HEALTH HUMAN CAPITAL AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA: A DYNAMC PANEL DATA ANALYSIS

By

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DECLARATION

I, Mwimba Chewe, declare that this dissertation:

a) Represents my own work;

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APPROVAL

This dissertation of **Chewe, Mwimba** has been approved as a partial fulfilment of the requirements for the award of the degree of Master of Arts in Economics by the University of Zambia.

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ABSTRACT

This study set out to determine the relationship between health human capital and economic growth for 30 sub Saharan African countries during the period 1995 and 2014. The study did this in two parts. First, we first estimated a model of health production to ascertain the impact of economic growth and other factors on population health. Second, an economic growth model was estimated focusing on the impact of the stock of, investments into and quality of health on economic growth rates. The analysis was extended to examine the long term and short term influence of health stock on economic growth.

Due to expected endogeneity in the health and growth models, the Arellano Bond two step Generalised Method of Moments (GMM) estimator was employed. Using life expectancy and infant mortality as measures of health, the study found that population health had a significant long term impact on economic growth in the region with a 1 percent rise in average life expectancy leading to a 0.3 percent rise in GDP per capita in 10 and 12 years. Similarly, infant mortality has a negative significant impact on growth when lagged by 12 years. While life expectancy did not show evidence of a short term impact on growth, infant mortality had a negative and significant impact on economic growth in the short term.

As for the determinants of population health, education, health expenditure, health care quality and alcohol consumption significantly determined both the levels of infant mortality and life expectancy in the region. The study concluded that the accumulation of population health capital would raise economic growth levels in the long term for the region. To exploit this growth effect, there is need for policy makers to invest in improving population health by focusing on the main determinants of health (education, health quality, health expenditure and life style factors).

Key Words: Health human capital, economic growth, long term, Sub Saharan Africa, Dynamic Panel Data, GMM difference estimator

DEDICATION

For My Parents, Mr Laston and Mrs Betty Chewe

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LIST OF ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
AIDS	Acquired Immune Deficiency Syndrome
DPD	Dynamic Panel Data
GDP	Gross Domestic Product
GHO	Global Health Observatory
GLS	Generalized Least Squares
GMM	Generalised Method of Moments
HIV	Human Immune-deficiency Virus
IFC	International Finance Corporation
IMF	International Monetary Fund
MENA	Middle East and North Africa
NCDs	Non Communicable Diseases
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
TB	Tuberculosis
US	United States
WDI	World Development Indicators
WHO	World Health Organization
FE	Fixed Effects
RE	Random Effects

CHAPTER 1

INTRODUCTION

1.1 Background

Over the last two decades, Sub Saharan Africa (SSA) has been recording slow but progressive improvements in its levels of economic growth, with regional GDP growth rates peaking at 11 percent in 2004 (IMF, 2017). Despite this, the region continues to have some of the least favourable health outcomes in the world (World Health Organization, 2014). Sub-Saharan Africa is home to only 12% of the world's population and yet accounts for close to 50 percent of all deaths due to infectious diseases (World Health Organization, 2014; Narayan, 2016). Even though regional per capita health expenditure more than doubled between 1995 and 2014 (from $US41 to $US 98), the region still has the lowest regional life expectancy at 59 years, the highest regional infant mortality rate at 53 deaths per 1000 live births and accounts for over half of world's maternal deaths (Musango *et al.*, 2013; World Health Organization, 2014). These poor health outcomes directly stem from the region's weak health systems that are characterised by poor service delivery, inadequate human resources, poor infrastructure, unsatisfactory procurement systems and poor management (Mooketsane and Phirinyane, 2015).

Overall, the condition of population health and the health systems in the region is dire. This raises some important economic questions. Firstly, does the health status of the population affect growth prospects in the region? Secondly, should the region increase its investments in the health sector despite its poor performance? Thirdly, over what time horizon does health impact economic growth in Sub-Saharan Africa and importantly, how does economic growth in turn, along with other factors, impact health in the region?

In recent years, health has emerged as one of the main drivers of economic development and an ultimate indicator of a population's wellbeing (Schultz, 1999; Acemoglu and Johnson, 2007). Just as an individual's productivity depends on his/her health status, the productivity of a country's labour force and ultimately that of its economy depends on the health status of its population. According to the World Health Organization (WHO), health is defined as the state of total physical, social and mental well-being and not just the absence of disease or infirmity (Nutbeam and

Kickbusch, 1998). In economic terms, health is viewed as a form of human capital since it is an asset or resource embodied in individuals that enables them to be productive (Gupta *et al.*, 2002; Weil, 2014). Combined with other components of human capital such as education, training and work experience, health possessed by the labour force complements physical capital, leading to increases the level of per capita income via accelerated resource productivity, resource accumulation and technical change (Benhabib and Spiegel, 1994)

Since most low- and middle-income countries in SSA are still largely dependent on human labour for productivity (International Labor Organization, 2017), attaining high stocks of population health is necessary for accelerating economic growth. In the same vein, bettering population health in low income regions has been viewed as an end in itself and a means to eradicating poverty and improving the economic outcomes of marginalized individuals (Gallup and Sachs, 2001; Weil, 2014).

The economic literature around the relationship between health and economic growth has taken two approaches. While some studies have focused on the impact of health on economic growth through its effect on human capital quality and accumulation, other studies have focused on the impact of income or economic growth on health outcomes. That is, higher levels of economic growth are expected to improve population health through better access to social services such as education, better nutrition, reductions in poverty among other channels (Bloom and Canning, 2003; Bloom David Canning et al., 2008). The relationship between health and economic growth therefore suggests bidirectional causality(Smith, 1999), with debate arising as to which of the two relationships is more prominent.

Considering the important role health plays in growth dynamics and vice versa, this study sets out to explore the health-growth nexus in the Sub-Saharan African context. With population health being regarded as a form of human capital, the study assesses the impact of the stock of and investments into health on economic growth for a sample of SSA countries. Appreciating the complexity of the relationship between health and economic growth, the study also evaluates the impact of economic growth and other determinants on the region’s population health.

1.2 Statement of the Problem

Studies have shown that sustained growth in more developed regions such as Europe and Central Asia was preceded by significant gains in the two pillars of human capital – education and health (Tilak, 2016). Even in Sub-Saharan Africa, countries with relatively high levels of human capital within the region such as Botswana, Ghana, Mauritius and South Africa have experienced longer growth periods compared to countries with lower human capital (Widner, 2005).Therefore, investing in health and education is considered a necessary condition for sustained economic growth in developing regions (Sachs, 2001). With the deplorable state of population health and accompanying dismal investments in the health sector in SSA, questions have arisen as to whether this has served as a hindrance to sustained economic growth. Further, it is yet to be clear whether differences in population health could provide an explanation for the vast differences in income growth rates among countries in the SSA region. In 2016, GDP per capita growth rates among countries in the region ranged between -9.8 percent (Chad) and 5.6 percent (Cote d'Ivoire) (World Bank Group, 2017)

While the impact of human capital on economic growth has been widely studied in empirical literature, very few studies focusing on the SSA region exist. Most of the studies on the impact of human capital in sub Saharan Africa have largely focused on the impact of education as a form of human capital on economic growth while downplaying the impact of health capital (Eggoh *et al.*, 2015). Of the studies that have incorporated health in their growth models, few have accounted for the quality of either education or health care in their models representing a gap in the estimation. Despite the importance of time horizon in the health- growth nexus, the short term and long term impact of health on economic growth has not been widely explored, particularly in cross country studies. Overall, the results from studies on the impact of health on economic growth in both developed and developing countries have been mixed and far from conclusive.

Previous studies have also neglected to examine the possible two-way causality between health and economic growth. While it is generally assumed that the direction of causality is from health to economic growth, the impact of economic growth on health for SSA remains largely unexplored.

In light of this, this study aims to answer the following questions: What is the effect of the stock of and investments into population health on economic growth in Sub Saharan Africa in the long and short term? How does economic growth in turn impact population health in Sub Saharan Africa?

1.3 Objectives

1.3.1 General Objective

To examine the impact of economic growth and other determinants of health on population health and estimate the magnitude of the impact of population health on economic growth in 30 SSA countries for the period between 1995 and 2014.

1.3.2 Specific Objectives

The specific objectives of the study are;

1. To measure the magnitude of the effect of health stock (life expectancy and infant mortality) on economic growth in SSA in the short-term and long-term.
2. To determine whether increases in investments into health (health expenditure) and health care quality are associated with increases in economic growth rates in the SSA region.
3. To measure the impact of economic growth along with the impact of social, healthcare, environmental and lifestyle variables on the level of health stock (life expectancy and infant mortality) in SSA.

1.4 Hypotheses

The hypotheses related to this study are motivated by the theoretical and empirical relationships established between the variables to be used in the analysis.

1. ***Increases in the health stock, health care quality and investments into health each lead to an increase in economic growth rates***

Increased health stocks, investments into the health as well as better quality of healthcare services is expected to improve overall population health and raise the productivity of labour and investments into educational human capital. (Grossman, 1999; Finlay, 2007). It is also expected that the population health stock will have both a short term and long term impact on economic growth (Mayer, 2001).

2. ***Increased income, higher levels of education, better access to clean water, higher health expenditure, improved quality of institutions and increased food availability each have a positive and significant impact on population health***

Higher levels of GDP per capita are expected to lead to improvements in life expectancy and reductions in mortality thus increasing the population health stock (Cervellati and Sunde, 2009). Better education is expected to result in increased utilization of health care services and knowledge of preventative measures to maintain health and thus is anticipated to raise the stocks of population health (Hahn and Truman, 2015). Access to clean water is associated with reductions in common infectious diseases in the region such as diarrhoea and typhoid. Therefore, access to clean water is expected to improve population health (Hunter et. al, 2010, Cha et al, 2015). Access to sufficient amounts of food is considered as a preventative measure to maintain individual health. Thus, food availability is expected to be positively associated with the population health stock (Fogel, 1994). Political institutional quality is associated with the efficacy of health policy particularly in the use of evidence to inform policy decisions (Liverani, Hawkins and Parkhurst, 2013). Increased health expenditure is expected to lead to improvements in the health stock of the population due to the availability of financing for drugs, medical personnel, medical equipment as well as the implementation of programs and initiatives aimed at improving population health (Novignon, Nonvignon and Arthur, 2015).

3. ***Alcohol consumption, urbanization and the HIV prevalence rate each have a negative and significant impact on life expectancy***

Alcohol consumption is expected to have a negative impact on the health status of the population. Excessive alcohol consumption is associated with a shorter life expectancy as it increases the risk of contracting non-communicable diseases such as cancer and cardio vascular diseases. Also, increased alcohol consumption in women has been associated with increases in the risk of infant mortality (WHO, 2018). The prevalence of HIV is also expected to negatively impact life expectancy as the illness reduces an individual’s life span. It is however expected to have a positive impact on infant mortality due increased chance of infection and subsequent mortality for infants (Mba, 2008). Urbanization is expected to have a negative impact on population health as most urban areas in the region are characterised by slum dwellings and unplanned settlements that are incubators of infectious diseases (Neiderud, 2015).

1.5 Significance of the Study

The contribution of the study to existing empirical literature is twofold. Firstly, to the best of my knowledge, the study is the first to use a dynamic panel data estimator to highlight the difference in the short-term and long-term impact of health stocks - life expectancy and infant mortality on economic growth for the SSA region. The method is preferred to other econometric methods because it addresses the problem of endogeneity using lagged values as instruments. This reduces the likelihood of bias and inconsistency in the estimators making the results of the estimation more robust. Secondly, the study introduces the concept of health care quality in determining both population health and economic growth. While health care quality has been represented in literature on determining the factors that influence population health, it has not been included as an additional determinant of economic growth. Moreover, it has been absent in most of the studies on health and economic growth in the region. The study therefore aims to fill these gaps with its analysis. Also the study explores the factors that influence population health in the region using two measures of health. This is done in an effort to better understand the relationship from economic growth to population health.

Knowing the magnitude of the impact of population health on economic growth will enable policy makers to efficiently allocate resources to the health sector as they strive to achieve specific growth targets. Correspondingly, understanding the extent to which different factors influence population health could serve as a guide for policy makers in terms of what areas to target if they are to improve overall population health and subsequently economic growth rates. It may very well be that environmental factors such as water and sanitation and lifestyle factors such as alcohol consumption play a much more important role in improving population health and would thus require more investments in preventative efforts if better population health is to be achieved. Additionally, accounting for the quality of health care and its impact on both population health and growth would allow for a better understanding on what healthcare quality improvements would be necessary to raise both the levels of population health stock and economic growth.

1.6 Organization of the Dissertation

The remainder of the Dissertation is organized as follows: Chapter 2 gives a brief outline of the Sub Saharan Africa context, Chapter 3 reviews theoretical framework whereas Chapter 4 reviews the existing literature, that is, cross country studies and single country studies. The methodology and data sources are discussed in Chapter 5. Chapter 6 summarises the main results and findings and Chapter 7 discusses these findings. Finally Chapter 8 concludes the study and provides policy recommendations.

CHAPTER 2

CONTEXT OF THE STUDY

2.1 Trends in Economic Growth for Sub Saharan Africa

As most countries in SSA became liberated from colonialism in the 1960's, their economies were relatively stable and held a lot of potential for growth. By the late 1970's however, a greater proportion of countries began to experience social, economic, political and governance crises. The two oil shocks of 1973 and 1978 left the majority of SSA countries unable to sustain growth momentum in the 1980s (Sundaram, Schwank and von Arnim, 2011). As a result, the region experienced its worst economic performance recorded in the 1980s, leading the decade to be dubbed the 'lost decade' for SSA. Despite the efforts made by the IMF and the World Bank to revive SSA economies through the structural adjustment programmes, the regions' economies recorded little improvement (Heidhues and Obare, 2011). Consequently, the poor economic performance carried over to the 1990's that were characterised by stagnation in industrial production (Jerven, 2016).

