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Health And Natural Capital In An Augmented Solow Growth Model

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HEALTH AND NATURAL CAPITAL IN AN AUGMENTED SOLOW GROWTH MODEL

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DEDICATION

I dedicate this dissertation to my loving Mother, Hajia Maria, who has been my pillar of support since childhood. Also, to my uncles, brothers, sisters and aunties for their immense support and guidance in my life. Lastly, I dedicate this dissertation to my children.

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CHAPTER 1 INTRODUCTION

1.1 Background

Growth models have touched on the important role capital plays in economic growth and development of nations. Health is a form of capital which is important in the growth process since a healthy citizenry implies higher productivity and higher economic growth. Health capital's impact on economic growth in a country, cannot be underestimated since it serves as a catalyst to achieving higher income per capita.

Due to this, there is a global consensus among the World leaders and Policymakers that health is a vital component to socioeconomic development. Good health in a country would lead to improvements in the population's capacity and increase productivity, thus increase in income per capita growth. Good health coupled with good education and a sustainable ecosystem, would increase wellbeing and increase economic growth. Clean water from the oceans and underground water, adds more to the health of a population than polluted waterbodies. From natural capital, we can drive such services as drinking water, flood controls, oxygen, of which are all important towards in determining the health status of a population. Thus natural capital is an extension of the economic concept of capital and entails resources from which goods and services are produced for human survival.

1.2 Purpose of Dissertation

From a macroeconomic point of view, no economist has been able to formulate a one-size-fits-all model to describe economic growth and development in nations. Growth theories such as classical theory and neoclassical theories were all developed to explain an aspect(s) of the economy and how they affect income growth. This dissertation also attempts to explain output growth using two different forms of capital (health and natural capital) in separate models under chapter 2 and 3.

In chapter 2, this dissertation models output growth in emerging market economies and developing economies using health capital. Previous studies done on health capital and output growth have mostly focused on Organization for Economic Co-operation and Development (OECD) and advanced economies. This dissertation dwells on the emerging market economies to examine if investment in health capital has any significant impact on the rising income per capita growth experienced by countries such as China. To achieve this, an extension of the Solow Model is made to include health capital. Health Capital is proxied by total health care expenditure (HEX) per capita with data from the Global Health Expenditure Database.

In chapter 3, this dissertation models output growth in developing economies using natural capital. Previous studies on natural capital have focused more on theoretical research than empirical research. This dissertation takes a different route and focuses on national level data on natural capita. Chapter 4 concludes the dissertation.

1.3 Dissertation Objectives

The main objective of this dissertation is to examine the impact of health and natural capital on economic growth in the selected economies and identify a sustainable policy for governments.

The Specific objectives are:

1. To examine if good health care and sustainable ecosystem translates to wealth
2. To examine if the selected economies growth is related to health and natural capital.
3. To set as a guide for further research in emerging market economies on health capital and economic growth

CHAPTER 2 HEALTH CAPITAL AND ECONOMIC GROWTH: A PANEL STUDY OF 89 COUNTRIES

2.0 Abstract

The paper examines the association between health capital and economic growth in an augmented Solow Model, using total HEX per capita and GDP per worker as proxies for health capital and economic growth respectively. Results suggest that there are long-run and two-way causality relationships between income and HEX.

Keywords: Economic growth, Emerging market economies, Health care expenditure, Income per capita

2.1 Introduction

The old adage that health is wealth is something that cannot be underestimated. The health of citizens plays a critical role in the growth of every economy. Health can be viewed as a valuable investment to an individual, the absence of which can cause zero or low productivity. Due to the important role health plays in productivity, its impact on economic growth cannot be neglected. Over the years, researchers have examined the role health plays in a nation's growth and development by viewing health as part of human capital formation. The literature available on Human capital, mostly refers to education and health. Unfortunately, more attention has been given to the education component of human capital in explaining how it affects economic growth and development to the neglect of health. Only recently have researchers begun to examine the role of health in economic growth and development. Health care has become an international issue with numerous international bodies expressing great interest in health and producing extensive reports on global health and Country-specific health care systems. One such body is the World Health Organization (WHO).

Health is at the center of WHO's Millennium Development Goals (MDGs). It recognizes the role of health in the global development agenda of poverty reduction as well as improved welfare and standard of living. Health is included in three of the eight goals of MDGS. The WHO believes that through health, the other goals of the MDGs can be achieved, especially those related to poverty eradication, hunger, education, and gender equality (WHO, 2005, p.7).

2.2 Purpose of Study

There has been considerable interest in examining the linkage between health and economic growth recently. International bodies like the WHO and the European Commission (EC) have researched health and have suggested that both developed and developing countries to increase spending on health care as a means of improving economic. Previously, the notion was that countries with higher GDP will have healthy citizens, as income leads to improved health. However, the reverse is also possible and equally important as better health care could influence rising GDP (Swift, 2011, p.306). Based on the importance good health care plays in the economic growth and development process, the main purpose of this paper is to examine the impact of health care on economics growth by using total HEX per capita as a proxy for health capital and income per working age person as a proxy for economic growth. The study will be conducted on selected Emerging Markets Economies[1] and developing countries using an augmented Solow (1956) Model. The list of the countries is shown is Table A.1 of Appendix A. Further tests will be conducted to examine how significant the relation is between the two variables, using other econometric models. Variables other than HEX will also be examined as additional independent variables to ascertain their impact on economic growth.

2.3 Research Objectives

The major objective of this research is to examine the impact of total HEX per capita on economic growth in selected countries and identify a sustainable policy for governments.

The specific objectives are:

1. To examine if good health care translates to wealth.
2. To examine if the growth of emerging markets and developing economies is related to health capital.
3. To set further research in emerging market economies.

2.4 Research Question

The research question for this study is: Do the data suggest that HEX per capita in selected emerging markets and developing economies has a positive impact on economic growth?

Null Hypothesis: Health care expenditure per capita in emerging markets and developing economies has no impact on income per capita growth.

Alternative Hypothesis: Health care expenditure per capita in emerging markets and developing economies has a positive impact on income per capita growth.

2.5 Literature Review

Researchers studying the association between HEX and economic growth have relied more on developed rather than developing countries' and have also concentrated more on the income elasticity of HEX. Atella and Marini (2006) categorized previous studies into three generations. The first group examined the association between HEX and economic growth in a country based on country specific control variable(s). The second group studied the association between HEX and economic growth like that used in cross-sectional studies. However they used panel data of the Organization for Economic Co-operation and Development (OECD) countries to control for the presence of country-specific and time-specific effects. The third group analyzed co-integration association between economic growth and HEX.

The first generation made use of cross-sectional data and included Newhouse (1977), Gerdtham et al (1992), Murthy (2004) and the second generation made use of pooled data and includes Gerdtham (1992). The third generation made use of panel data and also allowed for non-stationarity and co-integration. They included Hansen and King (1996), McCoskey and Selden (1998), and Dreger and Reimers (2005).

Newhouse (1977) examined the association between a country's HEXs and its income for thirteen (13) developed countries using a simple regression. The study concluded that income elasticity of HEX is greater than one. Gerdtham et al (1992) also in their studies of 19 OECD countries examined the determinants of aggregate HEX and concluded that income elasticity is significantly above one. However, contrary to the results of earlier studies, Gerdtham (1992) in examining the association between real HEX and economic growth found that HEX does not appear to be income elastic. The study was conducted on twenty-two (22) OECD countries from 1972-1987 using five different statistical methods. In addition to these contrary results, Blomqvist and Carter (1997) using OLS regression on twenty-four (24) OECD countries data, in their results also cast doubt on the notion of income elasticity of HEX being greater than one.

Using the Augmented Solow growth model and investigating the causality relationship between income and HEX, Heshmati (2001) found that HEX has a positive impact on economic growth. This empirical analysis was based OECD countries data from 1970-1992. Guissan and Arranz (2003) in studying the impact of HEX on economic growth, concluded that an increase in

HEX is generally positive for welfare. They used least squares regression and the white heteroskedastic test for their study which involved 24 selected OECD countries from 1970-1996.

The role of health human capital in economic growth was further explored by Kwabena and Wilson (2004) using panel data from 21 Sub-Saharan African countries from 1975 to 1994, and from 23 OECD countries for the period 1961 to 1995. They used a dynamic panel estimator and found that an increase in stocks of health capital leads to higher economic growth. Baldacci et al (2004) also used panel data of 120 developing countries for the period 1975-2000 to examine the direct and indirect relationship between health capital and economic growth. Their findings, based on five (5) estimations[2], concluded that both education and HEXs have a positive and significant impact on economic growth.

Dreger and Reimers (2005) estimated the association between HEXs and economic growth using data from 21 OECD countries from 1975-2001. Their findings established the existence of a long run co-integration relationship between health expenditures and income.

In another paper examining the association between health spending and economic growth, Bukhari and Butt (2007) used data from 1972-2005 for Pakistan and employed the error correction model (ECM) to test the direction of causality between health spending and GDP. Their findings confirmed that changes in health spending's' are influenced by changes in GDP. Akram et al (2008) used data from 1972-2006 to estimate the long-term impact of health on economic growth in Pakistan. Using the Johansen co-integration test and Error Correction Model (ECM) to analyze the dynamics of health capital on economic growth, their result shows a negative relationship between HEX and economic growth.

[2] Fixed-effect model (LSDV), Feasible Generalized Least Squares (FGLS) estimator, two-stage least squares estimator (EC2SLS), fixed-effect instrumental variable estimator (2SLS), General Method of Moment (GMM) estimator.

In the same year, Baldacci et al (2008) estimated the impact of education and health spending on economic growth using a panel data of 118 developing countries for the period 1971-2000. Employing least square dummy variables (LSDV), two-stage least squares (2SLS) and general method of moment (GMM) estimators; they found that both education and health capital have a significant impact on economic growth.

Erdil and Yetkiner (2009) also examined the association between per capita HEX and economic growth using Granger-causality. Using a panel data set for 75 countries[3] for the period 1990-2000, they found a bidirectional Granger-Causality as the dominant causality type between HEX and economic growth.

Baltagi and Francesco (2010) examined the linkage between HEX and economic growth using a panel data of 20 OECD countries from 1971 to 2004. They examined the non-stationarity and co-integration relationship between HEX and economic growth. Their findings suggest that health care is a necessity good. Hartwig (2010) also revisited the association between HEX and economic growth by studying HEX and GDP data for 21 OECD countries. His results do not support the view that health capital impacts long-run economic growth.

Adeniyi and Abiodun (2011) also contributed to the literature on the association between HEX and economic growth. Using data from 1985-2009 for Nigeria and employing an ordinary least square (OLS) estimation, they found a significantly positive relationship between HEX and economic growth.

Amiri and Ventelou (2012) also examine the association between total health expenditure and economic growth using data from 20 OECD countries from 1970-2009. Employing the Toda-Yamamoto Granger causality, they discovered bidirectional causality between HEX and

[3] "19 low-income (LIC), 22 lower middle-income (LMIC), 10 upper middle-income (UMIC) and 24 high-income countries (HIC)"

economic growth. Kowalczuk and Torój (2015) also studied the association between health expenditure and economic growth using panel data for 34 OECD countries from 1990 to 2012. Pooled ordinary least squares, random effects, fixed effects, and two-stage least squares regressions were employed on three separate panels and the results of all three showed that health expenditure has a positive impact on income.

Bedir (2016) examined the association between HEX and economic growth in developing countries using a modified version of the Granger (1969) causality test. Data on emerging markets economies from 1995-2013 was used for the study. The results found that income is an important contributory factor in variations of health care spending across countries.

In a summary of the literature review depicted in Table A.2 of Appendix A, when doing research, the choice of data to be included in a model is very relevant in determining the results.

2.6 This paper's contribution to the existing literature

From the literature above and at the time of conducting this study, little to no study has been done on economic growth in relation to health capital regarding the emerging market economies. Previous studies done on health capital have mostly focused on OECD and advanced countries. The rise in the growth of China, India, Indonesia and other emerging market economies, has attracted global attention, leaving economists to ask questions as to what is promoting economic growth in these emerging economies. This paper dwells on emerging market economies to examine if an investment in health capital has any significant impact on the rising economic growth experienced by these nations. Selected developing countries are added to the sample study as well. Health capital is proxied by total HEX per capita in purchasing power parity, with the assumptions that HEXs translates to good health status of the citizens, leading to improvement in labor productivity, thus contributing to an increase in output of the study countries.

This paper extends the Mankiw-Romer-Wiel (MRW, 1992) version of the Solow Model by augmenting it to include health capital. I used HEX per capita[4] as a proxy for health capital and went further to examine the causality between total HEX and economic growth using the Granger causality method. I also used the two-stage least squares (2SLS) regression method to address endogeneity issue. Finally, I used an F-test to test the fitness of the Model into the framework of SGM.

2.7 Health in the Growth Equation

Over the years, economists have examined the role of human capital in the growth equation. Research on human capital talks of education and health but more attention has been given to education and training as a component of human capital than health. However, recent studies have explained the role of health in the growth process with some using extensions of growth models in explaining how health impacts economic growth.

Barro (2013) extended the neoclassical growth model to include health. The analysis was to determine the bidirectional causality between health and economic growth, as health impacts economic growth positively and advancement in growth of the economy also enhances health capital accumulation. The model[5] is represented as below:

$$Y = AK^{\alpha} S^{\beta} H^{\gamma} (Le^{xt})^{1-\alpha-\beta-\gamma} \quad (1)$$

[4] Knowles and Owen (1995) used life expectancy as a proxy for health capital. Heshmati (2001) used public HEX as a proxy for health capital.
[5] From the Model (Barro, 2013, p.328), $\alpha > 0, \beta > 0, \gamma > 0$ and $0 < \alpha + \beta + \gamma < 1$.

where Y is output, K is physical capital, S is school, H is health capital, and L is labor. The introduction of health *(H)* in the production function in equation (1) is that, output depends on worker's health and not only on conventional inputs.[6]

Zon and Muysken (2001) also included health in an endogenous growth model using the Lucas (1988) framework. The original Lucas Model is summarized as:

$$Y = B[(1 - w)eP]^{\alpha}K^{1-\alpha} \quad (2)$$

where Y is output, K is capital stock, and B is productivity parameter, P is population size, e is average efficiency per worker and $1 - w$ is the fraction of labor time used in final output production.

