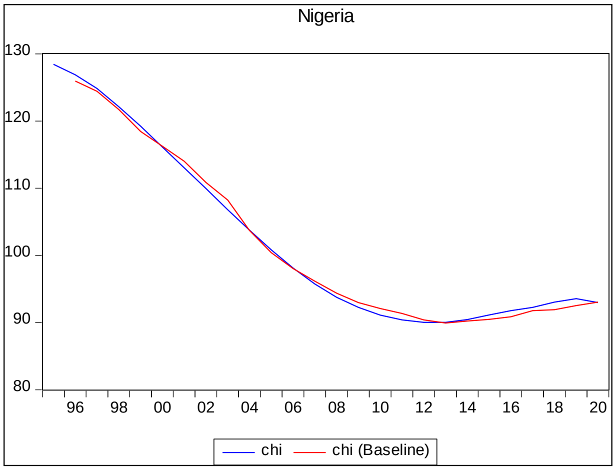
In the figure, the x-axis represents the years, while the y-axis represents child mortality per 1,000 live births. The relationship depicted in the figure indicates a downward trend in child mortality over time amongst the countries in SSA. This suggests that CMRs decreased during the analysed period. However, despite this declining trend, child mortality remained a significant burden in these countries. The reduction in child mortality was positive but insufficient, indicating the need for further efforts to address this issue comprehensively, such as an increase in PHE.

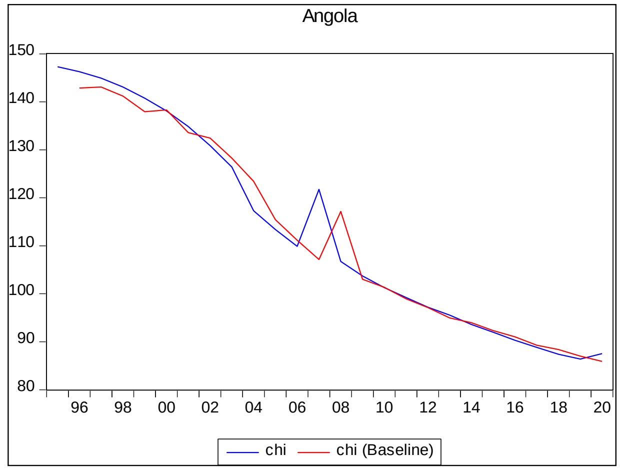
In Figure 4.2 below, the red curve represents the observed or actual child mortality, while the blue curve represents the forecast child mortality. The close alignment between these curves indicated the model's ability to capture the patterns and trends in child mortality within the in-sample data.

In-sample predictions aim to assess the model's performance and evaluate its capability to forecast out-of-sample data accurately. They are a validation step, ensuring that the model can effectively predict future outcomes beyond the analysed data.

By demonstrating the declining trend in child mortality, the figure highlights the progress made in reducing CMRs among the countries in SSA. However, it also underscores the continued challenges and the need for sustained efforts to reduce child mortality further and improve child health outcomes in the region.

Figure 4.2 below presents the in-sample forecast for child mortality in selected countries in SSA.


Nigeria
130
120
110
100
90
80
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Angola
150
140
130
120
110
100
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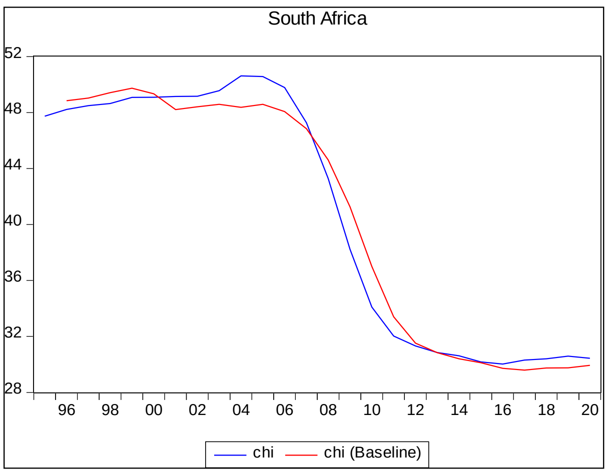
80
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


South Africa
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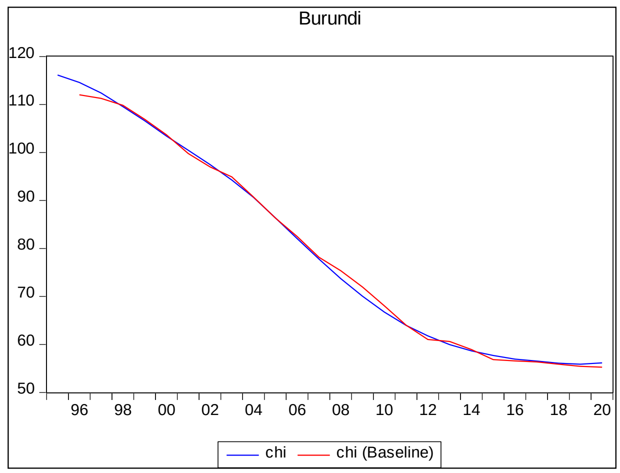
40
36
32
28
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Burundi
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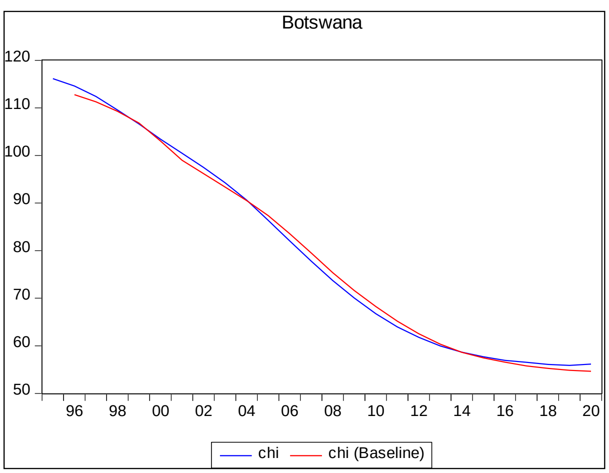
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Botswana
120
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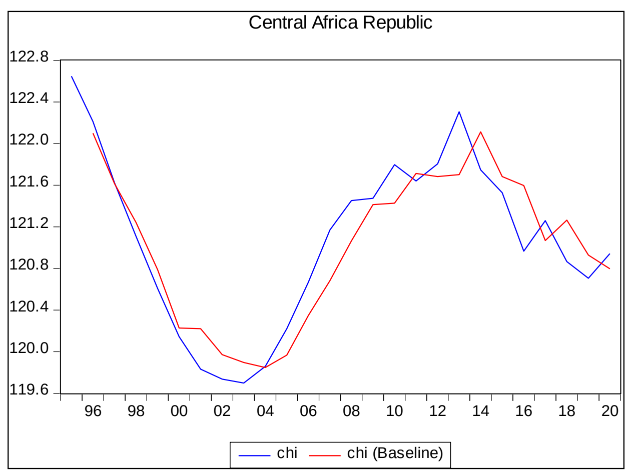
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)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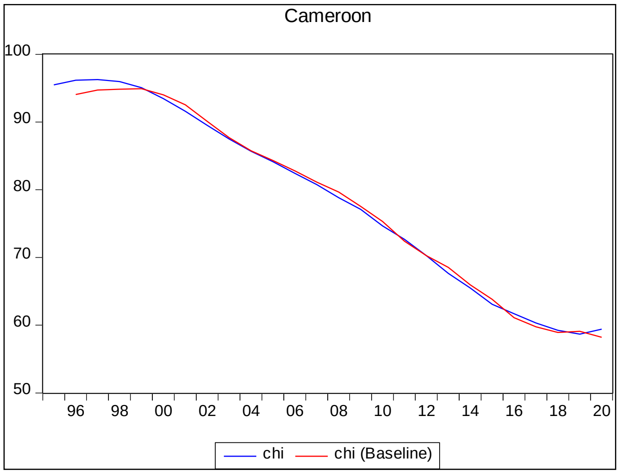
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Cameroon
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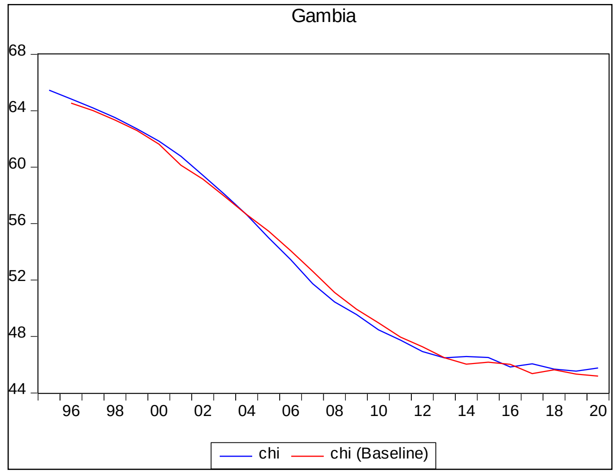
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)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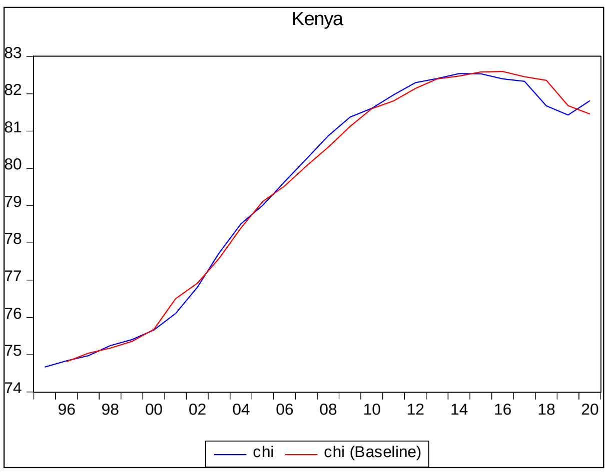
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)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74
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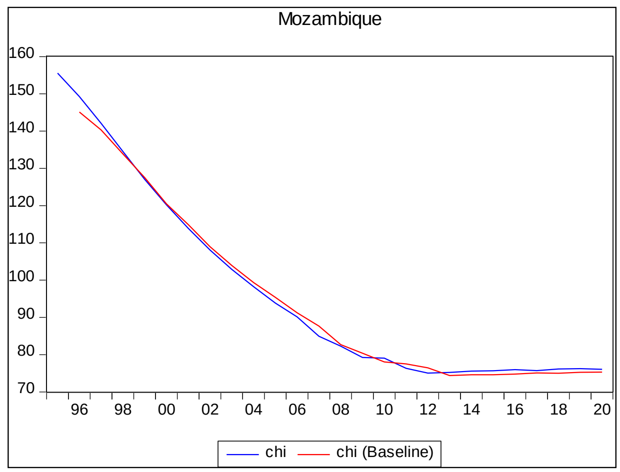
chi (Baseline)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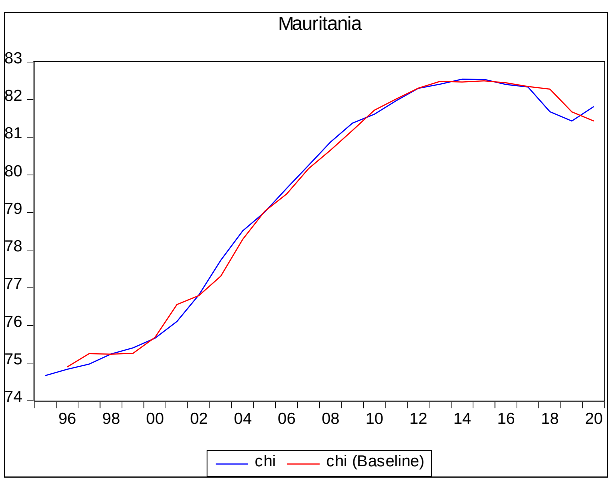
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)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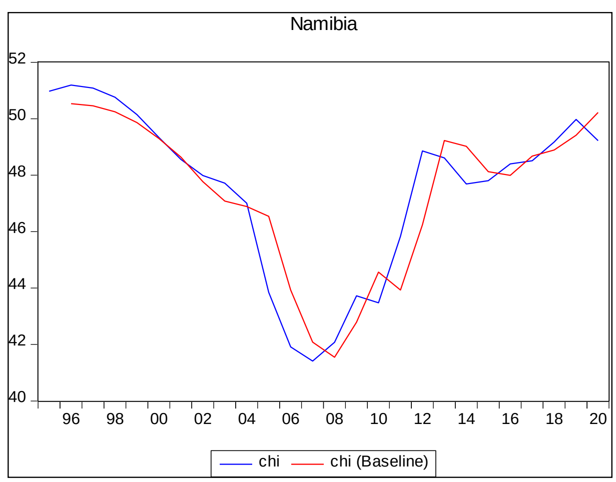
74
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Namibia
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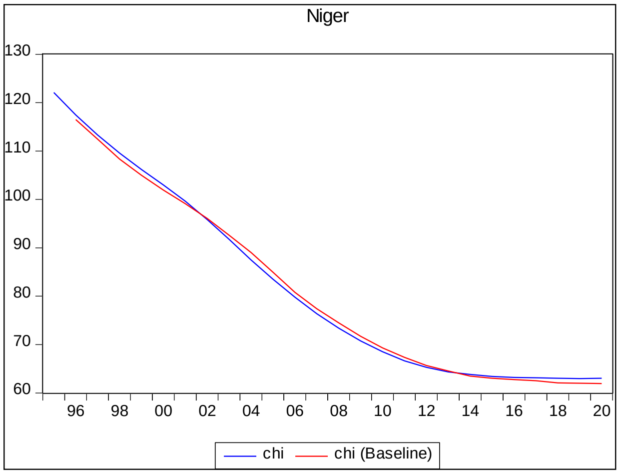
42
40
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)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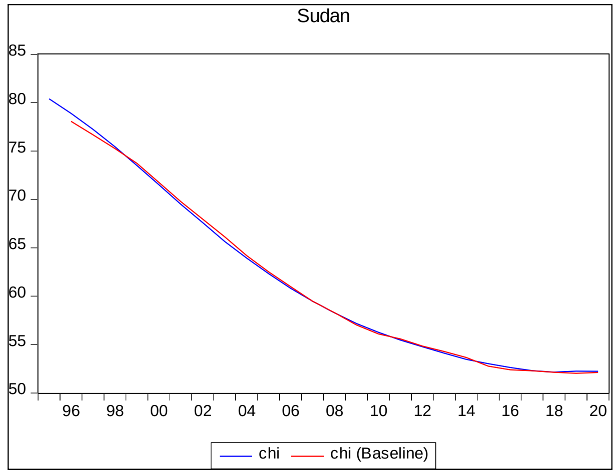
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Sudan
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50
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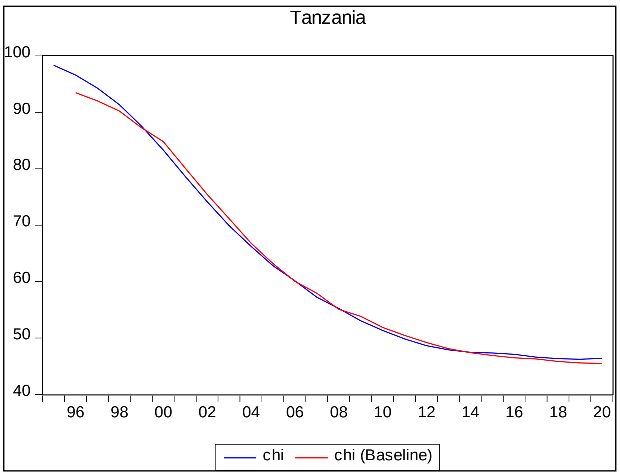
chi
chi (Baseline)


Tanzania
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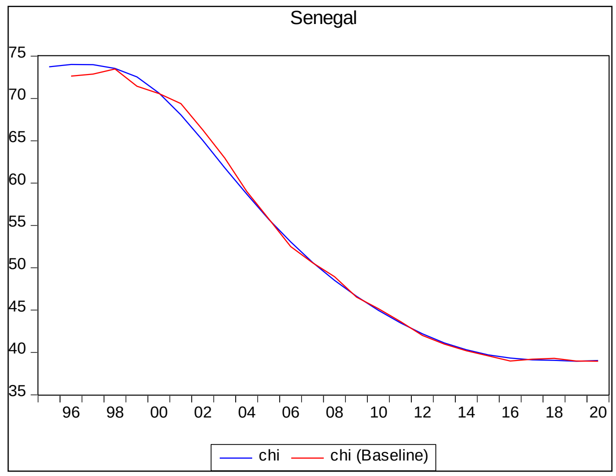
chi (Baseline)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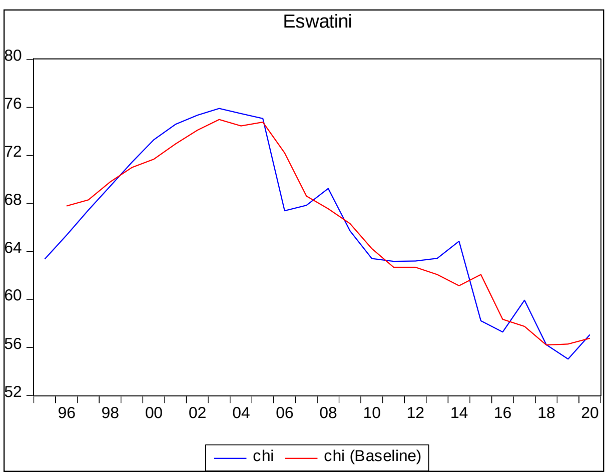
chi (Baseline)


Eswatini
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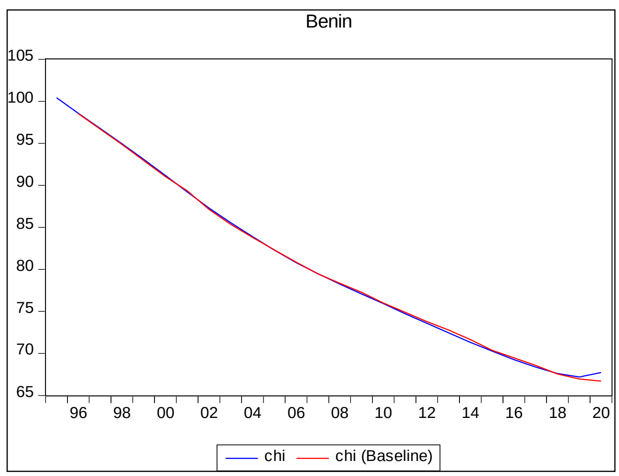
52
96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)


Benin
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70
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96 98 00 02 04 06 08 10 12 14 16 18 20
chi
chi (Baseline)

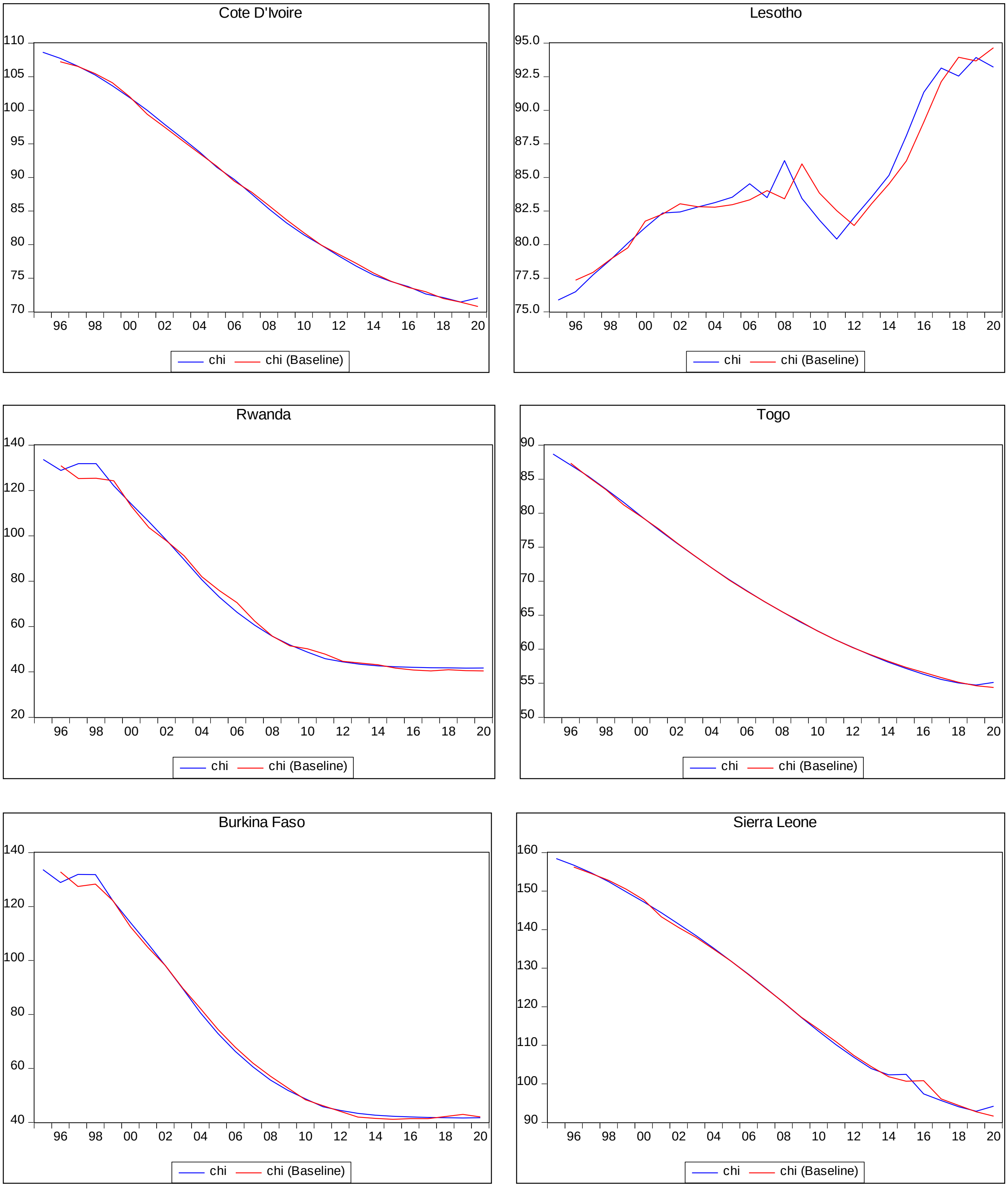

Figure 4.2: In-sample child mortality prediction

Figure 4.2 above shows the in-sample predictions for child mortality in the selected countries. The table below presents out-of-sample predictions of child mortality given a 10% increase in the PHE of the SSA countries from 2021 to 2030. The term "Nil" indicates a non-negative relationship between PHE and child mortality in the respective country, suggesting that higher PHE might not reduce child mortality. The table presents the out-of-sample forecasts for child mortality at three specific time points: 2021, 2025 and 2030. The year 2030 aligns with the end of the SDGs timeline when the target is expected to be achieved.

The out-of-sample forecast provides insights into the potential outcomes for child mortality with a 10% increase in PHE. Notably, two countries, South Africa and Senegal, are projected to achieve the SDG target of 25 child deaths per 1,000 live births by 2030 if they increase their PHE by 10%. Specifically, with the specified increase in PHE, child mortality is estimated to decrease to 21 in South Africa and 18 in Senegal.

To achieve these outcomes, South Africa would need to increase its PHE per capita to approximately $1,558, while Senegal would need to raise its PHE per capita to around $85. These figures highlight the importance of adequate investment in PHE to improve child health outcomes and work towards achieving the SDG target.

The out-of-sample forecasting in Table 4.3 provides valuable insights into the potential impact of increased PHE on child mortality. It underscores the significance of allocating resources and implementing effective PHE strategies to reduce CMRs and progress towards achieving global health goals.

