The impact of crude oil-led economic growth on health and its determinants

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Abstract

Background and aims: There is a close connection between the demographic and epidemiological transitions which many countries undergo. Shifts in population structure and population health go hand in hand. In theory, increased economic capacity in a country generates resources for development of infrastructure and basic amenities and, in turn, health improvement. Countries that have oil resources to exploit, might expect the economic benefits to drive health improvement. However, limited evidence suggests that crude oil and other natural resources may not guarantee population health benefits. The thesis sought evidence for a pathway from oil resources to population health improvement in two linked quantitative studies. The first study was an international comparison. The second focused on Nigeria as a case study country with crude oil abundance, yet relatively poor economic performance.

Methods: A theoretical model was developed to describe how oil resources could drive social, economic, and infrastructure transition, and ultimately health improvement. In the first phase study, evidence for this relationship between crude oil resources and population health was assessed globally via panel models and the relationship between oil-led economic growth and population health was assessed via cross-sectional models. Data were drawn from the World Health Organisation and United States energy information administration (n = 156 countries) and were analysed using structural equation modelling. The panel models spanned from 2000 to 2015, at 5-year intervals while the cross-sectional models explored the 2000-2015 growth in oil economy on health and its determinants in 2015. In the second phase, relationships between oil-led economic growth at state-level and household-level with health and its determinants were explored in Nigeria (n=38,522 households). Multilevel modelling was used to allow for the nested structure of the data.

Results: The panel analysis in the phase one study showed that the relationship between all the markers for crude oil resources and health/determinants were not statistically significant, except for crude oil export and access to basic sanitary facility (Coefficient = -0.01, $p<0.05$), over the study period. For oil-based income (oil-rent contribution to GDP), there was no significant association with access to basic drinking water sources (Coefficient = -0.01; $p>0.05$) or access to basic sanitary facilities (Coefficient = 0.01; $p>0.05$), over the study period. There was also no significant association between oil-based income and health over the study period: for infant mortality (Coefficient = 0.05; $p>0.05$) and for life expectancy (Coefficient = -0.01; $p>0.05$). Income group was not significant in these relationships. However, the cross-sectional analysis in the phase one study showed that the oil-rent contribution to GDP measure of oil-led economic growth was directly associated with health determinants. For example, there was a significant positive association with access to drinking water sources in low-income (Coefficient = 0.48; $p<0.05$) and high-income countries (Coefficient = 0.53; $p<0.05$). There was also a significant positive association with access to sanitary facilities in low-income countries (Coefficient = 0.38; $p<0.05$) but this was not found in high-income countries. Results were inconsistent between markers of health and relationships were sensitive to the measure of oil-led economic growth. This study also found that crude oil export measure of oil-led economic growth was directly associated with some markers of population health: with infant mortality (Coefficient = -0.10; $p<0.05$) in high-income countries and with life expectancy (Coefficient = -0.20; $p<0.05$) for low-income countries.

There was no significant association between oil-led economic growth and household deaths in Nigeria (Coefficient = -0.0001; $p>0.05$). However, oil-led economic growth did seem to be related to the type of household sanitary facilities available, indicating a possible role in improving infrastructure related to health. For example, greater oil-led economic growth was associated with the likelihood of households having flush toilet relative to no facility (Coefficient = 0.005; $p<0.05$). Yet, there was no significant association with other markers such as water supply for example. Overall, the results showed very weak support for a well-trodden pathway from oil to improved population health, via improved infrastructure. If anything, they supported the pathway in already higher income countries only.

Conclusion: Within the necessary caveats of a very methodologically challenging study, the conclusion of these analyses must be that having oil wealth does not readily translate to population health improvement. Measurement of all steps on the pathway was difficult, but the results hint that the mediating effects of institutions are important influences. Channelling crude oil wealth into health improvement requires strong institutions as seen with high-income countries. Where these are absent, governments (particularly in low-income countries) seem to have failed to convert their oil revenues to population health benefits. The implications are that appropriate models of managing oil revenue should be established. Without strong governance, the social, economic and environmental harms from crude oil activities may actually outweigh the benefits. Since governance and priority setting determines the amount of oil revenue allocated for health improvement in a country, the potential remains for oil to be a positive resource for population health.

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Published Conference Proceedings and Presentations

Oral presentation

Okon, M. E. (2015). Do the health benefits of oil led economic development outweigh the potential health harms from environmental pollution in Nigeria? Institute of Health and Wellbeing Knowledge Exchange Students Conference: University of Glasgow, Glasgow.

Dedication

This thesis is dedicated to my late parents HRH Etinyin Emmanuel Edet Okon and Josephine Emmanuel Okon. Thanks to both of you, I understood what platform a good education will give to my future. Your unwavering love and believe in me, built a great part of my life, making me who I am today. I remember how you told me every single day that I can be whatever I choose to be, I am glad I took this step.

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Above all, I give thanks to the Almighty God for His favour and grace, which gave me hope and strengthened me in the face of challenges. I return all the glory to you Jehovah.

Author’s Declaration

I hereby declare that the contents of this thesis are my own work and I have indicated and appropriately referenced where the work of others has been used. It has not been submitted in any form for another degree at the University of Glasgow or any other institution.

Marian Emmanuel Okon

October 2020

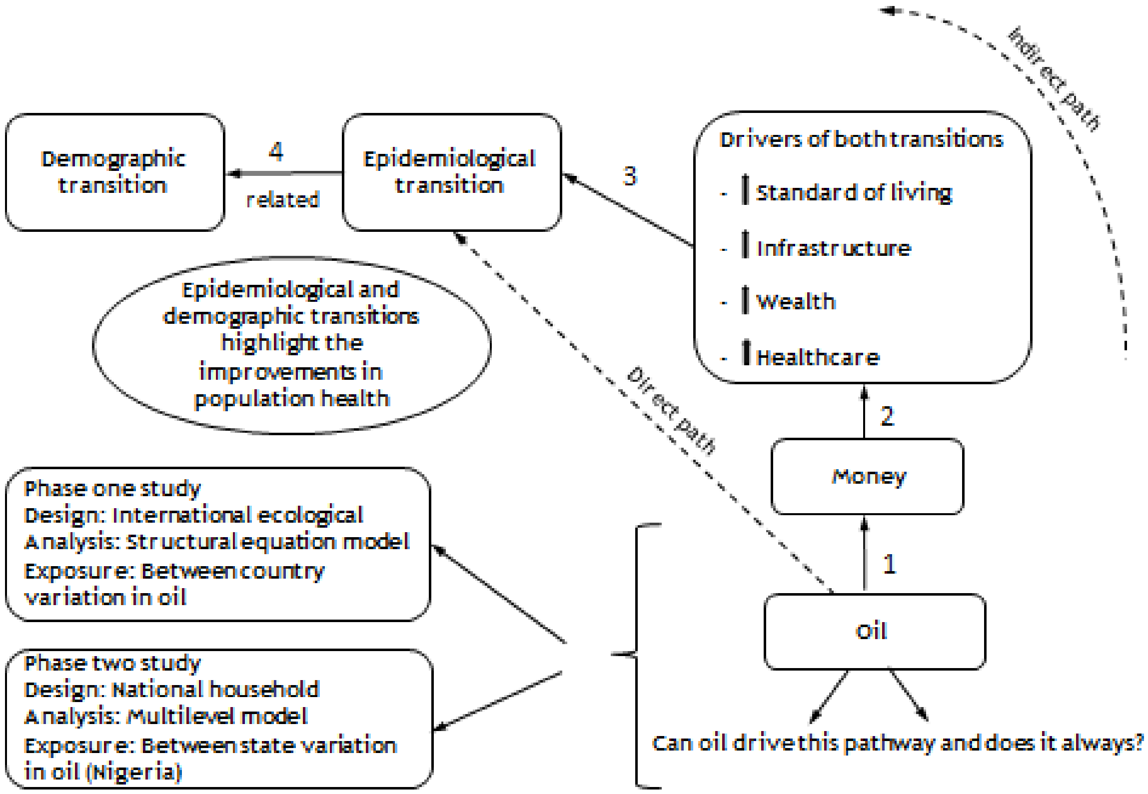
Definitions/Abbreviations

AIC	Akaike information criterion
BIC	Bayesian information criterion
CASP	Critical Appraisal Skills Program
CD	Coefficient of Determination
DIC	Deviance Information Criterion
EIA	Energy information Administration
GDP	Gross Domestic Product
ICC	Intraclass Correlation
MCMC	Markov chain Monte Carlo
MENA	Middle East and North African Countries
MLMV	Maximum Likelihood Estimation Technique with Missing Values
NBS	National Bureau of Statistics (Nigeria)
NDHS	Nigerian Demographic and Health Survey
SEM	Structural Equation Modelling
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VCE	Variance–Covariance Matrix of the Estimators
WHO	World Health Organisation

1. Introduction

This thesis stems from the question: have nations with crude oil resources been able to use their resources to improve their country's economy and health outcomes? This is indicative of how crude oil resources drive demographic transition and the connected epidemiological transition. In general, as a country gets richer, infrastructure and basic amenities are provided, and this development improves population health. But how do oil resources affect this process? Therefore, this thesis looks at the possibilities that crude oil economy[1] influences health, highlighting the role of demographic and epidemiological transition and social determinants of health. This hypothesised relationship is demonstrated in this thesis map (figure 1.1).

Figure 1.1: Thesis Map



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[1] Crude oil economy has different meanings in the literature, but it is used in this thesis to refer to an economy where crude oil resource is a significant contributor to the gross domestic product of the nation (Market Business News, 2018a).

This thesis map, starting in the lower right-hand corner, shows that in theory oil resources generate money, which in turn influences the drivers of epidemiological and demographic transitions. Figure 1.1 suggests that oil resources generate money and this money influences the drivers of transition. These drivers are measured by indicators of economic growth. This research seeks to explore the relationship between crude oil resources and population health[2], then the relationship between oil-led economic growth and population health through the influences of several drivers including employment, education and infrastructure. This will be conducted using a twin-track approach whereby datasets from different geographical scales are used to model the relationships between oil-led economic growth and population health. First, there is an international comparative study of one hundred and fifty six countries, exploring this relationship. The countries include a mix of developed and developing countries across the world, with and without crude oil. Then, a case study of Nigeria is conducted, primarily because it makes an appropriate case considering how it has abundant crude oil resources and is currently undergoing demographic transition. Also, as a Nigerian, I am particularly interested in looking at the hypothesised relationship in Nigeria, to make a case for my country. Every state within Nigeria has a different relationship to oil production and a different contribution of oil revenue to their state income. This makes for a natural experiment-populations within the same country, but potentially exposed to differing levels of influence from oil.

This chapter will address steps 2, 3 and 4 of the thesis map. It will describe the concept of demographic and epidemiological transition. It will consider the concepts and theories of both transitions together and explore the different models developed by researchers. This will give an understanding of the influences on economic development and population health; how demographic transition can be beneficial to the economy and how the changes in the patterns of disease and the causes of death is related to population health. The chapter then discusses the concepts of natural resource curse, describes Nigeria’s crude oil economy and discusses the effects of crude oil

[2] Population health describes the health outcomes and the distribution of these outcomes within a group of people (Kindig and Stoddart, 2003). This also encompasses the pattern of the determinants of the health outcomes across the life course and the policies as well as the interventions that influence these determinants.

production on population health. Finally, a summary of the thesis structure will be outlined based on the two studies in this thesis.

1.1. Concept of natural resource curse

This refers to the paradox that in the modern era, natural resource endowment often seems to be detrimental to a nation's development (Auty, 2002). It is expected that a nation's endowment with natural resources will spur economic growth as a result of the rents generated from these resources, however, this is not always the case. Natural resource wealth has been reported to have varying effects on economic growth. In developed nations such as the United States and Australia, natural resources have contributed to economic growth. Historically, the successes of these countries were seen in the intense trade/manufacturing exports of natural resources such as minerals, alongside their political decisions and institutions (Wright, 1990; Wright and Czelusta, 2004; McLean, 2004). Nowadays, natural resources play a minor role on their economy. However, research notes that most developing countries richly endowed with natural resources such as crude oil have tended to have slower economic growth than those that are not resource-rich (Sachs and Warner, 1999; Gylfason et al., 1999; Gylfason, 2001; Sachs and Warner, 2001; Auty, 2002; Gylfason and Zoega, 2006). Similarly, Arezki et al. (2017) further used big oil discoveries to identify the effect of resource windfall at a cross-country level and their results showed that the resource discovery had an initial negative effect on employment, GDP and national investment.

Karl (2004) illustrated how oil resource curse[3] can occur in several ways: i) through "Dutch disease" where oil windfalls pushes up the real exchange rate of the currency in a country, rendering exports in other sectors of the economy noncompetitive, thereby hindering diversification of the economy and reinforcing oil dependence; ii) through "oil price fall and volatility" which hinders economic development, making oil economies more likely to experience economic shocks, with resultant negative effect on management of oil revenues, investment and income distribution in an economy; iii) through "rentier state" where a country lives from the external profits of oil instead of the excess

[3] Oil resource curse describes the negative growth outcome associated with a country's huge dependence on crude oil (Karl, 2004).

production from its people. Such countries are inclined to policy failure, rent-seeking behaviours and activities that are not productive to the economy. Countries whose economies are heavily dependent on the trade of their natural resources are subjected to resource price volatility and consequently economic instability (Cavalcanti et al., 2015). They demonstrated that price volatility of natural resources rather than resource abundance drives resource curse. For example, as the price of commodities such as crude oil rose from the year 2000, the rate of economic development in oil-rich developing nations did speed up but only to similar levels seen in resource-poor nations (International Monetary Fund, 2012). Therefore, the term resource curse captures the weak economic performance of countries like Nigeria in the face of resource abundance (Auty, 2002).

Nigeria is one of the largest crude oil producers in the world with about 2.4 million barrels per day but has been classified by the World Bank as a lower-middle income economy with a gross national income per capita of US$ 2,970 in the year 2014 (World Bank, 2015b; U.S. Department of Energy, 2015). This pattern is not unique to Nigeria. It is seen in many other developing nations with large reserve of natural resources (such as Yemen, India, Indonesia and Egypt).

The varying routes to economic success provide interesting evidence that natural resources are not a pre-requisite for economic, epidemiological and ultimately demographic transition. It is noteworthy that rich countries, including Switzerland, Japan and Hong Kong for example, do not owe their economic wealth to natural resources (Gylfason and Zoega, 2006). To also buttress this, Gylfason (2001) demonstrated that some nations in Asia like Singapore that have shortage of natural resources do better economically than resource-rich ones like Indonesia. However, as countries such as Norway and Botswana show, natural resource wealth can unlock prosperity (Gylfason and Zoega, 2006).

1.2. Concepts of demographic and epidemiological transition

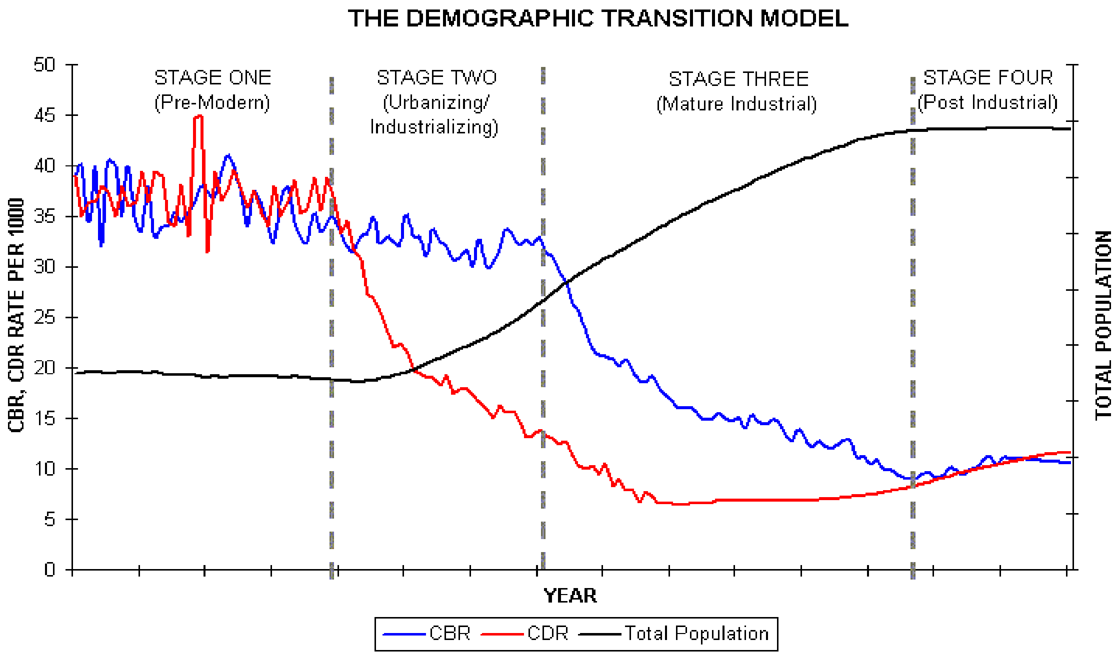
This thesis map hypothesised that crude oil resources are related to changes in demography and population health. In order to understand the changes in the two concepts, this section will describe how the demography of a country changes as well as the changes in population health.

1.2.1. The concept of demographic transition

A change in the population structure of a nation is a key driver of economic development. This change leads to a transformation in the nation's demography and is termed demographic transition. Demographic transition theory was originally described by Thompson (1929) and he elucidated the different patterns of death and fertility, following the First World War in countries such as Italy, Spain, Australia, Germany, Canada, Russia, Japan, India, England and Wales. He described demographic transition using a classification of nations into three groups based on their combination of mortality and fertility rates, and in turn, their rates of population growth.

This theory was further developed by Davis (1945) and Notestein (1945). However, Notestein (1945) described the transition as a shift from a rural agricultural society with high birth and death rates to an urban industrialised society with low birth and death rates. Davis (1945) enhanced the theory by adding the influence of biological and sociological factors on the changes in the fertility and mortality patterns, which in turn affects population growth. This change began with a gradual decline in mortality and was associated with an abundant, consistent, and diverse food supply partly due to improvements in agriculture and to improved transportation system which resulted in advancement of commercial agriculture. Consequently, this produced a sizable decline in famine, malnutrition and susceptibility to disease, bringing about a substantial decline in mortality. Afterwards, improved sanitation and medical advances resulted in disease prevention. This process was slow but had a substantial effect on mortality decline. The reduction in mortality was also influenced by social changes as this described people's behaviour and their interaction with their environment (Davis, 1945). Subsequently, Gage (2005) drew upon these ideas and proposed a transition in four stages, with respect to fertility and mortality processes (Figure 1.2).

Figure 1.2: Four stage demographic transition model



Source: Montgomery (2009). CBR and CDR represent crude birth rate and crude death rate respectively.

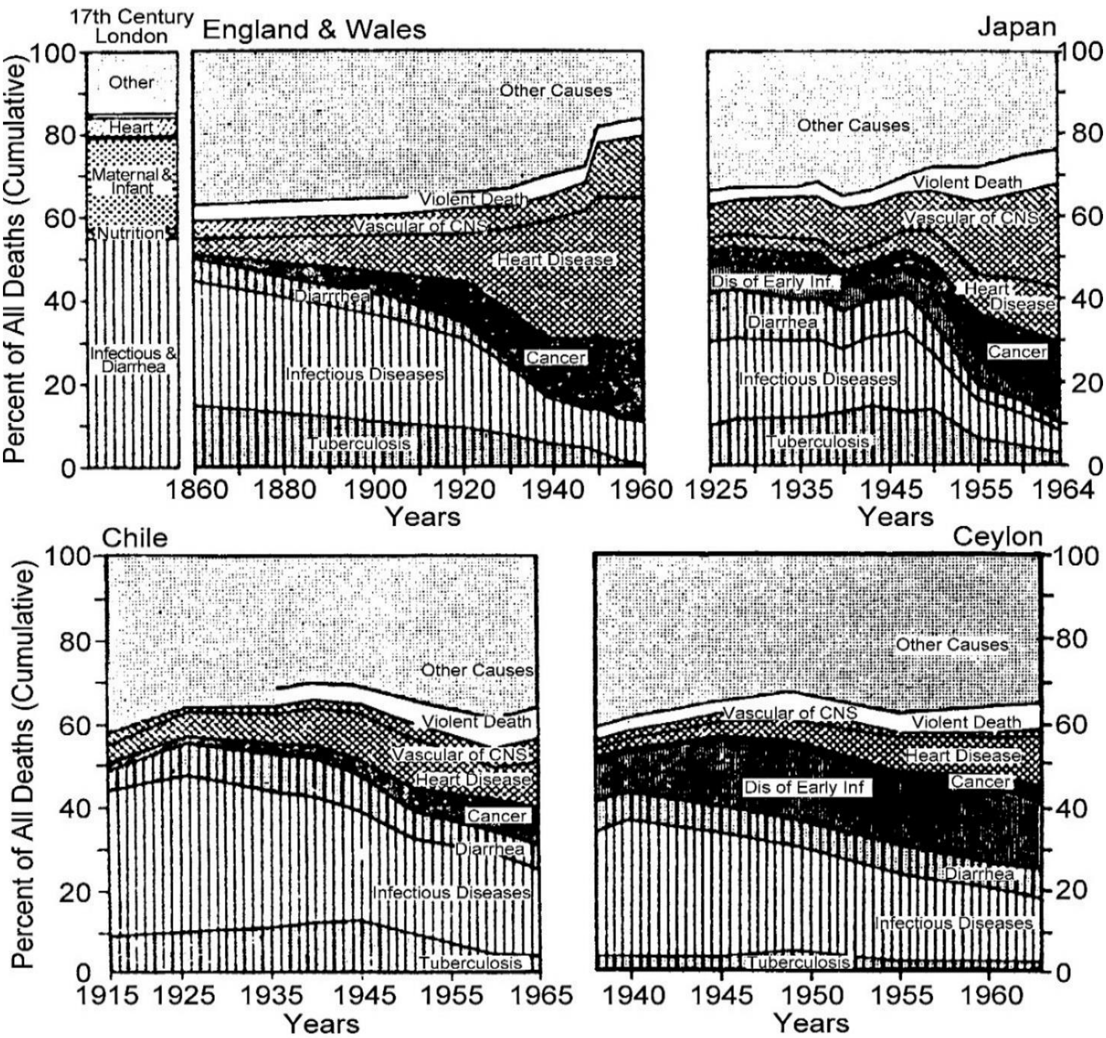
At stage one, a nation experiences very high fertility and death rates, resulting in little increase in the population size (Gage, 2005). In the second stage, there is a rapid rise in population size due to the decrease in death rates whilst fertility rates remain high. The third stage is characterised by low death rates and declining birth rates leading to a reduced population growth, with the fourth stage resulting in no change in the population size as death and fertility rates become low (Figure 1.2).

Overall, the key components of the transition are the changes in mortality and fertility rates, from long- term high rates to sustained low rates (Defo, 2014). In the course of this transition, mortality declines initiate the process before fertility rates begin to decrease with a gap of about 50 years or more between both declines. The decline in fertility rates are considered as an adjustment in response to decline in mortality rates. The causes of such changes in mortality and fertility rates are of great significance in determining whether and when a country experiences this transition. The literature suggests that they are largely explained by reduction of epidemics through medical advances, decline in infant and child mortality, reduction of famine and wars as well as improvement of living standards (Defo, 2014; Grigoriev et al., 2014; Yount et al., 2014). This shift in population health, which initiate demographic transition is described and explained by a related concept called the epidemiological transition.

1.2.2. The Concept of epidemiological transition

A shift in the demography of a country accompanies epidemiological transition. Epidemiological transition is described as a shift in the fundamental cause of death from acute infectious to chronic degenerative diseases as illustrated in Figure 1.3[4] (Omran, 1971).

Figure 1.3: Trends in the cause of death



Source: Omran (1971)

[4] Figure 1.3 is the best version of the graphs and a description of this figure is on the next page.

This figure shows a graph of the cumulative cause of death in both males and females, starting from England and Wales in the top left to Japan, then Chile and Ceylon in the bottom right. The causes of death listed from the top to the bottom of each graph are other causes, violent death, vascular disease of central nervous system, heart disease, cancer, diarrhea, infectious diseases and tuberculosis.

The epidemiological transition theory was originally proposed by Omran (1971) to provide an understanding of human evolution, transmission and patterns of disease. Abdel Omran's theory attempted to account for the healthcare improvements made in industrialized nations from the 18th century. Accordingly, Omran suggested that all countries experienced three sequential eras in the course of modernisation, namely: “the age of pestilence and famine” featuring high and vacillating mortality rates due to increase in microbial infections, dietary deficiencies, communicable and endemic diseases, together with average life expectancy fluctuating between 20 and 40 years; “the age of receding pandemics”, during which life expectancy increases substantially from 30 to approximately 50 years and there is an abrupt decrease in mortality as the rates of epidemics decline, together with a shift from infections to degenerative diseases; and “the age of degenerative and man-made diseases” which is characterised by a reduced rate of mortality decline, with considerable decline in infections and rise in degenerative, man-made diseases as well as an average life expectancy exceeding 50 years. In this latter era, fertility plays a fundamental role in population growth. Omran suggested that these changes occurred over two centuries in various countries including; western European countries, Japan and developing nations.

1.2.2.1. Limitations of Omran’s epidemiological transition theory

Omran’s theory has been controversial since its inception. Several contradictions in the theory have created a need for researchers to modify it. These modifications were designed to remove an exclusive focus on fundamental environmental factors such as climate and eco-biological factors to include broader cultural (May, 1960), political (Turshen, 1977), and social factors (Adler et al., 1994; Link and Phelan, 1995). This accommodated a wider consideration of the causes of disease and connected the theory to contemporary thinking about population health as a socio-ecological system. The social conditions encompass the relationships a person has with others and the conditions include intimate associations, socioeconomic class, ethnicity, gender, stressful social life events such as job loss as well as social support. Amongst these factors, perhaps the most important is the well-established link between health outcomes and socioeconomic situation (Adler et al., 1994; Link and Phelan, 1995). Lower socioeconomic situation is linked to lower life expectancy, greater mortality rates and greater risk of developing several diseases.

Researchers have also documented other limitations in the Omran theory. They critiqued his consideration of the effect of poverty on disease risk, death, patterns and pace of transition, which do not necessarily apply to all geographic regions or historical era (Mackenbach,1994; Popkin, 2001; Mckeown, 2009). Another critique of Omran's theory lies on the continuously changing definitions and concepts of health and disease over time, which is based on new information and research. Likewise, the importance of several social determinants e.g. poverty and income inequality, on the patterns of mortality and disease has been discussed (Wilkinson, 1994; Caldwell, 2001; Pearson, 2003; Lynch et al, 2004; Armelagos et al., 2005; Wilkinson and Pickett, 2006; Mckeown, 2009; Alsan et al., 2011). In summary, Omran failed to consider inequalities in transition rate within the population and the overall impact of inequalities on population health.

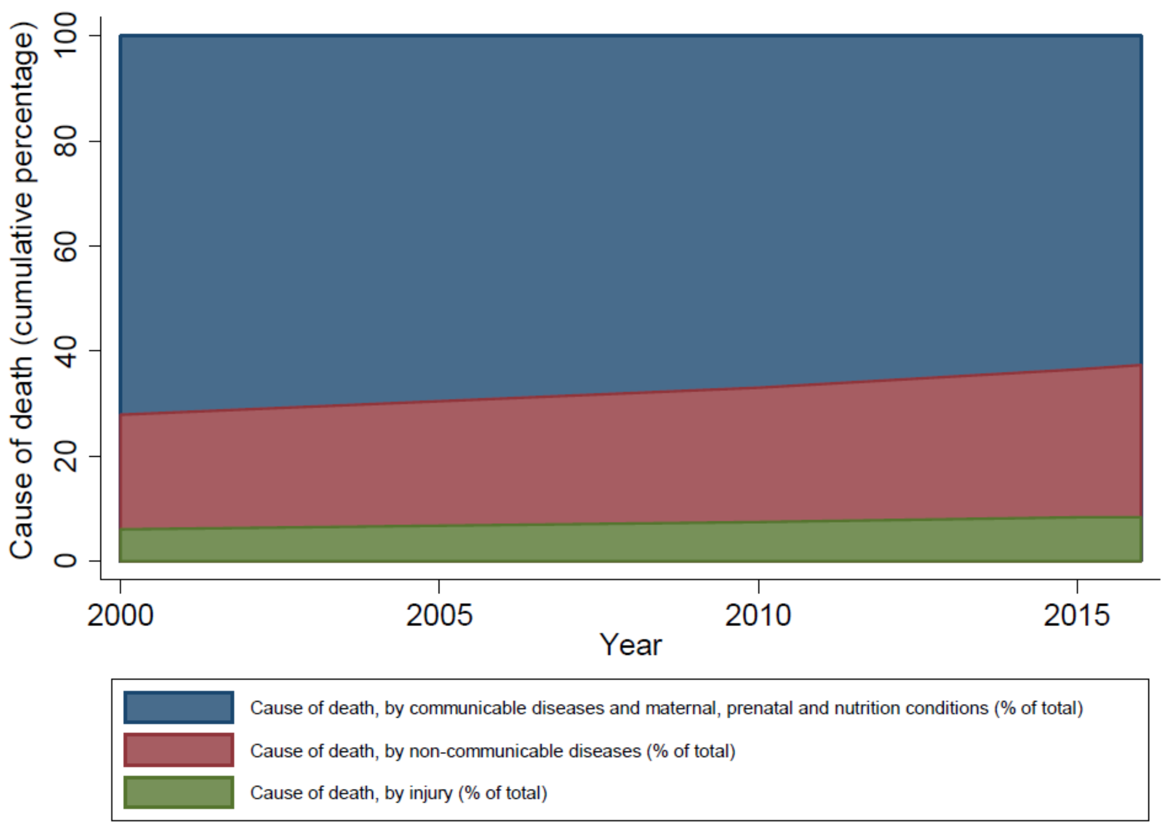
Whilst the epidemiological transition is a useful framework to consider population health over time and provides obvious places for the influence of the huge financial resources that crude oil might bring to a nation, it is more complex than described by Omran. His concept cannot be directly applied to the experiences of all countries. There is a need to account for the varying pace of transition occurring in different countries.

1.3. Demographic and epidemiological transition in Nigeria

The demographic trend in Nigeria is similar to that of the countries described in the contemporary model of Omran's epidemiological transition theory. In this model, there is a reduction in the mortality rates while fertility rates remain high (Omran, 1971). The consequences of these changes are apparent in the rapid population growth of Nigeria (World Bank, 2018a). A widening of the gap between birth and death rates, resulted in a population explosion from about 45 million in 1960 to about 172 million in 2013 and then 186 million in 2016.

Nigeria is also slowly passing through an epidemiological transition. There has been a gradual shift in the cause of death from infectious disease to degenerative diseases (World Bank, 2015a). Nigeria recorded a decline in the mortality rates due to infectious disease (figure 1.4) from 72.1% in 2000 to 67.0% in 2010 and 62.7% in 2016 and a rise in deaths attributed to non-infectious diseases from 21.9% in 2000 to 25.6% in 2010 and 29.0% in 2016 (World Bank, 2018a). Figure 1.4 shows the cumulative percentage of cause of deaths in Nigeria from the year 2000 to 2016. The data for Nigeria was only available for this duration in the World Bank database.

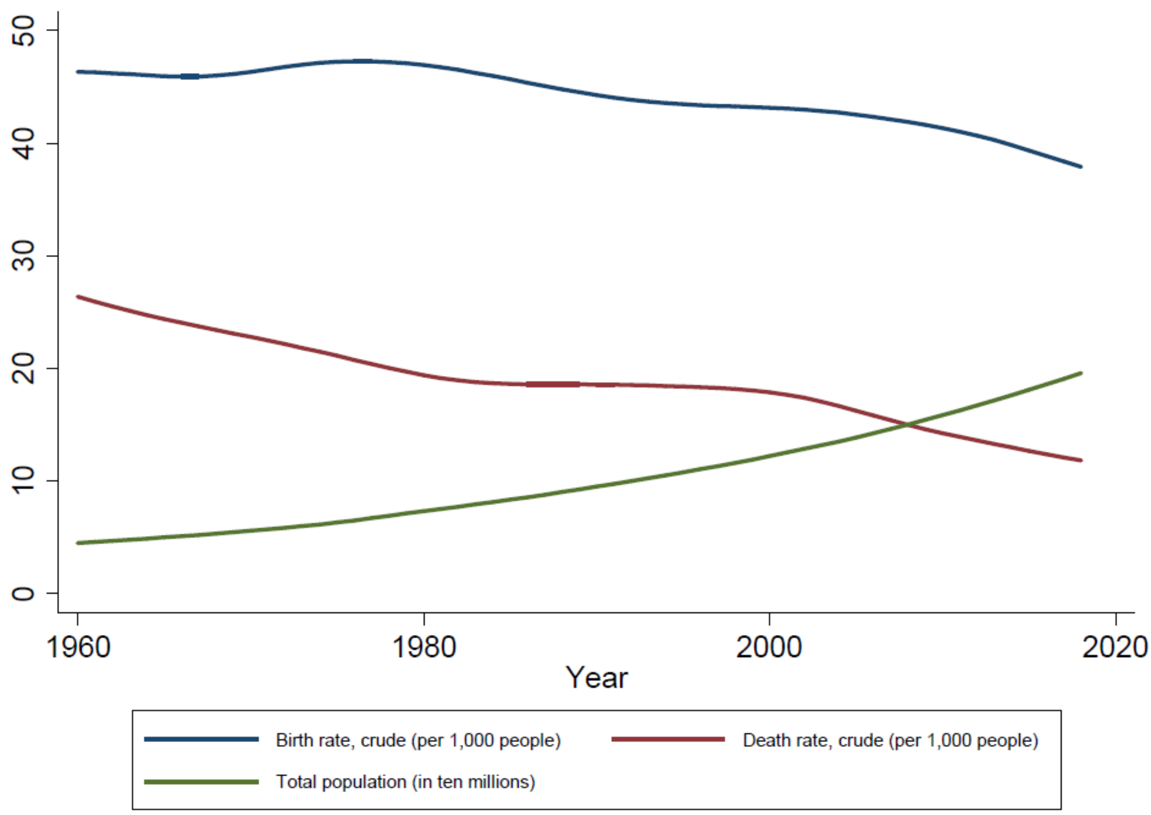
Figure 1.4: Epidemiological transition in Nigeria (2000 - 2016)



Data source: The World Bank (2018a)

Currently, Nigeria is in stage two of demographic transition, with a rapid increase in population size due to the decrease in birth and death rates, though birth rate remains high (Figure 1.5). There was a fall in mortality rates in Nigeria from 26.4 deaths/1000 people in 1960 to 19.4 deaths/1000 people in 1980, as huge investments were made in the health sector (Orubuloye, 1995; World Bank, 2018a). However, the impact of this investment was diminished as the resources of the country declined in the face of economic crisis due both to political unrest and a crash in export earnings from crude oil. The country actually recorded *elevated* mortality rates of 17.9 deaths/1000 people by the year 2000 and by the year 2018, mortality rates had declined again to 11.9 deaths/1000 people (World Bank, 2018a).