The extended Lucas model by Zon and Muyken with the inclusion of health looks as follows:

$$Y = B[(1 - u - v)hgnA]^{\alpha}K^{1-\alpha} \quad (3)$$

where Y is output, K is Capital Stock, and B is productivity parameter, u and v is fractions spent on human capital accumulation and health services production. Health is produced under decreasing returns conditions while human capital is produced under increasing returns conditions. Using the model, they show that the health sector has a size that is consistent with maximum economic growth. Health is seen as a complement to economic growth and growth may disappear for countries with high rates of decay of health and as well as low productivity of the health sector.

Also other researchers like Knowles and Owen (1995), and Heshmati (2001) used the augmented Solow Model suggested by Mankiw et al (1992) to explain the role of health in the

[6] The conventional inputs are physical capital, physical labor, and human capital.

growth equation. Health capital has been proxied differently in the Model[7] and different from what is being used in this Model. The Original Solow (1956) Model is summarized below:

$$Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha} \qquad 0 < \alpha < 1 \tag{4}$$

where Y represents output, K is physical capital, L is Labor, A is technology level and subscript *t* represents country and time periods. Labor (L) is assumed to grow at exogenous population growth rate (n) and technology (A) is assumed to grow exogenously at g;

$$L(t) = L(0)e^{nt} \tag{5}$$

$$A(t) = A(0)e^{gt} \tag{6}$$

Define effective units of labor $(A(t)L(t))$ to grow at the rate of $n + g$, and also let output per effective unit of labor to be $y(t) = \left(\frac{Y(t)}{A(t)L(t)}\right)$ and finally let $k_t = \left(\frac{K(t)}{A(t)L(t)}\right)$ be the stock of physical capital per effective unit of labor. Based on these, the evolution of the economy is expressed as:

$$\dot{k}(t) = s_k y(t) - (n + g + \delta)k(t) = s_k k(t)^{\alpha} - (n + g + \delta)k(t) \tag{7}$$

where δ is depreciation, a dot denotes change over time, and (s_k) denotes a fraction of income invested in physical capital at time t. From equation (7), the stock of physical capital $k(t)$ converges to a steady state value of capital k^* expressed as

$$s_k k(t)^{\alpha} = (n + g + \delta)k(t) \quad \Rightarrow \ k^* = \left[\frac{s_k}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha}} \tag{8}$$

Equation (8) above portrays that the steady state value of (k^*) is positively related to the savings rate and negatively related to the population growth rates and depreciation. Substituting equation (8) into (4) and taking natural logs on both sides of the equation yields the steady state per capita income as follows;

[7] Knowles and Owen (1995) used life expectancy as a proxy for health capital. Heshmati (2001) used public HEX as a proxy for health capital.

$$ln\left[\frac{Y}{L}\right] = \beta_0 + \frac{\alpha}{1-\alpha}\ln(s_k) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) \tag{9}$$

where $\beta_0 = \ln A_0 + gt$. The preliminary technology is A_0 with the rate of technological advancement being g and α representing capital share. From equation (9), the Solow Model is predicting that, income per capita at a steady state level is determined by savings, the growth rate of working age population plus rate of depreciation, and the initial technology parameter. Also based on the literature, capital share in income (α) is 1/3 and the model in equation (9) implies that the elasticity of income per capita with respect to s and $(n+g+\delta)$ is 0.5 and -0.5, respectively.

2.8 Methodology and Data

2.8.1 Health Capital in the Augmented Solow Model

The addition of education as a proxy for Human Capital (H_t) by Mankiw et al (1992) transforms the above model in equation (4) to the following:

$$Y(t) = K(t)^{\alpha}H(t)^{\beta}(A(t)L(t))^{1-\alpha-\beta} \qquad 0 < \alpha + \beta < 1 \tag{10}$$

Where $\alpha + \beta < 1$ indicates decreasing returns to scale. The evolution of the stock of human capital growth is;

$$\dot{h}(t) = s_h y(t) - (n+g+\delta)h(t) = s_h h(t)^{\beta} - (n+g+\delta)h(t) \tag{11}$$

where s_h is the proportion of income invested in human capital at time t, and $h(t) = \left(\frac{H(t)}{A(t)L(t)}\right)$ is the human capital per effective unit of labor. Solving equation (7) and (11), the steady state value of physical and human capital is;

$$k^* = \left[\frac{s_k^{1-\beta}s_h^{\beta}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}} \tag{12}$$

$$h^* = \left[\frac{s_k^{\alpha}s_h^{1-\alpha}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}} \tag{13}$$

Substituting equation (12) and (13) into (10), and taking the logs on both sides, the steady state income per capita is:

$$\ln\left[\frac{Y}{L}\right] = \beta_0 + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) \quad (14)$$

Equation (14) implies that income per capita is determined by the growth rate of population plus depreciation, physical capital and human capital.

Following the approach and assumptions of Mankiw-Romer-Weil (MRW), this paper includes health capital in the educational component of human capital. The extended MRW equation (10) becomes;

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} Z(t)^{\theta} (A(t)L(t))^{1-\alpha-\beta-\theta} \qquad 0 < \alpha+\beta+\theta < 1 \quad (15)$$

where Y is income, K is physical capital, H is education human capital, Z is stock of health capital, L is Labor, A is technological capital and subscript t denotes the time period. The evolution of the economy is equation (7), (11) and this equation below;

$$\dot{z}(t) = s_z y(t) - (n+g+\delta)z(t) = s_z z(t)^{\theta} - (n+g+\delta)z(t) \quad (16)$$

where s_z is fraction of income invested in health capital at time t. Also $z(t) = \left(\frac{Z(t)}{A(t)L(t)}\right)$ denotes health capital per effective unit of labor respectively. Following MKW, this paper assumes the existence of a steady state (with $\alpha+\beta+\theta < 1$), which implies using equation (7), (11), and (16), and the economy converges to a steady state defined as:

$$k^* = \left(\frac{s_k^{1-\beta-\theta} s_h^{\beta} s_z^{\theta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\theta}} \quad (17)$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha-\theta} s_z^{\theta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\theta}} \quad (18)$$

$$z^* = \left(\frac{s_k^{\alpha} s_h^{\beta} s_z^{1-\alpha-\beta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\theta}} \quad (19)$$

Substituting equations (17), (18), and (19) into (15) and taking the logs, the steady state income per capita is written as

$$ln\left[\frac{Y(t)}{L(t)}\right] = \beta_0 + \frac{\alpha}{1-\alpha-\beta-\theta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta-\theta}ln(s_h) + \frac{\theta}{1-\alpha-\beta-\theta}ln(s_z) - \frac{\alpha+\beta+\theta}{1-\alpha-\beta-\theta}\ln(n+g+\delta) \quad (20)$$

Based on the assumption that g (0.02) and δ (0.03) are constant across countries and A_0 reflects not just technology but weather, the performance level of institutions in countries, among others (thus the stochastic country specific shock ϵ), equation (20) translates to equation (21) below.

$$ln\left[\frac{Y(t)}{L(t)}\right] = \beta_0 + \frac{\alpha}{1-\alpha-\beta-\theta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta-\theta}ln(s_h) + \frac{\theta}{1-\alpha-\beta-\theta}ln(s_z) - \frac{\alpha+\beta+\theta}{1-\alpha-\beta-\theta}\ln(n+g+\delta) + \epsilon_t \quad (21)$$

From equation (21), using an augmented Solow Model, I am predicting that, income per capita at steady state level is determined by the rate of accumulations of physical, human, and health capital as well as the growth rate of the working age population plus the rate of depreciation and the initial technology parameter, plus the country specific shock. With the assumption that saving and population growth rates being independent of ϵ, the model in equation (21) can be estimated using ordinary least squares (OLS).[8] Also, from the production function in equation (15), the rate of returns to capitals (physical, human and natural capital) equals the marginal product of each capital. That is the rate of returns of each capital equals the capital's share in income divided by the capital-output ratio of each capital, as shown in Appendix B.

[8] The reasons for making these assumptions of independence can be found in Mankiw et al (1992), pages 410-412.

2.8.2 Data

I hypothesized that health capital will have a significant impact on economic growth. That is, increases in total HEX per capita in selected countries would have a positive significant impact on per capita income growth.

To test the hypotheses, the panel data of 20 emerging market economies and 69 developing economies[9] were used from the years 2000 to 2014.The time frame and the countries for the study were selected based on the availability of data on the major independent variables (total HEX per capita) used as proxy for health capital, respectively. Data for Gross domestic product (GDP), total HEX per capita, education, investments, and working age population were all obtained from various sources.

The data on real GDP was taken from the World Bank World development indicators database (WDI).[10] This indicator is the sum of the gross value added of productions in the economy. It also adds any product taxes and deducts any subsidies that were not included in the value of the products. Data for this indicator is reported in constant 2010 U.S dollars. Working age population (15-64) data was also taken from WDI. GDP and working age population data were used to calculate income per worker $\left(\frac{Y}{L}\right)$. This was then used as a proxy for economic growth.

Also, using the working age population, the average growth rate of the workforce for each country was calculated using the formula[11];

$$Q = Q_0(1 + n)^t \tag{22}$$

[9] The countries are classified emerging market using the MSCI Market Classification [See MSCI (2018)] and the IMF classifications for emerging market and developing economies using World Economic Outlook Database April 2018 [See IMF (2018)].

[10] GDP (constant 2010 US$), See The World Bank (2018a)
[11] See a YouTube example at https://www.youtube.com/watch?v=451bNqIhZqM

where Q = Beginning population

Q_0 = Ending Population

t = Time frame (2014 – 2000 = 14)

n = Average growth rate

In STATA 15, the average growth rate of the working age population (n) could be calculated by taking the natural log of the ending workforce population for each country minus the natural log of the beginning workforce population for each country and dividing the difference by the time frame. The value of n is then added to the value of technological growth g and depreciation δ where $g + \delta = 0.05$ in literature.[12]

Data on investments and education were obtained from Penn World database (PWT9).[13] The human capital index was used to represent the average years in schooling.[14] Share of gross capital formation at current purchasing power parity is used as a proxy for investments.[15] Data on total HEX per capita in purchasing power parity was obtained from the Global Health Expenditure database which is maintained the WHO.[16] This was used as a proxy for health capital. Table 2.1 shows the summary of the variables, and Table 2.2 summarizes the statistics of the variables.

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[12] See Mankiw-Romer-Weil (1992) page 413
[13] https://www.rug.nl/ggdc/productivity/pwt/
[14] More information on the calculations of the human capital index is available in the Penn World Database is available here https://www.rug.nl/ggdc/docs/human_capital_in_pwt_90.pdf
[15] More information can be obtained here http://data-planet.libguides.com/pennworldtables
[16] http://apps.who.int/nha/database/Select/Indicators/en

Table 2.1: Variables Summary

Variable	Unit of Measurement	Data Source	Measurement Period
GDP (constant 2010 US$)	US $	World Development Indicator (WDI), World Bank	Annual
Population 15-64, Total	Number	WDI	Annual
human Capital (Education)	Index	Penn World Database (PWT9)	Annual
Share of gross capital formation at current PPPs (Investment)	Percent	Penn World Database (PWT9)	Annual
Health care expenditure per capita in PPP	US $	Global Health Expenditure database, World Health Organization	Annual

Source: Author's Creation

Table 2.2: Summary Statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Total health care expenditure per capita	1335	422.889	435.547	6.037	2899.586
Population 15-64, Total	1335	38.500*	127.000*	0.137*	996.000*
GDP	1335	206.000**	626.000**	0.653**	8330.000**
Education	1335	2.184	0.621	1.069	3.653
Investment	1335	0.204	0.077	0.020	0.562

* denotes number in million, ** denotes number in billion

Source: Author's Creation

2.9 Empirical Analysis

2.9.1 Models

From the above, two models are estimated in this paper using the assumptions of MRW[17]. Model 1 estimates the augmented Solow Model by MRW, and Model 2 estimates the health capital extension of Model 1 using total HEX per capita as a proxy.

Model 1:

$$ln\left[\frac{Y}{L}\right] = \beta_0 + \beta_1 ln(s_k) + \beta_2\, ln(s_h) + \beta_3\, ln(n + g + \delta) + \epsilon_t \tag{23}$$

Where;

Y/L is income per worker

s_k is investment

s_h is education

[17] See Mankiw-Romer-Weil (1992) page 410-412

$(n + g + \delta)$ is rate of working age population plus rate of depreciation, and the initial technology parameter

Model 2:

$$ln\left[\frac{Y}{L}\right] = \beta_0 + \beta_1\, ln(s_k) + \beta_2 ln(s_h) + \beta_3 ln(s_z) + \beta_4\, ln(n + g + \delta) + \epsilon_t \qquad (24)$$

Where;

$Y/_L$ is income per worker

s_k is investment

s_h is education

s_z is Total health care expenditure per capita

$(n + g + \delta)$ is rate of working age population plus rate of depreciation, and the initial technology parameter.

2.9.2 Data Testing: Unit roots and Co-integration Tests

Most macro time series data have proven to be non-stationary, which often results in spurious regressions. Data testing is usually required to determine the presence of unit roots. The panel unit roots tests suggested in Baltagi (2005) were employed. The Fisher unit root test based on augmented Dickey-Fuller (ADF) test and the Im-Pesaran-Shin (IPS) unit-root tests were employed. The Fisher uses p-values for each cross-section i for panel unit root testing, with the null hypothesis that all panels contain a unit root, against the alternative that at least one panel is stationary. The Im-Pesaran-Shin (IPS) unit-root test allows for heterogeneous coefficients and also averages individual unit root test statistics, with the null hypothesis that all panels are contain unit roots verses the alternative that some panels are stationary.[18] Testing for unit root under the ADF and IPS test, we include a time trend with a three lag structure and removes

[18] See Baltagi (2005) pages 242-246

cross-sectional mean using *demean*. This is done to improve the testing power of both unit roots test.