Table 4.3 below presents the out-of-sample child mortality forecasting, which assumes an annual 10% increase in current PHE per capita (real terms).

Table 4.3: Out-of-sample child mortality forecasting with a 10% annual increase in PHE per capita

Country	2021	2025	2030
Angola	86	82	74
Burkina Faso	42	40	34
Benin	67	65	63
Botswana	54	49	44
Burundi	55	49	40
Cameroon	58	52	40
CAR	121	121	120
Côte d’Ivoire	Nil	Nil	Nil
Eswatini	55	48	39
Gambia	45	43	41
Kenya	82	81	80
Lesotho	93	87	72
Mauritania	83	80	78
Mozambique	75	72	70
Namibia	49	45	34
Niger	61	57	52
Nigeria	92	87	77
Rwanda	40	37	35
Sierra Leone	Nil	Nil	Nil
South Africa	29	26	21
Senegal	38	33	18
Sudan	52	50	47
Tanzania	45	41	36
Togo	54	49	40

Note: This table presents the forecasts for child mortality relative to a 10% increase in PHE in the out-of-sample period, 2021 to 2030. “Nil” indicates a non-negative relationship between PHE and child mortality in the country in question. Therefore, higher PHE would not reduce child mortality.

Table 4.4 below presents the out-of-sample forecasts for maternal mortality given a 20% increase in PHE from 2021 to 2030.

Amongst the countries analysed, only South Africa was projected to achieve the SDG target of 70 maternal deaths per 100,000 women by 2030. With a 20% increase in PHE, which equates to approximately $3,700, the forecast number of maternal deaths in South Africa is estimated to be 62 by 2030. This value of $3,700 was derived by multiplying the country's current PHE by 20%, and subsequent iterations were obtained by multiplying the results from the preceding iteration by an additional 20%. These results underscore the critical role of increased PHE in reducing maternal mortality.

Table 4.4 below presents the out-of-sample maternal mortality forecasting, which assumes an annual 20% increase in current PHE per capita (real terms).

Table 4.4: Out-of-sample maternal mortality forecast with a 20% annual increase in PHE

Country	2021	2025	2030
Angola	219	171	118
Burkina Faso	281	235	186
Benin	351	298	240
Botswana	128	104	82
Burundi	512	435	332
Cameroon	501	438	361
CAR	770	679	584
Côte d'Ivoire	578	505	421
Eswatini	412	373	317
Gambia	230	198	164
Kenya	325	254	174
Lesotho	527	430	323
Mauritania	734	666	592
Mozambique	242	171	112
Namibia	169	134	91
Niger	460	353	244
Nigeria	875	756	610
Rwanda	217	186	164
Sierra Leone	Nil	Nil	Nil
South Africa	104	84	62
Senegal	275	211	144
Sudan	263	210	148
Tanzania	482	399	312
Togo	373	330	279

Note: This table presents the forecasts for maternal mortality relative to a 20% increase in PHE in the out-of-sample period, 2021 to 2030. "Nil" indicates a non-negative relationship between PHE and maternal mortality in the country in question. Therefore, higher PHE would not reduce maternal mortality.

Table 4.5 below presents the out-of-sample forecasts for child mortality regarding a 20% increase in PHE from 2021 to 2030. The designation "Nil" indicates a non-negative relationship between PHE and child mortality in the respective country, implying that higher PHE would not reduce child mortality. However, by 2030, the following countries in SSA were projected to achieve the SDG target for child mortality through a 20% increase in PHE: Burkina Faso, Burundi, Cameroon, Eswatini, Gambia, Namibia, Rwanda, South Africa, Senegal, and Tanzania.

In Sierra Leone, an increase in PHE may not significantly impact child mortality. This is due to the country's fragile health system, which was adversely affected by the Ebola epidemic from 2014 to 2016. Furthermore, a substantial portion of PHE in Sierra Leone is financed through OOP spending (62%), which can limit the potential impact of increased PHE (Brolin, Van & Nordenstedt, 2016).

These forecast outcomes shed light on the potential effects of increased PHE on child mortality reduction. However, specific contextual factors such as the state of the health system and financing mechanisms need to be considered.

Table 4.5 below presents the out-of-sample child mortality forecasting, which assumes an annual 20% increase in current PHE per capita (real terms).

Table 4.5: Out-of-sample child mortality forecast with a 20% annual increase in PHE

Child mortality	2021	2025	2030
Angola	79	69	57
Burkina Faso	39	31	24
Benin	60	54	48
Botswana	47	39	30
Burundi	48	39	25
Cameroon	50	39	25
CAR	110	105	94
Côte d'Ivoire	Nil	Nil	Nil
Eswatini	46	36	25
Gambia	39	31	24
Kenya	75	68	60
Lesotho	84	73	55
Mauritania	76	68	60
Mozambique	68	60	53
Namibia	42	35	22
Niger	54	47	39
Nigeria	85	74	60
Rwanda	34	28	23
Sierra Leone	Nil	Nil	Nil
South Africa	23	18	12
Senegal	32	25	15
Sudan	45	40	33
Tanzania	39	32	25
Togo	47	39	28

Note: This table presents the forecasts for child mortality relative to a 20% increase in PHE in the out-of-sample period, 2021 to 2030. "Nil" indicates a non-negative relationship between PHE and child mortality in the country in question. Therefore, higher PHE would not reduce child mortality.

Table 4.6 below presents the forecasts for maternal mortality relative to a 30% increase in PHE in the out-of-sample period, 2021 to 2030. “Nil” indicates a non-negative relationship between PHE and maternal mortality in the country in question, which suggests that higher PHE would not reduce maternal mortality. However, the table shows that despite increasing PHE by 30%, only Botswana, Namibia, and South Africa would be able to achieve the SDG target of 70 maternal deaths per 100,000 women by 2030. Burundi, Cameroon, Central African Republic, Côte d’ Ivoire, Eswatini, Lesotho, Mauritania, Niger, Nigeria, Tanzania and Togo might experience more than 200 maternal deaths before 2030, whilst Nigeria would still have more than 500.

These forecast outcomes shed light on the potential effects of increased PHE on maternal mortality reduction. However, specific contextual factors such as the state of the health system and financing mechanisms need to be considered.

Table 4.6 below presents the out-of-sample maternal mortality forecasting, which assumes an annual 30% increase in current PHE per capita (real terms).

Table 4.6: Out-of-sample maternal mortality forecast with a 30% annual increase in PHE

Country	2021	2025	2030
Angola	209	150	94
Burkina Faso	270	209	152
Benin	338	267	198
Botswana	120	89	59
Burundi	496	389	276
Cameroon	485	390	301
CAR	748	615	490
Côte d'Ivoire	560	456	352
Eswatini	392	335	263
Gambia	220	175	133
Kenya	313	226	142
Lesotho	510	387	268
Mauritania	692	550	420
Mozambique	231	150	89
Namibia	160	117	70
Niger	445	317	201
Nigeria	851	685	512
Rwanda	207	184	133
Sierra Leone	Nil	Nil	Nil
South Africa	96	71	46
Senegal	262	187	116
Sudan	252	186	120
Tanzania	466	359	259
Togo	360	296	231

Note: This table presents the forecasts for maternal mortality relative to a 30% increase in PHE in the out-of-sample period, 2021 to 2030. "Nil" indicates a non-negative relationship between PHE and maternal mortality in the country in question. Therefore, higher PHE would not reduce maternal mortality.

Table 4.7 below presents the forecasts for child mortality relative to a 30% annual increase in PHE in the out-of-sample period, 2021 to 2030. “Nil” indicates a non-negative relationship between PHE and child mortality in the country in question, which indicates that higher PHE would not reduce child mortality. The table reflects that with a 30% increase in PHE, the following countries would achieve the SDG target of 25 child deaths per year by 2030: Burkina Faso, Botswana, Burundi, Cameroon, Eswatini, Gambia, Namibia, Rwanda, South Africa, Senegal, Sudan, Tanzania and Togo. Thus, about 60% of the countries in SSA could achieve the SDG target for child mortality by 2030.

These forecast outcomes shed light on the potential effects of increased PHE on child mortality reduction. However, specific contextual factors such as the state of the health system and financing mechanisms need to be considered.

Table 4.7 below presents the out-of-sample child mortality forecasting, which assumes an annual 30% increase in current PHE per capita (real terms).

Table 4.7: Out-of-sample child mortality forecast with a 30% annual increase in PHE

Country	2021	2025	2030
Angola	72	57	42
Burkina Faso	30	22	13
Benin	53	43	35
Botswana	40	30	21
Burundi	41	30	18
Cameroon	44	32	18
CAR	105	90	75
Côte d'Ivoire	Nil	Nil	Nil
Eswatini	41	29	18
Gambia	33	25	17
Kenya	68	57	46
Lesotho	79	62	41
Mauritania	69	56	46
Mozambique	61	49	40
Namibia	36	27	13
Niger	47	37	27
Nigeria	78	62	45
Rwanda	28	20	14
Sierra Leone	Nil	Nil	Nil
South Africa	21	16	10
Senegal	30	21	9
Sudan	43	39	25
Tanzania	38	27	19
Togo	44	38	23

Note: This table presents the forecasts for child mortality relative to a 30% increase in PHE in the out-of-sample period, 2021 to 2030. "Nil" indicates a non-negative relationship between PHE and child mortality in the country in question. Therefore, higher PHE would not reduce child mortality.

4.6.1 Implications of the forecast results for SSA

The forecast results revealed the inadequacy of PHE in SSA, which, on average, stood at 1.9% of GNP from 2000 to 2020 (WHO, 2022), while the most current available data revealed that PHE was 2.02% of GNP. However, this was far from the minimum threshold for improving the health outcomes of SSA countries, earlier estimated to be 3.65% of GNP. Furthermore, the forecasts of maternal and child mortality based on a 10%, 20% and 30% annual increase in PHE revealed that many countries in SSA would not meet SDG Targets 3.1 and 3.2 despite these increases.

The forecasts, therefore, revealed that in the case of many of the countries in SSA, meeting the threshold of 3.65% of GNP for PHE might not mean achieving SDG Targets 3.1 and 3.2. This suggests that a state of emergency needs to be declared in health financing in SSA, especially in the case of maternal mortality.

Despite various attempts by African leaders to increase PHE for better health outcomes, they remain poor, with inadequate PHE. The severity of health outcomes in SSA calls for urgent attention to resolve the prevailing health emergency in the region. This chapter establishes a predictive link between health outcomes and PHE. The analysis provides solutions to the research hypothesis that a 10%, 20%, and 30% increase in PHE may not accomplish the SDG targets. The forecast values for the outcomes from the forecasting analysis show the percentage increase in PHE required every year to meet the expected child and maternal mortality that will achieve these targets. The methodology section explained how other factors affecting child and maternal mortality, including PHE, were considered and how the forecasting was performed. The projection scenario of a 10%, 20%, and 30% increase in PHE was explained and justified (see forecasting procedure). The addition of 10%, 20%, and 30% on the current level of spending was maintained throughout the projection period.

The models (1995-2020) were estimated employing a time series forecasting technique. The FGLS approach was adopted to examine the causal relationship between per capita PHE and health outcomes, focusing on the expected negative sign indicated by theory, where higher PHE results in lower mortality. The estimated results were then used for in-sample and out-of-sample forecasting, including an optimistic scenario analysis examining the likely impact of consistent growth in public expenditure by approximately 10%, 20%, and 30%. Consequently, in the out-of-sample forecasting analysis period (2021-2030), reductions in mortality across the SSA countries were observed.

The forecast results indicate a need for a 30% increase in PHE to achieve the SDG target of 70 maternal deaths per 100,000 women by 2030 for countries such as Botswana, Namibia, and South Africa, while those like Burundi, Cameroon, Central African Republic, Cote d'Ivoire, Eswatini, Lesotho, Mauritania, Niger, Nigeria, Tanzania, and Togo may experience more than 200 maternal deaths by 2030. According to the forecast, Nigeria will still have more than 500 maternal deaths by 2030, even with a 30% increase in PHE. The outcome underscores the low and inadequate PHE in these countries, aligning with the Cox proportional hazard model and the study by Stenberg, Hanssen, Edejer and Bertram (2017) that predicted an increase in PHE for the achievement of UHC in low- and middle-income countries. However, about 60% of the countries in SSA are projected to achieve the SDG target for child mortality by 2030 with a 30% increase in PHE.

The results suggest the need for improvement in the level of PHE based on each country's needs to position the region to achieve the UN 2030 targets. The projection results highlight significant policy challenges in SSA, including the need to address wasteful spending, corrupt practices, and inadequate PHE while improving the depth and quality of healthcare delivery. Based on the analysis, we recommend that governments steadily increase PHE beyond the forecast level to improve maternal and infant mortality rates, as current funding of the health sector in the region is low and insufficient to achieve the UN 2030 targets.

The forecasting model's results further corroborate the inadequacy of PHE in SSA as it averaged 1.9% of GNP from 2000 to 2020 (WHO, 2022), with the most recent PHE standing at 2.02% of GNP.

4.6.2 Discussion of the results

Despite various attempts by African leaders to increase PHE for better health outcomes, they remain poor in SSA, with inadequate PHE. The severity of health outcomes calls for urgent attention to resolve the prevailing health emergency in the region. The study established a predictive link between health outcomes and PHE. The analysis proved the research hypothesis that a 10%, 20%, and 30% increase in PHE may not accomplish the SDG targets. In addition, the forecast values for the outcomes from the forecasting analysis showed the percentage increase in PHE required each year to meet the expected child and maternal mortality rates that would achieve these targets.

The research methodology section explained how other factors affecting child and maternal mortality, including PHE, were considered and how the forecasting was done. The projection scenarios of a 10%, 20%, and 30% increase in PHE were explained and justified in the section on the forecasting procedure. In addition, the chapter specified that the addition of 10%, 20%, and 30% to the current level of spending was maintained throughout the projection period.

A time series forecasting technique was employed to estimate the models for 1995 to 2020. The feasible quasi-generalized least squares approach was adopted to examine the causal relationship between per capita PHE and health outcomes, focusing on the expected negative sign indicated by theory whereby higher PHE is expected to result in lower mortality. The chapter explained how the estimated results were used for in-sample and out-of-sample forecasting, including an optimistic scenario analysis examining the likely impact of consistent growth in public expenditure by approximately 10%, 20% and 30%. Consequently, in the out-of-sample forecasting analysis period 2021 to 2030, reductions in mortality across the SSA countries were observed.

The forecast results indicated a need for a 30% increase in PHE to achieve the SDG target of 70 maternal deaths by 2030 for countries such as Botswana, Namibia and South Africa, while countries like Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Lesotho, Mauritania, Niger, Nigeria, Tanzania and Togo might still experience more than 200 maternal deaths before 2030. According to the forecast, Nigeria might still have more than 500 maternal deaths before 2030, even with a 30% increase in PHE. This outcome underscores the low and inadequate PHE in these countries, aligning with the study conducted by Stenberg *et al.* (2017), which predicted an increase in PHE to achieve UHC in low- and middle-income countries. However, in the current study, about 60% of the countries in SSA were projected to achieve the SDG target for child mortality by 2030 with a 30% increase in PHE.

The results suggest the need for improvement in the level of PHE based on each country's needs to position the region to achieve the UN 2030 targets. The projection results highlighted the need for significant policy challenges in SSA, including addressing wasteful spending, corrupt practices and inadequate PHE, while improving the depth and quality of healthcare delivery. Based on the analysis, governments should steadily increase PHE beyond the forecast level to improve maternal and child mortality rates, as current PHE in the region is low and insufficient to achieve the SDG targets.

The forecasting model's results corroborated the inadequacy of PHE in SSA, which averaged 1.9% of GNP from 2000 to 2020 (WHO, 2022), with the most recent figure standing at 2.02% of GNP. In the previous chapter, the minimum threshold estimated to achieve better health outcomes for SSA countries was 3.65% of GNP, indicating that the region is still far from reaching the minimum threshold. Furthermore, the forecast levels of maternal and child mortality due to a 10%, 20% and 30% increase in PHE revealed that SSA should strive hard to achieve the SDG targets of 70 maternal deaths per 100,000 births and 25 child deaths per 1,000 live births by 2030.

Although the results are insightful, the study's limitations must be acknowledged. One limitation is the constrained study period, which only covered 1995 to 2020. Extending the study period beyond these years would allow for more robust analysis and improved projections. Furthermore, additional predictors could enhance the accuracy and reliability of the predictions or projections. By expanding the temporal scope and incorporating more relevant variables, future research might provide a more comprehensive and nuanced understanding of the subject matter.

Nevertheless, the results presented in this chapter highlight the urgent need to address the poor health outcomes and inadequate PHE in SSA. The forecasts indicated that current levels of PHE were insufficient to achieve the SDG targets for maternal and child mortality. Steady increases in PHE based on each country's specific needs are required for the region to progress towards the UN 2030 goals. Therefore, policymakers should prioritise allocating more resources to the health sector and addressing issues like wasteful spending and corruption. By improving the depth and quality of healthcare delivery and increasing PHE, SSA could work towards achieving better health outcomes and ultimately realising the SDG health goals.

4.7 Chapter Summary

In this chapter, maternal and child mortality was forecast based on a 10%, 20% and 30% increase in PHE in countries in SSA to achieve SDG Targets 3.1 and 3.2**.** The forecasts indicated the need for increases in PHE above those percentages in several countries. Thus, the forecasts revealed the need for policy changes to increase PHE, and address wasteful spending, corrupt practices, and poor quality healthcare. It is recommended that governments should steadily increase PHE to reach and move beyond the forecast levels to reduce maternal and child mortality in line with SDG Targets 3.1 and 3.2.

Despite increasing PHE by 30%, only Botswana, Namibia and South Africa would achieve the SDG target of 70 maternal deaths by 2030, indicating PHE's inadequacy in most SSA countries. However, Burundi, Cameroon, Central African Republic, Côte d Ivoire, Eswatini, Lesotho, Mauritania, Niger, Nigeria, Tanzania and Togo will experience more than 200 maternal deaths before 2030 unless a state of emergency is declared in their health sectors. Moreover, the forecast results revealed that Nigeria would experience more than 500 maternal deaths before 2030 even with a 30% increase in its PHE. Nevertheless, the forecasts revealed that about 60% of the countries in SSA could achieve the SDG target for child mortality by 2030 if they increased their PHE by 30%.

CHAPTER 5

LINEAR AND NONLINEAR EFFECT OF PUBLIC HEALTH EXPENDITURE ON TOTAL FACTOR PRODUCTIVITY

5.1 Introduction

The previous chapters focused on the link between PHE and health outcomes. However, PHE is also expected to impact TFP by influencing health outcomes. This chapter delves into the linear effect of PHE and health outcomes on TFP and PHE's nonlinear effect on TFP, which has not been previously studied in the context of SSA.

The chapter is organised as follows: It begins with the background of the study in Section 5.2. Section 5.3 outlines the overall aim of the part of the study covered in this chapter and specifies the objectives and hypotheses. Section 5.4 reviews the relevant literature, highlighting the study's contribution to the existing body of knowledge. Section 5.5 discusses the methodology employed, and Section 5.6 presents and analyses the results in relation to the research objectives. The chapter concludes with a summary in Section 5.7.

5.2 Background

Lucas' (1988) theory supports the assertion that policies aimed at improving the quality of health and education, which are proxied by the human capital theory in this study, can enhance productivity by increasing factor inputs and raising outputs. Cole and Neumayer (2006) argue that health impacts TFP, demonstrating that diseases and poor health such as malaria, waterborne diseases and malnutrition negatively affect human productivity and, in turn national productivity. However, the current study differs from that of Cole and Neumayer (2006) as it sought to assess the effects of PHE and health outcomes (specifically maternal/child mortality, LEB, HIV prevalence and the TB rate in selected SSA countries) on TFP.

According to the Penn World Table 10.0, SSA countries have experienced a decline in TFP growth from 1980 to the present. For example, Botswana's TFP level at current PPP was 0.77 in 1980 and 0.57 in 2014, Côte d'Ivoire's was 0.76 and 0.46, Egypt's was 1.11 and 1.08, Nigeria's was 1.44 and 0.65, and South Africa's was 0.97 and 0.53 (Feenstra *et al.,* 2015). Solow (1956) identified technological progress as the primary driver of long-term growth. Without the invention of new technologies, capital accumulation would be distributed amongst existing inputs, leading to diminishing returns and stagnated growth.

Total factor productivity growth is essential to prevent diminishing marginal returns and ensure continued economic growth. Focusing solely on capital accumulation without attention to technological frontiers can result in diminishing returns and a shrinking economy (Solow, 1956). Also known as productivity growth, TFP is critical in determining a firm's profitability, competitiveness and growth. The literature points to growing interest in understanding the factors that affect productivity (Fallahi *et al.*, 2010), as TFP measures overall production efficiency within a system by examining the ratio of inputs to outputs (Krugman, 1994).

In the current study, TFP is defined as output growth that traditional inputs in the production function cannot explain but rather, health and, by extension, PHE, and represents the residual growth in total output. Improvements in population health can be linked to TFP because good health enhances individual productivity, and a healthier labour force contributes to efficient human capital accumulation. Thus, a healthier population is likely to be more productive. However, inadequate funding of health in SSA has led to poor health outcomes, which in turn have affected regional productivity growth. Consequently, the TFP growth rate in the region has remained low (UN, 2017). This situation calls for an investigation of the nature (linear or nonlinear) of the relationship between health and TFP and an estimation of the level of PHE required to achieve TFP growth if a threshold point exists. Confirming the nature of the relationship between health and TFP (whether linear or nonlinear) is crucial to provide baseline results that support nonlinear and threshold analyses.

5.3 Research aim, objectives and hypotheses

This chapter examines the linear and nonlinear effects of PHE and health outcomes on TFP. The study's specific objectives were as follows:

- To investigate the controlled effect of PHE and health outcomes on TFP in SSA
- To analyse the presence of a threshold relationship between PHE and TFP in SSA
- To analyse the presence of a threshold relationship between non-health factors and TFP in SSA

The sub-hypotheses addressed were as follows:

- Health expenditure and health outcomes did not affect TFP in SSA
- There was no threshold relationship between PHE and TFP in SSA
- No threshold relationship existed between the non-health factors and TFP in SSA

5.4 Literature review

The following sections review the theoretical and empirical literature.

5.4.1 Theoretical literature

This section presents theories on the linear and nonlinear relationships between the variables under study as well as those on the relationship between expenditure and productivity. The motive behind the discussion on theories is to establish the most appropriate ones that explain these relationships.

5.4.1.1 Theoretical perspectives on linear relationships

a) Growth Theories

Growth theories are a set of economic frameworks that aim to explain the factors and mechanisms that contribute to economic growth and development over time. They provide insights into the drivers of long-term economic expansion and help policymakers understand the conditions necessary for sustained and inclusive growth.

***Lucas' (1998) theory**

Lucas (1988) developed an endogenous growth model whereby internal rather than external factors cause growth. Moreover, the theory proposes that investment in the health and education sectors produces human capital, a key determinant of economic growth. In addition, Lucas (1988) distinguishes between the internal effects of human capital, whereby the individual worker undergoing training and receiving healthcare services becomes more productive, and the external effects, whereby workers' collective productivity leads to economic growth.

Therefore, human capital investment is preferable to physical capital investment, entrenched in the theory proposed by Harrod-Domer whose economic growth model views savings and investment as sources of economic growth. The current study hinged on Lucas' theory of investment in human capital, which will ensure productivity.