By the mid to late 1990s a few countries in SSA began to again experience some economic growth momentum (*Figure 1)*. Subsequently, the early 2000s were characterised by an 'African economic boom' with GDP growth rates in countries like Angola, Ethiopia and Mauritania rising to over 10 percent in 2004 (World Bank Group, 2017). This rise in GDP growth was largely attributed to factors including higher commodity prices, improved macroeconomic policy, technology advancements, better social policy and quality of governance, urbanization as well as substantial flows of foreign aid (Bhorat and Tarp, 2011). More recently however, economic growth in SSA has been gradually declining. As depicted in *Figure 1*, the GDP growth rate for the region went from a peak of 11.in 2004 to around 1.4 percent in 2016 which represented the worst economic performance of the region in two decades. Despite the recent trend, growth in the region is forecast to pick up to 2.6 percent in 2017 and average at 3.4 percent by 2018 (IMF, 2016)

Figure 1: Trend in GDP growth rates in Sub Saharan Africa*[1]*, 1982-2016

Source: World Bank Data, 2016

Clearly, GDP growth in SSA has been unstable and unsustainable over long periods and future projections do not necessarily portray a picture of stability in growth trends (IMF, 2016). Most countries in SSA still show volatile growth rates with some years having very high GDP growth rates and others extremely low and sometimes negative growth rates (World Bank Group, 2017)

2.2 Trends in Health Indicators for Sub Saharan Africa

Over the past 25 years, health indicators in SSA have improved considerably. Under-five mortality, maternal mortality and HIV incidence rates reduced by 120 percent, 49 percent and 50 percent respectively between 1990 and 2015 (United Nations, 2015). Immunization coverage for routine vaccines such as Diphtheria-Tetanus-Pertussis (DTP) has also improved substantially, rising by close to 20 percent between 2000 and 2015 (Mihigo *et al.*, 2017)

Despite these improvements, communicable, maternal, nutritional and new-born diseases continue to dominate as the leading causes of death in the region (World Health Organization, 2016). Compared to other regions, SSA has consistently had the lowest life expectancy and the highest levels of infant mortality in the last 30 years (*Figure 2 and 3*). In 2015, Sub-Saharan Africa's

[1] Without High income countries

average life expectancy was 59 years which was the lowest of all world regions (World Bank, 2017). Both indicators have also been far below the world average in the same period.

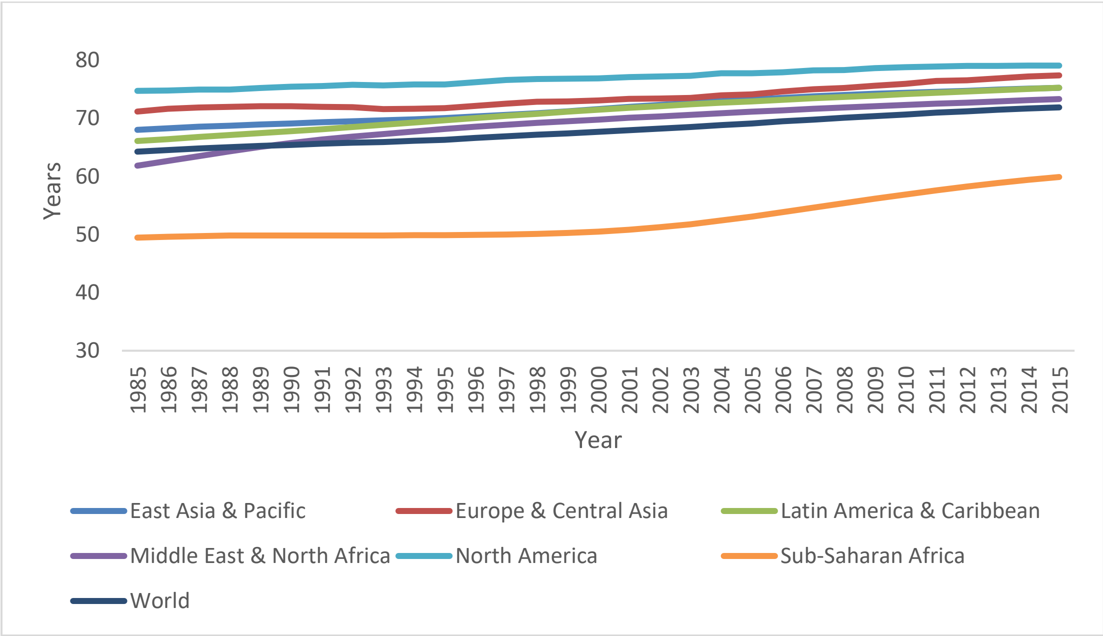

Figure 2: Life expectancy for several regions between 1985 and 2015

Source: World Bank Data (WDI data), 2017

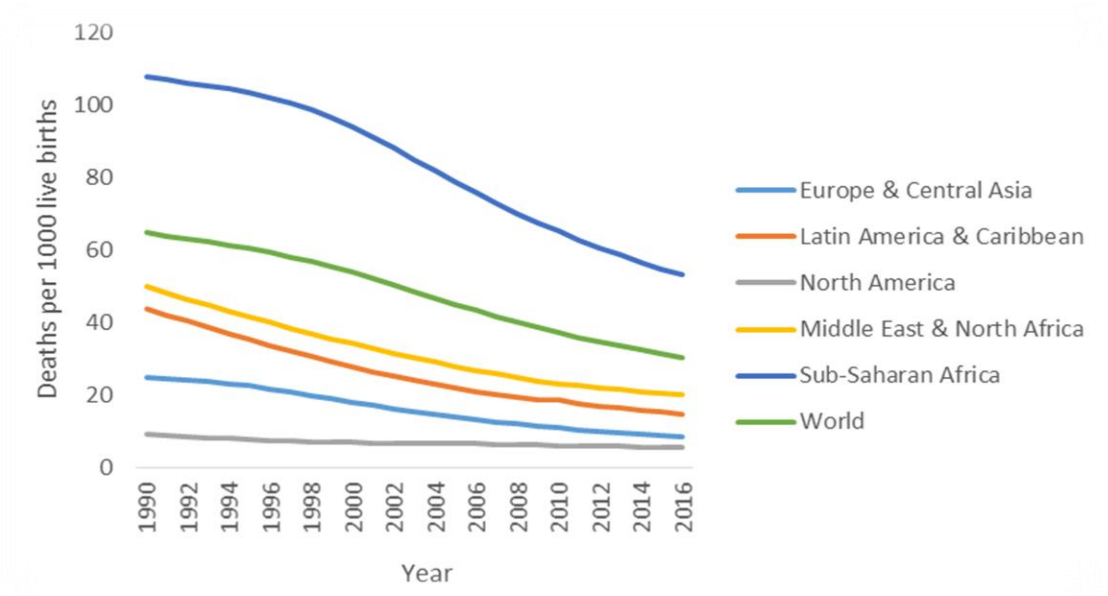

Figure 3: Infant Mortality for Several Regions between 1990 and 2016

Source: World Bank Data (WDI data), 2017

In 2014, SSA accounted for 90 percent of malaria deaths, 70 percent of all people living with HIV and 25 percent of all TB cases (World Health Organization, 2014). This is particularly worrying because HIV, malaria and TB impose indirect health costs on individuals as they tend to affect people in their most productive years and thus contribute negatively to human capital development (Russel, 2004). Annually, malaria alone costs an estimated $12 billion in lost wage earnings across Sub-Saharan Africa (Featherson and Ferreira, 2017).

Aside from the already high disease burden due to communicable diseases, SSA has a growing burden of non-communicable diseases (NCDs). Deaths due to NCDs in SSA rose by 46 percent between 1990 and 2010, with projections indicating that by 2030, NCDs will account for close to half of all deaths in the region (Mathers and Loncar, 2006; Naghavi and Forouzanfar, 2013). This not only worsens health outcomes in the region, it exerts pressure on the health systems in SSA which are ill equipped to handle the double burden of communicable and non-communicable diseases (Maher, Smeeth and Sekajugo, 2010; Mthuli Ncube, Aly Abou-Sabaa, 2013)

An often overlooked indicator of health is the quality of health care arising from existing health systems. Relative to the rest of the world, the health care systems in SSA are among the poorest in the world (Africa Health Forum, 2013). The majority of SSA countries lack the infrastructure, facilities and medical personnel to deliver even minimal levels of health services and product (Africa Health Forum, 2013).

Even though healthcare quality indicators such as physician density in SSA increased threefold between 1990 and 2012, the region accounts for only 4 percent of the world's health work force, pointing to the acute shortage of medical professionals in the region (World Health Organization, 2014). Furthermore, the quality of health care provided in the region is perceived as the worst in the world (Deaton and Tortora, 2015). Not only is wellbeing in the region ranked as the lowest in the world, people in the region also have the least satisfaction with their health care system (Deaton and Tortora, 2015).

The poor quality of health care in SSA could be attributed to low public health expenditures. The majority of SSA countries generally have the lowest overall health care expenditures in the world. Despite per capita health expenditure rising from US$32.8 in 2000 to US$98.2 in 2015, average per capita health expenditure in the region was just a fraction of the $3150 per capita spent in high income countries (WHO, 2016). In response to this, there has been increasing advocacy for more financial investment into the health sector. A key example of this is the Abuja Declaration of 2001, a pledge signed by various African countries to have at least 15 percent of their total annual budget reserved for the health sector (WHO, 2001). This emphasis on increased spending on health care has stirred debate on the effectiveness of health expenditure in the region. The debate raises additional questions such as 'Do investments in the health sector actually translate into gains in population health and economic growth for the SSA region and if so how significant are these gains?'

Although regional public spending on healthcare is very low on average, health care financing varies widely among countries in Sub Saharan Africa. Public expenditure on health is about 8 percent of GDP in countries like Lesotho and Rwanda whereas many SSA countries continue to spend far less. Cameroon and Nigeria, for example, spend less than 1 percent of their GDP on health (African Development Bank Group, 2015). Generally, health expenditure remains below the 15 percent of government spending threshold prescribed under the 2001 Abuja Agreement.

2.3 The Relationship between Health and Economic Growth

Considering that health is a key component of labour force productivity (Grossman, 1999), it is anticipated that countries with better health outcomes will have higher levels of per capita income. In Sub-Saharan Africa, countries such as Mauritius, Gabon, Botswana and the Seychelles which had higher per capita income also had a higher life expectancy (*Figure 4*). This points to a potentially positive macroeconomic relationship between the two variables.

Determining the macroeconomic relationship between health and its investments (e.g., health expenditure) on economic growth however, comes with three main challenges. Firstly, there is possible bidirectional causality between health and economic growth (Smith, 1999), with the relationship between health and economic growth considered as endogenous. Secondly, health is a multi-dimensional concept which makes it is difficult to obtain comparable indictors that measure all the different dimensions of population health (Bloom et al., 2008). This is especially true for Sub-Saharan Africa as the region has poor data on health indicators (Deaton and Tortora, 2015). Previous studies have focused on representing population health in terms of health stocks such as life expectancy and child mortality and investments into health expressed by annual public expenditures on health. Very little consideration has been given to the quality aspect of health, particularly the quality of health or health care services.

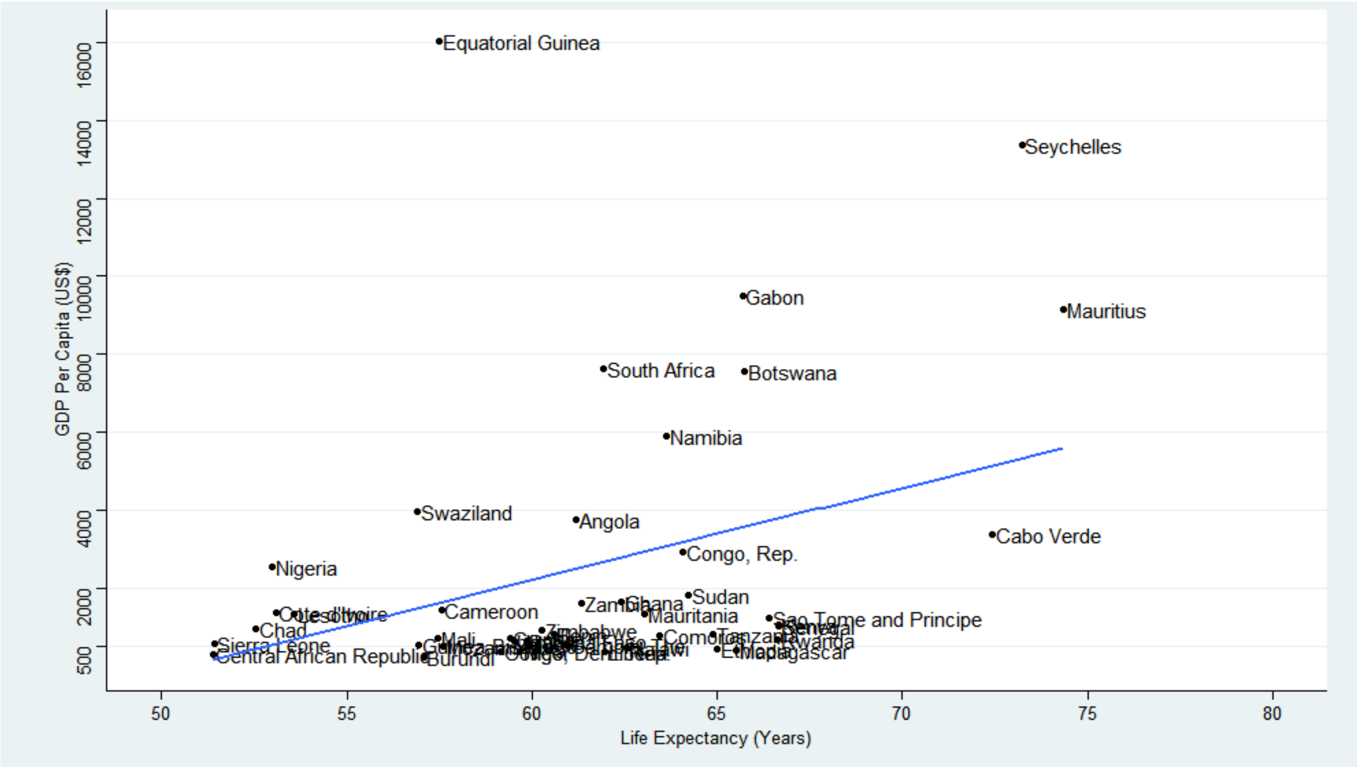

Figure 4: Life Expectancy against GDP Per Capita for Sub Saharan African Countries in 2016 - *Source: World Bank WDI 2016*

Thirdly, the impact of health on economic growth may vary over different time periods (Weil, 2014). There is growing evidence that health influences growth in the long term, since child and maternal health serves as a precursor to an adults cognitive and physical abilities which ultimately determines their productivity (Victora *et al.*, 2008; Nandi *et al.*, 2017). Therefore, the macroeconomic effects of health on economic growth may have significantly long time lags. This necessitates a long term analysis of the relationship between health and growth (Bloom David Canning et al., 2008).