The unit root test results prove the presence of unit roots in the data, with the exception of log of school variable which came out as stationary under the ADF test. Initially, testing the association between two non-stationary variables would have involved first-differencing and converting variables to stationary before running a regression. However, this method has proven to be biased if those two non-stationary variables are co-integrated. In a macroeconomic time series, y_t and x_t are said to be co-integrated if y_t and x_t are both nonstationary variables and there exists a linear combination of y_t and x_t which is stationary. According to Bilgili (1998), for a non-stationarity time series to be used in a forecasting model, one should investigate if these variables are co-integrated or not. If they are co-integrated, then the regression results "would not suffer from losing any valuable long-term information."[19]

Thus if the nonstationary variables have a long-run relationship between them (co-integrated), then the OLS estimator is consistent.[20] This paper employs Pedroni (1999, 2004) and Westerlund (2005) tests of co-integration on a panel dataset. The Pedroni test has the null hypothesis of no co-integration verses the alternative of all panels are co-integrated and it uses a panel-specific autoregressive (AR) term and a panel-specific time trend. The Westlund test derives a pair of variance ratio test statistics for the null hypothesis of no co-integration. The alternative hypothesis for this test is some panels are co-integrated. The Pedroni test statistics all reject the null of no co-integration in favor of the alternative hypothesis that all panels are co-integrated. The Westlund variance ratio test statistic also rejects the null hypothesis of no co-integration between the variables. A test of the long run relationship among the variables was

[19] See Bilgili (1998) pages 1-2

[20] See Wang and Wu (2012) pages 532-534.

conducted using the Pedroni and Westlund co-integration test, and the results showed a positive long run relation among all the variables (co-integrated). A further test of the association between GDP and HEX alone was conducted using Pedroni and the Westlund tests. The results proved that there exists a long-run relationship between economic growth and health capital using log of GDP per worker as a proxy for economic growth and log of total HEX per capita as a proxy for health capital. The test results are displayed in Table 2.3.

Table 2.3: Results of Unit roots and Co-integration Test

	All Sample Countries					
	Fisher-ADF Unit root Test			Im-Pesaran-Shin unit-root test		
Unit root Test:	L-Statistic	P-value	Result	W-t-bar Statistic	P-value	Result
log of GDP per worker	3.1301	0.9991	Unit root	1.5039	0.9337	Unit root
log of total health care expenditure per capita	1.9373	0.8254	Unit root	0.6722	0.7493	Unit root
log of working age Population	1.7402	0.9587	Unit root	4.6148	1.0000	Unit root
log of investment	1.1137	0.8670	Unit root	-0.3748	0.3539	Unit root
log of school	-3.2752	0.0006***	stationary	3.4925	0.9998	Unit root
	Test of long run relationship among all variables					
	Test-Statistic	P-value				
Co-integration Test:						
1. Pedroni Test						
Modified Phillips-Perron t	8.9793	0.0000***				

Phillips-Perron t	-7.3589	0.0000***
Augmented Dickey-Fuller t	-6.3899	0.0000***
2. Westlund Test		
Variance ratio	-3.4067	0.0003***

	Test of long run relationship between economic growth and health care expenditure	
	Test-Statistic	P-value
Co-integration Test:		
1. Pedroni Test		
Modified Phillips-Perron t	1.4394	0.0750*
Phillips-Perron t	-4.0783	0.0000***
Augmented Dickey-Fuller t	-2.8600	0.0021***
2. Westlund Test		
Variance ratio	-4.0927	0.0000***

*** p<0.01, ** p<0.05, * p<0.1

2.9.3 Granger-Causality Test

We suspected an endogeneity in the variable total HEX per capita. There seems to be a reserve relationship between GDP per capita and HEX per capita. An increase in HEX could bring about an increase in GDP, as this could mean better health care for the population and a healthy population would produce more output, thus enhancing GDP and GDP per capita growth. However, an increase in GDP or GDP per capita may also be the reason for countries to increase their HEX. The issue of causality between GDP per worker and total HEX per capita is estimated using Granger causality by transforming the log of both variables into a stationary series using first difference. Granger (1969) developed a method for studying the causal relationship between variables. Suppose y_t and x_t are two stationary series with a zero means. Then the causal relationship between y and x can be tested using these two equations:

$$y_t = \alpha_0 + \Sigma_{k=1}^{K} \alpha_k^1 y_{t-k} + \Sigma_{k-1}^{K} \alpha_k^2 x_{t-k} + \epsilon_t \quad (25)$$

$$x_t = \beta_0 + \Sigma_{k=1}^{K} \beta_k^1 x_{t-k} + \Sigma_{k-1}^{K} \beta_k^2 y_{t-k} + \vartheta_t \quad (26)$$

Equation (25) implies that x is causing y as long as α_k^2 is not zero, and a reverse causality could be establish using equation (26). That is, y causes x provided that β_k^2 is not zero. Based on this model, an F-test can be applied on either of the equations. For instance, one can apply the F-test on equation (25) to determine if x causes y with the null hypothesis that:

$$H_0 = \alpha_1^2 = \ldots = \alpha_K^2 = 0 \quad (27)$$

A rejection of the null H_0 would conclude that x causes y. Using this same analogy[21], two models are tested in equation (28) and (29) below:

Part A: $$\Delta lny_t = \alpha_0 + \alpha_1 \Delta lny_{t-1} + \alpha_2 \Delta lnhealth_{t-1} + \epsilon_t \quad (28)$$

Part B: $$\Delta lnhealth_t = \beta_0 + \beta_1 \Delta lnhealth_{t-1} + \beta_2 \Delta lny_{t-1} + \vartheta_t \quad (29)$$

One lag was chosen in this paper for the Granger causality test due to few sample years (2000-2014) and a small number of observations. More observations may have required more than one lag of the variables. Table 2.4 illustrates the results below:

[21] See Granger (1969) page 431.

Table 2.4: Granger Causality Test: GDP and Total Health Care Expenditure

		All	Emerging	Developing
	Dependent Variable: First difference log of GDP per worker			
Part A: Does Total health care Expenditure Granger-cause GDP	Δlny_{t-1}	0.272***	0.456***	0.240***
		(0.0280)	(0.0549)	(0.0322)
	$\Delta lnhealth_{t-1}$	0.0397***	0.0490*	0.0390***
		(0.0110)	(0.0293)	(0.0122)
	Constant	0.0152***	0.0133***	0.0148***
		(0.0014)	(0.00259)	(0.0016)
	R-squared	0.103	0.263	0.084
	F-Test(p-value)	0.0003***	0.0964*	0.0015***
		All	Emerging	Developing
	Dependent Variable: First difference log of total health care expenditure per capita			
Part B: Does GDP Granger-Causes Total Health Care Expenditure	$\Delta lnhealth_{t-1}$	-0.0477*	0.0807	-0.0574*
		(0.0295)	(0.0589)	(0.0334)
	Δlny_{t-1}	0.230***	0.727***	0.142*
		(0.0750)	(0.110)	(0.0882)
	Constant	0.0574***	0.0375***	0.0600***
		(0.0038)	(0.00521)	(0.0045)
	R-squared	0.010	0.185	0.010
	F-Test(p-value)	0.0025***	0.0000***	0.1089

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The results for Part A show that total health care expenditure Granger-cause GDP. In Part B, the reverse causality is established. Thus, as total HEX Granger-cause GDP, so does GDP also Granger-cause total HEX. Therefore, there is a two-way causality between the variables. This result established is consistent with previous findings such as Erdil and Yetkiner (2009), and Amiri and Ventelou (2012).

2.9.4 Model 1 Results

Table 2.5 depicts the results of the MRW version of the Solow growth model. It illustrates the regression estimates of the log of GDP per working age person on the log of physical capital $({}^{I}/_{GDP})$ and education human capital $ln(School)$, as well as the log of the average growth of working age population $\ln(n+g+\delta)$.

The results show a statistically significant level of less than 1% at 95% confidence level, between the dependent variable and all the independent variables with the exception of physical capital $({}^{I}/_{GDP})$ for the emerging economies. All the signs for the regression coefficients were significant as in literature[22]: negative coefficient for population growth rate $(n+g+\delta)$ and positive coefficients for physical capital $({}^{I}/_{GDP})$ and human capital $ln(School)$, respectively. The OLS regression parameters produce an elasticity of income per worker with respect to physical capital $ln({}^{I}/_{GDP})$ of approximately 0.5 and elasticity with respect to population growth rate $ln(n+g+\delta)$ of approximately -1.0. The elasticity of income per worker with respect to human capital $ln(School)$ was approximately 2.8.

2.9.5 Model 2 Results

Augmenting the Solow model to include heath capital, we used total HEX per capita as a proxy for health capital in Model 2. Looking at the regression results in Table 2.5, adding health

[22] Mankiw-Romer-Weil (1992)

capital to the augmented Solow growth model increases the R^2 from 0.614 in model 1 to 0.870 in model 2 for all the countries under study.

The OLS and the 2SLS regressions parameters, produce an elasticity of income per worker with respect to physical capital $ln(^{I}/_{GDP})$ of approximately 0.14 and elasticity with respect to population growth rate $ln(n + g + \delta)$ of approximately -0.2. The elasticity of income per worker with respects to human capital $ln(School)$ and health capital $ln(Health)$ were approximately 0.3 and 0.9, respectively.

From the regression results, there exists a positive relationship between physical capital and GDP per capita. For instance, a 1% increase in physical capital leads to a 0.0951% increase in income per worker, all things being equal, and this is very statistically significant at a p-value of less than 1% level for all the study countries. This is consistent with the hypothesis. Also, a 1% increase in physical capital increases income per worker more in the emerging economies than the developing economies. Physical capital (such as investments in buildings, machinery, equipment and computer) directly impact on the productive capacity of an economy. Economists have considered physical capital as a part of the production process, and the greater its presence in a country, the more chances of high income per worker being recorded, as shown in Figure C.1 of Appendix C, all things being equal. This is consistent with previous findings such as Mankiw et al. (1992), and Knowles and Owen (1995).

Table 2.5: Regression Results

		OLS Estimation			2SLS IV Estimation		
		All	Emerging	Developing	All	Emerging	Developing
	Dependent Variable: Log of GDP per working age person						
Model 1.	Countries:	89	20	69			
	Observations	1,335	300	1,035			
	ln(I/GDP)	0.494***	0.0886	0.513***			
		(0.0454)	(0.109)	(0.0489)			
	ln(n + g + δ)	-0.693***	-1.086***	-0.462***			
		(0.136)	(0.297)	(0.151)			
	ln(School)	2.338***	2.786***	2.157***			
		(0.0859)	(0.251)	(0.0927)			
	Constant	5.503***	3.610***	6.198***			
		(0.335)	(0.720)	(0.370)			
	R-squared	0.614	0.581	0.563			
	Test of Restriction: F-Test (p-value)	0.0000***	0.0006***	0.0000***			
	Countries:	89	20	69	89	20	69
	Observations	1,335	300	1,035	1,246	280	966
	ln(I/GDP)	0.0951***	0.137***	0.0904***	0.108***	0.141***	0.105***
		(0.0277)	(0.0475)	(0.0320)	(0.0285)	(0.0460)	(0.0333)
	ln(n + g + δ)	-0.162**	-0.0678	-0.109	-0.135*	-0.0174	-0.0938
		(0.0805)	(0.132)	(0.0940)	(0.0819)	(0.131)	(0.0958)

Model 2.	ln(School)	0.318***	0.305**	0.308***	0.289***	0.285**	0.279***
		(0.0641)	(0.129)	(0.0732)	(0.0658)	(0.130)	(0.0754)
	ln(Health)	0.823***	0.867***	0.795***	0.843***	0.883***	0.817***
		(0.0163)	(0.0244)	(0.0195)	(0.0170)	(0.0246)	(0.0205)
	Constant	3.204***	3.381***	3.4580***	3.189***	3.431***	3.412***
		(0.201)	(0.314)	(0.239)	(0.204)	(0.308)	(0.244)
	R-squared	0.870	0.921	0.832	0.872	0.927	0.837
	Test of Restriction: F-Test (p-value)	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	Tests of endogeneity: Durbin-Wu-Hausman (P-value)				0.0000***	0.6946	0.0000***
	Test of Instrument: First-stage regression summary statistics (Partial R-square)				0.9749	0.9904	0.9704
	(F-Statistic)				48242.1	28279	31453.2
	(P-value)				0.0000***	0.0000***	0.0000***

Standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

The coefficient (-0.162) of $\ln(n+g+\delta)$ in Model 2 OLS regression, implies that a higher population growth rate of the working age population reduces income per worker at a statistically significance p-value level of less than 1%. This is consistent with the Solow Model predictions, as shown in Figure C.2 of Appendix C, that the higher the rate of population growth, the lower the income per worker. The result in this decline in income per worker is as a result of diminishing marginal product of labor. This is consistent with previous literature such as Mankiw-Romer-Weil (1992) and Heshmati (2001).

Also, the results show a positive relationship between education and income per worker. A 1% increase in education leads to a 0.32% increase in income per worker, and this is very statistically significant at a p-value of less than 1% level. This is consistent with the research hypothesis. Education has over the years has been a contributory factor to higher productivity. Countries can build a strong foundation for economic success and shared prosperity by investing in education. Providing expanded access to high quality education will not only expand economic opportunity for residents, but it also likely does-more to strengthen the overall economy of the country. Therefore, the higher the level of the educated working age population in the selected countries, the higher the GDP per worker as shown by the regression results. This is consistent with previous literature such as Mankiw-Romer-Weil (1992), and Baldacci et al (2004, 2008).