***Romer's (1990a) theory**

Romer (1990a) proposes an endogenous growth theory whereby technological change, an internal economic factor leading to economic growth, results from researchers' and entrepreneurs' efforts to respond to economic incentives (Romer, 1990a, b). The theory was relevant to the study because it emphasises that technological progress leads to economic development, which is relevant to the developing and emerging economies of SSA.

***Schumpeter's (1942) theory**

The Schumpeterian theory, which is also an endogenous growth theory, proposes that an increase in the size of a population should cause long-run economic growth by increasing the size of the workforce, the market for innovative products and the rate of innovation through technological research and development. This theory was relevant to the current study because investment in better health care can reduce the death rate in an economy, thereby increasing the population, which will lead to long-run economic growth.

***Solow's (1956) growth model**

Solow's (1956) growth model, which is also endogenous, proposes that increased human capital as productive labour driven by technological advancement causes long-run economic growth. Therefore, according to this theory, the labour force needs to be healthy to be productive, and the population needs to grow, which is relevant to the current study.

5.4.1.2 Theoretical perspectives on nonlinear relationships

a) Threshold theories

According to the *Macmillan Dictionary*, a threshold is any amount, level, extent or limit at which an arrangement or set of goals changes. A nonlinear relationship between two variables means that changes in one variable are not directly proportional to changes in the other. Moreover, in economics, threshold analysis is used to determine the threshold value of a variable in a nonlinear relationship with other variables. In a study on the effect of a variable on health outcomes, the threshold value could be the point at which a healthcare strategy would realise a particular health outcome. An example would be the determination of the threshold value of PHE to ensure TFP with these variables being in a nonlinear relationship.

***Laffer's (2004) curve theory**

Laffer's (2004) curve theory, which was initially based on the idea that reducing or increasing tax rates beyond a certain point will be counter-productive for increasing tax revenue, is a macroeconomic concept that has often been used to explain the nonlinear and threshold relationship between variables (Sheehey, 1993; Vedder & Gallaway, 1998; Chen & Lee, 2005; Laffer, 2004). Determining the threshold level of PHE, which is in a nonlinear relationship with TFP, could be linked to the Laffer curve.

Arney (1995) adapted the Laffer curve into the Arney curve, which Adepoh (2019) used to explain the optimal level of public expenditure that can influence economic growth in Côte d'Ivoire. Therefore, in this study, TFP growth is based on the views of Arney (1995), Herath (2010) and Adepoh (2019) on the Laffer curve. Public health expenditure is a variable that changes. It can be increased or decreased depending on the focus of the government and its budget plan.

Public health expenditure has increased and decreased in SSA, impacting the region's productivity growth. Therefore, the optimal point at which an increase or decrease in PHE will not be detrimental to TFP growth needs to be estimated. Thus, following Adepoh's (2019) use of the Laffer curve, Figure 5.1 below explains the quadratic relationship between PHE and TFP in SSA.

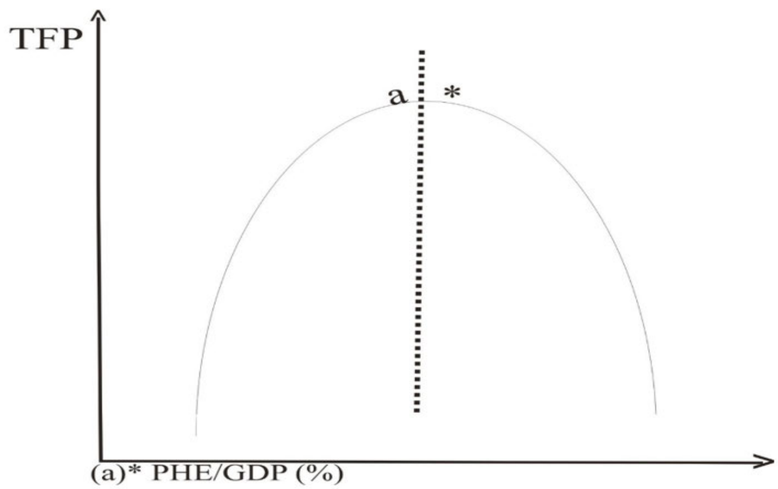

Figure 5.1: Laffer's curve

The vertical axis in Figure 5.1 above shows PHE as a percentage of GDP, and the horizontal axis depicts the TFP growth rate, while * indicates the optimal point at which PHE maximises TFP.

5.4.1.3 Theories on the relationship between expenditure and productivity

a) Wagner's (1883) theory

Wagner's theory proposes that public expenditure increases at a steady and faster rate than the economy's output. Moreover, the theory posits that demand for health and education grows faster than per capita income because the income elasticity of demand for these services is greater than 1. This theory was applied to the current study, which was premised on the effect of human capital on economic growth (Arora & Jalilian, 2020).

Wagner's theory analysed the trend in the growth of public expenditure. It reiterated the functional cause-and-effect relationship between the growth of an economy and the relative growth of its public sector expenditure. Wagner explained the cause of growth in public expenditure in terms of the law of increasing state activities. This law has universal applicability in that the growth or productivity of a country depends on the increase in public expenditure. Specifically, Wagner examined the changes in the ratio between public spending and per capita income.

c) Keynes' (1936) theory

The Keynesian theory proposes that an increase in public spending gives individuals purchasing power, and thus, more products are produced, thereby creating more employment. Keynes describes the influence of public expenditure on national income as the multiplier effect. In addition, he regards public expenditure as an exogenous/independent variable that can be used to influence growth. Increasing government spending on health could increase the national income because people will be healthier and more productive. This theory was applied to the current study, which investigated the relationship between increased government spending on health and health in individuals who become more productive and increase their income (Keynes, 1936).

d) Peacock and Wiseman's (1961) hypothesis

Peacock and Wiseman's hypothesis is that an increase in public expenditure should occur step-like rather than a smooth transition. These steps are:

- The displacement effect whereby tax increases to meet increased public expenditure.
- The inspection effect when the government inspects the effectiveness of tax and expenditure, adjusts if necessary or finds other revenue.
- The concentration effect whereby public expenditure increases more than that of local government.

This theory is more convincing than Wagner’s theory because public expenditure is seen as occurring in steps instead of a steady increase. It was applied to the study because increases in government spending were viewed as occurring in stages (Peacock & Wiseman, 1979). The theory also applies to the analysis conducted in the study because increased government spending on health may be gradual and effective. In advocating for an increase in public health spending, lags in its implementation and manifestation need to be taken into account.

5.4.1.4 Summary of theoretical literature

This study was based on Lucas' theory, highlighting the significance of investing in the health and education sectors to develop human capital, a key determinant of TFP growth. The theory distinguishes between the internal and external effects of investing in human capital.

The internal effects of investing in human capital refer to the education and health of individuals who acquire valuable skills and better health, leading to increased productivity and output. The external effects refer to the spillover benefits extending beyond individuals. As individuals improve their education and health, their enhanced productivity benefits them and positively influences productivity and, thus, overall economic growth.

By considering Lucas' theory, the study recognised the importance of the individual- and economy-wide impacts of investing in human capital. It thus explored how investment in education and healthcare could boost productivity and aggregate levels, fostering economic growth.

5.4.2 Empirical literature

The empirical literature has examined the relationships between the variables of interest based on the theories highlighted above in many ways. Some of the studies are reviewed in this section.

5.4.2.1 Relationship between health outcomes and economic growth

Akinbode *et al.* (2021) investigated the effect of health outcomes on economic growth in SSA. The study employed GMM to analyse data from 2000 to 2008 for 41 countries in this region. It confirmed the positive relationship between LEB and economic growth, which had already been revealed in the literature. Ogunjimi and Adebayo (2019) examined the relationship between PHE, health outcomes and economic growth in Nigeria between 1981 and 2017. Adebayo's (2019) study conducted a Toda-Yamamoto causality analysis, and the results revealed the following:

- Unidirectional causality running from PHE to infant mortality
- No causality between real GDP and infant mortality
- Unidirectional causality running from PHE and real GDP to LEB and maternal mortality
- Unidirectional causality running from real GDP to PHE

Wang and Lee (2018) investigated the asymmetrical impact of life insurance on PHE and economic growth. The dynamic panel threshold model (DPTM) was employed to analyse 24 developed countries between 1999 and 2012. The variables included in the model were per capita GDP, per capita total PHE and per capita life insurance premiums. Life insurance growth was taken as the regime switch factor. The results showed a positive relationship between the variables in a low life insurance growth regime. In contrast, the per capita life insurance regime did not affect per capita PHE or GDP in a high life insurance regime. Moreover, the effect of per capita PHE on per capita GDP was not significant, although the effect of per capita GDP on per capita PHE was significant and positive.

Aboubacar and Xu (2017) researched the relationship between PHE and economic growth in countries in SSA using GMM. Aboubacar and Xu (2017) discovered a positive relationship between PHE and economic growth. Arthur and Oaikhnan (2017) investigated the effect of health outcomes on economic growth. A significant inelastic relationship was found between the variables. Kurt (2015) studied the direct and indirect effects of PHE on economic growth between 2006 and 2013. Using the Feder-Ram model, the researcher found that government PHE had a positive, significant and direct effect on economic growth, while the indirect effect was negative and significant.

Eggoh, Houeninvo and Sossou (2015) analysed the relationship between education, health and economic growth in 49 African countries between 1996 and 2010. The study incorporated traditional cross-section and dynamic panel techniques. The results revealed that public expenditure on health and education had a negative impact on economic growth. However, Eggoh *et al.*'s (2015) research revealed a complementary relationship between education and health in African countries. Eggoh *et al.* (2015) concluded that public investment in education and health should be increased simultaneously to positively and significantly impact economic growth in African countries.

Boussalem, Boussalem and Taiba (2014) investigated the effect of PHE on economic growth in Algeria using the error correction model. The study revealed no strong relationship between PHE and economic growth. Ogunleye (2014) examined the effect of health outcomes on economic growth in countries in SSA using GMM. The results revealed that none of the health indicators significantly impacted economic growth. Gyimah-Brempong and Wilson (2004) studied the relationship between health, which ensures human capital, and GDP per capita growth in SSA and OECD countries using Solow's (1956) growth model. The results revealed that GDP per capita growth decreased at a high level of health. However, a positive relationship was found between economic growth represented by per capita income and investment in human capital. As these studies show, despite the literature on the effect of health expenditure on economic growth in SSA, no study exists on the effect of health expenditure on TFP.

5.4.2.2 Health Determinants of TFP

Saha's (2013a) study found a one-way relationship between LEB and TFP and that LEB had a positive, significant effect on TFP in India. Raiespour and Pajooyan (2013) investigated the effect of PHE on TFP growth in 28 provinces in Iran to show that government investment in the health sector would positively affect TFP, while government investment in health infrastructure alone would have no effect.

Cole and Neumayer (2006) examined the impact of poor health on TFP in developing countries between 1990 and 2000. Fixed- and random-effects models were used in the analysis, which revealed that malaria, malnutrition and a lack of access to water were significant health determinants of TFP in developing countries. Alemu, Roe and Smith (2005) analysed the impact of HIV on TFP in 100 countries around the world between 1994 and 2002.

Alemu *et al.* (2005) concluded that HIV had a negative impact on TFP in Southern African countries. It reduced TFP by 23% in Lesotho, and by 15% in South Africa. In addition, Alemu *et al.* (2005) found that HIV had a negative impact on both countries' per capita and aggregate GDP.

Table 5.1 below summarises the empirical literature on the health determinants of TFP.

Table 5.1: Empirical literature on health determinants of TFP

Author and year	Country and scope	Variables	Method of analysis	Results
Cole and Neumayer (2006)	Countries across the world (1990-2000)	Waterborne diseases, malaria, malnutrition, TFP	Two-stage least squares	All variables considered determinants of TFP
Saha (2013a)	India (1990-2000)	LEB, TFP	Two-stage least squares	Life expectancy at birth had a significant positive effect on TFP
Raiespour and Pajooyan (2013)	Iran (2000-2013)	Government expenditure on the health sector, health infrastructure, TFP	ECM	PHE had a significant positive effect on TFP, while expenditure on health infrastructure alone had no effect

5.4.2.3 Non-health Determinants of TFP

Olomola and Osinubi (2018) researched the determinants of TFP in the economies of Mexico, Indonesia, Nigeria, and Turkey (MINT) from 1980 to 2014. The study concluded that GDP, labour force, gross fixed capital formation, FDI and human capital developed through education and inflation were drivers of TFP growth in the MINT countries. Fadiran and Akanbi (2017) investigated the determinants of TFP growth in SSA from 1990 to 2011. The results confirmed market-based institutions rather than political institutions, research and development, human capital, infrastructure and financial development as the determinants of TFP.

Timuno (2017) examined the determinants of TFP in Botswana from 1977 to 2014 using an ARDL bounds test. The study identified economic diversification, openness to trade, and human capital development through education and inflation as determinants of TFP in Botswana. Akinlo and Adeyemo (2016) studied the determinants of TFP in Nigeria from 1970 to 2009 using an error correction model, impulse-response functions and variance decomposition. The results revealed that human capital, trade openness, FDI and unemployment significantly negatively impacted TFP.

Sukazi (2010) investigated the determinants of TFP in the Canadian economy using two-stage OLS and a vector error correction model. The study concluded that FDI, trade openness, infrastructure and inflation were positively related to TFP. Filip's (2016) research on the determinants of TFP in a group of developed European countries from 2000 to 2013 concluded that knowledge, technology, infrastructure development, education, health level, the intensity of capital use and manifestations of financial crises were determinants of TFP.

Alvi and Ahmed (2014) investigated the impact of health and education on TFP in 37 developed and developing countries using a dataset spanning 1990 to 2010. The Cobb-Douglas prediction function was employed to derive TFP. Random- and fixed-effects models were used to determine the determinants of TFP. The research results revealed a positive and significant relationship between health and TFP, on the one hand, and education and TFP, on the other.

Using principal component analysis and dynamic panel data modelling, Loko and Diouf (2009) examined the determinants of TFP in Mahgreb countries. The results showed that FDI, the rationalisation of government size, shifting resources to the most productive areas, increasing the share of women in the labour force, a large stock of human capital, strong institutions, and trade openness were determinants of TFP. Jajri (2007) investigated the determinants of TFP in Malaysia from 1971 to 2004. The results pointed to an increase in the number of skilled workers who operate sophisticated technology, the adoption of new technology, and effective use of human capital in the labour market as determinants of TFP. However, despite these and other factors considered as determinants of TFP, given the current level of development globally, no output could be efficient without ICT, which this study included as a variable.

Table 5.2 below summarises the empirical literature on the non-health determinants of TFP.

Table 5.2: Empirical literature on the non-health determinants of TFP

Author and year	Country and scope	Variables	Method of analysis	Results

Akinlo and Adejumo (2016)	**Nigeria (1970-2009)**	**FDI, unemployment, inflation, trade openness and human capital, TFP**	**ECM, impulse response and variance decomposition**	**All variables had a significant negative impact on TFP**
Filip (2015)	**Developed European countries (2000-2013)**	**Knowledge, technology, health level, financial crisis, TFP**	**Logistic regression**	**All variables considered determinants of TFP**
Loko and Diouf (2009)	**Maghreb countries**	**Research and development, human capital development through education, trade openness, strong institutions, the share of women in the labour force, FDI, TFP**	**ECM**	**All variables considered determinants of TFP**
Fadiran and Akanbi (2017)	**Countries in SSA (1990-2011)**	**Research and development, human capital development through education, infrastructure, financial development, TFP**	**ECM, impulse response and variance decomposition**	**All variables considered determinants of TFP**
Jajri (2007)	**Malaysia (1971-2004)**	**New technology, skilled workers, human capital, TFP**	**ECM, impulse response and variance decomposition**	**All variables considered determinants of TFP**

5.4.2.4 Threshold relationship between health expenditure and economic growth

Sirag and Nor (2021) conducted a study to examine the relationship between OOP health expenditure and poverty across 145 countries globally from 2000 to 2017. Their results indicated that when OOP health expenditure exceeded 29% of total health expenditure, it increased poverty. The study also accounted for heterogeneity amongst income groups and found that OOP health expenditure had a positive but insignificant effect on poverty reduction among low-income groups below the 29% threshold. Conversely, OOP health expenditure above the threshold caused a higher poverty rate in the high-income group.

Another study by Yang (2020) investigated the relationship between health expenditure and economic growth considering different levels of human capital in 21 developing countries from 2000 to 2016. The panel threshold method was employed, and the results showed a significant negative relationship between health expenditure and economic growth at low levels of human capital. However, at medium human capital levels, the effect of health expenditure on economic growth was positive but not significant. Lastly, the effect became positive and significant at high levels of human capital.

Kouton, Nguessan, and Ayivodji (2018) analysed the nonlinear relationship between health and economic growth in sub-Saharan African countries. They employed the dynamic panel threshold method and found that LEB impacted economic growth through its interaction with PHE, indicating that the impact on economic growth was higher when the share of PHE exceeded 3.46% of GNP.

Chakroun (2012) explored the nonlinear relationship between economic growth and health. The study revealed a positive but decreasing marginal effect between health outcome variables and economic growth. In addition, Chakroun (2012) found that the effect of LEB was lower in countries where PHE was above 1.77% of GDP. Similarly, Desbordes (2011) investigated the nonlinear relationship between LEB and economic growth across 47 countries using data from 1940 to 1980. The findings indicated that the impact of LEB on per capita income was negative and significant when initial life expectancy was less than 43 years. However, life expectancy exceeding 43 years positively impacted per capita income.

While several studies have examined the threshold relationship between health and economic growth in SSA, a gap exists regarding the threshold effect of health expenditure and outcomes on TFP.

5.4.2.5 Gap in the literature

The current study aimed to address a gap in the existing literature by examining the impact of health expenditure and health outcomes on TFP. It also sought to confirm the threshold relationship between the variables in SSA. Previous discussions on TFP growth in SSA have raised concerns about the impact of non-health variables. Little is known about the impact of health expenditure and health outcomes on TFP, reducing the effectiveness of non-health factors in enhancing TFP in SSA. By including these factors in the analysis, a more comprehensive understanding of the impact of non-health factors on TFP in SSA can be achieved.

5.5 Research methodology

The study determined the linear and nonlinear relationships between PHE and TFP based on the Cobb-Douglas production function. This theoretical framework is explained in this section as well as the variables, a priori expectation, estimating techniques and the model specification.

5.5.1 Theoretical framework

The study was based on endogenous growth theory, expressed by the simple equation of the Cobb-Douglas production function, as set out below. Keynesians and monetarists disagree on the role of government and money supply in influencing the economy. Keynesians emphasise the role of government in terms of government spending and the use of tax to ensure economic growth. However, monetarists place importance on the role of money in terms of money supply and interest rates in explaining growth.

The study supported the Keynesian view and endogenous growth theory, especially the Lucas theory, considering its emphasis on the role of TFP in long-term growth. Moreover, Lucas (1988), Bernanke and Gurkaynak (2002), Acemoglu (2006), Ivkovic (2008), Todaro and Smith (2009), 2012) and Atesagaoglu, Elgin and Oztunali (2017) highlight the health of human capital assisted by technology innovation as an endogenous factor influencing TFP and economic growth (Romer, 1990b).

The Cobb-Douglas production function expressing endogenous growth as stated by Romer (1986):

The AK model can be expressed as: $Y_t = AK_t$ [1]

$$K_t = sY_t - \delta K_t \quad [2]$$

Where A is an exogenous and constant productivity parameter, and s is an exogenous, constant investment rate. In this study, K is interpreted as physical capital, but in Romer (1986), K was interpreted as knowledge, and in Lucas (1988), it was replaced by human capital.

Putting these equations together:

$$gY \equiv \frac{Y_t}{Y_t} = sA - \delta \quad [3]$$

The production can also be written in per capita terms as:

$$y = AK^{\propto}(\ell h)^{1-\propto} \quad [4]$$

Which is a constant return to the scale production function in K and ℓh.

Capital accumulation proceeds via the usual differential equation,

$$k = y - c - (\xi + \delta)k \quad [5]$$

While h accumulates according to

$$\hbar = \emptyset h(1-\ell) \quad [6]$$

$$\hbar / h = \emptyset h(1-\ell)$$

Lucas (1988) also assumes that human capital will be more productive if it is enclosed with other human capital. The production form will then be written as:

$$y_i = Ak_i^{\propto}(\ell_i h_i)^{1-\propto}h^{\psi} \quad [7]$$

Where h is the average human wealth in the population (and other variables reflect the values for the individual).

The decentralised solution shows that the steady-state growth rate of human capital for an individual consumer will be:

$$\gamma h = \frac{p^{-1}(\emptyset - \theta)}{1+\psi(1-1/p)/(1-\alpha)} \quad [8]$$

The part of the overall study covered in this chapter addressed the status of PHE as a predictor for productivity growth in developing countries in SSA. Moreover, it highlighted health as an integral part of human capital development alongside education and emphasised TFP as the target variable, an indicator of economic growth function. Therefore, the study contributes to the literature on the role of health and education systems in developing human capital, which, alongside technological advancement, improves TFP (Solow, 1956; Swan, 1956; Aghion & Howitt, 1998; Romer, 1990a).

Total factor productivity measures the productive efficiency and capacity of input factors such as labour and physical capital to increase the output of goods and services (Dhyne & Fuss, 2014; Adnan, Chowdhury & Mallik, 2020). Moreover, the Cobb-Douglas production function (of which TFP is a component) can be divided into two parts: input factors and factor productivity (Olomola & Osinubi, 2018). The first part depends on the number of inputs (labour and capital), which are finite, which means that continuous output is unsustainable. The law of diminishing returns governs the inputs. The second part, which is not input-driven but rather powered by technology, knowledge and skilful and healthy labour, means that TFP is the source of long-run economic growth performance. Thus, a healthy labour force is required to improve factor productivity and achieve economic development in developing countries (Akinlo & Adejumo, 2016).

The current study was not the first to specify health as a predictor for productivity growth. It relies on previous theoretical foundations that argue that a healthy workforce directly or indirectly increases TFP (Nachega & Fontaine, 2006; Alvi & Ahmed, 2014; Ezoji *et al.*, 2018). However, the current study considers health in terms of the level of PHE and other variables that boost TFP, such as technological innovation, capital investment, ICT, training, education, and research and development (Ceccobelli, Gitto, & Mancuso, 2012; Eric, Ng & Ng, 2016). Moreover, macroeconomic variables such as inflation, GDP, national income, and unemployment levels play a role (Anyanwu & Erhijakpor, 2009; Mosley & Chen, 1984; Akinlo & Adejumo, 2016; Badulescu *et al.,* 2019; Pakdaman *et al.,* 2019; Zhou *et al.*, 2020). Zhou *et al.* (2020) maintain that intervening macroeconomic variables must be accounted for to determine the benefits of health spending for health outcomes.

5.5.2 Data definition

The annual data for the period 2000 to 2020 on the study variables derived from the literature and explained below were sourced from the WHO (2021). The number of observations was considered suitable and robust to achieve the objectives of the part of the overall study explained in this chapter.

In the study, TFP was the target variable explained by several regressors, chief of which were PHE and health outcomes (maternal and infant mortality). In addition, the role of education was considered a component of human capital development and health. The effects of macroeconomic variables such as domestic and foreign investment, the role of ICT and control of corruption were also included.

These variables, which formed the basis for the model specification detailed later in this chapter, are explained below.

5.5.2.1 Dependent variable (TFP)

Total factor productivity is a determinant of long-run economic growth. It also measures the residual growth in the total output of a firm or industry that the inclusion of conventional inputs such as labour and capital in the production function cannot explain. Feenstra *et al*.'s (2015) work shows that TFP is measured as the TFP level at current PPP.

