University of Botswana

DEPARTMENT OF ECONOMICS

THE IMPACT OF HEALTH STATUS ON ECONOMIC GROWTH IN BOTSWANA – A SIMULTANEOUS MODEL APPROACH

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DECLARATION

I declare that this study has not been undertaken previously and that the contents are my original work except where references have been made.

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Christopher K. K. Chambo

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Date

CERTIFICATE OF APPROVAL

The dissertation has been examined and approved as meeting the requirements for the partial fulfilment of the Masters of Art Degree in Economics.

Ms N. Setshegetso **Supervisor**	Date

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LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

HIV:	Human Immunodeficiency Virus
AIDS:	Acquired Immunodeficiency Syndrome
GDP:	Gross Domestic Product
FDI:	Foreign Direct Investment
GFCF:	Gross Fixed Capital Formation
WHO:	World Health Organisation
2SLS:	Two-Stage Least Squares
OLS:	Ordinary Least Squares
ARDL:	Autoregressive Distributed Lag Model
ECM:	Error Correction Model
WDI:	World Development Indicators
VAR:	Vector Autoregression

ABSTRACT

Human capital most especially health status has been gaining traction as an economic engine in economic growth whereby it is both an input and output of economic growth. Growth models using health variables do state the existing endogeneity and so far have either ignored or used econometric procedures to account for it. This study makes use of the Kaldor-Verdoorn law to capture the endogeneity along with the augmented Solow growth model, solves the two as a system of equations using 2SLS regression. The study is conducted between the period 1975 and 2015. The resulting growth equation yielded life expectancy and under-5 mortality as significant health variables in determining economic growth. Both have a negative relationship to economic growth which for life expectancy goes against economic theory. However, this is due to specific underlying factors affecting the country.

Keywords: Human capital, Life expectancy, Mortality, Augmented Solow growth model Kaldor-Verdoorn law and Two-stage least squares

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TABLE OF CONTENTS

CHAPTER ONE

Introduction

Chapter one introduces the concept of health as a factor affecting economic growth in addition to being an output of economic growth, giving health a dual nature.

1.1 Background of the Study

Empirical studies over the last 5 decades have raised concerns over the unidirectional relationship between wealth and health. Whereas older studies assert that improving economic conditions lead to improved health, newer studies and emerging evidence suggest that health is a form of ‘economic engine’ and supports the hypothesis that better health enhances economic development (Chang, et al., 2008). Similarly Mirvis & Clay (2008), suggest that the relationship between health status and economic development is two-way in nature.

Long term studies on developed countries have helped highlight this new perspective on economic growth. Studies conducted by Arora (2001); Becker (1995) and World Bank (1993) have shown a long term relation between economic perfomance of countries and health status variables such as life expectancy and other human capital measures. Health in this context is considered as an essential input into the economy rather than simply being an output of increased health care expenditure resulting from higher economic growth (Mirvis & Clay, 2008). Consequently, the view on health expenditure has begun changing from one of a recurrent expenditure to one of a capital or investment expenditure (Grossman, 1972; World Bank, 1993; Mirvis & Clay, 2008).

Health affects economic growth through increasing worker productivity. To individuals, health is a key component of welfare and standard of living (Bloom & Canning, 2003). Furthermore, illnesses, diseases - communicable or non-communicable and risk of death play a role in shaping human capabilities and behaviour (Bloom & Canning, 2003). The formation of such behaviour and capabilities has tremendous impact on the individual’s productivity. The largest effect of improved health on productivity occurs in the attainment of education (Leveson, et al., 1969), with the second being improved long term perspectives of individuals allowing for greater savings and investment potential (Mirvis & Clay, 2008). This occurs in conditions where individuals can earn a return on the long term nature of investments in education and savings. Another source of increased productivity is the less number of work days lost to illness (World Bank, 1993). The mechanisms above highlight the transfer of health status into productivity. Working through productivity, it allows health status to influence economic growth.

Developing countries' studies on the relationship of health affecting economic growth is limited. Additionally, developing countries face huge challenges in provision of adequate health care. The composition of ailments facing developing nations mostly comprises of infectious and communicable diseases, though of late there has been an increase in cases of non-communicable diseases. Evidence suggests that inefficiencies in governments of developing countries prevent infectious diseases from being effectively taken care of (World Bank, 1993). Such inefficiencies include focusing on less cost-effective interventions, lack of private sector involvement and lack of funds (World Bank, 1993).

The prevalence of these health challenges and difficulties in finding lasting solutions could have adverse impacts on the long run growth potentials of developing countries. This could also account for the general low productivity levels in developing countries.

1.2 Statement of the Problem and Its Significance

Literature has placed greater emphasis on obtaining the significance of the relationship of health status on economic growth in developing countries. Scholars therefore, have theorised that developing nations are not only in the best position to formally test the theory of 'health as an economic engine' but also implement it. There is a larger gain to economic performance from increased health care of developing countries compared to those of developed countries as they will not yield as large results (Bloom & Canning, 2003). The strength of the empirical evidence, from developed nations, on this new model requires that developing nations need to at a bare minimum test the significance of the relationship.

There are two main research problems this study intends to deal with. First is the need to establish whether there exists a significant relationship between health, given by health status indicators, on the economic growth of Botswana. Second, is the need to account for endogeneity arising from health being regarded as an input in economic growth as it is also an output of economic growth.

By testing the significance of the relationship between health and economic growth, we can determine whether more effort is needed in the health sector. More effort does not necessarily mean more spending in the sector. Filmer, et al. (2000) has shown that for developing countries, increasing health expenditure does not lead to substantial improvements in health status of individuals. Therefore, more effort in the sector can be seen as improvements in all aspects of efficiency considering the already high per capita spending in health care for Botswana. Findings from the study will benefit society from the individual level to the economy as a whole. At the individual level there would be an increase in quality of health care received, leading to increased health and thereby increasing health status indicators that would increase individual productivity. The increased productivity benefits the overall economy in itself being a new avenue of economic growth potential.

1.3 Objective of the Study and Statement of the Hypothesis

Following the two research problems the respective research objectives are as follows. The overall objective of the study seeks to investigate the relationship between health and economic growth using time-series data from 1975 to 2015. Empirical testing is done using a system of simultaneous equations to account for the endogeneity of health, which is regarded as the secondary objective.

Available literature has established sufficient evidence in support of the impact and gain of economic performance from increased health status of developed countries (Anyanwu, 1997/98; Arora, 2001; Akram, et al., 2009; Piabuo and Tieguhong, 2017). The study hypothesises that there exists a positive and significant relationship between health and economic growth.

CHAPTER TWO:

Overview of the Economy

Botswana being the focus of the study, chapter two discusses a multitude of issues about the country. Section 2.1 compares current health budgeting with other human capital elements. Section 2.2 provides an overview of the interactions between health status and economic growth from 1960 to present day.

2.1 Motivation for Botswana

Government of Botswana has committed to the development of human capital as one of its main strategies for promoting economic growth (Government of Botswana , 2014). It allocates a large amount of effort and portion of recurrent expenditure to the portfolio as seen in Table 2.1 below. Human capital in this regard caters for education, capacity building and skill development and is represented by the budget of the Ministry of Education and Skills Development. The government views human capital and health as separate components and rightfully so for the sake of ministerial resource distribution. Table 2.1 compiled from budget speeches compares recurrent and development expenditures between human capital and health.

Table 2.1
Budget Allocation Per Sector (Pula in millions)

	Human Capital				Health			
Year	Recurrent		Development		Recurrent		Development	
	Pula	% share	Pula	% share	Pula	% share	Pula	% share
2013	7930	23	1180	3.4	4420	12.8	NA	NA
2014	9260	27.8	NA	NA	5220	15.7	NA	NA
2015	1031	28.1	845	6.5	5670	15.5	204	1.5
2016	1064	28.8	741	5	5750	15.5	741	5
2017	6800	17.2	845	NA	6590	16.6	NA	NA
2018	7970	17.7	NA	NA	7540	16.7	NA	NA

Source: Botswana Budget Speeches: 2013, 2014, 2015, 2016, 2017 & 2018

Human capital is on average allocated 28 percent of recurrent expenditures whilst health about 16 percent, where developmental budgets are explicitly stated human capital receives an equal or greater allocation compared to health. It is evident that there is a large focus and effort placed in human capital growth.

The health sector does receive its fair share of effort in that it is usually the second highest allocation amongst recurrent expenditure. However, it is not one for receiving development expenditures. Between 2014 and 2018 Botswana has managed to allocate a minimum of 15 percent of its government expenditure to health as confirmed in Table 2.1. As a result, the country has one of the highest per capita health spending in the region. However, while large progress has been made in the health sector with improvements in health status indicators, the health services are not the best in the region. An example is where certain specialised procedures require exportation from South Africa. This highlights the room for growth in the sector. Furthermore, this study asserts that more can be done in the sector as health status indicators are not as well off as those in developed nations. Botswana's health sector cannot be directly compared to developed nations as it is a middle income developing nation. The health sectors of developed nations serve as a benchmark for improvements in the health sector. It is simply not enough to be the best amongst developing nations but to also meet the standards of developed nations.

2.2 Health and Health Status Indicators

On an aggregate level, Botswana continues to suffer from high rates of communicable diseases. Over the years the country has been burdened by HIV and its concomitant sicknesses being the most prevalent. Table 2.2 below shows prevalence rates as well as respective incidence rates. It is worth noting that there have been significant improvements in containing prevalence which is vital for a non-curable disease.

Table 2.2
HIV Prevalence and Incidence Rates, 2004-2013

Year	Prevalence rate	Incidence rate
2004	17.1	NA
2008	17.6	2.9
2013	18.5	1.35

Source: BAIS II, III, IV Reports.