Furthermore, there is a positive relationship between total HEX per capita and income per worker. For instance, the $\ln(Health)$ coefficient of 0.823 in Model 2, indicate that a 1% increase in total HEX per capita would lead to a 0.82% increase in income per worker, and this is very statistically significant at a p-value of less than 1% level. This is consistent with the hypothesis and the data, as shown in Figure C.3 of Appendix C. Also a 1% increase in HEX increases income per worker more in the emerging economies than the developing economies. Increase in total HEX implies that more resources are devoted to the health sector, and it is intended to improve the quality of health provided, which translates to higher productivity and higher longevity, as depicted in Figure C.4 of Appendix C. One can conclude that good health is a necessary condition for people to be able to live long and also to provide labor services for productivity to increase: thus rise in GDP and income per worker. This is consistent with previous findings such as Blomqvist and Carter (1997), and Heshmati (2001).

The presence of endogeneity and the establishment of bi-directional causal relationship between GDP and HEX necessitated the use of two-least stage squares (2SLS) estimator using the lagged values of the log of total HEX per capita as an instrument. Due to the short-time frame and small number of samples, lag one was chosen. The procedure of using lagged values as the instrument variable (IV) is a very common practice in econometrics, due to the difficulty in finding a suitable instrument.[23] The 2SLS findings gives similar significant results as in the OLS estimation for emerging market economies, developing economies and for all the countries combined together. The strength of the choice of lagged values of HEX as the instrument variable was tested in STATA 15 using the command $estat\ firststage$. The "First stage regression summary statistics" F statistic in the findings is above the rule of the tomb threshold of 10; also, the R-square and Partial R-square were all high, which do not imply a weak-instrument problem. Thus, the null hypothesis of our instrument being weak, is rejected.

The relationships between the dependent variable and each independent variable were further measured using scatterplot diagrams as shown by the Figures in Appendix D. The scatterplot diagrams showed a positive relationship between income per worker and physical, human and health capital, respectively, and a negative relationship between income per worker and population growth.

2.10 Model Testing

Adding HEX to the Solow Growth Model (SGM) in Model 2, the coefficients were tested to see if the new model fits into the SGM framework. Using F-test, the null hypothesis is that

[23] See Wheeler (1980), Knowles and Owen (1995), and Kowalczuk and Torój (2015).

the sum of the coefficients of the variables is equal to or close to zero. A high F-statistic would mean we reject the null hypothesis, implying that Model 2 does not fit into the SGM. A low F-statistic would mean Model 2 fits into the SGM framework.

$$\frac{\alpha}{1-\alpha-\beta-\theta}+\frac{\beta}{1-\alpha-\beta-\theta}+\frac{\theta}{1-\alpha-\beta-\theta}-\frac{\alpha+\beta+\theta}{1-\alpha-\beta-\theta}=0 \quad (30)$$

The results of the F-tests (p-value reported) for Model 2 for both the OLS and 2SLS estimations were all statistically significant at less than 1% confidence level for emerging markets, developing economies and the combined countries study. This implies Model 2 fits into the SGM framework.

2.11 Conclusions

The objective of this study was to examine whether HEX has a significant positive impact on economic growth and to further determine if other independent variables might have a significant impact on income per worker. The results show a statistically significant level between the dependent variable and all the independent variables. All the signs for the regression coefficients were significant as in previous studies under both the OLS estimation and the 2SLS estimation. A long-run relationship (co-integration) existed among the variables, as well as between GDP and HEX. The Granger causality test proved a two-way causality relationship between GDP and HEX. Although the study showed that the impact of HEX on income per worker is very statistically significant at less than 5% in the combined countries study and the separated emerging markets and developing economies, the impact of education, physical capital, and working age population growth rate on income per worker was equally statistically significant in both Models 1 and 2. This means that more efforts and resources should be channeled by governments towards improving health care systems, physical capital and educational systems. As the citizens enjoy improved health care and can attain quality education, more quality will be added to the existing labor and impact the GDP growth more positively.

CHAPTER 3 THE RELATIONSHIP BETWEEN NATURAL CAPITAL AND ECONOMIC GROWTH: A PANEL STUDY APPROACH

3.0 Abstract

This paper employs panel data study of 63 developing countries to examine the association between natural capital and economic growth. Natural capital per capita and GDP per worker are used as proxies for natural capital and economic growth respectively. Using three regression models, the results suggest there is a statistically significant positive relationship between natural capital and economic growth, and a long-run relationship (co-integration) between the variables.

Keywords: Developing countries, Economic growth, GDP per capita, Natural capital

3.1 Introduction

Growth theories such as mercantilism, classical theory, neoclassical theory, endogenous growth, and limits to growth, have all been proposed over the past years. These theories were developed to explain an aspect or aspects of the economy and how they contribute to output growth because there is no model which captures all the macroeconomic aspects of the economy.

The term natural capital has been used by economists. It was used first by Schumacher (1973)[24] and later by Herman Daly, Robert Costanza, Partha Dasgupta and other international bodies such as the World Bank.[25] Natural capital is an extension of the economic concept of capital (human, health, and physical capital) and encompasses resources from which goods and services are produced for human survival.[26] Natural capital is defined as the resources such as minerals, forest, soil and oceans, which are provided by nature and they have intrinsic and

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[24] Schumacher (1973) page 5
[25] The World Bank (2016)
[26] Jansson et al (1994), Costanza and Daly (1992), Dasgupta (2007)

economic value for human survival. From natural capital we can drive services such as drinking water, flood controls, and oxygen. These are services which may not have an economics value as they cannot be effectively priced in the market, but they are of useful importance to humans. We all breathe daily, which is one of the numerous benefits we drive from natural capital.

Natural capital can be categorized into two major categories: renewable and non-renewable (Pearce and Barbier, 2000, Jansson et al., 1994, Prugh et al., 1999). Renewable natural capital comprises natural capital that is able of replacing itself mostly with the help of solar energy. However, although it is regenerative, overuse of renewable natural capital can also limit or destroy its ability to regenerate itself to sustain the flow of goods and services on which humans depends. Nonrenewable natural capital is that which exists in fixed amounts and if consumed or overused, it can no longer be replaced. Examples include mineral deposits and fossil-fuels. However, the use or overuse of such natural capital depends mostly on a country's specific policies.

Natural capital and manufactured capital both conform to the working definition of capital as a stock which produces the flow of goods and services (Prugh et al., 1999). Humans drive a wide range of services (such as ecosystem services) from natural capital. Food, water, medicines, fuel, and building materials, all come from the ecosystem. Natural capital also provides less visible services to humans, such as pollination of crops by insects and flood defenses by forest reserves.

3.2 Purpose of Study

Despite all the vital ecosystem services provided through natural capital, it remains poorly defined and discussed less in economic literature. The debate whether natural capital is irreplaceable is still ongoing. Ecological economists are of the view that natural capital is essential and has no replacement. This view is termed strong sustainability. Other economists are also of the view that investments in technology can substitute for natural capital and sustain growth indefinitely. This view is termed weak sustainability.[27] Regarding the latter, cutting down trees from forest reserves and using them in the construction of roads and buildings, can be sustainable, as long as future generations benefits from these constructions. However, proponents of this theory fail to acknowledge the multiple benefits that the ecosystem provides for human survival. Thus, placing one form of capital asset over another is most likely to be a myopic way to increase economic growth and over-all human welfare. Therefore, the motive of this paper is to examine the impact of natural capital as a factor of production on economic growth by using natural capital per capita as a proxy for natural capital and GDP per capita as a proxy for economic growth. Selected developing countries will be used for the study using the Solow (1956) Model augmented by Mankiw-Romer-Weil (1992).

3.3 Research Objectives

The major objective of this research is to examine the impact of natural capital on economic growth in selected developing countries and identify a sustainable policy for governments.

The specific objectives are as follows:

1. To examine if natural capital translates to wealth
2. To examine if the growth of developing countries is related to natural capital.
3. To develop the foundation for further empirical research on natural capital and economic growth.

[27] Dasgupta (2008) pages 2-3

3.4 Research Question

Does data suggest that natural capital per capita in the selected developing countries has a positive impact on economic growth?

Null Hypothesis: Developing countries' natural capital per capita has no impact on GDP per capita growth.

Alternative Hypothesis: Developing countries' natural capital per capita has a positive impact on GDP per capita growth.

3.5 Literature Review

Economic growth theories over the years have mostly focused on physical and other forms of capital with few models related to natural capital. Natural capital in growth models began in the 1970s. Stiglitz (1974) developed a production function that includes the rate of utilization of natural resources. He indicates that the scarcity of natural resources does not mean growth stagnation of the economy; thus, technical change and capital accumulation can offset natural resource scarcity. Aghion and Howit (1998) also introduce natural resources and environmental pollution into their growth model. However in their Schumpeterian model, they recognized that "the technology of innovation is relatively clean compared to the technology of producing tangible capital goods", and accumulation of intellectual capital can propel long run growth.[28]

Shafik and Bandyopadhyay (1992) also studied the association between natural capital and income using indicators for environmental quality as proxies. The study was conducted on 149 countries for the period between 1960-1990 using panel regressions. The study found that some environmental indicators like water and sanitation improves as GDP rises while others like

[28] Aghion and Howit (1998), pages 151-165

sulfur oxides worsen and then later improves. Indicators like oxygen in rivers and carbon emissions, rather, showed signs of worsening steadily as GDP rises. Also macro indicators such as high investment rates and high GDP, puts more pressure on natural resources and creates more environmental problems such as pollution.

Wackernagel et al (1999) developed a framework for national and global natural capital accounting based on an ecological footprint concept, using the example of Italy. With their framework, both human consumption and natural capital production can be compared at national and global level, which gives a realistic picture of where we are in ecological terms and how we can use that to achieve sustainable development. England (2000) also explored the association between capital accumulation and economic growth in relation to the natural world. Natural capital is treated as a compliment to human-made capital in the aggregate production function, and the scale of economic activity will be constrained when natural capital is no longer in relative abundance.

Welsch (2003) also studied the association between economic growth and natural capital. Using cross-sectional data on well-being for 54 countries and employing OLS regression, the study found that GDP has a significant impact on happiness and that natural capital depletion (environmental pollution) negatively affects GDP growth and happiness.

Milton et al (2003) discusses how technical and economic factors affect the restoration of the ecosystem in Southern Africa and they identify new commercial and government initiatives that are turning environmental degradations into economic opportunities for restorations. They conclude that by identifying labor-intensive techniques to stabilize environmental degradation, natural capital will be restored in the regions; they claim that this will boost employment among the rural poor and improve income growth in the Southern African regions. Russo (2003) also used Federal Energy Regulatory Commission (FERC) wind energy projects data from California for the period 1979-1992 to examine the association between economic growth and natural capital. Employing a negative binomial model, the regression result found that greater wind energy is experience in locations where natural, social and economic influences converges.

Arrow et al (2004) identify several factors that influences natural capital consumption and “underpricing of natural resources” is one of the factors that contributes to excessive consumption of natural capital. They conclude that proper government regulations and taxes as well as establishments of property rights, can help determine the pricing of natural resources and their social cost. They claim that this will help protect natural capital from excessive use and depletion, as well as sustain the welfare of future generations.

Vemuri and Costanza (2006) also studied the association between natural capital and economic growth using data[29] from the 1990s on human, social, built and natural capital for 171 countries. Employing OLS regression estimation, they found that natural capital has significant positive impact on life satisfaction. Thus people often consider their natural environmental surroundings as a major life satisfaction contributor.

Crowe (2008) also contributed to the natural capital research in the study of how natural capital affects growth and development. Employing binomial and Poison regression on data from 101 communities in Oregon and Washington from summer and fall 2006, the study found that there is a positive relationship between natural capital and economic development. The study concludes that “unless researchers, policymakers, and community leaders pay attention to natural factors, communities may continue to spend time and resources pursuing certain types of

[29] Data on proxies for human, social, built, and natural capital were from the 1998 United Nations Human Development Report , Freedom House (1999) and Sutton and Costanza (2002).

economic development strategies to no avail, while failing to implement alternative economic development strategies that may be of extreme benefit to community citizens."[30]

Dasgupta (2010) contributes to the discussion of natural capital and income per capita growth by using data from the world's poorest regions and countries. Using the shadow price concept to measure comprehensive wealth, he concludes that the measure of wealth should not only include human-made capital but also natural capital as well. The inclusion of all capital should then give a good measure of the comprehensive wealth of nations.

3.6 This paper's contribution to the existing literature

In general, literature on natural capital[31] has focused more on theoretical research than empirical research. This paper takes a different route by focusing on data.

The aim of this paper is to access national level data on physical capital, human capital, and natural capital, in order to explain the determinants of economic growth. From a macroeconomic point of view, no economist has been able to formulate a one-size-fits-all model to describe economic growth and human welfare. Thus, this paper hypothesizes that each of the three types of capital identified will have a positive significant impact on economic growth. To test this hypothesis, the national data from 63 developing countries national is used. An extension of the Solow Model is made by augmenting it to include natural capital. First, natural capital is proxied by natural capital per capita. Second, natural capital is used in the paper as the main determinant of economic growth. Finally, ways of investing in natural capital for sustainability are identified. The list of the countries is shown is Table E.1 of Appendix E.