CHAPTER 3

THEORETICAL FRAMEWORK

The theoretical framework section will give a brief overview of the health production and growth models that the study is based on. The aim of this section of the research is not necessarily to provide an exhaustive overview of all theories involving health and growth but instead, it will focus on the theories that have had the most significant impact on the reviewed empirical literature.

3.1 Health Production Model

The determinants of population health can be modelled from Grossman's health production model. In his 1972 paper titled '*The Human Capital Model of the Demand for Health'*, he made use of human capital theory to derive the demand for health and health care. It is this initial work and later extended models that help to explain relations such as the health production function and how it is determined by external factors (Shultz, 2004). Here we focus on the health production model.

To derive an aggregate health production function, we begin from a micro model of household utility where utility is expressed as;

$$U = f(H, Z) \qquad (1)$$

The stated equation implies that the household derives utility (U) from consumption of goods and services (Z) and on its stock of health capital, (H). We assume that both consumption and health capital have positive marginal utilities such that;

$$\frac{\partial U}{\partial H} > 0,\ \ \frac{\partial^2 U}{\partial H^2} < 0\ \ and\ \frac{\partial U}{\partial Z} > 0,\ \ \frac{\partial^2 U}{\partial Z^2} < 0 \qquad (2)$$

Now suppose that a central planner would like to maximise the utility of the household over two periods with respect to health capital and consumption. We specify a simplified Grossman model derived from Zweifel and Johnson (2009) to express a household utility equation for two periods. Let H_0 and Z_0 denote initial health capital and consumption and H_1 and Z_1 denote health capital and consumption in period 1 respectively. To this we add some assumptions;

- The household spends time equal to t^s in ill health, which is reduced the higher H is.
- The household gets disutility from the time spent in ill health.

- The utility and preferences are time independent

With this we define our utility over the two periods as;

$$U = f[t^s(H_0), Z_0] + \beta f[t^s(H_1), Z_1] \quad (3)$$

Where β is the discount factor for utility in the next period and the following marginal effects hold;

$$\frac{\partial U}{\partial t^s} < 0, \quad \frac{\partial^2 U}{\partial (t^s)^2} > 0, \quad \frac{\partial (t^s)}{\partial H} < 0 \quad (4)$$

The important feature with of the Grossman model with regards to health capital is concerned with the health investment model that defines the change in the households' health stock between the two periods. The model is expressed as;

$$H_1 = H_0(1 - \delta) + I(M_0, t^I) \quad (5)$$

Where; δ denotes depreciation of health capital, I represents investments into health capital that are a function of medical services (M) in the initial period and time spent on preventative efforts to maintain health, t^I[2]. Further, we expect that the marginal effects of M and t^I on I are as follows;

$$\frac{\partial I}{\partial M} > 0, \quad \frac{\partial^2 I}{\partial M^2} < 0, \quad \frac{\partial I}{\partial t^I} > 0 \quad \frac{\partial^2 I}{\partial (t^I)^2} < 0 \quad (6)$$

To set up this household's utility maximization problem we add a few more assumptions;

- Savings from initial period consumption are available in the next period. These savings accumulate interest such that total savings equal RS_0 where R = 1+r, r being the rate of interest
- Expenditure on medical services (p (cost of medical services) *M) is financed out of labour wage (w_0) and initial wealth (A_0)
- Consumption in both periods is positive and time available in both periods is normalized at 1

After discounting to the present value, the following budget constraint holds;

[2] Depreciation is assumed to be constant but it may depend on other factors such as environment and lifestyle factors. See Zwiefel et al (2009)

$$A_0 + w_0(1 - t^s(H_0) - t^I) + \frac{w_1(1-t^s(H_1))}{R} = pM + cZ_0 + \frac{cZ_1}{R} \quad (7)$$

Where c represents the price of consumption. The household utility maximization problem is thus expressed as;

$$L(H_1, t^s, M, Z_0, Z_1) = U[t^s(H_0), Z_0] + \beta\, U[t^s(H_1), Z_1] + \mu\, [H_0(1-\delta) + I(M_0, t^I) - H_1] +$$
$$\lambda\, [A_0 + w_0(1 - t^s(H_0) - t^I) + \frac{w_1(1-t^s(H_1))}{R} - pM - cZ_0 - \frac{cZ_1}{R}] \quad (8)$$

We however want to focus on the amount of health capital that the household chooses optimally to maximize utility. First, suppose our investment function is a Cobb Douglas function given by;

$$I = M^{\alpha_M}(t^I)^{1-\alpha_M} e^{\alpha_E E} \quad (9)$$

Where E is education that serves to magnify the effects of medical services M and time spent in favour of health (t^I). Also, α_M and $1 - \alpha_M$ are the production elasticities of M and (t^I), whereas α_E is the effectiveness of education in the investment model. We then specify how sick time depends on health capital and represent this as;

$$t^s(H_0) = \theta_1 H_1^{-\theta_2}, \quad \text{where;} \quad \theta_1 > 0, \quad \theta_2 > 0 \quad (10)$$

With these modifications and some derivations, we end up with the following model of the demand for health capital;

$$\ln H_1 = \varphi - \varepsilon\alpha_M \ln p + \varepsilon\alpha_M \ln w + \varepsilon\alpha_M E \quad (11)$$

Where φ is a constant, ε is the marginal efficiency of health capital and $w = w_0 = w_1$. This implies that increases in the price of medical services p increases the cost of investment into health and this is associated with a decline in health capital. Similarly, increases in the wage earnings and education of the household raise investments into health capital and are associated with increased health capital.

For our estimation of the model on a macro scale, we will adopt the above model transposed to the macroeconomic level as expressed by Fayissa and Gutema (2005). It is represented as a double log linear production function and stated as;

$$\ln H = \ln\varphi - \sum \alpha_i (\ln Y_i) + \sum \beta_j (\ln S_j) + \sum \gamma_k (\ln V_k) \quad (12)$$

Where *ln H* represents the log of population health status, Y_i represents the vector of per capita economic variables, S_j is the vector of per capita social variables and V_k is the vector of per capita environmental factors. φ is an estimate of the initial health stock and β, α and γ represent elasticities.

3.2 Economic Growth Model

The study will adopt an extended neoclassical growth model that draws from the work of Mankiw Romer and Weil (1992), Lucas (1988) and Knowles and Owen (1995). In their influential contribution, Mankiw Romer and Weil (1992) introduced human capital into the standard Solow growth model by letting human capital enter as a separate input into a standard Cobb-Douglas production. Knowles and Owen (1995) extended the Augmented Growth model by breaking down the human capital component into education and health capital respectively. Generally, the model can be expressed as;

$$Y_{it} = A_{it}K_{it}^{\alpha}E_{it}^{\beta}H_{it}^{\varphi}L_{it}^{\gamma} \tag{13}$$

Where Y is real output, K is the stock of physical capital, E is the stock of educational human capital, H is the stock of health capital, L is the labour input and A is the level of technology. The exponents, α, β, γ and φ measure the elasticity of the output relative to their respective inputs. The subscripts *i* and *t* represent country *i* and period *t* respectively. We can rewrite equation (13) in per capita terms as;

$$y_{it} = A_{it}k_{it}^{\alpha}e_{it}^{\beta}h_{it}^{\varphi}L_{it}^{\gamma+\alpha+\beta+\varphi-1} \tag{14}$$

Where, $y_{it} = {}^{Y_{it}}/_{L_{it}}, \quad k_{it} = {}^{K_{it}}/_{L_{it}}, \quad e_{it} = {}^{E_{it}}/_{L_{it}}, \quad h_{it} = {}^{H_{it}}/_{L_{it}}$

We further assume that labour and physical capital grow exogenously such that;

$$L_{it} = L_{i0}e^{n_i t} \tag{15}$$

$$A_{it} = A_t = A_0e^{gt} \tag{16}$$

Where $\boldsymbol{n}$ is the exogenous rate of growth of the labour force in country $\boldsymbol{i}$ and $\boldsymbol{g}$ is the exogenous growth rate of technology. Taking logs on both sides of equation (14) we establish a model that can be expressed as;

$$\ln y_{it} = \ln A_{it} + \alpha \ln k_{it} + \beta \ln e_{it} + \varphi \ln h_{it} + (\gamma + \alpha + \beta + \varphi - 1) \ln L_{it} \quad (17)$$

Substituting equation (15) and (16) into equation (17) and following a growth accounting framework we arrive at the equation;

$$\Delta\ln(y_{it}) = g_t + \alpha\, \Delta\ln(k_{it}) + \beta\, \Delta\ln(e_{it}) + \varphi\, \Delta\ln(h_{it}) + (\gamma + \alpha + \beta + \varphi - 1) n_{it} \quad (18)$$

Equation (18) can be written in regression form as;

$$\Delta\ln(y_{it}) = g_t + \beta_{i1}\, \Delta\ln(k_{it}) + \beta_{i2}\, \Delta\ln(e_{it}) + \beta_{i3}\, \Delta\ln(h_{it}) + \beta_{i5} n_{it} + \boldsymbol{\beta X}_{it} + \varepsilon_{it} \quad (19)$$

Where X denotes all the additional variables that affect the growth rate of per capita output and ε_{it} represents the error term that is iid $(0,\sigma_{\varepsilon}^{2})$.

The model implies that economic growth is influenced by the rate of accumulation of the factors of production, that is, education capital, health capital and physical capital. Focusing on the impact of health capital on economic growth, we see from equation (17) that φ measures the technical contribution of health to economic growth. Thus, increased accumulation of health stocks will increase economic growth by raising the levels of per capita output.

The increase in health stocks, as seen from the empirical literature reviewed usually refers to the increase in life expectancy or a decrease in mortality rates. However, as was expressed in the health production model, investments into health care in the form of health expenditure are also associated with the accumulation of population health and could directly affect growth rates. Similarly, as expressed by Banergee, Deaton and Duflo (2004) and Head et al (2015), health care quality is an essential factor for health capital accumulation and subsequently economic growth. Overall, the expression of the growth model allows for direct econometric estimation and provides rationale for the inclusion of additional variables.

CHAPTER 4

LITERATURE REVIEW

This chapter provides an overview of the empirical literature concerning the relationship between health and economic growth. It serves as a guide in terms of expected outcomes and suitable variables and proxies to be used in the empirical analyses. The empirical literature review surveys both single and multi-country studies that determined the relationship between economic growth and health. It also gives a brief outline of studies that estimated the determinants of population health in multiple countries, highlighting the relative importance of each factor in each study.

4.1 Empirical Literature Review

The concept of health as a determinant of economic growth is by no means recent in economic literature. However, the inclusion of health in the growth models became more popular in the mid to late 90's with studies by Barro, Knowles and Owen, and Barro and Sala-i-martin (Knowles and Owen, 1995; Barro, 2013). The rationale for this was that the general acceptance of human capital formation as a source of economic growth necessitates a closer look at how changes in the health-state of the population may influence growth and total welfare (Schultz, 1999). Since the early 2000s, more rigorous studies on the relationship between health and economic growth have emerged whose results, as will be seen, have been generally mixed.

4.1.1 Health and Economic Growth

4.1.1.1 Cross Country Studies

In arguably one of the most important recent empirical literature on health and economic growth, Bloom *et al.* (2004) investigated the relationship between health and economic growth for a period between 1960 and 1990 for 104 countries, with observations expressed in 10 year averages. The study focused specifically on the impact that health has on labour force productivity. As such, the study incorporated measures for input productivity and technological diffusion as well as a measure for work experience to control for its effects across countries. Using a production function model of economic growth and a nonlinear least squares regression approach, the study found that health measured by life expectancy had a positive and significant impact on aggregate output measured by per capita GDP even when the work experience of the labour force was controlled for (Bloom, Canning and Sevilla, 2004). Specifically, the study found that each extra year of life expectancy raised the productivity of workers and led to an increase of 4% in output. One of the drawbacks of this study however is that it only used one measure of population health, which may have influenced the findings of the study. Also, the study did not fully address problems that might have arisen due to endogeneity in the model from the health measure. Lastly, the study did not control for the quality of either health or education in its analysis, representing a gap in the estimation.

