Strathmore UNIVERSITY

Pro-Cyclical Modelling of Cancer Mortalities Based on Macroeconomic Factors

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094704

Submitted in partial fulfilment of the requirements for the Degree of

Bachelor of Business Science in Financial Economics at Strathmore University

Strathmore Institute of Mathematical Sciences
Strathmore University
Nairobi, Kenya

NOVEMBER, 2019

Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Project contains no material previously published or written by another person except where due reference is made in the Research Project itself.

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This Research Project has been submitted for examination with my approval as the Supervisor.

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Abstract

This paper tests for the procyclicality of the cancer mortalities and the economic regimes for the various regions, herein outlined as per the World Bank rankings as either high income, upper middle income, lower middle income or low-income countries. Previous studies have been carried out to examine the relationship between business cycles and cancer mortalities for advanced economies, less is known about the relationship existing between the existing macroeconomic variables and the cancer mortalities for the less developed countries.

This study thus assemble unique panel data set containing country-specific crude cancer mortalities, the GDP per capita, the share of the GDP spent on health(GDPEH), the annual cancer incidences, the 5-year prevalence rates and the disability-adjusted life years lost as a result of cancer. The results show a procyclical relationship between cancer mortalities and the economic growths a finding consistent with that of (Chen, et al., 2017), whereas there exists a countercyclical relationship between cancer mortalities and the investment in the health sector.

Keywords: Crude cancer mortalities, cancer incidences, economic growth, panel data, mortality-to-incident ratio

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Abbreviations

OLS – Ordinary Least Squares

GDP – Gross Domestic Product

UK – United Kingdom

US – The United States of America

GDPEH – Gross Domestic Product Expenditure on Health

MIR – Mortality to Incidence Ratio

NCDS – Noncommunicable Diseases

WHO – World Health Organization

ECM – Error Correction Model

VECM – Vector Error Correction Model

DALYs – Disability Adjusted Life Years

HI – High Income

UMI – Upper Middle Income

LMI – Lower Middle Income

LI – Low Income

Chapter One: Introduction

1.1 Background information

Noncommunicable diseases are chronic and more often than not long duration diseases that result from a combination of genetic, physiological, environmental and behavioral factors (WHO, World Health Organisation, 2018).

The noncommunicable diseases are usually divided into cardiovascular diseases (e.g. heart attacks and stroke), cancers, chronic respiratory diseases as asthma, and diabetes. There has been an increasing number of deaths as a result of noncommunicable disease as depicted in figure 1 below. This shows that over the years, there has been a general increase in the number of death cases resulting from the NCDs whereas there is a decreasing trend in the number of deaths as a result of communicable diseases. Of these NCDs, however, there is a notable trend in the increase in the number of deaths as a result of cancer cases (Chan, 2010).

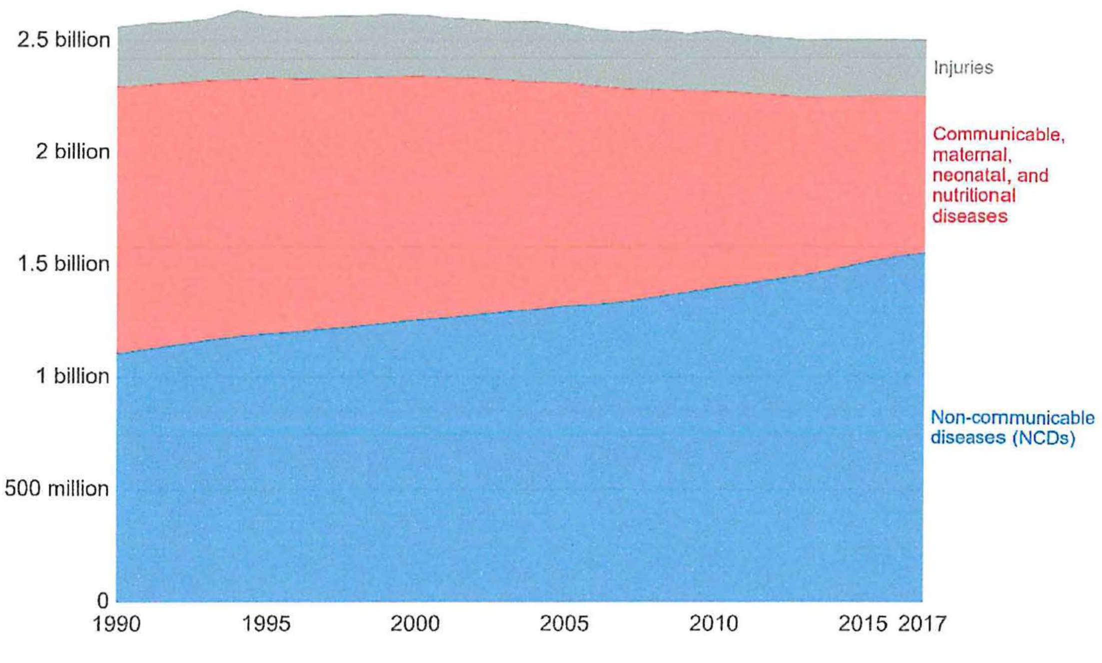

Figure 1: Total disease burden measured as the number of DALYs[1] per year. Source: IHME, Global Burden of Disease

Cancer is a large group of diseases characterized by the growth of abnormal cells beyond their usual boundaries and hence such cells then more often than not invade the adjoining parts of the body and finally spread to the other organs (WHO, World Health Organisation, 2019). Cancer affects potentially all body parts and is the second leading cause of death after

[1] DALYs - Disability-Adjusted Life Years

cardiovascular diseases (WHO, World Health Organisation, 2019). Cancer is a lifestyle disease and according to the WHO, ranging from 30% to 50% of cancer deaths could be prevented by avoiding risk factors such as tobacco usage and excess alcohol consumption (WHO, World Health Organisation, 2019).

In men, the most common cancer types are lung, prostate, colorectal, stomach and liver cancers whereas breast, colorectal, lung, cervix and thyroid cancers are most prevalent among women. Cancer often causes disability to the affected person and this usually escalates to continued suffering and eventual death. As such, health practitioners only try to manage cancer through surgery, drugs and radiotherapy.

1.1.1 Cancer Incidences and Mortality trends

Cancer incidence is the occurrence of new cancer cases over any given time period, whereas cancer prevalence is the number of people living who have been diagnosed with cancer and thus a combination of past and current diagnoses. As shown in figure 2 below, the largest portion of the cancer patients suffers from breast cancer. Cancer mortality gives the number of deaths per 10,000 people that is attributed to cancer whereas the cancer Mortality rate indicates the percentage of the population that dies from cancer at any given time whilst cancer survival shows the proportion of the patients alive at some point subsequent to the diagnosis of their cancer. The cancer mortality to incidence rate gives the ratio of the mortality due to cancer to the reported new cancer cases at any given time period. This has been found to be highest in the less developed countries compared to the developed countries (Chen, et al., 2017).

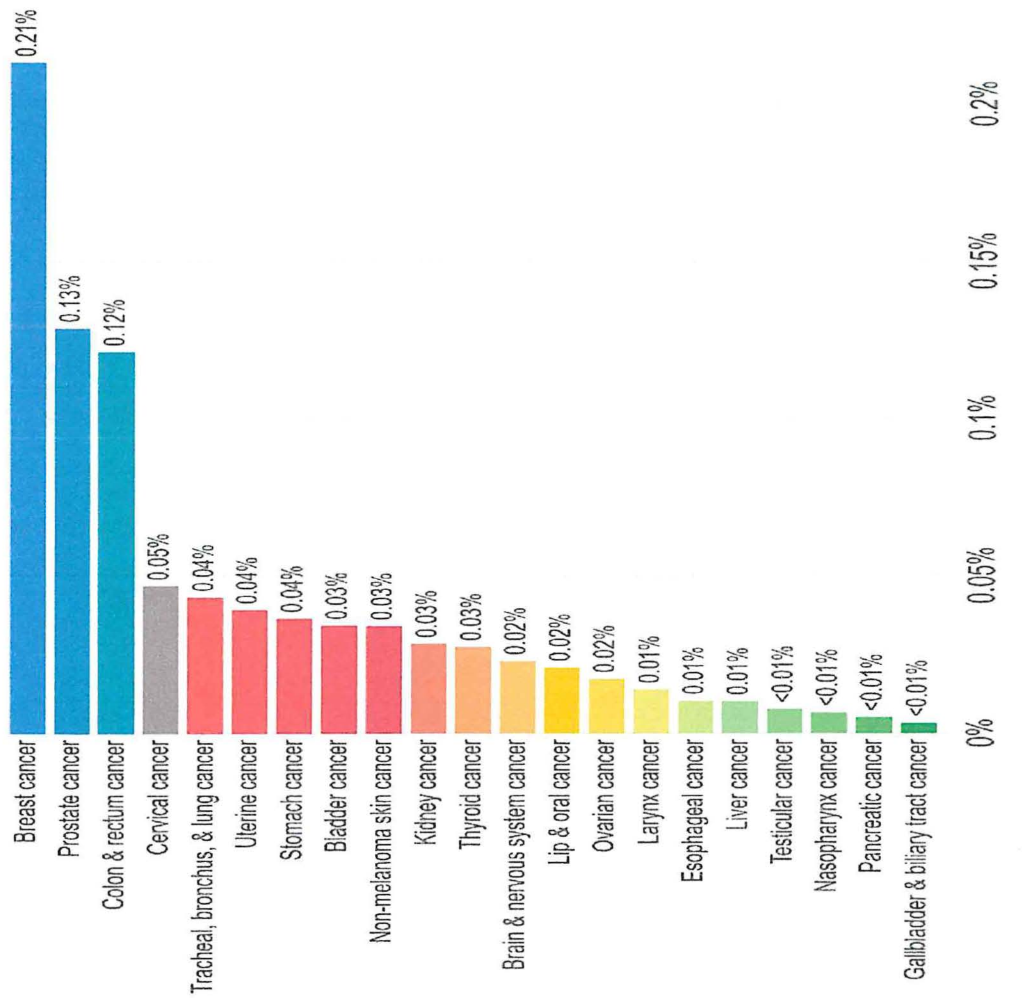

Figure 2: Percentage of the world population with cancer: Source: IHME, Global Burden of Disease

Generally, an upward trend, as in figure 3 below, for cancer is observed over the years, and there is an upward trend in the total number of people with cancer as a percentage of the whole population. Similarly, the number of deaths resulting from cancer cases have also been on the rise worldwide.