5.5.2.2 Independent variables

a) PHE (health variable)

In the study, the independent variable, PHE per capita, or PHE, is the capital outlay on health provided by a country's government, including NHIS. It was measured as domestic government PHE as a percentage of GDP per capita.

b) Maternal mortality (health variable)

In the study, the maternal mortality variable referred to pregnancy-related deaths per 100,000 women during and six weeks after delivery.

c) Child mortality (health variable)

The child mortality variable in the study referred to the number of deaths per 1,000 live births of under-five children.

d) Life expectancy at birth (health variable)

In this study, LEB referred to the number of years a new born is expected to live if exposed to prevailing conditions at the time of birth.

e) Human immunodeficiency virus (health variable)

In the study, this variable referred to individuals living with the human immunodeficiency virus (HIV).

e) Tuberculosis (health variable)

In the study, this variable referred to individuals living with TB.

f) Education (non-health variable)

In the study, education was proxied by the human capital index, which quantifies a country's citizens' economic and professional potential as the measure for education. Education is the process of acquiring knowledge and information, which refines an individual's capacity, proficiency, ability to interact, state of mind and values.

g) Information communication technology (non-health variable)

In the study, the information communication technology (ICT) variable referred to the percentage of the population using the Internet, which would provide health information, thereby promoting good health. For example, an individual might find information about an ailment, which will prompt him/her to arrange an appointment with a doctor and, in some cases, lead to early diagnosis and survival.

h) Control of corruption (non-health variable)

Corruption can be described as dishonesty in many forms, cutting across every sphere of life. It is not limited to public institutions but is most common among public officeholders. Corruption can be the reason for a lack of transparency and accountability, poor governance and non-adherence to the rule of law. According to Kaufmann, Kray and Mastruzzi (2010), it is measured by the extent of its control, which prevents public leaders from serving their interests instead of those of the public. Corruption was adopted in this study as it is one of the prevalent problems associated with SSA (Hsiao *et al.*, (2019)

5.5.3 A priori expectations

A positive relationship was expected between PHE and TFP and between health outcomes and TFP, whereby maternal and child mortality would be reduced (Anyanwu & Erhijakpor, 2009). This expectation was in line with Cole and Neumayer's (2006) research results, which established that poor health factors such as malaria, waterborne diseases and malnutrition reduce TFP, and thus, removing these factors would increase TFP. It was also in line with Alvi and Ahmed's (2014) finding that an increase in health proxied by life expectancy positively impacted TFP. In addition, Sharpe, Alexander and Bailey (1998) argue that public commitment to education enhances TFP, which suggests that ICT as an educational tool would have the same effect.

The impact of inflation was expected to be negative since higher prices raise the cost of health care and health equipment, which may limit the achievement of the health-related SDGs. Akinlo and Adejumo's (2016) study found a long-run negative effect of inflation on TFP in Nigeria. In addition, the impact of domestic investment on TFP should be positive.

In line with Hsiao *et al.*'s (2019) research, the current study accounted for control of corruption, which was expected to be negatively correlated with TFP productivity growth, since it could mean that resources allocated to healthcare are mismanaged.

5.5.4 Estimating techniques

5.5.4.1 Panel two-stage least squares regression analysis

Panel two-stage least squares (P2SLS) regression analysis extends OLS regression. It is used when the error terms of the dependent variable are correlated with the independent variables. This estimation model was preferred due to the suspected endogeneity of the PHE variable with health variables such as maternal mortality, child mortality, HIV and TB.

Several assumptions are followed in using the P2SLS: (1) the equations are well stated, (2) the error variance of all variables are the same, (3) error terms are normally distributed, (4) outliers have been removed from the data, and (5) observations are dependent on each other.

5.5.4.2 Fixed- and random-effects models

As fixed- and random-effects models estimate heterogeneous panels differently, they were chosen for the static panel data analysis, given the heterogeneity of the countries in SSA. Pooled regression would only have been suitable for the panel analysis if the countries were homogeneous.

Hausman's (1978) test is performed to judge the different coefficients indicated by the alternative static panel estimators, the fixed- and random-effects models.

5.5.4.3 Panel Threshold Regression Model

The panel threshold regression model can be dynamic or static based on choice. The static panel threshold model developed by Hansen (1999) was adopted for the study. The threshold variable is strictly exogenous, which makes the threshold estimator consistent. Moreover, although the assumption of the homogeneity of the regressors was rejected by Caner and Hansen (2004), a threshold variable must be exogenous. Thus, apart from the assumption of exogeneity, the regression coefficients can take on a small number of different values depending on the value of the exogenous stationary variable. Gonzalez *et al.* (2005) designed a regression model that permits the coefficients to change gradually from one regime to another.

5.5.5 Model specification

5.5.5.1 Main linear model

The linear/fixed and random panel model specification relied heavily on the interactions established in the theoretical framework. Total factor productivity measured the efficiency of factor inputs, increasing productivity despite limited inputs. In Equation 5.1 below, TFP is represented by A is the residual part of the Cobb-Douglas production function, which relates output y_t to inputs l_t (labour) and k_t (capital) as follows:

$$y_t = A k_t^{\alpha} l_t^{1-\alpha}; \alpha < 1 \qquad [5.1]$$

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha} = f(A_{it}, H_{it}, P_{it}, L_{it}) \qquad [5.2]$$

Where Y is aggregate income, A is productivity, efficiency or TFP, K is capital stock, and L is labour. Capital stock (K) includes both human capital (H) and physical capital (P), but there are no diminishing returns to capital. In addition, α and 1- α are the output elasticities regarding inputs.

TFP is A in Equation 5.1 above. Equation 5.2 can be expressed as the function of other variables in the model as follows:

$$A_{it} = \left[\frac{Y_{it}}{(H_{it})(P_{it})(L_{it})} \right] \qquad [5.3]$$

Taking the natural logarithm of Equation 5.3, a model that explains productivity growth as a function of other variables in the model is formulated as follows:

$$\ln A_{it} = \exp\left[\ln Y_{it} - \gamma \ln H_{it} - \psi \ln P_{it} - \varphi \ln L_{it} \right] \qquad [5.4]$$

Productivity growth can thus, be written as a function of aggregate income, human capital and physical capital stock.

This study aimed to explain the residual unexplained portion by considering the impact of health components such as PHE and health outcomes on productivity. This is built on previous arguments suggesting that health would influence productivity through human capital development. A study conducted by Aísa, Clemente and Pueyo (2014) supports this notion, demonstrating a positive relationship between public expenditure on health, as measured by PHE and life expectancy in OECD countries.

Equation 5.5 below represents the specification of the time series model without control variables. In contrast, Equation 5.6 introduces additional economic and non-economic factors, including education, FDI, corruption, ICT diffusion and inflation into the time series model.

$$tfp_t = \alpha + \beta health_t + \varepsilon_t \qquad [5.5])$$

$$tfp_t = \alpha + \beta health_t + \gamma' x_t + \varepsilon_t \qquad [5.6]$$

Where;

$health_t$ captures PHE for each of the sub-Saharan African countries, β is the coefficient that measures the impact of PHE on TFP, γ is the vector of the coefficients of the control variables listed earlier, and x_t is the vector of the control variables.

For the sub-Saharan African countries, the panel data forms of the country-specific specifications were specified as follows:

$$tfp_{it} = \eta_i + \beta health_{it} + v_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad (5.7)$$

$$tfp_{it} = \eta_i + \beta health_{it} + \gamma_i' x_{it} + v_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad (5.8)$$

Where;

η_i captures the individual effects, that is, the heterogeneity/differences inherent in the countries in SSA and measures the fixed effect.

Equation 5.7 above was estimated using fixed and random effect estimators. Both estimators estimate short panels, specifically panel models with a short time dimension. In the case of the study, the time dimension of the panel was short, covering 18 observations between 2000 and 2017. The fixed and random effect estimators were also considered appropriate since the panel (unit) dimension was large enough to encompass 25 countries in SSA. However, as there were two competing estimators (i.e., fixed effect and random effect estimators), a decision needed to be made to choose the better estimator. To make this choice, the use of the Hausman test was relevant. One of the estimators was deemed consistent under the null hypothesis and preferred. Alternatively, the other model was preferred if the Hausman test statistic was statistically significant.

5.5.5.2 Linear model for robustness check

The study objective was re-estimated using panel two-stage least squares regression for the robustness check. The linear model specification for the robustness check relied on the interactions established in the theoretical framework, where health factors, specifically PHE, explained TFP. This was based on the previous arguments highlighting the impact of health on productivity through human capital development. Therefore, the relationship between health and TFP was specified in Equation 5.7a below without control variables and in Equation 5.7b below with additional economic and non-economic factors, such as education, ICT diffusion and control of corruption.

$$tfp_{it} = \alpha_i + \beta phe_{it} + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.9a]$$

$$tfp_{it} = \alpha_i + \beta health_{it} + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.9b]$$

$$tfp_{it} = \alpha_i + \beta phe_{it} + \gamma' x_{it} + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.10a]$$

$$tfp_{it} = \alpha_i + \beta health_{it} + \gamma' x_{it} + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.10b]$$

Where;

phe_{it} is PHE as a percentage of GDP, $health_{it}$ is the other variant of health measured as per capita PHE for each of the sub-Saharan African countries, β is the coefficient that measures the impact of PHE on TFP, γ is the vector of coefficients of the control variables listed earlier and x_t is the vector of the control variables (education, ICT diffusion and control of corruption). In addition, α_i captures the individual effects, that is, the heterogeneity/differences inherent in the countries in SSA and measures the fixed effect.

The 2SLS was expressed in the following models:

$$tfp_{it} = \alpha_i + \beta phe_{it} + \phi X + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.11a]$$

$$phe_{it} = \alpha_i + \phi X + \vartheta Z + v_{it} \quad [5.11b]$$

$$tfp_{it} = \alpha_i + \beta health_{it} + \phi X + \varepsilon_{it};\ i = 1, 2, ...N;\ t = 1, 2, ...T. \quad [5.12a]$$

$$health_{it} = \alpha_i + \phi X + \vartheta Z + v_{it} \quad [5.12b]$$

In Equations 5.11 and 5.12 above, tfp_{it} is the dependent variable, phe_{it} or $health_{it}$ is the endogenous variable, X is the vector of the exogenous variables (education, ICT diffusion and control of corruption), and Z is the vector of instrumental variables (maternal mortality, child mortality, HIV prevalence and TB prevalence). The models were executed in Stata using the instrumental variable regression ('ivreg') command.

5.5.5.3 *Nonlinear model*

5.5.5.3.1 Panel static threshold regression model

The nonlinear model, namely, panel threshold regression, was employed to demonstrate the point at which the effect of PHE on TFP changed from positive to negative or vice versa. The level of PHE determined this point as a ratio to GDP. Consequently, the panel threshold regression allowed for a distinction between the two coefficients corresponding to the two halves of the threshold point, indicating the change in the sign of the relationship between PHE and TFP.

The panel threshold regression, as described by Hansen (1999, 2000), Caner and Hansen (2004) and Wang (2015), was used to identify the threshold point that divides the data into two regimes. This model employed a single threshold and was specified as follows:

$$tfp_t = \alpha + \phi_1 h\exp_t(h\exp_t < \ell) + \phi_2 h\exp_t(h\exp_t \geq \ell) + \xi_t \quad (5.13)$$

$$tfp_t = \alpha + \phi_1 h\exp_t(edu_t < \ell) + \phi_2 h\exp_t(edu_t \geq \ell) + \xi_t \quad (5.14)$$

$$tfp_t = \alpha + \phi_1 h\exp_t(ict_t < \ell) + \phi_2 h\exp_t(ict_t \geq \ell) + \xi_t \quad (5.15)$$

Where

tfp_t is TFP as the dependent variable, $h\exp_t$ is PHE as a ratio of GDP and the regime-dependent variable and $\alpha_i = \alpha$ is the common intercept. Different threshold variables exist in Equations 5.13-5.15: $h\exp_t$ in 5.13, edu_t in 5.14 and ict_t in 5.15. Moreover, ℓ is the threshold value, which splits the estimation into lower regime (ϕ_1) and upper regime (ϕ_2).

A further aspect was explored whereby PHE per capita was substituted as the regime-dependent variable instead of PHE as a ratio of GDP. This substitution provided an alternative perspective by considering the per capita measurement of PHE. The model was specified as follows:

$$tfp_t = \alpha + \phi_1 health_t(h\exp_t < \ell) + \phi_2 health_t(h\exp_t \geq \ell) + \xi_t \quad (5.16)$$

$$tfp_t = \alpha + \phi_1 health_t(edu_t < \ell) + \phi_2 health_t(edu_t \geq \ell) + \xi_t \quad (5.17)$$

$$tfp_t = \alpha + \phi_1 health_t(ict_t < \ell) + \phi_2 health_t(ict_t \geq \ell) + \xi_t \quad (5.18)$$

Where;

tfp_t is TFP as the dependent variable, $health_t$ PHE per capita is the regime dependent variable, $\alpha_i = \alpha$ and is the common intercept. In addition, there are different threshold variables in Equations 5.16-5.18: $h\exp_t$ in 5.16, edu_t in 5.17 and ict_t in 5.18. Moreover, ℓ is the value of the threshold, which splits the estimation into lower regime (ϕ_1) and upper regime (ϕ_2)

The threshold parameter was estimated using the least squares approach as follows:

$$\hat{\ell} = \underset{\ell}{argmin}\, SSE_{thr}(\ell) \qquad [5.19]$$

The critical values for the threshold effect were computed using a bootstrap procedure to test the null hypothesis of no threshold effect. The procedure involved generating bootstrap samples and estimating the threshold effect for each sample. This allowed for a distribution of threshold effects under the null hypothesis. The critical values were determined by comparing the estimated threshold effect from the original sample to this bootstrap distribution to assess the significance of the threshold effect as follows.

$$F = \frac{SSE_a - SSE_b(\hat{\ell})}{\hat{\sigma}^2} = \frac{SSE_a - SSE_b(\hat{\ell})}{SSE_b(\hat{\ell}) / nT} \qquad [5.20]$$

Where;

SSE_a is the sum of the squares error of the linear model, and SSE_b is the sum of the squares error of the threshold model. The statistical significance of the F-test indicated rejection of the null hypothesis of no threshold effect, which showed that the relationship was nonlinear.

5.5.5.3.2 Panel Dynamic Threshold Regression Model

Following the work of Hansen (1999), a dynamic threshold regression model is specified as

$$tfp_{it} = \beta_i + \rho tfp_{i,t-1} + \delta(hexp_{it} < \lambda)I(hexp_{it} \geq \lambda) + \varepsilon_{it}(1) \qquad [5.21]$$

$$tfp_{it} = \beta_i + \rho tfp_{i,t-1} + \delta(edu_{it} < \lambda)I(edu_{it} \geq \lambda) + \varepsilon_{it} \qquad [5.22]$$

$$tfp_{it} = \beta_i + \rho tfp_{i,t-1} + \delta(ict_{it} < \lambda)I(ict_{it} \geq \lambda) + \varepsilon_{it} \qquad [5.23]$$

$$\delta = \frac{\hat{\delta}_1(\hat{\lambda})}{\hat{\delta}_2(\hat{\lambda})} \qquad [5.24]$$

$$H_0: \hat{\delta}_1 = \hat{\delta}_2;\ H_a: \hat{\delta}_1 \neq \hat{\delta}_2 \qquad [5.25]$$

where tfp_{it} is the dependent variable, TFP, the threshold variable could either be health expenditure ($hexp_{it}$), education (edu_{it}) or ICT variable (ict_{it}) as in equations 1, 2 or 3; lambda (λ) is the threshold value which divides the estimation into two regimes; δ_1 and δ_2 are the coefficients estimated for the lower and upper regimes respectively; I (.) is an indicator function which is 1 when the endogenous threshold is below λ and zero otherwise; Eq. 5 describes the null and alternative hypotheses for the threshold test where the rejection of the null hypothesis indicates the presence of threshold effect (nonlinearity) and therefore confirms the need to employ threshold regression.

5.6 Results

5.6.1 Preliminary results

Table 5.3 below presents the descriptive results of TFP for the countries in SSA considered in the study. The mean values of TFP for the respective countries were as follows: Angola (0.68%), Burkina Faso (0.46%), Benin (0.39%), Botswana (0.67%), Burundi (0.18%), Cameroon (0.42%), Central African Republic (0.33%), Côte d'Ivoire (0.001%), Eswatini (0.84%), Gabon (0.48%), Kenya (0.35%), Lesotho (0.37%), Mauritania (0.39%), Mauritius (1.14%), Mozambique (0.45%), Namibia (0.72%), Niger (0.25%), Nigeria (0.39%), Rwanda (0.30%), Sierra Leone (0.33%), South Africa (0.68%), Senegal (0.50%), Sudan (0.51%), Tanzania (0.33%) and Togo (0.21%). Mauritius thus had the highest TFP, while Côte d'Ivoire had the lowest amongst the countries under consideration.

The mean values of total PHE for the respective countries were as follows: Angola (3.49%), Burkina Faso (1.65%), Benin (0.71%), Botswana (3.56%), Burundi (2.06%), Cameroon (0.73%), Central African Republic (1.22%), Côte d'Ivoire (0.89%), Eswatini (3.31%), Gabon (1.43%), Kenya (0.70%), Lesotho (4.25%), Mauritania (1.16%), Mauritius (1.87%), Mozambique (1.97%), Namibia (4.34%), Niger (1.83%), Nigeria (0.68%), Rwanda (1.91%), Sierra Leone (1.54%), South Africa (3.49%), Senegal (1.31%), Sudan (1.56%), Tanzania (1.55%) and Togo (0.97%). This implied that Namibia had the highest PHE, while Nigeria had the lowest, highlighting potential reasons for the inefficiency in healthcare and service delivery in Nigeria.

Furthermore, the rates at which TFP deviated from the means for the respective countries were as follows: Angola (0.08%), Burkina Faso (0.03%), Benin (0.05%), Botswana (0.08%), Burundi (0.03%), Cameroon (0.02%), Central African Republic (0.08%), Côte d'Ivoire (0.001%), Eswatini (0.12%), Gabon (0.07%), Kenya (0.01%), Lesotho (0.03%), Mauritania (0.03%), Mauritius (0.08%), Mozambique (0.08%), Namibia (0.05%), Niger (0.01%), Nigeria (0.13%), Rwanda (0.02%), Sierra Leone (0.06%), South Africa (0.08%), Senegal (0.03%), Sudan (0.07%), Tanzania (0.03%) and Togo (0.04%). Regarding TFP volatility, Nigeria exhibited the highest volatility, while Côte d'Ivoire was the least volatile among the countries studied.

The rates at which PHE deviated from the means for the respective countries were as follows: Angola (0.75%), Burkina Faso (0.53%), Benin (0.10%), Botswana (0.45%), Burundi (0.55%), Cameroon (0.15%), Central African Republic (0.47%), Côte d'Ivoire (0.17%), Eswatini (0.65%), Gabon (0.27%), Kenya (0.26%), Lesotho (1.04%), Mauritania (0.33%), Mauritius (0.35%), Mozambique (0.93%), Namibia (0.53%), Niger (0.41%), Nigeria (0.24%), Rwanda (0.55%), Sierra Leone (0.63%), South Africa (0.75%), Senegal (0.23%), Sudan (0.42%), Tanzania (0.47%) and Togo (0.42%). This indicated that Lesotho had the highest volatility in PHE, while Benin exhibited the lowest amongst the countries considered in the study.

Moving on to skewness, the TFP skewness coefficients for the respective countries were as follows: Angola (-0.05), Cameroon (-0.99), Central African Republic (-0.70), Gabon (-0.13), Kenya (-0.002), Mauritius (-0.65), Namibia (-0.28), Nigeria (-0.28), Rwanda (-0.60), South Africa (-0.05), Senegal (-0.05) and Tanzania (-1.03). Hence, these variables were skewed to the left of the means. In addition, the TFP skewness coefficients for Burkina Faso (0.50), Benin (0.59), Botswana (0.19), Burundi (0.57), Côte d'Ivoire (0.25), Eswatini (0.32), Lesotho (0.09), Mauritania (0.63), Mozambique (0.12), Niger (0.03), Sierra Leone (0.81), Sudan (0.23) and Togo (1.94) indicated positive skewness, meaning they were skewed to the right of the mean.

The total PHE skewness coefficients for the respective countries were as follows: Angola (-0.16), Central African Republic (-0.99), Lesotho (-0.15), Mozambique (-0.09), Rwanda (-1.12) and South Africa (-0.16). These variables were skewed to the left of the means. Moreover, the PHE skewness coefficients for Burkina Faso (1.34), Benin (1.18), Botswana (0.23), Burundi (0.76), Cameroon (1.10), Côte d'Ivoire (0.79), Eswatini (0.31), Gabon (0.35), Kenya (0.37), Mauritania (0.57), Mauritius (0.74), Namibia (0.37), Niger (0.92), Nigeria (1.02), Sierra Leone (0.37), South Africa (0.05), Senegal (1.10), Tanzania (0.50) and Togo (0.09) indicated positive skewness, reflecting a right-skewed distribution.

Lastly, the kurtosis results revealed that TFP for Mauritania, Rwanda, Sierra Leone, Tanzania and Togo exhibited leptokurtic distributions with kurtosis coefficients greater than 3. However, TFP for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Niger, Nigeria, South Africa, Senegal and Sudan was observed to be platykurtic with kurtosis coefficients less than 3. This indicated a flattening of the TFP distribution.

The kurtosis results for PHE revealed that PHE for Burkina Faso, Botswana, Burundi, Cameroon, Rwanda and Sudan exhibited leptokurtic distributions with kurtosis coefficients greater than 3. However, PHE for Angola, Benin, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Sierra Leone, South Africa, Senegal, Tanzania and Togo was observed to be platykurtic with kurtosis coefficients less than 3, indicating a flattening of the PHE distribution.

In conclusion, the descriptive results of TFP and PHE amongst the countries in SSA under consideration provided valuable insights into their productivity and expenditure patterns. The results highlighted variations in TFP levels, volatility, skewness and kurtosis across different countries. However, further analysis is needed to interpret these results in the context of the study's objectives and explore the underlying factors contributing to these patterns.

Table 5.3 below presents the above descriptive statistics on TFP and PHE in various countries in SSA.