[30] Crowe (2008) page 848
[31] Dasgupta (2007, 2008, 2010), Dasgupta et al (2000), Helm (2013), Hinterberger et al (1997), Faucheux et al (1997), Farley (2008), Costanza and Daly (1992)

3.7 Methodology and Data Sources

3.7.1 Natural Capital in the Growth Model

Mankiw et al's (1992) augmentation of Solow's (1956) model with the inclusion of human capital (E_t), proxied by school enrollments levels, transforms the Cobb-Douglas production function to:

$$Y(t) = K(t)^{\alpha} E(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \qquad 0 < \alpha + \beta < 1 \tag{31}$$

where $\alpha + \beta < 1$ indicates decreasing returns to scale, Y represents output, K is physical capital, L is labor, A is technology level and subscript t represents country and time periods. Labor and technology are assumed to grow at the exogenous population growth rates (n) and (g), respectively, at:

$$L(t) = L(0)e^{nt} \tag{32}$$

$$A(t) = A(0)e^{gt} \tag{33}$$

From equations (32) and (33), we define effective units of labor $(A(t)L(t))$ to grow at the rate of $n + g$, and output per effective unit of labor to be $y(t) = \left[{Y(t)}/{A(t)L(t)}\right]$, and we define $k(t) = \left[{K(t)}/{A(t)L(t)}\right]$ and $e(t) = \left[{E(t)}/{A(t)L(t)}\right]$ to be the stock of physical capital and human capital per effective unit of labor, respectively. Thus, the accumulation of both physical and human capital (evolution of the economy) is identified as:

$$\dot{k}(t) = s_k y(t) - (n + g + \delta)k(t) = s_k k(t)^{\alpha} - (n + g + \delta)k(t) \tag{34}$$

$$\dot{e}(t) = s_e y(t) - (n + g + \delta)e(t) = s_e e(t)^{\beta} - (n + g + \delta)e(t) \tag{35}$$

where s_k and s_e represents the fractions of income invested in physical and human capital, respectively, at time t and δ is depreciation, with a dot denoting change over time. The stock of physical capital (k_t) and human capital converges to a steady state capital value (k^*) and (e^*) is expressed as:

$$k^* = \left[\frac{s_k^{1-\beta} s_e^{\beta}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}} \tag{36}$$

$$e^* = \left[\frac{s_k^{\alpha} s_e^{1-\alpha}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}} \tag{37}$$

Substituting equations (36) and (37) into (31) and taking the logs on both sides yields the steady state per capita income as follows:

$$\ln\left[\frac{Y(t)}{L(t)}\right] = \beta_0 + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_e) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \epsilon_t \tag{38}$$

where $\beta_0 = \ln A_0 + gt$ represents technology and ϵ is country specific shock. The preliminary technology is A_0 with the rate of technological advancement being g and α representing capital share. Capital share in income (α) is 1/3 in the original Solow model, with the elasticity of income per capita with respect to s and $(n + g + \delta)$ being 0.5 and -0.5, respectively[32]. From equation (38), income per capita is determined by the growth rate of population and technology plus depreciation, and physical and human capital.

Following the Mankiw et al's (1992) model's assumptions and extending it to natural capital, the extended model is expressed as:

$$Y(t) = K(t)^{\alpha} E(t)^{\beta} C(t)^{\psi} (A(t)L(t))^{1-\alpha-\beta-\psi} \qquad 0 < \alpha + \beta + \psi < 1 \tag{39}$$

where Y is output, K is physical capital, E is human capital, C is natural capital, L is labor, and A denotes technological level, with subscript t denoting the time period. The accumulation of capital is equation (40) below, plus equations (34) and (35) previously:

$$\dot{c}(t) = s_c y(t) - (n+g+\delta)c(t) = s_c c(t)^{\psi} - (n+g+\delta)c(t) \tag{40}$$

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[32] See Mankiw et al (1992), page 410

where s_c is the proportion of income invested in natural capital at time t and $c_t = \left[{C(t)}/{A(t)L(t)}\right]$ represents the natural capital per effective unit of labor, respectively. With the assumption of the existence of a steady state in the economy (with $\alpha + \beta + \psi < 1$), using equations (34), (35), and (40), the economy converges to a steady state ($k^* h^* c^*$) expressed as:

$$k^* = \left(\frac{s_k^{1-\beta-\psi} s_e^{\beta} s_c^{\psi}}{n + g + \delta}\right)^{\frac{1}{1-\alpha-\beta-\psi}} \tag{41}$$

$$h^* = \left(\frac{s_k^{\alpha} s_e^{1-\alpha-\psi} s_c^{\psi}}{n + g + \delta}\right)^{\frac{1}{1-\alpha-\beta-\psi}} \tag{42}$$

$$c^* = \left(\frac{s_k^{\alpha} s_e^{\beta} s_c^{1-\alpha-\beta}}{n + g + \delta}\right)^{\frac{1}{1-\alpha-\beta-\psi}} \tag{43}$$

Substituting equations (41), (42) and (43), into equation (39) above, and taking the logs on both sides of the equation, will yield the steady state of income per capita. The steady state income per capita is expressed as:

$$ln\left[\frac{Y(t)}{L(t)}\right] = \beta_0 + \frac{\alpha}{1-\alpha-\beta-\psi}\ln(s_k) + \frac{\beta}{1-\alpha-\beta-\psi} ln(s_e) + \frac{\psi}{1-\alpha-\beta-\psi} ln(s_c) - \frac{\alpha+\beta+\psi}{1-\alpha-\beta-\psi}\ln(n + g + \delta) + \epsilon_t \tag{44}$$

With the assumptions that g (0.02) and δ (0.03) are constant across countries, A_0 reflects not just technology but also weather and the saving and population growth rates are independent of ϵ, the model in equation (44) can be estimated using ordinary least squares (OLS).[33] In using an augmented Solow Model, this paper predicts that income per capita at a steady state level is determined by the accumulations of physical, human, and natural capital and also by the growth rate of working age population plus rate of depreciation and the initial technology parameter.

[33] See Mankiw et al (1992), pages 410-412.

Also from the production function in equation (42), the rate of returns to the various capitals (physical, human and natural capital) equals the marginal product of each capital. Thus the rate of returns to each capital equals the capital's share in income divided by the capital-output ratio as shown in Appendix F.

3.7.2 Data Sources

This paper hypothesizes that natural capital will have a significant impact on economic growth. That is increases in natural capita per capita in the selected developing countries would have a positive impact on economic growth. To test the null and alternative hypotheses, the national data of 63 developing countries is used for the time period of 2000-2014. Data for the study was retrieved from World Bank and Penn World databases.

Real gross domestic product (GDP) is obtained from the World Development Indicators database (WDI).[34] Data is represented in "constant 2010 U.S dollars". The GDP indicator is the total gross value added of production in each country. Also, product taxes are added, and subsidies are deducted from the product values. Working age population (ages 15-64) data was also obtained from the WDI database. The GDP and working age population are used in calculating income per worker (Y/L), which is used as a proxy for economic growth. The average growth rate of the population (n) is also calculated using the working age population data. The values of (n) are added to the value of technological growth and deprecation[35] for each country in the study.

[34] GDP source: The World Bank (2018a)

[35] The assumed value of $g +$ $= 0.05$ as in Mankiw-Romer-Weil (1992) page 413

Natural capital per capita data was also obtained from World Bank development indicators[36] and used as a proxy for natural capital. This is used as a proxy because the data from the World Bank has gaps in them, resulting in inaccuracies in measurement of natural capital in each nation. The natural capital indicator sums up the value of fossil fuel energy, minerals, agricultural land, forests and other protected areas which adds value to human life. Human activities have the tendency to affect air quality, water & sanitation, heavy metals, biodiversity and habitat, forests, fisheries, climate and energy, air pollution, water resources, and agriculture and can reduce the value of natural capital, thereby negatively affecting output growth.[37] Data for this indicator is available for the years 2000, 2005, 2010, and 2014. Due to the gaps in the data, two natural capital per capita values are used, involving one with the missing data and another with the linear interpolation method to fill in the missing data. Both data results are reported. The linear interpolation method is used due to the linear growth of the indicator over time across the countries under study. For instance, data for the years between 2010-2014, were estimated using both years as benchmarks.

Human capital (education) and physical capital (investments) data were both taken from the Penn World database (PWT9).[38] The human capital index in the PWT9 is calculated using the average years in schooling[39], and "share of gross capital formation at current purchasing power parity" is proxied as investment data in the PWT9.[40] The variables obtained for the study are summarized in Table 3.1 and a summary statistics of them are displayed in Table 3.2.

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[36] More information can be found here https://datacatalog.worldbank.org/dataset/wealth-accounting
[37] https://epi.envirocenter.yale.edu/
[38] https://www.rug.nl/ggdc/productivity/pwt/
[39] See PWT9 https://www.rug.nl/ggdc/docs/human_capital_in_pwt_90.pdf
[40] See http://data-planet.libguides.com/pennworldtables

Table 3.1: Variables Summary

Variable	Unit of Measurement	Data Source	Measurement Period
Natural capital per capita	US $	WDI	Non-Annual
GDP (constant 2010 US$)	US $	WDI	Annual
Population 15-64, Total	Number	WDI	Annual
human Capital (Education)	Index	Penn World Database (PWT9)	Annual
Share of gross capital formation at current PPPs (Investment)	Percent	Penn World Database (PWT9)	Annual

WDI denotes World Development Indicator, World Bank

Source: Author's Creation

Table 3.2: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Working age Population 15-64, Total	945	11.300*	17.000*	0.137*	104.000*
GDP	945	42.400**	77.200**	0.653**	455.000**
Education	945	2.101	0.616	1.069	3.411
Investment	945	0.195	0.079	0.020	0.562
Natural capital per capita	252	12205.640	13660.540	708.180	100650.300
Natural capital per capita	945	12082.870	13408.480	708.180	100650.300

* denotes number in million, ** denotes number in billion

Source: Author's Creation

3.8 Empirical Analysis

3.8.1 Model

This paper uses the assumptions of MRW[41] to estimate the impact of natural capital on economic growth using natural capital per capita as a proxy for natural capital and income per worker as a proxy for economic growth. The model estimated is expressed as below:

$$ln\left[\frac{Y}{L}\right] = \beta_0 + \beta_1 \ln(s_k) + \beta_2 ln(s_e) + \beta_3 ln(s_c) - \beta_4 \ln(n + g + \delta) + \epsilon_t \quad (45)$$

Where;

${Y}/{L}$ is income per worker

s_k is investment

s_e is education

s_c is Natural capital per capita

$(n + g + \delta)$ is the rate of the working age population plus the rate of depreciation, and the initial technology parameter.

3.8.2 Data Testing: Unit roots and Co-integration Tests

Im-Pesaran-Shin (IPS) and the Fisher unit-root test were employed to test the non-stationarity of the series. The Im-Pesaran-Shin (IPS) unit-root test allows for heterogeneous coefficients and averages individual unit root test statistics. The test null hypothesis is that all panels contain unit roots against the alternative of some panels being stationary.[42] Fisher unit roots testing on the other hand, uses p-values from the unit root test for each cross-section i. It goes by the null hypothesis that all panels in the panel contain a unit root, against an alternative hypothesis that at least one panel is stationary. Macro data appears to be nonstationary due to

[41] Mankiw-Romer-Weil (1992) page 410-412
[42] Baltagi (2005) pages 242-243

time trends in series. According to Baltagi (2005), McCoskey and Selden employed the IPS unit root test on HEXs per capita and gross domestic product (GDP) data for 20 OECD countries and found both series to be stationary, while Gerdtham and Lothgren in applying the same data, concluded that both series are nonstationary and contained unit roots, and that the stationary results were found by McCoskey and Selden because they omitted time trends in their ADF regression[43]. This paper includes the time trend in the unit root testing with one lag structure, as a way of improving the results from both unit root tests. One lag period structure is also adopted due to the small number of observations. Table 3 of both unit roots test results proves that variables are nonstationary and contains unit roots. The results suggest the possibility of a long-run relationship (co-integration) between the variables; therefore, a test of co-integration is carried out further.

Table 3.3 shows that using Pedroni's (1999, 2004) and Westerlund's (2005) tests of co-integration, the variables are co-integrated. The Pedroni test specifies that the null hypothesis of no co-integration against the alternative of all panels is co-integrated. It also employs a panel-specific autoregressive (AR) term and a panel-specific time trends in testing for co-integration among panels. The Westertlund co-integration test calculates a pair of variance ratio test statistics for the null hypothesis of no co-integration against the alternative that some panels are co-integrated. The presence of co-integration means that employing a co-integration panel regression is necessary.

[43] Baltagi (2005) page 244

Table 3.3: Unit roots test and Co-integration Test

	All Sample Countries					
	Fisher-ADF Unit root Test			Im-Pesaran-Shin unit-root test		
Unit root Test:	L-Statistic	P-value	Result	W-t-bar Statistic	P-value	Result
log of GDP per worker	-0.9976	0.1596	Unit root	-0.3834	0.3507	Unit root
log of natural capita per capita(A*)	0.8034	0.7888	Unit root	1.5340	0.9375	Unit root
log of working age Population	5.4089	1	Unit root	6.7573	1	Unit root
log of investment	0.1977	0.5783	Unit root	-0.7306	0.2325	Unit root
log of school	4.8296	1	Unit root	5.1166	1	Unit root

	Test of long run relationship among variables	
	Test-Statistic	P-value
Co-integration Test:		

1. Pedroni Test		
Modified Phillips-Perron t	6.4748	0.0000***
Phillips-Perron t	-6.5623	0.0000***
Augmented Dickey-Fuller t	-8.1455	0.0000***
2. Westlund Test		
Variance ratio	-4.2582	0.0000***

A* denotes natural capital with fill in data

Standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

3.8.3 Discussion of Results

This paper employs panel ordinary least square regression (OLS). Also, the paper employed the fully modified OLS and dynamic OLS for further analysis. Table 3.4 shows the regression results from the three models, with all the signs for the regression coefficients being significant as in previous studies[44]: negative coefficient for population growth rate $ln(n + g + \delta)$ and the positive coefficients for physical capital $ln(^{I}/_{GDP})$ and human capital $ln(School)$, respectively, with a relatively high R-squared for all three regression estimators. The upper part of the table shows the regression results with commuted natural capital per capita using the linear interpolation method, ln(Natural) A^*, while the bottom part of the table shows the natural capital per capita data for 2000, 2005, 2010, and 2014, ln(Natural)B^*. All the three regression models produce an elasticity of income per worker with respect to physical capital $ln(^{I}/_{GDP})$ of

[44] Mankiw-Romer-Weil (1992), Knowles and Owen (1995), Baldacci et al (2004, 2008)

approximately one and elasticity with respect to population growth rate $ln(n + g + \delta)$ of approximately -1.3. The elasticity of income per worker with respect to human capital $ln(School)$ was approximately 1.4. For natural capital, elasticity of income per worker with respect to natural capital $ln(Natural)\ A^*$ and $ln(Natural)B^*$ were both approximately 0.5.