Botswana has not completely ironed out other communicable diseases outside of HIV, as can be seen by sporadic outbreaks of either malaria or diarrhoea from time to time. This however, could be due to heavier than expected rainfall in certain seasons (Ministry of Health and Wellness, 2017).

The government of Botswana accounts for just over 70 percent of medical care provided, thereby falling into the concerns of the World Bank stated earlier in the study. They include focusing on less cost-effective interventions, lack of private sector involvement and lack of funds (World Bank, 1993). Increasing government efficiency would therefore be an effective means of improving health care along with increasing private participation. This highlights the growth potential in the sector and therefore such a study could give an impetus to improving the system. Government efforts to improve health status have been successful as can be seen in the figures below.

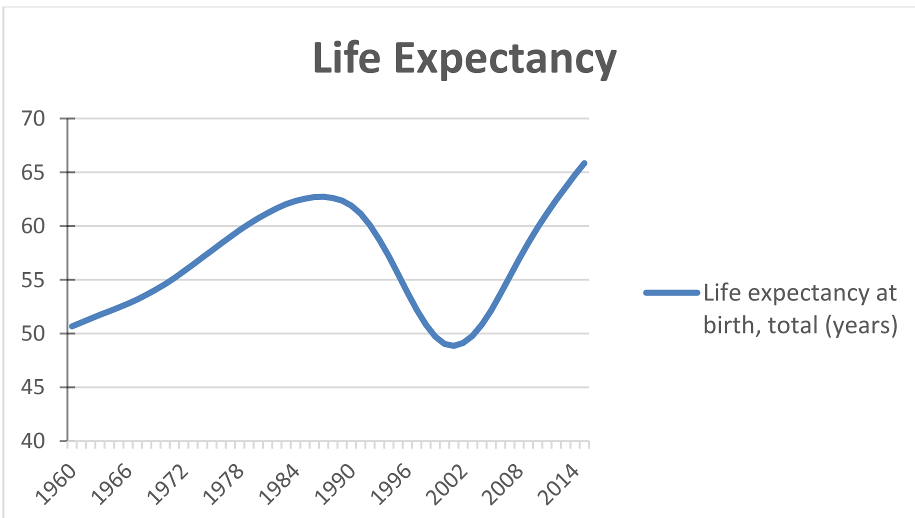

Figure 2.1: Life Expectancy at birth in Botswana, 1960-2017

Source: WDI, 2018

Life expectancy steadily rose from 49 to just over 65 over the 56 years of record keeping as shown in Figure 2.1 above. It represents an over 30 percentage improvement in life expectancy in half a century. It is not a smooth curve in line with most developing countries that face epidemics. Ethiopia and Kenya are countries that have a similar life expectancy pattern and both faced large malaria epidemics in their histories (Kebede, et al., 2010). The drop in life expectancy can be explained by the HIV epidemic that emerged in the mid 1980's, which was controlled after the introduction of national strategic frameworks (Governement of Botswana, 2014). The relationship between life expectancy and GDP per capita is highlighted in Figure 2.2 below.

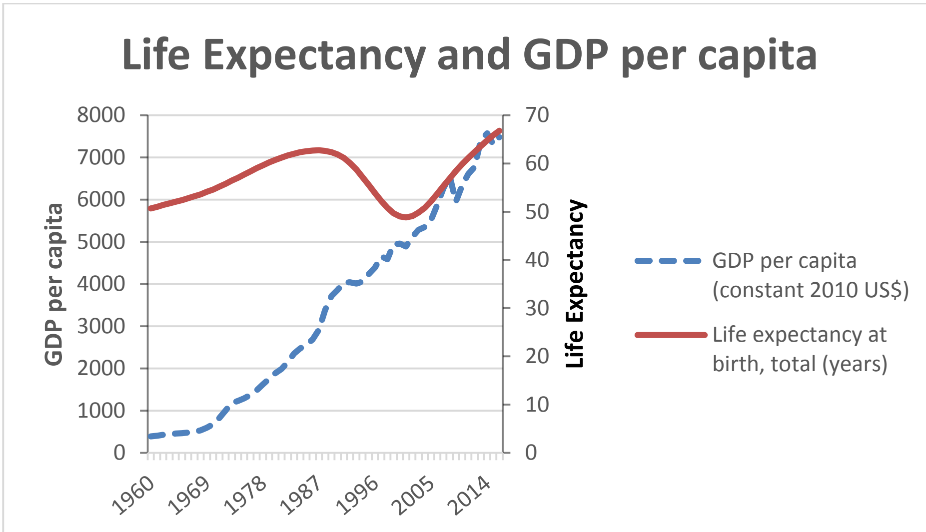

Figure 2.2: Life Expectancy and GDP per capita, 1960-2017

Source: WDI, 2018.

Despite the drop in life expectancy in 1990's GDP per capita steadily increased throughout the period of observation, with the exception of the period of the global financial crisis. Due to a drop in population occurring from an epidemic, GDP per capita has to be read with caution as it tends to increase with a decreasing population.

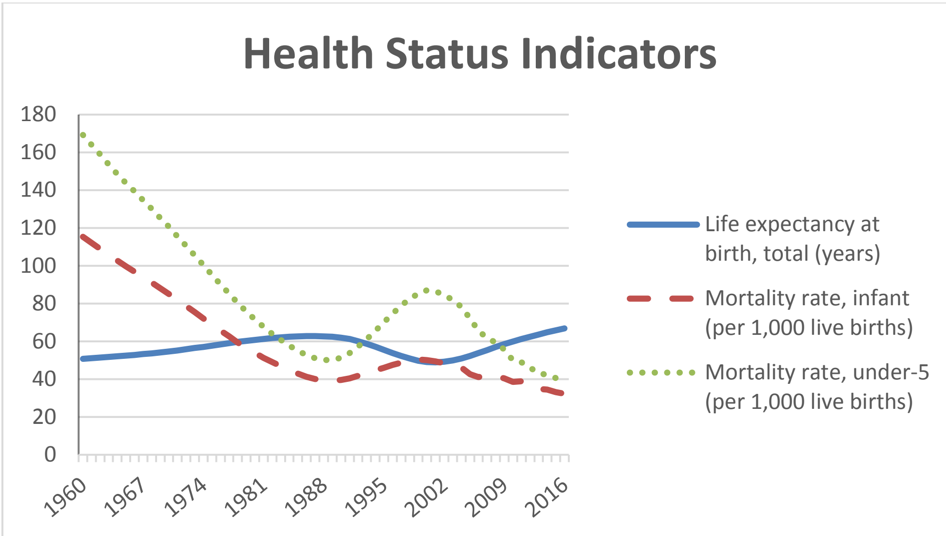

Figure 2.3: Life Expectancy, Infant Mortality rate and Under-5 Mortality Rate, 1960-2016

Source: WDI, 2018.

As expected mortality rates increased after the HIV/AIDS epidemic broke, with under-5 mortality rate almost doubling from its minimum point. Similarly there was an increase in infant mortality rate though not to the degree of the under-5 rate. Health status indicators improved substantially over the observation period however there is still room for growth. Figure 2.3 highlights the changes over time, in the major health indicators.

Household health consumption behaviour in the sector can be partially viewed using out-of-pocket expenditures. Figure 2.4 below compares per capita GDP with private and total out-of-pocket expenditures. An important observation from Figure 2.4 is that the early 2000's saw a drastic decrease in out-of-pocket expenditures. Whereby, total out-of-pocket expenditures comprised just over 5 percent of total expenditure on health. This could be due to 2 main factors being an improvement in private health insurance and the governments' drive to provide free universal health care at public facilities.

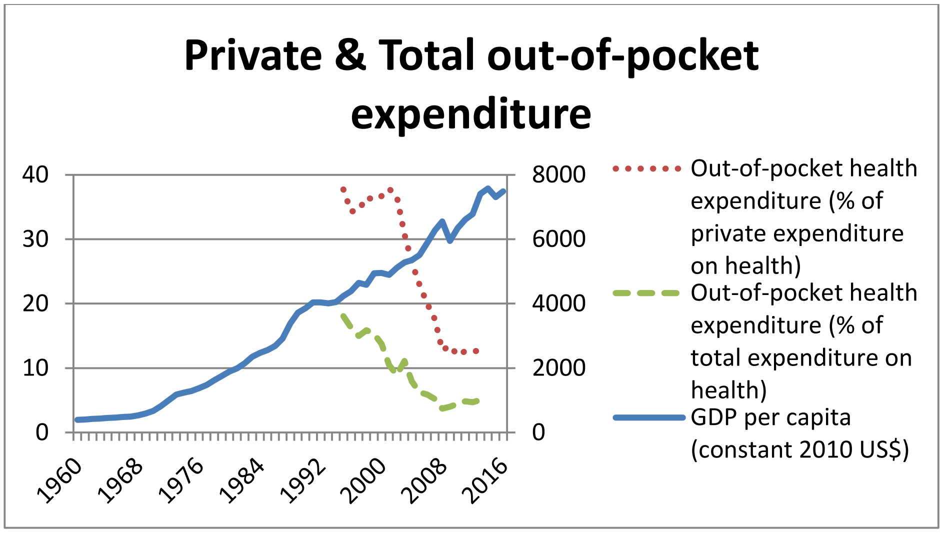

Figure 2.4: Private and Total out-of-pocket expenditure, 1960-2016

Source: WDI, 2017.

CHAPTER THREE:

Literature Review

This chapter discusses how health can be included in growth equations, based on previous literature, providing a comparison of growth theories and a motivation of using a system of equations. Along with establishing the health variables in use, the chapter describes the outcomes of research done in similar studies.