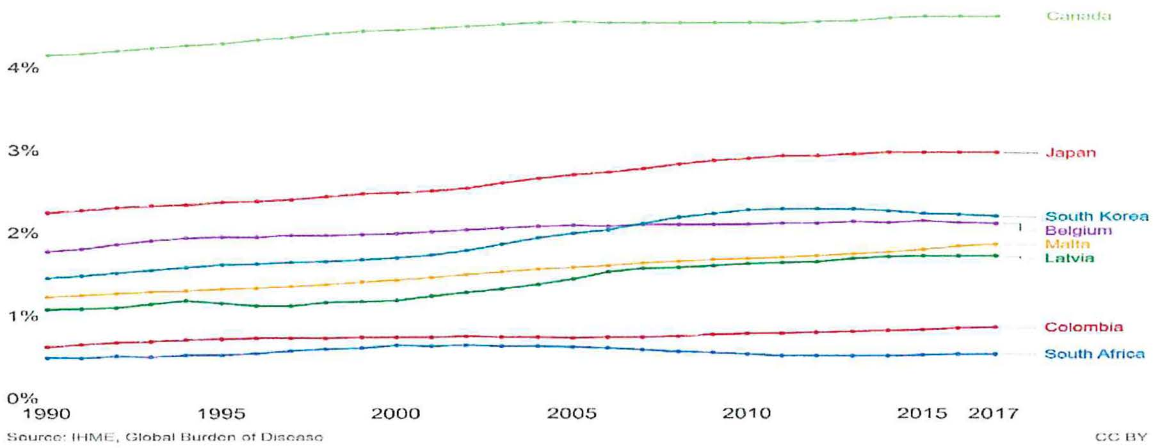

Figure 3: Share of the total population with cancer for selected countries[2]

1.1.2 Cancer in Kenya, Uganda and Brazil

In Kenya, cancer cases are more common in women, with the world health organization reporting the cases of death at 13,600 and 11,800 deaths for men and women respectively for the year 2018, the most common cancer type in men being prostate cancer at 17.1% of all the cancer cases in men, followed by cancer of the esophagus at 14.4% as depicted in figure 4 below. In women, cervix uteri are most common at 17.1% followed by breast cancer at 13.8% as shown in figure 5 below.

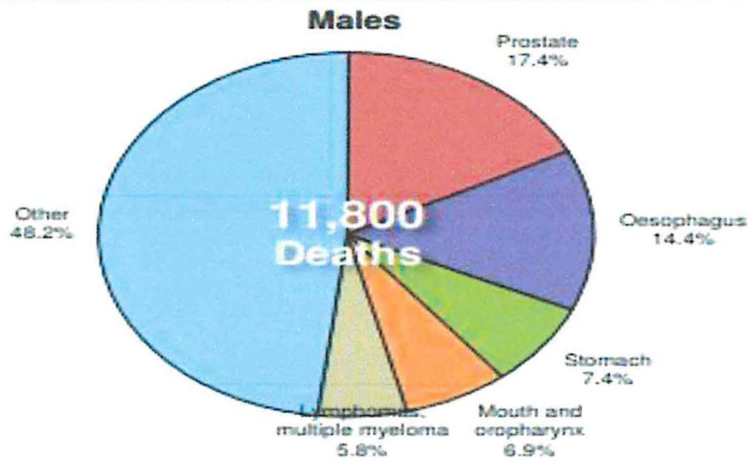

Figure 4: Kenya - Cancer mortalities in men, 2018[3]

[2] See: https://ourworldindata.org/cancer
[3] Retrieved from WHO; https://www.who.int/cancer/country-profiles/ken_en.pdf

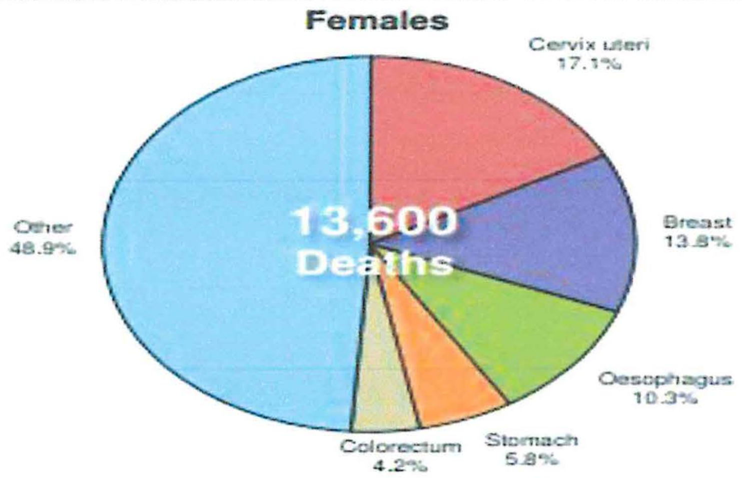

Figure 5: Kenya - Cancer mortalities in women, 2018

By the year 2018, there were 32,617 new cancer cases recorded in Uganda, with 21,829 deaths resulting from cancer and the five-year prevalent cases stood at 56,238. In women, cervix cancer is the biggest menace and accounts for 35.5% of all the cancer cases for the year 2018, followed by breast cancer at 12.8%. Unlike Kenya, however, men in Uganda are mostly at the risk of suffering from Kaposi Sarcoma which stands at 18.8% of the cancer cases followed by prostate cancer at 14.3%[4].

More men succumbed to cancer than women in Brazil for the year 2018. Over the years, prostate cancer has been the biggest concern for the men in Brazil, attributing to 14.9% of the cancer cases closely followed by trachea, lung and bronchus cancer at 14.1%. In women, just like the men of Brazil, trachea, lung and bronchus cancer comes second at 10.6% after breast cancer that accounts for 16.8% of the cancer cases in women. Figure 5 below shows the number of cases recorded in Brazil for the year 2018.

[4] Details of cancer in Uganda were obtained from the World Health Organization: http://gco.iarc.fr/today/data/factsheets/populations/800-uganda-fact-sheets.pdf

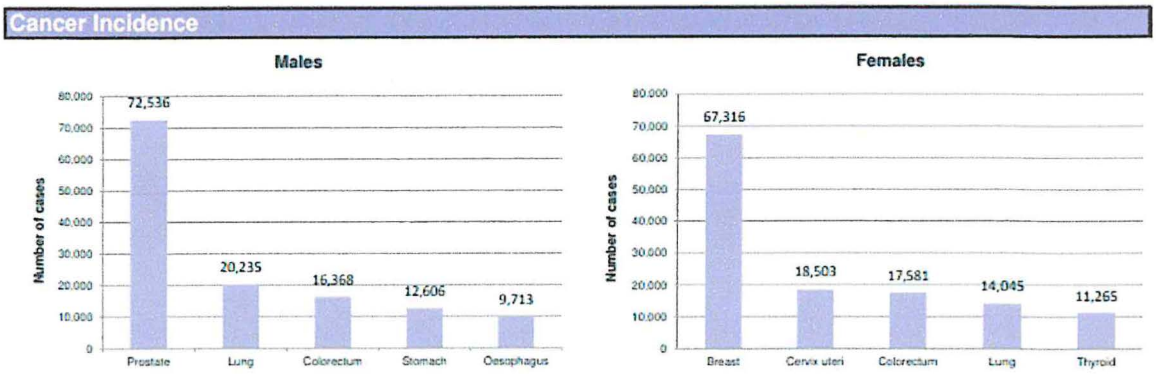

Figure 6: Brazil - Cancer Incidence - 2018; Source: World Health Organization[5]

1.1.3 Macro and microeconomic factors associated with mortality

The choice of the macroeconomic variables to use in cancer mortality modelling is critical in determining the strength of the proposed model. Berrin et al.,(2007) suggested that the macroeconomic factors associated with cancer include the nominal GDP, the GDP per capita and the GDP expenditure on health.