Table 5.3: Descriptive statistics of TFP and PHE in various countries in SSA

Countries in SSA	Total Factor Productivity				Public Health Expenditure			
	Mean	Std D.	Skew	Kurt	Mean	Std D.	Skew	Kurt
Angola	0.6777	0.0813	-0.0508	1.3086	3.4884	0.7526	-0.1606	1.4978
Burkina Faso	0.4572	0.0255	0.4972	2.1753	1.6466	0.5322	1.3400	4.2859
Benin	0.3859	0.0479	0.5922	2.3293	0.7083	0.1006	0.1772	2.5380
Botswana	0.6716	0.0801	0.1858	1.4984	3.5556	0.4485	0.2304	3.5231
Burundi	0.1774	0.0289	0.5708	1.7517	2.0699	0.5502	0.7630	3.2841
Cameroon	0.4208	0.0237	-0.9911	2.7232	0.7313	0.1500	1.1042	3.6600
CAR	0.3318	0.0792	-0.6990	1.8824	1.2228	0.4738	-0.0262	1.4416
Côte d'Ivoire	0.0014	0.0007	0.2538	1.2818	0.8921	0.1689	0.7899	2.4080
Eswatini	0.8378	0.1171	0.3239	1.6246	3.3083	0.6527	0.3094	2.1732
Gabon in SSA	0.4832	0.0698	-0.1310	1.9057	1.4304	0.2729	0.3454	2.4030
Kenya	0.3449	0.0106	-0.0019	1.9374	1.6968	0.2642	0.3712	1.8305
Lesotho	0.3731	0.0330	0.0881	2.3384	4.2560	1.0409	-0.1544	1.6829
Mauritania	0.3949	0.0272	0.6340	3.4262	1.1607	0.3323	0.5681	2.3921
Mauritius	1.1439	0.0835	-0.6503	2.3080	1.8724	0.3568	0.7415	2.2213
Mozambique	0.4461	0.0827	0.1197	1.4850	1.9735	0.9306	-0.0888	1.7577
Namibia	0.7190	0.0528	-0.2780	1.9879	4.3361	0.5318	0.3668	1.9552
Niger	0.2533	0.0129	0.0299	1.7082	1.8266	0.4090	0.9251	2.6252
Nigeria	0.3946	0.1343	-0.2832	1.8296	0.6757	0.2372	1.0200	2.8092
Rwanda	0.2991	0.0194	-0.5965	3.1603	1.9087	0.5516	-1.1226	3.1119
Sierra Leone	0.3335	0.0550	0.8119	3.1247	1.5402	0.6345	0.3667	2.0503
South Africa	0.6777	0.0813	-0.0508	1.3086	3.4884	0.7526	-0.1606	1.4978
Senegal	0.4970	0.0249	-0.0505	1.4706	1.3125	0.2270	0.0496	2.3562
Sudan	0.5113	0.0730	0.2349	2.2718	1.5549	0.4166	1.1026	3.6441
Tanzania	0.3323	0.0307	-1.0284	3.3576	1.5488	0.4677	0.4964	2.3655
Togo	0.2129	0.0388	1.9418	7.8443	0.9728	0.4160	0.0893	1.5899

Table 5.4 below presents the descriptive results of total maternal and child mortality in the countries in SSA under consideration in the study. The mean values of total maternal mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo were 164.39%, 407.28%, 470.17%, 206.33%, 731.11%, 653.50%, 1085.33%, 690.11%, 480.00%, 318.00%, 507.22%, 615.78%, 814.78%, 59.33%, 490.06%, 286.00%, 681.00%, 1031.83%, 543.67%, 1571.11%, 164.39%, 455.56%, 459.89%, 670.50% and 449.72%, respectively. This indicates that Mauritius had the lowest MMR, while Sierra Leone had the highest amongst the countries in SSA under investigation.

The mean values of total child mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo were 58.77%, 133.67%, 115.19%, 45.46%, 103.51%, 113.93%, 149.20%, 112.90%, 91.67%, 65.32%, 67.04%, 103.12%, 98.55%, 15.45%, 116.30%, 59.19%, 143.69%, 145.97%, 88.00%, 172.91%, 58.77%, 79.33%, 80.35%, 82.54% and 92.94%, respectively. Again, Mauritius had the lowest CMR, while Sierra Leone had the highest amongst the countries in SSA under investigation.

The rates at which total maternal mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo deviated from their mean were 29.33%, 59.33%, 38.61%, 47.83%, 149.11%, 109.82%, 148.50%, 26.72%, 44.23%, 41.80%, 141.21%, 43.31%, 20.95%, 6.18%, 160.43%, 58.99%, 99.66%, 101.11%, 300.18%, 417.57%, 29.33%, 81.17%, 122.92%, 96.98% and 40.19%, respectively. This indicates that Sierra Leone had the highest volatility in maternal mortality, while the lowest volatility was associated with Mauritius amongst the countries in SSA considered in this study.

The rates at which total child mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo deviated from their mean were 17.81%, 28.58%, 13.39%, 11.12%, 31.32%, 19.81%, 17.02%, 18.47%, 22.48%, 12.64%, 16.63%, 8.91%, 12.01%, 1.15%, 28.09%, 11.72%, 45.56%, 19.16%, 46.38%, 35.11%, 17.81%, 25.92%, 12.81%, 23.41% and 14.60%, respectively. This suggests that Rwanda had the highest volatility in child mortality, while the lowest volatility was associated with Mauritius amongst the countries in SSA under consideration in this study.

Regarding skewness, the total maternal mortality for Angola, Benin, Central African Republic, Côte d'Ivoire, Gabon, Mauritania, Namibia, Niger, South Africa, Senegal and Togo was negatively skewed, with skewness coefficients of -0.28, -0.43, -0.04, -1.17, -0.27, -1.07, -0.06, -0.29, -0.28, -0.43 and -0.28, respectively. This indicates that the variables were skewed to the left of the means. However, the total maternal mortality for Burkina Faso, Botswana, Burundi, Cameroon, Eswatini, Kenya, Lesotho, Mauritius, Mozambique, Nigeria, Rwanda, Sierra Leone, Sudan and Tanzania was positively skewed, with skewness coefficients of 0.37, 0.33, 0.39, 0.83, 0.20, 0.19, 0.12, 0.85, 0.49, 0.62, 0.90, 0.70, 0.27 and 0.25, respectively, indicating a right-skewed distribution.

For total child mortality, the skewness coefficients for Angola, Cameroon, Central African Republic, Eswatini, Gabon, Lesotho, Mauritania and South Africa were negative, with values of -0.17, -0.17, -0.49, -0.28, -0.07, -0.34 and -0.17, respectively. These variables were skewed to the left of the means. Conversely, the total child mortality for Burkina Faso, Benin, Botswana, Burundi, Côte d'Ivoire, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, Senegal, Sudan, Tanzania and Togo was positively skewed, with skewness coefficients of

0.19, 0.21, 1.02, 0.22, 0.07, 0.51, 1.68, 0.42, 0.31, 0.39, 0.60, 0.65, 0.05, 0.59, 0.31, 0.56 and 0.17, respectively, indicating a right-skewed distribution.

Regarding kurtosis, the results indicated that the total maternal mortality for Côte d'Ivoire and Mauritania exhibited leptokurtic distributions, as their kurtosis coefficients were greater than 3. In contrast, the total maternal mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Eswatini, Gabon, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo was observed to be platykurtic, with kurtosis coefficients less than 3. This suggests a flattening of the total maternal mortality distribution.

Similarly, the kurtosis results for total child mortality showed that Mauritius had a leptokurtic distribution, indicated by a kurtosis coefficient greater than 3. On the other hand, the total child mortality for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo exhibited platykurtic distributions, with kurtosis coefficients less than 3, emphasising the flattening of the total child mortality distribution.

In summary, the descriptive results presented in Table 5.4 below revealed the mean values, volatility (deviation from the mean), skewness and kurtosis of total maternal and child mortality for the various countries in SSA under investigation. These results highlighted the variations and distribution characteristics of maternal and child mortality rates amongst the countries, with Mauritius generally exhibiting the lowest rates and Sierra Leone often having the highest rates. Therefore, Mauritius consistently demonstrated the lowest maternal and child mortality rates, signifying a relatively superior overall healthcare situation. Conversely, Sierra Leone emerged as a country frequently grappling with the highest rates of maternal and child mortality, indicating significant challenges in ensuring the well-being and survival of mothers and children.

Table 5.4 below presents the above-mentioned descriptive statistics.

Table 5.4: Descriptive statistics of total maternal/child mortality in SSA

Countries in SSA	Total Maternal Mortality				Total Child Mortality			
	Mean	Std D.	Skew	Kurt	Mean	Std	Skew	Kurt
Angola	164.3889	29.3321	-0.2809	1.6418	58.7696	17.8086	-0.1689	1.2622
Burkina Faso	407.2778	59.3284	0.3656	2.0233	133.6662	28.5842	0.1845	1.6571
Benin	470.1667	38.6131	-0.4253	1.9881	115.1932	13.3898	0.2063	1.9129
Botswana	206.3333	47.8269	0.3280	1.5956	45.4586	11.1166	1.0150	2.5970
Burundi	731.1111	149.1126	0.3892	1.8779	103.5107	31.3281	0.2220	1.6868
Cameroon	653.5000	109.8166	0.8301	2.4279	113.9305	19.8147	-0.1707	1.8111
CAR	1085.333	148.4952	-0.0407	1.7100	149.1969	17.0177	-0.4866	1.9198
Cote D'Ivoire	690.1111	26.72274	-1.7148	4.7707	112.9004	18.4665	0.0734	1.7129
Eswatini	480.0000	44.2333	0.2012	1.2686	91.6659	22.4878	-0.2812	1.4063
Gabon	318.0000	41.7950	-0.2707	1.7320	65.3160	12.6357	-0.0793	1.7126
Kenya	507.2222	141.2097	0.1913	1.4288	67.0426	16.9392	0.5080	1.9115
Lesotho	615.7778	43.3054	0.1160	1.7415	103.1244	8.9137	-0.2015	1.4139
Mauritania	814.7778	20.9469	-1.0704	3.0449	98.5512	12.0103	-0.3432	1.7103
Mauritius	59.3333	6.1835	0.8503	2.5737	15.4468	1.1490	1.6847	5.1713
Mozambique	490.0556	160.4349	0.4872	1.9953	116.3029	28.0907	0.4239	1.9893
Namibia	286.0000	58.9985	-0.0577	1.4898	59.1990	11.7191	0.3121	1.4002
Niger	681.0000	99.6588	-0.2913	1.7478	143.6887	45.5625	0.3986	1.8222
Nigeria	1031.8330	101.1134	0.6224	1.8509	145.9676	19.1638	0.5964	2.0618
Rwanda	543.6667	300.1866	0.8980	2.4184	88.0012	46.3809	0.6524	2.1051
Sierra Leone	1571.1110	417.5684	0.6982	2.3977	172.9192	35.1127	0.0458	1.7082
South Africa	164.3889	29.3321	-0.2809	1.6418	58.7696	17.8086	-0.1689	1.2622
Senegal	455.5556	81.1696	-0.4370	1.7029	79.3268	25.9165	0.5921	2.0574
Sudan	459.8889	122.9232	0.2703	1.7312	80.3539	12.8051	0.3095	1.9225
Tanzania	670.5000	96.9768	0.2543	2.1013	82.5390	23.4124	0.5586	2.1253
Togo	449.7222	40.1861	-0.2843	1.3048	92.9432	14.5994	0.1669	1.8234

Table 5.5 below presents the descriptive statistics of total HIV prevalence and education in the countries in SSA examined in this study. The mean values of total HIV prevalence for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo were 17.18%, 1.32%, 1.18%, 23.72%, 1.97%, 4.31%, 5.31%, 4.16%, 26.47%, 4.23%, 6.27%, 24.13%, 0.38%, 1.11%, 11.21%, 12.88%, 0.46%, 1.31%, 3.41%, 1.59%, 17.18%, 0.58%, 0.20%, 5.36% and 2.88%, respectively. Therefore, it can be concluded that Sudan had the lowest HIV prevalence, while Eswatini had the highest amongst the countries in SSA under investigation.

The mean values of education for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo were 2.44%, 1.16%, 1.58%, 2.68%, 1.29%, 1.83%, 1.46%, 1.53%, 1.72%, 2.43%, 2.13%, 2.03%, 1.63%, 2.45%, 1.18%, 2.12%, 1.16%, 1.71%, 1.57%, 1.48%, 2.44%, 1.44%, 1.50%, 1.59% and 1.76%, respectively. Hence, Burkina Faso and Niger had the lowest education levels, while Botswana had the highest amongst the countries in SSA under investigation.

The analysis of deviation from the mean revealed that total HIV prevalence for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo deviated by 2.08%, 0.38%, 0.11%, 1.37%, 0.70%, 0.46%, 1.03%, 1.11%, 2.20%, 0.31%, 1.21%, 0.34%, 0.11%, 0.29%, 1.27%, 0.53%, 0.16%, 0.03%, 0.48%, 0.02%, 2.08%, 0.11%, 0.00%, 0.39%, and 0.32%, respectively. Thus, Eswatini exhibited the highest volatility in HIV prevalence, while Sudan had the lowest volatility amongst the countries in SSA under consideration.

The deviation from the mean in education for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo was found to be 0.23%, 0.06%, 0.14%, 0.13%, 0.06%, 0.05%, 0.04%, 0.07%, 0.15%, 0.21%, 0.12%, 0.16%, 0.10%, 0.10%, 0.03%, 0.07%, 0.03%, 0.15%, 0.15%, 0.08%, 0.23%, 0.08%, 0.06%, 0.06% and 0.03%, respectively. Therefore, Angola and South Africa had the highest volatility in education. In contrast, the lowest volatility was associated with Togo amongst the countries in SSA under consideration.

The skewness analysis revealed that total HIV prevalence for Angola, Cameroon, Eswatini, Gabon, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Sierra Leone, South Africa and Senegal was negatively skewed, with skewness coefficients of -0.80, -0.67, -0.56, -0.35, -0.60, -0.34, -1.42, -0.90, -0.05, -0.43, -3.88, and -0.34, respectively. Thus, the variables were skewed to the left of the means. It was also found that total HIV prevalence for Burkina Faso, Benin, Botswana, Burundi, Central African Republic, Côte d'Ivoire, Kenya, Niger, Nigeria, Rwanda and Tanzania was positively skewed, with skewness coefficients of 0.54, 0.34, 0.22, 0.83, 0.21, 0.35, 0.85, 0.14, 2.48, 0.84 and 1.08, respectively, indicating a right-skewed distribution.

Education in Botswana, Cameroon, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Sudan, and Togo was negatively skewed, with skewness coefficients of -0.09, -0.53, -0.07, -0.18, -0.02, -0.05, -0.14, -0.16, -0.39 and -0.62, respectively, demonstrating a left-skewed distribution. However, education in Angola, Burkina Faso, Benin, Burundi, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Mauritania, Niger, Rwanda, Sierra Leone, South Africa, Senegal, and Tanzania was positively skewed, with skewness coefficients of 0.03, 0.21, 0.62, 0.23, 0.25, 0.38, 0.64, 0.21, 0.07, 0.17, 0.26, 0.03, 0.03, 0.16, and 0.21, respectively, indicating a right-skewed distribution.

The kurtosis results revealed that total HIV prevalence for Lesotho, Mauritius, Nigeria and Sierra Leone was leptokurtic, with kurtosis coefficients greater than 3. This indicated that these countries had distributions with heavy tails and a higher concentration of data around the mean. Conversely, total HIV prevalence for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Mauritania, Mozambique, Namibia, Niger, Rwanda, South Africa, Senegal, Sudan, Tanzania and Togo was observed to be platykurtic, with kurtosis coefficients less than 3. This suggested that the distributions for these countries were flatter and more dispersed than a normal distribution.

The kurtosis of education for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo was found to be platykurtic, with kurtosis coefficients less than 3. This indicated that education distributions for all the countries under consideration in the study were relatively flatter and more dispersed than a normal distribution.

These results facilitated an understanding of the HIV prevalence and education landscape in the countries in SSA. Variations in mean values indicated that some countries had higher HIV prevalence rates or better education outcomes than others. Deviations from the mean indicated that certain countries experienced greater volatility in HIV prevalence or education while others maintained more stable levels. Negative skewness indicated that some countries had values below the average level of HIV prevalence or education. Positive skewness indicated that certain countries had values above the average HIV prevalence or education level. The kurtosis coefficient helped in understanding whether the prevalence of HIV and education levels was concentrated around the mean or spread out across a wider range. It led to an understanding of whether most countries had similar rates of HIV prevalence and education levels or if there was significant variation among them.

Table 5.5 below presents the above-mentioned descriptive statistics of total HIV prevalence and education in countries in SSA.

Table 5.5: Descriptive statistics of total HIV prevalence and education in SSA

Countries in SSA	Total HIV Prevalence				Education			
	Mean	Std D.	Skew	Kurt	Mean	Std D.	Skew	Kurt
Angola	17.1778	2.0837	-0.7969	2.5436	2.4411	0.2290	0.0301	1.7555
Burkina Faso	1.3222	0.3750	0.5375	2.2720	1.1565	0.0589	0.2070	1.8597
Benin	1.1833	0.1098	0.3352	1.9899	1.5755	0.1380	0.6202	2.0528
Botswana	23.7222	1.3735	0.2219	2.0513	2.6824	0.1268	-0.0882	1.9650
Burundi	1.9667	0.7021	0.8298	2.5833	1.2898	0.0569	0.2343	1.8743
Cameroon	4.3056	0.4595	-0.6768	2.1735	1.8338	0.0515	-0.5396	1.8406
CAR	5.3111	1.0261	0.2195	1.9295	1.4625	0.0444	0.2462	1.8813
Cote D'Ivoire	4.1611	1.1089	0.3523	1.9599	1.5264	0.0714	0.3750	1.9590
Eswatini	26.4722	2.1983	-0.5597	2.0585	1.7179	0.1535	0.6377	2.2486
Gabon	4.2333	0.3049	-0.3518	1.7377	2.4302	0.2081	0.2102	1.8252
Kenya	6.2667	1.2127	0.8465	2.5961	2.1251	0.1172	-0.0734	1.7583
Lesotho	24.1333	0.3378	-0.5977	3.1556	2.0278	0.1599	-0.1840	1.8679
Mauritania	0.3778	0.1114	-0.3380	1.8106	1.6332	0.0953	0.0703	1.7446
Mauritius	1.1111	0.2948	-1.4153	3.6163	2.4471	0.1033	-0.0221	1.7255
Mozambique	11.2111	1.2741	-0.8963	2.7608	1.1746	0.0269	-0.0482	1.9180
Namibia	12.8833	0.5339	-0.0504	2.1289	2.1189	0.0682	-0.1390	1.9250
Niger	0.4611	0.1614	0.1399	1.7401	1.1620	0.0293	0.1661	1.8432
Nigeria	1.3111	0.0323	2.4749	7.1250	1.7045	0.1472	-0.1633	1.7848
Rwanda	3.4056	0.4795	0.8441	2.6209	1.5701	0.1538	0.2648	1.8036
Sierra Leone	1.5944	0.0236	-3.8806	16.0588	1.4849	0.0795	0.0313	1.7921
South Africa	17.1778	2.0837	-0.7969	2.5436	2.4411	0.2290	0.0301	1.7555
Senegal	0.5778	0.1114	-0.3380	1.8106	1.4375	0.0834	0.1629	1.8373
Sudan	0.2000	0.0000	NA	NA	1.5025	0.0606	-0.3848	2.1656
Tanzania	5.3611	0.3867	1.0827	2.7336	1.5868	0.0595	0.2100	1.8624
Togo	2.8833	0.3240	0.1109	1.8839	1.7568	0.0256	-0.6195	2.3869

Table 5.6 below presents the descriptive statistics of control of corruption in the countries under study in SSA. The table shows that the mean values for controlling corruption varied across the countries. For Angola, Botswana, Lesotho, Mauritius, Namibia, Rwanda and South Africa, the mean values were 0.20%, 0.93%, 0.03%, 0.37%, 0.31%, 0.14% and 0.20%, respectively. This indicates that corruption was positively controlled in these countries. Conversely, in Burkina Faso, Benin, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Mauritania, Mozambique, Niger, Nigeria, Sierra Leone, Senegal, Sudan, Tanzania and Togo, the mean values were -0.25%, -0.59%, -1.14%, -1.12%, -1.15%, -0.86%, -0.33%, -0.81%, -0.97%, -0.63%, -0.60%, -0.73%, -1.15%, -0.86%, -0.20%, -1.31%, -0.58% and -0.89%, respectively. This suggested that corruption had a negative impact on these countries, indicating that their control mechanisms were not yielding positive results.

An examination of the deviations from the mean values reveals that control of corruption for Angola, Burkina Faso, Benin, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo deviated by 0.23%, 0.16%, 0.14%, 0.14%, 0.21%, 0.08%, 0.13%, 0.29%, 0.11%, 0.15%, 0.07%, 0.12%, 0.26%, 0.12%, 0.14%, 0.12%, 0.12%, 0.14%, 0.49%, 0.14%, 0.23%, 0.24%, 0.19%, 0.17% and 0.13%, respectively. This indicated the extent of volatility in controlling corruption. Rwanda had the highest volatility, while Kenya had the lowest among the countries in SSA under consideration.

The skewness results indicated the distribution pattern of control of corruption. In Burkina Faso, Benin, Eswatini, Gabon, Mozambique, Niger, Nigeria, Rwanda and Senegal, it was negatively skewed with skewness coefficients of -0.06, -0.58, -0.22, -0.44, -0.69 and -0.36, respectively. This meant that the variables were skewed to the left of the means. In contrast, control of corruption in Angola, Botswana, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Kenya, Lesotho, Mauritania, Mauritius, Namibia, Sierra Leone, South Africa, Sudan, Tanzania and Togo was positively skewed with skewness coefficients of 0.41, 0.11, 0.16, 0.25, 0.18, 0.22, 0.002, 0.25, 1.37, 0.40, 1.00, 1.31, 0.41, 0.77, 0.26 and 0.49, respectively. This meant that the distribution of control of corruption variables was skewed to the right of the mean.

The kurtosis results provided insights into whether control of corruption was concentrated around the mean or spread out across a wider range. Botswana, Mauritania, Namibia, Sierra Leone, South Africa, Senegal, Sudan, Tanzania and Togo exhibited leptokurtic distributions with kurtosis coefficients greater than 3. This indicated concentration of control of corruption values around the mean for these countries. Conversely, Angola, Burkina Faso, Benin, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eswatini, Gabon, Kenya, Lesotho, Mauritius, Mozambique, Niger, Nigeria, Rwanda and Sierra Leone displayed platykurtic distributions with kurtosis coefficients less than 3. This suggested a wider spread of control of corruption values.

In conclusion, the descriptive statistics for controlling corruption in the SSA countries under investigation revealed variations in mean values, deviations from the mean, skewness, and kurtosis. These results provided insights into the distribution and characteristics of control of corruption, highlighting countries with positive or negative control, volatility and different distribution patterns. Policymakers could utilise these findings to assess the effectiveness of corruption control mechanisms and identify countries with successful approaches or areas that require improvement. For example, Botswana demonstrated effective control of corruption, while Sudan faced significant challenges in combating it within its economy.

Table 5.6 below presents the above-mentioned descriptive statistics of control of corruption in SSA countries.

Table 5.6: Descriptive statistics of control of corruption in SSA

Countries in SSA	Control of Corruption			
	Mean	Std D.	Skew	Kurt
Angola	0.1947	0.2303	0.4119	1.9714
Burkina Faso	-0.2476	0.1626	-0.0554	1.8455
Benin	-0.5940	0.1345	-0.5770	2.4460
Botswana	0.9331	0.1368	0.1096	3.0310
Burundi	-1.1407	0.2049	0.1600	2.0280
Cameroon	-1.1210	0.0802	0.2493	2.0176
CAR	-1.1500	0.1284	0.1833	2.2744
Côte D'Ivoire	-0.8627	0.2932	0.2241	1.5272
Eswatini	-0.3307	0.1105	-0.2237	1.5323
Gabon	-0.8066	0.1502	-0.4385	2.0265
Kenya	-0.9686	0.0739	0.0021	1.8823
Lesotho	0.0338	0.1221	0.2494	2.1409
Mauritania	-0.6349	0.2562	1.3719	4.1993
Mauritius	0.3648	0.1163	0.3960	1.8936
Mozambique	-0.5976	0.1358	-0.6902	2.3913
Namibia	0.3144	0.1207	1.0032	4.2887
Niger	-0.7254	0.1203	-0.8870	2.6205
Nigeria	-1.1516	0.1382	-0.3520	2.5718
Rwanda	0.1434	0.4921	-0.3155	1.5577
Sierra Leone	-0.8627	0.1424	1.3102	4.4234
South Africa	0.1947	0.2303	0.4119	1.9714
Senegal	-0.2000	0.2422	-0.3563	1.8414
Sudan	-1.3094	0.1853	0.7716	2.8640
Tanzania	-0.5775	0.1691	0.2576	2.1370
Togo	-0.8932	0.1246	0.4899	1.7104

5.6.2 Main results

5.6.2.1 Impact of health factors on TFP

Table 5.7 below presents the results of the analysis of the relationship between various independent variables and the dependent variable, TFP, measured at current PPP. The analysis compares the fixed effect model, random effect model and Driscoll-Kraay standard errors.