3.1 Economic Theory

The two schools of thoughts allowing health to affect growth are the neoclassical with exogenous growth and non-neo-classical focusing on endogenous growth. Arora (2001) tested over 100 years of growth headed by health improvements in developed nations and obtained endogenous growth models as better for explaining the relationship. This is due to the greater explanatory power of endogenous variables in accounting for permanent increases in long-term growth rates of per capita outputs, of which improved health status accounted for 30-40 percent of their growth. Furthermore, aspects of exogenous growth theories that were not consistent with the empirical data include convergence of steady states of differing nations of which is currently not the case. Mankiw, Romer and Weil (1992) suggested an augmented Solow growth model that accounted for the effect of human capital on growth. They further argued that about 80 percent of cross country variation in output per capita could be explained using the augmented Solow growth model.

The use of simultaneous equations to study this relationship can be argued in the same manner that economic theory uses to solve supply and demand simultaneously. Graddy & Kennedy (2010) give an example of the Futon fish market and argue that while supply and demand are indeed solved simultaneously the relationship comprises of a recursive model as supply is determined by the previous day's catch. It implies the recursive nature is only due to specific conditions being met as the overall effect is simultaneous. They further argue that for such a market to be recursive the frequency of observations must be short enough to limit feedback of current price to supply and inventory changes not affect price changes. In short the two criteria for a recursive market depend on frequency of observation and feedback of the other variables. It has to be noted that they were studying a high-frequency market. This study argues that both criteria are not satisfied when looking at relationship between GDP per capita and health status indicators such as life expectancy hence the possibility of using a simultaneous system. Figure 2.2 shows that changes in both GDP per capita and life expectancy move together over a long time period negating the first criterion. Literature has established the existence of the effect of life expectancy on the growth of the economy thereby providing the feedback necessary to negate the second criterion.

3.2 Choice of Variables

Understanding the mechanism through which health affects economic performance is vital and in order to do so there needs to be a thorough understanding of the relationship between health and productivity of workers (Bloom & Canning, 2000).

Life Expectancy: One of the first mechanisms affecting productivity is that of life expectancy. It has been observed that an individual’s ability to generate income is directly affected by duration and quality of life (World Bank, 2006). Improving health care leads to better life expectancies which not only directly improve worker productivity but also carry spill over effects (Bloom & Canning, 2003). It is important to emphasize that life expectancy on its own is not health, however, a closer look at the calculation of life expectancy shows that it highlights certain characteristics about population health thereby making it a useful health status indicator on overall health of a country (Arora, 2001). Arora (2001) further argues that diseases are the primary cause of death resulting in high death rates and low life expectancy. Therefore, it can be surmised that life expectancy not only shows the overall health of a nation but also the prevalence of diseases should it be low, that may or may not constrain human ability (Arora, 2001). Direct effects of life expectancy on productivity are an improvement of number of working years along with increasing productivity of each year due to higher work experience (Mirvis & Clay, 2008). Additionally, increased life expectancy enables the postponement of early retirement due to illness.

One of the most notable spill overs for not only life expectancy but health status in general is the impact on education attainment. Characteristics of education are that it requires a long period of time to acquire and subsequently earn an economic return from such an investment. As a result it creates an incentive for adults of good health and higher life expectancy to pursue more education due to the longer time period that they have available to recuperate the investment (Mirvis & Clay, 2008). It has been estimated that a 1 percent increase in longevity of individuals is attributed to a 1 percent increase in schooling thereby providing structural evidence for this spill over of life expectancy (Kalemi-Ozcan, et al., 2000). The effect of poor health on children is quite significant and affects them in numerous ways (Leveson, et al., 1969). For children an increased life expectancy would generally result in lowering of child mortality rates and this also carries forward its own direct effects and spill over effects. Much like adults, educational attainability in children is affected by health. This effect works through the channel as quoted by Leveson, et al. (1969), "health affects the number of years of school completed, attentiveness in school, absenteeism and time devoted to homework". All the factors mentioned are critical to childhood education.

Productivity and economic growth have long existed and been tracked such that it is undeniable that increased worker productivity leads to increased economic growth. Therefore, it is necessary to highlight some of the losses to economic growth that are a result of lost productivity. In developing countries, studies in Cote d'Ivoire and Ghana highlight significantly lower wages for each day of disability (WHO, 1999). Furthermore, men more likely to fall ill in Cote d'Ivoire were estimated to earn a 19 percent lower wage compared to healthier men (World Bank, 1993). The yearly earnings loss from illness is calculated at between 2.1-6.5 percent for developing nations whilst only about 2 percent for developed nations (Anyanwu, 1997/98). This becomes more exacerbated in countries that face large epidemics such HIV/AIDS, whereby a large number of caregivers in families of AIDS patients allowed a reduction in income or educational generating activities to care for the sick (Steinberg, et al., 2002).

Infant mortality and Fertility rate: According to Figure 2.3 above and collaborating literature, data on other health research tends to match the trend of life expectancy (Weil, 2013). Infant mortality is clearly seen to decrease with increases in life expectancy. Such decreases in infant mortality and increases in life expectancy also aid in decreasing the fertility rate. While fertility rate is not outright a health status indicator, a low fertility of a country rate is often associated with greater development (Arora, 2001). Anyanwu (1997/98) and Barro (2003) both made use of life expectancy, mortality rate and fertility rate in the study of this relationship.

3.3 Outcomes of Similar Research

Literature on developing countries is indeed minimal. Anyanwu (1997/98) investigated the relationship between health status indicators and economic growth in Nigeria. The relationship was estimated using a log-linear form with OLS and found that life expectancy and population growth exerted large significant effects on economic growth.

Piabuo and Tieguhong (2017), equally investigated health expenditure and economic growth in central African states and included all the 5 states currently adhering to the Abuja Declaration including Botswana. They made use of Panel OLS, Fully modified OLS and Dynamic panel OLS on their data sets. Their results showed evidence of cointegration between health expenditure and economic growth along with a long run relationship between health expenditures, life expectancy and economic growth.

Boachie (2015) conducted a similar study in Ghana which made use of ARDL bounds test to cointegration and the error correction model (ECM) for both long and short run dynamics respectively. The study proxies life expectation at birth as the main health indicator variable and obtains that for both the short and long run, health is a positive and significant variable in determining economic growth. However in the short run, the significance of the relationship is lower.

A study conducted in Pakistan by Akram, et al. (2009), made use of cointegration to obtain a long run significant relationship between health indicators and economic growth. The ECM was used for the short run and showed an insignificant relationship between health and economic growth.

Overall, there have been positive findings from empirical studies on the effect of health status on economic growth. Short run dynamics have been found to be less significant as compared to the long run dynamics.

3.4 Literature Gap

The majority of studies in this field have made use of various econometric methods to try and account for the subsequent endogeneity in measuring health status indicators. Anyanwu (1997/98) made use of ordinary least squares (OLS) and did not account for the possible endogeneity in the health variables. This entailed that his results were inconsistent and biased, but were able to give the directional effect of the tested relationship (Maddala, 1992). Akram, et al. (2009) made use of cointegration. Cointegrating regressions with two or more dependent variables and a small sample size have asymptotic differences based on the choice of dependent variable (Maddala, 1992). Cointegration alone does not account for possible endogeneity. Lastly Boachie (2015) made use of the auto-regressive distributed lag (ARDL) bounds test to cointegration. While ARDL does not account for endogeneity issues, it is not necessary as regressors are in lagged differences. Cointegration in the presence of ARDL ensures OLS to be consistent.

This study aims to add to the literature by using a system of simultaneous equations in order to account for the factors that affect growth of health status indicators in addition to the standard growth equation. Furthermore, it seeks to investigate the relationship between health and economic growth in the context of Botswana.

CHAPTER FOUR

Methodology

The augmented Solow growth model forms the first structural equation with economic growth as the endogenous variable. The Kaldor-Verdoorn law forms the second structural equation with human capital as the endogenous variable. Necessary control variables established from literature were used to capture their respective effects in the equations whilst focusing on the health variables. This chapter builds the system of equations effective in testing the problem statement.

4.1 The Growth Model

Following the framework of the Augmented Solow Model, output is derived from labour (*L*), physical capital (*K*) and human capital (*H*) as inputs in combination with technology (*A*) (Mankiw, et al., 1992; Knowles and Owen, 1997; Bloom, et al.; 2001, 2004). Equation 4.1 represents this relationship along with the decomposition of human capital (*H*) into its initial level (*H(0)*) and variables representing growth of human capital namely health status indicators (*h*), education (*s*) and error term (μ).

$$Y = AK^{\alpha}L^{\beta}H(0).e^{\omega h + \sigma s + \mu t} \qquad (4.1)$$

Labour economics literature stipulates that individuals are born with a stock of human capital denoted by H(0) ≥ 0. This study makes one assumption further in that it standardises the initial stock of human capital to 1 for ease of modelling, hence, (H(0)) is equated to 1. Furthermore, Labour is divided on both sides of the equation to produce an output per labour endogenous variable. The endogenous variable is therefore modelled using GDP per capita. With the manipulations above, Equation 1 is transformed to:

$$y = ak^{\alpha}e^{\omega h + \sigma s + \mu t} \qquad (4.2)$$

Taking logs of the per worker production function, Equation 2, yields:

$$lny = lna + \alpha lnk + \omega h + \sigma s + \mu t \qquad (4.3)$$

The variables in Equation 4.3 are specified as follows. A represents technological advancement that accounts for output growth not accounted by capital and labour, also known as the Solow Residual. The variable (A) has been represented in literature by inflation, international trade and foreign direct investment as being those that have an influence on level of technology (Barro 1999; Boachie, 2015). Physical capital (K) is represented by gross fixed capital formation (Boachie, 2015), health (h) represented by life expectancy at birth with infant mortality rates as additional health variables. Education variable (s) is measured by number of pupils enrolled in secondary education. Due to a lack of data on total years of education this study resorted to using an enrolment rate which is considered as a conventional measurement in OECD (Dae-Bong, 2009). The empirical growth model is represented in Equation 4.4 as the first structural equation:

$$lnGDPPC = C_1 + C_2 MORTINF_t + C_3 MORTU5_t + C_4 EDUC_t + C_5 lnINT_t + C_6 lnFDI_t + C_7 lnINF_t + C_8 lnGFCF_t + C_9 LIFEEXP_t + \mu_1 \quad (4.4)$$

Variables in Equation 4.4 are as defined in sub-section 4.4, and parameters C_2, C_3, C_4, C_5, C_6, C_7, C_8 and C_9 are to be estimated with C_1 as the constant.