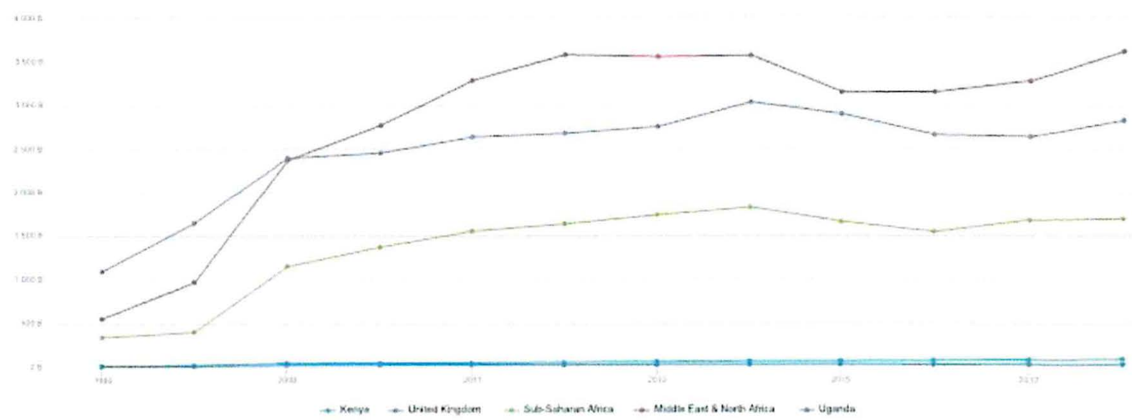

Figure 7: GDP in Billion USD[6]: Source World Development Indicators

Figure 6 above shows a general rise in the GDP levels per the country/region over the years for the period between 1990 and 2017. The current GDP in US Dollar terms has been on the rise for the above-mentioned countries, with a spike noted for the United States and the United Kingdom for the period 1990-2000, followed by a relatively level state. However, the spike for the US exceeds that of the UK for this mentioned period and this could be attributed to the "dot com" era over which there was heavy investment in technology, mostly in the US. A similar

[5] Retrieved from WHO; https://www.who.int/cancer/country-profiles/bra_en.pdf
[6] See source: https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=KEN,GBR,USA,SSF,MEA,UGA

trend is also realized for the GDP expenditure on health as a percentage of the real GDP as depicted in figure 7 below;

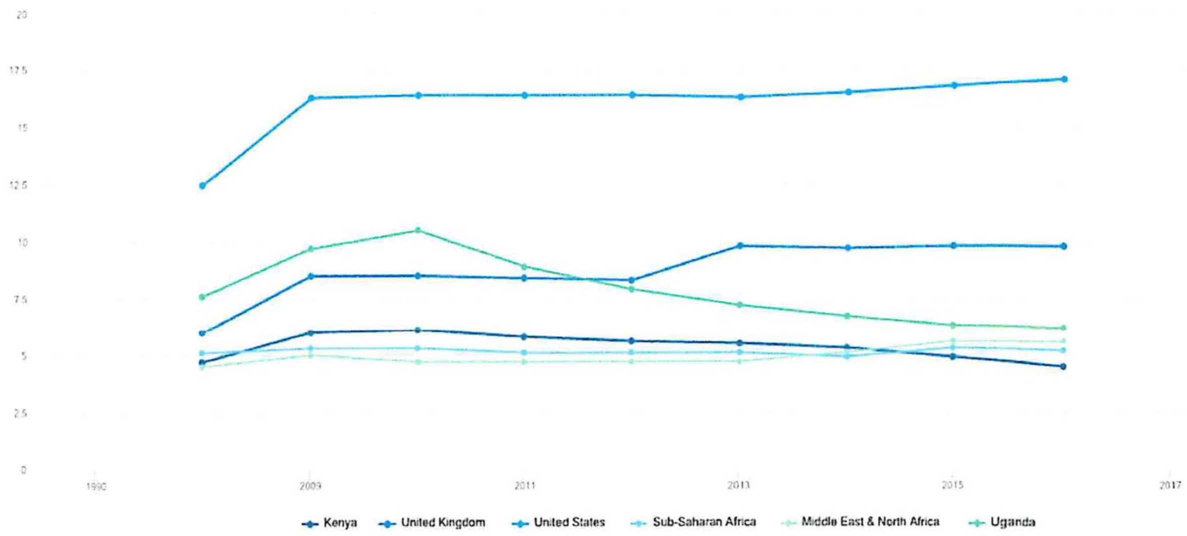

Figure 8: GDPEH as a percentage of real GDP[7]*;* Source: World Development Indicators

Prior studies show that countries with higher GDP per capita and higher GDPEH, that is, countries with higher WHO rankings have higher incidence rates compared to those with lower ranks (Chen, et al., 2017), whereas countries with lower WHO rankings tend to have relatively higher MIRs over time (Pritchard & Hickish, 2011).

1.1.4 Cancer over the world

The world has made a big commitment in recent years to treat and prevent infectious diseases like tuberculosis, AIDS and malaria (Chan, 2010). But another threat to global health is on the rise: Cancer rates, which were traditionally viewed as a concern only for the developed countries, are going up in the developing world (Singh, 2015). As such, it is important to recognize that cancer is a huge problem in rich and poor countries alike.

The majority of cancer cases — 57 per cent — now occur in low- and middle-income countries and 65 per cent of cancer deaths worldwide occur in these countries and this is partially because in some cases, people with treatable conditions don't have access to the medication they need. According to Singh(2015), in sub-Saharan Africa, for every 10 new patients diagnosed with cancer, 9 will die.

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[7] Source:
https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=KEN,GBR,USA,SSF,MEA,UGA

The World Health Organization estimates the global cancer burden to have risen to 18.1 million new cases and 9.6 million deaths in 2018. 20% of men are identified as having a high-risk factor of developing cancer at some point within their lifetime, whereas about 17% of women are at the risk of suffering from cancer at some point of their lives.

> *"Global patterns show that for men and women combined, nearly half of the new cases and more than half of the cancer deaths worldwide in 2018 are estimated to occur in Asia, in part because the region has nearly 60% of the global population. Europe accounts for 23.4% of the global cancer cases and 20.3% of the cancer deaths, although it has only 9.0% of the global population. The Americas have 13.3% of the global population and account for 21.0% of incidence and 14.4% of mortality worldwide. In contrast to other world regions, the proportions of cancer deaths in Asia and in Africa (57.3% and 7.3%, respectively) are higher than the proportions of incident cases (48.4% and 5.8%, respectively), because these regions have a higher frequency of certain cancer types associated with poorer prognosis and higher mortality rates, in addition to limited access to timely diagnosis and treatment in many countries"* (WHO W. , 2018).

1.2 Problem statement

There has been an increase in the number of cancer cases as well as mortalities that result from cancer. In the European Union as well as the Americas, there has been a continued fight on cancer over the years. In the developing countries of Asia as well as Africa, the threat from cancer has been a major concern and hence the declaration of national war on cancer by these countries.

One of the ideas in the Big Four Agenda of the Kenyan Government is the attainment of Universal Healthcare, an improvement on the prior ideas as the Millennium Development Goals, the Sustainable Development Goals and the Vision 2030. Towards the attainment of this, the government has invested heavily in the health sector with the hope of improving the quality of the health care given to patients[8]. Despite these investments, however, and specifically on the fight on cancer, the number of lives claimed by this disease has been on the

[8] See http://www.nationalplanningcycles.org/sites/default/files/country_docs/Kenya/draft_khssp_-_14_november_5_.pdf

rise, from 11,995 in 2010 to 15,762 in 2016[9]. The government has officially declared its fight on cancer and as mentioned by the Health Cabinet Secretary, Sicily Kariuki, the recently launched five-year project targeting cancer eradication seeks to have at least basic cancer treatment capabilities in all the 47 counties in the country under the National Cancer Strategy[10].

The drive to invest more heavily in the health sector shows the lack of sufficient resources that has persisted in Kenya and the other less developed economies could also be the explanation for the late cancer detection, and hence the high mortality to incident rates in such countries despite the growing levels of the economy as shown by the upward trend in the GDP growth rate over the years for both developed and the less developed countries alike. This study thus tests for the association between the economic growth rates and the cancer mortalities and evaluates how the macro and microeconomic factors that influence economic growth can be exploited to manage the cancer patients and to reduce the overall cancer MIRs.

1.3 Research objectives

1.3.1 General research objective

To compare the macro and microeconomic factors and cancer patterns across developed and developing countries

1.3.2 Specific research objectives

i. To test the procyclicality of cancer mortality based on economic cycles.
ii. To determine the macroeconomic factors that predict pro-cyclical cancer mortalities for different countries.
iii. To determine the relationship between economic growth and cancer mortalities for different countries.

[9] See https://www.ieakenya.or.ke/number_of_the_week/major-causes-of-mortality-rates

[10] https://www.businessdailyafrica.com/economy/Kenya-eyes-regional-cancer-hub-status-with-8-centres/3946234-4649146-9kg0v6z/index.html

Chapter Two: Literature review

2.0 Introduction

Many types of research have been done to estimate the worldwide cancer incidences and mortality over the years (Ferlay, et al., 2010). This increased number of studies on cancer and NCDs, in general, give a clear picture of the concern on the increasing casualties due to the NCDs worldwide (Schmidt, et al., 2011).

According to the WHO, noncommunicable diseases kill 41 million people each year, which accounts for slightly over seventy-one percent of the global annual deaths. Of these deaths, the cardiovascular diseases are a top, followed closely by the deaths as a result of cancer which has been on the rise over the past few years (WHO, World Health Organisation, 2018).

2.1 The developments in the study of cancer

2.1.1 Cancer mortality and business cycles

Cancer continues to be a global concern over time, with specific cancer types being studied in isolation to assess their distribution in the specific target groups. In light of the cancer mortalities vis a vis economic performance, (Ruhm, 2000) notes that there exist comovements between business cycles and specific causes of death. This comovement is also noted across different age groups with notable mortality increasing among young people (Cutler, Knaul, Lozano, Mendez, & Beatriz, 2000). Ferretti(2008) noted a negative long term influence of economic growth on cancer, a proposition later questioned in the analysis of the macroeconomic changes and mortality in Mexico where it was found out that cancer incidences tend to rise, though less proportionately, with increase in real per capita income, with an increase in mortality rates during economic expansions.

2.1.2 Cancer and government expenditure on health

Despite the good endowments enjoyed by the developed countries, there is a continued increase in cancer cases in the developed world (Berrino, et al., 2007), compared to the less developed countries. This is despite the major commitments by the various governments in fighting cancer with a notable increase in the expenditure on the health sector (Pritchard & Hickish, 2011). Recent studies show that cancer survival rates, however, cannot be attributed solely to the economic wellbeing of a country (Coleman, et al., 2011), and though the national expenditure on health has a high correlation with the mortality rates recorded annually in a country (Pritchard & Hickish, 2011).

The Variation in the mortality-to-incidence ratio (MIRs) among countries reflects the clinical outcomes and the available interventions for cancer treatments. In analyzing the trends for bladder cancer in the European Union, more than 120,000 people are diagnosed with bladder cancer annually in the 28 countries, with over 40,000 people dying every year from it every year (Leal, Fernandez, Sullivan, & Witjes, 2016). Later studies would show that the association between MIR of the specific cancer types, for example, prostate and bladder cancer and cancer care disparities among countries hardly investigated as there are no specific studies that have been carried out for this analysis (Chen, et al., 2017).