Using a much smaller sample of countries, Mayer (2001) sought to determine the long term impact of health on economic growth for 18 Latin American countries over a 40 year period. Using the generalised least squares method with the probability of survival between several age groups as a measure of population health, Mayer found that health, had a positive and significant impact on economic growth in Latin America. The study included up to 30 lags for the health measure. He also found that there exists a long term conditional granger causality from health to income and the impact of health on income was greatest for the age groups between 50 and 75. Male and female young adult's health increments of the 1950s were associated in the long term with income growth rates of between 0.8% and 1.1 %. By comparison, the growth associated with the health increments of the older segment of the population was between 1.2% and 1.6%. This signalled that the income effect of health differed significantly by age group (Mayer, 2001).

Taking an instrumental variable approach, Acemoglu and Johnson (2007) conducted a study to determine the effect of changes in life expectancy on economic growth for a sample of 59 countries over a 40 year period (between 1940 and 1980). Using estimates of mortality before the 1940s, they constructed an instrument for changes in life expectancy called 'predicted mortality'. The measure was meant to capture the distribution of mortality prior to the innovations in medicine and public health that led to significant improvements in life expectancy post 1940. The study found that the instrumented life expectancy had a very small and negative impact on economic growth both in the short run and over a 40-year period. They thus concluded that there was no evidence to support the hypothesis that large increases in life expectancy led to a significant increase in per capita GDP growth in that period. Like Bloom et al (2004), the quality of the healthcare was not controlled for. Also, like Mayer (2001) the use of a single measure of health (life expectancy) even though instrumented may have meant that the findings of the study were dependent on the measure of health used.

Focusing on health as a component of human capital, Gyimah-Brempong and Wilson (2004) conducted a study to investigate the effects of health human capital on the growth rate of per capita income in SSA and OECD countries. The study made use of panel data from 21 SSA countries over a 20-year period and 22 OECD countries over a 35-year period, both datasets were averaged in 4 year periods. The study adopted the Generalized Method of Moments dynamic panel data (DPD) estimator and proxied health stock with child mortality and life expectancy at birth. Investments into health capital were represented by health expenditure as a percentage of GDP. The study found that the stock of health capital had a positive and significant effect on per capita GDP growth in both OECD and SSA countries. Specifically, the findings indicated that at the mean of health stocks, about 22% of the average growth rate of per capita income in SSA countries could be attributed to health. This effect was further established to be quadratic with a diminishing marginal effect at higher levels of life expectancy. Investments into health also had a positive and significant impact on per capita GDP growth in both OECD and SSA countries (Gyimah-Brempong and Wilson, 2004).

Taking special focus on the Sub Saharan African region, Ogunleye (2014) set out to establish the determinants of health outcomes in SSA countries using the health production technique and, in turn, verifying the impact of health stock on economic growth in the region. The study used data from 40 countries for a period between 1980 and 2007 in 5-year intervals. Due to the nature of the study objectives, the study had two empirical models, one for economic growth and the other for health production. Like Gyimah-Brempong and Wilson (2004), the study used the Dynamic GMM estimation technique with child mortality and life expectancy as proxies for health outcomes and GDP per capita representing growth. The health stock variables were lagged by 20 years to account for the delayed effect of health on economic growth. The study found that all health variables had a positive but insignificant effect on growth but growth had a significant impact on both measures of health. These findings are consistent with Acemoglu and Johnson (2006) whose health stock variable had an insignificant impact on growth.

In another study done for the Sub Saharan African region, Eggoh et al. (2015) used data from 49 African countries for the period between 1996 and 2010 to compare the relative impact of human capital indicators (health and education) and their interaction with economic growth. The study used two kinds of estimators, (Ordinary Least Squares) OLS estimators for the cross-sectional analysis and the (Generalized Method of Moments) GMM system estimators on panel data for short run dynamics. The indicators for health and education were divided into stock and investment variables. Economic growth was measured by per capita real GDP growth and the health component was estimated using Life expectancy at birth, Survival to age 65 as a percentage of a cohort (stock) and health expenditure as a percentage of GDP (investment). The study found that health expenditure was not significantly related to growth. The study also found that despite not being significant on their own, education and health expenditures were complements.

Of the three studies done on the Sub Saharan African region, none have explicitly compared the difference in the impact of health in the short term and the long term. Additionally, no efforts were made to control for the quality of either health or education in their analyses representing a gap in the analysis.

The preceding literature reviewed provides some important insights for the study. Firstly, most of the studies find that health outcomes such as life expectancy have a positive and significant impact on economic growth except for Acemoglu and Johnson (2006) and Ogunleye (2014) who found that life expectancy was insignificantly related to growth. While investments into health measured by health expenditures generally had a positive and significant impact on economic growth, Eggoh et al (2015) found that the converse was true for their sample of 49 African countries. None of the studies on growth incorporated the impact of health care quality in their analysis. Also, only Ogunleye (2014) and Mayer (2001) estimated the long term impact of health on growth by including lags for the health measure in their analyses. This leaves room for further insight on short and long term dynamics of health for cross country studies. While the overall research findings on the relationship between health capital and growth have been mixed, the majority of the studies reach the consensus that health is an important and significant determinant of economic growth.

4.1.1.2 Single country Studies

Prior to his multi country study on the impact of health on growth in Latin America, Mayer (2000) estimated the long term impact of economic growth for Mexico during the period between 1950 and 1990. The study used life expectancy, mortality by age groups and infant mortality as health measures. While age specific mortality rates had between 5 and 25 year lags, life expectancy was only lagged up to 20 years. Mayer found health measured by both life expectancy and age specific mortality had a significant impact on economic growth rates for Mexico. This impact was greater among adults and for greater lag lengths of the health measure, pointing to the stronger impact of health for the working age population and over a longer period of time. The study further concluded that there was bi-directional causality between health and economic growth since income was found to be a significant determinant of health.

Using a simultaneous equation approach, Babatunde (2003) estimated the relationship between health and economic growth for Nigeria using annual data spanning the period between 1997 and 2008. He used life expectancy at birth, health expenditure, the death rate and the mortality rate as measures of population health and estimated the economic growth and health functions simultaneously using Three Stage Least Squares (3SLS) estimation. He found that for the period under consideration, all the health measures except for health expenditure had a significant impact on economic growth. He also found that there was two way causality in the relationship between health and economic growth for Nigeria (Babatunde, 2003).

Taking a different methodological approach, Akram et al (2008) conducted a study to investigate the short term and long term impact of health on economic growth in Pakistan for the period between 1972 and 2008. Using infant mortality and life expectancy as measures of population health, GDP per capita as a measure of economic growth and employing a Vector Auto regressive Cointegration, approach he found that both health measures did not exhibit any significant short term relationship with economic growth. However, life expectancy and infant mortality both had a significant long term impact on economic growth in Pakistan (Akram, Padda and Khan, 2008). Similarly, using an ADRL approach, Boachie (2015) found that there was a significant long term relationship between life expectancy and economic growth in Ghana for the period between 1982 and 2012. Unlike Akram et al (2008) however, he found that the short term relationship between life expectancy and growth was also significant (Koki Boachie, 2015).

Overall, the single country studies reached the consensus that there is a long term relationship between health and economic growth. However, these studies are not without their shortcomings. Aside from Babatunde (2003), the studies did not adequately address the problem of endogeneity in their analyses. Further, not much effort was made to control for the influence of health care quality or investments into health care representing a gap in the analyses. The studies did however use multiple health measures and most included education as one of the control variables in their analyses.

4.1.2 The Impact of Economic growth and other determinants on health

As earlier alluded to in the background, there is likely two-way causality between health and economic growth making it possible for the two to be determined simultaneously. There is a rich body of literature that analyses the impact of several social, economic, and environmental factors on population health in different individual countries and regions mostly from the developed world. However there is a paucity of studies specifically focused on countries in the Sub Saharan African region.

Generally, the literature analysing the determinants or main influences of health focuses on four broad areas; personal factors, social factors, environmental factors and economic factors (WHO, 2014). Invariably, income is considered as one of the most important economic determinants of personal health. This has been well established in microeconomic literature and expressed explicitly in Grossmans theory of human capital model (Grossman, 1999). On a macro level, increases in national income have been linked to improved health outcomes of the population. Auster, Leveson and Saracheck (1969) in their influential study in the United States found that increases in income significantly reduced mortality rates. This relationship between income and population health was further confirmed by studies by Preston (1976), Anand and Ravallion (1993) as well as Pritchett and Summers (1996) among others.

In more recent literature, environmental factors such as access to safe drinking water and sanitation and carbon emissions have increasingly been associated with the overall health status of the population. Kamiya (2010), Kabir (2008) and Gulis (2000) all conclude that access to safe water contributes positively to improved population health particularly for developing countries. Not surprisingly, carbon emissions and pollution have however been negatively associated with health measures like life expectancy and infant mortality in developing countries (Ogunleye, 2014; Fotourechi, 2016).

With the rise in the global burden of non-communicable diseases, more empirical studies began to link lifestyle factors to the levels of overall population health status. Chouquet and Ledoux (1989) as well as Shaw et al. (2005) show that alcohol consumption and smoking tend to have a negative impact on the health outcomes of the population. Further, Shaw et al (2005) demonstrates that the consumption of vegetables is positively related to life expectancy for OECD countries. Similarly, food availability and nutrition have been associated with significant improvements in the health status of the population. Fogel (1994) found that nutrition and food availability were major determinants of population health in Europe whereas Shabaz et al (2015) found that food availability had a positive and significant impact on life expectancy in Pakistan.

In terms of the social factors related to health status, higher levels of education have been associated with longer life spans and reduced risk of death for adult populations in both developed and developing countries. Shen (1999) argued that education had a significant impact on life expectancy through increases in productivity and income that in turn led to a greater impact on health. Williamson and Boehmar (1997) on the other hand, found that education had a positive impact only on female life expectancy. More recent studies find overwhelming evidence that better education is associated with improvements in health status. For instance Hahn and Truman (2015) find that even increases in the basic levels of education lead to better population health outcomes.

Developing regions like sub-Saharan Africa are urbanizing rapidly. Subsequently, urbanization, has been found to be one of the core environmental factors linked to population health in both developed and developing countries. Empirical literature shows that the impact of urbanization could either be positive or negative. For instance, Kaldiene and Petrauskiene (2000) argue that urbanization has a positive impact on health in both developed and developing countries because urban populations tend to have better access to medical facilities, education as well as other socioeconomic infrastructure. Scwarcwald (2000) on the other hand found that urbanization had a negative impact on health outcomes in Brazil as urban populations are more prone to the spread of communicable diseases. Fayissa and Gutema (2005) found that urbanization was positively related to life expectancy in Sub Saharan Africa.

Health delivery and quality as well as health expenditure contribute greatly to the health status of the population. Public expenditure has been found by several studies in both industrialized and low-income countries to be positively and significantly related to population health (Filmer and Pritchett, 1999; Jaba et. al., 2014; Linden and Ray, 2017). Higher health expenditure could translate into more initiatives, programmes targeted at improving health care. More expenditure on health also means better financing for health care related costs such as medical personnel and equipment, drugs and medication, as well as infrastructure.

While health expenditure may provide resources for the health sector, institutional quality plays an important role in how those resources are utilized for better health. Consequently, institutional quality is an important factor in the quest to achieve better health outcomes. This is largely because institutional quality is likely to impact budget allocation to the health sector and also affect how allocated funds are used to implement policies and projects related to health care (Bousmah et al, 2016). Bousmah et al (2016) finds evidence that increases in health expenditure lead to increases in health outcomes in MENA countries only when they are coupled with high quality political, legal and economic institutions.

Measures of health care quality such as vaccination coverage as well as physician density also tend to have a positive impact on health. As such, Banergee, Deaton and Duflo (2004) point out that low quality health care eventually leads to poor health outcomes. Similarly, Head et al. (2015) find that life expectancy in non-industrialised countries in the East Mediterranean region was significantly related to vaccinations and physician density. Contrary to Head's findings, Kamiya (2010) found that immunisation coverage; number of physicians per 1000 people and skilled birth attendants did not have a significant impact on child mortality in study done on 141 developing countries. This shows that measures of health care quality can yield mixed results depending on the measure used.

Specific diseases or illnesses that have had a major impact on population health can also be included among the determinants of health in the region. HIV/AIDS has had a significant and negative impact on the life expectancy for most countries in Sub Saharan Africa. In 2005, Sub Saharan Africa, particularly southern Africa accounted for close to 80 percent of the global HIV disease burden, which when coupled with already existing health issues in the region had devastating effects on the life expectancy of the population (Mbuop et al., 2006). Mba (2007) in a study to determine the impact of HIV/AIDS on life expectancy found that a gain of 26 years in terms of life expectancy would have been realised in the absence of HIV/AIDS in South Africa.

Other studies like those of Ntozi and Nakanaabi (1997) as well as Hanmer and Naschold (2001) found that HIV/AIDS had a negative impact on infant and child mortality in Uganda and other developing countries respectively.

From the literature on the determinants of population health, it can be seen that income, education environmental factors such as access to water and carbon emissions, health quality and health delivery measures, urbanization as well as food and nutrition are among the main determinants of population health in developing countries. Findings for all these factors have however been mixed. Overall the literature on the determinants of health implies that population health determinants largely depend on the characteristics of countries under investigation.

CHAPTER 5

METHODOLOGY AND DATA

The following chapter will give an outline of the data sources the study will employ as well as a brief description of the estimation technique and the variables included in the estimation models. It will also highlight the econometric application of the theoretical models introduced in Chapter 3.

5.1 Research Design

The study is quantitative in nature thus we employ a non-experimental research design, using an analytic approach and secondary quantitative data.

5.2 Model Specification and Estimation Technique

Making the assumption that the econometric relationship between health and economic growth is a dynamic one, the study adopts a Dynamic Panel Data (DPD) estimator based on the Generalised Method of Moments (GMM) methodology as expressed by Arellano and Bond (1990).