Overall, the table provides information on the coefficients, standard errors and significance tests for the fixed effect, random effect and Driscoll-Kraay models, allowing for the evaluation of the relationship between the independent and dependent variables.

The results showed that an increase in PHE was associated with a positive impact on TFP. The random effect model indicated a statistically significant relationship, meaning that the increase in PHE was likely to contribute to higher TFP levels. In addition, the results showed that higher

MMRs have a negative impact on TFP. The effect was statistically significant, indicating that reducing maternal mortality could improve TFP. The findings also showed that child mortality had a negative effect on TFP. The significance of this effect implied that reducing child mortality would lead to improvements in TFP.

The results in the table indicated that higher life expectancy was associated with improvements in TFP. The effect was statistically significant, meaning that longer life expectancy would contribute positively to TFP levels. Moreover, the results revealed that higher HIV prevalence had a negative impact on TFP. Therefore, reducing HIV prevalence could potentially lead to improvements in TFP levels. However, the constant term in the models represented the baseline level of TFP that was not directly influenced by the independent variables.

The statistical measures provided in the table helped to assess the reliability and significance of the results. The F test indicated that the overall regression models were statistically significant. The F and Hausman statistics suggested that the random effect model should be preferred over the fixed effect model, indicating a better explanation of the relationship between the independent variables and TFP, the dependent variable. In other words, the statistical measures in the table, including the F test, F statistic, and Hausman statistic, established the overall statistical significance of the regression models and indicated that the random effect model was superior to the fixed effect model in explaining the relationship between the independent variables and TFP, the dependent variable.

The results in the table indicate several important relationships between the independent variables and TFP. Increasing PHE is associated with higher TFP levels, suggesting that allocating more resources to public health initiatives can positively impact productivity. The findings suggest that reducing maternal and child mortality rates could positively affect TFP. This implies that efforts to improve healthcare and reduce mortality rates among mothers and children can contribute to increased productivity. The results indicate that improving life expectancy is also associated with higher TFP levels. This suggests that advancements in healthcare and factors contributing to longer life expectancy can positively influence productivity. However, higher HIV prevalence is associated with lower TFP levels, indicating a negative impact on productivity.

Table 5.7 below presents the results of the analysis of the impact of the various health factors on TFP.

Table 5.7: Impact of health factors on TFP

Dependent Variable: Total Factor Productivity			
Variables	Fixed effect	Random effect	Driscoll-Kraay Robust Standard Error
Public Health expenditure	0.133***(0.0179)	0.132*** (0.0182)	0.005 (0.0018)
Education	0.023 (0.038)	0.065*(0.034)	0.023(0.095)
ICT	-0.0006 (0.0004)	-0.0008**(0.0004)	-0.0006*(0.0008)
Control of corruption	0.082*** (0.015)	0.092***(0.015)	0.082***(0.028)
Constant	0.476*** (0.067)	0.408***(0.065)	0.476**(0.169)
F test	112.98***		
F stat	7.05***		28.17***
Wald		43.79***	
Hausman statistic		3.43*	
Units	25	25	25
Time	21	21	21
NOBS	525	525	525

Note: Table 5.7 above presents the results for the fixed effect and random effect models. The two models were evaluated using the Hausman test. The Hausman test was constructed with a fixed effect as consistent under the null hypothesis. The statistical significance of the Hausman test indicated that the random effect was the preferred model, while its insignificance indicated that the fixed effect model was preferred. The standard errors associated with the coefficients are in brackets. Robust standard errors are in brackets in column 3. ***, **, and * represent 1%, 5%, and 10% statistical significance, respectively. Units are the number of units or entities included in the analysis. NOBS represents the total number of observations available for the analysis.

5.6.2.2 *Impact of PHE and non-health factors on TFP*

Table 5.8 below presents the regression analysis results on the relationship between PHE and various non-health independent variables, and the dependent variable, TFP, which represents the overall productivity level in the given context. Moreover, the table includes three different models: the fixed effect model, the random effect model and the Driscoll-Kraay model. These models are commonly used in econometrics to analyse panel data and account for potential biases and variations.

The table offers valuable insights into the relationships between PHE and non-health independent variables, and TFP. The results suggested that PHE and control of corruption had positive and statistically significant impacts on TFP. This implied that higher investment in public health and effective control of corruption were associated with increased productivity. However, the effects of education and ICT on TFP were found to be statistically insignificant. This meant there was no conclusive evidence to suggest that education or ICT significantly impacted TFP in the study context.

Table 5.8: Impact of PHE and non-health factors on TFP

Dependent Variable: Total Factor Productivity			
Variables	Fixed effect	Random effect	Driscoll-Kraay Robust Standard Error
PHE	0.133***(0.0179)	0.132*** (0.0182)	0.005 (0.0018)
Education	0.023 (0.038)	0.065*(0.034)	0.023(0.095)
ICT	-0.0006 (0.0004)	-0.0008**(0.0004)	-0.0006*(0.0008)
Control of corruption	0.082*** (0.015)	0.092***(0.015)	0.082***(0.028)
Constant	0.476*** (0.067)	0.408***(0.065)	0.476**(0.169)
F test	112.98***		
F stat	7.05***		28.17***
Wald		43.79***	
Hausman statistic		3.43*	
Units	25	25	25
Time	21	21	21
NOBS	525	525	525

Note: The table presents results for the fixed effect and random effect models. The two models are evaluated using the Hausman test. The Hausman test is constructed with a fixed effect as consistent under the null hypothesis. The statistical significance of the Hausman test indicates that the random effect is the preferred model, while its insignificance indicates that the fixed effect model is preferred. The standard errors associated with the coefficients are in brackets. Robust standard errors are in brackets in column 3. ***, **, and * represent 1%, 5% and 10% statistical significance, respectively. NOBS is the number of observations in the panel. "Units" represents the total number of entities analysed. "Time" represents the number of periods included in the analysis.

Table 5.9: P2SLS estimation of impact of endogenous variables with no control variables

Model characteristics	Health expenditure (%)	Health expenditure per capita
Constant	0.246*** (0.0235)	-0.147*** (0.0405)
PHE	0.117*** (0.0113)	0.159*** (0.0102)
F-statistic	108.79***	243.07***
Endogeneity test		
‘e’	-0.1168*** (0.0148)	-0.0007*** (0.0001)
Time	21	21
Units	25	25
NOBS	525	525

Note: The coefficients reported in the table represent the estimated effects of the endogenous variables on PHE, with statistical significance denoted by ***, **, and *, indicating 1%, 5%, and 10% significance levels, respectively. NOBS is the number of observations in the panel. "Units" represents the total number of entities analysed. "Time" represents the number of periods included in the analysis.

5.6.2.4 P2SLS estimation of the impact of endogenous variables with control variables

Table 5.10 below presents the results of the P2SLS estimation conducted to examine the relationship between the endogenous variables.

A change in PHE and health expenditure per capita would increase TFP in SSA. Similarly, education expenditure significantly positively impacts TFP in this region. In this study, ICT had a significant positive impact on TFP in SSA. Controlling corruption also had positive impacts on TFP. The measurement of corruption in this study is control of corruption. Therefore, an increase in control of corruption should enhance TFP growth. The panel two-stage least squares estimation result aligns with our fixed and random effect that health expenditure and its other variants and non-health factors will significantly impact TFP in SSA.

Table 5.10: P2SLS estimation of endogenous variables with control variables

Endogenous Variables	**Health expenditure (%)**	**Health expenditure per capita**
Constant	0.256*** (0.0490)	0.191*** (0.0678)
PHE.	0.0156 (0.0133)	0.0414* (0.0238)
Education	0.136*** (0.0229)	0.0966*** (0.0325)
ICT	0.00195*** (0.000680)	0.00129* (0.000778)
Control of Corruption	0.124*** (0.0192)	0.112*** (0.0208)
F-stat	379.92***	411.51***
Endogeneity test		
‘e’	-0.0509*** (0.0144)	-0.0002* (0.0001)
Time	21	21
Units	25	25
NOBS	525	525

Note: ***, ** and * represent 1%, 5% and 10% statistical significance, respectively. NOBS is the number of observations in the panel. "Units" represents the total number of entities analysed. "Time" represents the number of periods in the analysis.

5.6.2.5 Panel Threshold Regression Analysis

Table 5.11 helps to assess the impact of the threshold variables, PHE (%), Education and ICT, on the regime-dependent variable, which was PHE in this case. By considering different regimes and their corresponding coefficients, the table provides insights into how the relationship between the threshold variables and PHE might change based on the specified threshold values. The F-test statistics assessed the overall significance of the regression models for each regime.

Overall, the assessment aimed to uncover nonlinear relationships, identify threshold points, and understand how the impact of the threshold variables on the regime-dependent variable may change across different regimes. This information enhances understanding of the complex relationship between the variables under investigation and provides insights into potential nonlinearities or regime-specific effects.

The assessment helped me to understand how different factors (PHE [%], Education and ICT) affected a particular outcome (PHE) in different situations. By dividing the data into different groups based on these points, the change in the relationship between the factors and the outcome in each group could be seen. The assessment also determined whether the models used to analyse the data were meaningful overall and provided a good explanation for the outcome in each group.

Table 5.11: Panel threshold regression (PHE as the regime-dependent variable)

Model characteristics	**PHE (%)**	**Education**	**ICT**
Constant	0.4588*** (0.0134)	0.4649*** (0.0124)	0.4842*** (0.0118)
Regime 1	0.1897*** (0.0383)	0.0177** (0.00728)	0.0013 (0.0063)
Regime 2	-0.0109* (0.0059)	-0.0207*** (0.0071)	-0.0197*** (0.0061)
Threshold value	3.56	2.56	21.00
F-test	189.87***	163.45***	176.96***
Time	26	26	26
Units	25	25	25
NOBS	650	650	650

Note: ***, ** and * represent 1%, 5% and 10% statistical significance, respectively. NOBS is the number of observations in the panel. "Units" represents the total number of entities analysed. "Time" represents the number of periods included in the analysis.

5.6.2.6 Additional Result

Table 5.12 presents the results on the threshold relationship between PHE and TFP growth via a dynamic panel threshold regression analysis. With the basis provided by the model, we estimate the threshold level of PHE that maximises TFP as 1.1%. We also unveil the threshold relationship between TFP and some non-health variables like education and ICT at 2.07% and 12%, respectively. Given the results provided by the dynamic threshold analysis, the static panel threshold regression was more suitable for this study because the target threshold variable (PHE) performed better via the static threshold regression than the dynamic one.

Table 5.12: Dynamic Panel Threshold

	TFP-Health	TFP-Education	TFP-ICT
Constant	0.2631	-4.8794***	0.0900
	(0.2079)	(0.5192)	(0.1301)
Regime 1 ($\hat{\delta}_1$)	0.4582***	-1.3030***	-0.0138*
	(0.1489)	(0.1606)	(0.0080)
Regime 2 ($\hat{\delta}_2$)	-0.5008***	2.3949***	0.0110
	(0.1548)	(0.2651)	(0.0085)
Threshold ($\hat{\lambda}$)	1.1081***	2.0778***	12.5603***
	(0.1653)	(0.1589)	(3.1251)
Threshold effect?	Yes	Yes	Yes

5.6.2.7 Mean of PHE and thresholds

Table 5.13 below provides information on the mean values of PHE and the thresholds for different countries. It reveals that most countries have a PHE mean below the specified threshold, although Lesotho and Namibia's mean met or exceeded the threshold.

Table 5.13: Mean of PHE and thresholds

Country	**PHE Mean**	**Threshold of PHE per capita (highest range in the logarithm of expenditure). Actual PHE in brackets)**	**Remarks**
Angola	3.4884	3.56 (35%)	Below threshold
Burkina Faso	1.6466	3.56 (35%)	Below threshold
Benin	0.7083	3.56 (35%)	Below threshold
Botswana	3.5556	3.56 (35%)	Below threshold
Burundi	2.0699	3.56 (35%)	Below threshold
Cameroon	0.7313	3.56 (35%)	Below threshold
Central African Republic	1.2228	3.56 (35%)	Below threshold
Côte d'Ivoire	0.8921	3.56 (35%)	Below threshold
Eswatini	3.3083	3.56 (35%)	Below threshold
Gabon	1.4304	3.56 (35%)	Below threshold
Kenya	1.6968	3.56 (35%)	Below threshold
Lesotho	4.2560	3.56 (35%)	Threshold met
Mauritania	1.1607	3.56 (35%)	Below threshold
Mauritius	1.8724	3.56 (35%)	Below threshold
Mozambique	1.9735	3.56 (35%)	Below threshold
Namibia	4.3361	3.56 (35%)	Threshold met
Niger	1.8266	3.56 (35%)	Below threshold
Nigeria	0.6757	3.56 (35%)	Below threshold
Rwanda	1.9087	3.56 (35%)	Below threshold
Sierra Leone	1.5402	3.56 (35%)	Below threshold
South Africa	3.4884	3.56 (35%)	Below threshold
Senegal	1.3125	3.56 (35%)	Below threshold
Sudan	1.5549	3.56 (35%)	Below threshold
Tanzania	1.5488	3.56 (35%)	Below threshold
Togo	0.9728	3.56 (35%)	Below threshold

5.6.3 Discussion of Results

This third analysis of the study was motivated by previous PHE analyses on health outcomes that did not convey linear or nonlinear information on the relationship between PHE and TFP. In the current study, TFP was measured following the definition specified and directly available in the Penn World Table 10.0. Moreover, this chapter highlighted how the study differed from other studies and tested the hypothesis that PHE and health outcomes did not affect TFP in SSA. The study also examined whether there was a threshold relationship between PHE and TFP in SSA, on the one hand, and between non-health factors and TFP in SSA, on the other.

The chapter presented the effect of PHE and health outcomes on TFP and the controlled effect of PHE on TFP (Tables 5.8-5.11). It also presented the results of the controlled threshold analysis on the effect of PHE on TFP and those of the threshold analysis of non-health factors, ICT, and education on TFP (Table 5.12).

5.6.3.1 Linear results

To avoid the problem of multicollinearity and over-fitting in the model, the impacts of health variables were considered separately from PHE and other non-health variables. The results revealed that a 1% change in PHE would have resulted in a 0.011% increase in TFP in SSA in the health-TFP model, while in the controlled health-TFP model, a 1% change in PHE would have led to a 0.132% increase in TFP. Both results were similar, but the controlled health-TFP model was preferred because the elasticity was higher, possibly because of the health indices' interaction with other macroeconomic factors.

This analysis aimed to validate the inclusion of health in the TFP model since other macroeconomic variables had been recognised as determinants of TFP in SSA. The results revealed that a change in PHE would increase TFP in SSA and thus confirmed Raiespour and Pajooyan's (2013) work in Iran and that of Saha (2013b) in India. In terms of the roles played by other health factors or health outcomes, MMR, CMR, and HIV prevalence negatively impacted TFP in SSA. This was in accordance with the a priori expectation that an increase in MMR and HIV prevalence would reduce TFP and also corroborated the study by Cole and Neumayer (2006).

In contrast, based on the research results, the LEB rate was negatively related to TFP. Although the fixed and random effect models are known for their ability to account for cross-sectional dependence, the Driscoll-Kraay model circumvents the deficiencies of these models. Thus, the Driscoll-Kraay results corroborated the fixed and random results in Columns 1 and 2, and the results were tallied with the random results in terms of significance and direction.

Amongst other non-health factors, education and control of corruption positively impacted TFP, while ICT had a significant negative impact on TFP in SSA. In addition, education expenditure significantly positively impacted TFP in this region. This result was in line with those of Alvi and Hamed (2014), Fillip (2016), Timuno (2017) and Olomola and Osinubi (2018).

The same direction of the relationship (positive) was expected for education as well as ICT as a contemporary education tool, given the assertion traceable to Sharpe *et al.* (1998) that in a steady macroeconomic environment, strong public commitment to education enhances productivity in the economy. Aker and Mbiti (2010) identify the importance of mobile phones in an economy that can improve access to and use of information and coordination amongst agents and increase market efficiency.

In the study, ICT had a significant positive impact on TFP in SSA. This followed the a priori expectation and the extant literature that posited that mobile phones would increase efficiency (Lehr & Lichtenberg, 1998; Kuusi, 2015; Pieri, Vecchi & Venturini, 2017), although Stiroh (2002) found no significant positive relationship between ICT and TFP in 20 US manufacturing industries. Furthermore, in the current study, control of corruption was found to have a positive impact on TFP. Thus, in line with Hsiao *et al.* (2019) and the a priori expectation, there was a need to account for the role of corruption in preventing access to and delivering quality healthcare services due to mismanagement of PHE. Therefore, an increase in control of corruption would enhance TFP growth.

5.6.3.2 Nonlinear results

The nonlinear impact of PHE on TFP was presented in Table 5.11, the baseline result on which others were built. To recap, there were two coefficients for the impact of PHE on TFP: linear and nonlinear. The linear coefficient was expected to be positive. In contrast, the nonlinear coefficient was expected to be negative if the relationship was truly an inverted U-shape, such that there was a threshold point after which the relationship turned positive to negative. Based on the model, the threshold point of PHE that maximised TFP was estimated at 3.56%. This indicated that a 35% increase in PHE would have to be pursued for improved TFP growth. In addition, a threshold relationship between TFP and some non-health variables like education and ICT was estimated at 2.56% and 21%, respectively. By implication, this meant that SSA countries would have to spend a minimum of 4% of their GNP on the health sector for PHE to have a meaningful impact on TFP. The increase in PHE needs to reach an optimum level before having an incremental impact on TFP, and beyond the optimum point, it could translate to a decreasing impact. Policymakers should, therefore, refrain from assuming that an increment in spending results in an equal increase in productivity. In other words, education and ICT development should also be increased in line with certain threshold points.

Table 5.13presented average PHE in the countries in SSA under study for comparison to give an idea of current and expected spending. The results showed that average PHE was 1.967%, far below the threshold level of 4%. Funding of the health sector in countries like Nigeria, Benin, Cameroon, Côte d'Ivoire, and Togo would have to be increased for PHE to have a reasonable effect on health outcomes and TFP.

The study's strengths lay in the linear analysis being estimated via the fixed and random effect models, given their ability to account for cross-sectional dependence. The Driscoll and Kraay model was incorporated to address the deficiencies in these models. The analysis was re-estimated via the panel two-stage least square model for robustness checks. However, a major limitation of the study was the unavailability of PHE and TFP data for some SSA countries. A complete set of data on PHE and TFP for all the SSA countries would have improved the robustness and generalisability of the results.

The analysis, nevertheless, provided valuable insights into the relationship between PHE, health outcomes and TFP in SSA. The results indicated that increasing PHE positively impacted TFP, confirming the importance of investing in the health sector. However, the analysis also revealed the presence of threshold effects, suggesting that there are optimal levels of PHE, education, and ICT expenditure that maximise TFP growth.

Policymakers in SSA countries should consider increasing their investment in the health sector, aiming to reach a minimum threshold of 4% of GNP for PHE. Furthermore, efforts should be made to improve education and ICT development, aligning with the identified threshold levels to enhance regional productivity.

The research results were based on the available data and the specific methodologies. Further research and data collection efforts are needed to refine and validate these results. Nonetheless, the study contributes to the existing literature on the relationship between PHE, health outcomes and TFP, providing valuable insights for policymakers and researchers interested in promoting sustainable economic growth and improved healthcare in SSA.

5.7 Chapter Summary

The study aimed to investigate PHE's linear and nonlinear effects on TFP growth in 25 selected sub-Saharan African countries from 2000 to 2020. In addition, it tested the hypothesis that PHE had no significant effect on TFP in the countries under study and examined whether a threshold relationship existed between PHE in the context of data gathered on SSA.

While previous studies explored the determinants of TFP both within and outside of SSA, most focused on non-health factors. There is limited research that incorporates health as a determinant of TFP, primarily conducted in countries such as Iran, India and Canada. To the best of the researcher's knowledge, the current study was the first to construct a predictive TFP model based exclusively on SSA data that incorporated the role of health.

The study provided empirical evidence to validate the existence of a threshold relationship between PHE and TFP in SSA. A panel threshold regression methodology was followed to estimate the threshold level of PHE required for sustainable TFP growth. The analysis revealed that a change in the percentage of GNP allocated to PHE and PHE per capita positively impacted TFP in SSA.

The threshold analysis demonstrated the importance of increasing PHE to at least 4% of GDP for sustainable TFP growth. In addition, threshold relationships between TFP and other non-health variables, specifically education and ICT, were identified at 2.56% and 21%, respectively. These results suggested that policymakers should consider increasing investment in these areas in line with the identified threshold levels to maximise productivity in the SSA region.

In conclusion, this study confirmed the inclusion of health as a determinant of TFP and established a nonlinear relationship between PHE and TFP in SSA. The results emphasised the significance of increasing PHE and highlighted the specific threshold levels required for sustainable TFP growth. The study contributes to the existing literature by providing novel insights into the relationship between PHE and TFP in SSA. It offers valuable guidance to policymakers and researchers interested in promoting economic growth and improving regional healthcare outcomes.

CHAPTER 6

MODERATION EFFECT OF PUBLIC HEALTH EXPENDITURE AND EDUCATION ON TOTAL FACTOR PRODUCTIVITY

6.1 Introduction

Insufficient PHE in countries in SSA and the subsequent negative impact on health indicators were discussed in the previous chapter that focused on the relationship between PHE and TFP through the lens of PHE's influence on health outcomes. However, when discussing TFP, it is crucial to consider the role of education as it is vital to human capital. Therefore, this chapter investigates the interactive effect of education and PHE on TFP. Moreover, to fully grasp TFP growth, it is necessary to account for the interaction between PHE and education and the synergy between PHE and other sectors such as agriculture and manufacturing. Therefore, this chapter delves into the interactive impact of PHE, education, manufacturing and agriculture on TFP. By exploring these interactive effects, which other studies have not covered, this analysis contributes to improved understanding of the problem.

The chapter is organised as follows: It begins with the background of the study in Section 6.2, whilst Section 6.3 outlines the overall aim of the part of the study explained in this chapter along with the specific objectives. Section 6.4 reviews the relevant literature and highlights the study's contribution to the existing body of knowledge. Section 6.5 discusses the research methodology, while section 6.6 presents and discusses the results in light of the research objectives and hypotheses. The chapter concludes with a summary in Section 6.7.

6.2 Background

The sub-Saharan African region is characterised by inadequate PHE, which has led to a decline in health outcomes and, ultimately, TFP (Akinola, 2017). However, PHE might relate to other variables. Therefore, understanding the potential impact of the interaction between PHE and education, for example, on TFP, could lead to insights into TFP growth. While several studies have examined the impact of education on TFP (Akingba, Shivee & Hanny, 2019; Qutb, 2017; Wei &

Hao, 2020; Liu & Bi, 2019), none have explored its interactive or moderating effect on the relationship between PHE and TFP. This study therefore adds to the body of literature in this field.

In addition to examining the long-run interactive effect of PHE and education on TFP, the study also explored whether the impact of PHE benefitted from the spill-over effect of other sectors, particularly agriculture and manufacturing, in determining TFP growth through improved health outcomes. Given that PHE has often been overlooked in the TFP framework in SSA, the study tested whether PHE and agriculture and manufacturing output might collectively ultimately enhance or reduce TFP growth, thereby filling a gap in the literature.