A negative association between the World Health Organization (WHO) rankings and the MIR for cancer cases is also noted for prostate as well as other cancer types (Chen, et al., 2017). It comes out that countries with higher WHO rankings and higher total expenditure on health per gross domestic product GDP have a significantly low correlation with low MIR. Gradually, there has been an increase in the incidences of prostate cancer which is attributed to the cancer screenings occurring in the western countries. The incidence rate is much lower in the less developed countries of Africa and Asia which also have the highest MIRs. Other types of cancer such as prostate and uterus cancer are found to have very strong ethnic propensity and it is more prevalent in the Europeans and the African Americans (Chen, et al., 2017).

The major causes of deaths related to cancer are depicted as lung cancer, followed by colorectal cancer (WHO, World Health Organisation, 2018). The most common cancers are; Lung (2.09 million cases), Breast (2.09 million cases), Colorectal (1.80 million cases), Prostate (1.28 million cases), Skin cancer (non-melanoma) (1.04 million cases) and Stomach (1.03 million cases). The most common causes of cancer death are cancers of; Lung (1.76 million deaths), Colorectal (862 000 deaths), Stomach (783 000 deaths), Liver (782 000 deaths) and Breast (627 000 deaths). All these figures are for the year 2018.

2.1.3 Cancer incidences and the survival rates

Cancer continues to be a major cause of death in developed countries, with an upward trend noted in developing countries (Ferretti, 2008), and this trend is noted across the whole globe (Chan, 2010). In concurrence with the findings by Ferretti, the world health organization has also pointed out that the burden of cancer has been rising steadily in the developing countries, though the effects of this growth have not been determined in isolation (Chan, 2010). For public health, the complexity of cancer control increased enormously following the shift of the disease burden from wealthy to less affluent countries. According to the latest WHO statistics, cancer causes around 7.9 million deaths worldwide each year. Of these deaths, around 70%, that means 5.5 million, are now occurring in the developing world. The disease that was once associated with affluence now places its heaviest burden on poor and disadvantaged populations (Chan, 2010).

According to Chen et al., (2017), the incidence trend of prostate cancer has increased over time in both the developed and the developing regions for the period from 1990 through 2013, and that prostate cancer has higher incidences and mortality in the regions of Americas and Europe. They also attribute the high MIRs in Africa and other less developed worlds to lack of or late screening, and hence the detection of the diseases at advanced stages and the less efficient are delivery techniques.

2.2 Theoretical literature review

2.2.1 Effectiveness ratio analysis

The principle of extended dominance was applied by Scott Cantor to estimate the cost-effectiveness analysis. In this study, Cantor made ethical considerations in analyzing the effectiveness of investment in the health sector vis a vis the gains realized by the patients treated and the government and other sponsors (Cantor, 1994). The research works that followed used the same methodology and in 2010, Da carried out utility analysis to assess the cost of cancer treatment. The results obtained indicated that no particular model has been developed to effectively tap all the investments in the fight against cancer as there still are numerous avenues through the investment into the sector still leaks to other non-intended projects (Greenberg, Earle, Fang, Eldar-Lissai, & Neumann, 2010). In their study that could follow that of Greenberg et al(2010), Pritchard and Hickish analyzed the effects of the economic investments vis a vis the resulting cancer cases and mortalities based on the various categories of the patients. The analysis was done based on the gender of the patients, age stratification, that is to say, the age category of the patient. These patients were also grouped based on the cancer types they suffered from, and hence an analysis based on what type of gender suffer from what cancer type and from what age (Pritchard & Hickish, 2011). The results were thus compared for the various countries under study to get international trends based on the findings per country.

2.2.2 Temporal trends analysis

Temporal analysis of cancer is based on the study of the other lifestyle diseases associated with cancer such as obesity and heart diseases. It was found out that in the short run, obesity may contribute to about 6% of the total annual USA cancer incidences (Polednak, 2008). However, in carrying out the temporal analysis of the data, (Luzzati, Parenti, & Rughi, 2018) used graphs to analyze the trend in the cancer incidences and mortality based on the age and the gender of the cancer patients. Scatter plots were then used to make the trends more visible, and this was based on the correlation matrix that was developed for all the cancer types. Based on the trends from the scatter plots, even after controlling for the population ageing, it was found that cancer incidences are higher in high-income countries (Luzzati, Parenti, & Rughi, 2018).[11]

2.2.3 Average and political system analysis

In this study, Harding and Pritchard(2016) calculated the average expenditures on health and used this to compare the performance of the UK health system to her peers in the European Union and the Americas. A large portion of the underperformance of the UK health system was attributed to the politics of the country which is identified as being heavily behind the government agencies expenditure on health. The UK GDPEH is found to have remained stagnant at an average of 6.2% whereas the general EU average for the same period staggered at 7.7% (Harding & Pritchard, 2016).

2.3 Empirical literature review

In his work, (Ruhm, 2000) showed that economic conditions have been assumed to have only contemporaneous impact on mortality. However, summary statistics weighted by the total resident population shows that mortality and most specific sources of fatalities declined subsequently over the study period. Although the time profile varies with the source of death, a sustained deterioration in state economic conditions is frequently associated with larger short run than permanent reductions in mortality.

Most of the research works used to model the progression of cancer and the expenditure by various parties involved in the fight against cancer using the OLS approach for their analysis. OLS has been used by (Ferretti, 2008) who assessed the elasticities of income and cancer incidences and mortality and found out that there existed more cancer cases in the western world which depicted a higher trend than the world's average. A similar approach was also employed by Gonzalez and Quast(2009) to study the Macroeconomic Changes and the Mortality in Mexico, in which they transformed the OLS equation to a panel data model to allow for an analysis of the cancer effects in the different states of Mexico.

In his analysis of the impact of old age on the cancer incidences and mortality in Australia, (Swift, 2010) used more robust models from the previous studies. First of all, he transformed

[11] This model has been derived under the section for the Appendix.

the Cobb Douglas function to allow for two-way causation between health and economic growth with the assumption that households maximize utility by dividing output between consumption goods and investment in capital. He then develops a panel data analysis model that defines the relationship between the expenditure on health and economic growth. The system of equations developed are then transformed to form vector error correction models which he uses to model the data set. In the end, Robyn uses Johansen multivariate cointegration analysis for his analysis.[12]

2.4 Conclusion

Much work has been done on the study of cancer, but not so with respect to the comparison of the macro and microeconomic factors of the various economies of the world. As such, there is need to carry out a cancer mapping and to examine the cancer patterns over the years for all the types of economy, the less developed, the developing and the developed economies.

2.5 The research gap

Even though a lot of work has been done about cancer and economic growth, not much work has been done as regards the global cancer mapping based on economic categories of the various countries. As such, there exists the research gap in the area of cancer mapping based on economic factors across the globe that underlie improvement of the health facilities of the countries under study.

2.6 Conceptual framework

The framework underpinning the study is defined as depicted below;

[12] This model is also discussed under the appendix.

Chapter Three: Methodology

3.0 Introduction

This chapter contains the research design, the population and sampling used for the study, and the empirical analysis techniques for the collected data sets. It is aimed at giving the framework for testing for the relationship between the macroeconomic factors and cancer mortality to incident ratios(MIR) over the various cross-sections under study across time. The chapter thus describes the econometric model to be used, the data types and their sources as used for the study.

3.1 The research designs

This study uses exploratory design to quantitatively analyze the relationship between cancer mortalities and GDP per capita and GDPEH over the years. The quantitative research design is selected for this study because it gives a more elaborate description of the variables in question, and thus leads to the use of appropriate models to analyze the variables.

3.2 Population and sampling

The data for this study represents the four economic regions as classified by the World Bank as either High Income, Upper Middle Income, Lower Middle Income or Low Income. The High-Income countries for this study include France, South Korea, Spain and the United States, whereas the Upper Middle-Income countries are represented by Algeria, Brazil, Fiji and Venezuela. Kenya represents the Lower Middle Income while Uganda represents the Low-Income countries[13].

3.3 Data collection

The annual cancer mortality to incident ratios data is used in the model as the proxy for the measure of the development in the fight of cancer. The explanatory variables used in the model encompass the GDP per capita used as a measure of economic growth of each country, the GDP expenditure on health as a proxy for the government's investment in the fight of cancer, the cancer burden as the losses the governments incur as a result of the new cancer cases and the cancer prevalence rates. The macroeconomic data was obtained from the World Bank and the details on cancer obtained from the World Health Organization[14].

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[13] This is as per the World Bank's classification as of 2019. See: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

[14] Some information was obtained from the data world as regards cancer cases. See https://ourworldindata.org/

3.4 Data analysis

3.4.1 Model specification

Economic theory and reviewed literature established that cancer mortality to incident ratios are affected by the expenditure on cancer (herein defined as the percentage of GDP spent on the health sector) and the annual cancer prevalence rates. The country-specific annual cancer MIRs are also heavily reliant on the percentage of the population with cancer at any given time. This is, however, not included in the model due to the heavy correlation that exists between it and the cancer incidences as well as with the annual cancer prevalence rates. The econometric model is thus specified as[15]

$$lmort_{i,t} = \beta_0 + \beta_1 lgdpc_{i,t} + \beta_2 lgdpeh_{i,t} + \beta_3 l\text{burden}_{\,i,t} + \beta_4 lprev_{i,t} + \varepsilon_{i,t}$$

Where;

MIR is the mortality-to-incident ratios

GDPC is the Gross Domestic Product per capita,

GDPEH is the percentage of the GDP spent on health,

Burden is aggregate loss due to cancer cases and deaths in dollar terms, and

Prev is the cancer prevalence rate.

The model is employed due to its suitability in analyzing panel data and its flexibility and ease of use.