4.2 The Productivity Model

Following the Kaldor-Verdoorn law, human productivity is derived from total output growth and per capita GDP (Magacho, 2014). It is represented by Equation 4.5.

$$H = \alpha_0 + \alpha_1 q + \alpha_2 y \quad (4.5)$$

Where H is human capital, q is total output growth given by GDP change in this study, y is per capita GDP and α_0 is the Verdoorn's coefficient. Equation 4.6 shows the second structural equation with the expanded human capital equation, with parameters C_{11}, C_{12}, C_{13}, C_{14} and C_{15} to be estimated with C_{10} as the constant.

$$LIFEEXP_t = C_{10} + C_{11} MORTINF_t + C_{12} MORTU5_t + C_{13} EDUC_t + C_{14} lnGC + C_{15} lnGDPPC + \mu_2 \quad (4.6)$$

Expected sign for coefficients C_{11}, C_{12} is negative while C_{13}, C_{14} and C_{15} are expected positive.

4.3 Model Estimation

The methodology employed in this study captures the recursive equations as follows:

(1) $lnGDPPC = C_1 + C_2MORTINF_t + C_3MORTU5_t + C_4EDUC_t + C_5lnINT_t + C_6lnFDI_t + C_7lnINF_t + C_8lnGFCF_t + C_9LIFEEXP_t + \mu_1$

(2) $LIFEEXP_t = C_{10} + C_{11}MORTINF_t + C_{12}MORTU5_t + C_{13}EDUC_t + C_{14}lnGC + C_{15}lnGDPPC + \mu_2$

The system of equations will henceforth be referenced to as equation (1) and (2). Use of the augmented Kaldor-Verdoorn Law in Equation 4.6 allows the system of equations to be at minimum exactly identified. Inclusion of the variable total output change allows for easier identification of the system and would not require treating the system as a nonseparable model (Chesher, 2003; Bartels, 2008). Further tests of rank and order criteria for identification are carried out on the system of equations.

Due to the time series nature of the data it is vital that variables in use are stationary prior to estimation, hence important to test for unit roots. The Augmented Dickey-Fuller and Phillips Pheron tests were used to examine each variable's time-series characteristic.

This study makes use of two-stage least squares regression analysis (2SLS) for the estimation of the system of equations. 2SLS is an estimation technique that can handle endogeneity in a system of equations such as that being examined in this study. In simple terms it derives an expected parameter of the endogenous variable in equation (2) of the system ($\widehat{LIFEEXP_t}$), the expected parameter replaces the exogenous variable in equation (1) of the system of which equation (1) is then estimated. Endogeneity is therefore controlled as the expected parameter will not be correlated to the error term μ_1.

4.4 Data and Variables

Data used for the empirical analysis is sourced from the World Bank's 2018 World Development Indicators (WDI) and is time series in nature. The time period set for the analysis was between 1975 and 2015. The variables in use are specified in Table 4.1 below.

Table 4.1
Variable Description

GDPPC	GDP per capita (current US$)
LIFEEXT	Life expectancy at birth, total (years)
MORTINF	Mortality rate, infant (per 1,000 live births)
MORTU5	Mortality rate, under-5 (per 1,000 live births)
INT	International Trade (% of GDP)
FDI	Foreign direct investment, net (BoP, current US$)
INF	Inflation, GDP deflator (annual %)
EDUC	Secondary education, general pupils
GFCF	Gross fixed capital formation (% of GDP)
GC	GDP change (current US$)

Source: WDI, 2018

Current health expenditure per capita was considered a variable in the determination of life expectancy in equation (2). However, data for the variable and all Botswana WDI health expenditure variables were only available from year 2000 up to year 2015. This means the exclusion of any form of health expenditure from this study. Due to four missing entries in the education variable, this study made use of multiple imputation technique to handle the missing data. Variables with negative entries that required log transformations were shifted upwards to ensure their minimum values could still be calculated. Doing so rids the regression intercept of meaning however variation between variables will still be captured by the regression. Variable summary statistics are found in the appendix, specifically Appendix Table 1.

To summarise, the system of equations was built from the two economic theories highlighted in this chapter with the aim of solving the growth equation while accounting for endogeneity in the human capital variables.

CHAPTER FIVE

Empirical Results

This chapter presents the outcomes of the various procedures stated in the previous chapter. Brief discussions are done on the identification of the system and unit root test results. Longer discussions are done on the outcome of the two-stage least squares estimation for both equations in the system. Variables that required log-transformations are treated as having been transformed for analysis in this chapter.

5.1 Identification of Equations

In order to estimate the system of equations, the hypothesized equations were examined for their respective rank and order conditions necessary for identification of structural equations. Both equations' (1) and (2) of the system above satisfy the rank and order conditions for identification. Appendix Tables 3 and 4 in the appendix highlight this examination. Furthermore equation (1) is exactly identified and equation (2) is over identified. Overall the system passes the necessary and sufficient conditions for the structural equations to be identified.

5.2 Unit Root Tests

Prior to the conducting the unit root tests the augmented Dickey Fuller was used to determine whether each variable contained either an intercept or both trend and intercept for unit root testing. This required making use of the F-test for linear restrictions that compared the sum of squared residuals between restricted and unrestricted models. The model containing both trend and intercept is the least restrictive, followed by that containing the intercept and most restrictive is that containing neither. The variables life expectancy, infant mortality, under-5 mortality, inflation and education were found to contain both a trend and intercept. While GDP per capita, international trade, foreign direct investment (FDI), gross fixed capital formation (GFCF) and GDP change were found to only possess an intercept. Therefore unit root tests were done according to the characteristic portrayed by each variable. The outcome of the unit root tests established that observed variables were a mixture of stationarity at levels, first difference and second difference. Life expectancy, under-5 mortality, inflation, FDI, GDP change were stationary at levels at the 1 percent level of significance while international trade at the 5 percent level of significance. GDP per capita, GFCF and education were stationary at first difference with all having a 1 percent level of significance. Infant mortality was found stationary at second difference at the 1 percent level of significance. Results from both the augmented Dickey Fuller and Phillips Pheron were compared and tabulated in appendix Table 2.

5.3 Results from the Two-Stage Least Squares

The regression output separates coefficients for each model in the system as highlighted in Table 5.1. The variable column represents all exogenous variables estimated in accordance to the system of equations specified above. Removal of the variable infant mortality yielded the best regression output and this may be due to its high correlation with under-5 mortality. Therefore the infant mortality variable was removed from both equations in the system of equations for the regression analysis.

Observed in the growth model, the intercept can be considered as the expected mean for GDP per capita when all the exogenous variables are equal to 0. It is significant at the 5 percent level, however does not hold much interpretation value. Due to the difference in linearity between the endogenous variable and non-log transformed exogenous variables, interpretation of each coefficient is mathematically approximated with $(e^{C_i} - 1) * 100$, that yields slightly different outcomes compared to simply approximating with $C_i * (100)$. The remaining log transformed variables are elasticities and for their interpretations are estimated using $((1.01)^{C_i} - 1) * 100$. Aside from the intercept, four independent variables in the growth model were statistically significant. Health, measured using life expectancy and under-5 mortality of which both were significant at the 5 percent level. The coefficient for life expectancy at birth was –0.348, interpreted as a 29.39 percent decrease in GDP per capita from a 1 year increase in life expectancy at birth. Under-5 mortality had coefficient of -0.1097, interpreted as a 10.39 percent decrease in GDP per capita per unit increase of mortality rate. International trade and inflation were the remaining significant variables, both significant at the 5 percent level.

Table 5.1

Output from Two-Stage Least Square Regression

Dependent Variable: lnGDPPC	Variable	Coefficient (p-value)
	Constant	27.9594** (0.0155)
	MORTU5	-0.1097** (0.0174)
	EDUC	-7.37E-06 (0.792)
	lnINT	-1.1114** (0.0259)
	lnFDI	0.0582 (0.233)
	lnINF	0.7652** (0.0311)
	lnGFCF	0.0628 (0.968)
	LIFEEXT	-0.3480** (0.0148)
R^2 = -35.8527	Adjusted R^2 = -43.9142	Observations: 40
Dependent Variable: LIFEEXT		
	Constant	152.6796*** (0.000)
	MORTU5	-0.3507*** (0.000)
	EDUC	-3.71E-06 (0.9336)
	lnGC	-0.7382 (0.272)
	lnGDPPC	-6.7766*** (0.000)
R^2 = 0.9360	Adjusted R^2 = 0.9286	Observations: 40

***Significant at 1% **Significant at 5% *Significant at 10%

Source: Authors calculations

The education variable yielded estimations close to 0 and was statistically insignificant. The international trade elasticity of GDP per capita was -1.11%, foreign direct investment elasticity of 0.058%, inflation rate elasticity of 0.76% and gross fixed capital formation as 0.063%. From the economic variables, FDI and GFCF were found to be insignificant variables.