The Arellano Bond (AB) GMM estimator has been chosen primarily because the health production and growth models include several non-exogenous regressors, including the lagged dependent variable for a dynamic model. The presence of endogeneity in a model causes the more commonly used Fixed Effects (FE) and Generalised Least Squares (GLS) estimators to be inconsistent. Additionally, the FE and GLS estimators are biased in the presence of dynamics or lags of the dependent variable in the regression Baltagi (2013). Additionally, for small samples (i.e. $T<30$) the Ordinary Least Squares (OLS) estimator is both biased and inconsistent (Green, 2003). Therefore, the GMM estimator is ideal because it is an instrumental variable (IV) estimator designed for dynamic panel data regressions that can correct for correlated country fixed effects as well as account for the endogeneity of the regressors. Also, the GMM estimator performs well in finite samples, particularly for data with $N>T$ (Roodman, 2009).

The Arellano-Bond GMM estimator provides a framework within which the explanatory variables that are assumed to be endogenous or predetermined can be instrumented using their lagged values and the subsequent instruments can be tested for validity (Baltagi, 2013). The model also allows for the inclusion of external instruments aside from the lagged dependent and independent variables in the model.

In mathematical terms, the AB GMM estimator can be expressed as;

$$\hat{\beta} = \left[\left(\sum_{i=1}^{N} \tilde{X}_i' Z_i\right) W_N \left(\sum_{i=1}^{N} Z_i' \tilde{X}_i\right)\right]^{-1} \left(\sum_{i=1}^{N} \tilde{X}_i' Z_i\right) W_N \left(\sum_{i=1}^{N} Z_i' \tilde{y}_i\right) \quad (20)$$

Where; $\tilde{X}_i$is a (T-2) × (K+1) matrix, with t = 3……… T, $\tilde{y}_i$ is a (T-2) ×1 vector and Z_i is a (T-2) × r matrix of instruments. The matrix Z_i is expressed as;

$$Z_i = \begin{bmatrix} z_{i3}' & 0 & \cdots & 0 \\ 0 & z_{i4}' & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & z_{iT}' \end{bmatrix}$$

Where $z_{it}' = (y_{i,t-2}, y_{i,t-3}, \dots \dots \dots \dots, y_{i,1}, \Delta x_{it}')$. Finally, W_N is an r × r weighting matrix which is different for the two stage least squares and two step GMM methods respectively. Lags of x_{it} or Δx_{it} can additionally be used as instruments, and for moderate or large T there may be a maximum lag of y_{it} that is used as an instrument, such as not more than $y_{i,t-4}$. The consistency of the AB GMM estimator relies on the moment conditions that $E[y_{is}\Delta u_{it}] = 0$, and $E[x_{is}\Delta u_{it}] = 0$ for s ≤ t – 2, where, $u_{it} = \varepsilon_{it} + \alpha_i$, with α_i representing the unobserved country specific effects (Cameron and Trivedi, 2015)

Due to the dimensions of the data, that is an N that is relatively larger than the T (N=30, T=20), the study makes use of the two-step difference GMM estimator. The two-step difference estimator is more efficient than the one step estimator and it possesses better asymptotic properties, especially for finite samples (Roodman, 2006). For a relatively large T, the more recently used and common System GMM estimator uses more instruments than the difference estimator. To avoid the proliferation of instruments that would lead to over identification, the Difference GMM is adopted as the better choice (Labra and Torrecillas, 2018)

While the AB GMM estimator is an excellent choice due to its expected robustness to heteroscedasticity and non-normality of disturbances as well as its use of internal instruments to address endogeneity (Baltagi, 2013), it is not without its limitations. One important limitation is that the estimator is prone to the proliferation of instruments especially in samples with a large T.

This can in turn affect the asymptotic properties of the estimators and the specification tests (Roodman, 2006). To avoid this, the model specification will include restrictions for the number of instruments included in the model. Further, the validity of the set of instruments are tested using the appropriate post estimation tests. Another concern with the dynamic Panel data estimation methods is the presence of serial correlation which would lead to inconsistent estimates. To address this, the model will make use of robust standard errors. Also, appropriate post estimation tests will be used.

5.2.1 Health Production Model

Anchoring on Grossman's (1972) model of health production and deriving from the work of Fayissa and Gutema (2005), the modified log linear health production function, continuing from equation (12) will be represented by;

$$\ln h = \ln \varphi + \sum \alpha_i S_i + \sum \beta_i L_i + \sum \gamma_i V_i + \sum \theta_i E_i + \mu_i \qquad (21)$$

Where the dependent variable h is the health measure, φ is the initial health stock, *S*, *L*, *V* and *E* represent the socio economic, lifestyle, environmental and health factors as presented in section 4.3, *Table 1* and μ is the error term for country *i*.

Expressing the health model in terms of a dynamic panel regression model we get;

$$\Delta h_{it} = \alpha \Delta h_{i,t-1} + \beta \Delta x'_{it} + \gamma D_t + \Delta \varepsilon_{it} \qquad (22)$$

Where; Δh_{it} is the first difference of the log of life expectancy at birth, $\Delta h_{i,t-1}$ is the lagged first difference dependant variable, $\Delta x'_{it}$ is a vector of the first differenced explanatory variables, $D_t$is the vector of time dummies and $\Delta \varepsilon_{it}$ is the first differenced error term for country ***i*** at time ***t***. The error term is given by;

$$\varepsilon_{it} = \mu_i + v_{it} \qquad (23)$$

Where $\mu_i \sim iid(0, \sigma_\mu^2)$ and $v_{it} \sim iid(0, \sigma_v^2)$ are independent amongst themselves and each other. First differencing the model takes care of the individual country effects and enables us to obtain internal instruments for the endogenous regressors. For the purposes of the estimation, the study will employ the following specification of the Dynamic Panel Data model;

$$\Delta\ln LE_{i,t} = \beta_1\Delta\ln LE_{i.t-1} + \beta_2\Delta\ln GDP_{i,t} + \beta_3\,\Delta\ln HE_{i,t} + \beta_4\,\Delta\ln FP_{i,t} + \beta_5\,\Delta HAQI_{i,t} + \beta_6\Delta HIV_{i,t} + \beta_7\Delta AYS_{i,t} + \beta_8\Delta UP_{i,t} + \beta_9\Delta WS_{i,t} + \beta_{10}\Delta AL_{i,t} + \beta_{11}\Delta PIQ_{i,t} + \boldsymbol{\beta D_t} + \Delta\varepsilon_{it}$$

(24)

Where; LE represents life expectancy, GDP is real GDP per capita, HE is total health expenditure, FP is the food production index, HAQI is the healthcare access quality index, HIV is the HIV prevalence rate, AYS represents average years of schooling, UP is the urban population as a percentage of the total population, WS is the percentage of the population with access to a clean water source, PIQ is the political institutional quality and AL is annual per capital alcohol consumption as defined by *Table 1*. D_t denotes the vector of time dummies that are included as controls in the model. As in the previous equations, i represents the country, t represents time and ε_{it} is the error term as defined in equation (28). For this model, instruments will be used for the lagged dependent variable, average years of schooling, per capita GDP and the food production index as they are expected to be endogenous regressors.

5.2.2 Economic Growth Model

As with the health production model, continuing from equation (19) and adopting the AB GMM estimation technique, we generate the following DPD equation for the growth model;

$$\Delta\ln Y_{i,t} = \alpha_1\Delta\ln Y_{i,t-1} + \tau_i\Delta\ln K_{i,t} + \pi_i\Delta\ln L_{i,t} + \gamma_{i,}\Delta\ln H_{i,t} + \partial_i\Delta X_{i,t} + \rho_i D_t + \varepsilon_t$$

(25)

Y represents GDP per capita and H represents population health which is our variable of interest. X is the vector of additional control variables such as initial conditions, institution variables, and education variables and ε_t is the error term after differencing out the country time-invariant fixed effects. K represents the physical capital stock and L represents the labour force. As with the health model, i and t indicate country and time respectively. Specifically, the model can be written as;

$$\begin{aligned}\Delta\ln GDP_{i,t} = {} & \alpha_1\Delta\ln GDP_{i,t-1} + \alpha_2\Delta\ln LE_{i,t} + \alpha_3\,\Delta\ln HE_{i,t} + \alpha_4\,\Delta\ln GCF_{i,t} + \alpha_5\Delta\ln LF_{i,t} \\ & + \alpha_6\Delta HAQI_{i,t} + \alpha_7\Delta PIQ_{i,t} + \alpha_8\Delta AYS_{i,t} + \alpha_9\Delta TPR_{i,t} + \alpha_{10}\Delta TRD_{i,t} + \boldsymbol{\beta D_t} \\ & + \Delta\varepsilon_{i,t}\end{aligned}$$

(26)

Where GDP, LE, HE, HAQI, AYS, $\boldsymbol{D_t}$ and PIQ are as previously defined. Physical capital stock will be proxied by Gross Capital Formation (GCF), investment into physical capital will be proxied by foreign direct investments (FDI) and the labour force will be proxied by the population aged between 15 and 65 (LE). Trade openness (TRD), and the Teacher pupil ratio (TPR) which is a proxy for education quality are included as additional control variables. The model will include instruments for the lagged dependent variable, life expectancy, health care access quality index and average years of schooling which are expected to be endogenous.

Since the coefficients of the dynamic panel data estimator are interpreted as short-run coefficients, the long term impact of health on economic growth will be obtained by lagging the health variable (life expectancy and infant mortality) by 10, 11 and 12 years respectively. The period of ten years and over was chosen because it represents a long enough period of time over which life expectancy could impact economic growth (Wilkinson et al, 2006). This approach is chosen because in the absence of omitted variable bias and mis-measurement bias, lagged effects depict differential effects in long term and short term conditions. Thus, the coefficient on the lagged health stock will denote a long-term effect of health on economic growth (Mckinnish, 2002).

5.3 Data Sources

This study uses annual secondary data from 30 sub-Saharan countries for the period 1995—2014.[3] The countries and time period are chosen based on data availability for all variables included in the model.[4] This is done to reduce the number of gaps in the panel dataset. Specifically, data on life expectancy at birth, infant mortality, GDP per capita, gross capital formation, population aged between 15 and 64, access to a clean water source, the food production index, trade openness and the teacher pupil ratio was sourced from the World Bank World Development Indicators (WDI) (World Bank, 2016). The World Development Indicators are compiled by the World Bank using officially recognised international sources and represent current and accurate development data at national, regional and global level. The selected data was accessed from the World Bank official website.

[3] The list of countries included in the analysis is expressed in the appendix
[4] The links to all data sources are included in the Appendix

Data on alcohol consumption and HIV prevalence rates was sourced from the World Health Organization (WHO) Global Health Observatory (GHO) data base. The World Health Organization compiles its data from multiple sources such as household surveys, routine reporting by health services, censuses and disease surveillance systems. The data sets were accessed via the WHO official website.

Additional data sources included the United Nations Development Programme (UNDP) Human Development Reports Data base from which data on average years of schooling was sourced. The data is compiled by the Human Development Report Office (HDRO) at the United Nations Development Programme (UNDP) and it relies on the expertise of the leading international data providers in their specialized fields (UNDP, 2017). Data for political institutional quality was accessed from the information provided in Kuncic's paper on data on institutional quality (Kuncic, 2013). The estimates were generated from several data sources as expressed in the paper. The study also used data from the Global Burden of Disease (GBD) database for the indicator Health Care Access Quality Index (HAQI) which was a proxy for health care quality.

5.4 Definition of Variables

As alluded to in the theoretical framework, the study employs two models for its analysis; the health production model to estimate the determinants of population health stock and a growth model to determine the impact of health human capital on economic growth. Appropriate proxies for health and other variables were chosen according to the guidelines laid out by Li and Liang (2010). The dependant and explanatory variables for the health production model and the growth model and their definitions are given in *Table 2*.

The indicator ***life expectancy at birth*** was used as a measure of population health stock and dependent variable for the health production model. Life expectancy is an ideal choice because it provides a measure of the health impact of the disease environment since premature death is the most significant and observable impact of disease (Weil, 2014). ***Infant mortality*** served as additional measure of health stock which is an indicator of poor health. Infant mortality was chosen as an additional health measure because it is comparable across countries in the region (Reidpath and Allotey, 2003). GDP per capita will measure output growth in both models. GDP per capita is chosen mainly because of the theoretical model adopted. Also, GDP per capita can be a proxy measure for the productivity of an economy, which is also of concern in this study (Marattin and Salotti, 2011)

For the health production model, the independent variables were grouped into social, economic, environmental, healthcare and lifestyle variables. The social and economic variables include *average years of schooling* as a measure for education, the *food production index* as a measure of food availability and *GDP per capita* as a measure of aggregate income.

Table 1: Definition of Variables

Variable	Description	Source
Life Expectancy at birth	Average number of years that a new-born could expect to live if he or she were to pass through life subject to the age-specific mortality rates of the prevailing period	WDI
Food Production index	An index that covers food crops that are considered edible and that contain nutrients. It measures the changes in the production of food commodities in a given year relative to base year	WDI
GDP per capita	Ratio between the GDP and the total number of people in a country	WDI
Healthcare Access Quality Index	An index that standardises mortality from causes that should not be fatal in the presence of effective medical care	IHME
HIV prevalence	Percentage of people aged 15-49 living with HIV	WHO
Education	Average number of years of education received by people aged 25 and older	UNDP
Alcohol consumption	Litres of pure alcohol consumed by people aged 15 and older	WHO
Urbanization	Annual percentage growth in the Urban population	WDI
Access to clean water	Percentage of the total population that have access to a clean water source	WDI
Health expenditure	Total annual Health expenditure (in US$)	WDI
Labour force	Population aged between 15 and 64 years	WDI
Gross Capital formation	Net increase in physical assets within the measurement period	WDI
Trade Openness	Ratio of total trade (exports and imports) to GDP	WDI
Political Institutional Quality	An index that shows the relative competitiveness of every country in terms of the quality of the underlying political institutional environment. It includes factors like Checks and balances, Democratic accountability, Corruption, Bureaucratic quality, Internal conflict and Military in politics	Kuncic (2013)
Infant Mortality	The number of deaths occurring in the first year of life per 1,000 live births.	WDI
Teacher Pupil ratio	The ratio of pupils in primary school to full time primary school teachers	WDI

Source: ***World Bank World Development Indicators (WDI) (2016), UNDP (2016), WHO (2017), Kuncic (2013), Institute for Health Metrics and Evaluation (IHME) 2016***

The environmental indicators include the *percentage of the population with improved water source* as a proxy for access to clean water and sanitation and the *percentage growth of the urban* *population* as a proxy for urbanization. *Total Health expenditure*, *the Healthcare Access Quality Index* and the *annual HIV prevalence rate* will account for the health care factors whereas *alcohol consumption in litres per capita* will represent lifestyle factors that influence population health.