Figure 1.5: Demographic transition in Nigeria (1960 – 2018)



Data source: The World Bank (2018a)

Whilst Nigeria experienced these fluctuating, but ultimately declining, mortality rates, changes in the birth rates in Nigeria were not very substantial. Birth rates fluctuated from 46.3 births/ 1000 women in 1960 to 46.9 births/ 1000 women in 1980, then to 43.2 and 37.9 births/ 1000 women in 2000 and 2018 respectively (World Bank, 2018a). The birth rate is still high in Nigeria. This perhaps stems from several sociocultural factors including low rates of contraception, early marriage, low levels of education in women, use of children and youth labour for family economic yields, low child survival as well as high infant and child mortality (Orubuloye, 1995).

It is important to note that regional disparity in fertility rates exists in the country. These rates are higher, for example, in the northern region than in the southern region of Nigeria perhaps due to factors such as low levels of education in women and early marriage (National Population Commission, 2014).

It is also noteworthy that the timing and magnitude of demographic dividend[5] in Nigeria varies geographically within the nation (World Economic Forum, 2014). The southern regions (South-South, South-West and South -East) are currently experiencing a demographic transition with a slow population growth and lower dependency ratio[6] (when compared with the northern regions: North-West, North-East, and North-Central), thus creating a higher per capita income growth (World Economic Forum, 2014).

1.4. The consequences of crude oil activity on health

Crude oil activity such as exploration, extraction and refining are invasive and can have detrimental impacts on the environment, socioeconomic development and population health (Epstein and Selber, 2002). These impacts of crude oil activity on health and the environment include loss of biodiversity, pollution of air, land and water bodies, as well as a range of health complications such as skin diseases, pulmonary conditions and several forms of cancers due to exposure to benzene, arsenic etc.

[5] Demographic dividend refers to cycles of economic growth that occur as a nation move through demographic transition, from high fertility and death rates to a low fertility and death rates, resulting in an increase in the size of the working age population (Bloom et al., 2007).

[6] Dependency ratio is the ratio of the dependent population (proportion of the population that are usually not part of the labour force) to the economically active or working age population (Harwood et al., 2004).

However, the direct impacts of oil production on health are not fixed and inevitable. Flaring natural gas from crude oil extraction, for example, pollutes the environment with smoke and soot; as well as leading to the production of acid rain (Moffat and Linden, 1995), but the degree to which flaring occurs varies markedly. The percentage of natural gas flared from crude oil extraction in Nigeria is very high (76%) compared to that of several successful oil producing nations (Iran 19%; Mexico 5%; Algeria 4%; U.S. A. 0.6%).

Also, crude oil naturally leaks into the environment and this leakage accounts for about 50% of the crude oil that annually gets into the ocean (Kvenvolden and Cooper, 2003). Similarly, the transportation of crude oil from the point of extraction to designated refining points as well as the distribution of distilled products creates an avenue for accidents to occur. This leads to oil spillage on land or in water bodies.

The effect of this spillage on the living organisms in the affected environment includes death from ingestion of crude oil, coating of the external surfaces of aquatic animals which can cause drowning, destruction of vegetation as oil prevents the exchange of gases between plants and the atmosphere, development of cancers due to the hydrocarbons present in crude oil as well as reproductive anomalies (Briggs et al., 1996; Jenssen, 1996). The recording of oil spillage in Nigeria is inconsistent, as several bodies report different results for the quantity of oil spilled into the environment (Epstein and Selber, 2002).

Oil extraction and refining also exposes people in the surrounding environment to noise and thermal pollution (Runion, 1988). The refinery workers are more exposed to these harms and dangerous substances such as asphalt, benzene, hydrogen sulphide, asbestos, carbon monoxide etc. (Epstein and Selber, 2002). The fumes from the refineries which typically contain harmful levels of benzene and hydrogen sulphide may lead to dermatitis and bronchitis, asphalt causes skin and eye irritation, asphyxiation from carbon monoxide poisoning, asbestos used in thermal insulation of pipes can cause lung cancer and malignant mesothelioma. The risk of developing cancers from exposure to substances like benzene, hexavalent chromium, arsenic and toluene are not only predominant in refinery workers but also in the people living around such industries (Hayes et al., 1996; Knox and Gilman, 1997; Pukkala, 1998).

Additionally, the air pollutants emitted from flaring and other crude oil activities include volatile organic compounds such as benzene, nitrogen oxides, carbon monoxide, particulate matters with diameters of around 10 microns or less and 2.5 microns or less (for PM-10 and PM-2.5 respectively), sulphur dioxide, and tetraethyl lead (Epstein and Selber, 2002). Nitrogen oxides and sulphur dioxide are precursors of acids that are responsible for acid rain which can cause acidification of water bodies which is toxic to fish (Baker et al., 1996), increased soil acidity which aids the mobilisation of aluminium in the soil and ultimately threatens the survival of plants (Anderson, 1988). Nitrogen oxides also react with volatile organic compounds, leading to the production of smog which is injurious to plants and in turn threatens agriculture (Feng et al., 2015). Similarly, these air pollutants are also injurious to humans as they are associated with cardiovascular diseases (Franchini and Mannucci, 2012), respiratory complications and diseases (Ostro et al., 1991; MacIntyre et al., 2014), cancers such as lung cancer (Pope et al., 2002) and death (Katsouyanni et al., 1997).

1.5. Summary

There are long standing theories which describe and explain the inter-related demographic and epidemiological transitions which nations undergo. As these theories have developed, the influences of several factors such as socioeconomic, political, and cultural factors have been emphasised. There are good reasons to believe that the possession of large-scale natural resources, and crude oil in particular, would speed a nation’s progress along these transitions. Although crude oil production carries direct threats to population health, the resources it offers in terms of money and work ought perhaps to outweigh the detrimental effects. However, existing research suggest that many economically developing nations which possess oil have not benefited from the anticipated ways. This has led to the idea of “resource curse”.

Nigeria is gradually undergoing epidemiological and demographic transition. However, in the face of crude oil abundance, there is poor economic performance and evidence supports that ethnic disparities, inadequate structural and institutional policies may explain this.

Though there is vast literature on the consequences of crude oil activity on health, very little has been provided on the effect of crude oil economy on health. The health harms from crude oil exploration have been widely documented, but evidence on the direct and indirect effect of oil economy on health is scarce and needs to be assessed.

1.6. Thesis outline

This thesis consists of seven chapters: Introduction, Systematic Review, Aims, Methods, Results, Discussion and Conclusion. Chapter one contains the background information for this thesis. Chapter two describes a review of the evidence found in the literature and presents the hypotheses of the thesis. The first review explores the relationship between crude oil wealth and economic growth, then sets the context for the second review which explores the impact of oil-led economy on health and its determinants. A critique of the evidence highlights the need for a twin-track approach of international and nationwide studies to address the research hypotheses, with the phase one (international study) and phase two (nationwide study) studies assessing the impact of crude oil resources on the economy as well as its overall impact on health and associated determinants.

Chapter three outlines the aims and research questions, while chapter four discusses how the data were collected, the rationale for the methods used in the thesis and how the hypothesis in the thesis were assessed. Two sub-chapters describe the methods for phase one and phase two studies. The first sub-chapter describes the assessment of country-level data using structural equation modelling and the second sub-chapter discusses a cross-sectional analysis of household-level data using multilevel modelling, to explore the above relationship. Chapter five presents the results of the analyses and interpretations, under two sub-chapters for phase one and two studies. Chapter six discusses the findings of this research and answers the research questions. The last chapter presents the conclusions, recommendations and highlights future research implications.

2. Systematic Review

This chapter will discuss evidence about the mechanisms by which crude oil develops an economy and how oil economy is thought to influence health. The aim is to assess the benefits and detriments of crude oil on the economy and determine its overall impact on health and its determinants.

A systematic review of the literature will outline the mechanisms by which oil influences economic growth and how oil economy can influence health and its determinants. The methodological limitations of the literature will be addressed.

2.1. Background: Crude Oil, Economic Growth and Health

To efficiently assess the association between oil economy and health, an understanding of the terms: economic growth, population health and oil-led economy is necessary. This chapter will outline these terms and explore the relationship between them. Equally, a single case review of the economic development in Nigeria with emphasis on the revenue from crude oil will be discussed, to put these terms in perspective.

2.1.1. Economic growth

Every nation's economy differs in various aspects such as the major source of revenue, government policies, nature of workforce and access to technology. Such factors influence the rate of economic growth in a nation. These variations in economic growth have led several cross-country studies (Barro, 2003; Petrakos and Arvanitidis, 2008) to explore this topic. Economic growth refers to an increase in the value of a country's output, as indicated by gross domestic product but economic development is a broader term, which in addition, reflects an improvement in the living standards and wellbeing of the people in a country (Market Business News, 2018b).

Economic growth is favoured under transparent and fair governance, as well as favourable conditions for trade. Barro (2003) documented high economic growth for nations with more human capital and consequently increased GDP. This was supported by several factors including rule of law, investment, fair governance and trade. In addition, Petrakos and Arvanitidis (2008) also documented the positive role of capital investment and trade on economic growth and reported the positive effect of human capital on an economy. Human capital refers to the skills and knowledge that a workforce has acquired through education and it remains a prerequisite for economic growth in every nation. Based on this, previous studies have reported that an educated or skilled work force is an important contributor to economic growth (Barro, 1991; Hanushek and Kimko, 2000), but this has also been challenged. Pritchett (2001), for example, suggested that education has contributed far less than might be expected and that the effect of a skilled workforce varies widely across nations. He believed skills acquired through education were in high demand in some nations but less so in others due to weak institutions and policies; the supply of skilled labour grew while the demand stayed constant. Also, the low quality of education in some nations translated into a 'lack' of human capital over time as this created an environment of inadequate skills.

Empirical findings on the drivers of economic growth (Easterly and Levine, 1997; Barro and McCleary, 2003) have shown that socio-cultural factors such as religion, ethnic and cultural diversity can impede economic growth. The low income and slow economic growth in many African nations has been attributed to poor education, political instability and insufficient infrastructure (Easterly and Levine, 1997). These factors are closely linked to high ethnic diversity in a nation. The finding of Easterly and Levine (1997) supports the theories that ethnic diversity promotes polarization and results in rent-seeking behaviour[7], as well as adoption of policies that discourages growth. Furthermore, religious beliefs can stimulate growth as they influence individual traits that enhance productivity (Barro and McCleary, 2003). However, the total effect from higher attendance in church may reduce economic growth. The *net* effect on economic growth depends on the extent of attendance in church and beliefs.

[7] Rent-seeking behaviour involves taking the profits from the sales of a crude oil, in a way that is not beneficial to the nation, especially when political elites take oil money to enrich themselves and not for the betterment of the whole population (Karl, 2004).

A change in the population structure of a nation is also a key driver of development. The demographic transition theory was described by various scholars (Thompson, 1929; Davis, 1945; Notestein, 1945; Gage, 2005; Defo, 2014) and the key components of this transition on economy operate via population size. Several researchers (Barro, 1991; Bloom and Williamson, 1998) reported that demography influenced economic growth. Increase in population size potentially has a detrimental effect on economic growth, as it may lead to high dependency ratio and low quality of human capital. However, a larger proportion of working-age individuals in a nation increases income and promote growth compared to nations with more young and elderly dependents. Growing population size also stimulates demand.

2.1.1.1. Natural resources and economic growth

Natural resources in general can influence the growth of the economy in a nation. Many conflicting opinions exist in the body of research on the impact of natural resource on a nation's economic growth. Stijns (2005) had demonstrated that the presence of natural resources (e.g. coal, minerals, oil and gas) have either positive or negative effect on drivers of economic growth (functional economic policies, better education and government investments), depending on the type of natural resource. Natural resources such as land was reported to be inversely related to all these drivers of economic growth, while oil and gas, coal and mineral reserves exhibited a mix of either a direct or inverse association with the different drivers of economic growth.

However, Mehlum and colleagues (2006b) reported that the growth of an economy in the presence of natural resource abundance can only be promoted where there are efficient institutional settings and national structures. They believed that resource abundance had an adverse effect on economic growth for countries with inefficient institutions and governance structure, where rent-seeking and production are competing, and not complementary, activities in the nation. They conducted a study with eighty-seven countries, based on data availability, from the year 1965 to 1990, using regression analysis. Several countries rich in natural resources (such as Botswana which is rich in diamonds, Norway rich in oil and gas) had used their natural resources to develop their economy due to their good institutional systems which promoted national growth and curb corruption. A typical case of an efficient national policy and practice is seen in the case of Norway's Statoil as described by Heum (2008). This oil company got rid of the large foreign engineering, procurement and construction firms who served as intermediate between the company and local stakeholders. They directly negotiated local content activities with the local stakeholders in Norway, allowing for better programmes tailored to the nation's needs. Likewise, natural resource abundance has also been seen to promote economic growth in Botswana where the revenues from its diamond exports contribute to their development, but Sierra Leone's economy dwindles in the face of diamond exports as poor leadership and policies in the nation led to conflicts and poverty (Gylfason and Zoega, 2006). Gylfason and Zoega (2006) used regression to analyse evidence from a cross-section of eighty-five countries, from the year 1965 to 1998. Ultimately, weak institutions and policy enforcement translates to non-functional economic policies and negatively shapes the effect of natural resource boom on economic growth.

In contrast, Brunnschweiler (2008) reported that resource abundance promotes economic growth even after controlling for the quality of institutional settings in a nation. Interestingly, in a sample of eighty-four countries, he found a positive association between natural resource abundance and economic growth over a thirty-year period (1970 to 2000). This association was not seen for resource abundance and institutional quality, contradicting the natural resource curse hypothesis. These findings on resource abundance and economic growth are largely robust to additional economic and social controls.

Hodler (2006) explored the differences in the impact of natural resources in four countries: Angola, Nigeria, Botswana and Norway. He noted that national resources tend to deter development in nations that have been divided into different conflicting groups based on ethnicity, such as Nigeria and Angola, but promote economic growth in nations with ethnically alike regions (e.g. Norway and Botswana). Hodler concluded that there is positive effect of natural resources on national income in Norway as most of the population belong to the same ethnic group and there are few conflicts. As ethnic fragmentation increases within a population, the occurrence of conflicts can increase and the association between natural resources and national income becomes progressively negative. This finding shows that variability in cultures may bring about national disunity. A nation which does not operate as one body will tend to have conflicting views on national issues. These opposing views bring about disharmony and economic growth typically diminishes in the face of conflict.

Looking at the evidence from previous research, Venables (2016) concluded that a multi-stage approach is needed for the successful use of natural resources to improve a nation's economy. These included appropriate division and utilisation of revenue generated from the natural resources, investment in national projects with beneficial effects on the local economies, as well as resource management practices that favour private sector investments as they create sustainable employment and promote economic growth.

Consequently, this thesis will look at a case study of an oil-rich country to supplement the findings from cross-country studies as well as use aggregate measures of institutional quality to produce a more robust finding.

2.1.2. Economic growth and Crude Oil in Nigeria

This section describes economic growth in Nigeria in relation to demographic trends, which is of importance in the context of this study. It will specifically highlight the country's heavy dependence on crude oil and the progression of the economy over time.

2.1.2.1. Demographic trends and economic growth in Nigeria

Nigeria stands to reap the benefits of economic growth from its population structure. With a population of approximately 170 million people, Nigeria ranks seventh among the world most populous countries and the nation has quite a youthful age structure with approximately half of its population under the age of 15 years (World Economic Forum, 2014). This structure influences the economy of the country. The young population creates an extensive pressure on the nation's capability to offer quality social services and create sufficient jobs for the large number of youths going into the labour market annually. Furthermore, the patterns of mortality and fertility rates in Nigeria have resulted in a population structure where the percentage of children aged 0-14 years has risen from 41.6% in 1960 to 43.6% in 2000 and 44.1% in 2016 (The World Bank, 2018a). Also, the proportion of the population aged 15-64 years has fallen from 55.6% in

1960 to 53.6% and 53.2% in 2000 and 2016 respectively, with a fairly stable proportion of those aged 65 years and above being about 2.8%. Altogether, Nigeria is undergoing a slow demographic transition (Olaniyan et al., 2012).

Although providing for this large population creates a huge economic problem, its population age structure can be a possible instrument to a sustainable economic growth for Nigeria (World Economic Forum, 2014, Olaniyan et al., 2012). This economic benefit which arises from a significant rise in the proportion of the working age population compared to the young and old dependents is termed “the demographic dividend”. As birth rates decrease considerably, the population age structure moves towards more working age people (World Economic Forum, 2014). This can, in turn, aid the acceleration of economic growth via an increase in productivity, more household possessions and lowered costs of basic service provision. Nigeria started experiencing the first demographic dividend in 2003 (Olaniyan et al., 2012). This was characterised by rapid growth of the productive population compared to the consuming population and is anticipated to last beyond 2050. As the dividend progresses to the second stage, the population will age, leading to accumulation of wealth. It is noteworthy that the timing and magnitude of demographic dividend in Nigeria varies between the geopolitical zones of the nation (World Economic Forum, 2014). The southern regions such as the South South, South West and South East are currently experiencing a demographic transition with a slow population growth, lower dependency ratio when compared with the northern regions viz North West, North East, and North Central, thus creating a higher per capita income growth. In light of the above, the northern region compared to the southern region, are likely to gain more from the demographic dividend in Nigeria because of their higher dependency ratios and lower per capita income growth.

Within the context of this study, it is important to note that every state in Nigeria is different from the others in terms of the contribution of oil revenue to their state income as well as the barrels of crude oil produced per day. Health widely varies across these states and we want to ascertain whether the revenue from crude oil contributes to these inequalities in health. Also, developing nations including Nigeria, may only benefit from the change in the population age structure if essential structural and institutional provisions, such as an effective health care system, infrastructural development, laws and policies, are implemented and enforced (Lee et al., 2006; Bloom et al., 2007). Bloom and colleagues suggested that demographic transition does not, on its own, influence economic growth but has an effect on the growth of a nation's economy when combined with strong institutions (Bloom et al., 2007). This is because a stable economic climate is necessary for the productivity of the working population. Productivity may be lost as a result of weak institutions, offsetting the gains from the demographic dividend.

2.1.2.2. Nigeria's oil economy

Natural resource-rich nations have been described by the International Monetary Fund (IMF, 2012) as countries whose non-renewable natural resource make up at least an average of 20% of their total exports or revenue. Nigeria is one of the many oil-rich developing countries. Its economy depends hugely on crude oil, accounting for about ninety percent of the nation's income and about eighty-five percent of Government revenue, with agriculture and manufacturing contributing to less than ten percent of the nation's economy (Ogunleye, 2008; Onoh, 2017). This level of dependence on crude oil renders the country at the risk of economic shock due to the volatility of crude oil price.

The oil industry has greatly impacted on the Nigerian economy, with enormous oil reserves distributed around the country. Crude oil contributed to gross domestic product (GDP) from about 1% in 1960, rose to 11.3% and 20.3% in 1970 and 1981 respectively (Ogunleye, 2008). There was a further rise to 26.9% in 1990 and 34.3% in 2004. This incremental value of crude oil to GDP was markedly driven by increased production which rose from about 396 million barrels in 1970 to 760 million and 919 million barrels in 1980 and 2005 respectively (Akinlo, 2012). Nevertheless, crude oil production experienced a drop to approximately 759 million barrels in 2009, perhaps due to pipeline vandalism and conflicts in the oil-rich regions of Nigeria. Likewise, crude oil *exports* rose from about 510 million barrels in 1970 to 808 million barrels in 1979 (Akinlo, 2012). This then fell to about 391 million barrels in 1987 but rose again in 1998 to 675 million barrels and kept rising beyond 2000. Moreover, revenue from crude oil rose in 1970 from about 167 million naira to about 1.6 billion naira in 2000 and a further rise to 3.2 billion naira in 2009. This large amount of revenue generated from crude oil activity potentially provided Nigeria with the resources needed for national investments.

Before oil discovery, non-oil sectors were the key players in the country's economy. During the 1960s, agriculture was a major part of the Nigerian economy, contributing about 70% of the gross domestic product and 90% of federal government revenue and foreign earnings (Adedipe, 2004). The manufacturing sector also developed, with a rise in its contribution to gross domestic product from 4.8% to 8.2% in 1960 and 1970 respectively. This sector's contribution fell to 5.5% by 2002. The agricultural sector remained the highest contributor (compared to crude oil and manufacturing) to the economy till around year 2000, when crude oil became the largest contributor to gross domestic product with a contribution of 47.5%.

The Nigerian situation captures a phenomenon termed "Dutch Disease" (Gylfason et al., 1997), which describes the decline in the productivity of other sectors of the economy because of influx of oil revenue as well as its impediment to the growth of the economy due to lack of investment in non-oil sectors. The economy of oil dependent nations is vulnerable to financial crisis due to the volatility of oil prices. This is problematic for national development as such nations tend to go into debt when the oil price plummets (Auty, 2004), borrowing more than nations with non-oil revenue (Aluko, 2004) to account for the fall in their national income. Often accompanying these vulnerabilities is a lack of accountability which results in corruption, weak institutions and poor governance.

In countries where exports of natural resources are high, revenues from these resources can change the structure of the nation's economy (Venables, 2016). The impact of crude oil revenue to the Nigerian economy has been debated by many researchers. Mehrara (2009) demonstrated that oil revenue positively influences economic growth in countries like Nigeria. This relationship is stronger in countries like United Arab Emirates, perhaps as they have better governance and institutional quality, which promotes growth. Akinlo (2012) demonstrated that Nigeria's oil sector has varying effects on different sectors of the economy. He provided evidence which suggests that Nigeria's crude oil sector deters the growth of the manufacturing sector, promotes the growth of the building and construction sector and has no impact on the agricultural sector. This indicates that policy changes on crude oil activity can be targeted to promote the development of non-oil sectors. Recently, Nweze and Edame (2016) suggested that a long-term positive relationship exists between oil revenue and economic growth in Nigeria, due to the contribution of the revenue to government expenditure. On the other hand, they also showed a short-term negative relationship between oil revenue and economic growth, due to the heavy dependence on crude oil which hinders the growth of other sectors.

The implication for Nigeria is that oil revenue is yet to be effectively used to develop the economy. Nigeria's economy stands a good chance of benefiting from crude oil revenue, if good policies are adopted to stabilize the situation in the country and to develop other sectors of the economy like the agricultural sector and manufacturing sector. This will expand the source of revenue for the country and improve the value of gross domestic product.

2.1.3. Population health

This section discusses health and determinants of health in the context of this study. It outlines the models of health and elaborates on health inequalities. It also describes the relationship between economic growth and health.

Health is an all-encompassing state of being physically, mentally and socially well, which also includes the absence of disease or infirmity (World Health Organisation, 1946). Population health describes the health outcomes and the distribution of these outcomes within a group of people (Kindig and Stoddart, 2003). This also encompasses the pattern of the determinants of the health outcomes across the life course and the policies as well as the interventions that influence these determinants.

Over the years, many different conceptual frameworks or models that describe health have been proposed. Within the context of our research, we will look at the determinants of health with reference to the Dahlgren and Whitehead model of health determinants (Dahlgren and Whitehead, 1991). This model is discussed in relation to this present research in chapter four (methods), under the theoretical framework and conceptual model.

2.1.3.1. Determinants of health

Several factors influence health through either positive or negative pathways and they are termed the determinants of health. The major determinants of health as documented by Dahlgren and Whitehead (1991) include economic factors, structural environment, individual behaviour, social influences and constitutional factors (such as genetic make-up and age). In other to completely address health, these factors need to be considered and they have been highlighted in several researches on the models of health explored by different scholars over time.

2.1.4. Economic growth and population health

This section briefly discusses how economic growth is related to population health.

Economic growth is a key contributor to population health. Growth in national income or gross domestic product (GDP) has a strong positive effect on health outcomes such as mortality rate and life expectancy at birth (Pritchett and Summers, 1996; Biggs et al., 2010; Baird et al., 2011), across and within nations. Economic growth promotes health by providing more resources for the improvement of health infrastructure in a nation and increased household income for people to spend on healthy diets and medical care.

The unidirectional nature of the wealth-health relationship has been challenged by other researchers (Rivera and Currais, 1999; World Health Organization, 2001; Cutler et al., 2006a) who demonstrate that there is also a feedback from health to income. Health is a key determinant of increased workforce productivity, as it has a positive effect on income growth. Countries with high income levels are likely to have more educated, with better healthcare systems, which in turn improve the health outcomes. With these varying findings, (Rivera and Currais, 1999) demonstrated that the relationship between economic growth and health is bi-directional (Rivera and Currais, 1999). Some researchers have also suggested that the effect of economic growth on population health is modified by poverty (Anand and Ravallion, 1993; Dollar & Kraay, 2002) and public spending on health (Anand and Ravallion, 1993; Houweling et al., 2005).

However, to understand the relationship between economic growth and population health in depth, the subsequent subsections will systematically highlight the evidence gathered from literature, specifically looking at the impact of crude oil wealth on economic growth followed by the impact of crude oil economy on health/its determinants.

2.2. Review of the literature

In the previous sections, literature on economic growth, demographic trends, oil-led economy and health was introduced. There are varying findings on the impact of crude oil on economic growth discussed earlier and the limited studies that investigated the impact of crude oil revenues specifically on health. Some of these studies have explored the economic and health impact of natural resources including crude oil, but they discussed economic growth in varying context such as living standards of the population, not on economic indicators like national income or gross domestic product. They also discussed these relationships using crude oil production or oil industries as indicators of crude oil resource, without deeply exploring the revenues or wealth from crude oil. However, a more systematic approach that will narrow the search of evidence to robustly investigate the effect of crude-oil revenue both on economic growth, and on health and its associated determinants is needed. Therefore, the aim of this review is to systematically review evidence on this association.

Firstly, a systematic review on the impact of crude oil wealth on economic growth will be conducted, followed by a review of evidence on the impact of crude-oil economy on health and its determinants. The Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines was followed during these reviews.

2.2.1. Review 1: Impact of crude oil wealth on economic growth

2.2.1.1. Literature Search

This review explored the relationship between crude oil wealth and economic growth using evidence retrieved from both the electronic search of databases and the hand search of grey literature.

2.2.1.1.1. Electronic Search of Databases

The first literature search was conducted in 13th April 2017. A second and updated review was conducted independent of the first review and the results were compared. The final search of the literature was conducted on 04th June 2018 in four major electronic databases including MEDLINE (OVID), EMBASE (OVID), CINAHL and Web of Science (core collection). The search strategy is detailed in Appendix A. These terms were searched independently and grouped using the Boolean operators such as “OR” and “AND”. Two hundred and twenty-four articles were retrieved. The reference lists of included papers were also searched to increase the likelihood of identifying all the relevant papers. The papers retrieved from the reference list of included papers were from journals that were not captured in the major electronic databases, for example, papers in African journals. These journals were further searched for other papers.

2.2.1.1.2. Hand Search of Grey Literature

A Google Scholar search for other relevant documents was conducted, using the following search combinations with “crude oil” "oil abundance", “oil wealth”, "oil revenue", “oil rent”, "economic development" and "economic growth". Five potentially relevant papers were extracted. The abstracts of these papers were read and subsequently the full documents for relevant papers were read. Only two papers from Google Scholar were included in the review.

2.2.1.2. Inclusion and Exclusion Criteria

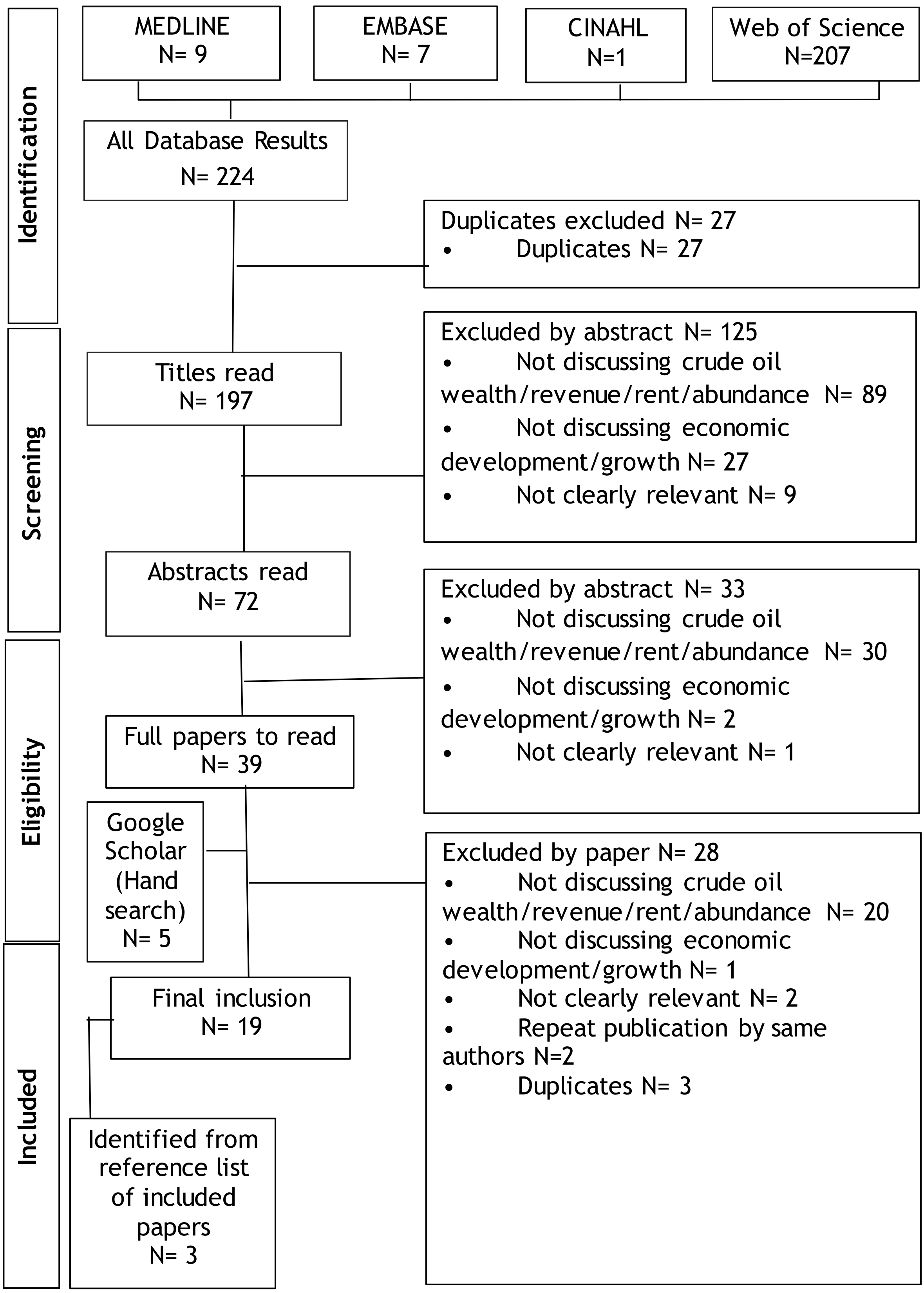
The search of all articles for this review was limited to the criteria listed in table 2.1. The search was conducted by me and checked by the librarian for the college of medical, veterinary and life sciences to ensure accuracy. Potentially relevant papers were selected and their suitability for inclusion was also checked. The studies that did not meet all the criteria listed in table 2.1 and duplicates were excluded from this review.

A PRISMA flow diagram (Moher, 2009) showing the reasons for the inclusion and exclusion of studies is shown in figure 2.1.

Table 2.1: Criteria for considering studies for this review

	Criteria for review on impact of crude oil wealth on economic growth
1	Use of empirical data to explore the impact of crude oil on economic growth.
2	Studies used changes in gross domestic product as measure of economic growth.
3	Independent variable is oil wealth.
4	Studies published in peer reviewed journals. All study methodologies were included.
5	Papers written in English Language

Figure 2.1: Flow diagram for review 1



2.2.1.3. Result of the search

The search strategy was executed for each literature search and the titles of the resulting article were examined in relation to the research question. Abstracts of the articles considered to be potentially relevant to the research question were read and a full-text viewing of the articles considered relevant was done. The relevant papers were then included in the review. Figure 2.1 details the number of articles identified and excluded at each stage of the review.

Retrieved articles were added to Endnote, a reference manager, which also identified and excluded duplicates.

2.2.1.4. Review of the Articles

The electronic database search of existing literature yielded a total of two hundred and twenty-four papers. Hand search of existing literature yielded five papers. After exclusion of duplicates and studies that did not meet the inclusion criteria, nineteen papers remained relevant to this thesis and were included in this review. These studies cut across different countries in the world, including Algeria, Angola, Egypt, Libya, Nigeria, Kingdom of Bahrain and Norway. The number of studies included in the review showed the wide and varying investigation into the impact of crude oil wealth on economic growth.

As the studies varied in their method of capturing and reporting crude oil wealth and economic growth, a narrative synthesis of the findings was undertaken, and a meta-analysis was not conducted. The statistical level of significance was p value less than 0.05 for all the studies.

2.2.1.4.1. Data Extraction

The key information extracted from the articles included in the review was summarised in appendix B. This summary table outlines the authors, year, study location, study aims, study design, findings, limitations and quality appraisal literature for each paper.

2.2.1.4.2. Quality Appraisal of the Literature

The quality of the studies included in the review was systematically examined using the Critical Appraisal Skills Program (CASP) 2017 tool. This tool assessed the validity of the results of each study, the findings and the significance of each study.

The CASP checklists for systematic review, case control and cohort studies were drawn from to develop the checklist for the quantitative studies included in this review (Appendix C). The check assessed each article under the following sections: statement of aims, methodology, research design, inclusion criteria, variable selection, confounders, validity of result, data analysis, statement of findings and value of research. Each section was assigned a score of either 0 or 1, where “0” was for the response “no” and “1” was for “yes”. The maximum possible score for this assessment was “10”, for all the sections in the checklist. The lowest score for the included papers was six out of ten, suggesting that the included papers were of fairly good quality.

2.2.1.4.3. Review

The economic impact of crude oil wealth has been widely looked at for many years and researchers have explored this by looking at the experiences of individual countries or by cross-county evaluation. Divergent opinions exist on the economic impact of crude oil wealth or abundance on economic growth. Crude oil wealth has the potential to have either positive or negative effect on the economy. Though a large body of literature has established that there is a relationship between crude oil wealth and economic growth, factors including institutional quality and governance structures have been shown to influence this relationship.