3.4.2 Stationarity tests

Stationarity refers to statistical properties, that is, the mean, variance and the autocorrelation being constant over time. Time series data sets, and by extension, panel data sets, are often faced with the problem of dependence across time with nonstationary data causing unreliable and spurious results and hence poor understanding, interpretation and prediction based on the data available. Differencing is thus applied to transform the data and thus make it stationary, and if the data shows a deterministic trend, then detrending is applied to bring about the stationarity of the data set. For panel analysis, the stationarity tests include Harris-Tzavalis Test(1999), Levin-Lin-Chu Test(2002), the Fisher-Type Test and the Im, Pesaran and Shin Test(IPS).

[15] The model has been derived under Appendix. See Appendix 1.

The Levin-Lin-Chu test

Individual unit root tests have limited power and so is the power of rejecting the null when it is false and when unit root exists. The LLC test suggests the following hypotheses;

H0: each time series contains a unit root.

Ha: each time series is stationary with the lag order allowed to vary across individual cross-sections.

The Im, Pesaran and Shin test

This test is a little more relaxed compared to the LLC which has numerous restrictions. The IPS test assumes a null that all the individuals follow a unit root process, i.e.,

$$H_0 : \rho_i = 0 \; \forall i$$

$$H_a : \begin{cases} \rho_i < 0 \; \forall \; i = 1, 2, \dots, N \\ \rho_i = 0 \; \forall \; i \; N_1 + 1, \dots, N \end{cases}$$

Where the alternative hypothesis allows some, but not all, of the individuals to have unit-roots.

The Fisher-Type test

The Fisher-Type Test uses p-values from the unit root tests for each cross-section with the test defined as

$$p = -2 \sum_{i=1}^{N} ln \, p_i$$

The test is asymptotically Chi-Square distributed with 2N degrees of freedom.

For this study, I use the Fisher-Type test over the other panel unit root tests since it can handle both balanced and unbalanced panels. Furthermore, it allows the lag lengths of the individual Augmented Dickey-Fuller tests to vary.

3.4.3 Cointegration test

To carry out the cointegration test for the various panels, I carry out the Maddala-Wu Test. This test is conducted when the order of integration between the variables is not the same. The reason for carrying out this test is to test for cointegration of variables if they are integrated with mixed order of cointegration like I(0) or I(1) can also yield better results for the finite time series data. The null hypothesis is defined as H_0: $\beta_t = \alpha_t = \gamma_t = \delta_t = \theta_t$ if and only if there is no cointegration among the variables. On the other hand, there exists cointegration if the alternative hypothesis Ha: $\beta_t \neq \alpha_t \neq \gamma_t \neq \delta_t \neq \theta_t$ holds true. The critical bounds are used for this test and if the F-statistic is greater than the upper critical bound, then the null hypothesis is rejected. This is useful in identifying the existence of any long-run relationship between the variables across cross-sections over time.

3.4.4 The error correction model

The error correction model is used after the establishment of cointegration. This model combines both the short run and the long-run relationships between the variables without losing any information through detrending and differencing which leads to the loss of long-run time series data. The model also estimates how fast the regressand, cancer mortalities, returns to equilibrium after a change in the endogenous variables.[16]

3.4.5 Tests for individual effects and time effect.

The fixed-effects model

This model assumes that the marginal effects of the explanatory variables on the dependent variable are the same for all the units. This corresponds to the restrictions that the slopes are constant across units and to account for this difference, the constant terms are allowed to vary among the cross-sections.

The fixed effects(FE) model for a general variable $y_{i,t}$ is outlined as

$$y_{i,t} = \alpha_0 + \beta x_{i,t} + u_i + v_{i,t}$$

Where u_i captures all the factors that affect $y_{i,t}$ cross-sectionally but do not vary across time.

The individual fixed effects model

This tests for the fixed effects that result from the variations across cross-sections but remains constant over time. It captures the information contained in u_i. Using the least-squares dummy variables model, we introduce dummy variables for all the cross-sections and test for their individual significance. For a general variable $y_{i,t}$, the LSDV model is

$$y_{i,t} = \alpha + \beta x_{i,t} + \sum_{q=1}^{N} \mu_q . Dq_i + v_{i,t}$$

[16] Following Barro(1996), the model is defined as outlined under Appendix 2.

With each Dq_i being a dummy variable that takes a value of 1 for all the observations specific to the cross-sections, and zeroes otherwise.

The time fixed effects model

This model captures the values of the variables that change over time but do not change across cross-sections. We thus allow the intercepts to vary over time while remaining constant cross-sectionally. The time fixed effects model is written as

$$y_{i,t} = \alpha_0 + \beta x_{i,t} + \lambda_t + v_{i,t}$$

Where λ_t captures all the variables that affect $y_{i,t}$ and vary over time but are constant cross-sectionally.

The random-effects model

The random-effects model proposes different intercept terms for each entity which are constant over time, with the relationship between the regressor and the regressand assumed to be the same both cross-sectionally and temporally. The heterogeneity across individual cross-sections is treated as a random component with the unobserved effect assumed to be uncorrelated with the explanatory variables in each time period.

This model is most viable if we think that the unobserved error term is uncorrelated with the explanatory variables as the estimation of the random effects is done by the generalized least squares method.

The intercepts for each cross-sectional unit are assumed to arise from a common intercept α which remains constant for every cross-section and over time, plus a random variable ε_i that varies cross-sectionally but remains the same over time. ε_i measures the random deviation of each entity's intercept term from the "global" intercept α.

The random-effects model is thus described as

$$y_{i,t} = \alpha + \beta x_{i,t} + \omega_{i,t} \text{ ; } \omega_{i,t} = \varepsilon_i + v_{i,t}$$

The Hausmann test

Since fixed effects allow arbitrary correlation between α_i and $x_{i,t}$, while the random effects model does not, fixed effects model is normally widely thought to be a more convincing tool for estimating ceteris paribus effects. The random effect model is however used in a number of occasions for example, in the case where the explanatory variable is constant over time and hence, we cannot use its effect on the dependent variable.

The Hausmann Test helps with the choice between which model to use while comparing the random and fixed effects estimates. Under the null hypothesis the individual effects are random, and hence both random and fixed effects are consistent.

$$H_0 : RE\ provides\ consistent\ and\ efficinet\ estimates$$

$$H_a : FE\ provides\ consistent\ estimates$$

Rejecting the null means that the fixed effects model is a better model.

Chapter 4: Data analysis and figures

4.1 introduction

This chapter presents the data analytical results from the tests carried out. The data presented is based on the research objectives which encompass determining the relationship between macroeconomic variables and the cancer mortality over the years, as well as test for the procyclicality of the cancer mortalities and the business cycles in the economy.

4.2 Descriptive statistics

In this section, I analyze the overall statistical summaries of both the independent and dependent variables.

4.2.1 The overall summary statistics

The pooled statistics in table 1 show that generally, there is a 54% per cent chance that anyone diagnosed with cancer will succumb to the disease within five years, with averagely low 5-year prevalence rate at 23% and an overall average of 10% as the share of the GDP spent on the health sector. Comparing the average mortalities recorded yearly vis-à-vis the cancer incidences show relatively higher chances of deaths in the whole data set.

Pooled summary stats							
Variable	Obs		Mean	Std. Dev.	Min		Max
				$	$		
gdpc	250	$	18,123.21	14,199.62	769.45	$	51,922.00
gdpeh	250		10.66%	3.98%	1.34%		21.29%
gdpg	250		3.34%	2.82%	-5.47%		11.52%
inc	250		328.86	308.88	94.00		1282.00
mir	250		0.54	0.23	0.10		1.21
mort	250		123.98	29.27	66.00		175.00
percan	250		0.93%	0.63%	0.28%		2.36%
prev	250		1.51%	1.68%	0.05%		9.32%
				$	$		
burden	250	$	2,811,258.00	3,697,249.00	12,809.30	$	14,000,000.00

Table 1: Pooled summary statistics

4.2.2 The gross domestic product per capita

Table 2 shows the summary statistics for the various countries under study. Uganda has the lowest GDP per capita followed by Kenya at slightly over 2000 Kenyan shillings. As such, using the GDP per capita as the proxy for economic performance, Uganda is the least performing economy while the United States has the best-performing economy.

Country	Mean	Std. Dev.	Freq.
Algeria	11,178.65	1518.06	25
Brazil	12,270.56	1736.95	25
Fiji	6,889.60	679.22	25
France	34,377.92	3011.70	25
Kenya	2,305.61	182.24	25
South Korea	22,667.16	6820.70	25
Spain	29,434.40	3626.40	25
Uganda	1,172.95	291.07	25
United States	45,376.18	5216.43	25
Venezuela	15,558.99	1499.27	25
Total	18,123.20	14199.62	250

Table 2: The Gross Domestic Product per capita

4.2.3 The share of the GDP spent on health

Despite the world health organization's rankings that show France as the country with the most vibrant and well-invested-in health sector (Tandon, Murray, Lauer, & Evans, 2013), the United States of America remains to have the highest average share of the GPD spent on health at 16.95% followed by France at 13.58% while of the entire data set, brazil records the lowest average contribution to the health sector at 6.77% as shown in table 3.

There is, however, a considerable variation in these percentages for the more developed countries as compared to the less developed world as is the case for France with a standard deviation of 3.633 against that of Algeria at 0.63 against their expenditure on health that stands at 8.77%.

Country	Mean	Std. Dev.	Freq.
Algeria	8.767	0.630	25
Brazil	6.774	1.773	25
Fiji	10.530	2.715	25
France	13.580	3.633	25
Kenya	8.737	2.060	25
South Korea	8.169	3.526	25
Spain	13.500	1.868	25
Uganda	12.040	2.842	25
United States	16.950	3.148	25
Venezuela	7.529	1.373	25
Total	10.650	3.984	250

Table 3: The average annual share of GDP spent on health

4.2.4 The disability-adjusted life years lost

The disability life years lost herein show us the annual burdens of cancer that each country incurs due to cancer mortalities. From table 4, Venezuela is the most hit country, losing an average of 12 million US dollars to cancer mortalities each year. The United States, however, despite having a relatively lower DALYs have the highest variation of the same variable with a standard variation of over two million US Dollars.