For the growth model, *GDP per capita* is the dependent variable representing national income per person whereas the explanatory variables include physical capital proxied by *gross capital formation*, educational human capital proxied by *average years of schooling*, the stock of health human capital proxied by *life expectancy (and the alternative infant mortality)*, investment into health human capital will be proxied by *nominal health expenditure* and the labour force will be represented by the *population aged between 15 and 64*. The model will include a number of control variables including the *political institutional quality index*, *trade openness*, *teacher pupil ratio* as a measure of education quality and the *health care access quality index* as a measure of health care quality.

5.5 Data Analysis

Data was Analysed using STATA 14.0 Software package. It was chosen because it has the best package for the analysis of dynamic panel data methods. The analysis is done using the '**xtdpd**' command in STATA.

5.6 Limitations

Despite using the appropriate methods and analysis, the study however is not without its limitations. One of the main limitations of the study was the availability of data for the proposed study period. The lack of adequate observations may affected the robustness of the results. The study tried to reduce this as much as possible by controlling for any missing values in the analysis. The lack of availability of data restricted the number of countries that could be included in the study as well as the proxies that could be employed in the analysis.

A second limitation of the study is related to the policy recommendations of the study. Policy recommendations based on the results of the study were made with caution. This is because the authors recognize that each sub Saharan country possesses different characteristics which play a role in policy implementation. Therefore, the study can only provide broad recommendations for the region as whole and not necessarily in the context of individual countries. This would require further study at the country level.

A third limitation of the study is with regards to the methodology. While the AB GMM estimator provides solutions to the problems of endogeneity, the method is not a panacea for all the possible issues that may arise in the estimation such as confounding and variable omission. There is need to further develop these methods to ensure more robust estimation in future or to adopt more advanced procedures such as general equilibrium analyses.

CHAPTER 6

RESULTS

The following section illustrates the main findings of the study. We begin first by looking at the descriptive statistics and then go on to estimate the health production and growth models. Thereafter, a robustness checks section is included as part of the results to test the robustness of the study's findings.

6.1 Descriptive Statistics

Descriptive statistics provide some important insight into the characteristics of the data prior to running any econometric model. Table 2 depicts the summary statistics of the sample data the chosen 30 SSA countries spanning the period between 1995 and 2014. All the variables used in the estimation along with their means, standard deviation and labels are presented in Table 2 below.

Table 2: Summary Statistics of the Sample Data

Variable	Label	Mean	Std. Deviation
GDP per capita (constant 2011 US$)	**GDP**	2250.86	3217.48
Life Expectancy (years)	**LE**	54.21	6.62
Health expenditure (log)	**HE**	24.38	2.52
Food Production index	**FP**	101.49	25.12
Education (years)	**AYS**	4.79	2.00
HIV Prevalence (percent)	**HIV**	7.94	7.68
Urban Population (percent growth rate)	**UP**	4.01	1.79
Pop with access to clean water source (percent)	**WS**	67.03	16.45
Alcohol consumption (litres)	**AL**	4.10	2.85
Healthcare Access Quality Index (1-100)	**HAQI**	41.44	6.30
Political Institutional Quality Index	**AIQ**	0.41	0.14
Labour Force (log)	**LF**	15.41	1.30
Trade openness (percent of GDP)	**TRD**	77.77	49.98
Teacher pupil ratio (number of primary school pupils/teacher)	**TPR**	42.87	12.13
Gross Capital Formation	**GCF**	21.99	19.12
Infant Mortality (deaths/1000 births)	**INFM**	72.31	27.53

Notes: The table shows the means and standard deviations of the all variables in the model for 30 countries for the period between 1995 and 2014.

6.2 Growth Model

Table 3 depicts the results of the growth model. Column 2 shows the coefficients of the growth model estimated with life expectancy as a measure of health whereas Columns 3 to 5 depict the results of the model with life expectancy lagged by 10, 11 and 12 years respectively. The Wald tests reject the null hypothesis that the coefficients of all the explanatory variables jointly equal 0 for all four models.

Table 3: The Growth Model

Variable	**Coefficient Estimates Dependent Variable- Log GDP per capita**			
	(1)	**(2)**	**(3)**	**(4)**
$ln\ GDP_{t-1}$	0.828***	0.892***	1.003***	0.963***
ln LE	0.314	0.332**	0.179	0.298*
ln GCF	-0.006	0.031***	0.040***	0.053***
HAQI	-0.001	-0.006	-0.009*	-0.011**
PIQ	0.328**	0.018	0.057**	0.034
ln HE	0.046	-0.014	-0.040***	0.038***
AYS	0.072**	0.159***	0.062	0.132***
ln LF	-0.287**	-0.332***	-0.075	-0.300**
TP	-0.000	-0.001***	-0.001***	-0.001***
TRO	0.000	-0.000***	-0.000***	-0.001***
Time dummies	Yes	Yes	Yes	Yes
Number of Obs.	496	268	239	210
Number of instruments	64	35	32	29
First Order Serial Correlation	-2.56 (0.011)	-2.30 (0.021)	-2.70 (0.007)	-2.16 (0.031)
Second Order Serial Correlation	-0.89 (0.369)	-1.57 (0.117)	-2.01 (0.044)	-1.33 (0.183)
Sargan Test	13.21 (1.00)	21.06 (0.517)	17.26 (0.572)	20.03 (0.219)
Wald Test	12688.43	11409.43	60446.67	6923.67

Note; * p < 0.1, **p < 0.05 and ***p < 0.01; P-values in parentheses for Sargan test and Serial correlation tests

1: Life Expectancy is not lagged
2: Life expectancy is lagged by 10 years
3: Life expectancy is lagged by 11 years
4: Life expectancy is lagged by 12 years

In line with the **objective 1** of the study, we estimate the relationship between population health stock (life expectancy) and economic growth (per capita GDP). Column 2 of Table 4 shows that health stock measured by life expectancy has a positive yet insignificant effect on GDP per capita growth in the short term. This finding is contrary to the first study hypothesis.

The estimations 2, 3 and 4 represent the long term impact of life expectancy on economic growth. Model 2 shows that the impact of life expectancy on economic growth after 10 years is positive and significant with a 1 percent rise in life expectancy leading to a 0.3 percent rise in future GDP per capita. This finding is very similar to Model 4 that finds that a 1 percent rise in life expectancy leads to a 0.29 percent rise in GDP per capita in 12 years. In model 4 however, the impact of life expectancy on per capita GDP growth is insignificant at the 5 percent level

To achieve **objective 2** of the study, we determine the association between investments into health (health expenditure and health care quality) and economic growth. Healthcare quality has a negative and insignificant impact on per capita GDP growth which is also contrary to the first study hypothesis. Health expenditure which was a proxy for investments into population health has a positive but insignificant effect on economic growth.

Among the significant determinants of per capita GDP growth were the political institutional quality, average years of schooling and the labour force proxied by the population aged between 15 and 64. All these variables had the expected sign with increases in the labour force leading to a decline in per capita GDP whereas improvements in the political institutional quality and average years of schooling that measured education having a positive impact on per capita GDP growth. The teacher pupil ratio, trade openness and gross capital formation were not significant determinants of per capita GDP growth.

Overall, the health variables have an insignificant impact on per capita GDP in the short term. However, life expectancy, which is the population health stock did have a positive and significant impact on growth when lagged by 10 and 12 years respectively.

6.2.1 Post Estimation Tests

The results of the first and second order tests for serial correlation indicate that there is no evidence of second order serial correlation in all the models except for model 3 which has evidence of second order serial correlation but no evidence of third order serial correlation (presented in Appendix B).

The model uses instruments for the variables average years of schooling, life expectancy and the lagged dependent variable. The instruments used for each variable are explicitly presented in

Appendix B. Additionally, the Sargan tests of over identifying restrictions show that the set of instruments used in all the estimations are valid and that there is no over-identification in all the four models

6.3 Alternative Health Measure

To ensure that the results of the study are not based on the measure of health used or the model specification, we estimate the growth equation using an alternative measure of health (infant mortality). Consider the results presented in Table 4 that indicate the impact of health measured by infant mortality on economic growth measured by per capita GDP growth.

Table 4: Growth Model with Infant Mortality as Health Measure

Variable	**Coefficient Estimates Dependent Variable- Log GDP per capita**			
	(1)	**(2)**	**(3)**	**(4)**
$ln\ GDP_{t-1}$	0.659***	0.929***	0.879***	0.772***
ln INFM	-0.463***	-0.057	-0.037	-0.709***
ln GCF	-0.005	0.037***	0.033***	0.035***
HAQI	-0.010	0.0002	-0.002	0.003
PIQ	0.291*	0.056***	0.032*	0.034
ln HE	0.035	-0.016*	-0.011	-0.016*
AYS	0.076	0.037***	0.018	0.055
ln LF	-0.444*	-0.139	-0.009	-0.784***
TP	0.000	-0.001***	-0.001***	-0.002***
TRO	0.000	-0.001***	-0.001***	-0.001***
Time Dummies	Yes	Yes	Yes	Yes
Number of observations	496	268	239	210
Number of instruments	64	35	32	29
First Order Serial Correlation	-1.98 (0.048)	-2.60 (0.009)	-2.36 (0.018)	-1.02 (0.305)
Second Order Serial Correlation	-0.58 (0.561)	-1.79 (0.074)	-1.95 (0.051)	-0.89 (0.369)
Sargan Test	15.25 (1.00)	21.96 (0.462)	18.05 (0.519)	18.01 (0.32)
Wald Test	23360.43	29727.68	50754.88	1715.53

Note; * p < 0.1, **p < 0.05 and ***p < 0.01, P-values in parentheses for Sargan test and Serial correlation tests

1: Infant Mortality is not lagged
2: Infant Mortality is lagged by 10 years
3: Infant Mortality is lagged by 11 years
4: Infant Mortality is lagged by 12 years

The main finding depicted in Table 4 is that infant mortality has a significant impact on economic growth both in the short term and the long term. Infant mortality, like life expectancy has a significant impact on economic growth when lagged by 12 years. However, infant mortality also has a significant impact on economic growth in the short-term with a percentage increase in the infant mortality rate reducing per capita GDP growth by 0.46 percent. This shows that impact of health on economic growth in the short-term depends to some extent on the measure of health used in the analysis. In the same vein, the long-term impact of health on economic growth is significant regardless of the health measure used.

Overall, health measured by either life expectancy or infant mortality has a significant impact on economic growth when it was lagged by 12 years. However, life expectancy does not significantly impact growth in the short term whereas infant mortality does. We therefore conclude that the health measure used matters when considering the impact of economic growth in the short and mid-term but not in the long term.

6.4 Health Production Model

In line with **objective 3** of the study we estimate the health production model from equation 24. The results of the estimation of the health production model are represented in Table 5. The estimates in Column 2 and 3 of Table 5 are based on the health production model with life expectancy and infant mortality as the dependent variables respectively[5]. Some of the continuous variables, for instance health expenditure and GDP per capita were logged so that their effects can be expressed as elasticities. The table also indicates the number of instruments used in the analysis, the number of observations used in the analysis, the inclusion of time dummies, some post estimation tests for serial correlation and over identification and the joint test of significance.

[5] The estimation was done using the "xtdpd" command in STATA

Table 5: The Health Production Model

Variables	Coefficient Estimates Dependent Variable- Log Health			
	LE		INFM	
$ln\ HEALTH_{t-1}$	0.854***	(0.0308)	0.850***	(0.0363)
ln GDP per capita	0.045**	(0.0202)	0.032	(0.0293)
ln Food Production	-0.001	(0.0103)	-0.021	(0.0158)
ln Health Expenditure	0.013***	(0.0025)	-0.007*	(0. 0039)
Political Institutional Quality	0.001	(0.0196)	-0.035	(0.0239)
HIV prevalence	-0.004***	(0.0012)	-0.001	(0.0042)
Healthcare Access Quality Index	-0.002*	(0.0009)	-0.004**	(0.0020)
Average Years of Schooling	0.009*	(0.0052)	-0.037***	(0.0117)
Urban Population growth	0.002**	(0. 0008)	-0.013	(0.0140)
Access to Clean Water	0.0001	(0.0004)	-0.001	(0.0007)
Alcohol Consumption	0.0005*	(0.0003)	0.001***	(0.0003)
Time Dummies	Yes		Yes	
First Order Serial Correlation	2.08	(0.038)	- 0.71	(0.471)
Second Order Serial Correlation	1.93	(0.053)	-0.88	(0.377)
Sargan Test	12.59	(1.000)	17.15	(1.000)
Wald Test	1.29e+06		296540.35	
Number of Obs.	520		491	
Number of Instruments	99		87	

Note; * p < 0.1, **p < 0.05 and ***p < 0.01, Standard Errors in Parentheses for Coefficients: P-values in parentheses for Sargan test and Serial correlation tests

LE – Health stock is measured by Life expectancy

INMF – Health stock is measured by Infant Mortality

From the results presented in Colum 2 of Table 5, population health measured by life expectancy is significantly determined by per capita GDP, total health expenditure, average years of schooling, urbanization, HIV prevalence, healthcare quality and alcohol consumption. Food availability (proxied by the food production index), political institutional quality and access to a clean water source were not significant determinants of life expectancy. GDP per capita, health expenditure and average years of schooling had the expected sign as predicted by the second hypothesis of the study. According to Table 5, a percentage increase in GDP per capita is associated with a 0.04 percent rise in life expectancy. Similarly, increasing nominal total health expenditure by 1 percent leads to a 0.01 percent rise in life expectancy whereas raising the average years of schooling by 1 year results in a 0.9 percent rise in life expectancy.