Few authors have reported a negative relationship between crude oil wealth and economic growth (Akanni, 2007; Apergis and Payne, 2014; Fuinhas et al., 2015), supporting the resource curse hypothesis. Oil resource curse can be explained by Dutch disease and rent seeking behaviours (Akanni, 2007). Dutch disease can occur when the real exchange rate of a nation appreciates and the output of other sectors such as the manufacturing sector falls, with a consequent decline in economic growth. For example, oil boom in Middle East and North African (MENA) Countries was reported to diminish productivity in agricultural sector

(Apergis et al., 2014). This could be due to the movement of resources from other sectors to the booming oil sector in the MENA countries, serving as an evidence of Dutch disease. Weak institutions also encouraged non-productive usage of oil revenues, through rent seeking behaviour, thus hindering economic growth in these countries. Other mechanisms of oil resource economic curse include: conflicts and war, as revenues from natural resources increases the likelihood of conflicts and war (Fearon, 2005; Park and Lee, 2006); revenues generated from resource abundance, enabling bad policies such as debt accumulation and corruption in resource rich nations (Manzano and Rigobon, 2001). The first cross-country evidence on resource curse (Sachs and Warner, 1995), documented this negative relationship but this study has been criticized because of their measure of resource abundance (resource exports to GDP). Eregha and Mesagan (2016) also reported that oil export measure of oil abundance had a negative effect on growth, indicating that these countries have not been able to channel their oil wealth into growth enhancing activities but oil production as a measure of oil abundance had a positive effect on growth. They argued that this difference in the growth effect of oil production and oil resource earnings is linked to the weak institutions in these countries. This oil export measure represents resource dependence not abundance (Wright and Czelusta, 2004). However, the studies that explore other measures of resource abundance such as reserves per capita, find that resource abundance is not negatively related to economic growth.

Apergis and Payne (2014) also documented the evidence on oil resource curse. It was based on the poor state of institutions, where economic activities that deter growth are encouraged. They reported that although there is a negative effect of oil abundance on economic growth in MENA countries, it is significantly reduced on improvement of institutional quality. The interaction between natural resources and economic growth, in the presence of strong institutions, can transform resource curse to blessing (Mehlum et al., 2006a; Nathan and Okon, 2013). In countries were the institutions are weak, rent seeking behaviour, poor governance structures and conflicts are more likely to occur, with oil wealth translating into resource curse. The role of weak institutions has also been explored in oil rich countries, especially in African countries, where evidence on resource curse through institutional channel have been suggested (Eregha and Mesagan, 2016). African countries such as Nigeria, Libya and

Algeria, have been ranked top amongst Africa's oil producers, since the year 1970 and a similar picture is seen for export, but the same top record was not recorded for the instruments of good institutional quality, as they ranked very poorly. The record for economic growth in these nations also shows poor economic performance (Eregha and Mesagan, 2016). The discrepancy between the economic benefits of crude oil produced and the actual contribution of oil revenue to the economy could be attributed to the inability of the institutions in these countries to curb corruption and bad policies in their governance structures, as well as the conflicts and political instability in these countries.

However, a large body of cross-country evidence found that crude oil resource wealth significantly promotes growth (Nili and Rastad, 2007; Ogwumike and Ogunleye, 2008; Alexeev and Conrad, 2009; Kurtz and Brooks, 2011; Cavalcanti et al., 2011a; Cotet and Tsui, 2013; Matallah and Matallah, 2016; Law and Moradbeigi, 2017; Aimer, 2018; Arin and Braunfels, 2018). The channels that can translates natural resource wealth to economic growth include: good institutional quality and governance (Obafemi et al., 2013; Arin and Braunfels, 2018); development and investment in human capital (Kurtz and Brooks, 2011); and the influence of financial institutions in promoting national investments (Law and Moradbeigi, 2017; Nili and Rastad, 2007). Human capital is a conditional factor for the existence of oil resource blessing (Kurtz and Brooks, 2011). The countries with high human capital endowment are better able to capture growth-enhancing effects from oil resource, thus avoiding resource curse. However, human capital has to be channelled into productive activities, for it to positively contribute to economic growth. For example, strengthening the educational capacities of the people via government investments can incorporate technological innovations into the nation's economy, thus shaping the use of oil wealth to promote economic growth. This occurs in the presence of several industrial policies and public investments (Haggard, 2004). On the other hand, financial systems function as channels for the allocation of resources, facilitation of trade and mobilisation of funds for national investments (Law and Moradbeigi, 2017; Nili and Rastad, 2007). Hence, financial development plays a role in moderating oil resource curse, by channelling the oil revenues into more productive activities. Poor quality of financial institutions translates into poor economic performance, as mismanagement of funds arises within the governance structures. Levine and Renelt (1992) established a positive relationship between economic growth and financial development. A further study by Levine and Zervos (1998) added that the level of financial development is a strong predictor of economic growth over time, but their study suffered from statistical weaknesses as they did not control for country fixed effects or use of lagged dependent variables in the growth regression model. While addressing this and other study weaknesses, Beck and Levine (2004), emphasised the importance of financial development as a growth-enhancing factor in an economy.

The cross-country studies included large numbers of observations from different countries, therefore their findings are more generalisable. The evidence from these studies have added that the findings from studies that support the resource curse hypothesis may be as a result of data misinterpretation (Alexeev and Conrad, 2009). Their findings suffered from endogeneity bias as there was insufficient information on the time of oil discoveries for studies that used cross-sectional regression to explore this relationship, introducing bias on controlling for the initial income. Similarly, Cavalcanti et al. (2011a) also raised doubts on the resource curse literature, as they investigated the short-run effect of oil resource abundance on growth using the level and Error Correction Model regressions in order to capture country-specific unobserved factors like human capital, as well as address the concerns of omitted variables. However, the heterogeneity in the growth pattern of the countries included in their study was addressed using heterogeneous panel data technique approach, creating different outcomes for these countries. Arin and Braunfels (2017) used Bayesian model averaging techniques which included fifty-four potential growth determinants for ninety-one countries, addressing the model uncertainty of the choice of growth determinants to include in the analysis. They found no evidence of oil resource curse, as there was no harmful growth effect from oil rents[8]. Especially in the long-run (cross sectional analysis), oil revenues had growth-enhancing effects which may be majorly due to institutional quality. However, some growth determinants were not included in the panel setting (short-run to medium-run growth models) because of data availability, which may have affected the results. Aimer (2018) also highlighted the role of oil rent

[8] Oil rents refer to the revenues generated from crude oil production, in excess of all relevant costs (Karl, 2004). It represents the monetary gain from crude oil trade by a nation.

on economic growth of the Organization of the Petroleum Exporting Countries (OPEC) members. Oil rent was shown to have a positive impact on economic growth and employing panel co-integration model, highlighted that oil rent had strongly driven gross domestic product growth and no impact was observed from gross domestic product growth to oil rent. This result is not robust as only one growth determinant was used. Cotet and Tsui (2013) also found little evidence in support of resource curse, reporting that oil rents do not deter economic growth, even in the presence of poor institutional quality. They assessed the relationship between oil and growth, using cross-country regressions which identified long-run causal effects on growth, but this analysis suffered from omitted-variable bias due to unobserved heterogeneity. They also employed panel techniques to control for the country-specific omitted variables that are time-invariant. In order to test the impact of oil rents on economic growth, Matallah and Matallah (2016) explored this relationship in eleven Middle East and North Africa oil exporters, documenting the significant growth enhancing impact of oil rent on these countries. They also reported that good governance is a key factor in avoiding oil resource curse. However, they used the traditional panel and the generalised method of moments dynamic panel technique to address concerns on endogeneity and heterogeneity by choosing valid instrumental variables.

All but four of the studies in this review were single country studies and they argued against oil resource curse, demonstrating that oil abundance is growth-enhancing: (Chekouri et al., 2017) for Algeria; (Obafemi et al., 2013) for Nigeria; (Mideksa, 2013) for Norway; (Hamdi and Sbia, 2013) for the Kingdom of Bahrain. Though these studies have argued that oil resource abundance has growth-enhancing abilities, the impact varies from country to country. For example, Norway is a model country for demonstrating the economic benefits of oil abundance. A comparison of Norway and a synthetic unit of Organisation for Economic Co-operation and Development (OECD) member countries not endowed with oil (such as Australia, Belgium, Iceland, and Switzerland) showed that petroleum resource abundance enhances growth (Mideksa, 2013). This comparison yielded good estimates as these OECD countries had similar national income as Norway before her first major oil discovery, providing an efficient basis of exploring how the economy would evolve in the absence of the resource abundance. However, Norway has been able to achieve growth through their efficient national policy and practice, as described by Heum (2008), in the case of Norway's Statoil. This oil company got rid of the large foreign engineering, procurement and construction firms who served as intermediate between the company and local stakeholders. They directly negotiated local content activities with the local stakeholders in Norway, allowing for better programmes tailored to the nation's needs. However, this growth enhancing effect of oil cannot be generalised to other oil resource abundant countries as this study did not address all the factors driving this growth which could have been a result of other interventions. In line with this, Chekouri et al. (2017) examined the interaction between resource abundance and long-run economic growth in Algeria and showed that there was a strong positive association. The concern with this evidence is the use of export related revenue to measure oil resource abundance. This revenue may not reflect production or reserve for Algeria because it does not factor the products consumed in the country, introducing bias in the size of the effects. Therefore, a country that consumes most of its oil, exporting very little of it, will have relatively low gross domestic product even though there is oil abundance. These authors used vector error correction models to test for oil resource curse, which are useful in addressing cointegration in time series (long-run stochastic trend). In the Kingdom of Bahrain, Hamdi and Sbia (2013) also examined the long-run and short-run relationships between oil revenues, government expenditure and economic growth and their finding suggests that oil revenues remained the main source for economic growth as well as government spending, transforming expenditure into economic boost. The Kingdom of Bahrain had been shown to translate its oil wealth into economic growth through strong institutions, effective policies and good governance. For example, the Bahraini government had strengthened the structural reforms for infrastructural advancement as well as intensify efforts to diversify its economy, as oil revenue is the main source of government expenditure. The revenue from oil, provides resources for their government for economic inputs but in countries like Nigeria, oil wealth fails to yield economic growth because of weak institutional quality and rent seeking behaviours. Ogwumike and Ogunleye (2008) examined the long-run effect of the huge oil wealth in Nigeria on its economic growth using the vector error correction technique and reported that oil wealth did not translate into economic growth in Nigeria. They suggested that if the initial setback from corruption, lack of openness and fairness in governance are eliminated, oil wealth can induce development. Their findings on development appeared robust as they used different development indicators. This finding was also supported by Obafemi et al., (2013). They investigated the role of petroleum resource abundance and institutional quality in Nigeria's economic growth and concluded that petroleum resources abundance may boost economic performance if good institutional quality exists. They also used the error correction econometric technique to examine this relationship but, just like the other single country studies, they are limited as their findings are not generalisable to other countries. The adverse effect of resource abundance on economic growth cuts across other natural resources for countries with inefficient institutions and governance structure. Botswana, a country rich in diamonds, have used their natural resources to develop their economy due to their good institutional systems, which promote national growth and curb corruption. Though the revenues from its diamond exports contribute to their economic growth, Sierra Leone's economy dwindled in the face of diamond exports as poor leadership and policies in the nation led to conflicts and poverty (Gylfason and Zoega, 2006). Ultimately, weak institutions and policy enforcement translates to non-functional economic policies and negatively shapes the effect of resource boom on economic growth.

Looking at the evidence from these studies, a multi-stage approach is the requirement for the successful use of crude oil resources to improve a nation's economy. Venables (2016) had suggested this approach, which includes appropriate division and utilisation of revenue generated from the natural resources, Investment in national projects with beneficial effect on the local economy as well as resource management practices that favour productive national investments.

In summary, there are different evidence on the impact of crude oil wealth on economic growth. There are studies that support oil resource curse while others support oil resource blessing, especially conditional on factors such as the presence of good institutions in these oil rich countries. The studies that support oil resource curse documented the role of Dutch disease, rent seeking behaviours and bad economic policies in the economies that experience poor performance. However, oil resource blessing was reported in most studies, were factors such as good institutional quality or governance structures, human capital investment and development of financial systems play a part in the growth enhancing capacity of crude oil wealth. Most of the empirical evidence were from cross-country studies. The cross-country evidence provides an understanding of the impact of crude oil wealth on economic growth across many countries, hence the evidence can be generalised to a wide range of countries, unlike the studies on single economies that focusses on isolating this relationship for a specific country. Most of the studies used appropriate comparison units, either with countries without crude oil or for periods before the discovery of oil resource abundance, allowing for the estimation of the impact of crude oil wealth on economic growth. The estimation of the impact of crude oil wealth on economic growth was challenging because of the problem of determining how a country would have performed without crude oil resource, the influence of other interventions and political instability during the discovery of resource abundance.

Therefore, oil resource abundant nations have the potential to economically benefit from their crude oil wealth, if the growth-diminishing factors are curbed or the growth-enhancing factors discussed earlier are promoted. Whether the economic growth from crude oil wealth provides a better standard of living or improves population health is another issue for consideration. Thus, the benefits of this oil economy will be explored to further understand its impact on health improvements.

2.2.2. Review 2: Impact of crude oil economy on health and its determinants

2.2.2.1. Literature Search

There is no existing systematic review that has assessed this association. This review fully explored the evidence for a relationship between crude oil economy and (1) health, (2) determinants of health. It focussed on the determinants of health, drawing from the model by Dahlgren and Whitehead (1991). Like the strategy used for the search in review 1, both electronic search of databases and hand search of grey literature were done.

2.2.2.1.1. Electronic Search of Databases

The first literature search was conducted in 16th April 2017. A final search of the literature was conducted on 14th March 2018 in four major electronic databases including MEDLINE (OVID), EMBASE (OVID), CINAHL and Web of Science (core collection). The search strategy included relevant terms for oil-led economy, population health and health determinants, as seen in Appendix D. These terms were searched independently and grouped using the Boolean operators such as “OR” and “AND”. Two thousand, five hundred and twenty-six articles were retrieved, and the reference lists of included papers were also searched.

2.2.2.1.2. Hand Search of Grey Literature

A search was conducted in Google Scholar for other relevant documents including technical reports, using the following search combinations with "oil economy", “oil wealth”, "crude oil", "health determinants" and "human health". Ten potentially relevant papers that focussed on crude oil economy, health and its determinants were extracted. The abstracts of these papers were read and subsequently the full documents for relevant papers were read. Only two papers from Google Scholar were included in the review.

2.2.2.2. Inclusion and Exclusion Criteria

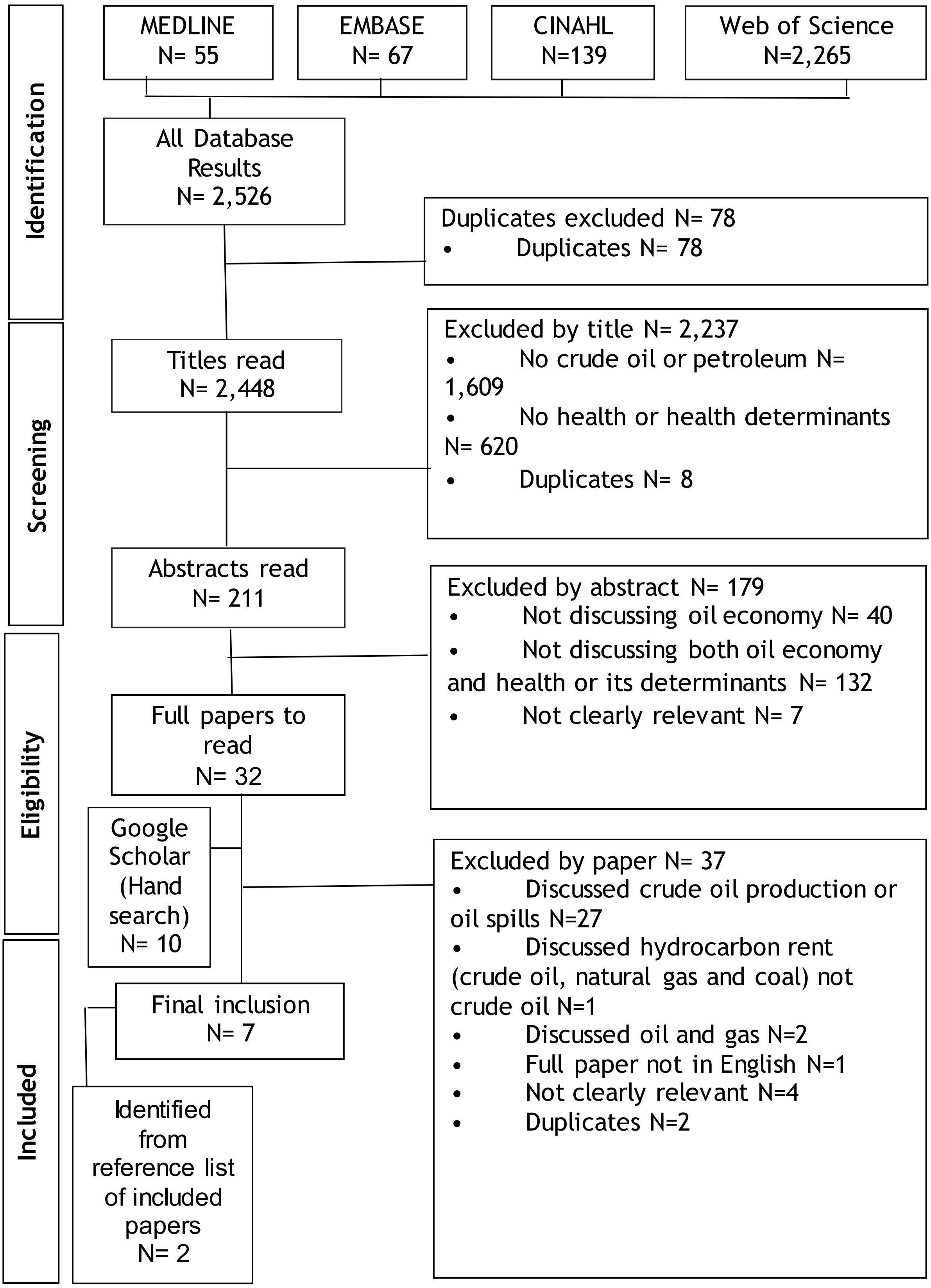
The search of all articles included in the review was limited to the criteria listed in table 2.2. The search was conducted by me and checked by the librarian for the college of medical, veterinary and life sciences in the same way as that of review 1. Potentially relevant papers were selected and their suitability for inclusion also checked.

The studies that did not meet all the criteria listed in table 2.2 were excluded from this review. Duplicates were also removed. A PRISMA flow diagram (Moher, 2009) showing the reasons for the inclusion and exclusion of studies was done as seen in figure 2.2.

Table 2.2: Criteria for considering studies for this review

	Criteria for review on impact of oil-led economy on health and its determinants
1	Use of empirical data to explore the impact of oil economy on health and determinants of health.
2	Studies used measures of health such as mortality and life expectancy; and measures of the determinants of health such as education, infrastructure, housing and expenditures on health and education.
3	Oil rent, oil revenue and oil wealth as measure of oil economy (independent variable).
4	Studies published in peer reviewed journals. All study methodologies were included.
5	Papers written in English Language

Figure 2.2: Flow diagram for review 2



2.2.2.3. Result of the search

The search strategy was executed for each literature search and the titles of the resulting article were examined in relation to the research question. Abstracts of the articles considered to be potentially relevant to the research question were read and a full-text viewing of the articles considered relevant was done. The relevant papers were then included in the review. Figure 2.2 details the number of articles identified and excluded at each stage of the review. Retrieved articles were entered into Endnote, and this also identified and excluded duplicates.

2.2.2.4. Review of the Articles

The electronic database search of existing literature yielded a total of two thousand five hundred and twenty-six papers. Hand search of existing literature yielded ten papers. After exclusion of duplicates and studies that did not meet the inclusion criteria, seven papers remained relevant to this thesis and were included in this review. These studies cut across different countries in the world, including Brazil, Algeria, Egypt, Nigeria and Cameroon. The number of studies included in the review showed the limited investigation into the impact of oil economy on health and health determinants.

As the studies varied in their method of capturing and reporting oil economy, health and determinants of health, only a narrative synthesis of the findings was done, and a meta-analysis was not conducted. The statistical level of significance was p value less than 0.05 for all the studies. Also, multiple relationships were reported in a few studies due to the varying definitions of health and the determinants being explored.

2.2.2.4.1. Data Extraction

The key information extracted from the articles included in the review was summarised in appendix E. This summary table outlines the authors, year, study location, study aims, study design, findings, limitations and quality appraisal literature for each paper.

2.2.2.4.2. Quality Appraisal of the Literature

The quality of the studies included in this review was systematically examined in the same way as section 2.2.1. The lowest score for the included papers was six out of ten, suggesting that the included papers were of good quality. Each paper lost a point for failing to address a question on the CASP checklist.

2.2.2.4.3. Review

Seven studies examined the effect of oil economy on health and its determinants (Omotor, 2009; Alexeeva and Conrad, 2011; Cotet and Tsui, 2013; Caselli and Michaels, 2013; Wigley, 2017; Hong, 2017; Opaleye et al., 2018). Cotet and Tsui (2013) demonstrated that oil wealth was associated with significantly lower infant mortality and longer life expectancy. They also argued that oil wealth led to better quality of life, especially in non-democratic oil-rich nations. However, Hong (2017) reported that oil resource abundance did not improve social spending in countries with authoritarian leadership when compared with democratic governments. He used panel data with authoritarian governments and observed that oil abundance led to significantly lower levels of social spending patterns, predominantly on spending for education and health. The findings are relatively robust as different measures of oil resource abundance were used to confirm the relationship but low spending on health does not necessarily translate to poor health. Also, previous reports indicated that the consequences of oil resource on health tends to be negative (Karl, 2004), with non-democratic countries and resource exporters, having poorer health (Besley and Kudamatsu, 2006). However, non-democratic countries with advanced welfare system such as Kuwait had far reaching health improvements and benefits across the general population (El-Katiri et al. 2011).

In contrast to previous reports which indicated poor health outcome measures in resource abundant countries with poorly managed welfare institutions (Besley and Kudamatsu, 2006; Robinson et al. 2006), the analyses of Cotet and Tsui (2013) accounted for variation in oil prices and resource abundance as well as the timing of oil discovery between countries. Their study strongly suggests that oil resource, in the long term, improves health outcomes regardless of the quality of welfare institutions or the democratic status of a nation. Their finding is in agreement with the notion that oil resource-driven economic growth stimulates health improvements partly due to improved population income (Lederman and Maloney, 2006; Brunnschweiler and Bulte, 2008; Alexeev and Conrad, 2009) or from government subsidised healthcare programmes in both democratic and undemocratic nations, as their leaders use these means to the boost the popularity of their regimes (Mulligan and Tsui, 2008; van der Ploeg and Poelhekke, 2009). However, Cotet and Tsui, 2013 used dynamic panel method with unbalanced panels, due to unavailability of data, which can address omitted variable bias typical in cross-sectional analysis but the relatively short panel structure of the data, may have increased measurement error bias.

On the contrary, other scholars have reported that oil wealth is positively associated with child mortality (Wigley, 2017; Opaleye et al., 2018). Child mortality is an important health indicator as it reflects the efficiency or availability of healthcare and welfare systems to the most vulnerable and poorest member of a country (de Looper and Lafortune, 2009; Yazbeck, 2009). It can also be a measure of disease control, the general health knowledge and sanitary awareness of a society. This is because half of infants' death around the world are due to preventable and treatable diseases and infections (Liu et al., 2015).

Wigley (2017) investigated whether oil resource curse affects child health and reported on a panel of one hundred and sixty-seven countries for the year 1961 to 2011. He demonstrated that oil poor countries performed better than oil rich countries in reducing under-five mortality. While the study accounted for well-known indicators of economic development such as oil income, war, trade policy, geographic distribution, it did not consider access to healthcare and education which are important independent indicators of health improvement and child mortality. Opaleye and colleagues (2018), using fixed effects and partial efficiency panel analysis, examined the effect of oil rent spending on health and several socioeconomic factors in Algeria and Egypt, Nigeria and Cameroon. These factors include some determinants of health such as education. They demonstrated that revenues from crude oil rent significantly increased child mortality but did not significantly improve education. The study did not control for oil price variation nor did they provide a basis of comparison between the period prior to or around the time of oil discovery. Also, the study did not provide a control country within the period of reference, which is either oil resource dependent or has abundance of resources. Hence, the reference period of 1995 to 2015 may not reveal much difference without control factor(s).

Similarly, oil resource wealth has also been shown to be associated with poorer health and lower education, in economies in transition (transition from socialism to markets), compared to other oil rich nations (Alexeeva and Conrad, 2011). This cross-sectional study examined the relationship between oil resource abundance and economy growth, institutional quality, human and physical capital development and social welfare such as life expectancy and infant mortality, using cross-sectional regression method. Their study does not address the concerns of endogeneity and omitted variable bias, which may result in unfair interpretations of their findings.

Only a few studies included in the review were based on a single country. Oil revenue significantly influenced the development of the socio-economic indicators including education, health, housing and water in non-oil producing areas than in oil producing areas in Nigeria (Omotor, 2009). He measured the effect of the oil industry on the residents of oil producing areas of Nigeria, using analysis of variance technique. A significant positive result for the impact of oil on education, health, housing, power, roads and water was observed only in the era of oil boom. Though in his study the oil industry significantly improves health, the analytical method is limited as it did not account for the variation across regions and states in Nigeria on oil-led health and infrastructural improvements and the measure of oil revenue or health were not clearly defined. Hence, there is need to explore the relationship with health indicators between regions in Nigeria. Caselli and Michaels (2013) reported that increased spending on services, housing, education and health from oil revenues but this translated into little improvement in services and health outcomes. To complement this finding, another study in Brazil demonstrated that oil discovery and extraction at municipal (small division) levels improved the local economy, as seen in the higher marginal productivity generated from the urban service sector as against subsistence agricultural services (Cavalcanti et al., 2019), though this is not necessarily seen at national level. They and others (Monteiro and Ferraz, 2010) argued this may be due to lack of political will of the Brazilian leaders to provide functional healthcare and other relevant programmes. This reflects institutional corruption or lack of political direction to utilise the proceeds of increased oil revenue for healthcare and welfare improvements. The findings of this study may not be generalisable to other countries and the study did not address the total effect of oil on Brazil as it examined only the differential effect of oil between oil rich areas and their poor counterparts.

Overall, all the studies in this review revealed that there is no comprehensive picture on the impact of oil economy on health and its determinants, as some studies did not address model uncertainties and heterogeneity of the countries included in their research. There was no definite measure of health outcomes in three studies; and only two studies explored both child mortality and life expectancy, therefore there is a need to consider robust measures of health and its determinants as well as address these gaps.

2.3. Methodological limitation and gaps in the literature

A limitation of most of the studies included in the review on the effect of oil wealth on economic growth was that they suffered from a central problem in growth regressions; where there is uncertainty on which of the possible growth elements to be included in the analysis. In this regard, Arin and Braunfels (2018) addressed this problem of model uncertainty regarding the factors that explain the outcome by using a Bayesian Model Averaging approach. This approach considered all the possible models and averages over the results, making the results less conditional on the model.

Studies that employed the homogenous panel data approach impose a high degree of homogeneity and may consequently give biased estimates of the parameters values, as the growth effect of oil resource abundance show substantial cross-sectional differences (Cavalcanti et al., 2011b). However, Cavalcanti et al. (2011a) employed an approach with heterogeneous panel data in a panel of 53 oil producing countries, to address this. Law and Moradbeigi (2017) also address this by examining the relationship between oil resource abundance and economic growth using the non-stationary panel method for their analysis or vector error correction methodology by Ogwumike and Ogunleye (2008). Another limitation was that few studies explored the association using treatment and control groups (Nili and Rastad, 2007; Mideksa, 2013).

Some studies also used cross-sectional methods to examine the oil resource curse hypothesis. This method raises concerns on endogeneity and omitted variable problems. It also did not consider the time dimension of the data. In macro panels, data from a long-time span increases the possibility for a panel to exhibit heterogeneity and cross-section dependence, thereby yielding inaccurate estimates.

A major finding of this systematic review was the limited number of studies on the impact of oil economy on health and its determinants. There is mixed evidence on the effect of oil economy on health and its determinants and most of these studies did not use multiple measures of health and health determinants for their analysis. There is a need to explore large-scale data to assess this relationship. With recent availability in data, there is a need to look at the relationship between oil economy and health and its determinants, over time.

2.4. Geographical Context

The geographical settings for the studies included in both reviews have been considered. The studies included in the review on the impact of oil wealth on economic development took place all around the world, including countries such as Organization of the petroleum exporting countries (OPEC) members and non-OPEC oil producing nations, Middle East and North African countries, Algeria, Angola, Egypt, Libya and Nigeria, Kingdom of Bahrain, Norway and so on. Cotet and Tsui (2013) captured as many as 152 countries across the world. Although the countries of study are oil economies, differences that could impact on the findings may be apparent. For instance, Norway is a developed nation with strong institutions and effective policies, however, countries like Nigeria are different in this respect.

The studies included in the review on the impact of oil economy on health and its determinants took place all around the world, including countries such as countries in Africa, Brazil and in a study by Cotet and Tsui (2013), as many as 152 countries across the world were captured. Although the countries of study are oil economies, differences that could impact on the findings may be apparent. For instance, some countries are in economic transition (from socialism to markets) while others are non-transitional economies; some are net exporters and others are net importers; some are developing nations while others are developed.

The growth effect of oil wealth has been a global topic, setting some nations ahead of other as countries like Norway (Mideksa, 2013), which has recorded success and developing nations like Nigeria (Obafemi et al., 2013; Ogwumike and Ogunleye, 2008), which has barely translated their oil wealth to growth.

2.5. Conclusion

The impact of oil wealth on economic growth is widely studied. The studies included in the review of this relationship demonstrated that oil resource abundant nations have the potential to economically benefit from their crude oil wealth in the presence of appropriate systems and institutions. Most of the studies indicated that governance, institutional quality, human capital development and financial development play a role in channelling oil wealth to growth. Oil production as a measure of oil wealth, did not have effect on economic growth but earnings from crude oil influenced economic growth, indicating the oil resource earnings plays a role in driving the economy in the presence of the necessary channels as stated above.

However, the review on the impact of oil economy on health and its determinants gave no conclusive evidence on this relationship, as there were contrasting views about this. Oil wealth was associated with better health in some situations, but perhaps not for economies in transition. The effect of oil on health and its determinants may depend on the oil exploration era, governance and democracy. Though oil revenues increased spending on health and its determinants, it translated into little improvement in the provision of services or living standards of the population.

The reviews show that there is robust information on the impact of oil wealth on economic growth, but weaker evidence on the impact of oil economy on health and its determinants. This thesis therefore addresses the gaps and limitations discussed in section 2.3 as follows:

- Panel data analysis will be conducted to look at the relationship between crude oil resources and health/its determinants over time

- A further assessment of the relationship between oil-led economic growth and health/its determinants; using a cross-country and case studies to explore this relationship

- The use of large datasets to include the countries of interest and capture relevant variables were available

- The use of appropriate statistical techniques that address data structures and limitations

- Addressing heterogeneity by categorising countries into low- and high-income groups in the phase one study; accounting for state level variations across Nigeria in the phase two study.

3. Aims and research questions

3.1. Aims

3.1.1. Phase one

The phase one study aims to explore the hypothesized pathway between crude oil resources and population health, operating through institutional quality, infrastructure and environmental consequences of crude oil activities in a sample of low- and high-income countries.

3.1.2. Phase two

The aim of the phase two study is to determine whether oil-led economic growth is related to population health in Nigeria specifically.

To address these aims, this thesis sought to answer three main research questions by carrying out two reviews, and then two empirical studies: one international and one focused on Nigeria as a case study.

3.2. Research questions

3.2.1. Phase one

The following research questions will be addressed:

1. How do crude oil resources influence economic growth and population health?

2. What is the relationship between oil-led economic growth and population health?

3.2.2. Phase two

The following research questions will be addressed:

1. Does oil-led economic growth influence population health in Nigeria?

4. Method

In this chapter, the theoretical framework and conceptual model of this research are discussed first. The chapter is then divided into two main sections: the phase one and the phase two studies. In the phase one study, research question 1(How do crude oil resources influence economic growth and population health?) and research question 2 (What is the relationship between oil-led economic growth and population health?) was be addressed through an international comparison of 156 countries. The phase two study on the other hand answered the research question "Does oil-led economic growth influence population health in Nigeria?" by exploring this relationship in Nigeria, a case study for crude oil abundant nations.

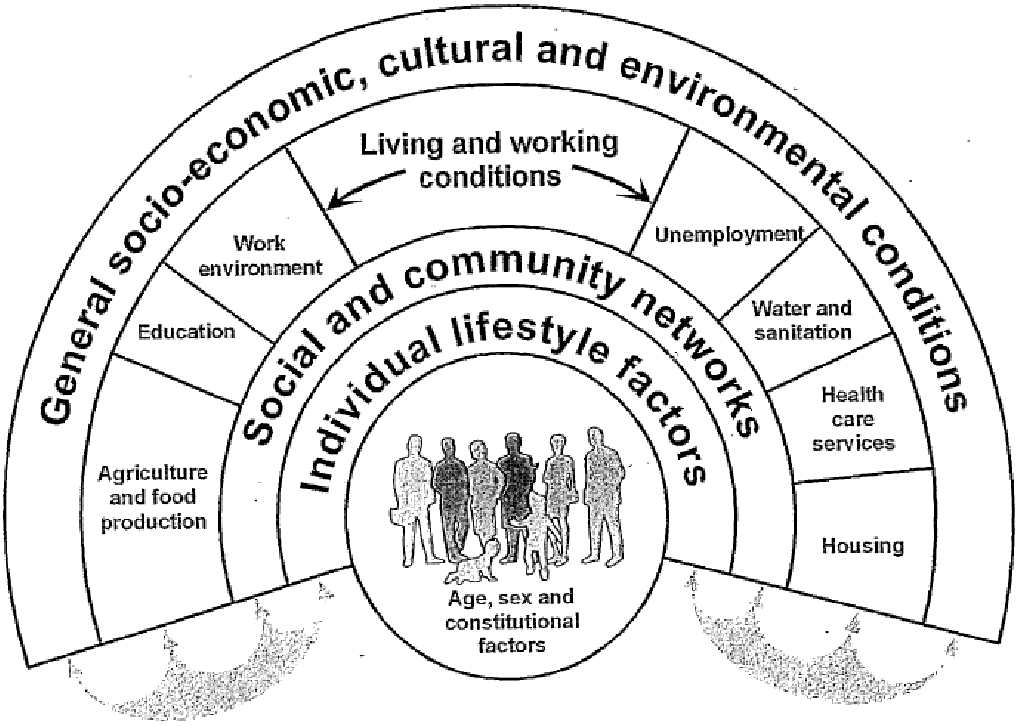
For both studies, the first section describes the data and variables chosen for phase one and two studies while the second section discusses the methodology, statistical software and technique as well as the rationale behind the approach chosen for the studies. Data preparation and cleaning will also be discussed. This chapter also gives a description of the missing data, technique used to handle this, the variables selected, the assumptions of the techniques chosen, and the goodness of fit tests applied.