From the results, there is a statistically significant positive relationship between natural capita and economic growth. For instance, an increase in natural capital by one percent, leads to an increase in income per worker by 0.501% under the OLS regression model, and by 0.528% and 0.505% under the FMOLS and DOLS models, respectively. This implies that an increase in natural capital base by one percent, causes an increase in economic growth in the nations and this is statistically significant at a P-value of less than 1% at a 95% confidence level. All the three regression models produce an elasticity of income per worker with respect to natural capital of approximately 0.5. This is consistent with the hypothesis and other studies results such as Welsch (2003), Vemuri and Costanza (2006), and Crowe (2008), which found that there is a positive relationship between natural capital and economic growth.

Table 3.4: Regression Results: OLS, FMOLS and DOLS

	Panel OLS	FMOLS	DOLS
	Dependent Variable: Log of GDP per working age person		
Countries:	63	63	63
Observations	945	944	942
ln(I/GDP)	0.466***	1.067***	0.566**
	(0.044)	(0.204)	(0.246)
$\ln(n + g + \delta)$	-1.111***	-1.299**	-1.172*
	(0.136)	(0.631)	(0.691)

ln(School)	1.356***	1.229***	1.337***
	(0.097)	(0.447)	(0.484)
ln(Natural)A*	0.501***	0.528***	0.505***
	(0.029)	(0.132)	(0.145)
Constant	0.361	0.748	0.359
	(0.453)	(2.096)	(2.297)
R-squared	0.685	0.509	0.693
Countries:	63	63	63
Observations	252	251	249
ln(I/GDP)	0.397***	0.772***	0.723**
	(0.086)	(0.197)	(0.335)
$\ln(n + g + \delta)$	-1.092***	-1.520***	-1.452*
	(0.271)	(0.624)	(0.860)
ln(School)	1.405***	1.198***	1.331**
	(0.190)	(0.437)	(0.573)
ln(Natural)B*	0.489***	0.525***	0.509***
	(0.056)	(0.130)	(0.184)
Constant	0.373	-0.280	-0.133
	(0.894)	(2.057)	(2.828)
R-squared	0.671	0.601	0.700

Standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1; A* denotes natural capital with fill in data; B* denotes natural capital with missing data

Despite the positive statistical relationship between natural capital and economic growth, the benefits from natural capital stocks are not captured by market transactions. Due to the difficulty of measuring these non-market transactions, pricing becomes a difficult task. This has led to a barrier in measuring the true value of natural capital in any region. Although some economists use shadow pricing[45] concept in valuing natural capital, this still does not reflect the "true" value of natural capital, as the societal cost may not be valued in equal magnitude.

The contribution of natural capital to economic growth has mostly focused on the rents that accrue from the use of natural resources. However, viewing natural capital in this manner is incorrect as the ecosystem generally suffers from depletion when over-used, which has the potential to endanger human welfare. Thus for the true sustainability of natural capital, it is important to recognize that the indirect use value of natural capital as well the non-use value of natural capital instead of just focusing on the direct use value.[46] In as much as some economists accept the *weak sustainability* view[47], this paper still holds onto the *strong sustainability* view. It is important for nations to outline policies regarding how best they can make use their total capital stocks today in order to increase economic growth and development, and also decide on how much to save or invest to accumulate for future generational use and wellbeing.

In this regard, each capital stock can perhaps be maintained intact separately or jointly in fixed values, as the productivity of one capital stock will depend on the availability of the other. With this view, the total capital stocks of a nation (man-made and natural capital) can be

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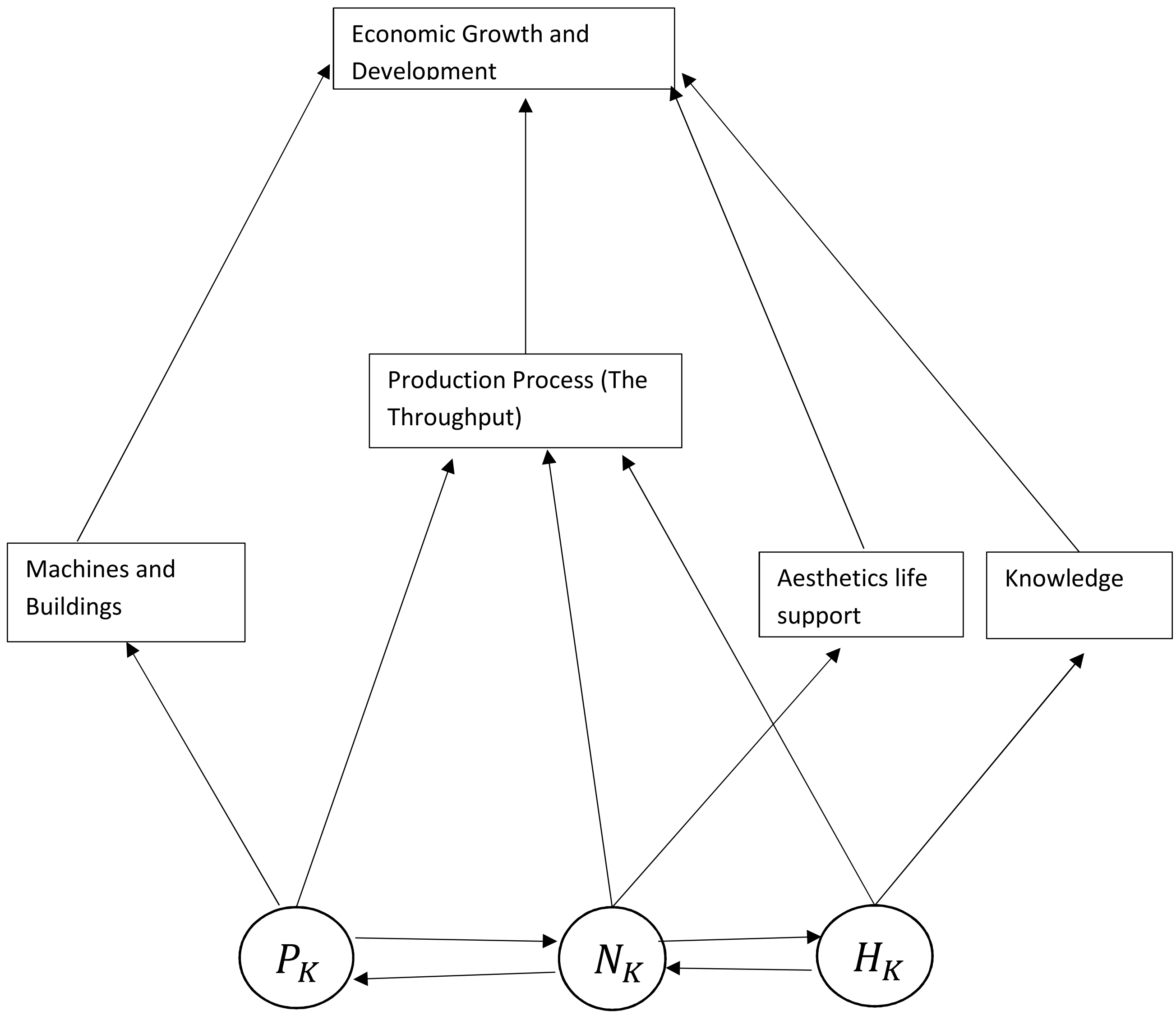
[45] That is the price of the extracted natural capital minus the societal cost of extracting that resource. See Dasgupta (2010)
[46] Direct use value of natural capital includes timber from the forest reserves, fish from the oceans and river bodies, drinking water, oil revenue from exports etc. Indirect use values of natural capital include flood controls, recreation etc. Non-use values include biodiversity, cultural values and identity, bequest to future generations.
[47] Pearce and Barbier (2000) pages 20-25

describe as complements and the measure of income growth should not only include human-made capital but also natural capital as well (Dasgupta, 2010). The complements nature of the capital stocks is depicted in Figure 3.1.

Figure 3.1: Physical, Natural and Human Capital in the Economic Process



Source: Modified from Pearce and Barbier (2000)

From the diagram, Natural Capital (N_k) serves as material resource and energy inputs in the production process. (N_k) also acts as the sink for waste emissions from the production process and as well provides a variety of ecological services for human survival. Human capital (H_k) consists of the needed skills and knowledge to manage the production process. Physical capital (P_k) consists of the tools, machines, investments, and buildings. All three capital stocks provide services and support to each other, and together contribute to economic growth and development.

3.9 Conclusions

This paper discovers a long run relationship (co-integration) between natural capital and economic growth. Furthermore, using three regression models, the regression results shows all the signs of regression coefficients being statistically significant, with a positive relationship existing between natural capita and economic growth as well. Natural capital stocks can be sustained through investments in natural capital. Nations should invest in natural capital by decreasing the level of throughput needed to maintain or sustain society welfare. This investment in decreasing the volume of throughput can be categorized as an indirect investment in natural capital and can take the form of reducing population growth[48] or increasing the level of efficiency of the throughput use.[49] Direct investments in natural capital can also take the form of assigning property rights to natural capital and creating and or enforcing existing environmental laws by national governments.

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[48] Nations can reduce the growth of their population by educating the population on protected sex and its advantages, encouraging the use of birth control pills by women, and educating females on maternity and child-bearing issues.

[49] This involves an efficient combination of both natural and man-made capital in the provision of goods and services to avoid the wastage of resources.

CHAPTER 4 CONCLUSION AND POLICY RECOMMENDATIONS

The aim of this dissertation is to contribute to the growth literature in attempting to explain output growth in nations. It is divided into two papers. In the first paper, health capital is introduced into the Mankiw-Romer-Wiel (MRW, 1992) version of the Slow Growth Model. Total HEX per capita is used as a proxy for health capital in determining income per worker growth in the nations. The results show that health capital is a significant factor in determining output growth. This confirms previous results by Blomqvist and Carter (1997), Heshmati (2001), and Piabuo and Tieguhong (2017), who all confirmed a statistically positive significant relationship between HEXs and economic growth. Also, the results indicate that a long-run relationship (co-integration) exists between HEXs and economic growth. Granger Causality tests proved a two-way causality between economic growth and health expenditures. In terms of longevity, the data shows that emerging markets economies spent more on HEXs, on average, than developing economies and had higher life expectancy at birth, than the developing economies.

The policy implication is that the important role HEX plays in the economic growth process cannot be overlooked. Therefore, it is important that developing countries' policymakers give credence to health care spending and allocates more of their budget towards health care spending. It is also important to note that spending more on health care alone may not necessarily increase economic growth that much due to the law of diminishing returns. Additional amounts of HEXs would be less productive if the amount of other capitals and factors of production are held constant. This makes health capital and the other economic capitals complements rather than substitutes.

The second paper in this dissertation introduces natural capital into the MRW version of the Solow Growth Model, to determine the association between economic growth and natural capital. Results from the study shows a long-run relationship (co-integration) between natural capital and economic growth. The results also indicate a statistically significant positive relationship between natural capital and economic growth. This result is consistent with previous studies such as Welsch (2003), Vemuri and Constanza (2006), and Crowe (2008), which all found that there is a positive relationship between natural capital and economic growth.

Natural capital serves as material resources and energy inputs in the production process. This form of capital also acts as the sink for waste emissions from the production process. It is therefore important that natural capital is sustained by national level governments so as to benefit current and future generational needs. This can be achieved in three (3) ways. First, this can be done through population growth control. Per the Malthusian theory, growth in population if unchecked, would exert more pressure on natural capital use, which will eventually outweigh the ability of the nature provided resources to generate enough food for human survival. Thus if population growth is left unchecked, then there would come a point in time at which nation's would no longer be able to meet their food requirements for present and future generations. Therefore, to help in the sustainability of natural capital for present and future generational needs, national level governments can establish and enforce policies aimed at reducing population growth. Policies that encourage the use of birth control methods by women, protective sex, and prevention of early marriages, would all go a long way in reducing the growth of the population. Secondly, educating the population on efficient sustainable production would help reduce the amount of waste and misuse of both natural capital and other man-made capitals in the throughput. Thirdly, national level governments can enhance the sustainability of natural capital for present and future generational use, by assigning property rights to natural capital use and also enforcing existing environmental laws.

All that being said, it is important for national level governments to recognize that investing in natural capital alone would not lead to economic growth that much on marginal terms. Other growth factors and conditions have to be put in place for any benefits to be derived from natural capital investments and sustainability. Also, treating natural capital as a substitute rather than as a complement in the production process, undermines the important role natural capital plays for human survival.