The r-squared of equation (1) of the system was -35.85. For 2SLS a negative r-squared does not imply that estimates are erroneous, it is the indication that the residual sum of squares (RSS) is greater than the total sum of squares (TSS). Provided that the standard errors of the structural equation are acceptable such as those in Table 5.1, the estimates obtained in the regression are good. The r-squared does not hold statistical meaning in the context of 2SLS estimation.

5.4 Discussion of Results: Growth Model

This subsection discusses the main objective of the study being the study of the growth model inclusive of human capital which in this case comprises of health and education. It is once again important to acknowledge the possible endogeneity in human capital variables hence the need for the secondary objective, to aid in solving the growth equation. The augmented Solow growth model comprised of economic and human capital variables. International trade, inflation, FDI and GFCF comprised the economic variables. Life expectancy, under-5 mortality were health variables along with education completing the human capital variables. In the period of study it was found that life expectancy, under-5 mortality, international trade and inflation were statistically significant at determining economic growth.

This study obtained a negative coefficient for life expectancy. Stated above, GDP per capita decreases by approximately 29.39 percent with a year increase in life expectancy. The outcome is contradictory not only to economic theory but also empirical evidence in other studies. Studies from developed nations such as Arora (2001), and developing nations such as Boachie (2015) both show a positive relationship between life expectancy and economic growth. It is also counter intuitive to the productivity theory stating that increases in life expectancy, increases productivity thereby increasing economic growth. This entails that the relationship observed in Botswana has more underlying effects. Looking at Figure 2.2 previously, the graphical relationship between the two variables in the studied timeframe showed GDP per capita increasing regardless of the decrease in life expectancy. It was also stated previously in this study that GDP per capita should be used with caution in periods of heavy epidemics as it is a per population measure. A resulting slowdown in GDP can still lead to an increase in GDP per capita provided the population decreases faster than the slowdown. In Botswana's case, due to the mining nature of the economy it might have been able to weather the HIV/AIDS epidemic. Diamond mining being both highly profitable and capital intensive as opposed to labour intensive may have contributed to keeping the economy afloat even with the declining working population. Additionally, data post the AIDS epidemic does not span a long enough time frame to affect a different relationship between the two variables. The trend however is changing and post year 2000, life expectancy has been correlating positively with economic growth. Given more time, this study deduces that the relationship between economic growth and life expectancy will not only be significant but also positive in nature. It is especially so as the government seeks to diversify the economy from natural resource commodities to a private sector and service based economy. In such a scenario life expectancy will play a major role in determining economic growth hence the need to constantly improve in health services.

Under-5 mortality had a statistically significant, inverse relationship on GDP per capita given by a 10.39 percent decrease in GDP per capita per unit increase of mortality rate. This is in line with the general expectations where increases in mortality should lead to economic decline. The two largest causes of under-5 mortality in Botswana are childhood malnutrition and preventable diseases that leave the country off track for meeting the Millennium Development Goals with regards to child mortality rates (World Bank, 2015). Government's effort to combat the high rates of mortality has been the establishment of a Maternal Mortality Audit Committee and increasing the number of health outposts hence decreasing their distances to the population (World Bank, 2015). However, with regards to child malnutrition World Bank (2015) has asserted that location is more an issue as compared to income. This therefore leaves room for improvement in the health sector and resource provision.

Education as a human capital variable in the model proved to be insignificant and had a coefficient that could be rounded off to 0. This could imply that the primary driver of economic growth did not require education. The outcome is consistent with an economy based on natural resources. Furthermore, the interaction between the education variable and economic growth show that the two did not have similar growth patterns that may lead to the insignificant outcome. The first large growth period between 1975 and 1985 did not coincide with similar growth in education. The period thereafter saw a slowdown in economic growth with a sharp increase in the education variable. In comparison Akram, et al. (2009) and Boachie (2015) obtained significant and positive relationships between education and economic growth for developing countries. Due to data limitations the education variable used in this study was enrollment in secondary school. Secondary school might not have been a requirement to work in certain fields of work such as mining which was a prevalent economic driving force in the period. With regards to mining, secondary school was probably not a requirement to be a mine labourer however, other more senior roles in the mines required secondary school qualification at a minimum. Arora (2001) argues that education in general is not a good human capital variable as it inadequately represents human abilities. Arora (2001) further argues that schooling only reflects investment during youth and does not account for on-the-job training and experience. Currently the Botswana government has placed an emphasis of improving education and skills as seen in Table 2.1, therefore there should be an expectation that general education levels will continue improving with time. It is worth noting that despite education's insignificance and coefficient being close to 0, its removal from estimation rendered the overall results worse off.

FDI has been found to be an insignificant contributor to economic growth and is given by a 0.58 percent increase in GDP per capita following a 10 percent increase of FDI. The insignificance arises from the minor of variation in the FDI variable. FDI spending has been consistent throughout the observation period and thus the minor variation may not be sufficient to provide a statistical relation to economic growth. In reality, FDI would most likely have an impact on economic growth. As the country diversifies from being mining dependent, variables such as FDI will play a greater role as it transitions to either a service or manufacturing based economy. In comparison, Boachie (2015) found FDI to be a negative and insignificant variable in determining economic growth, while asserting that for FDI to be effective it needs assistance in the form of a well laid out regulatory framework. Despite Botswana being a highly attractive target for FDI, topping at 6th in Africa between 2003 and 2011, volumes are small at just 3 percent of GDP on average for the past two decades (World Bank, 2015). This handedly explains FDI's insignificance in accounting for economic growth. The World Bank (2015) further states that while there are shortcomings in Botswana's investment policy, it is not a significant barrier as compared to structural problems concerning regional trade.

International trade is a significant variable with a negative elasticity to GDP per capita. A 10 percent increase in international trade leads to a 10.05 percent decrease of GDP per capita. The trade variable used was net exports as opposed to trade openness used in other developing nation studies such as Akram, et al. (2009). Both Akram, et al. (2009) and Boachie (2015) found a positive and significant relationship between trade and economic growth for their respective countries. Net exports calculated as exports less imports, implies that for the observation period the country's economic growth did not rely on a net positive trade balance. A possible reason could be the turnaround from a positive trade surplus influenced growth that was experienced shortly after diamond discovery from 1980's, to the current post 2008 consumption-driven import growth that has required running a trade deficit (World Bank, 2015). In all the other years in the period of observation economic growth was influenced by a negative trade balance. An inverse elasticity entails that a trade deficit is more beneficial, falling in line with the current growth trend experienced in the country. Around 90 percent of Botswana's exports still comprises of natural commodities, there is therefore need to diversify exports.

The estimated coefficient of inflation in Table 5.1 implies that a 10 percent rise in inflation leads to a 7.56 percent increase in GDP per capita. The relationship is significant at the 5 percent level. The significance or inflation varies among developing nations and their respective policies that governed economic growth. Boachie (2015) found inflation to be negative and significant in the short run but not the long run. In the case of Botswana inflation is found to have a positive effect on economic growth in the period of observation. Theoretically, controlled inflation is a catalyst for economic growth. A positive aspect of controlled inflation on the economy is the effect on borrowing as money borrowed can be paid back with less valuable money making it more desirable for debtors.

Lastly, GFCF is an insignificant variable with a positive elasticity whereby a 10 percent increase in GFCF leads to a 0.63 percent increase in GDP per capita. Among studies in developing nations Boachie (2015) obtained a positive and significant relationship between economic growth and GFCF. The insignificance of GFCF arises from the fact that it has barely increased, staying relatively constant, with increasing economic growth over the period of observation. While GFCF levels in the country are higher in comparison to its peers, it is still below that promised by the government in Vision 2016 (World Bank, 2015). The aim of GFCF was to aid in economic diversification, with significant progress made, however the country remains dependent on diamonds for its export (World Bank, 2015).

The use of the system of equations to estimate the growth model has proved to be successful and while some of the outcomes from the regression have proved to be contradictory to economic theory, they do support what is currently happening in the country. After estimation of the model the residuals were tested for autocorrelation and normality with the outcomes tabulated in appendix Tables 5 and 6 and are satisfactory for analysis of coefficients. The major challenge faced on using 2SLS estimation is the requirement of more data, which is a constraint when studying developing nations in general as not all entries for variables are available. The larger the sample size used, the more accurate 2SLS estimation will be.

5.5 Discussion of Results: Productivity Model

The productivity model captures the endogeneity in the human capital variables more specifically factors affecting life expectancy. The linearity of the equation is straight forward with regards to the non-transformed explanatory variables as it is an OLS regression. The logarithmic explanatory variables are mathematically approximated with $C_i * \ln(1.01)$. Significant variables affecting life expectancy were found to be under-5 mortality and GDP per capita at the 1 percent level of significance.

Under-5 mortality had a significant negative relationship on life expectancy, given by a 0.35 decrease in life expectancy per unit increase in mortality. Due to the calculation of life expectancy encompassing mortality the negative relationship is theoretically sound. The reasons affecting under-5 mortality have been discussed in section 5.2 along with the main areas for improvement.