4.1. Theoretical framework and conceptual model

This section explains the theoretical framework and conceptual model of this research. This research explored the relationship between crude oil money, economic development and health, based on the theory on the influences of social and economic factors on health. The thesis map (shown in figure 1.1 of chapter 1) highlights the broad design of both studies.

Social and economic systems are major structural factors that influence health (Dahlgren and Whitehead, 1991). They include health services, economy, structural factors, the social and physical environment (figure 4.1). These determinants of health are shaped by the distribution of power and resources, either locally, nationally or globally (World Health Organization, 2008).

Figure 4.1. Dahlgren and Whitehead model of health determinants (Dahlgren and Whitehead, 1991).



4.1.1. Theoretical Framework

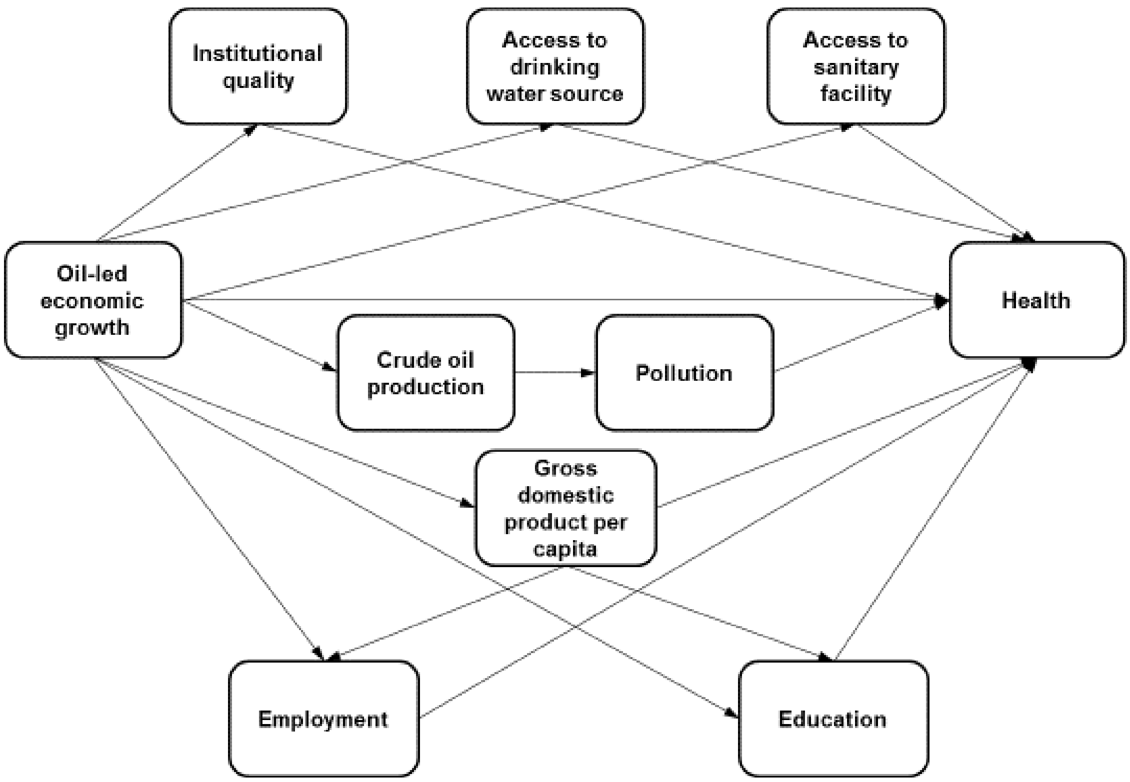
The theoretical framework for this research was based on the views and findings of researchers on the importance of crude oil resources on economic development and health (Karl, 2004; Alexeeva and Conrad, 2009; Cotet and Tsui, 2013).

This research examined the significance of crude oil resources in economic growth and health improvements, through interaction with drivers such as infrastructure, education, institutional quality, employment and environmental consequences of crude oil activities such as pollution.

4.1.2. Conceptual model

In providing an in-depth explanation of the relationship between crude oil resources and health, this research has developed a conceptual model following the of the contributions of Dahlgren and Whitehead (1991) on the determinants of health, as shown in Figure 4.1. The proposed model drew on the socioeconomic and political context of the health determinants described by the Commission on Social Determinants of Health (World Health Organization, 2008). They include governance and policy.

Figure 4.2: Conceptual model exploring the relationship between oil-led economic growth and population health through different pathways



The importance of governance and the quality of national policy in transforming natural resources to national development has been discussed extensively by various researchers (Papyrakis and Gerlagh, 2004; Mehlum et al., 2006b; Van der Ploeg, 2011). Following the varying views on natural resource curse in resource-abundant nations (Sachs and Warner, 1999; 2001; Gylfason et al., 1999; Auty, 2002), an assessment of the role of crude oil resources on economic development became crucial, drawing from the findings and addressing the gaps in previous research.

The conceptual model has an exogenous variables (oil-led economic growth) and nine endogenous variables (institutional quality, gross domestic product per capita, pollution, crude oil production, infrastructure such as access to drinking water sources and access to sanitary facilities, employment, education and health). Endogenous variables are directly influenced by other variables (excluding its disturbance) in the model and exogenous variables influence other variables. The arrows show the direction of the hypothesized relationship between the variables.

The two empirical studies were designed to answer two different research questions. The inconclusive evidence from the review on the impact of crude oil economy on health led to a more robust exploration of the relationship between crude oil resource and population health by me, using a large dataset across a fifteen-year period and controlling for the heterogeneity in the countries in my cross-country analysis by grouping the countries used in the study based on their economic performance. Furthermore, a cross-sectional analysis of the relationship between on oil-led economic growth and population health was done for these countries, giving a view of the economic contribution of crude oil on health outcomes. The second phase is an extension of the phase one study, but with a single country, Nigeria, as a case study. This country is of particular interest to me, as it is an appropriate case for countries with crude oil wealth, currently undergoing demographic transition.

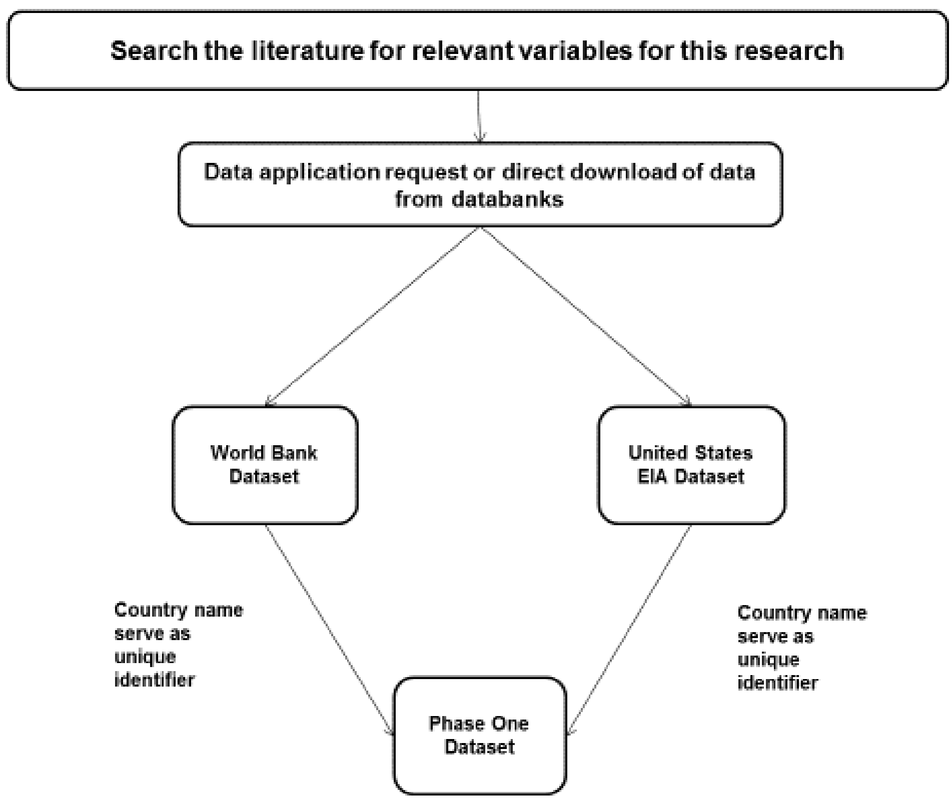
In summary, these models of health and the hypothesis on natural resources curse are synthesized into a conceptual model, making it the most comprehensive model to explore the relationship between crude oil economy and health.

4.2. Method: Phase one study

4.2.1. Data search

A search for databases containing information on crude oil and population health was conducted via google, and a search of relevant publications guided the search for the sources of data (figure 4.3). The World Health Organisation, United Nations, International labour Organisation and the Organisation of Petroleum Exporting Countries' databases were first discovered and explored. These databases did not have information for the period of interest and all the variables of interest. Further search on google scholar pointed towards the World Bank and EIA databases as relevant sources of data. These two databases contained all the information found in the World Health Organisation, United Nations, International labour Organisation and the Organisation of Petroleum Exporting Countries' databases and more, hence the choice of the databases for this study.

Figure 4.3: Flow diagram for data preparation



4.2.2. Data providers

The World Bank Group (The World Bank, 2018b) is a global partnership of five institutions including: the International Bank for Reconstruction and Development; the International Development Association; the International

Finance Corporation; the Multilateral Investment Guarantee Agency; as well as the International Centre for Settlement of Investment Disputes. These institutions have a commitment to reduce poverty, build shared prosperity as well as promote sustainable development. There are over one hundred and eighty member countries, with offices in more than one hundred and thirty locations.

The World Bank presents data that can be accessed on their online databank (http://databank.worldbank.org/data/databases), a collection of time series data, organised and published by different governments and private sectors. The databank provides a platform for selecting and downloading data based on different selections of countries, indicators and time. The World Bank has put together a cross-country development dataset known as the World Development Indicators (WDI). These are grouped under six themes including: people; environment; and economy (The World Bank, 2017). The WDI database consists of over one thousand and four hundred indicators, with some series going back for more than fifty years, for over two hundred countries or economies. Economies represent any area where authorities provide separate social or economic statistics. Another group of indicators is the Worldwide Governance Indicators (WGI) which contain individual and aggregate cross-country indicators grouped under six governance themes: voice and accountability; political stability, absence of violence and terrorism; regulatory quality; government effectiveness; control of corruption; as well as rule of law (The World Bank, 2018c). The WGI database consist of thirty-six indicators going back for about twenty years, covering more than 200 countries (Kaufmann et al., 2011). It highlights governance perceptions from survey respondents, public as well as private sector organisations.

The United States Energy Information Administration (EIA) is an agency in the United States Department of Energy, which collects and collates independent energy data. The data can be assessed online (http://www.eia.gov/beta/international/data/browser) via the EIA platform. These datasets contain information on energy production, consumption, imports, exports, reserves and prices (United States Energy Information Administration, 2018).

The activities of the EIA promote efficient policymaking and markets as well as enhances the public knowledge of energy and its relationship with the economy and environment. These activities include designing surveys, data collection and analysis, producing estimates and projections, dissemination of information, data provision for indicators on energy including petroleum, with some going back about forty years, for more than two hundred countries.

4.2.2.1. Data description

The details of the dataset used in the phase one study are described in this section. This study used longitudinal data from the World Bank's world development and EIA's energy databanks (The World Bank, 2018a; U.S. Department of Energy, 2016). The World Bank dataset contained information about economy, education, environment, health, infrastructure and employment for two hundred and seventeen countries, while the United States energy information administration contained the data on energy, crude oil and petroleum activities for two hundred and thirty countries. Both datasets had missing values and needed to be linked to provide data on health, determinants and oil for each country. Since these data were more likely to be missing for low-income countries than high-income countries, before the year 1995 and 1996 respectively and were missing not at random, it was a concern for analysis, as this is not ignorable. Both multiple imputation and maximum likelihood estimation techniques can only be used for data missing at random or missing completely as random. Imputation of economic data for countries in the low-income group could have resulted in biased parameter estimates. Hence, the use of these large datasets with the inclusion of the selected countries, limited me to the use of data from the year 2000.

The World Bank datafile pertaining to these countries across 16 years and across 15 years from the U.S. EIA datafile, were downloaded. After data linking and data cleaning, it was possible to include one hundred and fifty-six countries in phase one study. Sixty-one countries were then excluded from this study. This was because of lack of sufficient information or information not captured across the study years for the relevant variables on health and health determinants; as well as countries that did not exist as an entity from the year 2000, for example, East Timor-Leste, Montenegro, Serbia, Kosovo and South Sudan (see appendix F for list of excluded countries). Across both datafiles, only 2,496 records pertaining to 156 countries were successfully linked after data cleaning (table 4.1). Both country name and year were used as identifiers in the process of merging of both datasets.

Table 4.1: Data description: cleaned and used data

Datasets	Years	Records	Countries
World Bank	2000-2015	2496	156
U.S. EIA	2000-2015	2496	156

The countries in this study were classified into two groups by me, based on their level of development as measured by each country's previous year gross national income (GNI) per capita. The threshold for these two groups of countries were: the high-income countries with GNI per capita of more than or equal to US$4,125 (94 nations) and the low-income countries with GNI per capita of less than US$4,125 (62 nations). The list for the countries in both income groups is seen in table 4.2.

The classification of these countries in the phase one study was an adaptation of the World Bank's classification of economies. The World Bank (2015b) used GNI per capita values to classify the nations in the world into four groups namely: low-income economies; lower middle-income economies; upper middle-income economies; and high-income economies. GNI represents the total of the value added by all resident producers and it includes the product taxes and the net primary oversees income. This value divided by the midyear population of the nation and converted to U.S. dollars using the World Bank Atlas method, represents GNI per capita (the World Bank, 2015b). The Atlas method of conversion uses the Atlas conversion factor rather than the simple exchange rates to calculate gross national income. This factor minimises the effect of the fluctuations in the exchange rates due to inflation, when comparing national income.

The rationale behind the classification of these countries into two income groups (rather than the four groups by the World bank) in this present study is because the number of countries in the four-income group classification was too small in some groups for group level analysis using our statistical technique. Also, it was more reasonable to describe a country as performing well (as the high-income countries) or performing poorly (as the lower income countries), for the purpose of comparing economic growth.

Table 4.2: Countries listed in each income group

Low-income group (62)	High-income group (94)
Bangladesh, Benin, Bhutan, Bolivia, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Cote d'Ivoire, Egypt, El Salvador, Ethiopia, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, India, Indonesia, Jordan, Kenya, Kyrgyz Republic, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Moldova, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Republic of Yemen, Rwanda, Samoa, Senegal, Sierra Leone, Solomon Islands, Sri Lanka, Tajikistan, Tanzania, Togo, Uganda, Ukraine, Vanuatu, Vietnam, Zambia & Zimbabwe.	Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Barbados, Belarus, Belgium, Belize, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Estonia, Fiji, Finland, France, Georgia, Germany, Greece, Hungary, Iran, Islamic Republic of Iraq, Ireland, Israel, Italy, Jamaica, Japan, Kazakhstan, Kuwait, Latvia, Lebanon, Libya, Lithuania, Luxembourg, Macedonia, Malaysia, Maldives, Malta, Mauritius, Mexico, Namibia, Netherlands, New Zealand, Norway, Oman, Panama, Paraguay, Peru, Poland, Portugal, Qatar, Republic of Korea, Romania, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Sweden, Switzerland, Thailand, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, United Arab Emirates, United Kingdom, United States, Uruguay & Venezuela.

The indicators used in this study were part of the world development indicators gathered from the World Health Organization, United Nations and International Labour Organization (The World Bank, 2017). Data availability, quality and comparability were affected by limited statistical systems in developing nations, variations in statistical methods and poor documentation. Also, the challenges such as inaccurate reporting and differences in information captured in a survey by country data officials and incomplete data coverage influenced data quality. Although the World Bank (2017) has reported that the data were gathered from the most reliable sources and extensive steps were taken to standardise the data, care was taken when using the data for this study, including comparing the estimates with national updates. The estimates given by the World Bank for each country were compared with the figures from other sources including the World Health Organization and United Nations, for the countries.

The United States Energy Information Administration (2018) also reported the use of data gathered from reliable sources which undergo extensive reviews before dissemination. They also used published data generated from the surveys sponsored by them and these surveys takes into consideration the quality of the data generated by controlling for non-sampling and sampling errors through nonresponse analysis, imputation of missing data, and so on (where needed).

4.2.3. Datasets

The key datasets used in this study were summarised in table 4.3.

Table 4.3: Summary of data in the phase one study

Dataset	List of variables	Data description
World Bank databank	Gross national income, gross domestic product per capita, oil rent, life expectancy, infant mortality rate, access to safe drinking water and sanitation services and enrolment in basic education.	Country level data for each variable from the year 2000 to 2015.
United States energy information administration databank	Carbon dioxide emission from consumption of petroleum, crude oil production and exports.	Country level data for each variable from the year 2000 to 2015.

4.2.4. Selection and derivation of variables

The selection of the variables used in this research was guided by the earlier discussion on the theory of demographic and epidemiological transitions, the determinants of health in the Dahlgren and Whitehead model (discussed earlier in chapter one), and also involved looking at the health transition theory (Frenk et al., 1991). Health transition is considered a broader process, whereby variations in the health conditions of a population occurs, owing to the change in demography, technology, policy, culture, environment and socio-economic situation. Simply put, health transition reflects the socio-cultural and behavioural determinants of health (Caldwell, 1993). Therefore, to model and understand the changes in the health outcome of the population in this study, the demographic, environmental, social, economic and political/institutional factors were assessed.

The selection of the variables used in this research was also guided by the variables used in modelling crude oil economy on health by previous studies, as discussed in chapter two (systematic review). It equally depended on the extent of missing data in each variable and was also limited by the variables available in repository of the data providers. The indicators included in this study were drawn from World Bank (2017) and United States Energy Information Administration (2018) and they will be discussed under the following headings:

4.2.4.1. Health indicators and their determinants

The health indicators were life expectancy at birth and infant mortality, while the health determinants were access to drinking water sources and sanitation facilities. Other health indicators were initially considered for inclusion. For example health expenditure was not included in this study as it was not captured for many countries in this study, and Caselli and Michaels (2013) also suggested that health spending translates to little improvements in services and health outcomes, making it not suitable for the purpose of this study. Health adjusted life expectancy (HALE), which represents the healthy years of life that a child at birth is expected to live (World Bank, 2017), was also considered but it was not chosen because this information for the selected countries was only available for a shorter duration. The other determinant of health that was considered was "access to health care services" but again, this was not chosen because it was only available for a shorter duration.

As described by World Bank (2017), life expectancy at birth represents the average number of years a new-born would live for, as determined by the mortality patterns at the period in which they were born. Infant mortality rate refers to the number of infants that die before they reach one year of age (per one thousand live births) in a specified year. Access to safe sanitation and drinking services as well as health expenditure reflect the quality of life provided for the population. Access to safe sanitation refers to the proportion of the population that have access to improved sanitary facilities that will ensure safe disposal of the sanitary waste into sources compatible with human and environmental health. Access to safe drinking water refers to the proportion of the population that have access to improved water sources, safe for human consumption.

4.2.4.2. Economic indicators

Gross national income and gross domestic product per capita were initially considered for inclusion as major economic indicators in this study, but only gross domestic product per capita was included because it is a metric that sufficiently captures the level of production in a nation's economy, excluding the input from foreign investments. The other economic indicators were employment to population ratio and enrolment in basic education.

As described by World Bank (2017), gross domestic product per capita refers to the total value of goods made, and services provided in a country per annum. Employment to population ratio describes the percentage of people in a country that are employed compared to the total population in the country. Enrolment in basic education represents the total enrolment ratio (irrespective of age) to the population of the age group that corresponds to secondary education.

4.2.4.3. Environmental indicator

This was represented by carbon dioxide emission and was the only available environmental indicator associated with crude oil activity. It refers to the amount of carbon dioxide emitted from the consumption of petroleum (United States Energy Information Administration, 2018).

4.2.4.4. Crude oil resource indicator

These include crude oil production, crude oil export and oil rent contribution to GDP. As described by the United States Energy Information Administration (2018), crude oil production refers to the barrels of crude oil produced each day in a country while crude oil export (net) refers to the barrels of crude oil and lease condensate exported each day in a country (excluding all crude oil imports). Oil rent contribution to GDP describes the profit which is made from the actual national cost and world value of crude oil production that contributes to the gross domestic product of a nation United States Energy Information Administration (2018).

In the phase one study, a measure of "oil-led economic growth" was derived by me, by calculating the percentage growth of oil rent contribution to GDP or crude oil export, between the year 2000 and 2015, in each country.

4.2.4.5. Institutional quality indicator

Worldwide governance indicators (WGI) were adopted as measures of institutional quality because they are the broadest and most comprehensive measures that show the differences in governance and related activities, for a large number of countries. They are grouped under six governance themes: voice and accountability; political stability, absence of violence and terrorism; regulatory quality; government effectiveness; control of corruption; and rule of law (The World Bank, 2018c; Kaufmann et al., 2011). In the context of this thesis, Institutional quality represented the government's ability to develop and execute effective policies which will promote national growth. An index was derived by me, from an aggregate of three individual indicators (government effectiveness, corruption control and rule of law) chosen from the World Bank dataset, with a score ranging from -2.5 to 2.5 (The World Bank, 2018a). Government effectiveness represented views on the quality of services offered to the public, policy formulation and execution as well as how much it is independent of pressures from political involvements; corruption control represented views on how much public power and resources are used for personal gain; and rule of law described the views on how much agents trust in and obey the laws of the society. Though the six WGI measured related concepts on governance, only these three indicators were selected for this thesis because they capture the political environment and governance structure in a country (Akanni, 2007; Apaza, 2009). The other three dimensions of governance (voice and accountability; political stability and absence of violence; and regulatory quality) capture democracy, fairness and conflict which, for the purpose of this study, were excluded.

The reliability of these indicators was demonstrated by Langbein and Knack (2010) as they assessed the ability of these indicators to fit the model of measurement on effective governance. There are a lot of critiques on the validity of these indicators (Apaza, 2009), questioning the creation of aggregated indicators from individual factors obtained from different sources for different countries and periods, transparency and access to the different sources of data and the influences on these indicators by the level of development in each country. Kaufmann et al (2007) argued against these critiques as they demonstrated that the aggregation of the constructs used to create the indicators makes it possible to place very different sources data sources into common units, thereby comparing governance in these countries. Also, they used regression models to demonstrate that governance indicators for almost all countries did not correlated with economic indicators.

4.2.5. Ethics

The College of Medical, Veterinary and Life Sciences in the University of Glasgow had confirmed that ethics approval was not required for the use of data in this study or for this thesis. This is because no individual identifiable data were found in any of the datasets and the data were publicly available. The ethical considerations for access to each dataset varied across the data providers. The data used in this study were obtained from the different data providers by either data application request to the providers or directly by downloading the information from the databank.

4.2.5.1. Ethical consideration and data usage agreement

All the data used in this research were from unrestricted sources. The application for data access was done by me. All the data agreement procedures and data usage criteria were strictly adhered to by me. Based on their providers, the following data usage agreement accompanied this study (table 4.4).

Table 4.4: Summary of data and ethics for phase one study

Dataset	Data restrictions	Data availability and usage
World Bank dataset	The data are made available to the public with the exception of the information on personal information, confidential information provided by its member countries, information on security and finance. The data used in the research were obtained from the unrestricted group of information.	Most data can be accessed through the World Bank website but information that is unavailable on the website can be obtained by submitting a request to the World Bank, detailing the information needed.
United States Energy Information Administration (U.S.EIA) dataset	The data from the United States Energy Information Administration are open to the public and are not subject to copyright protection.	These data can be used and disseminated to others. All data should be properly acknowledged using its publication date and source.

4.2.6. Data preparation and cleaning

The data were cleaned by the providers but also screened for any missing values or errors by me. There were missing values in all the datasets. Before analyses were carried out, the data from the two different sources were merged to create the final datasets (as shown in figure 4.3). Data preparation and cleaning was done in Stata MP/14.1 (StataCorp, 2015).

4.2.6.1. Data Quality

Strict monitoring of data collection and documentation was carried out by each data provider, to ensure the provision of good quality data. The errors detected in the datasets were resolved by reviewing the parent data, especially when there was error in data entry or an update on published data.

4.2.6.2. Merging of datasets

A flow diagram of the steps involved in the data preparation is shown in figure 4.3. Merging of datasets involves matching the key variables in both data files and combining corresponding observations from the master file with the using file (Mitchell, 2010). The type of merging process used for the datasets in phase one and two studies is the many-to-one merge.

In this study, the two datasets were merged using “country name” as the key variable.

4.2.6.3. Details of the final dataset

The final dataset contained longitudinal data from 156 countries. The total rate of missingness was 5.0% for all the variables and listwise deletion of the observations with missing values would reduce this sample size. Since the extent of missingness is substantial, imputed data was used for our analyses.

4.2.7. Data limitation and missing data

Missing data in this study refer to data that were not available in each databank, either because they were not available at the country-level or were omitted because they were too small or not reported. The percentage of missing data affects the quality of the results generated from a statistical analysis. Missing data of more than 10% of the total information cannot be handled using deletion of the missing information as this percentage of missing data would result in substantial reduction in statistical power (Bennett, 2001; Little and Rubin, 2002). Most importantly, is the pattern of missingness discussed in the next section. In order to prevent loss of information and bias (Allison, 2001; Barnard and Meng, 1999), an appropriate imputation strategy must be used to create a realistic representation of the modelled association.

4.2.7.1. Missing data mechanism

The pattern of missing data affects the results produced from the modelling of the missing data (Little and Rubin, 2002). There are three main missing data mechanisms (Rubin, 2004; Little and Rubin, 2014). In missing at random (MAR), the missing data mechanism depends on the observed data but not dependent on the unobserved data while missing completely at random (MCAR) describes a missing data mechanism that does not depend on observed or unobserved data (Stata, 2013b; Schafer & Graham 2002). Hence, when imputing missing data, the assumption of MCAR or MAR should hold as these patterns yield consistent results with most imputation methods. On the other hand, missing not at random (MNAR) data could result in biased parameter estimates (Graham, 2009). In MNAR, the missing data mechanism is dependent on the unobserved data. Therefore, this pattern cannot be ignored when imputing missing data because the information on the missing data itself needs to be included when treating the missing data.

The data in this study were missing at random. The probability that the data are missing is dependent on observed data. Exclusion of the missing cases from the analyses will lead to a small reduction in sample size. However, appropriate analyses were conducted to handle the missing data.

The data in the phase one study were missing across both countries and years. It is not possible to test if the missing data mechanism in an observed data is 'missing at random' as the information needed to do this is missing. It was assumed that the data in the phase one study were missing at random because other variables in the dataset could be used to predict the missing data pattern. For example, data on pollution had missing values, not for a whole country but randomly in some years for some countries and the missing values for pollution were related to values of variables such as crude oil production and crude oil export; the missing values of enrolment in basic education were related to values of institutional quality.

4.2.7.2. Treatment of missing data

Missing data is common in research data and it had previously been dealt with by the list-wise deletion or complete case analysis (Allison 2001; Little and Rubin, 2014). This leads to a reduction in sample size as well as statistical power. Also, exclusion of variables with large proportions of missing values from the analysis may lead to the loss of relevant factors in the analysis, introducing either bias or large standard errors.

Weighting methods can also be used to treat missing predictor data (Carpenter et al. 2006). A model is fitted for the probability of missingness and their inverse values are used as weights for the non-missing cases. However, estimations using this method were not considered for treating missing data in this research as it is less manageable for multiple missing variables than for a single missing variable, considerably so when they are non-monotone.

Recently, missing data has been treated using the maximum likelihood estimation method (Little and Rubin, 2014) which estimates the parameter in the model using the available data and can only handle missing values on the response variable; or multiple imputation method (Rubin, 2004) which fills in the missing data from a distribution and pooled parameter estimates from the model(s) are produced. Multiple imputation can impute both predictors and response variables. These two statistical techniques require the assumption that the data is missing at random (MAR) or missing completely at random (MCAR) (Schumacker and Lomax, 2004; Stata, 2013b). The techniques are flexible and generate more accurate standard errors than other methods (Tomarken and Waller, 2005). SEM can handle missing data by list-wise deletion or imputation. Since list-wise deletion leads to loss of cases/observations, an imputation method known as the maximum likelihood estimation was used. This is the most commonly used estimation algorithm in SEM used for replacing missing values and it allows SEM to retain all the cases/observations in the dataset (Kline, 2015). Hence, the missing data in phase one study was handled using this technique. Since the assumption of MAR holds in the phase one dataset, the patterns will yield consistent results with SEM maximum likelihood estimation method.

4.2.8. Empirical model: phase one

A structural equation model with path analysis (Kline, 2015) was developed to explore the relationship between crude oil economy and health. Path analysis is the application of structural equation modelling (SEM) with only observed variables. Furthermore, this research model is recursive as all the connections and paths run in one direction and no variable feeds back to itself (Duncan, 1975). This structural equation model was subjected to several interactions where the direction of each path between the variables was assessed.

A panel analysis was used to analyse the effect of crude oil resources on health outcomes over time. Dynamic panel (or cross lagged panel) models were fitted, where the effect of the dependent variable is lagged on itself. The dependent and independent variables at time, T1 affects the dependent variables at time T2 and so on. In Stata, the specification of these models was simplified with the "xtdpdml" command. This command was used to fit dynamic panel data models using maximum likelihood estimation technique. It allowed for the inclusion of time-invariant variables in the model and used full information maximum likelihood (or maximum likelihood estimation with missing values, MLMV) to deal with missing data. The xtdpdml models assume that variables have a multivariate normal distribution for maximum likelihood to be efficient (Moral-Benito 2013). When this assumption is violated, like in this study, inconsistent estimates of the standard errors, and consequently incorrect p values and confidence intervals will be produced. To relax the normality assumption, the quasi-maximum likelihood estimation is used. Here, the VCE (robust) option is specified with MLMV. The data include measures of health (infant mortality and life expectancy at birth), health determinants (access to basic drinking water and basic sanitary facility), crude oil resources (oil rent contribution to GDP), employment to population ratio, institutional quality, crude oil production, air pollution and enrolment in basic education, for a sample of 156 countries. Each country is observed from the year 2000 to 2015 and the variables are observed at a five-year interval, producing four time points (on the year 2000, 2005, 2010 and 2015). However, the panel is not balanced, with varying number of observations for each country, due to missing data. The lag value of health or health determinant at time 1 is included in all the models. This value along with exogenous time-variant predictors and time-invariant variables are displayed on all the tables. To allow for the control of all known and unknown time-invariant unmeasured variables, that influence the dependent variable, random effect models were used in this assessment. This type of model assumes that the time-invariant variables that are omitted, are not correlated with the included time-variant covariates, unlike fixed effect models that allows correlation of these variables (Bollen and Brand, 2010). They also have greater efficiency to detect effects than fixed effect model, as it produces smaller standard errors and higher statistical power.

The relationship between oil-led economic growth and population health was explored using cross-sectional models. The cross-sectional analysis included 2015 data for the following variables: employment to population ratio, GDP per capita, infant mortality rate, people with basic drinking water sources, people with basic sanitary facilities, institutional quality, crude oil production, life expectancy at birth, pollution, enrolment in basic education. It also included a fifteen-year (2000-2015) percentage growth in oil rent contribution to GDP. Oil-led economic growth was measured by the change in oil rent contribution to GDP but to ascertain that this measure was robust, all models were alternatively fitted with a fifteen-year (2000-2015) percentage growth in crude oil export (as reported in the appendices).

Eleven observed variables were used to explore this relationship in phase one study. These models had structural paths between the observed variables.

4.2.8.1. Observed variables

The observed variables modelled in this research were: employment to population ratio (employment), Gross Domestic Product, crude oil production (oil production), crude oil export (oil export), carbon dioxide emission from petroleum consumption (pollution), oil rent contribution to GDP (oil rent), enrolment in basic education (education) and institutional quality. Institutional quality was represented by the unweighted average of three institutional indexes: government effectiveness; corruption control; and rule of law. This index runs from negative to positive values, where negative values represent poor institutions and positive values represent good institutions.

As discussed, life expectancy and infant mortality rates were used as the measures of health for this research. Note that high values of life expectancy in a population signify better health, but so do low values of mortality rates in a population signify better health. Access to drinking water sources and access to sanitary facilities were used as the measures of health determinants.

All the observed variables were ecological in that they represented the values for each country.

4.2.8.2. Structural Equation Modelling (SEM)

Structural equation modelling was used for data analysis in the phase one study as it is a multivariate technique that evaluates the relationship between variables, even for variables that were not directly observed or measured (Stata, 2013b). Hence, this technique was chosen over other methods of assessing relationships that exist between variables because it can assess both direct associations between variables and indirect effects mediated via another variable as well as create theoretical constructs from real variables present in this research dataset (though not applicable in this study). It simultaneously puts both the measurement and structural components into a statistical analysis. However, phase one study focused on analysing the structural models, which can be done independent of the measurement model.

Structural equation modelling is able to simultaneously assess several structures of regression equations such as single or multiple linear equations, when compared with ordinary regression (Nachtigall et al., 2003). It also integrates other techniques such as correlation, factor analysis, analysis of variance etc. Furthermore, SEM has been equipped with the technique to handle missing data. However, SEM is not without its demerits. It requires a large sample size and in most cases the assumption of joint multivariate normality.

Initially, methods such as correlation, linear regression and multilevel modelling were considered as techniques needed for this research. However, correlation and linear regression does not allow for simultaneous analysis of the association between the constructs in this research model as analysis has to be carried out separately and in sequence (Lani, 2009). Unlike SEM, they do not efficiently support the analysis of missing and non-normal data (Alavifar et al., 2012). Similarly, multilevel modelling has its advantages in efficiently modelling nested data, but it was not chosen for this research as SEM efficiently models relationships that exist within measurement variables in a latent variable (Curran, 2003). Furthermore, SEM allows for testing of mediation via the breakdown of total effects into direct and indirect effects, but multilevel modelling technique uses a slower and multi-step alternative for testing mediational interactions.

To explore the hypothesised relationships, the statistical techniques used were descriptive analysis and structural path analyses. A descriptive analysis was used to give a summary of the two groups of economies discussed in this study, as shown in result sections. These tables provided the percentage of missing values in each variable, mean, standard deviation and the range for each variable. Correlational analyses were also done to determine the extent to which a variable can be predicted by other variables (multicollinearity). Structural path analysis assessed the effect of the independent variables on the dependent variables. Fit statistics determined how well the hypothesised model in this study fitted the data.