APPENDICES

APPENDIX A

Table A.1: List of Study Countries in chapter 2

No.	Country	Type	No.	Country	Type	No.	Country	Type
1	Brazil	E	37	Costa Rica	D	73	Romania	D
2	Chile	E	38	Cote d'Ivoire	D	74	Rwanda	D
3	China	E	39	Croatia	D	75	Senegal	D
4	Colombia	E	40	Congo	D	76	Sierra Leone	D
5	Czech Rep.	E	41	D.R. Congo	D	77	Sri Lanka	D
6	Egypt, A.R.	E	42	Dominican Rep.	D	78	Sudan	D
7	Greece	E	43	Ecuador	D	79	Swaziland	D
8	Hungary	E	44	El Salvador	D	80	Togo	D
9	India	E	45	Ethiopia	D	81	Tunisia	D
10	Indonesia	E	46	Fiji	D	82	U.R of Tanzania	D
11	Malaysia	E	47	Gabon	D	83	Uganda	D
12	Mexico	E	48	Gambia, The	D	84	Ukraine	D
13	Pakistan	E	49	Ghana	D	85	Uruguay	D
14	Peru	E	50	Guatemala	D	86	Venezuela	D
15	Philippines	E	51	Haiti	D	87	Vietnam	D
16	Poland	E	52	Honduras	D	88	Yemen, Rep.	D
17	Russian Fed.	E	53	Iran, I. Rep.	D	89	Zambia	D
18	South Africa	E	54	Jamaica	D			
19	Thailand	E	55	Jordan	D			

20	Turkey	E	56	Kazakhstan	D			
21	Albania	D	57	Kenya	D			
22	Algeria	D	58	Kyrgyzstan	D			
23	Angola	D	59	Liberia	D			
24	Argentina	D	60	Malawi	D			
25	Armenia	D	61	Mali	D			
26	Bangladesh	D	62	Mauritania	D			
27	Belize	D	63	Mauritius	D			
28	Benin	D	64	Morocco	D			
29	Bolivia	D	65	Mozambique	D			
30	Botswana	D	66	Namibia	D			
31	Bulgaria	D	67	Nepal	D			
32	Burkina Faso	D	68	Nicaragua	D			
33	Burundi	D	69	Niger	D			
34	Cambodia	D	70	Nigeria	D			
35	Cameroon	D	71	Panama	D			
36	Central A.R.	D	72	Paraguay	D			

E denotes Emerging Market Economies

D denotes Developing Economies

Table A.2: Summary of Previous Studies in Chapter 2

Author(s)	Observations	Period(s)	Methodology	Results
Newhouse (1977)	13 Developed Countries	Countries had different year (either 1968, 1970, 1971, or 1972)	Ordinary Least Square (OLS) Regression	Income elasticity of health care expenditure (HCE) is greater than one. Health care is a luxury good
Gerdtham et al (1992)	19 OECD Countries	1987	Box-cox transformation analysis	Income elasticity HCE is greater than one
Gerdtham (1992)	22 OECD Countries	1972-1987	Error Correction Model (ECM), OLS, Fixed Effect Model (FE), Feasible Generalized least square (FGLS), Two-way FE, Two-way RE	HCE is not income elastic
Blomqvist and Carter (1997)	24 OECD Countries	1960-1991	OLS, Phillips-Perron Co-integration Test	HCE is not income elastic
Heshmati (2001)	129 OECD Countries	1970-1992	Linear and iterative non-linear methods	HCE has positive effect on economic growth
Guisan and Arranz (2003)	24 OECD Countries	1970-1996	Least Square regression	Increase of HCE is generally positive for welfare
Gyimah and Wilson (2004)	44 Countries	1975-1994, 1961-1995	Dynamic Panel estimator (DPD)	Increase stock of health human capital will lead to higher economic growth
Baldacci et el (2004)	120 Developing Countries	1975-2000	FE,FGLS,2SLS, General Method of Moment (GMM), Error Component 2SLS	Education and health spending have positive and significant impact on economic growth
Dreger and Reimers (2005)	21 OECD Countries	1975-2011	Panel Co-integration tests	Long-run positive relationship between HCE and economic growth
Bukhari and Butt	Pakistan	1972-2005	ECM	Income elasticity for health care is greater

(2007)				
Akram et al (2008)	Pakistan	1972-2006	ECM, Johansen Co-integration Test	HCE has no relationship with economic growth
Baldacci et el (2008)	118 Developing Countries	1971-2000	Least Square dummy variable (LSDV), 2SLS, GMM	Both education and health spending affect economic growth positively
Erdil and Yetkiner (2009)	75 Countries	1990-2000	Granger-Causality Test	Bidirectional causality between HCE and economic growth
Badi and Francesco (2010)	20 OECD Countries	1971-2004	FE, Maximum likelihood estimator (MLE), Pooled estimator	Health care is a necessity rather than luxury, with an elasticity of less than one
Hartwig (2010)	21 OECD Countries	1970-2005	Granger-Causality Test	Negative relationship between HCE and economic growth
Adeniyi and Abidun (2011)	Nigeria	1985-2009	OLS regression	Significant Positive relationship between HCE and economic growth
Swift (2011)	13 OECD Countries	1820-2001, 1921-2001	Johansen Co-integration Test	Long-run relationship between health and economic growth
Amiri and Ventelou (2012)	20 OECD Countries	1970-2009	Granger-Causality Test	Bidirectional causality between HCE and economic growth
Kowalczuk and Toroj (2015)	34 OECD Countries	1990-2012	Pooled OLS, FE, RE, 2SLS	Positive and significant relationship between HCE and economic growth
Bedir (2016)	Emerging Markets	1995-2013	Granger Causality	Increases in economic growth stimulates HCE in some emerging countries

APPENDIX B

Returns to capital for each of the various capitals in chapter 2 (physical, human and health capital)

The Production function in equation (15) is:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} Z(t)^{\theta} (A(t)L(t))^{1-\alpha-\beta-\theta}$$

1. Marginal Product of physical capital (MPK_K):

$\Rightarrow \frac{Y}{AL} = \frac{K^{\alpha} H^{\beta} Z^{\theta} (AL)^{1-\alpha-\beta-\theta}}{(AL)^{1-\alpha-\beta-\theta}(AL)^{\alpha}(AL)^{\beta}(AL)^{\theta}}$ (From the denominator$(AL)^{1-\alpha-\beta-\theta+\alpha+\beta+\theta} = AL$)

$$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{H}{AL}\right)^{\beta} \left(\frac{Z}{AL}\right)^{\theta}$$

$$\Rightarrow y = k^{\alpha} h^{\beta} z^{\theta}$$

$$\Rightarrow \frac{\partial y}{\partial k} = \alpha k^{\alpha-1} h^{\beta} z^{\theta} = \alpha \left(\frac{Y}{K}\right)$$

Therefore: $MPK_K = \frac{\alpha}{K/Y}$

Thus, the rate of returns to physical capital equals the physical capital's share in income (α) divided by the physical capital-output ratio (K/Y).

2. Marginal Product of human capital (MPK_H):

From the production function above:

$$\Rightarrow \frac{Y}{AL} = \frac{K^{\alpha} H^{\beta} Z^{\theta} (AL)^{1-\alpha-\beta-\theta}}{(AL)^{1-\alpha-\beta-\theta}(AL)^{\alpha}(AL)^{\beta}(AL)^{\theta}}$$

$$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{H}{AL}\right)^{\beta} \left(\frac{Z}{AL}\right)^{\theta}$$

$$\Rightarrow \ y = k^{\alpha} h^{\beta} z^{\theta}$$

$$\Rightarrow \ \frac{\partial y}{\partial h} = \beta k^{\alpha} h^{\beta-1} z^{\theta} = \beta \left(\frac{Y}{H}\right)$$

Therefore: $MPK_H = \frac{\beta}{H/Y}$

Thus, the rate of returns to human capital equals the human capital's share in income (β) divided by the human capital-output ratio (H/Y)

3. Marginal Product of health capital (MPK_Z):

From the production function above:

$$\Rightarrow \ \frac{Y}{AL} = \frac{K^{\alpha} H^{\beta} Z^{\theta} (AL)^{1-\alpha-\beta-\theta}}{(AL)^{1-\alpha-\beta-\theta} (AL)^{\alpha} (AL)^{\beta} (AL)^{\theta}}$$

$$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{H}{AL}\right)^{\beta} \left(\frac{Z}{AL}\right)^{\theta}$$

$$\Rightarrow \ y = k^{\alpha} h^{\beta} z^{\theta}$$

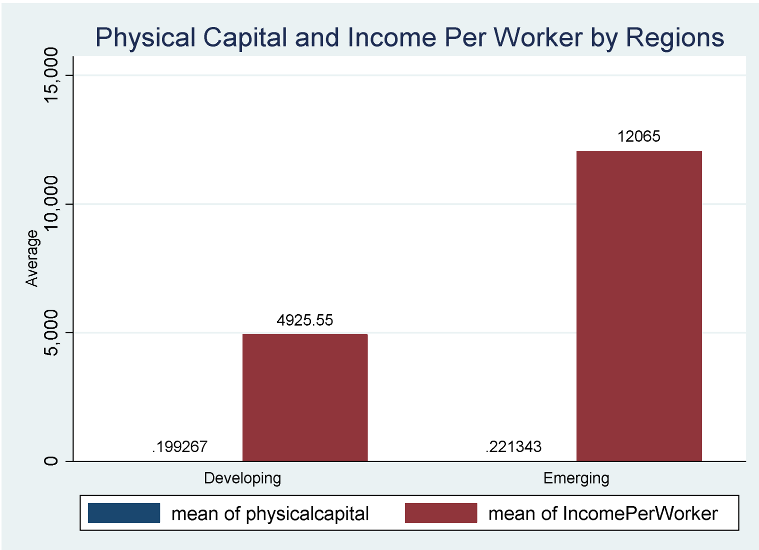
$$\Rightarrow \ \frac{\partial y}{\partial z} = \theta k^{\alpha} h^{\beta} z^{\theta-1} \ = \theta \left(\frac{Y}{Z}\right)$$

Therefore: $MPK_Z = \frac{\theta}{Z/Y}$

Thus, the rate of returns to health capital equals the health capital's share in income (θ) divided by the health capital-output ratio (Z/Y).

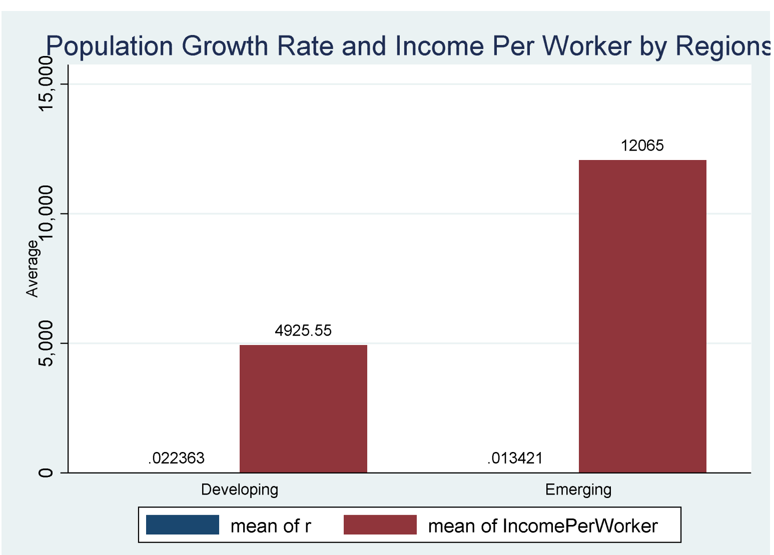
APPENDIX C

Figure C.1: Physical Capital and Income per worker by Regions, 2000-2014.



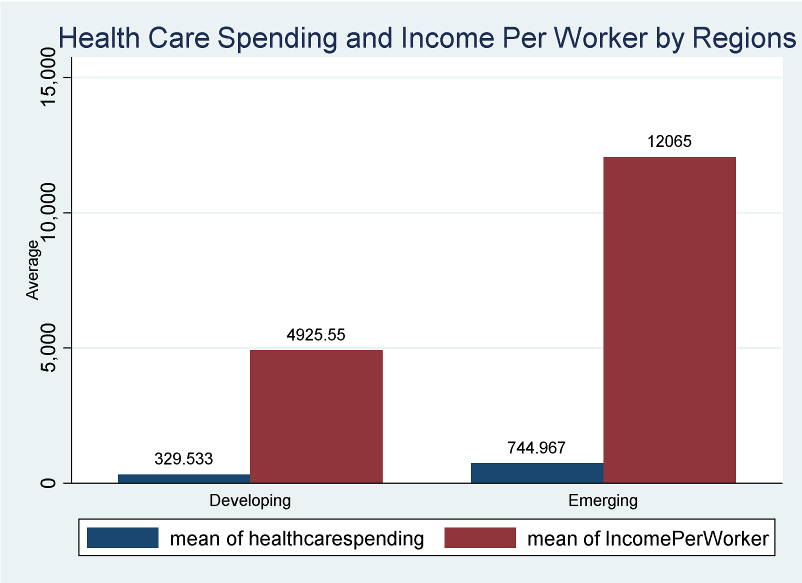
The diagram depicts that a 22.13% rate of investments in physical capital in the emerging market economies, on average, yields an income per worker of $12,065, higher than developing economies average rate of 19.93% and income per worker of $4925.55.

Figure C.2: Population Growth Rate and Income per worker by Regions, 2000-2014



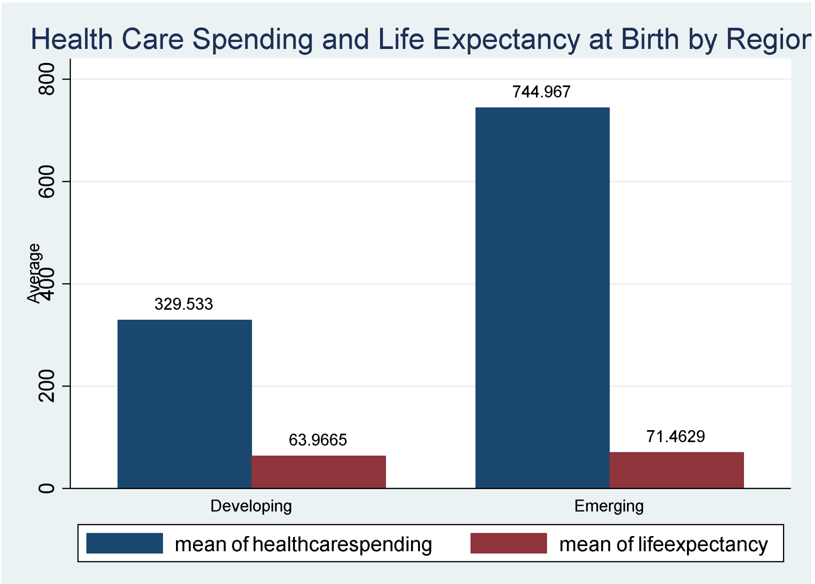
The diagram depicts that a 2.24% growth in working age population in the developing economies, on average, yields a lower income per worker of $4925.55, compared to the emerging market economies population growth of 1.34% and its income per worker of $12,065.