Following from the earlier findings, GDP per capita had a significant and negative relationship with life expectancy. A 10 percent increase in GDP per capita reduced life expectancy by -0.64. The discussion in sub-section 5.2 highlighted how life expectancy channels into economic growth. Equation (2) now shows how economic growth channels into life expectancy and while it is a significant relationship it is inverse in nature. Bearing in mind the current positive correlation between life expectancy and growth of the economy, the results show that it still has not offset the negative impact of the AIDS epidemic in the period of observation. This therefore raises the question concerning efficiency in provision of health care as the economy has progressed. As the economy has grown, more can be provisioned into the health sector. However, due to the negative relationship encountered here, it may be more beneficial to enhance efficiency before increasing such provisions. The outcome highlights the potential area for improvement in terms of translating economic growth to improvements in health.

Education and GDP change were both insignificant in affecting life expectancy. The education variable had a coefficient small enough to be approximated to 0. While the estimated coefficient for GDP change implies, a 10 percent increase in GDP change resulted in a -0.07 change in life expectancy.

Overall the productivity model was effective in determining factors that affect life expectancy in Botswana. The Kaldor-Verdoorn law has been effective in capturing the effect of economic growth on human capital variables in turn taking care of the endogeneity in the health variables.

CHAPTER SIX

Conclusion

The main objective of this study was to estimate the degree to which health variables contribute to the economic growth of Botswana using an augmented Solow growth model between the years of 1975 and 2015. The resulting endogeneity in the human capital variables was captured using a productivity model captured by the Kaldor-Verdoorn law. The systems of equations were solved simultaneously using 2SLS estimation that yielded interesting findings.

Of the health variables in the growth model, under-5 mortality and life expectancy were significant variables in explaining economic growth. Furthermore, this study obtained a negative relationship between life expectancy and economic growth that challenges convectional economic theory. However, this is due to peculiar circumstances facing the country at the time. Under-5 mortality also had a negative relationship with economic growth which is in accordance to literature. Other determinants of growth included international trade, inflation, FDI and GFCF of which inflation and international trade were found to be significant in determining economic growth in the study period.

The productivity model obtained under-5 mortality and GDP per capita as significant variables in explaining life expectancy, both variables being negatively related to life expectancy. This confirms the dual nature of life expectancy and its inverse relationship to the country's economic growth.

In Botswana's case health variables were found to be significant determinants of economic growth and will play a vital role in the future. Whilst current effort is being made to combat child mortality more needs to be done to significantly drop the mortality rates. Regardless of the negative relationship with economic growth as part of the outcome, the significance of life expectancy in the study provides an avenue in human capital improvement and economic growth as the country transitions from a mineral based economy.

6.1 Policy Recommendations

The study showed that health status has an impact on economic growth in Botswana with the two significant health variables being life expectancy and under-5 mortality. The country is currently behind in its own stated objective of curbing child mortality contained in its Vision 2016 objectives. However the country has established a Maternal Mortality Audit Committee that is inclusive of child mortality. Due to child mortality being affected by both malnutrition and preventable diseases, further effort can be placed in improving the provision of resources in rural areas. Rural areas in particular as The World Bank has singled out their receipt of fewer resources comparable to urban areas.

Life expectancy's' significance and being negatively affected by increases to economic growth, highlights the element of efficiency in general health care. Inefficiency in health care may arise as a result of the government contributing to a large portion of the medical care stated previously. Botswana may therefore be a country that benefits more from efficiency improvements as opposed to simply increasing its health budget. Efficiency improvements were stated earlier in the study being, focusing on more cost-effective interventions and increasing private sector involvement. Efficiency improvements should not only improve life expectancy but also overall health status.

6.2 Limitations of the Study and Areas of Further Studies

The main constraint in this study was the availability of data, a common challenge faced by studies in developing nations. Broken up into three limitations, the first is missing entries within variables, unavailability of specific variables that are found in comparative studies in developed nations and lastly a limited length period in availability of data. For this study the length of data recording was necessarily important as it improves the estimations from 2SLS estimation and would have allowed the inclusion of a variable such as health expenditure.

Vector autoregression (VAR) estimation with granger causality may be used to compare the results obtained in this study. This provides one area of further studies that may aid confirmation of results obtained here. Furthermore, due to the current positive correlation between life expectancy and economic growth, this study should be revisited after a period of about ten years to re-establish the empirical relationship between the two variables. Ten years would be a good starting point for the following reasons. Firstly it will provide more observations for a total of 50, improving the statistical analysis. Secondly it would allow for a sufficient period post the HIV/AIDS epidemic for life expectancy to normalize. This will better establish the current positive relationship between life expectancy and economic growth.

Appendix

Appendix Table 1
Variable Summary Statistics

Variable	Observations	Mean	Std Deviation	Min	Max
GDPPC	41	3237.00	2171.52	430.07	7493.75
LIFEEXT	41	58.02	4.96	48.83	65.84
MORTINF	41	45.8	8.1	33.1	68.8
MORTU5	41	65.6	15.09	40.6	95.1
INF	41	9.74	5.89	-0.09	22.89
INT	41	2.76	13.26	-21.82	26.69
FDI	41	-1.70E+08	2.82E+08	-1.40E+09	3.49E+08
GFCF	41	28.84	3.64	22.36	36.22
EDUC	41	99236.54	64906.71	12098.00	191639.44
GC	41	3.44E+08	8.02E+08	-1.84E+09	2.57E+09

Source: WDI, 2018.

Appendix Table 2

Summary of Unit Root Tests

Variable	Levels	First Difference	Second Difference
Augmented Dickey Fuller			
lnGDPPC	-2.9105	-4.5202***	
LIFEEXT	-5.9159***	-3.7411**	
MORTINF	-3.1267	-2.1247	-6.9185***
MORTU5	-4.7266***	-1.4364	-5.7267***
lnINT	-3.3338**	-6.6691***	
lnFDI	1.7634	4.3274	0.6691
lnINF	-5.4049***	-7.5845***	
EDUC	-1.8094	-8.0534***	
lnGFCF	-2.1627	-5.0260***	
lnGC	-3.3547**	-4.0594***	
Phillips Pheron			
lnGDPPC	-1.9941	-4.4320***	
LIFEEXT	-0.7121	-1.5334	-1.6299
MORTINF	-2.4459	-2.0422	-7.7896***
MORTU5	-1.7719	-1.6137	-5.8042***
lnINT	-3.3218**	-8.7690***	
lnFDI	-6.1879***	-38.3205***	
lnINF	-4.7764***	-13.3843***	
EDUC	-1.9281	-7.7887***	
lnGFCF	-2.4036	-5.0260***	
lnGC	-6.3441***	-7.9520***	

***Significant at 1% **Significant at 5% *Significant at 10%

Source: Authors calculations

Appendix Table 3
Order Condition for Identification

$$\underset{(Excluded\ Variables)}{K - M} \geq \underset{(Endogenous\ Variables\ less\ one)}{G - 1}$$

K $- Number\ of\ variables\ in\ the\ model\ (Endogenous\ and\ Exogenous)$
M $- Number\ of\ variables\ included\ in\ the\ considered\ equation$
G $- Total\ number\ of\ equations$

$$\text{lnGDPPC} = C_1 + C_2\text{MORTINF}_t + C_3\text{MORTU5}_t + C_4\text{EDUC}_t + C_5\text{lnINT}_t + C_6\text{lnFDI}_t + C_7\text{lnINF}_t + C_8\text{lnGFCF}_t + C_9\text{LIFEEXP}_t + \mu_1$$

$$\text{LIFEEXT} = C_{10} - C_{11}\text{MORTINF}_t - C_{12}\text{MORTU5}_t - C_{13}\text{EDUC}_t + C_{14}\text{lnGC}_t + C_{15}\text{lnGDPPC}_t + \mu_2$$

Equation 1

$K = 10$ $(\text{lnGDPPC}_t, \text{lnFDI}_t, \text{lnX}_t, \text{lnINF}_t, \text{lnGFCF}_t, \text{LIFEEXP}_t, \text{MORTINF}_t, \text{MORTu5}_t, \text{EDUC}_t, \text{lnGC}_t)$
$M = 9$ $(\text{lnGDPPC}_t, \text{lnFDI}_t, \text{lnX}_t, \text{lnINF}_t, \text{lnGFCF}_t, \text{LIFEEXP}_t, \text{MORTINF}_t, \text{MORTu5}_t, \text{EDUC}_t)$
$G = 2$ $(\text{lnGDPPC}_t, \text{LIFEEXP}_t)$

$$\text{K} - \text{M} \geq \text{G} - 1$$
$$10 - 9 = 1 \quad , \quad 2 - 1 = 1$$

$1 = 1$ (Equation 1 is exactly identified)

Equation 2

$K = 10$ $(\text{lnGDPPC}_t, \text{lnFDI}_t, \text{lnX}_t, \text{lnINF}_t, \text{lnGFCF}_t, \text{LIFEEXP}_t, \text{MORTINF}_t, \text{MORTu5}_t, \text{EDUC}_t, \text{lnGC}_t)$
$M = 6$ $(\text{lnGDPPC}_t, \text{LIFEEXP}_t, \text{MORTINF}_t, \text{MORTu5}_t, \text{EDUC}_t, \text{lnTG}_t)$
$G = 2$ $(\text{lnGDPPC}_t, \text{LIFEEXP}_t)$

$$\text{K} - \text{M} \geq \text{G} - 1$$
$$10 - 6 = 4 \quad , \quad 2 - 1 = 1$$

$4 \geq 1$ (Equation 2 is over – identified)

Source: Authors calculations

Appendix Table 4
Rank Condition for Identification

Equations

$$\ln GDPPC = C_1 + C_2 MORTINF_t + C_3 MORTU5_t + C_4 EDUC_t + C_5 \ln INT_t + C_6 \ln FDI_t + C_7 \ln INF_t + C_8 \ln GFCF_t + C_9 LIFEEXP_t + \mu_1$$

$$LIFEEXT = C_{10} - C_{11} MORTINF_t - C_{12} MORTU5_t - C_{13} EDUC_t + C_{14} \ln GC_t + C_{15} \ln GDPPC_t + \mu_2$$