Owing to the violation of multivariate normality and the data that are missing at random in this study, the quasimaximum likelihood estimation method (the robust calculation of variance–covariance matrix of the estimators, VCE, with maximum likelihood estimation) was used to fit the models, to produce standard errors that are valid under this relaxed normality assumptions. This technique deals with missing data by retrieving as much information as possible from the missing data without deletion of the cases with missing data.

4.2.8.2.1. Processes of structural equation modelling

To obtain a structural equation model, a sequence of five major processes is conducted (Schumacker and Lomax, 2004, Kline, 2015). They include:

Model specification involves the development of a theoretical model from research theories and information. Previous research theories guide the inclusion of relevant variables in the implied theoretical model, as inconsistencies between the true model that generated the data and the implied theoretical model shows misspecification of theoretical model. This may be as a result of inclusion of irrelevant and/or omission of relevant variables or parameters, which leads to biased parameter estimates (specification error).

Model identification is an important step in the construction of a structural equation model as it assesses whether a unique set of parameter estimates can be calculated. There are three levels of model identification. They are under-identification, just-identification and over-identification. Models with any of the latter two identifications described as identified. Under-identified models cannot be estimated, so they have to be modified by imposing additional constraints in the specified model.

Model estimation refers to the methods used to estimate parameters in a structural equation model. They include ordinary least squares (OLS), generalized least squares (GLS), maximum likelihood (ML) and asymptotic distribution free (ADF). OLS method is scale dependent as changes in the scale of the observed variable produce different estimates and this method does not depend on any distributional assumption. In GLS and ML methods, a large sample and the assumption of multivariate normality of the observed variables is required. The ADF method requires large sample size, but not the assumption of normality. However, the ML method is more robust under violation of normality assumption using Monte Carlo experiment.

Model testing shows how well the data fits the model after parameter have been estimated. This involves examining the fit of the whole model and the fit of each parameter in the model. Most model fit measures compare the implied model covariance matrix to the sample covariance matrix, to show that the data fits the theoretical model. Based on this overall model fit, a final model can be chosen. Measures of parameter fit are used to ensure that the free parameters are significantly different from zero, the sign of a parameter is similar to that expected from the theoretical model and the parameter estimates fall within an expected range.

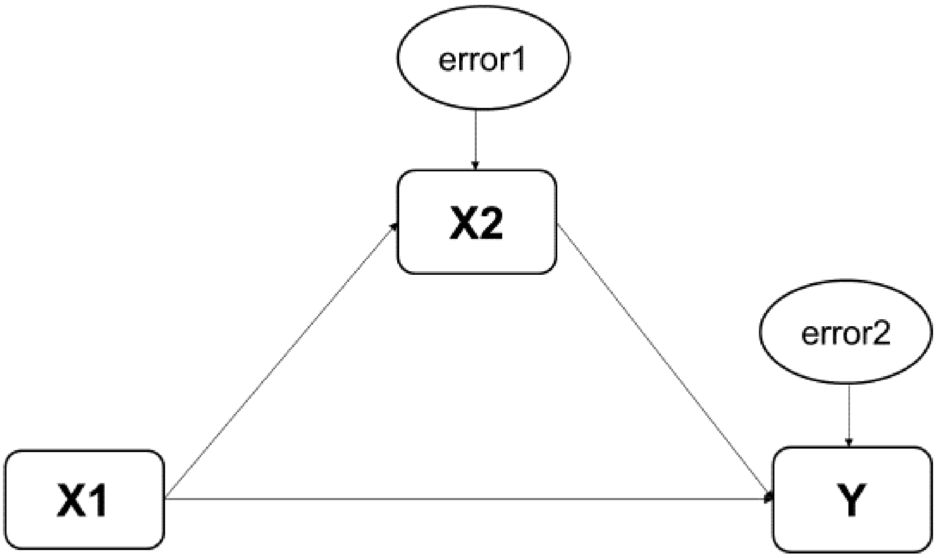
Model modification is required when the fit of the model is not strong. Here, a modification of the initial model is conducted, followed by an evaluation of the revised model to establish that the data fits the model. The detection of specification errors will determine how a model will be modified and model specification can be changed by adding a variable, putting constraints on parameters or changing estimation methods.

4.2.8.2.2. Model interpretation

Structural equation modelling can yield three types of effects based on the relationship between the variables (figure 4.5). They include direct effect where X1 has a direct influence on Y (X1 → Y); indirect effect where X1 influences Y through X2 (X1 → X2 → Y); and a total effect which is the combination of the direct and indirect effects.

A structural equation model can take into account both the direct and indirect effects. The total effects can be disintegrated into direct and indirect effects between exogenous variables and endogenous variable. Direct effect shows the unidirectional relationship between two variables and the indirect effect shows the effect of a variable on another, through one or more mediators.

Figure 4.5: Direct, indirect and total effects of independent variable (X1) on dependent variable (Y)



Note: Total effect of X1 on Y is disintegrated into direct effect (X1 → Y) and indirect effect (X1 → X2 → Y).

4.2.8.2.3. The structure of the model

The most common full information estimator is the maximum likelihood (ML) estimator and this was the estimator used in this study. The ML fitting function in structural equation model (equation 4.1) is as follows:

$$
\begin{aligned}
F_{ML} &= \ln|\Sigma(\theta)| = \ln|S| + \mathrm{tr}[\Sigma^{\,1}(\theta)S] \\
&= P_z + (z - \mu(\theta))'\Sigma^{\,1}(\theta)(\bar{z} - \mu(\theta)) \qquad (4.1)
\end{aligned}
$$

Where S is the matrix of the sample covariance and $\bar{z}$ represents the vector of the sample means while P_z is the number of the observed variables and ln represents natural log. $|\cdot|$ is the determinant and tr represents the trace of a matrix. $\hat{\theta}$ is the ML estimator which is chosen as it minimises F_{ML}.

4.2.8.2.4. Model building approach

Model building highlights the analysis of two conceptual models (Anderson and Gerbing, 1988) namely: the measurement model which illustrates the relationships between the observed variables and their posited latent variables; and the structural model which illustrates the relationships among the variables, based on the hypothesis.

No latent variables were included in this study, therefore only the structural models were tested. The testing of the structural model involves testing of this research hypotheses. Significant results obtained from the structural model are used to demonstrate the existence of a relationship between the variables of interest.

4.2.8.2.5. Assumptions for structural equation modelling

The assumptions for SEM guided the choice of statistical technique used for this research. The major assumptions of SEM are that there is a large sample size and multivariate normality. Furthermore, correct model specification is required for reliable estimations.

4.2.8.2.5.1. Sample size

Generally, a sample size of 100 or more is recommended when using maximum likelihood estimation method (Hoyle 1995). In addition, several suggestions have been made by different researchers. In 2003, Jackson recommended the C:p rule which has empirical support and shows a relationship between sample size and model complexity, where C is the number of cases and p is the parameter estimates. For a reliable result, an ideal ratio of 20:1 is required (Jackson, 2003; Kline, 2015). However, Nachtigall et al. (2003) suggested a minimum of ten times the number of estimated parameters as the sample size adequate for a stable and accurate model.

In the case of the asymptotic distribution-free estimation method (ADF), a larger sample size is required for an accurate result and it has been suggested that simple models require sample size of 200–500 observations and thousands of observations may be required for complex models (Kline, 2015).

Consequently, the MLMV method was chosen for this research in other to accommodate the sample size and retain the observations with missing data. Based on these recommendations for adequate sample size, the sample size of over one hundred and fifty observations, used in this study met the requirement for SEM.

4.2.8.2.5.2. Multivariate normality

The variables used in this research did not meet the assumption of normality needed for ML method. Therefore, an alternative calculation for the variance–covariance matrix of the estimators known as VCE (robust) was specified to provide standard errors that are robust against non-normality (Kline, 2015).

The assumption for univariate normality and/or multivariate normality is violated when the p-values for these tests are less than 0.05 at 5% significance level (Stata, 2013a). The results for skewness, kurtosis and joint univariate test were used to access the univariate test for normality. Henze-Zirkler consistent test, Doornik-Hansen omnibus tests, Mardia's measure of multivariate skewness and kurtosis were the multivariate tests of normality reported in this research.

In the case where the assumption of multivariate normality is violated, the quasimaximum likelihood estimation method will be used to fit the structural equation models. It fits the model parameters with maximum likelihood but relaxes the joint normality assumption. It does this by adjusting the standard errors.

4.2.8.2.5.3. Correct model specification

The models should be correctly specified by including only relevant variables that will explain the hypothesised relationship. A model that is specified correctly should have a good fit.

4.2.8.2.6. Goodness of Fit Test

Goodness of fit indices determine the degree of model fit and more than one indicator of goodness should be used to confirm that a model fits the data (Kline, 2015). There are two major groups of goodness of fit indices: absolute fit and incremental fit indices (Hooper et al, 2008). Absolute fit indices determine the degree to which the model fits the data and shows the model with the best fit. The indices include chi-square (χ^2) test, goodness of fit index, root mean square residual, standardised root mean square residual and root mean square error of approximation. The Incremental fit indices (includes normed fit index and comparative fit index). Another category of fit indices is the parsimony fit indices (Hooper et al, 2008), which compares values in alternative models and include parsimonious fit index, Akaike information criterion and Bayesian information criterion. A summary of the goodness of fit Indices and their recommended threshold is shown in table 4.5 (Schumacker and Lomax, 2004; Hooper et al, 2008). Coefficient of determination also provides a measure of how well the data fit the model (Renaud and Victoria-Feser, 2010).

The models used in the phase one study were compared using Akaike's information criterion (AIC) and Bayesian information criterion (BIC). The coefficient of determination was another goodness of fit statistic that was valid for these models. Chi-squared and other dependent statistics were not valid because of the quasi-likelihood estimation technique used to fit the models and the standardized root mean residuals were also not valid because of missing values.

4.2.8.2.7. Statistical software

Stata MP/14.1 (StataCorp, 2015) was used in this study for data handling and analysis.

Table 4.5: Description of the goodness of fit Indices and their recommended thresholds

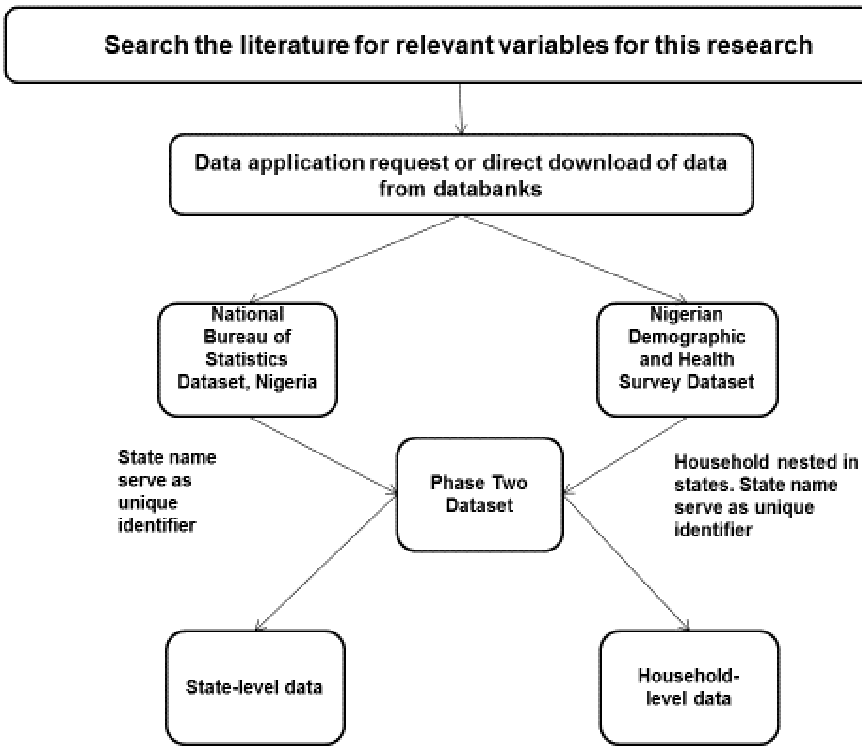
	Fit statistics	Recommended threshold	Range of value
1	Chi-square test	Insignificant result at a 0.05 threshold (p > 0.05)	Tabled chi-square
2	Goodness of fit index	Value close to 0.95 (0 = no fit, 1 = perfect fit)	0 to 1
3	Coefficient of determination	Value of 1 indicates perfect fit to data	Normally 0 to 1
4	Root mean square residual	Value define by researcher	Based on scale of indicator
5	Standardised root mean square residual	Value less than 0.05	0 to 1
6	Root mean square error of approximation	Value less than 0.05	0 to 1
7	Normed fit index	Value close to 0.95 (0 = no fit, 1 = perfect fit)	0 to 1
8	Comparative fit index	Value close to 0.95 (0 = no fit, 1 = perfect fit)	0 to 1
9	Parsimonious fit index	Value compared to alternative models (0 = no fit, 1 = perfect fit)	0 to 1
10	Akaike information criterion	Lower values indicate better fit	Negative to positive values
11	Bayesian information criterion	Same as AIC	Same as AIC

4.3. Method: Phase two study

4.3.1. Data search

Like in the phase one study, a search for the databases containing information on population health and crude oil in Nigeria was conducted via google, and a search of relevant publications guided the search for the sources of data (figure 4.6). The National Bureau of Statistics in Nigeria (NBS); the Nigerian Demographic and Health Survey (NDHS); and the Central Bank of Nigeria were first discovered and explored. The Central Bank of Nigeria did not have information for the period of interest and all the variables of interest, hence the choice of NBS and NDHS.

Figure 4.6: Flow diagram for data preparation



4.3.2. Data providers

The data used for this study were obtained from two organisations: the Demographic and Health Surveys Program and the National Bureau of Statistics in Nigeria.

The Demographic and Health Surveys Program has provided technical support to over three hundred surveys in more than ninety countries for the past thirty-four years (The Demographic and Health Surveys Program, 2018). The program has collected and disseminated nationally representative data on themes such as health, disease, nutrition and environment. Information on these subjects can be retrieved by downloading the available data for various countries including Nigeria (https://dhsprogram.com/data/available-datasets.cfm).

The program implements various surveys such as the Demographic and Health Surveys and Service Provision Assessment surveys and is carried out by Inner City Fund (ICF) International and partners Blue Raster, Avenir Health, the Johns Hopkins Bloomberg School of Public Health Center for Communication Programs, Program for Appropriate Technology in Health, Vysnova, EnCompass and Kimetrica. The surveys are also supported by contributions from other donors and funds from participating countries. The DHS Program is funded by the United States Agency for International Development.

The National Bureau of Statistics (NBS) was created from the merger between the Federal Office of Statistics and the National Data Bank in Nigeria. This made NBS the primary statistical agency for all the tiers of Government in Nigeria (National Bureau of Statistics, 2018). It collates and disseminates data for the 36 states and one federal capital territory in Nigeria, as far back as the year 1981. The NBS Data Portal contains data on health, household, demographics and socioeconomic indicators. Data were retrieved from publications available online (http://www.nigerianstat.gov.ng/elibrary).

4.3.3. Data description

The phase two study used cross-sectional data from the annual abstract of statistics, federal account allocation committee report and the Nigerian Demographic and Health Survey (NDHS). There were 38,522 households included in this study and they were nested in thirty-seven states/federal capital territory in Nigeria. NDHS is the largest database which provides household-level data on demographics, infrastructure and health indicators in Nigeria. The annual abstract of statistics provides state-level information on crude oil revenue and employment in Nigeria while the federal account allocation committee (FAAC) report contains information on the allocation of revenues in Nigeria. A summary of the data collection and research methodology for these data sources are given below but further details can be found in the research manuals for both data sources (National Bureau of Statistics, 2012; National Bureau of Statistics, 2014; National Population Commission and Inner City Fund International, 2014).

4.3.3.1.1. Nigeria Demographic and Health Survey

The Nigeria demographic and health survey is a nationally representative survey conducted in Nigeria as part of the programmes of the Demographic and Health Surveys. The 1990, 2003, 2008 and 2013 NDHS datasets were explored. The 1999 NDHS dataset was not available on the survey site. The 2003 and 2008 datasets did not contain information on health variables such as number of household deaths, thus was not considered for inclusion. The variables needed for this study were obtained from the 2013 NDHS dataset. The 2013 NDHS is the fifth demographic and health survey in Nigeria and was conducted by the National Population Commission. The survey provided household-level data on the demographics, infrastructure and health indicators in Nigeria, which was used in this study.

The 2013 NDHS included people living in non-institutionalised residence in Nigeria. The target population was women and men in Nigeria who were 15 to 49 years old as well as children in the age range of 1 month to 5 years old. The survey provides estimates on key indicators at national level; for the six geo-political zones; 36 states and Federal Capital Territory. The sampling frame was from a list of areas made for the 2006 Nigerian Population Census. The survey samples were selected using a stratified design consisting of 904 clusters (National Population Commission and Inner City Fund International, 2014). Documentation and mapping of households for each cluster were conducted between December 2012 and January 2013.

The 2013 NDHS was conducted by the NPC and ICF International, with a household response rate of 99%. 40,320 households were selected from 896 sampling locations. 38,904 households were occupied at the time of the data collection and 38,522 households were successfully interviewed. In these households, 98% of the 39,902 eligible women successfully interviewed while 95% of the 18,229 eligible men were successfully interviewed. The household response rates were slightly less in urban residence (98.7%) than in rural residence (99.3%).

4.3.1.2.2. Annual Abstract of Statistics and Federal Account Allocation Committee Report

While collating data on oil production, from the inception of oil exploration in late 1950s to date was initially considered, the paucity of data in Nigeria posed a great challenge. The only available data published by the Nigerian Government were the annual abstract of statistics and federal account allocation committee report. Data from the annual abstract of statistics (2010; 2011; 2012) were examined. The 2012 abstract of statistics was chosen as it contains the information included in the 2010 and 2011 abstracts and more. The 2012 abstract of statistics holds information on all the sectors in the Nigerian economy and was compiled by the National Bureau of Statistics. The data included in this abstract were not completely suitable for this study as the information on each variable were from different sources and era. The sources of data included the annual abstract of statistics included administrative records, surveys and censuses. These data may be subject to errors emanating from reporting errors, incomplete coverage and non-response. Although, the data included in the abstracts were labelled as authenticated by the National Bureau of Statistics, the steps taken by them to do so were not published. Emails and phone calls were placed to the National Bureau of Statistics to manually extract more data for specific years which were reported to be available in their repository, and subsequently a visit to the bureau's headquarters to obtain access to these data yielded no successful outcome. The data requests to the bureau were not acknowledged or responded to. Therefore, we could only extract some state-level variables from 2007 to 2011.

Therefore, the FAAC reports which holds information on the federal allocation of revenues accrued to Nigeria, to all tiers of government in the country, were explored. These reports are from the National Bureau of Statistics and Office of The Accountant General of The Federation (National Bureau of Statistics, 2014). The data used in this study was from the 2013 monthly federal account allocation committee report.

4.3.4. Datasets

The key datasets used in this study are summarised in tables 4.6.

Table 4.6: Summary of data in the phase two study

Dataset	List of variables	Data description
Nigerian Demographic and Health Survey	Wealth index, access to sanitary facilities, access to drinking water, number of household deaths, residential place, age of household head, sex of household head and educational attainment of household head.	Household data for the year 2013. These surveys are nationally representative population-based surveys.
Annual abstract of statistics, Nigeria	Crude oil revenue	State level data for the variables. Crude oil revenue was reported for the year 2003.
The Federal Account Allocation Committee Report, Nigeria	Crude oil revenue	The state level allocation of crude oil revenue for the year 2013

4.3.5. Selection and derivation of variables

This section contains details of all the variables included in phase two. In this segment, the data are nested (household nested in state), hence, this is a multilevel data. The data are discussed in the two categories: household- and state-level data.

4.3.5.1. Household-level variables

In this study, a household was defined as a person or group of people, living together in the same residence with one adult member recognised as the head of the household. Household-level or level-one variables were obtained from the annual abstract of statistics and NDHS (National Bureau of Statistics, 2012; National Population Commission and Inner City Fund International, 2014) and they include wealth index, access to sanitary facilities, access to drinking water, number of household deaths, residential place, age of household head, sex of household head and educational attainment of household head.

4.3.5.1.1. Wealth index

This is an indication of household economic position. The wealth index was created using household asset data (National Population Commission and Inner City Fund International, 2014). Firstly, a subset of indicators peculiar to urban and rural residences such as access to electricity and ownership of certain consumer goods, is used to create household wealth scores. The indicators are then assessed using a principal components analysis and a common factor score is produced for each household. Secondly, area-specific indicators are used to produce different factor scores for households in urban and rural areas. Thirdly, a nationally applicable index is then produced by adjusting area-specific scores. The computed wealth index is used to assign household scores to each person usually resident in the household. This score ranks each *person* in the population and the ranks are divided into five equal groups, each representing a fifth of the population. Twenty two percent of the households are in the highest wealth quintile while fifteen percent are in the lowest wealth quintile. No household had missing information for this variable. The unequal distribution of the households in each quintile is because this index is nationally calculated and assigned to each household *member* in Nigeria, with only a representative fraction of the households in Nigeria included in the dataset from the Nigerian demographic and health survey, hence the percentages will not be 20% across all quintiles. This variable was kept in an ordinal format but recategorised into three groups.

4.3.5.1.2. Access to sanitary facilities

Households with sanitary facilities whose method of disposal prevents the waste from coming in contact with humans and is also used by only household members, are said to have 'improved sanitary facilities' (WHO and UNICEF, 2010). However, the information on shared facilities was provided for about sixty nine percent of the households, making it difficult to accurately produce household information for improved sanitary facility. Therefore, the information on the *type* of sanitary facilities available, rather than their quality, was used. The sanitary facilities were grouped into the following sets: safely disposed and poorly disposed flush toilet; open/protected pit latrine; composting toilet; bucket toilet; hanging toilet/latrine; unspecified group; and no facility. This variable was originally an unordered categorical variable and some categories had as few as nine households, compelling re-grouping of this variable. A new category was created based on the type of sanitary facility and method of waste disposal. Its categories were: flushed toilet, pit toilet, bucket/composting toilet and no facility. This final variable is a nominal variable, where flushed toilet is the best sanitary facility.

4.3.5.1.3. Access to drinking water sources

Access to drinking water is best described using information relevant to improved source of drinking water in a household. An improved source of water is a source that provides water that is suitable for drinking (WHO and UNICEF, 2010). The improved water sources were piped water within the residence, public tap/stand pipe/borehole, protected well/spring, bottled water and rainwater. The non-improved water sources include unprotected well/spring, streams/lakes, tanker truck, cart with small tank, sachet water and unspecified group. This variable was originally an unordered categorical variable and some categories have as few as thirty-three households. As with access to sanitary facilities, the variable was re-grouped and re-coded. The new categories were: piped water; well water; open water; and tanker/packaged water sources. This final variable is a nominal variable, where piped/well water is the best source of drinking water.

4.3.5.1.4. Number of household deaths

This refers to the number of people in a household that died in the last 12 months before survey. In this survey, a household is typically made up of between one to forty-three members, but the maximum number of deaths recorded per household was six in the last twelve months before the survey. This variable is a count variable and was kept in its original format. About ninety five percent of the households did not have any deaths in the last twelve months before the survey while two households had between four and six deaths.

4.3.5.1.5. Residential place

The place of residence for each household was recorded as a binary variable. It could be an urban or rural residence. This variable was kept in its original format.

4.3.5.1.6. Age of the head of household

Age of the head of household is a discrete variable that describes the age of a household head during the survey. The youngest household head was ten years and the oldest household head was above ninety-five years old. This variable was kept in its original discrete format.

4.3.5.1.7. Gender of the head of household

Gender of the household head was recorded as a binary variable, as either male or female. This variable was kept in its original format. About eighty percent of the households have male household heads while twenty percent have female household heads.

4.3.5.1.8. Educational attainment of the head of household

The educational attainment of a person is related to various factors that significantly impact on health-seeking behaviours ((National Population Commission and Inner City Fund International, 2014). This describes the highest level of education a household member has received as at the time of the survey. The levels include no education, incomplete primary education, complete primary education, incomplete secondary education, complete secondary education and higher education. This variable was kept in its original ordinal format. Most of the household heads (thirty five percent) had no education while six percent had incomplete primary education. Four hundred and thirty-eight households had missing information for this variable.

4.3.5.2. State-level variables

A state-level or level-two variable was obtained from the annual abstract of statistics and FAAC report (National Bureau of Statistics, 2014). It includes crude oil revenue.

4.3.5.2.1. Crude oil revenue

Crude oil revenue is the oil excess proceeds in the state or territory where a household is located. This is a continuous variable. In the phase two study, oil-led economic growth was generated by me. It was calculated as the percentage growth in crude oil revenue in each state.

4.3.6. Ethics

The College of Medical, Veterinary and Life Sciences in the University of Glasgow had confirmed that ethics approval was not required for the use of data in this study. The ethical requirements were the same as in the phase one study. The data used were obtained from the different data providers by either data application request to the providers or directly by downloading the information from the databank.

4.3.6.1. Ethical consideration and data usage agreement

All the data used in this research were from unrestricted sources. The application for data access was done by me. Based on their providers, the following data usage agreement accompanied this study (table 4.7).

Table 4.7: Summary of data and ethics for phase two study

Dataset	Data restrictions	Data availability and usage
National Demographic and Demographic Survey (NDHS) dataset	The request for access to data was obtained by registering on the website to use the data for the purpose of this research only. Then data access request was reviewed, and access granted for all unrestricted survey datasets for Nigeria. Data used for this study were from the unrestricted datasets.	The terms of use of these data requires that it should not be given to others without the written consent of the demographic and health survey program and all reports based on these data should be sent in Portable Document Format to the program's data archive.
National Bureau of Statistics (NBS) dataset	The NBS dataset is openly available to the public. Publications can also be directly accessed through online data portal.	There was no restriction on usage of the data obtained from the NBS.

4.3.7. Data preparation and cleaning

The data were cleaned by the providers but to accomplish reliable and valid data analysis, the data used in this research were also screened for any missing values or errors by me. There were missing values in all the datasets. Before analyses were carried out, merging of datasets to create the final datasets (as shown in figure 4.6) and imputation of missing values where necessary, were conducted. Data preparation and cleaning was done using Stata MP/14.1 (StataCorp, 2015).

4.3.7.1. Data Quality

As for the dataset in the phase one study, strict monitoring of data collection and documentation was carried out by each data provider, to ensure the provision of good quality data for this study. The errors detected in the datasets were resolved by reviewing the parent data, especially when there was error in data entry or an update on published data.

4.3.7.2. Merging of datasets

Merging of data from the different sources was completed. A flow diagram of the steps involved in the data preparation is shown in figure 4.5. The two datasets were merged using “state name” as the key variable. In addition, the phase two study obtained household-level data and state-level data. To produce a dataset with all our variables of interest, we merged the datasets at state level.

4.3.7.3. Details of the final dataset

The final dataset contained cross-sectional data from 38,522 households within 36 states and a federal capital territory (table 4.8). The number of households per state ranges from 836 to 1,761 with an average of 1,041 households. The rate of missingness was less than 1.2% for all the variables and listwise deletion of the observations with missing values would reduce this sample size. Imputed data was used for this analysis. These data had two levels, with households (level-one units) nested within states (level-two units).

Table 4.8: Summary of states in each region and the number of households in phase two dataset

Regions	North Central	North East	North West	South East	South South	South West
States	Niger 1,062	Yobe 907	Sokoto 1,060	Anambra 959	Edo 1,004	Oyo 1,066
	Fct-Abuja 909	Borno 842	Zamfara 972	Enugu 1,047	Cross River 946	Osun 1,074
	Nasarawa 836	Adamawa 971	Katsina 1,069	Ebonyi 958	Akwa Ibom 1,015	Ekiti 990
	Plateau 952	Gombe 951	Jigawa 1,037	Abia 1,005	Rivers 1,050	Ondo 1,033
	Benue 976	Bauchi 1,006	Kano 1,761	Imo 1,015	Bayelsa 1,034	Lagos 1,729
	Kogi 1,047	Taraba 1,030	Kaduna 1,064		Delta 1,077	Ogun 1,061
	Kwara 1,010		Kebbi 997			
Region total	6,792	5,707	7,960	4,984	6,126	6,953
Country total	38,522					

4.3.8. Data limitation and missing data

Missing data in this study refer to values that were not available in each databank, either because they were not available at the state- or household-level or were omitted because they were too small or not reported. The percentage of missing data affects the quality of the results generated from a statistical analysis. The pattern of missingness discussed in the next section is of more importance.

4.3.8.1. Missing data mechanism

As discussed earlier, this refers to how the data are missing, either through an observed variable or through an indirect relationship with another variable. The data in this study were missing at random. The probability that the data are missing is dependent on observed data and analyses were conducted using the imputed data, as appropriate. The data in phase two study are missing randomly across states/households and years. Also, it was assumed that the data in phase two study were missing at random because the missing data pattern could be predicted by other variables in the dataset.

4.3.8.2. Treatment of missing data

The data in this study were multilevel. Missing values in multilevel data can occur in level-one outcomes or predictors, level-two predictors and class variable (Van Buuren, 2011). Missing data in level-one outcomes only can be solved by list-wise deletion and an appropriate likelihood-based analysis, when the data is missing at random. Missing data in level-one predictors means that the estimators are undefined and the deletion of variables with missing data produces biased estimates (Little, 1992). Therefore, it is useful to impute missing data and also account for the clustering in the multilevel data.

The phase two data contained missing data in the level-one outcomes and predictors. Due to the hierarchical nature of our data (two-level data), a two-level multiple imputation was used to impute the data, otherwise the estimates of the cluster-level variations would be reduced (Van Buuren, 2011). The missing data was handled using multiple imputation via the chained equations approach (Van Buuren and Oudshoorn, 2000; Van Buuren, et al., 2006). This approach allowed for a combination of continuous and categorical variables, with one procedure handling a variety of analyses. The approach combined several cycles, with each cycle having all the missing values replaced by the predictions from regression models that reflect the relationships observed in the data. Therefore, the imputation method in phase one dataset generated an imputed dataset with combined results from 10 cycles or iterations. The dataset contained imputed data for access to sanitary facilities, access to drinking water, age of household head, educational attainment of household head and number of deaths in a household. The results of the imputation will be described in detail in the result chapter of this thesis.

4.3.9. Empirical model: phase two

This section will describe the statistical technique, model choices and procedures used in the phase two study.

4.3.9.1. Statistical technique

This research used mixed effects or multilevel modelling for hypothesis testing. This type of model is an extension of the one-level regression model and it is used to analyse data which are considered to be structured within levels such as nested data (Snijders & Bosker, 2012). Nested data of this kind violate the assumption of independency of observations which applies to the ordinary least squares regression (Maas and Hox, 2005). As this assumption is not accounted for within groups, the standard errors estimated are small, leading to false significant results. To account for this, multilevel models allow for the assessment of between group variance and the factors associated with the variance. Since the households in the sample are believed to be random sample from the population of households in a multilevel model, inference can be made from the study findings to the population (Snijders & Bosker, 2012). The dataset in this study contained a randomly selected sample of 38,522 households from 37 states and federal capital territory in Nigeria.

These models are not without their disadvantages. They are more complex than conventional methods like regression models and are based on more assumptions. So, careful consideration needs to be taken when interpreting the results.

4.3.9.2. Multilevel models

This section gives the details and rationale for the statistical techniques used in this study as well as the method of estimating within and between group variance. Two-level models were required for this study as the households nested within states.

4.3.9.2.1. Fixed and random effects

The models were mixed effect models which are made up of both fixed effects and random effects (Snijders & Bosker, 2012). The fixed effects are measured directly and are equivalent to regression coefficients while the random effects are generated according to the variances and co-variances estimated. Households were nested within states in a random intercept multilevel model. State effects can be considered to randomly vary about an overall mean within a normal distribution of potential state effects. In the random intercept model, the mean of an outcome (household health) in each state was allowed to vary and the effects of any covariate added to the model were considered to be fixed in each state but in a random slope model, the effects of any covariate added to the model will vary across the states in Nigeria.

Although there is no consensus on the number of higher-level units to be used in a multilevel model, more than ten higher level units have been recommended (Snijders & Bosker, 2012). Biased estimates of between state variance may occur for models containing lower than fifty level-two units, although they are considered to be sufficient enough to produce reliable regression coefficients, standard errors and variance components (Maas and Hox, 2004). Based on this, the models had sufficient numbers of higher-level units as there were thirty-seven level-two units (states), but results on level-two variance were interpreted with caution.

Although multilevel models are usually estimated using the default maximum likelihood technique, which estimates model parameters using observed data (Little and Rubin, 2014), my models were estimated using the restricted maximum likelihood estimation (Snijders & Bosker, 2012), which is more precise and yields less biased standard errors for models with small numbers of level-two units than the default maximum likelihood estimation method. Furthermore, likelihood ratio tests were used to compare the model fit between multilevel models with the default maximum likelihood estimates and equivalent single level regression models.

However, the discrete response models were fitted by quasi-likelihood (Rasbash et al., 2000), which is an approximation of maximum likelihood, hence the log-likelihood statistics are not valid or reported. Also, the likelihood ratio tests were not reported. Therefore, all discrete response models were fitted by second order penalised quasi-likelihood (PQL2), which is the most accurate quasi-likelihood estimation procedure using Runmlwin. This method has been proven to be biased, especially when the size of the level 2 units is small. Hence these quasi-likelihood methods were used for model exploration and the full model was fitted using the Markov Chain Monte Carlo estimation (MCMC) method. MCMC is a simulation-based Bayesian method that tries to draw samples from the posterior distribution of the model (Browne, 2012). The quasi-likelihood estimates are used as starting values for the MCMC chains in the MCMC method when fitting these models and the Deviance Information Criterion (DIC) statistic obtained is the Bayesian equivalent of the Akaike Information Criterion (AIC) statistic from models fitted by maximum likelihood estimation. On comparing correctly fitted models, the model with the smallest DIC is estimated to be the one that best predicts a dataset with the same structure as that estimated.

4.3.9.2.2. Fixed effect multilevel models and conventional multilevel models

My study ran both the fixed effect multilevel model which controlled for the state-level heterogeneity and the conventional or standard multilevel regression which explains this heterogeneity. The fixed effect method prevents omitted variable bias (Allison, 2009). This bias occurs if relevant variables are not controlled for, leading to faulty estimators. This is not likely in my state-level sample size (37 states), as only few variables at the state-level will be included. In addition to preventing omitted variable bias, the fixed effect models were used to examine the robustness of the multilevel estimations.