Interestingly and contrary to the study's second hypothesis, a 1 unit rise in the healthcare access quality index leads to a 0.2 percent reduction in life expectancy whereas a 1 percent rise in the growth rate of the urban population leads to a 0.2 percent rise in life expectancy. Also, an additional litre of annual alcohol consumption is associated with a 0.05 percent rise in the level of life expectancy which opposed the third hypothesis of the study. The negative impact of the HIV prevalence rate is, however, in agreement with the third hypothesis of the study as a 1 percent rise in the HIV prevalence rate leads to a 0.4 percent reduction in life expectancy.

Using an alternative health measure, the results show that population health measured by infant mortality (presented in Column 3, Table 5) is significantly determined by only alcohol consumption, average years of schooling, healthcare quality and total health expenditure. All the significant variables have the expected sign and are consistent with the second and third hypotheses of the study. Specifically, an additional year of average years of schooling leads to a 3.7 percent reduction in the infant mortality rate. An extra litre of annual per capita alcohol consumption leads to a 0.1 percent increase in the infant mortality rate where as a unit increase in the health care access quality index led to 0.4 percent decline in the infant mortality rate. Health expenditure has a relatively small impact on the infant mortality rate with a percentage rise in the nominal total health expenditure leading to a 0.007 percent decline in the infant mortality rate. Per capita GDP, food availability, political institutional quality, HIV prevalence, urbanization and access to a clean water source were insignificant determinants of health measured by infant mortality.

Overall, health expenditure, healthcare quality, alcohol consumption and the average years of schooling were the main significant determinants of population health for the region in the sample period. However, we note that the magnitude of the impact of health expenditure on life expectancy is greater than that on infant mortality. On the other hand, the impact of education is stronger on infant mortality than life expectancy. The impact of per capita GDP growth on health is dependent on the measure of population health used, while it significantly contributes to the level of life expectancy it was not a significant determinant of the infant mortality rate.

6.4.1 Post estimation Tests

The post estimations tests of the model are presented in the last six rows of *Table 5*. The consistency of the AB GMM estimator depends on the assumption that there is no second order serial correlation for the disturbances of the first differenced equation (Baltagi, 2013). As such, the Arellano and Bond Test for serial correlation was used to test for both first and second order serial correlation. The null hypothesis of the test specifies that 'there is no autocorrelation' in the model. From the results of the tests we do not reject the null hypothesis that there is no second order serial correlation at the 5 percent level of significance for both models.

Table 5 also reports the results of the Sargan test of over identifying restrictions. This test verifies the validity of the instruments used in the analysis (Roodman, 2006). The variables that were considered to be endogenous and thus instrumented were average years of schooling, the food production index, GDP per capita and Life expectancy (infant mortality for model 2). The instruments used are presented in Appendix B. The null hypothesis of the test is that all the restrictions of over-identification are valid. The Sargan test does not reject the null hypothesis that the over-identifying restrictions used in both models are valid at the five percent level of significance. This means that the set of instruments used in both models are valid and there is no over-identification arising from too many instruments.

The analysis included time dummies to control for year effects which capture the influence of aggregate time-series trends, these are explicitly stated in Appendix B. The Wald test rejects the null hypothesis that the impact of all the variables on life expectancy and infant mortality respectively is equal to zero.

CHAPTER 7

DISCUSSION

This study set out to establish the determinants of health and the determine impact of health human capital on economic growth for a sample of 30 Sub Saharan countries during the period between 1995 and 2014. The findings of the study suggest two main points. First, the impact of population health on economic growth in Sub Saharan Africa depends on the period under consideration (short or long term) as well as the measure of health used in the analysis. Secondly, the study found that health stock measured by life expectancy and infant mortality in the region is significantly determined by the levels of education, health care quality, alcohol consumption and health expenditure.

6.5 The Impact of Health on Economic Growth

The study finds that population health stock measured by life expectancy has a significant impact on economic growth when lagged by 10 years or more whereas infant mortality showed evidence of having both a short term and long term impact on economic growth. This could be because a higher life expectancy results in extra years of schooling for the general population as well as a longer time spent in the labour force (Boucekkine, 2009). The implication of this is increased levels of educational human capital and more time devoted to output production by the labour force (ibid, 2009). This effect would only be apparent in the long run, or at least in the time within which these investments could have a positive impact on output growth.

Infant mortality was expected to negatively influence economic growth as it points to inadequacies and inefficiencies in the health care system (WHO, 2013). This can be both short term and long term. Also, higher infant mortality rates have been associated with higher fertility rates in the context of the ‘demographic transition theory’, this raised the dependency ratio and negatively affects economic growth in the short term (Yamada, 1985). Higher fertility rates further tend to raise the size of the dependency ratio and thus negatively impact economic growth in the long term (Finlay 2007).

This finding is in agreement with the study done by Akram et al (2008) who found a significant long term relationship between both infant mortality and life expectancy on economic growth but did not find a significant relationship between both health measures and growth in the short run in

Pakistan. Similarly, Mayer (2000) found that the impact of life expectancy was larger and more significant for longer time lags (between 5 and 20 years) using data for Mexico for the period between 1950 and 1995. His study on 18 countries in Latin America also revealed that the impact of health (measured by the probability of survival) was greater with higher lags of the health measure. However, the findings are contrary to those of Ogunleye (2014) who found an insignificant relationship between both infant mortality and life expectancy when they were lagged by 20 years.

Interestingly, the study found no evidence that increases in investments into health, proxied by total health expenditure as well as the health care quality proxied by the health care access quality index had led to significant increases in per capita GDP growth. This finding is contrary to a similar study done on the SSA region by Gyimah-Brempong and Wilson (2004). One explanation for this is that health expenditure in the region is so low and inefficient that it does not significantly impact economic growth region (Eggoh, 2015; Ogunleye 2014). Another reason for this effect could be that health expenditure only has a long term impact on economic growth since it indirectly affects growth via the improvements in health which later increase the productivity of the labour force. Other studies that did not find a significant relationship between health expenditure and economic growth were Ogunleye (2014) and Babatunde (2003).

Similarly, the weak impact of health care quality may be because of its indirect influence on the level of GDP growth through its impact on population health. Another explanation for the weak impact of health care quality on economic growth could be the measure of health care quality used which was the health care access and quality index (HAQI). The health care access quality index captures all mortality that could been avoided by better quality health care (GBD, 2017). Health care quality is made up of many components and thus the measure may not capture the full breadth of health care quality at either country or regional level.

6.6 The Impact of Economic growth and other Factors on Health

With regards to the determinants of health in the region, health expenditure, health care quality, alcohol consumption and education were significant determinants of both infant mortality and life expectancy. The results were similar to the findings of Fayissa and Gutema (2008), Ogunleye (2014), Kamiya (2010) and Lin et al (2012).

Increased per capita GDP was associated with significant improvements in life expectancy. This coincides with both the theoretical and empirical literature (Grossman 1999; Auster, Leveson and Saracheck, 1969; Preston, 1976; Anand and Ravallion, 1993; Pritchett and Summers, 1996). Higher income on a macro level translates into greater investments into the health sector that can in turn be used to improve the health status of the population.

An intriguing finding however, was that per capita income was not a significant determinant of infant mortality. This finding was contrary to several studies such as Erdoğan et al. (2013), Ogunleye (2014) and Bhalotra (2008). The finding was however similar to the work by Ensor et al (2010) who found that economic growth did not have a significant impact on infant mortality from 1965 to 2005 for a panel of developed countries. There could be a number of explanations for this. One important one is that the relationship between economic growth and infant mortality could be unidirectional with infant mortality having a significant impact on economic growth and not the other way around. The study showed this with the growth model in which infant mortality had a significant impact on economic growth.

The positive impact of education on population health coincides with both the theoretical literature and previous empirical studies (Kamiya 2010; Fayissa and Gutema (2008); Shabaz et al. (2015)). A natural explanation for this effect is drawn from Hahn and Truman (2015) who assert that education is both an important component of health and a major determinant of future health patterns. Therefore, even basic education and skills are associated with improvements in health outcomes.

As expected, the findings showed that health expenditure was one of the main contributors to improvements in population health. Increased health expenditure over the past few decades has been associated with an increase in the number health facilities and infrastructures as well as improvements in health care services and delivery (WHO, 2016). It thus follows naturally that the provision of better health care due to higher investments in health care contributes to the reduction in infant mortality and leads to increased levels of life expectancy and a reduction in infant mortality. This finding is similar to the work done by several studies such as Kim and Lane (2013) for 17 OECD countries and Fayissa and Gutema's (2013) for Eastern European countries among others.

Another interesting finding from the study was related to the relationship between health care quality, annual per capita consumption of alcohol and health measured by life expectancy. While it was hypothesised that alcohol consumption would have a negative impact on life expectancy and health care quality would have a positive impact on life expectancy, this was not the case for this study. This could be explained by the intuition that alcohol consumption may have a lagged effect on population health since excessive alcohol consumption is associated with non-communicable diseases that may have a delayed impact on life expectancy. For health care quality, the same is true. Improvements in health care quality may not have an immediate impact on life expectancy. The negative sign may be due to the very low levels of health quality in the region.

However, alcohol consumption and healthcare quality had the expected impact on infant mortality, with alcohol consumption leading to increases in infant mortality and better health care quality leading to reductions in infant mortality. This finding is similar to that of Ogunleye (2014).

The study further found evidence that HIV prevalence, per capita GDP growth and urbanization were significant determinants of health measured by life expectancy which was consistent with the findings of Mba (2007), Ogunleye (2015) and Fayissa and Gutema (2013). The negative impact of the HIV/AIDS prevalence was expected since the disease shortened the life span of the economically active population, who were most affected by the disease. Also, a greater percentage of the population residing in urban areas was associated with increases in the levels of life expectancy in the region. This may be because urban areas often have better infrastructure and thus provide improved access to a number of social services such as education, health care, sanitation and safer water supply that in turn are associated with improved population health (McDade and Adair 2001).

Overall, the study shows that the determinants of population health in the region vary with the measure of population health used. One reason could be that the two different measures of health capture different aspects of population health. This presents an area for future study with the analysis extending to additional health measures. While the study analyses short term and long term impact of population health on economic growth, an area for future investigation could be the long term and short term impact of investments into population health via health expenditure on economic growth. This is so as to determine whether its impact on growth is more long term.

CHAPTER 8

CONCLUSION AND POLICY IMPLICATIONS

Population health serves as an indicator of the overall wellbeing of a nation and thus has both direct and indirect effects on economic growth. There is a complex relationship between health and economic growth, particularly in developing countries as improved population health is tied to increased productivity, increased investments into education, and greater levels of income which in turn also influence the accumulation of population health capital.

The present study provides some useful insights on the relationship between economic growth and health in the Sub Saharan African region. The study finds that overall, population health has a significant long term impact on economic growth for the Sub Saharan Africa region. On the other hand, the short term impact of health largely depends on the health measure used. We thus conclude that growth effect of population health accumulation in the region is long term. This finding has some important implications for policy makers. Because current population health stocks will have an impact on future economic growth rates in the region, there is need to invest in improving current health indicators as they translate into future gains in per capita income. Policy makers in the region should take into account the long term impact of health in the planning process if they are to fully exploit the growth effects of population health.

Education, health care quality, health expenditure and alcohol consumption were the main significant determinants of population heath in the region. Other determinants such as income growth, HIV prevalence and urbanization were sensitive to the measure of population health used. In light of this, the study proposes that efforts to increase the levels of population health in the region should focus in increasing the years of schooling, improving health care quality, increasing expenditure on health and reducing the per capita consumption of alcohol. Specific policies targeting these issues can be put into place. For instance, taxation can be used to reduce alcohol consumption, whereas increased budget allocation towards the health sector would increase health expenditure.

An interesting insight from the study was that while health expenditure significantly impacts population health, it did not have a direct effect on economic growth. The implication of this for policy makers in the region that they should to not only increase the amount of health expenditure but also to invest in more cost effective health promotion strategies that will result in more population health for less expenditure. Policy makers must also look into spending more on health preventive measures rather than on the treatment of illnesses. This will not only have long term impact on population health but also significantly reduce future treatment costs. We further recommend that policy makers must put measures in place to ensure transparency in the way funds for the health sector are actually spent to reduce inefficiency in the health sector.