Sorting and rearranging

$$0 = -\ln GDPPC_t + C_2 MORTINF_t + C_3 MORTU5_t + C_4 EDUC_t + C_5 \ln INT_t + C_6 \ln FDI_t + C_7 \ln INF_t + C_8 \ln GFCF_t + C_9 LIFEEXP_t + \mu_1$$

$$0 = -LIFEEXP - C_{11} MORTINF_t - C_{12} MORTU5_t - C_{13} EDUC_t + C_{14} \ln GC_t + C_{15} \ln GDPPC_t + \mu_2$$

Equation 1

Step 1

	ln GDPPC	MORT INF	MORT U5	EDUC	lnINT	lnFDI	lnINF	ln GFCF	LIFE EXT	lnGC
Equation 1	-1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_8	0
Equation 2	C_{15}	$-C_{11}$	$-C_{12}$	$-C_{13}$	0	0	0	0	-1	C_{14}

Step 2: Strike out row of equation being examined for identification.

	ln GDPPC	MORT INF	MORT U5	EDUC	lnINT	lnFDI	lnINF	ln GFCF	LIFE EXT	lnGC
~~Equation 1~~	~~-1~~	~~C_2~~	~~C_3~~	~~C_4~~	~~C_5~~	~~C_6~~	~~C_7~~	~~C_8~~	~~C_8~~	~~0~~
Equation 2	C_{15}	$-C_{11}$	$-C_{12}$	$-C_{13}$	0	0	0	0	-1	C_{14}

Step 3: Strike out column in which non-zero coefficient appears in equation being examined

	~~ln GDPPC~~	~~MORT INF~~	~~MORT U5~~	~~EDUC~~	~~lnINT~~	~~lnFDI~~	~~lnINF~~	~~ln GFCF~~	~~LIFE EXT~~	lnGC
~~Equation 1~~	~~-1~~	~~C_2~~	~~C_3~~	~~C_4~~	~~C_5~~	~~C_6~~	~~C_7~~	~~C_8~~	~~C_8~~	~~0~~
Equation 2	~~C_{15}~~	~~$-C_{11}$~~	~~$-C_{12}$~~	~~$-C_{13}$~~	~~0~~	~~0~~	~~0~~	~~0~~	~~-1~~	C_{14}

Step 4: Form a matrix of the un-stroked numbers

In this case the outcome is C_{14} which is non-zero hence the order and rank condition ascertains that equation 1 is identified.

Equation 2

Step 1

	ln GDPPC	MORT INF	MORT U5	EDUC	lnINT	lnFDI	lnINF	ln GFCF	LIFE EXT	lnGC
Equation 1	-1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_8	0
Equation 2	C_{15}	$-C_{11}$	$-C_{12}$	$-C_{13}$	0	0	0	0	-1	C_{14}

Step 2: Strike out row of equation being examined for identification.

	ln GDPPC	MORT INF	MORT U5	EDUC	lnINT	lnFDI	lnINF	ln GFCF	LIFE EXT	lnGC
Equation 1	-1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_8	0
~~Equation 2~~	~~C_{15}~~	~~$-C_{11}$~~	~~$-C_{12}$~~	~~$-C_{13}$~~	~~0~~	~~0~~	~~0~~	~~0~~	~~-1~~	~~C_{14}~~

Step 3: Strike out column in which non-zero coefficient appears in equation being examined

	ln GDPPC	MORT INF	MORT U5	EDUC	lnINT	lnFDI	lnINF	ln GFCF	LIFE EXT	lnGC
Equation 1	-1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_8	0
~~Equation 2~~	~~C_{15}~~	~~$-C_{11}$~~	~~$-C_{12}$~~	~~$-C_{13}$~~	~~0~~	~~0~~	~~0~~	~~0~~	~~-1~~	~~C_{14}~~

Step 4: Form a matrix of the un-stroked numbers

In this case there is a choice of outcomes C_5, C_6, C_7, C_8 which are non-zero hence the order and rank condition ascertains that equation 2 is identified.

Source: Authors calculations

Appendix Table 5
System Residual Portmanteau Tests for Autocorrelations

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	41.44453	0.0000	42.50721	0.0000	4
2	61.08661	0.0000	63.18308	0.0000	8
3	78.58050	0.0000	82.09539	0.0000	12
4	98.38436	0.0000	104.09970	0.0000	16
5	117.79200	0.0000	126.27980	0.0000	20
6	130.78570	0.0000	141.56660	0.0000	24
7	139.00280	0.0000	151.52670	0.0000	28
8	147.17270	0.0000	161.73910	0.0000	32
9	156.86880	0.0000	174.25020	0.0000	36
10	165.17270	0.0000	185.32210	0.0000	40
11	169.37230	0.0000	191.11450	0.0000	44
12	171.46280	0.0000	194.10100	0.0000	48
13	174.09640	0.0000	198.00260	0.0000	52
14	178.33690	0.0000	204.52640	0.0000	56

*The test is valid only for lags larger than the System lag order.
df is degrees of freedom for (approximate) chi-square distribution

Source: Authors calculations

Appendix Table 6
System Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)

Component	Skewness	Chi-sq	df	Prob.
1	-0.89014	5.28230	1	0.0215
2	0.70382	3.30238	1	0.0692
Joint		8.58468	2	0.0137

Component	Kurtosis	Chi-sq	df	Prob.
1	4.04288	1.81268	1	0.1782
2	3.78517	1.02750	1	0.3107
Joint		2.84017	2	0.2417

Component	Jarque-Bera	df	Prob.
1	7.09498	2	0.0288
2	4.32988	2	0.1148
Joint	11.42485	4	0.0222

Source: Authors calculations

Appendix Table 7.1
Data used

Year	GDPPC (current US$)	LIFEEXT (years)	MORTINF (per 1,000 live births)	MORTU5 (per 1,000 live births)	INT (% of GDP)
1975	430.07	57.72	68.8	95.1	-20.20
1976	433.65	58.38	65.6	90	-15.94
1977	506.32	59.02	62.5	85.1	-18.41
1978	636.47	59.63	59.4	80.3	-16.46
1979	850.35	60.20	56.6	75.8	-11.13
1980	1,059.70	60.73	53.9	71.6	-13.38
1981	1,034.15	61.22	51.3	67.6	-21.83
1982	943.32	61.65	49	64	-14.71
1983	1,052.73	62.03	46.8	60.7	-0.48
1984	1,077.74	62.33	44.8	57.7	2.85
1985	937.47	62.56	42.9	55	15.06
1986	1,135.17	62.69	41.3	52.7	19.20
1987	1,554.42	62.72	40.1	51	26.69
1988	2,031.42	62.62	39.3	50.1	26.59
1989	2,301.99	62.37	39.1	50.2	13.09
1990	2,750.95	61.91	39.5	51.3	5.26
1991	2,783.02	61.15	40.4	53.7	6.50
1992	2,848.21	60.08	41.7	57.2	6.61
1993	2,783.24	58.75	43.1	61	7.98
1994	2,779.11	57.20	44.6	65.4	7.46
1995	3,014.87	55.53	46	70.1	7.08
1996	3,022.18	53.83	47.5	74.6	16.70
1997	3,065.53	52.21	48.7	78.8	13.16
1998	2,869.18	50.81	49.7	82.5	-3.26
1999	3,226.30	49.71	50.3	85.1	11.47
2000	3,349.07	49.03	50	87	11.74
2001	3,128.10	48.84	49.3	86.5	9.79
2002	3,055.62	49.11	48.4	84.5	12.48
2003	4,163.07	49.79	47.4	81.9	11.82
2004	4,896.58	50.83	46.1	78.2	8.23
2005	5,351.25	52.17	42.5	72	17.34
2006	5,374.55	53.70	41.1	65.7	18.17
2007	5,714.05	55.31	41.8	61.7	13.93
2008	5,623.38	56.92	41.5	59.3	-5.37
2009	5,185.73	58.45	40.3	55.6	-17.08
2010	6,346.16	59.87	38.5	49.9	-7.63
2011	7,483.88	61.18	38.9	48.8	-3.64

2012	6,901.97	62.43	36.8	46	-12.15
2013	7,001.03	63.63	34.8	43.1	0.08
2014	7,493.75	64.78	34.4	42.2	6.89
2015	6,521.15	65.85	33.1	40.6	-1.32

Source: WDI, 2018.