Each model was fit to each of the imputed dataset and the results combined using Rubin's method (Rubin, 2004). The models were fitted using Runmlwin command in Stata 14.1 (Leckie and Charlton, 2011). The multilevel models were built systematically, with a null model built first. The null model contained a random intercept for each state but had no explanatory variables. For the fixed effect method, the null model was a model with 37 state dummies and in the standard multilevel method, the null model was the model without predictors. This was used to demonstrate the amount of variation that comes from the state-level. A simple random intercept model with few fixed effects was run and I progressively added more fixed effects at level-one and level-two to create a more complex model. On arriving at a fixed effect structure that seemed to be best based on the model fit statistic, I fitted models which had a random intercept.

The results for the conventional multilevel models were similar to that of the fixed effect models. Therefore, we reported the results of the conventional multilevel models in this study.

4.3.9.2.3. Intraclass correlation (ICC)

Intraclass correlation refers to the correlation among observations within a cluster. ICC determines the amount of total variation that came from the state-level, by dividing the population variance between level-two units (states) by the total variance in the multilevel models (Snijders & Bosker, 2012). The total variance in an outcome can be decomposed into within group and between group variance. ICC ranges from 0 to 1, where 0 suggests that more variance in our outcome between states would likely occur by chance; and 1 suggests that all households in a state have the same outcome when the state-level variance has been accounted for, therefore 100% of the variance in the outcome is at the state-level.

In these discrete response models, single intraclass correlation coefficient (ICC) values were not reported, as level one variance is a function of the mean (Leckie and Charlton, 2011). ICC measures the expected correlation between level one units from the same level two unit. To calculate ICC in state, I generated a null model, with only the intercepts allowed to vary across groups. The amount of explained variance in the model (R^2) is equal to the ICC of this model.

4.3.9.3. Model specification

A linear regression model which examines the effect of an independent variable on the dependent variable is as follows:

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \tag{4.2}$$

Where $\boldsymbol{y_i}$ is the dependent variable, $\boldsymbol{\beta_0}$ $\boldsymbol{i}$s the y-intercept, $\boldsymbol{\beta_1}$ is its slope, $\boldsymbol{\varepsilon_i}$ is the unexplained model error, $\boldsymbol{x_i}$ is the independent variable, $\boldsymbol{i}$ is the index of households and takes values from 1 to the number of households in our data (Rasbash et al, 2002; Kutner et al., 2005). The expression $\boldsymbol{\beta_0} + \boldsymbol{\beta_1 x_i}$ is the fixed part of the model. The model error or residual is the part of this relationship $\boldsymbol{y_i}$ that is not predicted by the fixed part regression. This equation (4.2) is for a single level regression.

To fit a more useful model, the amount of model error needs to be reduced. This can be done by varying the model specification as error in a model can occur as a result of unknown factors which affect the behaviour of the dependent variable (Kutner et al., 2005). Therefore, additional predictors are added to the model. The linear regression model that examines this effect (Kutner et al., 2005) is as follows:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_n x_{ni} + \varepsilon_i \tag{4.3}$$

Where $\boldsymbol{\beta_1 x_{1i}}$ represents the effect of predictor 1, $\boldsymbol{\beta_2 x_{2i}}$ represents the effect of predictor 2, $\boldsymbol{\beta_n x_{ni}}$ represents the effect of predictor n, and … shows that the model can be extended to add more predictors. This equation (4.3) is for a multiple regression model.

However, it is not necessarily the addition of predictors that improves the fit of a model but the removal of a predictor, as the predictor may be insignificant. Also, predictors can be correlated with one another and an interaction term may be introduced into the model to reduce this effect. The interaction term is the product of two or more predictors and a new coefficient, where the interaction term for two predictors, $\boldsymbol{x_{1i}}$ and $\boldsymbol{x_{2i}}$ is $\boldsymbol{\beta_{21} x_{2i} x_{1i}}$ (Kutner et al., 2005).

Clustered data violates the assumption in a conventional linear regression because of the correlation of the values of the outcome as well as the error terms (Allison, 1999). This correlation increases the likelihood of obtaining smaller standard errors and false significant results from the regression. A multilevel model becomes necessary as it considers this correlation in calculating the standard errors. For a multilevel case, showing a two-level model (Rasbash et al, 2002), the equation (4.4) is as follows:

$$y_{ij} = \beta_0 x_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \cdots + \beta_n x_{nij} + u_{0j} x_0 + \varepsilon_{0ij} x_0 \quad (4.4)$$

In this equation, both $\boldsymbol{u}$ and $\boldsymbol{\varepsilon}$ are random quantities, with means that are zero. They are the random part of the model. We assume that these variables are uncorrelated since they are at different levels and that they also follow a normal distribution, so as to allow estimation of their variances $\boldsymbol{\sigma_u^2}$and $\boldsymbol{\sigma_e^2}$ respectively. $\boldsymbol{x_0}$ is a special explanatory variable with the value of one for all households and it is random at level one and level two, $\boldsymbol{\beta_0}$ to $\boldsymbol{\beta_n}$are the fixed parameters, where the subscripts 0 to n matches the explanatory variables to which the values are assigned. This model can be modified to fit higher level models.

4.3.9.4. Model structure

This section describes the types of models used in modelling the data, model comparison using various goodness-of-fit measures and the selection of the type of model used in this study. It also defines the characteristics and assumptions for all models in this study. Each analysis involves a two-level regression with households representing level one and states as level two. This study considered two major models based on the nature of the outcome variable obtained in the phase two dataset.

The two outcome variables that represent health determinants are access to drinking water sources and access to sanitary facilities. They are nominal response variables and were modelled with multilevel nominal logistic regression. The outcome variable that represents health in this model (household death) is a count variable. Count data are used to model the number of times an event occurs within a fixed time period (Hilbe, 2014) However, there are two common distributions used for modelling over-dispersed count data, they include generalised Poisson and negative binomial distribution. To allow for household size, the offset used for the models was the log value for the number of household members.

In examining the distribution of the number of deaths between and within households, two factors are of interest, the mean and variance or variability. The mean represents the expected number of deaths in the households and this is the total number of deaths in the households by the total number of households. It is the most appropriate measure of midpoint of the distribution than the mode and median. This can be looked at as either the population mean or true sample mean; where the population mean is the distribution mean from which all households in Nigeria are derived and the true sample mean is the observed mean number of deaths of the sampled households (Hilbe, 2014). The two means are the same only when all the households from the population are sampled. However, the mean used in this section of this study is the population mean.

The variability represents the dispersion in the number of household deaths. This can be assessed by examining the absolute standard deviation which is the variance between samples, but it is greatly affected by the mean (Hilbe, 2014). Therefore, another measure of variability which is standardized with respect to the mean of the distribution; coefficient of dispersion is used. This is the proportion of total variability observed between counts that can be ascribed to the variability of the counting process (Hilbe, 2014).

Both the generalised Poisson model and the negative binomial model were considered for this outcome variable and a description of the models are as follows:

4.3.9.4.1. Generalised poisson model

Poisson distribution describes the number of events in time interval (Cameron and Trivedi, 1998). This is used to model discrete random variable, Y and is used to explain rare occurrences. Therefore, the distribution function (Cameron and Trivedi, 1998) for a single Poisson distributed data point ($\boldsymbol{y}$) given an expected frequency (θ) is as follows:

$$P(y|\theta) = \frac{\theta^y e^{-\theta}}{y!} \qquad y = 0, 1, 2, \ldots \qquad (4.5)$$

Where $\boldsymbol{P(y|\theta)}$ is the probability of the occurrence of $\boldsymbol{y}$.

The mean of a Poisson distribution is as follows:

$$\mathrm{E}[\mathrm{Y}] = \theta. \tag{4.6}$$

The variance of a Poisson distribution is as follows:

$$\mathrm{V}[\mathrm{Y}] = \theta. \tag{4.7}$$

Poisson distribution assumes the equi-dispersion assumption as the mean is equal to its variance. Therefore, this distribution does not support the variance to be adjusted independent of the mean. The distribution is over-dispersed if the variance is greater than the mean and under-dispersed when the variance is less than the mean. For over-dispersed or under-dispersed data, the Poisson distribution is not a suitable model.

However, the probability mass function of a generalised Poisson distribution (Consul and Famoye, 1992) is:

$$P(Y = y \,|\, \lambda, \theta) = \begin{cases} \exp\{-\lambda - \theta y\} \dfrac{\lambda(\lambda + \theta y)^{y-1}}{y} & , 1, 2 \ldots \\ 0 & \text{for } y > m \text{ when } \theta < 0 \end{cases} \tag{4.8}$$

Where $\lambda > 0$, $\max \{-1, -\frac{\lambda}{4}\} \leq \theta \leq 1$. m is the largest positive integer. For $\theta = 0$, the generalised Poisson distribution reduces to the Poisson model. Over-dispersion is signified by positive values of θ.

4.3.9.4.2. Negative binomial model

Negative binomial distribution describes the number of successes occurring in a number of repeated actions (Hilbe, 2014). This is a parametric model which has an additional parameter over the Poisson distribution. The negative binomial distribution is a suitable model for over-dispersed data but it cannot model under-dispersed data.

The probability distribution function (Hilbe, 2014) of the negative binomial (r, p) distribution using the formulation with the mean of the distribution is as follows:

$$P(x) = \binom{x-1}{r-1} pr^{r}(1-pr)^{x-r} \tag{4.9}$$

Where P is the cumulative probability, pr is the probability of success and r = number of failures.

The mean of a negative binomial distribution is as follows:

$$E(y_i) = \frac{r}{pr} \tag{4.10}$$

The variance of a negative binomial distribution is as follows:

$$V(y_i) = \frac{r}{pr^2}(p+1) \tag{4.11}$$

Therefore, the negative binomial distribution in model form is as follows:

$$\ln\lambda_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon_i \tag{4.12}$$

Where λ_i is the value of the Poisson parameter in region i, $\beta_{1,2\ldots n}$ is the effect of a unit increase of the corresponding $x_{1,2\ldots n}$ and ε_i is the error associated in the estimation of y_i. The error term in the model form of the negative binomial distribution may be given a gamma distribution, which has a mean of 1 and a variance which is signified by σ^2.

The variance of the error term is related to the mean through the relationship (Hilbe, 2014) shown as follows:

$$V(y^2) = E(y_i) + \alpha E(y_i)^2 \tag{4.13}$$

Where α is the over-dispersion parameter, and also the square root of the variance, or standard deviation, of $\exp(\varepsilon_i)$. Therefore, modelling the relationship in equation (4.13) helps in overcoming the disadvantage of the Poisson distribution by estimating the over-dispersion term. Over-dispersion is signified by large α values and the variance of the distribution is equal to the mean as α tends towards zero.

4.3.9.5. Goodness of fit

After models are fitted, the estimates must be compared in order to determine the model that best fits to the data. Though there are various statistics that examine goodness of fit, this study looked at deviance information criterion.

4.3.9.5.1. Deviance information criterion (DIC)

The deviance information criterion is a hierarchical modelling generalisation of the Akaike information criterion, used for model assessment and comparison (Celeux et al., 2006). In this study, it is used in a Bayesian context for model selection, as my models were obtained by Markov chain Monte Carlo (MCMC) simulation.

4.3.9.6. Model selection

When fitting a model with a count outcome, several models including Poisson, negative binomial, zero-inflated Poisson and zero-inflated negative binomial models, can be used. To choose the most appropriate model, information on the process of data collection, distribution of the outcome and the number of zeros in the outcome was examined. Since, the empirical variance (0.07) in the outcome variable is greater than the mean (0.06), even though the difference is small; there is still an indication of over-dispersion. The negative binomial model is an appropriate model to fit the data in this study.

4.3.9.7. Modeling procedure

Firstly, the relationship between household death and crude oil revenue (measure of oil-led economic growth) was examined. This relationship was then tested with adjustment for household level covariates such as residential place, access to sanitary facilities, access to drinking water source, household head age, household head sex, wealth index and household head educational attainment . This was further tested with adjustment for state level covariates. Both the fixed effect multilevel models which control for the state-level heterogeneity in our model and prevents omitted variable bias as well as the conventional or standard multilevel models which explain this heterogeneity were fitted for the data in this study. The models were fitted using MLWIN (Rasbash et al, 2002) and accessed through Stata 14 (StataCorp, 2015) using the “runmlwin command” (Leckie and Charlton, 2011).

A series of models was fitted to the data, excluding and including predictors. Four models were used to explore each association. Firstly, a two-level null model or random intercept model was fitted, as shown in the model tables. This null model of households (level one) nested within states (level two) had no predictors. Then models one to three were fitted by gradually adding a predictor to the previous model. The coefficients and confidence intervals of the household and state level covariates were reported in the model tables at 5%, 1% and 0.1% statistically significant level. The model tables included the fixed-effect part of the model and the estimated variance components. The null model was used to determine whether the variation in the response variables was explained by the level-2 units (state). Model 1 showed the relationship between oil-led economic growth and the response variable. Model 2 showed if the addition of demographic variables (gender and age of household head) improves the model fit. Model 3 showed whether the addition of socioeconomic variables (wealth index, educational attainment of household head and residential place) improved the model fit. Model 4 (for modelling the number of household deaths only) showed whether the addition of source of drinking water and type of sanitary facility improved the fit.

The same steps were taken to model the relationship between health determinants (access to drinking water and access to sanitary facilities) and crude oil revenue (measure of oil-led economic growth).

4.3.9.8. Statistical software

Stata MP/14.1 (StataCorp, 2015) was used in this study for all data handling processes and building of multilevel models. Runmlwin command was used to fit the multilevel models for all the outcomes (Leckie and Charlton, 2011).

5. Results

This chapter will present the empirical findings for phase one and two studies. Two types of models were used in phase one study.

5.1. The phase one study

In the phase one study, the panel models explored the relationship between crude oil resources and health outcomes; and then the cross-sectional models assessed the relationship between oil-led economic growth and health, as well as with its determinants.

5.1.1. Panel model: Relationship between crude oil resources and health outcomes

As discussed in the methods, structural equation modelling was used to explore the relationship between crude oil resources and the determinants of health/health over time (the year 2000 to 2015). Dynamic panel (or cross lagged panel) models were fitted, using MLMV method.

Figures 5.1 and 5.2 showed the distribution of the measures of crude oil resources across the years 2000 to 2015. The graphs showed that there was variation in the distribution of these variables across income groups. The mean oil rent contribution to GDP (figure 5.1) was higher in the high-income group than the low-income group and there was an overall fall in the values across the reported years. The mean crude oil export (figure 5.2) was also higher in the high-income group than the low-income group. Though the value for the low-income group was fairly stable across these years, that of the high-income group increased across the reported year.

Figure 5.1: Global oil rent contribution to GDP by income group

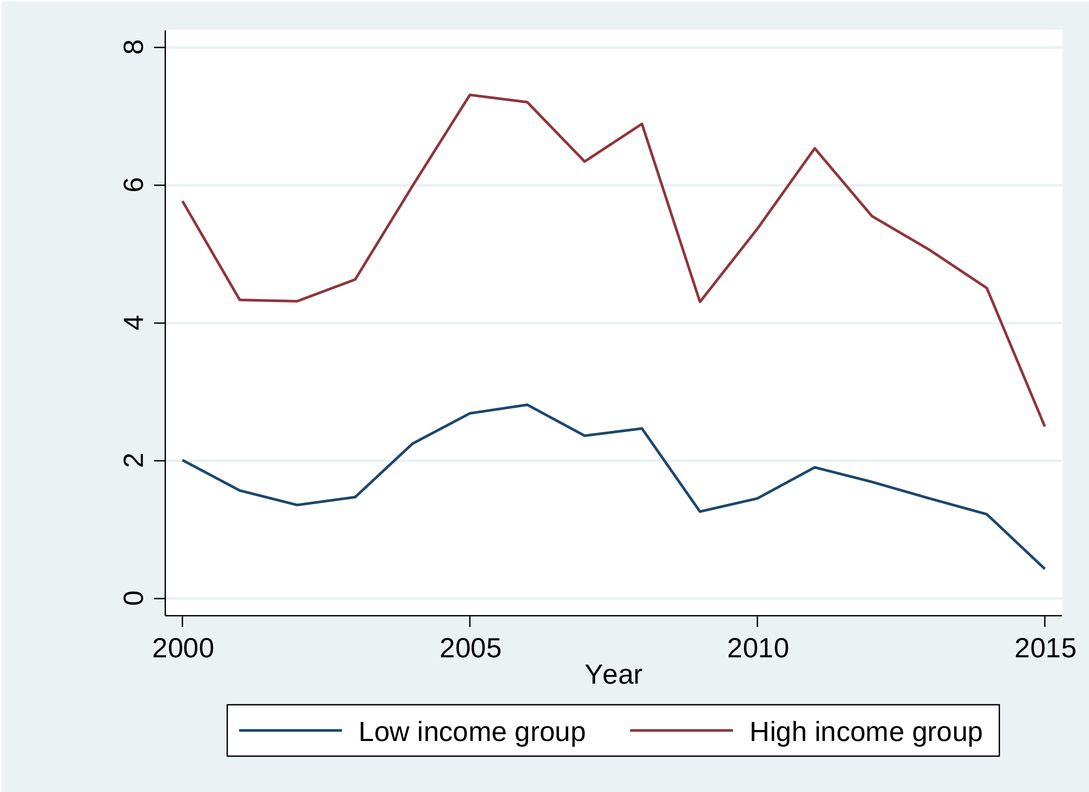
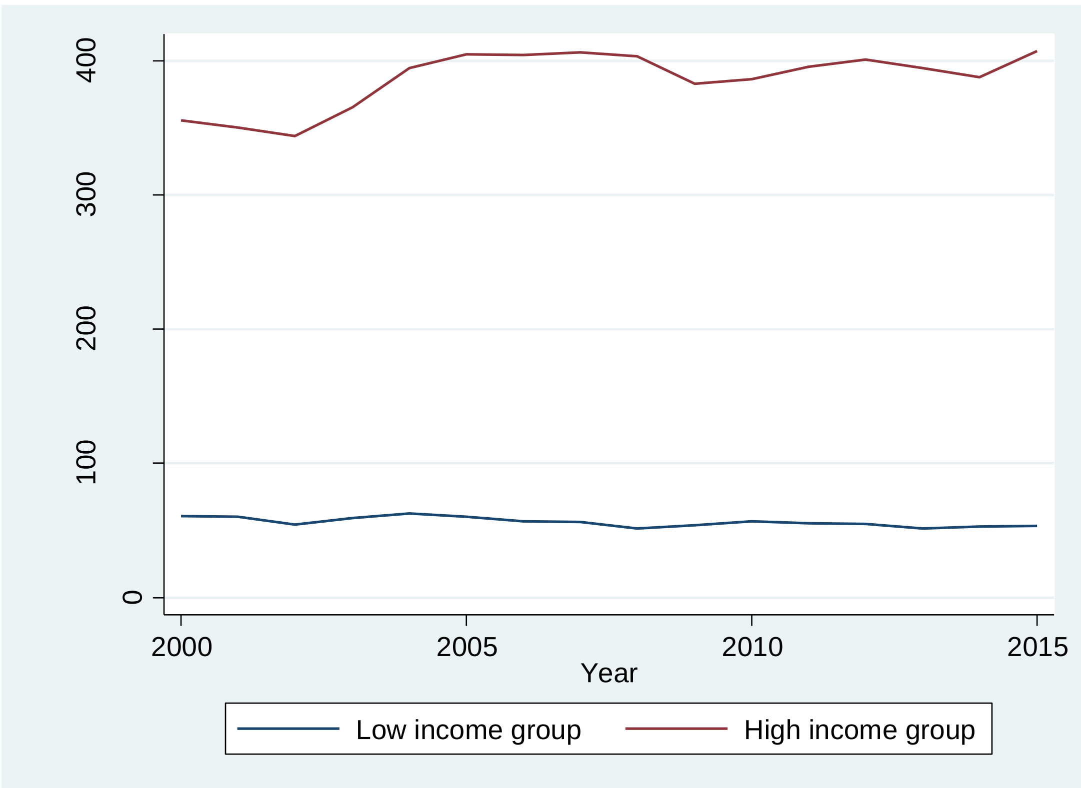


Figure 5.2: Global crude oil export by income group



Figures 5.3 and 5.4 showed the distribution of the measures of health across the years 2000 to 2015. The graphs showed that there was variation in the distribution of these variables across income groups. The mean infant mortality rate (figure 5.3) was lower in the high-income group than the low-income group and there was an overall fall in the values across the reported years. The mean life expectancy at birth (figure 5.4) was higher in the high-income group than the low-income group. There was an overall rise in the values across the reported years.

Figure 5.3: Global infant mortality rate by income group

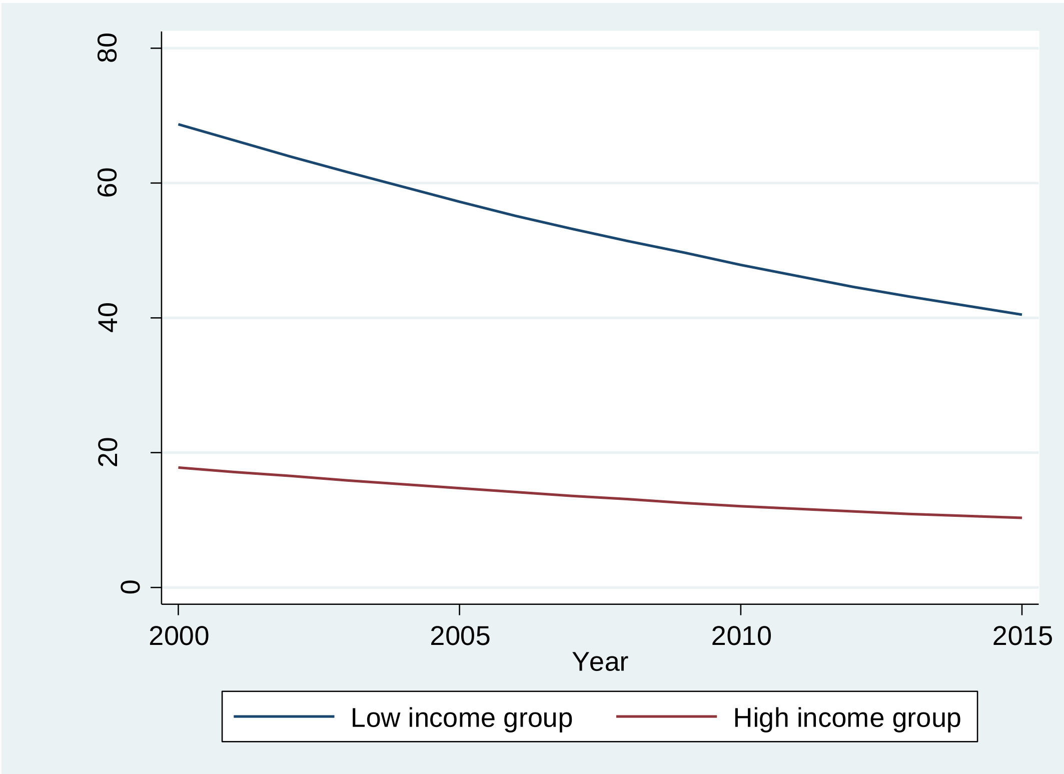
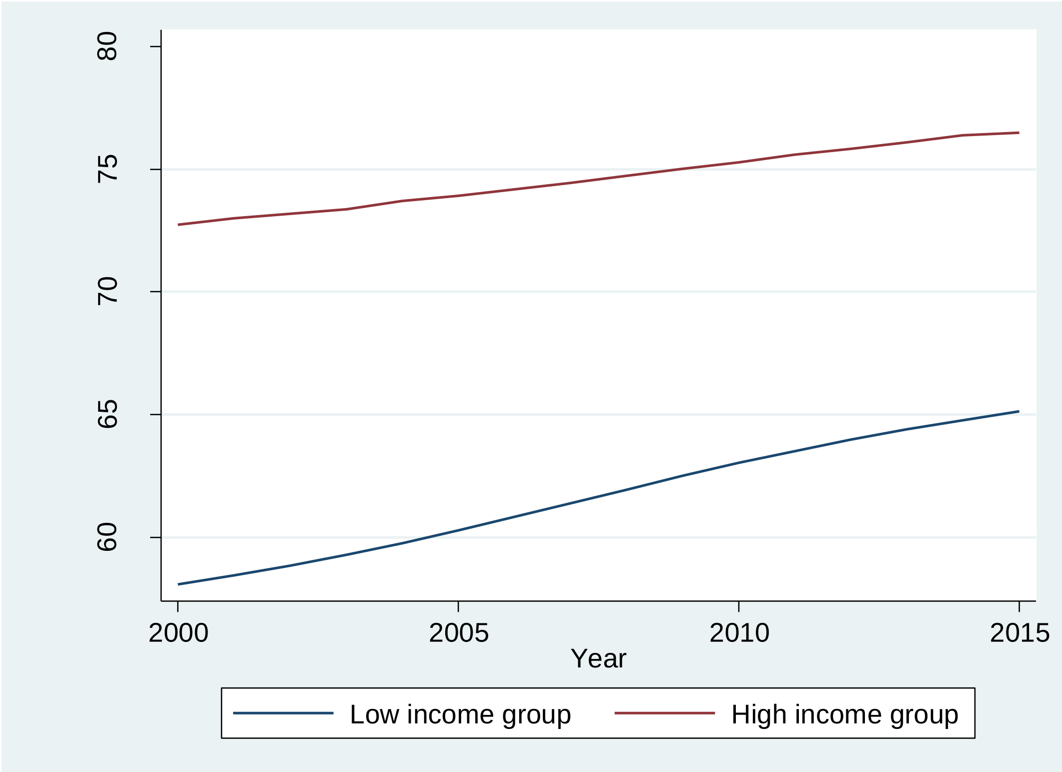


Figure 5.4: Global life expectancy at birth by income group



5.1.1.1. Descriptive statistics

A summary of all the variables for both income groups across the year 2000 to 2015 were described in terms of mean, median, standard deviation and range. Though the mean and median were reported in the tables, the mean was more intuitive and informative to discuss. A total of one hundred and fifty six countries were included in this study. There were sixty two countries in the low-income group and ninety four countries in the high-income group. In the low-income group (table 5.1), the rate of infant mortality ranged from 8.1 to 142.0 per 1000 live births. The mean was 53.2 per 1000 live births (SD 27.1). Life expectancy at birth ranged from 38.7 to 76.1 years. The mean was 61.6 years (SD 8.3). The observations for each variable were complete except for pollution (50.0% missing) and enrolment in basic education (32.6% missing). The missing data was handled by the MLMV method.

Preliminary findings on the relationships among study variables were demonstrated using the output for the bivariate correlation presented in table 5.2. This table shows that no multicollinearity problem was encountered for the low-income group, as the inter-correlation among variables ranged from 0.02 to 0.90, below the critical value of 0.90 (Kline, 2015). The strength of correlation (r) is commonly categorised into weak (0.10), moderate (0.30) and strong (0.50) correlation (Acock, 2008).

In the low-income group (table 5.2), the correlation between oil rent contribution to GDP and each health determinants was negative. The correlation with: access to basic drinking water source ($r=-0.16$, $p<0.05$) was weak and statistically significant; access to basic sanitary facility ($r=-0.03$, $p>0.05$) was weak and not statistically significant. The correlation between crude oil export and each health determinants was negative. The correlation with: access to basic drinking water source ($r=-0.16$, $p<0.05$) was weak and statistically significant; access to basic sanitary facility ($r=-0.02$, $p>0.05$) was weak and not statistically significant. This indicates that low-income countries with high oil rent contribution to GDP or high crude oil export had reduced access to basic drinking water sources, although this relationship was weak. Oil rent contribution to GDP or crude oil export were not related to access to basic sanitary facility. The correlation between oil rent contribution to GDP and health was: positive, weak and statistically significant for infant mortality ($r=0.11$, $p<0.05$); negative, weak and not statistically significant for life expectancy at birth ($r=-0.10$, $p>0.05$). The correlation between crude oil export and health was: positive, weak and statistically significant for infant mortality ($r=0.14$, $p<0.05$); negative, weak and statistically significant for life expectancy at birth ($r=-0.19$, $p<0.05$). This indicates that low-income countries with high oil rent contribution to GDP or high crude oil export had high infant mortality rate, although this relationship was weak. Countries with high crude oil export had low life expectancy at birth but oil rent contribution to GDP was not related to life expectancy at birth.

Table 5.1: Summary of data for low-income group

Variables	Number of observations	Missing observations	Mean	Median	Standard deviation	Minimum value	Maximum value
Oil rent contribution to GDP (% contribution)	992	0	1.8	0.0	5.4	0.0	40.7
Employment to population ratio (% employed)	992	0	61.9	62.3	13.2	29.2	87.8
Infant mortality rate (per 1000 live births)	992	0	53.2	52.6	27.1	8.1	142.0
Access to basic drinking water sources (% of population with access)	992	0	68.5	69.2	19.2	16.7	99.6
Access to basic sanitation facilities (% of population with access)	992	0	43.4	39.0	27.6	3.2	98.7
Institutional quality (score on an aggregated index)	992	0	-2.0	-2.1	1.4	-5.3	2.0
Crude oil production (1000 of barrels per day)	992	0	94.7	0.0	338.8	0.0	2,627.4
Crude oil export (1000 of barrels per day)	992	0	56.3	0.0	277.8	0.0	2,368.8
Life expectancy at birth (years)	992	0	61.6	62.5	8.3	38.7	76.1
Pollution (million metric tons)	496	496	39.5	32.0	24.6	3.3	190.9
Enrolment in basic education (% gross)	669	323	50.2	45.5	24.7	6.1	104.3

Table 5.2: Correlation among variables for low-income group

Low income	Oilrent	Oilexp	Infmort	Lifexp	Accwater	Accsanit	Emp	Instiqual	Oilprod	Pollu	Educ
Oilrent contribution to GDP (Oilrent)	1										
Crude oil export (Oilexp)	0.39*	1									
Infant mortality (Infmort)	0.11*	0.14*	1								
Life expectancy at birth (Lifexp)	-0.10	-0.19*	-0.90*	1							
Access to basic drinking water sources (Accwater)	-0.16*	-0.16*	-0.68*	0.71*	1						
Access to basic sanitary facility (Accsanit)	-0.03	-0.02	-0.73*	0.72*	0.73*	1					
Employment (Emp)	-0.18*	0.04	0.26*	-0.323*	-0.50*	-0.52*	1				
Institutional quality (Instiqual)	-0.22*	-0.22*	-0.47*	0.43*	0.37*	0.33*	-0.25*	1			
Oil production (Oilprod)	0.55*	0.41*	0.06	-0.05	0.04	0.05	-0.15*	-0.07	1		
Pollution (Pollu)	0.22*	-0.03	0.30*	-0.23*	-0.16	-0.17	0.04	-0.13	0.15	1	
Enrolment in basic education (Educ)	-0.11	-0.13	-0.79*	0.75*	0.76*	0.80*	-0.51*	0.26*	0.04	-0.32*	1

* represents correlations with p value less than 0.05 (statistical significance)

In the high-income group (table 5.3), the rate of infant mortality ranged from 30.6 to 87.4 per 1000 live births. The mean was 55.7 per 1000 live births (SD 9.1). Life expectancy at birth ranged from 47.1 to 83.8 years. The mean was 74.6 years (SD 5.6). The observations for each variable was complete except for pollution (50.0% missing), enrolment in basic education (19.6% missing), oil rent contribution to GDP (0.6% missing), GDP per capita (0.1% missing), access to basic drinking water sources (2.0% missing) and access with basic sanitation services (1.4% missing). Again, the missing data was handled by the MLMV method.

Table 5.4 shows that no multicollinearity problem was encountered for the high-income group, as the inter-correlation among variables ranged from 0.01 to 0.87. In the high-income group, the correlation between oil rent contribution to GDP and each health determinants was negative. The correlation with: access to basic drinking water source ($r=-0.40$, $p<0.05$) was moderate and statistically significant; access to basic sanitary facility ($r=-0.13$, $p<0.05$) was weak and statistically significant. The correlation between crude oil export and each health determinants was negative. The correlation with: access to basic drinking water source ($r=-0.14$, $p<0.05$) was weak and statistically significant; access to basic sanitary facility ($r=-0.07$, $p>0.05$) was weak and not statistically significant. This indicates that high-income countries with high oil rent contribution to GDP or high crude oil export had reduced access to basic drinking water sources. Countries with high oil rent contribution to GDP had reduced access to basic sanitary facility but crude oil export was not related to access to basic sanitary facility. The correlation between oil rent contribution to GDP and health was: positive, moderate and statistically significant for infant mortality ($r=0.39$, $p<0.05$); negative, weak and statistically significant for life expectancy at birth ($r=-0.29$, $p<0.05$). The correlation between crude oil export and health was: positive, weak and statistically significant for infant mortality ($r=0.17$, $p<0.05$); negative, weak and statistically significant for life expectancy at birth ($r=-0.19$, $p<0.05$). This indicates that high-income countries with high oil rent contribution to GDP or high crude oil export had high infant mortality rate and low life expectancy at birth.

Table 5.3: Summary of data for high-income group

Variables	Number of observations	Missing observations	Mean	Median	Standard deviation	Minimum value	Maximum value
Oil rent contribution to GDP (% contribution)	1,495	9	5.4	0.1	11.8	0.0	64.0
Employment to population ratio (% employed)	1,504	0	55.7	56.7	9.1	30.6	87.4
Infant mortality rate (per 1000 live births)	1,504	0	13.6	9.4	13.5	1.9	122.6
Access to basic drinking water sources (% of population with access)	1,474	30	95.1	98.0	8.2	37.8	100.0
Access to basic sanitation facilities (% of population with access)	1,483	21	90.5	94.9	12.9	20.5	100.0
Institutional quality (score on an aggregated index)	1,504	0	1.3	1.2	2.9	-4.9	6.7
Crude oil production (1000 of barrels per day)	1,504	0	701.7	12.4	1,640.3	0.0	10,252.9
Crude oil export (1000 of barrels per day)	1,504	0	386.5	1.1	986.7	0.0	7,553.3
Life expectancy at birth (years)	1,504	0	74.6	75.0	5.6	47.1	83.8
Pollution (million metric tons)	752	752	24.2	17.9	21.6	3.9	182.9
Enrolment in basic education (% gross)	1,209	295	95.2	95.9	17.5	12.4	163.9

Table 5.4: Correlation among variables for high-income group

High income	Oilrent	Oilexp	Infmort	Lifexp	Accwater	Accsanit	Emp	Instiqual	Oilprod	Pollu	Educ
Oilrent contribution to GDP (Oilrent)	1										
Crude oil export (Oilexp)	0.45*	1									
Infant mortality (Infmort)	0.39*	0.17*	1								
Life expectancy at birth (Lifexp)	-0.29*	-0.19*	-0.84*	1							
Access to basic drinking water source (Accwater)	-0.40*	-0.14*	-0.87*	0.73*	1						
Access to basic sanitary facility (Accsanit)	-0.13*	-0.07	-0.78*	0.76*	0.84*	1					
Employment (Emp)	0.10*	-0.03	-0.06	0.13*	0.02	0.07	1				
Institutional quality (Instiqual)	-0.38*	-0.25*	-0.59*	0.58*	0.52*	0.45*	0.19*	1			
Oil production (Oilprod)	0.45*	0.19*	0.04	-0.08	-0.04	-0.01	0.08	-0.17*	1		
Pollution (Pollu)	0.69*	0.44*	0.18*	-0.21*	-0.14	-0.08	0.10	-0.32*	0.44*	1	
Enrolment in basic education (Educ)	-0.19*	-0.10	-0.66*	0.53*	0.64*	0.62*	0.08	0.66*	-0.13*	-0.32*	1

* represents correlations with p value less than 0.05 (statistical significance)

The tests for multivariate normality shown in appendix G (Mardia's test for multivariate skewness, Mardia's test for multivariate kurtosis, Henze-Zirkler test and Doornik-Hansen test) reject the null hypothesis of multivariate normality ($p<0.05$), confirming the violation of multivariate normality in the data for both income groups. This supports the use of the VCE (robust option) in this study.