	The disability-adjusted life years lost		
Country	Mean	Std. Dev.	Freq.
Algeria	439,717.84	83,098.40	25
Brazil	3,868,226.80	1,390,407.80	25
Fiji	1,387,363.50	2,494,701.60	25
France	2,095,504.30	1,589,620.80	25
Kenya	1,816,096.20	1,553,560.00	25
South Korea	1,005,374.30	551,223.96	25
Spain	1,868,000.00	55,677.64	25
Uganda	1,837,444.90	653,411.74	25
United Sta..	1,034,856.30	2,286,510.70	25
Venezuela	12,760,000.00*	597,215.76	25
Total	2,811,258.40	3697249.40	250

Table 4: The DALYs(herein referred to as burden)

****Venezuela is the most hit country with an average of $12, 760, 000 lost annually due to cancer.***

4.2.5 The 5-year prevalence rate, annual cancer incidences, mortalities and mortality to incident ratios

The five-year cancer prevalence rate shows the average chance that an individual diagnosed with cancer now will be alive five years later. From the data set, the sample data gives an average of 1.5% prevalence rate, with the United States recording the highest value, way above the sample average at 4.28%. the rest of the countries from the high income regions, i.e., Spain, France and South Korea record average prevalence rates of 3.3%, 1.6% and 1.7% respectively while the third world countries represent generally lower prevalence rates, with Kenya recording the lowest rate at 0.35% followed by the other African countries at 0.52% and 0.53% for Uganda and Algeria respectively. This variation in the prevalence rates is negatively correlated with the cancer mortality to incident ratios for the specific countries.

On average, the highest number of cancer cases were recorded in the United States at 1,211 annually over the study period, a figure more than thrice of the number of cancer cases for France which comes second with the highest number of cases, while Kenya has the lowest cancer cases generally as shown the table 5 below. The annual trends in the cancer incidences have an upward trend over the years which is seen for all the countries but the United States which records a sharp drop between 1995 and the early 2000s, after which the upward trend continues and levels off beyond 2005.

On average;				
Country	Incidences	Mortality	MIR	Prevalence
Algeria	100	70.2	70%	0.5314
Brazil	270	113	42%	1.251
Fiji	160	101.56	63%	0.6301
France	386	144.64	37%	1.62
Kenya	132-	118.92-	90%++	0.3493++
South Korea	241	129.2	54%	1.701
Spain	353	138.44	39%	3.256
Uganda	173	131.96	76%	0.5155
United Sta..	1,211+	147.92+	12%-*-	4.275-*-
Venezuela	259	143.96	56%	0.9484
Total	328	123.98	38%	1.508

+*The United States records the highest annual cancer cases and mortalities on average*

-Kenya has the lowest numbers for both incidences and mortalities on average terms

++*The highest MIR is recorded in Kenya with the lowest annual prevalence rate*

-*- *The United States has the lowest MIR at 12% and the highest 5 year prevalence rate.*

Table 5: The average annual cancer incidences, mortalities, MIR and prevalence by country

The summary statistics for the cancer mortalities for data set show high crude deaths recorded for the United States of America as compared to the other countries. However, this number of crude deaths is way below the annual number of new cases. Kenya records the highest mortality to incident ratios at 0.9 meaning that anyone diagnosed with cancer in Kenya has a 90% chance of succumbing to cancer. This could be explained by the low prevalence rate as earlier reported for Kenya vis a vis that of the other countries. The United States, despite recording the highest crude incidences and mortalities, records the lowest MIR at 0.123. the comparison between the survival likelihood between Kenya and the United States gives over 8 times likelihood of dying in Kenya as a result of cancer compared to a similar case in the US.

4.3 Stationarity tests

The Fisher – Type Test for stationarity shows that the variables are non-stationary at level values, meaning that they are a unit root process. The log of the variables, however, is stationary at varying orders, and the logged variables are adopted due to the ease of interpretation of the results from the regression of such variables as any changes will represent a percentage point change in the dependent variable over time.

4.4 Cointegration tests

To carry out the cointegration test, the Kao test is carried out to determine the long term relationship between the dependent variable and the independent variables. At the resulting p-values of 0.0000 for the Augment Dickey-Fuller test as shown in table 6 below, we strongly reject the null hypothesis that there is no cointegration and adopt the alternative hypothesis that all panels are cointegrated. This means that there is a long term relationship between the dependent and the independent variables.

	Statistic	p-value
Modified Dickey-Fuller t	-0.4404	0.3298
Dickey-Fuller t	-0.8314	0.2029
Augmented Dickey-Fuller t	4.3766	0.0000
Unadjusted modified Dickey-Fuller t	-0.5422	0.2938
Unadjusted Dickey-Fuller t	-0.8950	0.1854

Table 6: Results from the cointegration tests

4.5 The Hausmann test

This test is used to determine the model to use between the fixed effects model and the random-effects model. With the null hypothesis that the random-effects model provides consistent and efficient estimates against the alternative hypothesis that the fixed effects model provides consistent estimates, the null is strongly rejected at 0.0000 p-values represented in table 7 here below, and thus going forward, the fixed effects model is used to estimate the coefficients of interest in the model.

The F-test carried out to test for the joint significance of the variable are jointly significant in explaining the model and hence all the independent variables, that is, the GDP per capita, the percentage of GDP spent on health, the cancer incidences, the five year prevalence rate and the cancer burden can be used to explain the cancer mortalities jointly but not individually.

Hausmann Test				
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
gdpc	0.0000003	-0.0000045	0.0000048	0.0000010
gdpeh	-0.0038721	0.0001890	-0.0040611	0.0002736
prev	0.0116087	0.0095113	0.0020974	.
burden	0.0000000	0.0000000	0.0000000	0.0000000
gdpg	-0.0002344	0.0002085	-0.0004428	.

Table 7: The Hausmann test results

4.6 Fitting the fixed effects model

Regression results						
lmort	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
lgdpc	0.7159	0.0959	7.4700	0.0000	0.5269	0.9049
lgpdeh	-0.1878	0.0397	-4.7300	0.0000	-0.2661	-0.1096
linc	0.6207	0.2035	3.0500	0.0030	0.2196	1.0218
lburden	0.0679	0.0061	11.0600	0.0000	0.0558	0.0800
lgdpg	0.0048	0.0032	1.5000	0.1350	-0.0015	0.0111
1990*	0.2886	0.0639	4.5200	0.0000	0.1627	0.4145
2004*	0.0717	0.0510	1.4100	0.1610	-0.0288	0.1722
2007*	0.0268	0.0490	0.5500	0.5850	-0.0698	0.1234
_cons	-5.9991	1.4161	-4.2400	0.0000	-8.7907	-3.2075
* Years of interest						
F test that all u_i=0: F (9, 210) = 1.70		Prob > F = 0.0000				

Table 8: The results from the regression

The panel model for the variables under examination is outlined as

$$lmort = -5.999 + 0.716lgdpc - 0.188lgdpeh + 0.621linc + 0.068lburden + \varepsilon_{i,t}$$

This result as shown in table 8 above depicts a positive relationship between cancer mortalities and the GDP per capita as well as the GDP growth rate over time. For a percentage point growth in the GDP per capita, the level of cancer mortalities increase by 0.72%, while the investment in the health sector has a negative relationship with cancer mortalities, that is with a one percentage point more investment in the health sector, cancer mortalities reduce by 0.19%.

The number of new cancer cases annually also has a positive relationship with the cancer mortalities, meaning that as the number of those suffering from cancer increases, the likelihood of dying increase by 0.62% for every percentage change in the new cancer cases, with an R – squared of 53% which implies that the variables in the model explain 53% of the cancer mortalities for the sample under study. Similar results are also realized for the model with the dependent variable as the mortality to incident ratios, with the list of the independent variables remains the same except for the cancer incidences.

Chapter 5: Discussions, recommendations and conclusions.

5.1 Introduction

This chapter provides an in-depth discussion of the findings from this research project. The discussions cover all the variables of key interest and the countries with unique or outstanding results vis-à-vis the other countries being studied. The second section of this chapter outline my recommendations based on my findings as regards the management of cancer and the resulting mortalities from it followed finally by the conclusions based on the findings as compared to the existing literature.

5.2 Discussions

5.2.1 The annual cancer incidences, mortalities, prevalence rates and mortality to incident ratios

For the study period as shown in table 5, the United States of America have the highest number of the crude new annual cancer cases per 100,000 individuals, more than thrice of the total new cases for France with the second-highest cases at 386 case per 100,000 individuals. The high number of cancer cases for the United States is also consistent with the high number of cancer deaths that it records in absolute terms, while France still records the second-highest number of deaths over time, with only one more case ahead of Venezuela at 143 deaths per 100,000 persons.

Kenya has the highest cancer mortalities viewed against the other African countries in the study. The resulting comparison as regards the cancer mortalities to incident ratios shows that Kenya is the most affected country out of the sample space with the highest average MIR at 90%. Up until early 2000s, Kenya has had the highest MIR, though with a steady decrease over the years, while the United States has consistently recorded the lowest MIR, meaning that relative to the number of cases of cancer recorded, the United States of America has the lowest cancer mortalities over time, while Kenya has the highest for the countries being studied. South Korea's MIR has been on the rise from the year 2004 from about 0.39 to 0.63 in 2008 at which it has remained relatively constant. This result is consistent with the findings of (Chen, et al., 2017) who found out that the MIR for prostate cancer is higher in less developed countries compared to the highly developed economies.

Despite recording generally low new cancer cases over time, the relatively high cancer deaths in Kenya is more of a concern compared to the other countries. This is because the five-year prevalence rate has also remained at the lowest level of less than one per cent, that is, 0.35%.