6.3 Research aim, objectives and hypotheses

This part of the study explored the interactive impact of PHE, education and other sectors on TFP via improved health outcomes.

The specific research objectives were as follows:

- Investigate the interactive impact of PHE and education on TFP in SSA
- Examine the collaborative impact of PHE and other sectors on TFP in SSA

The hypotheses formulated for this part of the study were:

- The interaction between education and PHE did not contribute to an improvement in TFP in SSA.
- The collaborative effect of PHE and other sectors such as agriculture and manufacturing did not enhance TFP in SSA.

6.4 Literature review

This section reviews the theories and empirical studies related to the topic of this chapter.

6.4.1 Theoretical literature

6.4.1.1 Tinbergen's (1942) model

Tinbergen's (1942) model, often called the neo-classical theory of economic growth, is amongst the earliest theories explaining TFP. This model captures the level of production efficiency and incorporates a time trend in terms of capital and labour inputs. At its core, the model relies on the aggregate production function initially introduced by Cobb and Douglas (1928) and later refined by Tinbergen (1942).

6.4.1.2 Solow's (1956) Production Function

Solow (1956) established a connection between aggregate production in an economy and TFP. Similarly, Tinbergen (1942) highlighted the role of productivity in explaining aggregate production. Moreover, Stigler (1947) introduced the notion of efficiency or TFP. However, the assumption of an aggregate production function in these models presents some challenges, as it relies on rigid assumptions about individual sectors of the economy. Solow and Tinbergen were not the only theorists to use an aggregate production function; the concept was also employed in the Cobb-Douglas production function (Cobb & Douglas, 1928). The notion of an aggregate production function in Solow's (1957) model was relevant to this study's macro-level investigation, and the model demonstrates as follows:

$$Q=AK^{\alpha}L^{1-\alpha} \qquad [1]$$

where

Q is the output, L denotes labour, input K denotes capital, while A denotes TFP $\propto$ output elasticities in labour and capital, respectively. Equation 1 can be restated for growth as follows:

$$\triangle \text{ In } \left(\frac{Q}{L}\right) = \propto \Delta \text{ In } \left(\frac{K}{L}\right) \triangle \text{ In A} \qquad [2]$$

6.4.2 Empirical literature

The empirical literature has examined the relationships between the variables of interest based on the theories highlighted above in many ways. Some of the studies are reviewed in this section.

6.4.2.1 Impact of education on TFP growth

Wei and Hao (2020) conducted a study on China's provincial TFP growth from 1985 to 2004, focusing on the role of human capital. The study employed a stochastic frontier approach to measure TFP growth and enrolment rates at different schooling levels to represent human capital composition. After considering endogeneity, it found that human capital had a significant and positive effect on TFP growth in Chinese provinces. However, incorporating education quality did not substantially impact TFP, except for the quality improvement in primary education at the general Chinese provincial level. Regional variations in the impact of human capital were observed across different living standards in China. Total factor productivity growth in the eastern region showed a significant association with secondary education, while in the central region, primary and university education played a more prominent role. Primary education emerged as the main driver of TFP growth in the western region.

Qutb (2017) investigated the long-run impact of education quality on TFP growth in Egypt from 1980 to 2014. The study employed a two-step approach, using the Gauss-Newton algorithm method to estimate the nonlinear Cobb-Douglas production function and calculate the TFP series. Education indicators and other control variables were considered to evaluate the determinants of TFP growth. The study applied the autoregressive distributed lag-bounds approach of co-integration. The findings revealed that TFP growth benefited significantly from improving the quality of higher education.

Liu and Bi (2019) examined the heterogeneous and spatial effects of higher education on regional TFP growth in China using a dynamic spatial econometric model and provincial panel data from 2003 to 2016. The results indicated that different higher education levels had varying impacts on TFP growth, primarily through spatial spillover effects. Bachelor’s and doctoral education showed significant positive effects, with the latter being particularly influential. However, technical schooling and master's education had a significant negative effect. The study decomposed this effect into technical efficiency and technical progress to explore the underlying mechanisms. The results suggested that promoting the expansion of bachelor’s and doctoral education and improving the quality of technical and master's education could enhance TFP growth and contribute to economic sustainability in China.

Akingba *et al.* (2019) analysed the impact of health capital on multi-factor productivity (TFP) in Singapore from 1980 to 2013. The study employed the autoregressive distributed lag (ARDL) bound test and found a stable and long-run co-integration between TFP, health capital, and education. The long-run estimates indicated that health capital and education positively and substantially contributed to TFP growth. This implied that increasing education and health capital investment could significantly enhance Singapore's TFP.

Jung (2017) explored the relationship between primary and lower secondary education completion rates and TFP growth rates using worldwide panels from 1970 to 2000, covering 60 to 71 countries. The study found that while secondary education positively influenced TFP growth, the completion rates of both primary and secondary education were found to have a positive association with technical efficiency change, specifically in terms of imitation. This meant that higher completion rates in primary and secondary education were linked to individuals and firms' improved ability to imitate and adopt existing technologies, leading to increased technical efficiency and ultimately contributing to productivity growth. These results suggested that basic education contributed to TFP growth by facilitating technology adoption.

6.4.2.2 Gap in the literature.

The current study aimed to address a gap in the existing literature by examining the moderating effect of education on the relationship between PHE and TFP in SSA. Previous discussions on TFP growth in this region raised concerns about the impact of inadequate PHE and poor health outcomes due to a lack of essential healthcare infrastructure, medical supplies and personnel, negatively impacting individuals' overall well-being and their participation in economic activities, their productivity levels and thus a country's TFP. However, education might impact health outcomes and, thus, the relationship between PHE and TFP. Moreover, the output of other sectors such as agriculture and manufacturing might contribute to the relationship. No studies have examined this possible dynamic, which might indicate regional economic strength (Okeyo, 2022).

The existing literature has, however, demonstrated the positive effect of manufacturing output on economic growth (Moyo & Le Roux, 2018; Marconi, Reis & Araujo, 2016; Olamade & Oni, 2016). Similarly, agricultural output has been shown to contribute to growth in Africa (Karimou, 2018). Considering these sectors' positive contributions, they are believed to improve PHE's effectiveness in enhancing TFP in SSA. By including their output in the analysis, a more comprehensive understanding of the impact of PHE on TFP in SSA can be achieved.

6.5 Research methodology

The methodology employed was based on a theoretical framework that drew on the aggregation models proposed by Tinbergen (1942), Solow (1956) and Denison (1962).

6.5.1 Theoretical framework

Regarding the theoretical framework, the study relied on the aggregate production function as the basis for its methodological approach. In terms of this framework, it was assumed that the technology utilised by each sector (education, agriculture and manufacturing) differed in terms of value-added, where value-added was a function of capital and labour inputs and the level of technology. Moreover, the value-added functions differed across all sectors, while the functions linking labour and capital inputs to their respective components were similar. In addition, each component of the input aggregate was expected to have a consistent price across all sectors. As a result, productivity measurement was conducted using a homogeneous production function for each of the industrial sectors, which was expressed as follows:

$$Q_i = F^i\,(X_i, K_i, L_i, T), \; (i = 1, 2\ldots n) \qquad [1]$$

where

T is time, Q_i is output, and X_i, K_i, and L_i are intermediate capital and labour inputs. The shares of intermediate, capital and labour inputs, say p^i_x, $p^i_{K,}$ and $p^i_{l,}$ in the value of output, can be defined as follows:

$$p^i_X = \frac{Aix\ Xi}{BiQi} \qquad [2]$$

$$p^i_K = \frac{Aik\ Ki}{BiQi} \qquad [3]$$

$$p^i_L = \frac{Aix\ Li}{BiQi} \qquad (\,_i = 1,2, \ldots.., n) \qquad [4]$$

B_i, $A^i_{X,}$ A^i_K, and A^i_L denote the prices of output and intermediate, capital and labour inputs, respectively.

To analyse substitution amongst the inputs, each sector's production function was combined with conditions for producer equilibrium.

$$p^i_X = \frac{\partial\, In\, Qi}{\partial\, In\, Xi} \qquad (X_i, K_i, L_{i,} T)\ ` \qquad [5]$$

$$p^i_K = \frac{\partial\, In\, Qi}{\partial\, In\, Ki} \qquad (X_i, K_i, L_{i,} T) \qquad [6]$$

$$p^{i}_{L} = \frac{\partial\, In\, Qi}{\partial\, In\, Li} \quad (X_i, K_i, L_{i,} T), \qquad (_{i} = 1,2, \ldots.., n) \qquad [7]$$

Under the assumption of constant returns to scale, the elasticities and value shares associated with all three inputs collectively summed up to unity, ensuring that the total output value was equal to the combined value of the inputs. Lastly, the rate of TFP growth, denoted as piT, could be defined for each sector as the growth rate of output over time while keeping intermediate, capital and labour inputs constant.

$$p^{i}_{T} = \frac{\partial\, In\, Qi}{\partial\, T} \quad (X_i, K_i, L_{i,} T), \qquad (_{i} = 1,2, \ldots.., n) \qquad [8]$$

It is important to note that this definition did not restrict substitution patterns amongst inputs. The study used the productivity growth rate to analyse changes in substitution possibilities over time.

Although the aggregate production function was one of the theoretical frameworks supporting the methodological approach followed in the study, the theories of Denison (1962) and the alternative Solow model were preferred due to their emphasis on the human capital aspect of the productivity framework. Similarly, Denison’s (1962) theory was embraced as it allowed for consideration of the residual in TFP and due to its ability to measure the contribution of labour quality through the effect of education as shown in the following equation:

$$Q = AK^{\alpha}(LE)^{1-\alpha} \qquad [9]$$

Where

E represents the average educational quality of labour force participation. Therefore, Equation 9 becomes:

$$\triangle \ln \left(\frac{Q}{L}\right) = \propto \left[\Delta \text{ In } \left(\frac{K}{L}\right)\right] + (1 - \propto) \triangle \text{ In E} + \triangle \ln A \qquad [10]$$

Denison’s (1962) model advanced the conventional Solow (1956) model by incorporating labour inputs for educational quality. However, an alternative model was developed by Solow to address the limitations of Denison's (1962) model by treating human capital as a distinct entity in the production function. This can be summarised as follows:

$$Q = Ak^{\gamma} W^{\mu} L^{\theta} \qquad [11]$$

Where

γ, μ, θ denote the elasticities of output in capital, human capital and labour, respectively. The elasticity of substitution must sum up to 1, and W denotes a reservoir of human capital. Thus, the growth theory model translates to the following:

$$\triangle \ln \left(\frac{\mathrm{Q}}{\mathrm{L}}\right) = \gamma \triangle \ln K + \mu \triangle \ln W - (1 - \theta) \triangle \mathrm{In\,L} + \triangle \ln \mathrm{A} \qquad [12]$$

Different sectors' contribution to overall economic growth can be accounted for by aggregating sectoral growth, as demonstrated in the work of Evsey-Domar (1961). In addition to examining the influence of education as observed in Denison's (1969) work, sector-specific inputs such as those of agriculture and manufacturing were introduced in this study one at a time as indicated in the following equations:

$$\triangle \ln \left(\frac{\mathrm{Q}}{\mathrm{L}}\right) = \propto \mathrm{Ko}\, \Delta \ln \left(\frac{Ko}{L}\right) + \alpha\, \mathrm{K\,AGR} \Delta \ln \left(\frac{\mathrm{KAGR}}{\mathrm{L}}\right) + \phi \Delta \ln \mathrm{A\,AGR} + \mathrm{n} \Delta \ln Ao \qquad [13]$$

$$\triangle \ln \left(\frac{\mathrm{Q}}{\mathrm{L}}\right) = \propto \mathrm{Ko}\, \Delta \ln \left(\frac{Ko}{L}\right) + \alpha\, \mathrm{K\,MAN} \Delta \ln \left(\frac{\mathrm{KMAN}}{\mathrm{L}}\right) + \phi \Delta \ln \mathrm{A\,MAN} + \eta \Delta \ln \mathrm{Ao} \qquad [14]$$

Where

ϕ and η denote Domar measures, K_{AGR} denotes capital employed in agricultural production, K_o denotes other capital stock, A_{AGR} denotes TFP in agricultural production, and A_o denotes TFP in another economy. Moreover, K_{MAN} denotes capital employed in manufacturing production, and A_{MAN} denotes TFP in manufacturing production.

6.5.2 Data definition

Data were gathered on several variables, including total TFP, education (measured by the HCI), PHE, and manufacturing and agriculture output. The study utilised annual data from 2000 to 2020 for 25 selected sub-Saharan African countries.

The data on education and TFP were obtained from the Penn World Table 10.0, while data on PHE, and manufacturing and agriculture output for 2022 were sourced from the WHO (WHO, 2022b).

The selected period and the number of observations provided a sufficient and reliable basis to obtain robust results. The variables used in the study were selected based on their relevance in the existing literature, and their significance is discussed in the following sections.

6.5.2.1 Dependent variable (TFP)

Total factor productivity played a critical role in the current study as it is a significant factor in long-run economic growth. Without TFP, economies would face stagnation. Total factor productivity represents growth in the total output of a firm or industry that cannot be solely attributed to conventional inputs like labour and capital in the production function. Similar to the research conducted by Feenstra *et al*. (2015), the current study measured TFP at the current PPP level, thereby providing insights into overall productivity levels.

6.5.2.2 Independent variables

a) PHE (health-related)

Public health expenditure serves as a measure of health-related spending, primarily contributed by the government through initiatives such as government expenditure and social security funds like the NHIS. The study quantified PHE as domestic general government PHE as a percentage of GNP. The existing literature suggests that PHE has the potential to stimulate long-term economic growth by addressing health-related challenges and improving overall population well-being.

b) Education (non-health-related)

Education encompasses acquiring knowledge and information to enhance a person's abilities, skills, interactions, mind-set and values. In the study, the measure of education was based on the HCI, which considers factors such as the number of years of schooling and the returns on education. This variable is a key component of human capital, reflecting investment in human development. The significance of human capital for long-term economic growth is supported by Lucas' (1988) theory and its emphasis on the role of knowledge and skills in driving productivity and innovation.

c) Manufacturing output (non-health-related)

In the study, manufacturing output, specifically measured as manufacturing value added, represented the net output generated by the manufacturing sector. It was calculated by subtracting the value of intermediate inputs from the total value of outputs in this sector. The resulting value, expressed as a percentage of GNP, indicated manufacturing activities' contribution to a country's overall economic output. This measure considered the value created by the manufacturing sector while accounting for the inputs required to produce the final goods.

d) Agricultural output (non-health-related)

In the study, agricultural output represented the agriculture, forestry and fishing sectors' contribution to a country's GNP. It was calculated using the value added by these sectors, which referred to the difference between the value of agricultural outputs and intermediate inputs used in the production process. This value was then expressed as a percentage of overall GNP. This measure provided insights into the relative importance of the agricultural sector in the economy, indicating agricultural activities' share in generating economic output.

6.5.3 A priori expectation

The study's theoretical framework revolved around the explanation of TFP by several explanatory variables, with a particular focus on PHE. In addition, education was considered another component of human capital development and health (Lucas, 1988). The manufacturing and agriculture sectors' inclusion in the analysis was motivated by their recognised significance in facilitating economic development and the fact that they serve as indicators of regional economic strength (Okeyo, 2022). The existing literature also provides evidence of manufacturing output's positive impact on economic growth (Moyo & Le Roux, 2018; Marconi *et al.,* 2016; Olamade & Oni, 2016), as well as agricultural output's contribution to economic growth in Africa (Karimou, 2018). Therefore, the expectation was that these sectors' contributions, along with PHE, would enhance PHE's effectiveness in improving TFP in SSA. Understanding these relationships would provide valuable insights into PHE's impact on TFP in this region.

The relationship between sector output (manufacturing/agriculture) and TFP was expected to be positive, indicating that increased output in these sectors would improve TFP. Similarly, a positive relationship was expected between PHE, agriculture, manufacturing and TFP. This would suggest that investment in public health, particularly targeting the well-being of workers in the agriculture and manufacturing sectors, could lead to healthier and more productive employees, ultimately driving TFP growth. While the study by Alvi and Ahmed (2014) did not specifically address the health outcomes of workers in the agriculture and manufacturing sectors, it revealed a positive impact of health indicators such as LEB on TFP across developed and developing economies, indicating the potential of healthcare investment to enhance overall TFP.

Furthermore, education was expected to have a positive relationship with TFP based on Sharpe *et al.*'s (1998) assertion that strong commitment to education by the public sector could enhance economic productivity. In a stable macroeconomic environment, prioritising education could lead to a more skilled workforce, thereby boosting overall productivity.

In summary, the theoretical expectation of the study was that health expenditure, agriculture, manufacturing and education would positively influence TFP. By examining the interactive effects of these factors, it aimed to provide insights into their combined impact on TFP.

6.5.4 Estimating technique

Country-specific effects can introduce bias in the OLS estimation of the coefficient on the lagged dependent variable. This arises because the lagged dependent variable positively correlated with the country-specific effect (Blundell & Bond, 1998). The fixed effects estimator is commonly used to address this issue. However, when examining the fixed effects of the coefficient on the lagged dependent variable, the assessment is likely to be biased against detecting negative effects (Arellano, 1995). As an alternative estimation method, Arellano (1995) proposes using GMM estimators, which allow for endogeneity in the other explanatory variables while addressing the endogeneity of the lagged dependent variable. The GMM estimator is applied after taking the first differences in the OLS estimator to remove the country-specific effect, and it employs lagged levels as instruments.

Blundell and Bond (1998) introduced the system GMM method to address the limitations of the first difference GMM estimators when dealing with persistent time series and short time intervals. The lagged levels of the series often provide insufficient instruments for the various equations, and differing the data to eliminate the country-specific effect results in the loss of cross-country variation in levels. To overcome these challenges, the system GMM estimator proposed by

Arellano (1995) and Blundell and Bond (1998) combines the usual set of time conditions from the first difference with lagged levels as instruments and an additional set of time conditions derived from the level equation. Additional moment conditions may be available depending on the assumptions regarding the relationship between the explanatory variables and the country-specific effect.

Robustness tests were conducted using five-year averages. Including five-year averages allows the extent of change in the model to be captured when the analysis is not performed every year. This approach was chosen because the impact of a policy change might not have been felt within one year, and a one-year analysis might not capture the full effect. Therefore, estimation was conducted using one- and five-year averages to account for different time horizons and capture potential longer-term effects of policy changes.

6.5.5 Model specification

According to Blundell and Bond (1998), the initial differences between these instruments are unrelated to the unobserved country effects. The general structure of this estimator is as follows:

$$y_{it} = w_{it}\delta + X_{it}\beta + \varepsilon_{it} \quad i = 1,...,N; \qquad t = 1,...,T \qquad [6.1]$$

$$\varepsilon_{it} = u_i + \eta_{it} \qquad [6.2]$$

Where

w_{it} is a vector of predetermined covariates (which may include the lag of y) and endogenous covariates, all of which may be correlated with u_i; y_{it} represents the regress, and for the individual, I over period t; X_{it} denotes the exogenous regressors, ε_{it} is the error term; u_i is the individual specific effects and η_{it} is the remainder disturbance term. The estimation equation for the system GMM can be specified as follows:

$$TFP_{it} = \beta_0 + \delta TFP_{it-1} + \beta_1 EDU_{it} + \beta_2 HEXP_{it} + \beta_3 MAN_{it} + \beta_4 AGRIC_{it} + \varepsilon_{it} \qquad (6.3)$$

where

TFP = total factor productivity

EDU = Education

HEXP = PHE

MAN = manufacturing

AGRIC = agriculture

6.6 Results

Table 6.1 below presents the results of the analysis of the impact of education, PHE, and sectorial factors on TFP. Two models are compared: the baseline and the collaborative model. The baseline model refers to the initial regression model that examines the impact of individual variables (education, PHE, manufacturing and agriculture) on TFP. It did not consider any interactions or collaborations between these variables. However, the collaborative model captured multiple factors' collaborative impact or combined effect on TFP. It thus incorporates the interaction between education and PHE (Education * PHE) and agriculture and manufacturing to assess their joint influence on TFP.

The coefficient estimate of TFP (lagged level) was -0.0288 in the baseline model and -0.0107 in the collaborative model. These values indicated the impact of the lagged level of TFP on current TFP. The coefficient estimate of education was 0.1976 in the baseline model and 0.4586 in the collaborative model. These values demonstrated the positive impact of education on TFP. The significance levels are denoted by asterisks (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$) in Table 6.1 below.

The coefficient estimate of PHE was -0.0681 in the baseline model and 0.2343 in the collaborative model. These values suggested that PHE had a significant positive effect on TFP. In the collaborative model, Education*PHE (representing the interaction between education and PHE in the regression model) was 0.5740, indicating a significant joint impact on TFP.

The coefficient estimate for manufacturing was 0.0357 in the baseline model and 0.0016 in the collaborative model. These values indicated the manufacturing sector's positive influence on TFP. Similarly, the coefficient estimate for agriculture was 0.3130 in the baseline model and 0.3849 in the collaborative model. These values demonstrated the positive impact of the agriculture sector on TFP.

In the table, the constant term represented the intercept in the regression model. Moreover, the Wald Test, Arellano-Bond Test and Hansen Test assessed the statistical validity of the model and the presence of autocorrelation and over-identification. The reported values provide information on the test statistics.

The results suggested that education, PHE, manufacturing and agriculture significantly influenced TFP. The collaborative model highlighted the interactive effects of education and PHE, indicating their combined influence on TFP. The statistical tests validated the model's robustness and supported the reliability of the results.

Table 6.1 below presents the results reflecting the impact of education and PHE on TFP, and the sectorial variables of education, agriculture and manufacturing on TFP.

Table 6.1: Impact of education, PHE and sectorial factors on TFP

Dependent Variable: Total factor productivity		
Variable	**Baseline model**	**Collaborative model)**
Total factor productivity (lagged level)	**-0.0288**	**-0.0107**
	(.044855)	**(0.0427)**
Education	**0.1976****	**0.4586*****
	(0.0842)	**(0.1057)**
Public Health expenditure	**-0.0681*****	**0.2343*****
	(0.0199)	**(.0687)**
Education *PHE		**0.5740*****
		(0.1021)
Manufacturing	**0.0357***	**0.0016***
	(0.0197)	**(0.0210)**
Agriculture	**0.3130*****	**0.3849*****
	(0.0247)	**(0.0262)**
Constant	**-0.1420**	**.04445**
	(0.1247)	**(0.1276)**
Wald test	**46315.37*****	**61502.71*****
Arellano-Bond test for AR(1)	**-4.40*****	**-4.46*****
Arellano-Bond test for AR(2)	**-1.23**	**-1.33**
Hansen test	**19.33**	**19.82**

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively. Figures in parentheses are the standard errors.

Table 6.1 above shows that the collaborative model provided a clearer understanding of the relationship between education, PHE and TFP. Although in the baseline model, education on its own showed a positive and significant effect on TFP, in the collaborative model, the positive coefficient of the interaction between education and PHE (Education *PHE**)** indicated that the presence of education enhanced PHE's impact on TFP. In addition, the coefficient for PHE in the collaborative model indicated that a 1% increase in PHE led to a 0.23% improvement in TFP. These results aligned with the theoretical framework proposed by Denison (1962) and Solow (1956), the results reported in the previous chapter.

As with education, manufacturing and agricultural output positively and significantly affected TFP in the baseline model. However, in the collaborative model, the synergy between agriculture, manufacturing, and education positively impacted and enhanced the PHE-TFP relationship. In other words, the presence of agriculture, manufacturing and education led to an increase in PHE's impact on TFP growth.