In this section, cross-lagged panel models were specified, with data that consist of a sample of 156 countries, each of whom is observed from the year 2000 to 2015. The analysis was done at five-year interval, producing four time points (on the year 2000, 2005, 2010 and 2015).

5.1.1.2. Oil rent contribution to GDP and health determinants

Figure 5.5: Path diagram for the Dynamic Panel Model with dependent variable (health determinant) and main independent predictor, T=4

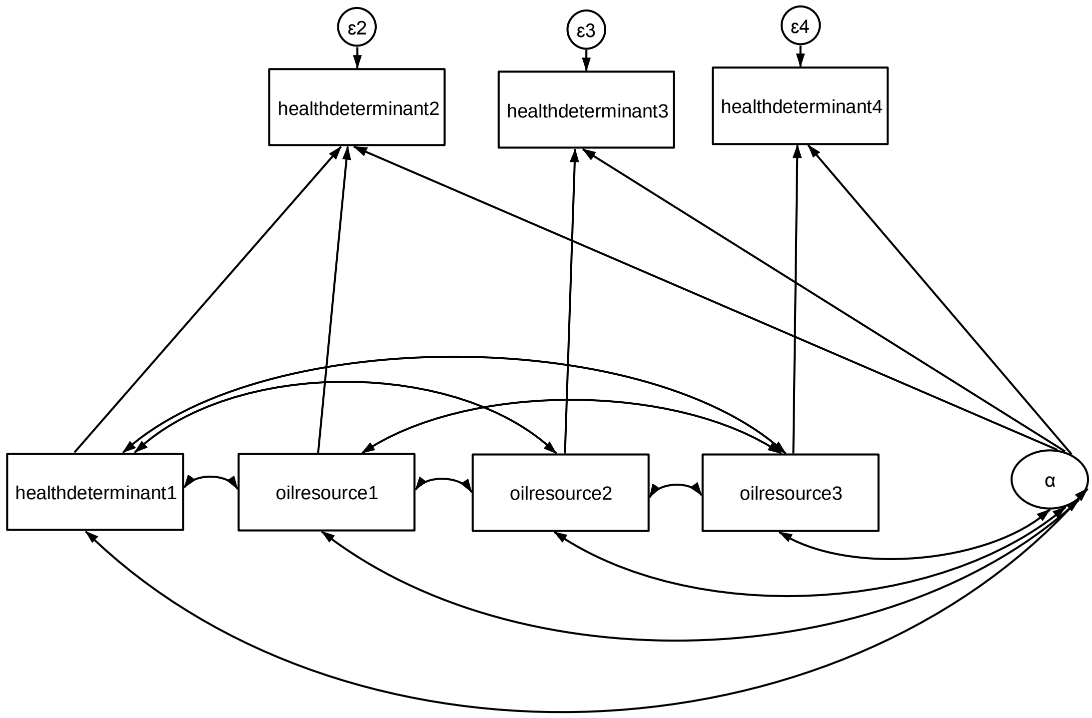


Figure 5.5 is a simplified demonstration of the path diagram for the dynamic panel model (Allison et al., 2017) on the effect of oil rent contribution to GDP at time t, on health determinant at time t + 1. It represents a path diagram for the four time intervals explored, with only endogenous/dependent variables (healthdeterminant) and predetermined variables (oilresource), excluding the control variables. All the predetermined variables are allowed to freely

correlate with each other as well as with the dependent variable at time point 1, which is being treated like an exogenous variable. They are predetermined variables because they correlate with the error terms. Also, the latent variable, α is the fixed effect variable that is common to all the equations and it is allowed to correlate with all the exogenous variables. These are the effects of time-invariant variables not in the model and the coefficient is constrained to have a value of one. In the full empirical model, the other time-varying variables controlled for were: employment to population ratio, institutional quality, oil production, pollution and basic enrolment in education. The other time-invariant variable included in the model was income group. For ease of presentation, these variables were not shown in figure 5.5 but the complete results for this model are presented in table 5.5.

With regards to the dynamic panel models, the coefficients for access to basic drinking was -0.01 ($p>0.05$) for oil rent contribution to GDP and the coefficients of access to basic sanitary facility was 0.01 ($p>0.05$) for oil rent contribution to GDP (table 5.8). This indicated that though there is a small negative impact of oil rent contribution on access to basic drinking water source (1%) and a small positive impact of oil rent contribution to GDP on access to basic sanitary facility (1%), this impact was not significant across time. The results also suggested that access to basic drinking water source at T1 predicted an increase in the access to basic drinking water T2 to T4, where the estimated coefficient for the lagged access to basic drinking water source was 0.94, $p<0.001$. Access to basic sanitary facility at birth at T1 predicted an increase in the access to basic sanitary facility at T2 to T4 (0.97, $p<0.001$). These positive effects on access to basic drinking water source (or access to basic sanitary facility) from the respective health determinants at earlier time period were both very large and highly significant.

The coefficient of the impact of income group on access to basic drinking water source (-0.19, $p>0.05$); and on access to basic sanitary facility (0.31, $p>0.05$) showed that income group had no statistically significant effect on access to basic drinking water source or access to basic sanitary facility. Hence, there is no observed significant difference across the income groups and the magnitudes of these effects were small.

In addition, appendix H also showed that the coefficients for access to basic drinking was positive and small (0.01, $p>0.05$) for crude oil export and the coefficients of access to basic sanitary facility was negative and small (-0.01, $p<0.05$) for crude oil export. The results also demonstrated that access to basic drinking water at T1 predicted an increase in the access to basic drinking water T2 to T4 (0.94, $p<0.001$). Access to basic sanitary facility at birth at T1 predicted an increase in the access to basic sanitary facility at T2 to T4 (0.97, $p<0.001$). These effects were highly significant and large.

Appendix I showed that the AIC and BIC statistics favoured the robust random effects models, confirming the earlier report on the distribution of the data. The coefficients of determination were 0.996 for both model 1 and 2, indicating a close to perfect fit.

Table 5.5: Panel model with random effect (relationship between crude oil resources and health determinants)

Variables	Access to basic drinking water source			Access to basic sanitary facility		
	Estimate	Robust S. E.	z	Estimate	Robust S. E.	z
Lagged effect of health determinant	0.94***	0.01	81.80	0.97***	0.03	28.16
Oil rent contribution to GDP	-0.01	0.01	-0.42	0.01	0.01	0.79
Employment to population ratio	0.00	0.01	-0.16	0.00	0.01	-0.26
Institutional quality	0.03	0.05	0.57	-0.11	0.11	-1.07
Crude oil production	0.01	0.01	0.68	0.01	0.01	-0.76
Pollution	0.01	0.01	1.56	0.01	0.01	1.77
Enrolment in basic education	-0.01	0.01	-1.26	0.01	0.06	0.02
Income group	-0.19	0.62	-0.30	0.31	1.04	0.30

Robust S.E = robust standard error; z= z-value; * p<0.05, ** p<0.01, *** p<0.001

5.1.1.3. Oil rent contribution to GDP and health

Figure 5.6: Path diagram for the Dynamic Panel Model with dependent variable (health) and main independent predictor, T=4

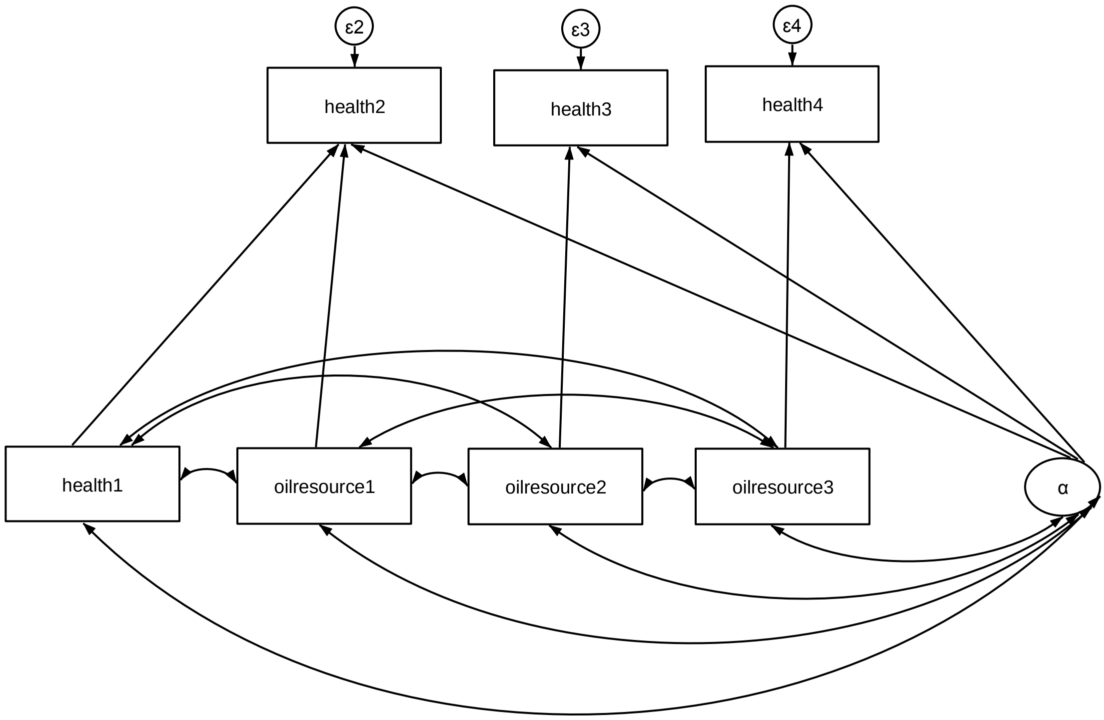


Figure 5.6 is a simplified demonstration of the path diagram for the dynamic panel model (Allison et al., 2017) on the effect of oil rent contribution to GDP at time t, on health at time t + 1. The model components and structure are the same as previous figure (figure 5.5). In the full empirical model, the other time-varying variables we controlled for were: employment to population ratio, institutional quality, oil production, pollution, basic enrolment in education, access to basic drinking water source and access to basic sanitary facility. The other time-invariant variable included in the model was income group. Again, these variables were not shown in figure 5.6 but the complete results for this model were presented in table 5.6.

With regards to the dynamic path models, the coefficients for infant mortality was 0.05 ($p>0.05$) for oil rent contribution to GDP and the coefficients of life expectancy at birth was -0.01 ($p>0.05$) for oil rent contribution to GDP (table 5.6). This indicated that though there is a small positive impact of oil rent contribution on infant mortality (5%) and a small negative impact of oil rent contribution to GDP on life expectancy (1%), this impact was not significant across time. The results also suggested that infant mortality at T1 predicted an increase in the infant mortality rate T2 to T4 (0.83, $p<0.001$). Life expectancy at birth at birth at T1 predicted an increase in the life expectancy at birth at T2 to T4, where the estimated coefficient for the lagged life expectancy was 0.84, $p<0.001$. Also, these highly significant positive effects on infant mortality (or life expectancy) from the respective health indicators at earlier time period were very large. An additional unit of employment to population ratio produced a six percent decrease in infant mortality. Institutional quality yielded a positive effect on life expectancy (0.12, $p<0.001$) and air pollution had a negative effect on life expectancy (-0.01, $p<0.01$) over time.

The coefficients of the impact of income group on infant mortality (-0.18, $p>0.05$); and on life expectancy (0.19, $p>0.05$) showed that income group has no statistically significant effect on infant mortality or life expectancy. Hence, this indicated that there is no observed significant difference across the income groups and the magnitudes of these effects were small.

Appendix J showed that the coefficients for infant mortality was 0.01 ($p>0.05$) for crude oil export and the coefficients of life expectancy at birth was 0.01 ($p>0.05$) for crude oil export. An additional unit of employment to population ratio produced a six percent decrease in infant mortality. Institutional quality yielded a positive effect on life expectancy (0.13, $p<0.001$) and air pollution had a negative effect on life expectancy (-0.01, $p<0.01$).

The AIC and BIC statistics for the models that fits the changes in crude oil export on health (Appendix K) all favoured the robust random effects models and confirmed the earlier report on the distribution of the data. The coefficients of determination were 0.998 and 0.997 for model 1 and 2 respectively, indicating a good fit.

Table 5.6: Panel model with random effect (relationship between crude oil resources and health)

Variables	Infant mortality			Life expectancy		
	Estimate	Robust S. E.	z	Estimate	Robust S. E.	z
Lagged effect of health	0.83***	0.18	4.60	0.84***	0.02	35.88
Oil rent contribution to GDP	0.05	0.61	0.07	-0.01	0.01	-0.85
Employment to population ratio	-0.06**	0.02	-3.28	0.01	0.01	1.22
Institutional quality	0.15	7.36	0.02	0.12***	0.03	3.64
Access to basic drinking water source	0.09	1.80	0.05	-0.02	0.01	-1.80
Access to basic sanitary facility	-0.07	0.42	-0.16	0.01	0.01	1.32
Crude oil production	0.01	0.01	-0.03	0.01	0.01	-0.24
Pollution	0.01	0.09	-0.02	-0.01**	0.01	-2.95
Enrolment in basic education	-0.01	2.66	0.01	0.01	0.01	1.02
Income group	-0.18	2.79	-0.01	0.19	0.21	0.94

Robust S.E = robust standard error; z= z-value; * p<0.05, ** p<0.01, *** p<0.001

5.1.2. Cross sectional model: Relationship between oil-led economic growth and health determinants/health

Firstly, this section quantitatively assesses the relationship between oil-led economic growth and the determinants of health as well as health outcomes. Then the direct relationship between oil-led economic growth and population health as well as the indirect relationship through institutional quality, education, employment, infrastructure and environmental pollution will be explored. This section will compare the relationship in high-income and low-income countries. Before each analysis, a test of the normality assumption for each structural equation model will be discussed. A summary of the data for each group will be briefly outlined. Each analysis is conducted using structural equation modelling and goodness of fit statistics (as appropriate) will also be reported.

All the variables were explored graphically and statistically to ascertain whether the follow a multivariate normal distribution (shown in appendices). The graphical technique used to explore the variables in this study is the quantile-normal (Q-Q) plot. The straight line on the plot represents the normal distribution and deviations from the line is an indication of non-normality. The Q-Q plot for all the variables across the two income groups (appendix L and M) suggest that most of the variables used for this analysis are not normally distributed as the plot curves away from the reference line.

Appendix N shows the joint univariate test of normality. Signifcant results ($p<0.05$) indicates that the observed variable does not appear to be normally distributed. Therefore the univariate test for most variables for both groups leads to the rejection of the null hypothesis of normality.

Since the univariate normality assumption for most variables is not met, there is an indication that multivariate normality will be violated. Multivariate normal distribution is followed if all variables have a normal distribution at the univariate level. Further test to demonstrate multivariate normality is shown in appendix O.

Appendix O shows that all the four multivariate tests (Mardia's test for multivariate skewness, Mardia's test for multivariate kurtosis, Henze-Zirkler test and Doornik-Hansen test) reject the null hypothesis of multivariate normality ($p<0.05$), confirming the violation of multivariate normality in the data for both income groups.

5.1.2.1. Summary statistics

The final data used in the cross-sectional analysis contained a total of 156 countries: 62 low-income countries and 94 high-income countries. A summary of all the variables for countries in both income groups were described in terms of mean, median, standard deviation and range (see table 5.7 and 5.8). Though the mean and median were reported in the tables, the mean was more intuitive and informative to discuss.

In the low-income group (table 5.7), the rate of infant mortality ranged from 8.1 to 91.6 per 1000 live births. The mean was 40.5 per 1000 live births (SD 20.5). Life expectancy at birth ranged from 51.4 to 76.1 years. The mean was 65.1 years (SD 6.8). The observations for each variable were complete except for enrolment in basic education which was 40.3%. In the high-income group (table 5.8), the rate of infant mortality ranged from 1.9 to 58.2 per 1000 live births. The mean was 10.3 per 1000 live births (SD 9.6). Life expectancy at birth ranged from 61.2 to 83.8 years. The mean was 76.5 years (SD 4.7). The percentage of missing observation for each variable was less than 4% except for enrolment in basic education which was 20.2%. The missing values for the educational variable were handled by the MLMV method.

Table 5.7: Summary Statistics for low-income group

Variables	Number of observations	Missing observations	Mean	Median	Standard deviation	Minimum value	Maximum value
Employment to population ratio (% employed)	62	0	61.8	62.6	13.4	29.2	85.4
GDP per capita (constant 2010 US Dollars)	62	0	1537.0	1124.1	1059.3	226.5	3827.6
Infant mortality rate (per 1000 live births)	62	0	40.5	39.0	20.5	8.1	91.6
Access to basic drinking water (% of population with access)	62	0	73.5	74.2	17.7	36.6	98.6
Access to basic sanitary facility (% of population with access)	62	0	48.5	44.4	27.8	7.1	96.7
Institutional quality (score on an aggregated index)	62	0	-1.9	-2.2	1.4	-4.8	2.0
Crude oil production (1000 of barrels per day)	62	0	87.4	0.0	314.4	0.0	2171.2
Life expectancy at birth (years)	62	0	65.1	65.9	6.8	51.4	76.1
Pollution (million metric tons)	62	0	50.8	38.9	37.3	3.9	190.9
Enrolment in basic education (% gross)	37	25 (40.3%)	56.5	54.8	20.9	20.6	93.3
Oil rent contribution to GDP (% growth)	62	0	-1.6	0.0	6.5	-37.6	6.8
Crude oil export (% growth)	62	0	-7.4	0.0	60.6	-316.9	115.7

Table 5.8: Summary Statistics for High-income group

Variables	Number of observations	Missing observations	Mean	Median	Standard deviation	Minimum value	Maximum value
Employment to population ratio (% employed)	94	0	56.7	58.2	9.3	33.8	87.4
GDP per capita (constant 2010 US Dollars)	93	1(1.1%)	22414.6	14088.1	21379.2	3694.5	107648.6
Infant mortality rate (per 1000 live births)	94	0	10.3	7.4	9.6	1.9	58.2
Access to basic drinking water (% of population with access)	94	0	96.5	98.9	7.2	41.0	100.0
Access to basic sanitary facility (% of population with access)	94	0	92.6	96.4	11.1	33.8	100.0
Institutional quality (score on an aggregated index)	94	0	1.3	1.1	2.8	-4.9	6.2
Crude oil production (1000 of barrels per day)	94	0	788.0	12.2	1943.2	0.0	10252.9
Life expectancy at birth (years)	94	0	76.5	76.5	4.7	61.2	83.8
Pollution (million metric tons)	94	0	26.5	18.4	28.1	4.0	182.9
Enrolment in basic education (% gross)	75	19(20.2%)	104.1	102.14	17.6	61.3	163.9
Oil rent contribution to GDP (% growth)	91	3(3.2%)	-3.2	-0.1	7.6	-48.9	0.7
Crude oil export (% growth)	94	0	51.5	0.0	439.5	-1583.2	1951.2

5.1.2.2. Health determinants

Access to basic drinking water sources and access to basic sanitary facilities are the measures of health determinants used in this study. The relationship between oil-led economic growth as measured by oil rent contribution to GDP (% growth) and these two determinants of health are shown in figure 5.7 to 5.10.

5.1.2.2.1. Relationship between oil-led economic growth and access to basic drinking water source

The full empirical model that showed the total, direct and indirect effects in the relationship between oil-led economic growth and access to basic drinking water source was displayed on tables 5.9 and 5.10. These tables reported the standardized parameter estimates for the structural portion of the model and the coefficients ranged from very small effects (0.01) to large effects (0.70).

After adjusting for crude oil production, pollution, GDP per capita, employment to population ratio, enrolment in basic education and institutional quality, the total effect estimates showed that oil-led economic growth was significantly related to access to basic drinking water sources (0.61, $p<0.05$) in high-income group, but no significant relationship was observed in the low-income group (0.04, $p>0.05$). The effect of oil-led economic growth on access to basic drinking water sources in high-income countries was positive, moderate and significant, but very small and not significant for low-income countries. The overall indication is that oil money makes access to basic drinking water sources better in high-income countries, but this is not observed in low-income countries. Oil-led economic growth had a small and positive effect (0.20, $p<0.05$ and 0.37, $p<0.05$) on institutional quality in low-income and high-income countries respectively. This indicates that as an oil economy grows, it fosters the development of better institution in both groups. However, institutional quality had a small but not significant effect (0.01, $p>0.05$ and -0.2, $p>0.05$) on access to basic drinking water source in low-income and high-income countries respectively.

Figures 5.7 and 5.8 demonstrated only the direct effects between each relationship measured for low-income and high-income countries respectively. On the figures, the standardised parameter estimates are in red and the constants (also known as y intercept, which is the predicted value of a variable when all other variables are zero) are in black. On disintegration of the total relationship as seen in tables 5.9 and 5.10, only the direct effect (figure 5.7) of oil-led economic growth in low-income countries on: institutional quality (0.2, $p<0.05$); education (-0.48, $p<0.05$); and access to basic drinking water source (0.48, $p<0.05$) were significant . This showed that for this group of countries, more economic growth from crude oil, yielded better quality of institution and less enrolment in basic education and more access to basic drinking water sources. In the high-income countries, only the direct effect (figure 5.8) of oil-led economic growth on: employment (-0.31, $p<0.05$); institutional quality (0.37, $p<0.05$); enrolment in basic education (0.4, $p<0.05$); oil production (-0.32, $p<0.05$); and access to basic drinking water source (0.53, $p<0.05$) were significant. This demonstrated that for countries in this group, more economic growth from crude oil, yielded better quality of institution, more enrolment in basic education and less oil production, less employment and more access to basic drinking water sources.

Oil-led economic growth also had a negative, moderate and significant indirect effect on access to basic drinking water source (-0.45, $p<0.05$), via employment, GDP, oil production and education in low-income countries. There was a moderate and significant indirect relationship between GDP per capita and access to basic drinking water source (0.68, $p<0.05$ and 0.41, $p<0.05$), via education and enrolment in basic education in low-income and high-income countries respectively.

There were negative and positive mediation channels (highlighted in grey on tables 5.9 and 5.10) from oil-led economic growth to access to basic drinking water sources in both income groups, with the size of the estimates ranging from small to large effects. A positive significant channel existed between oil-led economic growth and access to basic drinking water via: enrolment in basic education, GDP and oil production in the low-income group; and pollution, GDP, oil production and enrolment in basic education for the high-income group. A negative significant channel existed between oil-led economic growth and access to basic drinking water sources via employment in the low-income group; and no significant negative mediation channels existed for this relationship in the high-income group.

On the contrary, for the models with the measure of oil-led economic growth being crude oil export (% growth), oil-led economic growth was not significantly related, either directly or indirectly to access to basic drinking water source in both income groups (appendix P).

Figure 5.7: Direct relationship between oil-led economic growth and access to basic drinking water source in low-income countries

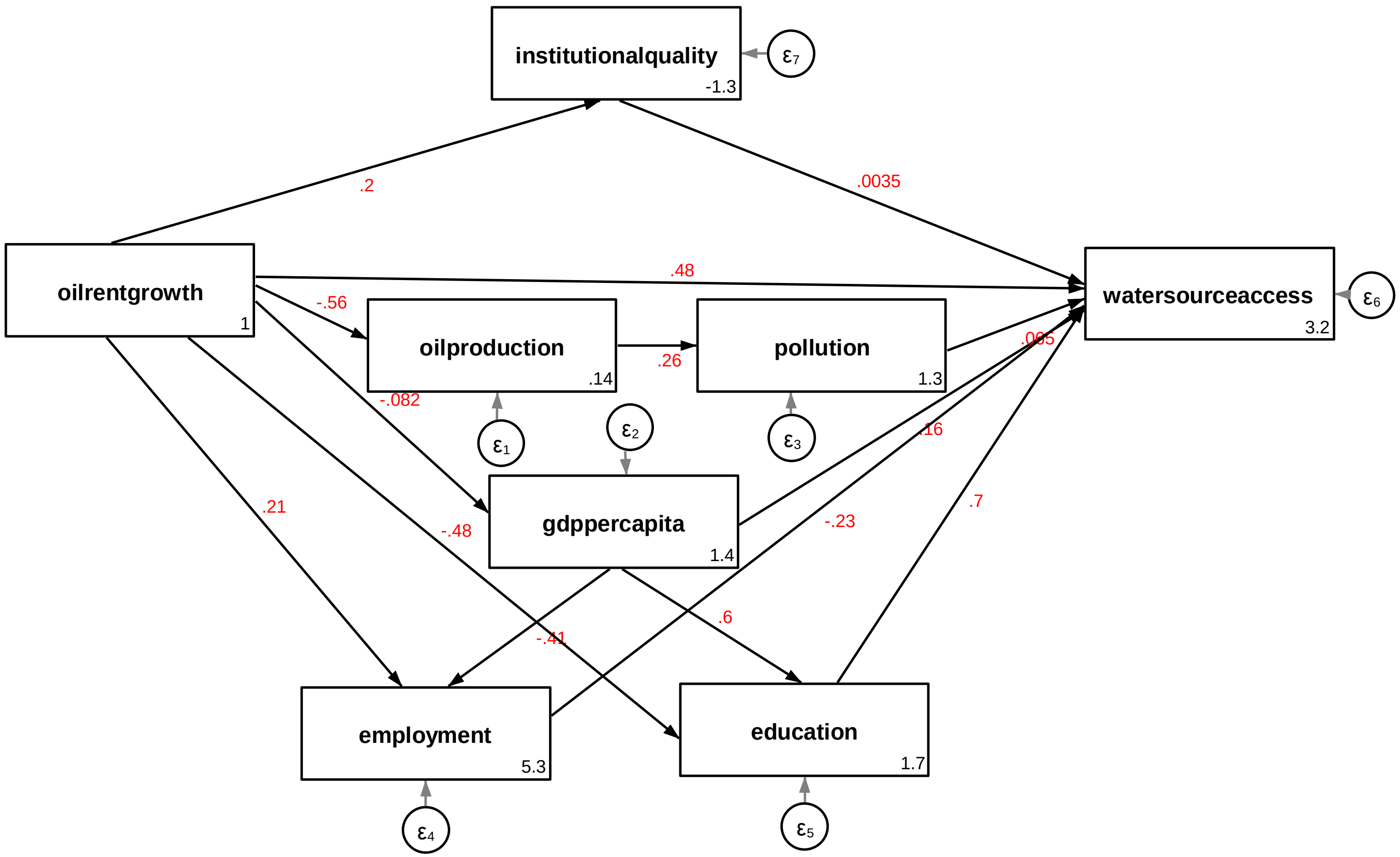


Figure 5.8: Direct relationship between oil-led economic growth and access to basic drinking water source in high-income countries

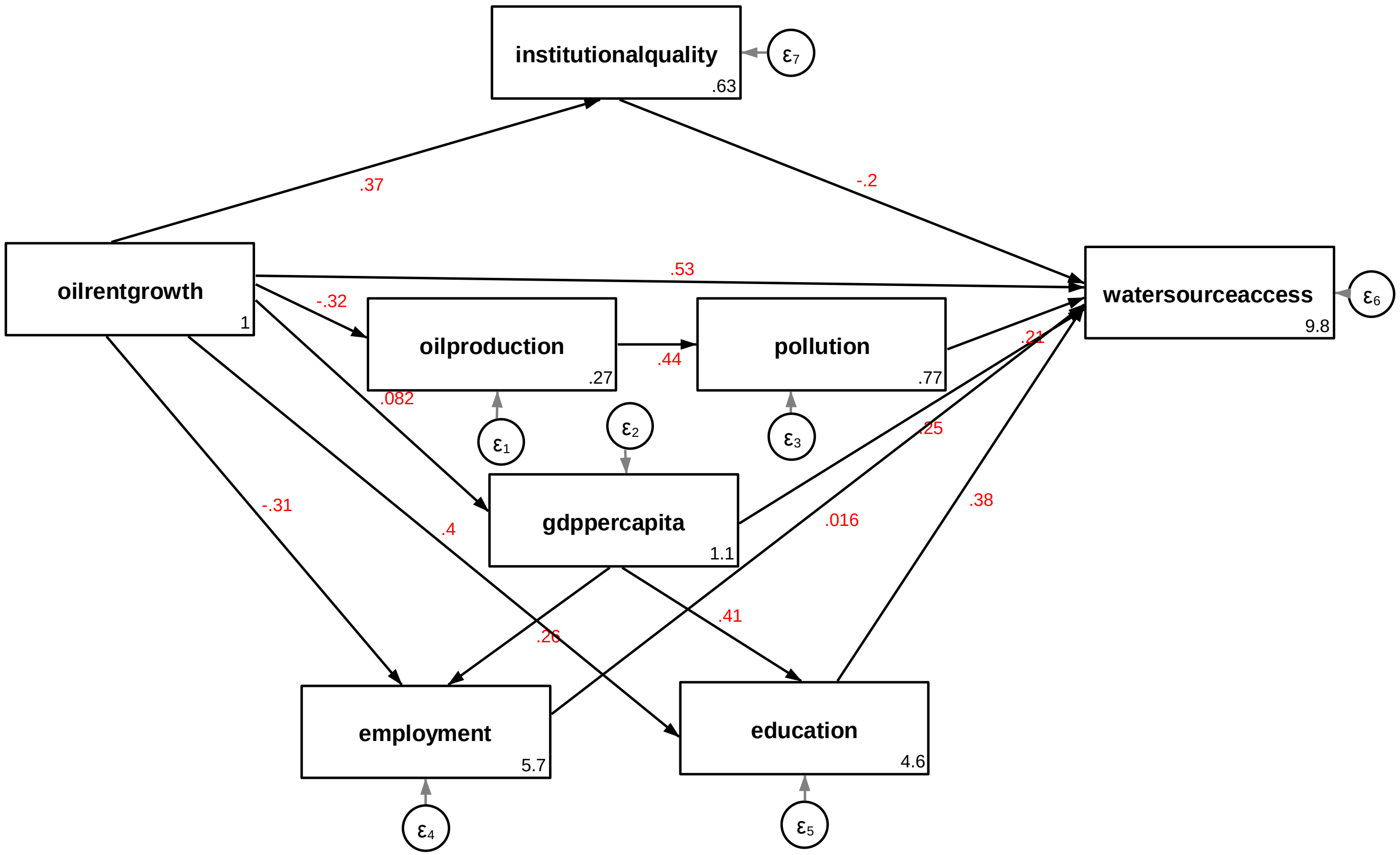


Table 5.9: Disintegration of standardised total relationship into direct/indirect relationship (access to basic drinking water source)

		Accwater			Emp			Instiqual			Oilprod		
	Income group	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Oilrent contribution to GDP (Oilrent)	Low	0.48*	-0.45*	0.04	0.21	0.03	0.24*	0.2*	-	0.2*	-0.56	-	-0.56
	High	0.53*	0.07	0.61*	-0.31*	0.02	-0.29*	0.37*	-	0.37*	-0.32*	-	-0.32*
Employment (Emp)	Low	-0.23*	-	-0.23*	-	-	-	-	-	-	-	-	-
	High	0.02	-	0.02	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	0.01	-	0.01	-	-	-	-	-	-	-	-	-
	High	-0.2	-	-0.2	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	0.02	0.02	-	-	-	-	-	-	-	-	-
	High	-	0.09	0.09	-	-	-	-	-	-	-	-	-
Pollution (Pollu)	Low	0.06	-	0.06	-	-	-	-	-	-	-	-	-
	High	0.21*	-	0.21*	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	0.70*	-	0.70*	-	-	-	-	-	-	-	-	-
	High	0.38*	-	0.38*	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	0.16	0.51*	0.68*	-0.41*	-	-0.41*	-	-	-	-	-	-
	High	0.25*	0.16*	0.41*	0.26*	-	0.26*	-	-	-	-	-	-

* represents estimates with p value less than 0.05 (statistical significance)

Table 5.10: Disintegration of standardised total relationship into direct/indirect relationship (access to basic drinking water source)

		Pollu			Educ			GDP		
	Income group	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Oilrent contribution to GDP (Oilrent)	Low	-	-0.15	-0.15	-0.48*	-0.05	-0.53*	-0.08	-	-0.08
	High	-	-0.14	-0.14	0.4*	0.03	0.43*	0.08	-	0.08
Employment (Emp)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	0.26*	-	0.26*	-	-	-	-	-	-
	High	0.44*	-	0.44*	-	-	-	-	-	-
Pollution (Pollu)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-	-	-	0.6*	-	0.60*	-	-	-
	High	-	-	-	0.41*	-	0.41*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance)

5.1.2.2.2. Relationship between oil-led economic growth and access to basic sanitary facility

The full empirical model that showed the total, direct and indirect effects in the relationship between oil-led economic growth and access to basic sanitary facility were displayed on tables 5.11 and 5.12. These tables reported the standardized parameter estimates for the model and the coefficients ranged from very small effects (0.01) to large effects (0.70).

After adjusting for crude oil production, pollution, GDP per capita, employment to population ratio, enrolment in basic education and institutional quality, the total effect estimates showed that oil-led economic growth was not significantly related to access to basic sanitary facility in both income groups. The effect of oil-led economic growth on access to basic sanitary facility in low-income countries was negative and small (-0.03, $p>0.05$) but positive and moderate (0.31, $p>0.05$) for high-income countries. This indicates that oil did not make access to basic sanitary facility better in both low- and high-income countries. Oil-led economic growth had a small and positive effect (0.20, $p<0.05$ and 0.36, $p<0.05$) on institutional quality in low-income and high-income countries respectively. This indicates that oil economy fosters the development of better institution in both groups but the effect of institutional quality (-0.03, $p>0.05$ and -0.1, $p>0.05$) on access to basic sanitary facility was negative, small and not significant in low-income and high-income countries respectively.