This means that there is a 99.65% chance that an individual diagnosed with cancer in Kenya will die before the elapse of five years. The study reveals that countries with high prevalence rates have generally had low MIRs as depicted in table 5above. Largely, these countries with low MIR also have the highest government spending on the health sector as a percentage of the GDP, with the United State's average being at 16.95% followed by France and Spain at 13.58% and 13.50% respectively as a share of the gross domestic product. Venezuela and Kenya that have very low public expenditure on health at the averages of 7.53% and 8.74% respectively tend to have higher MIRs over time throughout the study period. This implies that high MIRs are attributable to the less development in the healthcare sector for these countries.

5.2.2 The economic growth and the cancer mortalities

The output from the fitted panel model reveals a positive relationship between cancer mortalities and the economic growth(herein captured by the GDP per capita). (Granados, 2005) attributed this trend to the massive industrial production which results in change in lifestyle to fit in the prevailing economic conditions. Similar observations were observed six years later by Pritchard and Hickish (2011) who found out that heavily industrialized countries suffer significantly from lifestyle diseases, leading among which is cancer.

In converse, the relationship between cancer and the economic growth, the investment in the health sector, defined in this analysis as the share of the GDP spent on the health sector, has a negative relationship with the annual cancer mortalities. This means that the improvement in the investment in the health sector increase the survival rates of the cancer patients as it helps reduce the number of lives lost annually to cancer, and generally to all other diseases as indicated in the exclusive study by (Pritchard & Hickish, 2011). Subsequent to these studies, (Chen, et al., 2017) also indicated a generally inverse relationship between cancer mortalities and the development of the health sector. The development in the healthcare system is viewed to include the awareness level created within the societies by the various governments about cancer, and it is not only limited to the money put aside for the health sector(Rhum 2000; Chen, et al., 2017). In the long run, the mortalities due to cancer become more expensive for the government to manage in dollar terms compared to what it would have cost to treat the cancer patients (Leal, Fernandez, Sullivan, & Witjes, 2016) and hence the huge DALYs as recorded in the case of Venezuela as depicted in table 4.

5.3 Recommendations

5.3.1 Policy recommendations

Lifestyle management

The reviewed literature from the world health organization reveals that cancer is a lifestyle disease whose death cases can be reduced by between 30% to 50% through the proper management of people's lifestyle (WHO W. , 2018). To accommodate the growing economies and the increasing industrial production, enlightenment should be enhanced more to alert people of the impending danger that results from the changes in the ways of life. Reduction in such factors as cigarette smoking and alcohol consumption leads to higher chances of reducing cancer incidences and crude mortalities.

Frequent screenings and awareness creation

The high MIR has over the years been linked to the late discovery of the cancer cases in the less developed countries as compared to the economies that have higher development levels. Chen et al 2017 pointed out that the more advanced health systems in the more developed countries coupled with the frequent cancer screenings enhance the discovery of the disease at manageable levels while the late discovery is mostly sub-Saharan Africa and the less developed countries result into more deaths relative to the cancer cases reported. Therefore, it is imperative that the concerned bodies put in the required personnel to create awareness about cancer and to increase the frequency with which individuals can access the cancer screening services at affordable prices.

Improved health care system

The findings from the analysis communicate to us the fact that the cancer mortality to incident ratios for countries high up in the world health organization's ranking is lower compared to the less developed countries, which have extremely higher ratios as seen in the case of Kenya with the highest ratio at 90%. The study also reveals that the more the investment in the health sector, the lower the cancer deaths. Therefore, improved investments in the fight of cancer will have a direct negative relationship with the cancer mortalities, thus every increase in the number of investments in the fight on cancer would result into a decrease in the crude cancer mortalities in the long run.

5.3.2 Recommendations for further studies

To make the model more robust, more variables should be included to capture the variations not yet reflected in the model as the model only explains 53% of the cancer mortalities. Such factors to add to the model could include such variables as cancer mortalities and incidences by gender and age group among others.

Other than the prevalence rates and the macroeconomic variables included in this model, further study should be done to determine the factors that result in the high MIRs.

5.4 Conclusions

Business cycles in the economies under study have a procyclical relationship with the cancer mortalities over time, and hence the economic growth of an economy is not necessarily healthy for a country as far as the cancer mortalities are concerned.

Investments in the health sector reduce cancer mortalities over the years. Therefore, improved investments in the fight on cancer mortalities over the years will reduce cancer deaths.

Cancer is a lifestyle disease and the high numbers of the new cancer cases and crude deaths result from the increase in exposure to the risk factors. To reduce the cancer cases, therefore, it is prudent to minimize or completely avoid the aforementioned risk factors.

References

Barro, R. J. (1996). Health and Economic Growth. *Pan American Health Organisation*, 1-45. Retrieved June 26, 2019, from https://s3.amazonaws.com/academia.edu.documents/3949711/sala4750.pdf?response-content-disposition=inline%3B%20filename%3DHealth_and_economic_growth.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A%2F20190626%2Fus-east-1%2Fs3%2Faw

Berrino, F., Angelis, R. D., Sant, M., Rosso, S., Lasota, M. B., Coebergh, J. W., & Santaquilani, M. (2007). Survival for eight major cancers and all cancers combined for European adults diagnosed in 1995–99: results of the EUROCARE-4 study. *The Lancet Oncology*, 773-783. Retrieved June 2019, from https://www.sciencedirect.com/science/article/abs/pii/S1470204507702450

Cantor, S. B. (1994). *Society for Medical Decision Making*, 259-266. Retrieved June 30, 2019, from https://journals.sagepub.com/doi/abs/10.1177/0272989X9401400308

Chan, M. (2010, September 21). *WHO*. Retrieved from WHO: https://www.who.int/dg/speeches/2010/iaea_forum_20100921/en/

Chen, S. L., Wang, S. C., Ho, C. J., Kao, Y. K., Hiseh, T. Y., Chen, W. J., . . . Sung, W. W. (2017). Prostate Cancer Mortality-to-Incidence Ratios are Associated with Cancer Disparities in 35 Countries. *Nature Research: Scientific Reports*, 1-5. Retrieved April 2019, from https://www.nature.com/articles/srep40003.pdf

Coleman, P. M., Forman, D., Bryant, P. H., Butler, J., Rachet, B., Maringe, C., . . . Richards, P. M. (2011). Cancer survival in Australia, Canada, Denmark, Norway, Sweden, and the UK, 1995–2007 (the International Cancer Benchmarking Partnership): an analysis of population-based cancer registry data. *The Lancet*, 127-138. Retrieved June 2019, from https://www.sciencedirect.com/science/article/pii/S0140673610622313

Cutler, D. M., Knaul, F., Lozano, R., Mendez, O., & Beatriz, Z. (2000). Financial Crisis, Health Outcomes and Aging: Mexico in the 1980s and 1990s. *National Bureau of Economic Review*, 279-303.

Ferlay, J., Shin, H. R., Bray, F., Forman, D., Mathers, C., & Parkin, D. M. (2010). Estimates of Worldwide burden of Cancer in 2008: GLOBOCAN 2008. *International Journal of Cancer*, 1-10. Retrieved June 2019, from https://onlinelibrary.wiley.com/doi/full/10.1002/ijc.25516

Ferretti, F. (2008). Economic Growth anc Cancer Incidence. *Munich Personal RePEc Archive*, 1-15. Retrieved June 2019, from https://mpra.ub.uni-muenchen.de/18242/1/Ferretti_F_08_09_Economic_growth_and_Cancer_Incidence.PDF

Gonzalez, F., & Quast, T. (2009). Macroeconomic Changes and Mortality in Mexico. *SHSU Economics & Intl Business Working Paper Series*, 1-11.

Granados, J. A. (2005, July 28). Increasing mortality during the expansions of the US economy, 1900–1996. *International Journal of Epidemiology*, 1194-1202. Retrieved October 29, 2019, from https://academic.oup.com/ije/article/34/6/1194/707366

Greenberg, D., Earle, C., Fang, C.-H., Eldar-Lissai, A., & Neumann, P. J. (2010). When is cancer cost effective? A Systematic Overview of Cost-Utility Analysis in Oncology. *Journal of the National Cancer Institute*, 82-88. Retrieved June 30, 2019

Harding, A. J., & Pritchard, C. (2016). UK and Twenty Comparable Countries GDP-Expenditure-on-Health 1980-2013: The Historic and Continued Low Priority of UK Health-Related Expenditure. *International Journal of Health and Policy Management*, 519-523. Retrieved June 2019, from http://www.ijhpm.com/article_3241.html

Johansen, S. (1988, September). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, 231-254. Retrieved June 26, 2019, from https://www.sciencedirect.com/science/article/pii/0165188988900413

Johansen, S. (1991, November). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, 1551-1580. Retrieved June 26, 2019, from https://www.jstor.org/stable/pdf/2938278.pdf

Johansen, S., & Joselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, 169-210. Retrieved June 26, 2019, from https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1468-0084.1990.mp52002003.x

Leal, J., Fernandez, R. L., Sullivan, R., & Witjes, A. J. (2016). Economic Burden of Bladder Cancer Across the European Union. *European Association of Eurology*, 438-447. Retrieved June 2019, from https://www.ncbi.nlm.nih.gov/pubmed/26508308

Luzzati, T., Parenti, A., & Rughi, T. (2018). Investigating the relationship between cancer and economic development. *Ecological Economics*, 381-396. Retrieved June 2019, from http://www.isecoeco.org/wp-content/uploads/2016/09/Luzzati-and-Rughi.pdf

Polednak, A. P. (2008). Estimating the number of U.S incident cancers attributable to obesity and the impact on the temporal trends in incidence rates for obesity related cancers. *Cancer Detection and Prevention*, 190-199. Retrieved June 30, 2019, from https://www.sciencedirect.com/science/article/pii/S0361090X08001037

Pritchard, C., & Hickish, T. (2011). Comparing cancer mortality and GDP health expenditure in England and Wales with major developed countries from 1979 to 2006. *British Journal of Cancer*, 1788-1794. Retrieved June 4, 2019, from https://www.nature.com/articles/bjc2011393

Ruhm, C. J. (2000). Are Recessions Good For Your Health? *Quarterly Journal of Economics*, 617-650. Retrieved May 2019, from https://libres.uncg.edu/ir/uncg/f/C_Ruhm_Are_2000.pdf

Schmidt, M. I., Duncan, B. B., Gulnar, A. e., Menezes, A. M., Monteiro, C. A., Barreto, S. M., . . . Menzes, P. R. (2011). Chronic non-communicable diseases in Brazil: burden and current challenges. *The Lancet*, 1-21. Retrieved June 2019, from https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(11)60135-9/fulltext

Singh, M. (2015, December 15). *NPR*. Retrieved June 30, 2019, from NPR: https://www.npr.org/sections/goatsandsoda/2015/12/15/459827058/most-of-the-worlds-cancer-cases-are-now-in-developing-countries

Sun, E. C., Jena, A. B., Lakdawalla, D. N., Reyes, C. M., Philipson, T. J., & Goldman, D. P. (2009). An Economic Evaluation of the War on Cancer. *National Bureau of Economic Review*, 1-47.