Overall, the findings of this study support the importance of considering the collaborative effects of education, manufacturing and agricultural output and PHE in achieving higher TFP in SSA. In other words, a country should invest in agriculture and manufacturing to improve productivity, and education to ensure the workforce is equipped with the necessary knowledge and skills. However, it should also ensure sufficient PHE to promote health and, thus, the workforce's productivity. Thus, investing in PHE, education, agriculture, and manufacturing would promote TFP growth.

6.6.1 Robustness Check results

An analysis with five-year averages was conducted to capture the long-term trends and changes in the variables over a broader time frame. Using five-year averages allowed for a more robust analysis by increasing the number of observations and reducing the potential influence of outliers or random variations in the data. This enhanced the reliability and validity of the results and provided a more accurate representation of the long-term relationship between the independent variables and TFP. Using five-year averages, the analysis smoothed out short-term fluctuations and captured the underlying patterns and relationships between the variables over an extended period. Employing longer-term averages provided a comprehensive perspective on the impact of the independent variables on TFP growth, as it considered their cumulative effect over several years. Table 6.2 below presents the results on the collaborative impact of the independent variables on TFP.

Table 6.2: Impact of independent variables on TFP using 5-year averages

Dependent Variable: Total factor productivity		
Variable	**Baseline model**	**Collaborative model**
Total factor productivity (lagged level)	**-0.1775*** **	**-0.1959*** **
	(0.0268)	**(0.0115)**
Education	**0.3680*** **	**1.0930*** **
	(0.1083) **	**(1.0930)**
Health expenditure	**-0.2015*** **	**0.7015*** **
	(0.0595)	**(0.0628)**
Education * PHE		**1.6922*** **
		(0.1398)
Manufacturing	**0.06103*** **	**0.0537**
	(0.0415)	**(0.0342)**
Agriculture	**0.3909*** **	**0.5874** **
	(0.0241)	**(0.0445)**
Constant	**-0.0753**	**0.4013*** **
	(0.0807)	**(0.1485)**
Wald test	**19.65*** **	**2319.97*** **
Arellano-Bond test for AR(1)	**-1.98** **	**-1.94** **
Arellano-Bond test for AR(2)	**-0.16**	**-1.52**
Hansen test	**12.92**	**14.43**

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively. Figures in parentheses are the standard errors.

The results of the analysis were robust and consistent across various robustness checks, including five-year averages and Wald tests. It was essential to include five-year averages to capture changes in the models over a long time and account for the potential lagged effects of policy changes. Considering both one- and five-year averages ensured comprehensive understanding of the impact of the variables.

The Wald tests indicated that the models had a significant joint effect on TFP. This test examines the significance of the independent variables in explaining the dependent variable, and the significant results confirmed the overall influence of the explanatory variables on TFP.

The validity of the instruments used in the analysis was confirmed by the results of the Hansen test and the Arellano-Bond test for AR (2), as the null hypotheses were not rejected. This suggested that the instruments effectively captured the relevant dynamics of the variables.

In the baseline model, a 1% change in education was associated with a 0.368% increase in TFP. However, the collaborative model indicating the interaction between education and PHE showed a greater impact on TFP, indicating that a 1% increase in PHE would lead to a 1.09% increase in TFP.

The baseline model showed that a 1% increase in PHE would result in a 0.201% reduction in TFP. However, in the interactive model, the effect of PHE on TFP was positive, with a 1% increase in PHE associated with a 0.701% increase in TFP. This highlighted the moderating role of education in enhancing PHE's positive impact on TFP.

In the collaborative model, the coefficient for manufacturing was 0.0537, indicating a positive but relatively smaller effect on TFP compared to the baseline model, where the coefficient was 0.06103. This suggested that in the interactive model, manufacturing's impact on TFP was slightly reduced. Similarly, the coefficient for agriculture in the collaborative model was 0.5874, indicating a positive effect on TFP, but with a lower magnitude than the baseline model, where the coefficient was 0.3909. This suggested that in the collaborative model, agriculture's impact on TFP was also somewhat reduced. However, the coefficients for manufacturing and agriculture in the collaborative model were statistically significant at the 10% level (indicated by **), which implied that they had a meaningful impact on TFP even though the magnitude was slightly smaller compared with the baseline model.

Overall, the table shows that in the collaborative model, the presence of agriculture and manufacturing, along with education and PHE, contributed to an increase in TFP but with some reduction in magnitude compared with the baseline model. Thus, the analysis demonstrated the importance of education and its interaction with PHE in driving productivity growth, manufacturing, and agriculture, underscoring the significance of investing in these variables for sustainable economic development.

6.6.3 Discussion of Results

The analysis set out in this chapter was motivated by its contribution to achieving the research objective of investigating the moderation effect of PHE and education on TFP, as well as the effect of PHE in collaboration with education, agriculture and manufacturing on TFP in selected countries in SSA.

The analysis employed an aggregate production function which was estimated using the SGMM. The chapter explained how and why PHE and output from agriculture and manufacturing constituted an integral part of the production functions in SSA. Justification was provided for focusing on manufacturing and agricultural output in assessing these factors' moderation effect on TFP. The study tested the hypothesis that the interaction of education and PHE did not improve TFP in SSA and the one that the synergy of PHE, agriculture, and manufacturing did not improve TFP in this region.

The results for the relationship between health, education, and manufacturing and agricultural output revealed the moderating impact of education on PHE for improved TFP growth. In the baseline and collaborative models, education positively and significantly affected TFP. In the baseline model, it was found that a 1% change in education would lead to a 0.197% increase in TFP. Similarly, the interaction of education with PHE improved the impact of PHE on TFP, and the interaction of Education * PHE resulted in a 0.458% increase in TFP. This implied that an improvement in education enhanced PHE's overall impact on TFP in SSA. This is perhaps because an increase in human capital proxied by education contributed to citizens' wellness, thereby increasing productivity.

A 1% increase in PHE would have resulted in a 0.0681% reduction in TFP in the baseline model. Thus, PHE alone may not have achieved the expected increase in productivity growth. This result revealed the modifying power of education on PHE in determining TFP. The coefficient of the interaction term was positive, which meant that the presence of education enhanced PHE's impact on TFP. This result was in line with Akingba *et al.* (2015), Qutb (2017), Liu and Bi (2019), and Jung's (2017) studies on the impact of education on TFP.

The results suggested that PHE was a significant determinant of productivity. However, the current level of PHE could not translate into TFP growth, and PHE needed to be considered alongside education and the output of other sectors such as agriculture and manufacturing. In the collaborative model, the sign of the coefficient of PHE was now positive, implying that a 1% increase in PHE improved TFP by 0.234%, more than in the baseline model. This was consistent with the theory (Denison, 1962; Solow, 1956).

Both manufacturing and agricultural output had positive and significant effects on TFP. In the baseline model, a 1% change in manufacturing output would have resulted in a 0.035% increase in TFP. However, in the collaborative model, a 1% change in manufacturing output would have resulted in a 0.001% increase in TFP, which, although slightly less than in the baseline model, still indicated a positive effect. In the baseline model, a 1% change in agricultural output would have resulted in a 0.313% increase in TFP. In contrast, in the interactive model, a 1% change in agricultural output would have resulted in a 0.384% increase in TFP, thereby indicating increased impact due to interaction with the other variables.

The impact of education and manufacturing/agricultural output in the TFP framework would enhance PHE's effect on TFP growth. Including these sectors meant a more accurate consideration of PHE's impact on TFP in SSA. However, the elasticity of the impact of education on PHE and, thus, TFP was the highest. Therefore, by implication, countries in SSA should improve education levels and consider education as a supplementary health ingredient to achieve a meaningful increase in TFP. This result addressed a gap in the literature. Although previous studies have examined the education-TFP nexus, no attempt was made to test the interactive impact of education and PHE on TFP. Moreover, these studies did not determine the efficacy of the collaboration/association of PHE, education, and manufacturing/agricultural output on TFP in SSA.

A limitation of the part of the study described in this chapter was the adoption of PHE as the single source of health expenditure/funding. The emphasis was on PHE, whilst the variable should perhaps rather have been total health expenditure, which would have combined private, public and donor contributions. A disaggregation of the sources of PHE to include the three references (private, public, and donor contributions) could have enabled documentation of the effect of total health expenditure and other factors on TFP.

Nonetheless, the analysis contributed to achieving the objective of capturing the interactive effect of PHE and other sectors on TFP. It highlighted the moderating role of education in enhancing PHE’s impact on TFP in SSA. Furthermore, manufacturing and agricultural output's positive and significant effects on TFP emphasised their importance in the productivity equation. These results thus underscored the need for a comprehensive approach that considers education, PHE, manufacturing and agriculture in efforts to improve TFP in SSA.

6.8 Chapter Summary

This chapter explained the interactive effect of PHE, education and manufacturing/agricultural output on TFP growth in 25 selected sub-Saharan African countries from 2000 to 2020. The analysis aimed to test the hypothesis that the interaction of PHE and education had no significant effect on TFP in the countries under review and that there was no significant effect on TFP when PHE was associated with other sector outputs using data on SSA.

The chapter commenced with a discussion on the background of the study and an outline of the overall aim and specific objectives. Relevant literature was reviewed, highlighting the study’s contribution to the existing body of knowledge. The research methodology was then described, and the results regarding the research objectives and hypotheses were presented and analysed. Lastly, the findings were summarised and their implications for understanding the interactive effects of PHE, education, manufacturing and agriculture on TFP in SSA were discussed.

Previous studies provided limited evidence, mainly on the effect of education, often overlooking other determinants of TFP and neglecting to explore the interaction between education and PHE on the one hand, and collaboration between agriculture/manufacturing output and PHE on the other. This study found that the interaction of education and PHE enhanced its effect on TFP, and that the association between PHE, education, manufacturing and agriculture improved TFP. The discovery of the positive and significant impact of education and the joint association of PHE, education, manufacturing and agriculture underscored the importance of considering these factors for sustainable economic growth.

By examining the variables of interest's interactive effects on TFP, which have not been extensively covered in previous studies, the analysis contributed to a better understanding of the research problem. It provided valuable insights into the role of PHE, education and sectors such as agriculture and manufacturing in driving TFP growth in SSA.

CHAPTER 7

SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

7.1 Introduction

This chapter presents an overall summary and conclusion and discusses the policy implications of the research results. Section 7.2 summarises the research problem and objectives, Section 7.3 the methodology and Section 7.4 the results. Section 7.5 presents the study's conclusions and Sections 7.6 and 7.7 focus on the policy implications and the study's contributions to knowledge.

7.2 Summary of the research problem and objectives

The problem underpinning the study was poor health outcomes in SSA coupled with low PHE and TFP growth. The problem was exacerbated by the lack of knowledge on whether there was a threshold amount of PHE and education that would improve health outcomes and TFP in the countries and period under review. There was also a lack of evidence on whether the education level and the output of sectors such as agriculture and manufacturing had a moderating and interactive effect on PHE's influence on TFP. Lastly, the lack of information on the level of PHE that would assist in achieving the SDGs was a challenge. Therefore, the study sought evidence on the threshold amount beyond which PHE and education would positively affect health outcomes, and the moderating impact of education on PHE in influencing health outcomes (Objective 1). However, because knowledge of threshold effects would not necessarily prepare SSA to achieve the SDG targets, it forecast the level of PHE that would achieve them in different scenarios of a percentage increase in PHE (Objective 2).

Since positive health outcomes increase TFP, the study investigated the role of PHE and health outcomes as determinants of TFP in SSA (Objective 3). Moreover, because PHE might depend on other factors, it assessed the moderating, interactive role of education level and manufacturing/agricultural sector outputs on TFP (Objective 4).

7.3 Research methodology

To address Objective 1, the study employed PSCC-OLS and PSCC-FE models. Objective 2 was tackled using the FGLS model; Objective 3 involved fixed and random panel models, P2SLS and panel threshold regression and Objective 4 was approached using the GMM model. Further details regarding the methodologies can be found in the respective chapters (Chapters 3-6).

7.4 Key results

Objective 1 (covered in Chapter 3) revealed several results. First, the PSCC-OLS model reaffirmed that PHE and education were key determinants of health outcomes in SSA. Specifically, a 1% increase in PHE combined with education significantly reduced maternal and child mortality by 0.181% and 0.079%, respectively. Second, a nonlinear relationship was observed between PHE and health outcomes. The relationship between PHE and maternal/child mortality exhibited an inverted U-shaped curve. Third, due to the nonlinear effect of PHE, an initial 1% increase in PHE caused maternal and child mortality to increase by 0.708% and 0.175%, respectively, because funding was insufficient. Moreover, further increases in PHE resulted in only slight reductions in maternal/child mortality by 0.112% and 0.0321%, respectively, thereby supporting the literature's stance on the ineffectiveness of PHE alone in improving maternal/child mortality in SSA.

Fourth, the relationship between PHE and LEB was a U-shaped one whereby an initial increment of 1% in health spending led to a decline in life expectancy of 0.0594%, which meant that funding was insufficient to improve this health outcome. However, additional increases beyond the threshold level improved LEB by 3.198%. Fifth, it was found that beyond US$23.57 per capita and US$15.33 per capita, PHE reduced maternal and child mortality in SSA. Similarly, using the U-shaped parabola for the LEB model, it was observed that beyond the threshold point of US$38.47, PHE per capita would start contributing to improvements in life expectancy if other factors remained constant. Lastly, the study found that significant improvements in maternal/child mortality and LEB required high levels of education involving increases of 1.51%, 1.49% and 1.84%, respectively (results presented in antilog to capture the real value).

Objective 2 (covered in Chapter 4) focused on forecasting future scenarios. The results indicated that by 2030, no country in SSA would achieve the SDG target of an MMR of 70 per 100,000 women with a 10% increase in PHE. However, South Africa could achieve the target with a 20%

increase in PHE. Moreover, by 2030, South Africa and Senegal would achieve the SDG target of a CMR of 25 child deaths per 1,000 live births with a 10% increase in PHE. Thus, if South Africa and Senegal could increase their PHE by 10%, child mortality would be reduced to 21 and 18 deaths per 1,000 live births, respectively. In addition, a 30% increase in PHE from the current spending level in Burkina Faso, Burundi, Cameroon, Eswatini, Gambia, Namibia, Rwanda and Tanzania would enable the child mortality targets to be achieved.

Overall, the results for Objective 2 suggested that approximately 60% of the countries in SSA could achieve the SDG target for child mortality by 2030. However, only Botswana, Namibia, and South Africa could achieve the SDG target of 70 maternal deaths by 2030 with an overall increase in PHE of 30% from the current spending level.

Objective 3 (covered in Chapter 5) utilised fixed and random effect models and 2SLS to analyse the relationship between PHE and TFP. The results showed that PHE had a positive and significant impact on TFP, with a 1 % change in PHE resulting in a 0.132% increase in TFP, controlling for other factors. The analysis also revealed a threshold relationship between TFP and health expenditure, indicating that at a 3.5% level of PHE (antilog-35%), the effect on TFP became significant. In addition, a nonlinear relationship was observed between TFP and non-health variables such as education and ICT, with education exhibiting a 2.56% impact and ICT showing a 21% impact on TFP.

Achieving Objective 4 (covered in Chapter 6) involved an examination of PHE's interactive and collaborative effect on TFP. The results demonstrated that interaction between education and PHE had a significant and positive impact on TFP. The impact of manufacturing and agricultural outputs on TFP was also significant and positive. However, in the collaborative model, where PHE was considered together with other sectors' outputs, PHE’s impact on TFP was more positive and significant. This suggested that while PHE alone could be included in the TFP framework, only an increase in PHE in collaboration with other sectors leads to an increase in TFP growth. In other words, the study revealed that PHE was a significant determinant of productivity but on its own it could not translate into TFP growth. However, when combined with education and the outputs of other sectors such as manufacturing and agriculture, increased PHE impacted TFP. In addition, amongst the sectors considered, education had the highest elasticity of impact on TFP.

The study's key results indicated the importance of PHE and education in improving health outcomes and, thus, TFP. The findings highlighted the nonlinear relationships, threshold effect, and moderation impacts of education on PHE. Furthermore, the collaborative impact of PHE with other sectors such as manufacturing and agriculture underscores the complex dynamics involved in promoting TFP in SSA, with important policy implications for the region.

7.5 Policy Implications

The study's results have several policy implications for governments and stakeholders in the sub-Saharan African region.

Firstly, governments should increase per capita PHE and investment in education. Using the U-shaped parabola for the LEB model, it was observed that beyond the threshold point of US$38.47, PHE per capita would start contributing to improvements in life expectancy if other factors remained constant. Governments should, therefore, aim to reach a threshold of US$38 per capita for PHE and a minimum of 1.84% increase in education. Meeting these minimum thresholds in PHE and education would positively impact health outcomes and thus contribute to TFP growth in the region.

Secondly, the study highlighted the importance of education in moderating PHE's effect on health outcomes and sustainable TFP growth. Governments and stakeholders should prioritise strategies that enhance PHE and education, as improvements in these areas will significantly and positively impact health outcomes, including maternal/child mortality and LEB. In other words, the study emphasised that the education level could influence PHE's effect on health outcomes. Therefore, education should be considered crucial when designing any health framework or policy.

Thirdly, to achieve a reduction in maternal and child mortality and meet the SDGs for health by 2030, PHE should meet the forecast levels, which require a 30% increase. Although each country should determine its specific needs and increase PHE accordingly, achieving improvements in health outcomes calls for per capita PHE of US$38, with a threshold of 3.65% improvement as the minimum education level.

The study confirmed that PHE is a driver of improved TFP growth in SSA, provided that a country pursues a 35% increase in PHE at the threshold point of 3.5%. Understanding the threshold effect of PHE on health outcomes and TFP can help to reduce corruption and wastage in the health sector, as governments will have clear targets for increasing PHE to achieve better health outcomes. This will lead to more efficient allocation of health financing resources.

Lastly, the interaction of education with PHE and its association with manufacturing and agricultural outputs can generate higher TFP growth in SSA. However, this requires the interaction of these sectors. Therefore, the region's countries should prioritise improvements in PHE and manufacturing, education and agriculture to ensure sustainable increases in TFP.

7.6 Contributions to knowledge

The study makes a significant contribution to understanding the relationship between PHE, health outcomes and TFP in SSA.

The analysis explained in Chapter 3 established a nonlinear relationship between PHE and three health outcomes: maternal mortality, child mortality, and LEB. It also confirmed the moderating impact of education on the relationship between PHE and health outcomes. The study, therefore, filled a gap in the literature by providing the threshold levels of PHE and education that can lead to better health outcomes in SSA.

The analysis set out in Chapter 4 focused on projecting improvements in mortality based on assumed increases in PHE, with a specific focus on achieving the SDGs for child and maternal mortality. Thus, the study broke new ground by offering a unique approach to providing out-of-sample forecasts for mortality rates. It focused on examining the effects of increasing PHE on maternal and child mortality to support countries in achieving the UN 2030 targets.

The analysis explained in Chapter 5 of the study makes a significant contribution to the literature on the role of PHE and health outcomes as determinants of TFP in SSA. The results of this analysis validated the significance of health and its proxies as determinants of TFP. They reaffirmed the impact of non-health factors on TFP in the SSA region.

The analysis confirmed a threshold relationship between PHE and TFP in SSA, indicating that the PHE's effect on TFP growth is not linear but varies at different levels of PHE. This insight filled a notable gap in the literature, as there has been limited research on the threshold relationship between PHE and TFP in SSA. In addition, the analysis confirmed a threshold relationship between non-health factors and TFP in SSA, highlighting that factors beyond health also significantly influence TFP growth.

The analysis presented in Chapter 6 explored the moderating impact of education and PHE on TFP growth and examined the collaborative effect of PHE on TFP with other key sectors of the economy such as agriculture and manufacturing. Thus, the study confirmed the positive, collaborative effect of PHE, education and the manufacturing/agricultural sectors on TFP growth. Including these key sectors and education as moderating factors in the relationship between PHE and TFP is a novel contribution to the literature on the economic development of SSA.

As noted previously, there were limitations to the study. For example, it focused on PHE as the sole source of health funding, while it should perhaps have considered total health expenditure, which would have included PHE and private and donor funding. Future research could consider disaggregating the sources of health expenditure to examine their individual effects on health outcomes.

The unavailability of PHE and TFP data for some SSA countries and the lack of data for periods before 1995 limited the possibility of generalising the results. Including data from a broader range of countries and periods would have enhanced the robustness of the findings.

Future research could involve single-country analyses and incorporate control variables such as GNP per capita, urbanisation and development aid. Furthermore, exploring different measures of corruption and their impact on health outcomes could provide additional insights into the relationship between corruption, PHE and TFP. Moreover, it would be beneficial to expand the analysis by exploring various corruption measures and examining their specific impacts on health outcomes. For instance, corruption in the healthcare sector may lead to embezzlement of funds, diversion of resources, or bribery, resulting in inadequate healthcare services, reduced access to essential treatment and compromised health outcomes. By delving into these aspects, policymakers might better comprehend the intricate dynamics between corruption and health, thus enabling them to develop targeted strategies to tackle corruption and improve health outcomes.

7.7 Conclusion

In Chapter 3, the study concluded that PHE has a nonlinear effect on health outcomes, and that education played a moderating role in the relationship between PHE and health outcomes in the context of the countries under study. These results contribute significantly to the literature by confirming that PHE and education might determine health outcomes. In addition, the study provided evidence of a nonlinear relationship between PHE and health outcomes, with a threshold point identified at 3.65% or approximately USD$38 PHE per capita. Furthermore, it established that achieving an optimal balance between PHE and education could substantially reduce MMR and CMR and increase LEB.

In Chapter 4, the study focused on forecasting different PHE scenarios that could help achieve the SDG targets by 2030. Specifically, its projections indicated that a 30% increase in PHE would be necessary to reach the SDG targets for maternal mortality (70 deaths per 100,000 women) and child mortality (25 deaths per 1,000 live births) in certain sub-Saharan African countries. However, not all countries may be able to achieve the SDG targets for both maternal and child mortality rates.

In Chapter 5, the study validated the role of PHE and health outcomes as determinants of TFP in SSA. It provided empirical evidence to support a threshold relationship between PHE and TFP at approximately 3.5%. In addition, the study reaffirmed the significance of non-health factors such as education and ICT as determinants of TFP, with threshold points of 2.56% and 21%, respectively, in their impact on TFP.

Lastly, in Chapter 6, the study concluded that the interaction between education and PHE positively impacted TFP in the countries under review. In addition, it highlighted the association between PHE and manufacturing and agricultural output, which contributes to higher TFP growth in the SSA region when education and PHE are integrated with these variables.

Overall, the study provided valuable insights into the complex relationships between PHE, education, health outcomes, various sectors' outputs and TFP in SSA. The results confirmed the significance of optimal PHE levels, the moderating role of education, and the collaborative effects of different sectors in achieving improved health outcomes and TFP growth.

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05 January 2023

Mrs Yetunde Oluranti Adegoke (218086961)
School Of Acc Economics&Fin
Westville

Dear Mrs Yetunde Oluranti Adegoke,

Protocol reference number: HSSREC/004579/2019

Project title: Health and Productivity growth in Sub-Saharan African Countries.

Amended title: Health expenditures, health outcomes and productivity in Sub-Saharan Africa: Sustainable thresholds, moderation and forecasting.

Approval Notification – Amendment Application

This letter serves to notify you that your application and request for an amendment received on 04 January 2023 has now been approved as follows:

- Change in thesis /project title Approved

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form; Title of the Project, Location of the Study must be reviewed and approved through an amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

Best wishes for the successful completion of your research protocol.

Yours faithfully

PP [redacted]

Prof Bomi Cyril Nomlala
ACADEMIC LEADER RESEARCH
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/___

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