Figure C.3: Health Care Spending and Income per worker by Regions, 2000-2014



The diagram depicts that an average health care spending of $744.967 in the emerging market economies, yields a higher income per worker of $12,065, compared to the developing economies average health care spending of $329.533 and income per worker of $4925.55.

Figure C.4: Health Care Spending and Life Expectancy at Birth by Regions, 2000-2014



The diagram depicts that an average health care spending ($744.967) in the emerging market economies, yields a higher life expectancy at birth (71 years), compared to the developing economies average health care spending ($329.533) and life expectancy at birth (64 years).

APPENDIX D

Figure D.1: Log of income per worker and log of physical capital.

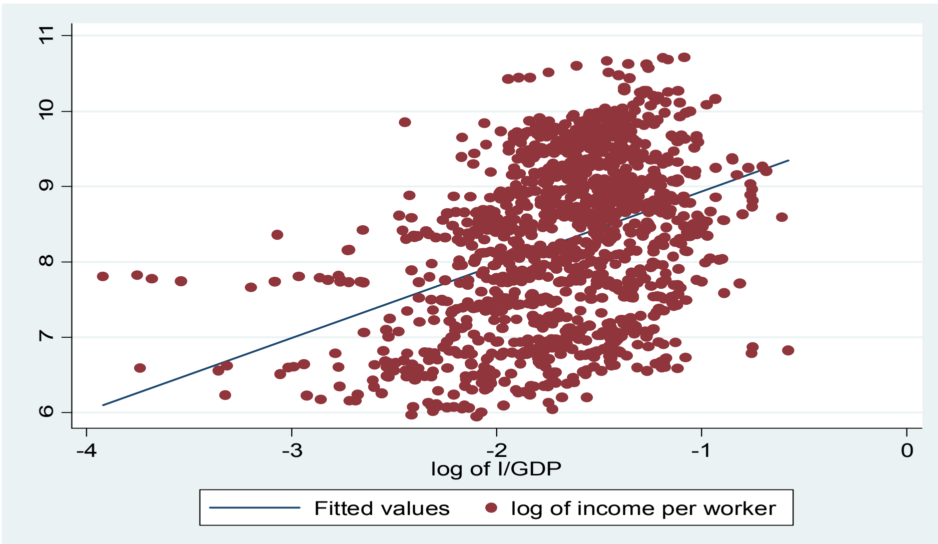


Figure D.2: Log of income per worker and log of population growth.

Figure D.3: Log of income per worker and log of human capital.

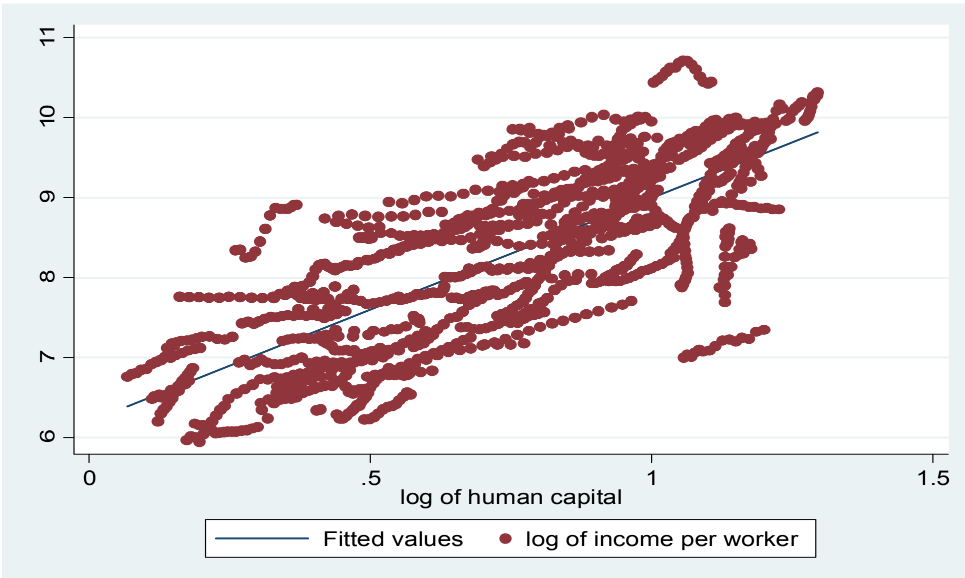
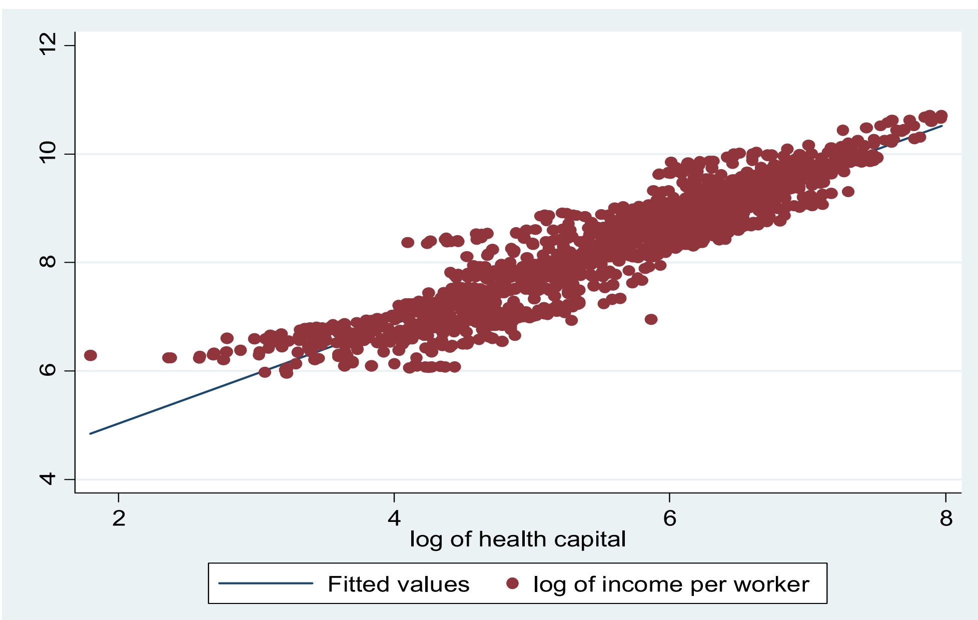


Figure D.4: Log of income per worker and log of health capital.



APPENDIX E

Table E.1: List of Countries in Study in Chapter 3

No.	Country	No.	Country	No.	Country
1	Albania	25	Ghana	49	Rwanda
2	Argentina	26	Guatemala	50	Senegal
3	Armenia	27	Haiti	51	Sierra Leone
4	Bangladesh	28	Honduras	52	Sri Lanka
5	Belize	29	Jamaica	53	Swaziland
6	Bolivia	30	Jordan	54	Togo
7	Botswana	31	Kazakhstan	55	Tunisia
8	Bulgaria	32	Kenya	56	Uganda
9	Burkina Faso	33	Kyrgyzstan	57	Ukraine
10	Burundi	34	Liberia	58	Uruguay
11	Cambodia	35	Malawi	59	Venezuela, RB
12	Cameroon	36	Mali	60	Vietnam
13	Central African Rep.	37	Mauritania	61	Yemen, Rep.
14	Costa Rica	38	Mauritius	62	Zambia
15	Cote d'Ivoire	39	Morocco	63	Zimbabwe
16	Croatia	40	Mozambique		
17	Congo	41	Namibia		
18	D.R. of the Congo	42	Nepal		
19	Dominican Republic	43	Nicaragua		
20	Ecuador	44	Niger		

21	El Salvador	45	Nigeria		
22	Ethiopia	46	Panama		
23	Gabon	47	Paraguay		
24	Gambia, The	48	Romania		

APPENDIX F

Returns to capital for each of the various capitals in chapter 3 (physical, human and natural capital).

The Production function in equation (39) is:

$$Y_t = K(t)^{\alpha} E(t)^{\beta} C(t)^{\psi} (A(t)L(t))^{1-\alpha-\beta-\psi}$$

1. Marginal Product of physical capital (MPK_K):

$\Rightarrow \frac{Y}{AL} = \frac{K^{\alpha}E^{\beta}C^{\psi}(AL)^{1-\alpha-\beta-\psi}}{(AL)^{1-\alpha-\beta-\psi}(AL)^{\alpha}(AL)^{\beta}(AL)^{\psi}}$ (From the denominator $(AL)^{1-\alpha-\beta-\psi+\alpha+\beta+\psi} = AL$)

$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{E}{AL}\right)^{\beta} \left(\frac{C}{AL}\right)^{\psi}$

$\Rightarrow y = k^{\alpha} e^{\beta} c^{\psi}$

$\Rightarrow \frac{\partial y}{\partial k} = \alpha k^{\alpha-1} e^{\beta} c^{\psi} = \alpha \left(\frac{Y}{K}\right)$

Therefore: $MPK_K = \frac{\alpha}{K/Y}$

Thus, the rate of returns to physical capital equals the physical capital's share in income (α) divided by the physical capital-output ratio (K/Y).

2. Marginal Product of human capital (MPK_E):

From the production function above:

$\Rightarrow \frac{Y}{AL} = \frac{K^{\alpha}E^{\beta}C^{\psi}(AL)^{1-\alpha-\beta-\psi}}{(AL)^{1-\alpha-\beta-\psi}(AL)^{\alpha}(AL)^{\beta}(AL)^{\psi}}$

$$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{E}{AL}\right)^{\beta} \left(\frac{C}{AL}\right)^{\psi}$$

$$\Rightarrow \ y = k^{\alpha} e^{\beta} c^{\psi}$$

$$\Rightarrow \ \frac{\partial y}{\partial e} = \beta k^{\alpha} e^{\beta-1} c^{\psi} \ = \beta \left(\frac{Y}{E}\right)$$

Therefore: $MPK_E = \frac{\beta}{E/Y}$

Thus, the rate of returns to human capital equals the human capital's share in income (β) divided by the human capital-output ratio (E/Y).

3. Marginal Product of natural capital (MPK_C):

From the production function above:

$$\Rightarrow \ \frac{Y}{AL} = \frac{K^{\alpha} E^{\beta} C^{\psi} (AL)^{1-\alpha-\beta-\psi}}{(AL)^{1-\alpha-\beta-\psi} (AL)^{\alpha} (AL)^{\beta} (AL)^{\psi}}$$

$$\Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^{\alpha} \left(\frac{E}{AL}\right)^{\beta} \left(\frac{C}{AL}\right)^{\psi}$$

$$\Rightarrow \ y = k^{\alpha} e^{\beta} c^{\psi}$$

$$\Rightarrow \ \frac{\partial y}{\partial c} = \psi k^{\alpha} e^{\beta} c^{\psi-1} \ = \psi \left(\frac{Y}{C}\right)$$

Therefore: $MPK_C = \frac{\psi}{C/Y}$

Thus, the rate of returns to natural capital equals the natural capital's share in income (ψ) divided by the natural capital-output ratio (C/Y).

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ABSTRACT

HEALTH AND NATURAL CAPITAL IN AN AUGMENTED SOLOW GROWTH MODEL

by

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Advisor: Dr. Allen C. Goodman

Major: Economics

Degree: Doctor of Philosophy

This dissertation explains output growth in nations using two different forms of economic capital (health and natural capital) in separate models under paper 1 and 2. In paper 1, income per worker's growth in the emerging market economies and developing economies is estimated using health capital. Previous studies done on health capital and output growth have mostly focused on Organization for Economic Co-operation and Development (OECD) and advanced economies, but I focused on emerging market economies and developing economies. I examined the association between health capital and economic growth in an augmented Solow Model, using total HEX per capita and GDP per worker as proxies for health capital and economic growth respectively. The finding suggests that there are long-run and two-way causality relationships between income and HEX.

In the second paper, I examined output growth in developing economies using natural capital. Previous studies on natural capital have focused more on theoretical research than empirical research. I took a different route and focused on national level data on natural capita, using an augmented Solow Model with natural capital as an independent variable to predict economic growth. Natural capital per capita and GDP per worker are used as proxies for natural

capital and economic growth respectively. The findings suggest that there is a statistically significant positive relationship between natural capital and economic growth, and a long-run relationship (co-integration) between the variables.

The policy implication of the study is that, health and natural capital plays an important role in the economic growth process. It is therefore important that national level governments give credence to investments in health and natural capital. Allocating more resources towards health care spending will improve health status of the population and increase productivity; and investing in natural capital would increase its sustainability and benefit both current and future generational needs.

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EDUCATION

- Ph.D. Economics, Wayne State University, Aug. 2015 – May 2019 (Expected)
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- B.A. Integrated Development Studies, University for Development Studies (UDS), Ghana, Sept. 2003 – June 2007

FIELDS OF INTEREST

- Macroeconomics Policy, Health Economics, and Industrial Organization

TEACHING EXPERIENCE (AS LEAD-INSTRUCTOR)

- Business School (Wayne State University)

Quantitative Methods 1: Fall 2018

- Department of Economics (Wayne State University)

Principles of Macroeconomics: Fall 2018, Summer 2018, Winter 2018, Winter 2017, Fall 2017, Summer 2016, Fall 2016, Fall 2015

- Department of Business (at Essex County College)

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AWARDS AND HONORS

- Graduate Teaching Assistantship award from Wayne State University for Academic years 2015-2019.
- Essex County College chapter, Adjunct Faculty Scholarship award, May 16, 2015.
- Alpha Epsilon Lambda, National Honor Society for Graduate Students, Kean University Alpha Pi Chapter, May 12, 2012
- Academic Excellence: *Summa Cum Laude*, Awarded by Concerned Black Personnel, Kean University, May 5, 2012
- Pi Alpha Alpha Honors Society, Kean University Chapter, May 3, 2012.
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- Dawood Farahi Public Service Endowed Scholarship, Kean University, Academic Year 2011-2012.

PROFESSIONAL EXPERIENCE

- Lead-Instructor, Wayne State University, Aug 2015 – Present
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- Supervisor and Training Officer, Command security Corporation, Dec 2009 – Aug 2015
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