Appendix Table 7.2
Data used

Variable ID	FDI (BoP, current US$)	INF (annual %)	EDUC (general pupils)	GFCF (% of GDP)	GC (current US$)
1975	38,268,702	16.47	12,098	26.61	49,138,565
1976	-11,155,003	11.32	13,991	24.93	16,837,706
1977	-11,995,824	4.94	15,496	25.51	79,593,206
1978	-40,813,517	12.47	16,086	28.81	138,773,395
1979	-127,851,715	21.86	16,736	31.47	229,500,580
1980	-109,234,778	10.19	18,325	34.52	241,046,529
1981	-88,558,151	-0.09	20,148	35.78	12,937,770
1982	-21,074,901	3.70	20,965	32.17	-58,954,345
1983	-25,070,063	8.75	22,252	27.23	157,350,928
1984	-62,385,755	15.43	27,364	26.33	68,538,183
1985	-52,140,091	22.89	32,172	22.83	-126,032,358
1986	-70,404,391	14.06	35,966	22.36	277,870,765
1987	-113,583,514	12.69	39,375	27.53	572,640,110
1988	-39,921,524	22.70	40,357	29.96	679,261,922
1989	-42,186,013	13.65	49,348	31.44	439,263,881
1990	-88,526,216	6.30	56,892	32.36	706,766,367
1991	16,719,789	5.18	73,909	31.27	152,225,785
1992	11,423,290	6.64	75,873	29.55	203,720,885
1993	296,441,505	13.06	85,687	26.95	13,572,531
1994	23,615,781	9.46	86,684	25.88	99,244,746
1995	-29,507,180	7.16	103,159	26.98	471,280,068
1996	-72,235,497	16.11	109,843	23.01	117,141,776
1997	-96,006,497	4.99	125,846	26.17	172,461,905
1998	-91,820,639	9.97	143,503	28.11	-229,755,910
1999	-35,161,354	14.24	148,195	26.68	693,798,580
2000	-54,918,579	14.17	152,105	25.14	304,072,192
2001	348,969,544	8.31	151,847	25.92	-298,721,309
2002	-365,114,576	1.19	155,207	27.47	-50,751,193
2003	-211,973,182	3.26	156,786	28.02	2,072,725,067
2004	-429,642,350	10.08	158,839	27.84	1,445,885,533
2005	-363,607,263	15.47	160,000	25.34	973,667,234
2006	-437,104,045	7.47	164,201	26.20	195,805,573
2007	-462,991,175	4.93	168,220	28.39	812,112,852
2008	-612,317,172	4.73	168,220	30.58	6,017,076
2009	-200,878,698	6.46	171,986	34.91	-677,937,264
2010	-217,484,022	8.92	172,328	33.62	2,519,521,188
2011	-1,380,796,401	13.96	172,498	32.04	2,565,317,861

2012	-533,915,719	0.19	172,669	36.23	-931,578,658
2013	-313,823,703	2.31	174,853	33.50	481,357,196
2014	-403,817,289	11.90	187,030	30.46	1,348,999,494
2015	-494,257,591	1.77	191,639	34.02	-1,844,253,795

Source: WDI, 2018.

References

Akram, N., Padda, I. u. H. & Khan, M., 2009. The Long Term Impact of Health on Economic Growth in Pakistan. *The Pakistan Development Review, Papers and Proceedings PARTS I and II Twenty-fourth Annual General Meeting and Conference of the Pakistan Society of Development Economics Islamabad,* 47(4), pp. 487-500.

Anyanwu, J. C., 1997/98. Does Health Matter in Economic Growth? Evidence from Nigeria. *Journal of African Research & Development, Vol. 27/28,* pp. 291-298.

Arora, S., 2001. Health, Human Productivity, and Long-Term Economic Growth. *The Journal of Economic History, Vol. 61, No. 3,* pp. 699-749.

Barro, R. J., 1999. Determinants of Economic Growth: Implications of the Global Evidence for Chile. *Latin American Journal of Economics-formerly Cuadernos de Economia,* 36(107), pp. 443-478.

Barro, R. J., 2013. Health and Economic Growth. *Annals of Economics and Finance,* 14(2), pp. 329-366.

Bartels , L. M., 1985. Alternative Misspecifications in Simultaneous-Equation Models. *Oxford Journals on behalf of the Society for Political Methodology,* 11(3/4), pp. 181-199.

Becker, G. S., 1995. *Human Capital and Poverty Alleviation,* Washington, DC: Human Resources Development and Operations Policy (HRD) Working Papers (HROWPS 52), World Bank.

Bloom, D. & Canning, D., 2003. Health as Human Capital and its Impact on Economic Performance. *The Geneva Papers on Risk and Insurance. Issues and Practice, Vol. 28, No. 2,* pp. 304-315.

Bloom, D. E. & Canning, D., 2000. The Health and Wealth of Nations. *Science,* pp. 1207-1208.

Bloom, D. E., Canning, D. & Sevilla, J., 2001. The Effect of Health on Economic Growth: Theory and Evidence. *NBER Working Paper No. 8587*, November.

Bloom, D. E., Canning, D. & Sevilla, J., 2004. The Effect of Health on Economic Growth: A Production Function Approach. *World Development, Elsevier,* 32(1), pp. 1-13.

Boachie, M. K., 2015. *Effect of health on economic growth in Ghana: An application of ARDL bounds test to cointegration,* Annamalai University: Munich Personal RePEc Archive.

Central Statistics Office, 2002. *Botswana AIDS Impact Survey 2001 [2001 BAIS-I],* Gaborone: Central Statistics Office.

Central Statistics Office, 2005. *Botswana AIDS Impact Survey II,* Gaborone: Central Statistics Office.

Central Statistics Office, 2009. *Botswana AIDS Impact Survey III,* Gaborone: Central Statistics Office.

Central Statistics Office, 2013. *Botswana AIDS Impact Survey IV, 2013,* Gaborone: Central Statistics Office.

Chang, C. F., Mirvis, D. M. & Cosby, A., 2008. Health as an Economic Engine: Evidence for the Importance of Health In Economic Development. *Journal of Health and Human Services Administration, Vol. 31, No. 1,* pp. 30-57.

Chesher, A., 2003. Identification in Noseparable Models. *Econometrica,* 71(5), pp. 1405-1441.

Christ, C. F., 1960. A Symposium on Simultaneous Equation Estimation: Simultaneous Equation Estimation: Any Verdict Yet?. *Econometrica,* 28(4), pp. 835-845.

Dae-Bong, K., 2009. *The 3rd OECD World Forum on "Statistics, Knowledge and Policy" Charting Progress, Building Visions, Improving Life.* Busan, Korea, Korea University.

Filmer, D., Hammer, J. S. & Pritchett, L. H., 2000. Weak Links in the Chain: A diagnosis of Health Policy in Poor Countries. *The World Bank Research Observer,* 15(2), pp. 199-224.

Frenk, J., 2014. Health and the Economy. *Harvard International Review,* pp. 62-64.

Governement of Botswana, 2014. *Progress Report of the National Response to the 2011 Declraration of Commitments on HIV and AIDS,* Gaborone: National AIDS Coordinating Agency.

Government of Botswana , 2013. *2013 Budget Speech,* Gaborone: Government Printing and Publishing Services.

Government of Botswana , 2014. *2014 Budget Speech,* Gaborone: Government Printing and Publishing Services.

Government of Botswana , 2015. *2015 Budget Speech,* Gaborone: Government Printing and Publishing Services.

Government of Botswana , 2016. *2016 Budget Speech,* Gaborone: Government Printing and Publishing Services.

Government of Botswana , 2017. *2017 Budget Speech,* Gaborone: Government Printing and Publishing Services.

Graddy, K. & Kennedy, P., 2010. When Are Supply and Demand Determined Recursively Rather Than Simultaneously. *Palgrave Macmillan,* 36(2), pp. 188-197.

Grossman, M., 1972. On the Concept of Health Capital and the Demand for Health. *The Journal of Political Economy,* 80(2), pp. 223-255.

Hsiao, C., 1997. Cointegration and Dynamic Simultaneous Equations Model. *Econometrica,* 65(3), pp. 647-670.

Kalemi-Ozcan, S., Ryder, H. E. & Weil, D. N., 2000. Mortality decline, human capital investment and economic growth.. *Journal of Developmental Economics,* 62(1), pp. 1-23.

Kebede, S., Duale, S., Yokouide, A. & Alemu, W., 2010. Trends of major Disease Outbreaks in the African Region. *East African Journal of Public Health,* 7(1), pp. 20-29.

Knowles, S. & Owen, D., 1997. Education and Health in an Effective-Labour Empirical Growth Model. *The Economic Record,* 73(223), pp. 314-328.

Leveson, I., Ullman, D. & Wassall, G., 1969. Effects of Health on Education and Productivity. *Inquiry, Vol. 6, No. 4,* pp. 3-11.

Maddala, G. S., 1992. *Introduction to Econometrics.* 2nd ed. New York: Macmillan Publishing Company.

Magacho, G. R., 2014. *Estimating Kaldor-Verdoorn's law across countries in different stages of development.* Natal, ANPEC - Brazilian Association of Graduate Programs in Economics.

Mankiw, G. N., Romer, D. & Weil, D. N., 1992. A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics,* 107(2), pp. 407-437.

Matzkin, R. L., 2008. Identification in Nonparametric Simultaneous Equation Models. *Econometrica,* 76(5), pp. 945-978.

Ministry of Health and Wellness, 2017. *Malaria Outbreak Awareness,* s.l.: Government of Botswana.

Mirvis, D. M. & Clay, J. A., 2008. Health and Economic Development: Reframing the Pathway. *Journal of Health and Human Services Administration,* pp. 134-155.

Piabuo, S. M. & Tieguhong, J. C., 2017. Health Expenditure and economic growth - a review of the literature and an analysis between the economic community for central African states (CEMAC) and selected African countries. *Health economics review,* 7(1), p. 23.

Psacharopoulos, G., 1995. *Building Human Capital for Better Lives,* Washington D.C: The World bank.

Steinberg, M., Johnson, S., Schierhout, G. & Nagawa, D., 2002. *Hitting home, how households cope with the impact of the HIV/AIDS epidemic.,* Washington, DC: The Kaiser Family Foundation.

Weil, D. N., 2013. *Health and Economic Growth,* s.l.: s.n.

WHO, 1999. WHO on Health and Economic Productivity. *Population and Development Review,* 25(2), pp. 396-401.

World Bank, 1993. *World Development Report 1993: Investing in Health,* New York: Oxford University Press.

World Bank, 2006. *Voices of the Poor,* Washington, DC: World Bank.

World Bank, 2015. *Botswana: Systematic Country Diagnostic,* Gaborone: World Bank Group.