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APPENDIX

Appendix A: Data

A) Data Sources

Source	Link
World Bank World Development Indicators (WDI)	https://data.worldbank.org/products/wdi
United Nations Development Programme (UNDP)	http://hdr.undp.org/en/data
The Institute for Health Metrics and Evaluation (IHME)	http://ghdx.healthdata.org/
World Health Organization Global Health Observatory Data	http://www.who.int/gho/en/
Kuncic (2013) Institutional Quality Data	https://sites.google.com/site/aljazkuncic/

B) List of countries in Sample

Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Congo Dem. Rep., Cote d'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Malawi, Mali, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe

Appendix B: Estimation Tables

A) Descriptive Statistics table

Variable	Observations	Mean	Standard Dev.	Minimum	Maximum
AL	542	4.096107	2.84551	0.04	11.89
AYS	568	4.797007	2.00019	0.9	10.3
FP	600	101.4968	25.1247	43.49	207.44
GCF	573	21.99555	19.1195	-2.424	219.07
GDP	600	2250.864	3217.479	170.5817	20333.94
HAQI	600	41.44267	6.298883	23.3	65.22
HIV	580	7.943448	7.682169	0.1	30
INFM	600	72.31333	27.53412	13.1	152.3
LE	600	54.21184	6.616138	31.96439	74.19439
LF	600	1.03e+07	1.44e+07	269264	9.36e+07
NHE	600	3.28e+11	7.75e+11	0	6.07e+12
PIQ	480	0.407709	0.138438	0.0425	0.697222
TPR	463	42.86218	12.12557	18.73281	80.67995
TRD	587	77.76537	49.97935	20.96405	531.7374

UP	600	4.0129	1.7927	-0.35122	17.62512
WS	600	67.02667	16.44868	34	99.9

B) Health Model : Life Expectancy and Infant Mortality

Two-Step Dynamic Panel-Data Estimation				
Dependent Variable	**Life Expectancy (log)**		**Infant Mortality (log)**	
$\boldsymbol{ln\ HEALTH_{t-1}}$	0.8540***	(0. 0308)	0.8500***	(0.0362)
ln_GDP	0.0452**	(0.0201)	0.0319	(0.0293)
ln_FP	-0.0007	(0.0103)	-0.0214	(0.0158)
ln_NHE	0.0127***	(0. 0024)	-0.0065*	(0.0039)
HIV	-0.0035***	(0.0012)	-0.0013	(0.0042)
HAQI	-0.0016*	(0.0009)	-0.0044**	(0.0020)
AYS	0.0094*	(0.0052)	-0.0371***	(0.0117)
UP	0.0016**	(0.0008)	-0.0131	(0.0140)
WS	0.0001	(0.0004)	-0.0009	(0.0006)
ALC	0.0004*	(0.0002)	0.0011***	(0.0003)
PIQ	0.0012	(0.0195)	-0.0352	(0.0239)
y7 - 2001	-0.0002	(0.0007)	-0.0015	(0.0015)
y8 - 2002	0.0012	(0.0008)	-0.0013	(0.0019)
y9 - 2003	0.0009	(0.0008)	-0.0010	(0.0017)
y10 - 2004	0.0001	(0.0006)	-0.0021	(0.0014)
y13 - 2007	0.0018***	(0.0005)	-0.0035**	(0.0016)
y14 - 2008	0.0027***	(0.0006)	-0.0006	(0.0013)
y15 - 2009	0.0032***	(0.0008)	0.0015	(0.0019)
y16- 2010	0.0028***	(0.0009)	0.0002	(0.0018)
Number of obs.	520		491	
Number of Instruments	99		87	
Wald chi2	1.29e+06	(0.0000	296540.35	(0.0000)
AR 1 test	2.0757	(0.0379)	-0.71998	(0.4715)
AR 2 test	1.9317	(0.0534)	-0.88393	(0.3767)
Sargan Test	12.59655	(1.0000)	17.1504	1.0000
Instruments for Differenced Equation	L(3/4).ln_LE , L(3/3).ln_GDP, L(3/3).AYS, L(3/3).ln_FP		L(2/2).ln_INFM, L(2/2).ln_GDP, L(2/2).AYS, L(2/2).ln_FP	

C) Growth Model: General Analysis

Dependent Variable	**Two-Step Dynamic Panel-Data Estimation** **GDP Per Capita (log)**	
$\boldsymbol{ln\ GDP_{t-1}}$	0.8277***	(0.1310)

ln_LE	0.3144	(0.3219)
ln_GCF	-0.0059	(0.0075)
ln_HAQI	-0.0007	(0.0139)
PIQ	0.3281**	(0.1455)
ln_NHE	0.0464	(0.0412)
AYS	0.0717**	(0.0365)
ln_LF	-0.2871**	(0.1217)
TP	-0.0002	(0.0002)
TRO	0.0004**	(0.0002)
y7 - 2001	-0.0173***	(0.0064)
y8 - 2002	-0.0099	(0.0094)
y9 - 2003	-0.0012	(0.0081)
y10 - 2004	0.0055	(0.0066)
y13 - 2007	0.0144***	(0.0034)
y14 - 2008	0.0022	(00056.)
y15 - 2009	-0.0230***	(0.0055)
Number of obs.	496	
Number of Instruments	64	
Wald chi2	12688.436	(0.0000
AR 1 test	-2.5585	(0.0105)
AR 2 test	-0.89978	(0.3682)
Sargan Test	13.2133	(1.0000)
Instruments for Differenced Equation	L(3/3).L.ln_GDP, L(3/3).AYS, L(3/3).ln_LE	

D) Growth Model Long Term Analysis

Dependent Variable - GDP Per Capita (log)	**Two-Step Dynamic Panel-Data Estimation**					
	Life expectancy lagged by 10 years		**Life expectancy lagged by 11 years**		**Life expectancy lagged by 12 years**	
$ln\ GDP_{t-1}$	0.8918***	(0.0753)	1.003***	(0.0793)	0.9646***	(0.0969)
Lag (ln_LE)	0.3323**	(0.1418)	0.1785	(0.1694)	0.2975*	(0.1536)
ln_GCF	0.0308***	(0.0059)	0.0396***	(0.0067)	0.0533***	(0.0070)
ln_HAQI	-0.0056	(0.0047)	-0.0086**	(0.0038)	-0.0107**	(0.0044)
PIQ	0.0181	(0.0167)	0.0567**	(0.0248)	0.0342	(0.0236)
ln_NHE	-0.0142	(0.0222)	-0.0403***	(0.0088)	-0.0379***	(0.0129)
AYS	0.1594***	(0.0373)	0.0624	(0.0524)	0.1319***	(0.0416)
ln_LF	-0.3322***	(0.1051)	-0.0747	(0.1108)	-0.3000**	(0.1260)
TP	-0.0008***	(0.0002)	-0.0009***	(0.0002)	-0.0013***	(0.0002)
TRO	-0.0005***	(0.0001)	-0.0004***	(0.0001)	-0.0007***	(0.0002)
y13 - 2007	0.0122***	(0.0021)	0.0059***	(0.0022)	-0.0048	(0.0061)
y14 - 2008	0.0075**	(0.0037)	0.0018	(0.0036)	-0.0071	(0.0055)

y15 - 2009	-0.0117***	(0.0028)	-0.0137***	(0.0027)	-0.0200***	(0.0048)
Number of obs.	268		239		210	
Number of Instruments	35		32		29	
Wald chi2	11409.43	(0.0000)	60446.67	(0.000)	6923.67	(0.0000)
AR 1 test	-2.302	(0.0213)	-2.7007	(0.006)	-2.1624	(0.0306)
AR 2 test	-1.5658	(0.1174)	|-2.0138	(0.0440)	-1.3327	(0.1826)
Sargan Test	21.0561	(0.5173)	17.2605	(0.5722)	20.03214	(0.2188)
Instruments for Differenced Equation	L(3/3).L.ln_GDP, L(3/3).AYS, L(3/3).ln_LE		L(3/3).L.ln_GDP, L(3/3).AYS, L(3/3).L11.ln_LE		L(3/3).L.ln_GDP L(3/3).AYS L(3/3).L12.ln_LE	

E) Robustness Checks – Growth Model with Infant Mortality

Variable	**Two-Step Dynamic Panel-Data Estimation Coefficient Estimates Dependent Variable- Log GDP per capita**	
ln GDP$_{t-1}$	0.659***	(0.1762)
ln INFM	-0.463***	(0.1671)
ln GCF	-0.005	(0.0052)
HAQI	-0.010	(0.0076)
PIQ	0.291*	(0.1583)
ln NHE	0.035	(0.0432)
AYS	0.076	(0.0596)
ln LF	-0.444*	(0.2347)
TP	0.0001	(0.0001)
TRO	0.0001	(0.0002)
y7 - 2001	-0.0135**	(0.0057)
y8 - 2002	-0.0128	(0.0086)
y9 - 2003	-0.0071	(0.0060)
y10 - 2004	0.0042	(0.0070)
y13 - 2007	0.0160***	(0.0038)
y14 - 2008	0.0025	(0.0054)
y15 - 2009	-0.0195***	(0.0061)
Number of observations	496	
Number of instruments	64	
AR 1 Test	-1.98	(0.048)
AR 2 Test	-0.58	(0.561)
Sargan Test	15.25	(1.00)
Wald Test	23360.43	
Instruments for Differenced Equation	L(3/3).L.ln_GDP, L(3/3).AYS, L(3/3).ln_INFM	

F) Growth Model With Infant Mortality – Long term Analysis

Variable	Coefficient Estimates Dependent Variable- Log GDP per capita		
	Infant Mortality lagged by 10 years	Infant Mortality lagged by 11 years	Infant mortality lagged by 12 years
ln GDP_{t-1}	0.929**8 (0.0560)	0.879*** (0.0259)	0.772*** (0.0923)
ln INFM	-0.057 (0.068)	-0.037 (0.0822)	-0.709*** (0.1536)
ln GCF	0.037*** (0.0043)	0.033*** (0.0041)	0.035*** (0.0070)
HAQI	0.0002 (0.0025)	-0.002 (0.0025)	0.003 (0.0055)
PIQ	0.056*** (0.0298)	0.032* (0.0184)	0.034 (0.0301)
ln NHE	-0.016* (0.0085)	-0.011 (0.0094)	-0.016* (0.0085)
AYS	0.037*** (0.0131)	0.018 (0.0171)	0.055 (0.0473)
ln LF	-0.139 (0.1143)	-0.009 (0.1025)	-0.784*** (0.1823)
TP	-0.001*** (0.0002)	-0.001*** (0.0001)	-0.002*** (0.0002)
TRO	-0.001*** (0.0001)	-0.001*** (0.0001)	-0.001*** (0.0002)
y13 - 2007	0.012***	0.009***	-0.038***
y14 - 2008	0.003	0.004	-0.026***
y15 - 2009	-0.014***	-0.017***	-0.027***
Number of observations	268	239	210
Number of instruments	35	32	29
First Order Serial Correlation	-2.60 (0.009)	-2.36 (0.018)	-1.02 (0.305)
Second Order Serial Correlation	-1.79 (0.074)	-1.95 (0.051)	-0.89 (0.369)
Sargan Test	21.96 (0.462)	18.05 (0.519)	18.01 (0.32)
Wald Test	29727.68	50754.88	1715.53
Instruments for Differenced Equation	L(3/3).L.ln_GDP L(3/3).AYS L(3/3).L10.ln_INFM	L(3/3).L.ln_GDP L(3/3).AYS L(3/3).L11.ln_INFM	L(3/3).L.ln_GDP L(3/3).AYS L(3/3).L12.ln_INFM

Appendix C: Calculation of the Health Care Access Quality Index

Age-standardised risk-standardised death rates

Using the wide range of risk factors assessed by GBD, we risk-standardized death rates to the global level of risk exposure. We did not risk-standardize for variations in metabolic risk factors directly targeted by personal health care: systolic blood pressure, total cholesterol, and fasting plasma glucose. For example, stroke deaths due to high systolic blood pressure are amenable to primary care management of hypertension.

To risk-standardize death rates, we removed the joint effects of national behavioural and environmental risk levels calculated in GBD, and added back the global levels of risk exposure:

$$mr_{jascy} = m_{jascy}\left(\frac{1 - JPAF_{jascy}}{1 - JPAF_{jasgy}}\right)$$

where *mjascy* is the death rate from cause *j* in age *a*, sex *s*, location *c*, and year *y*; *mrjascy* is the risk-standardised death rate; *JPAFjascy* is the joint population attributable fraction (PAF) for cause *j*, in age *a*, sex *s*, country *c*, and year *y* for all behavioural and environmental risks included in GBD; and *JPAFjasgy* is the joint PAF for cause *j*, in age *a*, sex *s*, and year *y* at the global level.

Construction of the Healthcare Access and Quality Index based on age-standardised risk standardised death rates

To construct the Healthcare Access and Quality (HAQ) Index, we first rescaled the log age-standardised risk-standardised death rate by cause to a scale of 0 to 100 such that the highest observed value from 1990 to 2015 was 0 and the lowest was 100. To avoid the effects of fluctuating death rates in small populations on rescaling, we excluded populations less than 1 million population from setting minimum and maximum values. Any location with a cause-specific death rate below the minimum or above the maximum from 1990 to 2015 was set to 100 or 0, respectively.

Because each included cause provided some signal on average levels of personal health-care access and quality, we explored four approaches to construct the HAQ Index: PCA, exploratory factor analysis, arithmetic mean, and geometric mean. We selected the PCA-derived HAQ Index because it provided the strongest correlations with six other currently available cross-country measures of access to care or health-system inputs. Three indicators came from the GBD Study 2015: health expenditure per capita, hospital beds per 1000, and the UHC tracer intervention index, a composite measure of 11 UHC tracer interventions (four childhood vaccinations; skilled birth attendance; coverage of at least one and four antenatal care visits; met need for family planning with modern contraception; tuberculosis case detection rates; insecticide-treated net coverage; and antiretroviral therapy coverage for populations living with HIV). Three indicators came from WHO (physicians, nurses, and midwives per 1000), the International Labour Organization, and the World Bank (coverage index based on diphtheria-pertussis-tetanus vaccine coverage, coverage of at least four antenatal care visits, and proportion of children with diarrhoea receiving appropriate treatment).

Source : Barber, R.M., et al. (2017). **Healthcare Access and Quality Index based on mortality from causes amenable to personal health care in 195 countries and territories, 1990–2015: a novel analysis from the Global Burden of Disease Study 2015**. *The Lancet*, pp.231–266. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)30818-8/fulltext [Accessed 1 May 2019]