Swift, R. (2010). Cancer and economic growth in an aging population: estimating the impact for Australia. *Discussion Papers in Economics: Griffith University, Department of*

Accounting, Finance and Economics, 1-29. Retrieved June 2019, from https://ideas.repec.org/p/gri/epaper/economics201001.html

Tandon, A., Murray, C. J., Lauer, J. A., & Evans, D. B. (2013, February 20). MEASURING OVERALL HEALTH SYSTEM PERFORMANCE FOR 191 COUNTRIES. *World Health Organization*, 1-23. Retrieved October 29, 2019, from https://www.who.int/healthinfo/paper30.pdf

WHO. (2018, September 12). *World Health Organisation*. Retrieved from World Health Organisation: https://www.who.int/news-room/fact-sheets/detail/cancer

WHO. (2018, June 1). *World Health Organisation*. Retrieved June 9, 2019, from World Health Organisation.: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

WHO. (2019, June 12). *World Health Organisation*. Retrieved June 13, 2019, from World Health Organisation: http://www.afcrn.org/

WHO, W. (2018). *Latest global cancer data: Cancer burden rises to 18.1 million new cases and 9.6 million cancer deaths in 2018.* Geneva: International Agency for Research on Cancer. Retrieved June 13, 2019, from https://www.who.int/cancer/PRGlobocanFinal.pdf?ua=1

Appendix

Appendix 1

For simplicity, we let

$$y = Mort;\ X_{1,t} = GDPC_{1,t};\ X_{2,t} = GDPEH_{1,t};\ X_{3,t} = Inc_{1,t}\ and\ X_{4,t} = MIR_{1,t}$$

Thus, the system of the equations is defined as,

$$y_{i,t} = \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \ \forall i = years\ over\ the\ study\ period$$

Where each y is the ith observation on the dependent variable y, $\beta_{i,t}$ is the coefficient on the t^{th} regressor x_{it}, and each ε is the ith observation on an unobserved error term ε. There are n observations and k regressors. All n observations in the model can be written as the set of equations;

$$y_1 = \beta_1 x_{11} + \beta_1 x_{12} + \beta_3 x_{13} + \cdots + \beta_k x_{1k} + \varepsilon_1$$

$$y_2 = \beta_1 x_{21} + \beta_1 x_{22} + \beta_3 x_{23} + \cdots + \beta_k x_{2k} + \varepsilon_2$$

$$\vdots$$

$$y_n = \beta_1 x_{n1} + \beta_1 x_{n2} + \beta_3 x_{n3} + \cdots + \beta_k x_{nk} + \varepsilon_n$$

This system is then re-expressed succinctly using matrix notation as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1k} \\ x_{21} & x_{22} & \cdots & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

Where y and u are n × 1 column vectors, β is a k × 1 column vector and X is an n × k matrix, each column corresponding to a different regressor. By convention, where the regression contains an intercept, this will be the first column of the matrix X will consist of a vector of ones, corresponding to an intercept in the model. β1 will then represent the coefficient on this intercept. The error term ε is a vector of random variables. It has an associated mean vector given by

$$E(\varepsilon) = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

Where E represents the expectations operator. Note that, because E is a linear operator, it can be taken inside matrices.

Appendix 2

(Barro, 1996) proposed that the output of goods (Y) depends on physical capital (K), labor hours (L) and two forms of human capital, worker schooling and education (S) and the state of worker health, or health capital (H). Assuming the Cobb-Douglas form for simplicity

$$Y = A.K^{\delta}S^{\lambda}H^{\gamma}(Le^{xt})^{1-\gamma-\lambda-\delta}$$

Where A is the exogenous baseline level of technology, x is the exogenous rate of labor-augmenting technological progress, $\delta > 0, \lambda > 0, \gamma > 0$, and $0 < \delta + \lambda + \gamma < 1$.

Dividing through by Le^{xt} gives

$$y = A.k^{\delta}s^{\lambda}h^{\gamma}$$

Where *y, k, s* and *h* are quantities per unit of effective labor.

A key feature of Barro's model is that it allows for two-way causation between health and economic growth. The model assumes that a household maximizes utility by dividing output (y) between consumption goods and investment in the three kinds of capital, k, s and h. An increase in output (y) increases health capital (h) because it increases the ability to invest, for example, in the purchase of medical treatment or in preventative measures such as exercise and nutrition.

At the same time, better health can increase output both directly and indirectly. An improvement in the health of workers (h) directly raises output for any given level of physical capital (k) and education (s). In addition, an improvement in health indirectly increases output because a longer life with less working time lost to illness 4 raises the rate of return on past investments in human capital, that is, it reduces the depreciation rate of both forms of human capital. Consequently, better health increases the incentive for further investments in both education and health. These indirect effects have important implications, particularly for higher-income countries. They suggest firstly that the economic gains from improving health by reducing death and illness from non-communicable diseases such as cancer and cardiovascular disease may be even greater than the gains from the control of infectious diseases that improved health in the past. Secondly, if the rates of return on investment in human capital increase as the economy grows, the ratios of education and health to physical capital and output should also increase, that is, education and health should become more important as income rises. The model for econometric estimation is based on the log form of the equation

$$lny_t = \beta_0 + \beta_1 lnk_t + \beta_2 lns_t + \beta_3 lnhc_t + \varepsilon_t$$

Where hc_t represents the improvements in health capital from a reduction in death and illness caused by cancer, and $\varepsilon_t$is an independent and identically distributed error term.

The long-run equilibrium relationship to which all the variables converge over time is given by the cointegrating relationship between the levels of the variables, as in equations. Each variable may temporarily diverge from the long-run relationship, but some proportion of the disequilibrium error will be corrected each period. In the short run, each variable may also be influenced by its own lagged differences and by the lagged differences of the other variables.

Formally, the system of equations estimated in the Johansen method is described as a vector error correction model (VECM) derived from a standard unrestricted vector autoregressive model (VAR) of lag length k. The VAR system of equations is algebraically re-arranged into a VECM, written as

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \cdots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mu + \Psi D_t + \varepsilon_t$$

Where Z_t is the vector of variables, μ is a vector of constants, and D_t a vector of other deterministic variables such as a time trend. The first group of terms ΔZ_{t-k+i} represents the short-run lagged effects of differences in the variables in *z* on each variable in the system. ΠZ_{t-1} is the error correction term (ECT) that represents the long-run cointegrating relationships between the levels of the variables in z. If there are n variables in the vector of variables Z_t there are (n – 1) potential cointegrating relationships between them. The number of cointegrating relationships is determined by the rank (r) of the matrix of long-run coefficients Π.

If a cointegrating relationship exists between the variables, Π can be factorized into $\Pi = \alpha\beta'$, where β' is the coefficients on the individual variables in the long-run cointegrating relationship and α is the coefficient on the ECT itself. Thus, if there is one cointegrating relationship between the five variables, the ECT in each of the five equations of the system can be represented by

$$ECT_n = \propto_n (\beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3 + \beta_4 z_4 + \beta_5 z_5)$$

Where n = 1, ..., 5. When the system is in long-run equilibrium, the long run or cointegrating vector in the ECT will be equal to zero:

$$\beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3 + \beta_4 z_4 + \beta_5 z_5 = 0$$

When the system is not in long-run equilibrium, the ECT will be non-zero and will measure the distance the system is away from equilibrium. The coefficient on the ECT$\propto_n$, represents the proportion of the disequilibrium error for variable n that is corrected each period, and so provides information on the speed of adjustment of each variable to the long-run equilibrium relationship.

If $\propto_n$ is not significantly different from zero in one of the equations of the system, then the long-run cointegrating relationship represented by the ECT does not have a significant influence on the dependent variable in that equation. This variable can then be said to be weakly exogenous for the long-run relationship in the Granger causality sense Johansen(1988; 1991) and Johansen and Joselius(1990), Johansen uses a canonical correlation technique, solved by calculating eigenvalues (λi), to provide a set of eigenvectors that form the maximum likelihood estimate of the long-run coefficients (β). A likelihood ratio (LR) statistic, the T statistic, is used to test the significance of the eigenvalues and thus to determine the maximum number of statistically significant vectors (r) within β.

Lag lengths for the Johansen estimation are determined by LR tests of paired comparisons of different lag lengths in the original VAR system. The choice was confirmed by Lagrange-Multiplier (LM) tests of the residuals which showed that the included lags were sufficient to avoid serial correlation in all systems. Doornik-Hansen tests for normality indicate that the residuals in all systems are free from skewness, although there is evidence of non-normality in some equations due to kurtosis. This should not cause problems for the estimates because, as noted by Johansen (1995), the "*asymptotic properties of the methods only depend on the i.i.d. assumption of the errors*".