Figures 5.9 and 5.10 demonstrated only the direct effects between each relationship measured for low-income and high-income countries respectively, with the standardised parameter estimates (in red) and the constants (in black). On disintegration of the total relationship as seen in tables 5.11 and 5.12, only the direct effect (figure 5.9) of oil-led economic growth on: institutional quality (0.30, $p<0.05$); enrolment in basic education (-0.52, $p<0.05$) and (0.38, $p<0.05$) access to basic sanitary facility in low-income countries were significant. This showed that for this group of countries, more economic growth from crude oil, yielded less enrolment in basic education, better quality of institution and more access to basic sanitary facilities.

In the high-income countries, only the direct effect (figure 5.10) of oil-led economic growth on: employment (-0.33, $p<0.05$); institutional quality (0.36,

$p<0.05$); enrolment in basic education (0.29, $p<0.05$); oil production (-0.31, $p<0.05$) were significant. This demonstrated that for countries in this group, more economic growth from crude oil, yielded better quality of institution, more enrolment in basic education, less oil production and less employment. Also, there was no significant direct relationship between oil-led economic growth and access to basic sanitary facility (0.20, $p>0.05$) in this group.

Oil-led economic growth also had a negative, moderate and significant indirect effect (-0.42, $p<0.05$) on access to basic sanitary facility, via employment, oil production, GDP and enrolment in basic education in low-income countries. There was a moderate and significant indirect relationship between GDP per capita and access to basic sanitary facility (0.69, $p<0.05$ and 0.43, $p<0.05$), via employment and access to basic education in low-income and high-income countries respectively.

There were negative and positive mediation channels (highlighted in grey on tables 5.11 and 5.12) from oil-led economic growth to access to basic sanitary facilities in both income groups, with the size of the estimates ranging from small to large effects. A positive significant channel existed between oil-led economic growth and access to basic drinking water via: enrolment in basic education, GDP, oil production in the low-income group; and via: pollution, GDP, oil production and enrolment in basic education in the high-income group. A negative significant channel existed between oil-led economic growth and access to basic drinking water sources via employment in the low-income group and there was no negative significant effect for this relationship in the high-income group.

On the contrary, for the models with the measure of oil-led economic growth being crude oil export (% growth), oil-led economic growth was not significantly related, either directly or indirectly to access to basic sanitary facilities in both income groups (appendix P).

Figure 5.9: Direct relationship between oil-led economic growth and access to basic sanitary facility in low-income countries

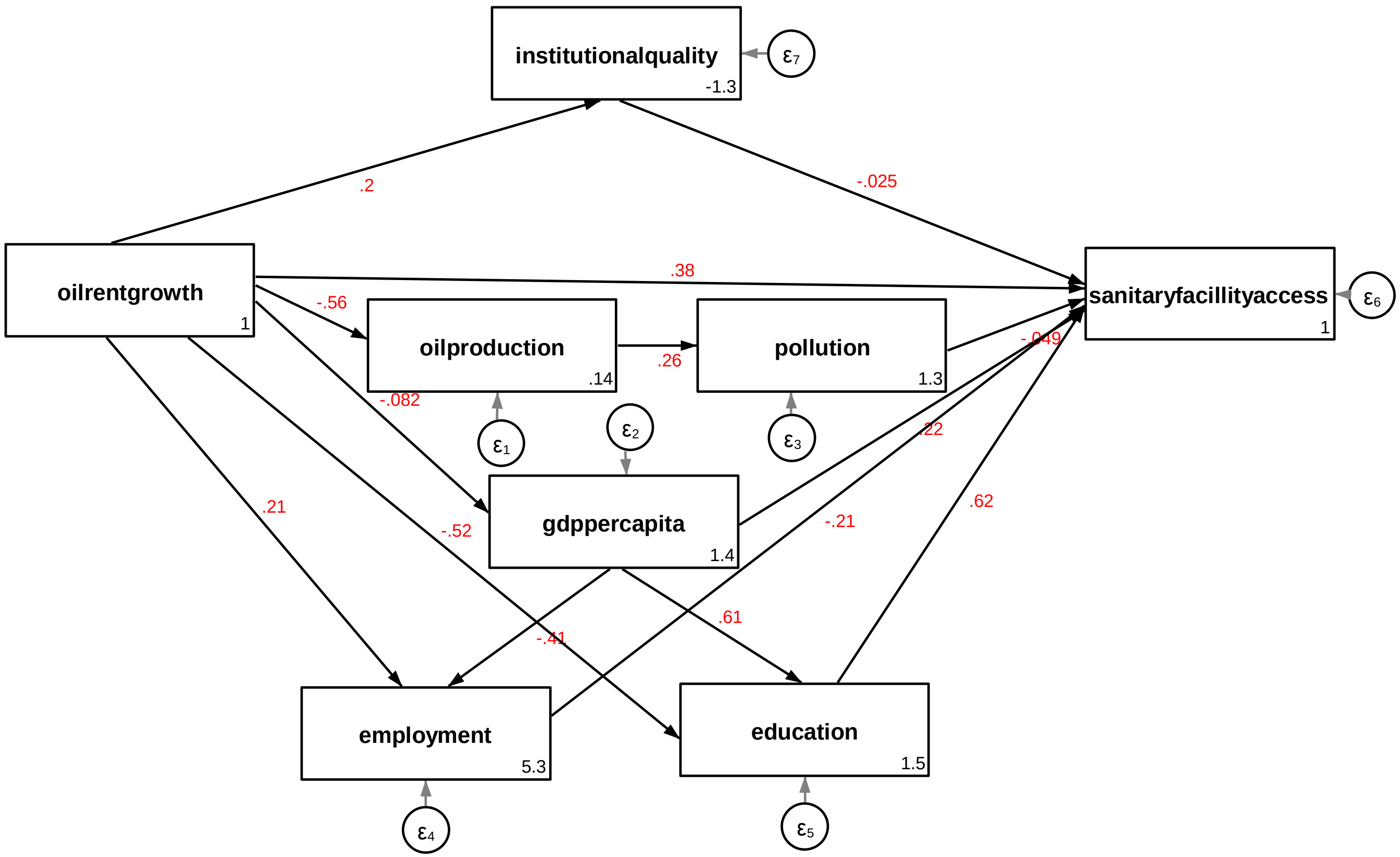


Figure 5.10: Direct relationship between oil-led economic growth and access to basic sanitary facility in high-income countries

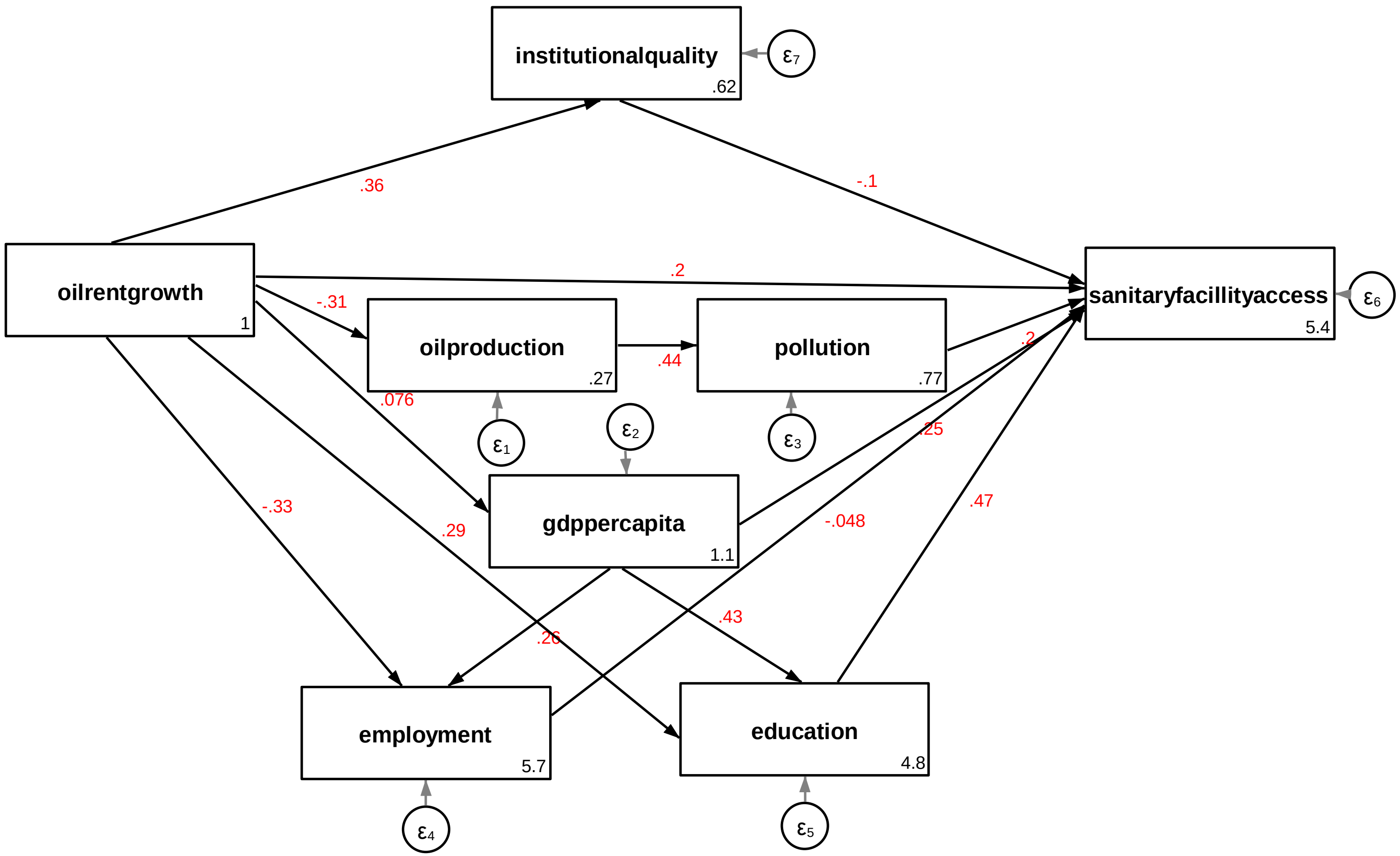


Table 5.11: Disintegration of standardised total relationship into direct/indirect relationship (access to basic sanitary facility)

		Accsanit			Emp			Instiqual			Oilprod		
	Income group	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Oilrent contribution to GDP (Oilrent)	Low	0.38*	-0.42*	-0.03	0.21	0.03	0.24*	0.20*	-	0.20*	-0.56	-	-0.56
	High	0.20	0.12	0.31	-0.33*	0.02	-0.31*	0.36*	-	0.36*	-0.31*	-	-0.31*
Employment (Emp)	Low	-0.21*	-	-0.21*	-	-	-	-	-	-	-	-	-
	High	-0.05	-	-0.05	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-0.03	-	-0.03	-	-	-	-	-	-	-	-	-
	High	-0.1	-	-0.1	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	-0.01	-0.01	-	-	-	-	-	-	-	-	-
	High	-	0.09	0.09	-	-	-	-	-	-	-	-	-
Pollution (Pollu)	Low	-0.05	-	-0.05	-	-	-	-	-	-	-	-	-
	High	0.2*	-	0.2*	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	0.62*	-	0.62*	-	-	-	-	-	-	-	-	-
	High	0.47*	-	0.47*	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	0.22	0.47*	0.69*	-0.41*	-	-0.41*	-	-	-	-	-	-
	High	0.25*	0.19*	0.43*	0.26*	-	0.26*	-	-	-	-	-	-

* represents estimates with p value less than 0.05 (statistical significance)

Table 5.12: Disintegration of standardised total relationship into direct/indirect relationship (access to basic sanitary facility)

		Pollu			Educ			GDP		
	Income group	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Oilrent contribution to GDP (Oilrent)	Low	-0.15	-	-0.15	-0.52*	-0.05	-0.57*	-0.08	-	-0.08
	High	-0.14	-	-0.14	0.29*	0.03	0.32*	0.08	-	0.08
Employment (Emp)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	0.26*	-	0.26*	-	-	-	-	-	-
	High	0.44*	-	0.44*	-	-	-	-	-	-
Pollution (Pollu)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-	-	-	0.61*	-	0.61*	-	-	-
	High	-	-	-	0.43*	-	0.43*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance)

The percentage of variance (R-squared) explained by each indicator and the total variance for models with access to basic drinking water source and access to basic sanitary facility as measures of health determinant, is shown in appendix Q. For the model with access to basic drinking water source, the proportion of variance explained by access to basic drinking water is 70% for low income group and 67% for high income group. For the model with access to basic sanitary facility, the proportion of variance explained by access to basic sanitary facility is 58% for low income group and 45% for high income group. The model variances for low- and high-income group for the model with access to basic drinking water source (0.7; 0.6) and for the model with access to basic sanitary facility (0.6; 0.3) respectively. The coefficient of determination (CD) shows that model with access to basic drinking water source was a good fit to the data (0.6) and model with access to basic sanitary facility was a fairly good fit to the data(0.5). A CD value close to 1 indicates a perfect fit.

As earlier discussed, the violation of multivariate normality of the data requires estimates with robust standard errors. Therefore, the models with robust standard error had a better fit to the data; based on the AIC and BIC statistics (appendix R), confirming the earlier report on the distribution of the data. Also, appendix S showed the coefficient of determination for the models that fits crude oil export (% growth) and health determinants. Model with access to basic drinking water source and the model with access to basic sanitary facility was also a fairly good fit to the data(0.5).

5.1.2.3. Health

Infant mortality and life expectancy at birth are the measures of health used in this study. The relationship between oil-led economic growth as measured by oil rent contribution to GDP (% growth) and health are shown in figure 5.11 to 5.14.

5.1.2.3.1. Relationship between oil-led economic growth and infant mortality

The full empirical model that showed the total, direct and indirect effects of the relationship between oil-led economic growth and infant mortality was displayed on tables 5.13 and 5.14. These tables reported the standardized parameter estimates for the structural portion of the model and the coefficients ranged from very small effects (0.02) to large effects (0.69).

After adjusting for crude oil production, pollution, GDP per capita, employment to population ratio, enrolment in basic education, institutional quality, access to basic drinking water source and access to basic sanitary facility, the total effect estimates showed that oil-led economic growth was significantly related to infant mortality (-0.64, $p<0.05$) in the high-income group but not significant in the low-income group (-0.07, $p>0.05$). The effect of oil-led economic growth on infant mortality in high-income countries was negative, large and significant, but small and not significant for low-income countries. The overall indication is that oil is related to better health in high-income countries only. Oil-led economic growth had a small, positive and significant effect (0.20, $p<0.05$ and 0.36, $p<0.05$) on institutional quality in low-income and high-income countries respectively. This indicates that as an oil economy grows, it fosters the development of better institution in both groups. However, institutional quality had a negative, small and significant effect (-0.27, $p>0.05$ and -0.25, $p>0.05$) on infant mortality in low-income and high-income countries respectively.

Figures 5.11 and 5.12 demonstrated only the direct effects between each relationship measured for low-income and high-income countries respectively. On the figures, the standardised parameter estimates are in red and the constants are in black. On disintegration of the total relationship (as seen in tables 5.13 and 5.14), there was no significant direct relationship between oil-led economic growth and infant mortality for both income groups (table 5.13). However, only the direct effect of oil-led economic growth on: institutional quality (0.20, $p<0.05$); employment (0.21, $p<0.05$); and enrolment in basic education (-0.64, $p<0.05$) were significant in the low-income group. This indicated that for this group of countries, more economic growth from crude oil yielded less enrolment in basic education, more employment and better quality of institutions.. In the high-income group, the direct effect of oil-led economic growth on access to basic drinking water source (0.62, $p<0.05$); institutional quality (0.36, $p<0.05$); enrolment in basic education (0.25, $p<0.05$); oil production (-0.32, $p<0.05$); and employment (-0.30, $p<0.05$) were significant. This indicated that for high-income countries, more economic growth from crude oil yielded more access to basic drinking water source, more enrolment in basic education, less oil production, less employment and better institutions.

Also, oil-led economic growth had a negative, moderate, statistically significant indirect relationship (-0.43, $p<0.05$) with infant mortality, through access to basic drinking water source, access to basic sanitary facility and institutional quality.

There were both negative and positive mediation channels from oil-led economic growth to infant mortality in both income groups (highlighted in grey on table 5.13 and 5.14). The magnitude of these effects ranged from small to large. There was no positive significant channel between oil-led economic growth and infant mortality in the low-income and high-income group. A negative significant channel existed between oil-led economic growth and infant mortality via: access to basic sanitary facility, employment and institutional quality in the low-income group; and via: access to basic water source, access to basic sanitary facility and institutional quality in the high-income group.

The total effect estimates in appendix T showed that crude oil export (% growth) as a measure of oil-led economic growth only had a positive, moderate and significant relationship with infant mortality (0.51, $p<0.05$) in the low-income group but small and not significant relationship for the low-income group (0.06, $p>0.05$). The overall indication is that oil is related to poorer health in low-income countries and contradicts the results for oil rent contribution to GDP (% growth) in table 5.13. Also, this measure of oil-led economic growth only had an indirect relationship with infant mortality (0.33, $p<0.05$) in the low-income group. Crude oil export (% growth) was directly related to infant mortality (-0.10, $p<0.05$) in the high-income group.

Figure 5.11: Direct relationship between oil-led economic growth and infant mortality in low-income countries

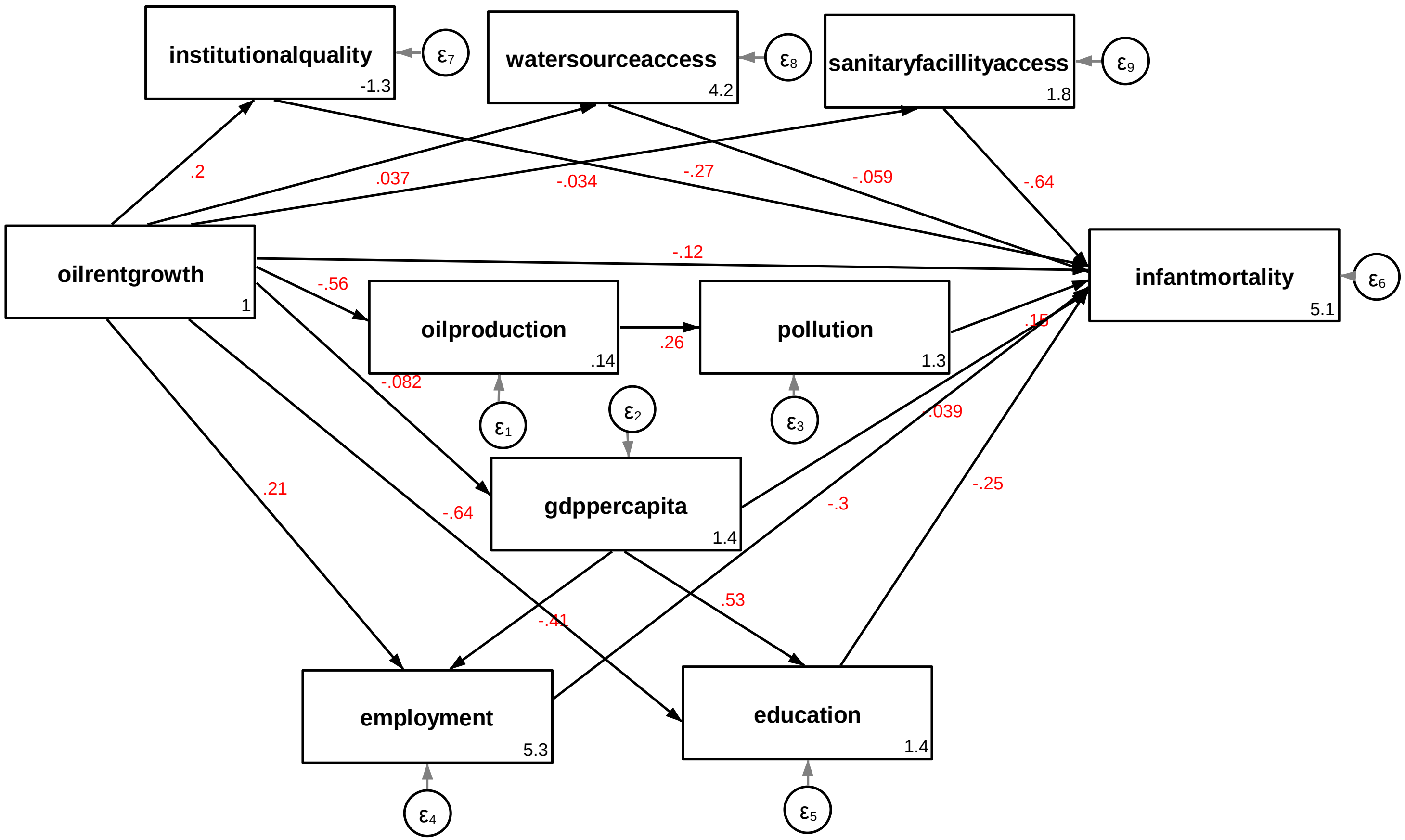


Figure 5.12: Direct relationship between oil-led economic growth and infant mortality in high-income countries

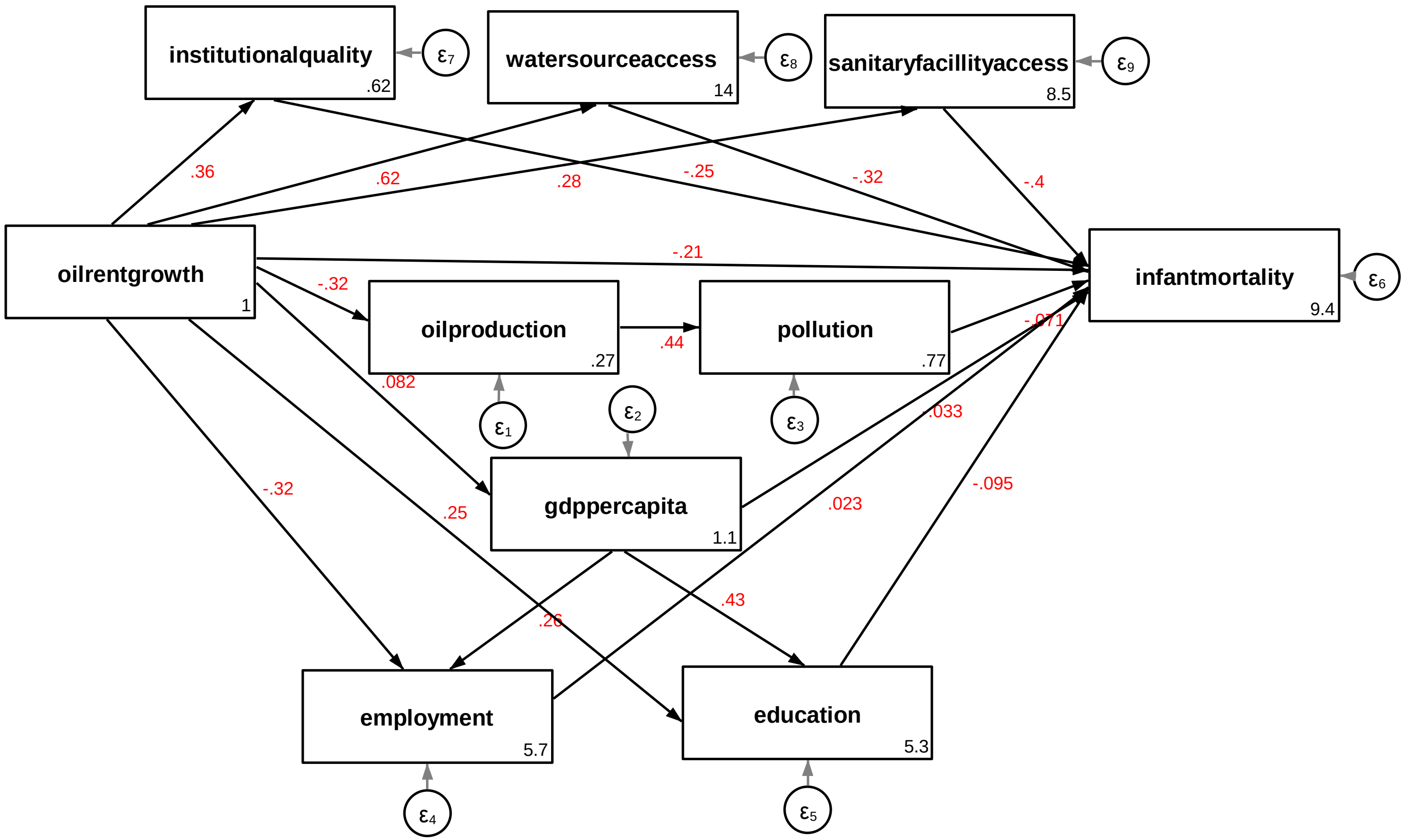


Table 5.13: Disintegration of standardised total effects into direct and indirect effect (infant mortality)

		Infmort			Accwater			Accsanit			Emp			Instiqual		
	Income group	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total
Oilrent contribution to GDP (Oilrent)	Low	-0.12	0.04	-0.07	0.04	-	0.04	-0.03	-	-0.03	0.21*	0.03	0.24*	0.20*	-	0.20*
	High	-0.21	-0.43*	-0.64*	0.62*	-	0.62*	0.28	-	0.28	-0.30*	0.02	-0.30*	0.36*	-	0.36*
Access to basic drinking water source (Accwater)	Low	-0.06	-	-0.06	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.32*	-	-0.32*	-	-	-	-	-	-	-	-	-	-	-	-
Access to basic sanitary facility (Accsanit)	Low	-0.64*	-	-0.64*	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.40*	-	-0.40*	-	-	-	-	-	-	-	-	-	-	-	-
Employment (Emp)	Low	-0.30*	-	-0.30*	-	-	-	-	-	-	-	-	-	-	-	-
	High	0.02	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-0.27*	-	-0.27*	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.25*	-	-0.25*	-	-	-	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	0.04	0.04	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-0.03	-0.03	-	-	-	-	-	-	-	-	-	-	-	-
Pollution (Pollu)	Low	0.15	-	0.15	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.07	-	-0.07	-	-	-	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	-0.25	-	-0.25	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.1	-	-0.1	-	-	-	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-0.04	-0.01	-0.05	-	-	-	-	-	-	-0.41*	-	-0.41*	-	-	-
	High	-0.03	-0.03	-0.07	-	-	-	-	-	-	0.26*	-	0.26*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance). Ind = indirect

Table 5.14: Disintegration of standardised total effects into direct and indirect effect (infant mortality)

		Oilprod			Pollu			Educ			GDP		
	Income group	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total
Oilrent contribution to GDP (Oilrent)	Low	-0.56	-	-0.56	-	-0.15	-0.15	-0.64*	-0.04	-0.69*	-0.08	-	-0.08
	High	-0.32*	-	-0.32*	-	-0.14	-0.14	0.25*	0.04	0.28*	0.08	-	0.08
Access to basic drinking water source (Accwater)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Access to basic sanitary facility (Accsanit)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Employment (Emp)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	-	-	0.26*	-	0.26*	-	-	-	-	-	-
	High	-	-	-	0.44*	-	0.44*	-	-	-	-	-	-
Pollution (Pollu)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-	-	-	-	-	-	0.53*	-	0.53*	-	-	-
	High	-	-	-	-	-	-	0.43*	-	0.43*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance). Ind = Indirect

5.1.2.3.2. Relationship between oil-led economic growth and life expectancy at birth

The full empirical model that showed the total, direct and indirect effects of the relationship between oil-led economic growth and life expectancy at birth was displayed on tables 5.15 and 5.16. These tables reported the standardized parameter estimates for the model and it ranged from very small effects (0.01) to large effects (0.68).

After adjusting for crude oil production, pollution, GDP per capita, employment to population ratio, enrolment in basic education, institutional quality, access to basic drinking water source and access to basic sanitary facility, the total effect estimates showed that oil-led economic growth was significantly related to life expectancy at birth (0.45, $p<0.05$) in the high-income group but not significant in the low-income group (0.09, $p>0.05$). The effect of oil-led economic growth on life expectancy at birth in high-income countries was positive, moderate and significant, but small and not significant for low-income countries. Again, like in the model with infant mortality as a measure of health, this indicates that oil is related to better health in high-income countries. Oil-led economic growth had a small, positive and significant effect (0.20, $p<0.05$ and 0.36, $p<0.05$) on institutional quality in low-income and high-income countries respectively. This indicates that as an oil economy grows, it fosters the development of better institution in both groups. Equally, institutional quality had a positive, small and significant effect (-0.25, $p>0.05$ and -0.30, $p>0.05$) on life expectancy at birth in low-income and high-income countries respectively.

Figures 5.13 and 5.14 demonstrated only the direct effects between each relationship measured for low-income and high-income countries respectively. The standardised parameter estimates are in red and the constants are in black. On disintegration of the total relationship, there was no significant direct relationship between oil-led economic growth and life expectancy at birth for both income groups (tables 5.15 and 5.16). However, only the direct effect of oil-led economic growth on: institutional quality (0.20, $p<0.05$); and enrolment in basic education (-0.63, $p<0.05$) were significant in the low-income group. This indicates that for this group of countries, more economic growth from crude oil yielded less enrolment in basic education and better quality of institutions. In the high income group, the direct effect of oil-led economic growth on: access to basic water source (0.62, $p<0.05$); employment (-0.32, $p<0.05$); institutional quality (0.36, $p<0.05$); oil production (-0.31, $p<0.05$) and enrolment in basic education (0.21, $p<0.05$) were significant in the high-income group. This indicated that for this group of countries, more economic growth from crude oil yielded more access to basic water source, less employment, better quality of institutions and less oil production and more enrolment in basic education.

Also, oil-led economic growth had a positive, moderate and statistically significant indirect relationship (0.38, $p<0.05$) with life expectancy at birth, through GDP, access to basic sanitary facility, institutional quality and pollution.

There were both negative and positive mediation channels from oil-led economic growth to life expectancy at birth in both income groups (highlighted in grey on table 5.15 and 5.16). The magnitude of these effects ranged from small to large effects. A positive significant channel existed between oil-led economic growth and life expectancy at birth via: institutional quality, employment and access to basic sanitary facility in the low-income group; and via: access to basic sanitary facility, GDP and institutional quality in the high-income group. A negative significant channel existed between oil-led economic growth and life expectancy at birth via: pollution in the low-income group; as well as via: pollution in the high-income group.

Appendix T shows that crude oil export (% growth) as a measure of oil-led economic growth was significantly related to life expectancy at birth in only low-income group. The total effect estimates showed that this measure of oil-led economic growth was negative, moderate and significantly related to life expectancy at birth (-0.54, $p<0.05$) in the low-income group. The overall indication is that economic growth from crude oil (measured by crude oil export % growth) is related to poorer health in low-income countries. Also, this measure of oil-led economic growth only had a significant indirect relationship with life expectancy at birth (-0.34, $p<0.05$) and a direct relationship to life expectancy at birth (-0.20, $p<0.05$) in the low-income group.

Figure 5.13: Direct relationship between oil-led economic growth and life expectancy at birth in low-income countries

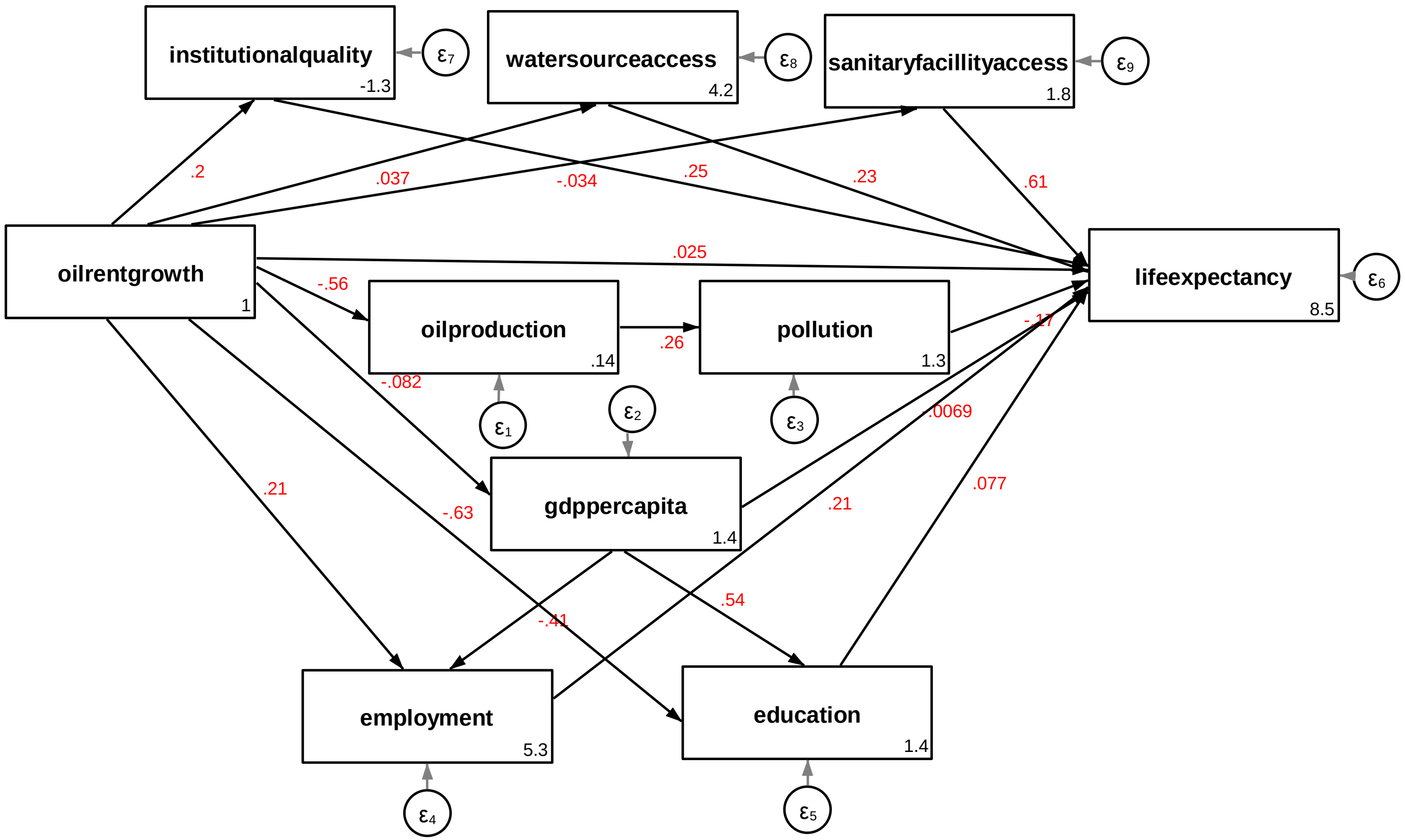


Figure 5.14: Direct relationship between oil-led economic growth and life expectancy at birth in high-income countries

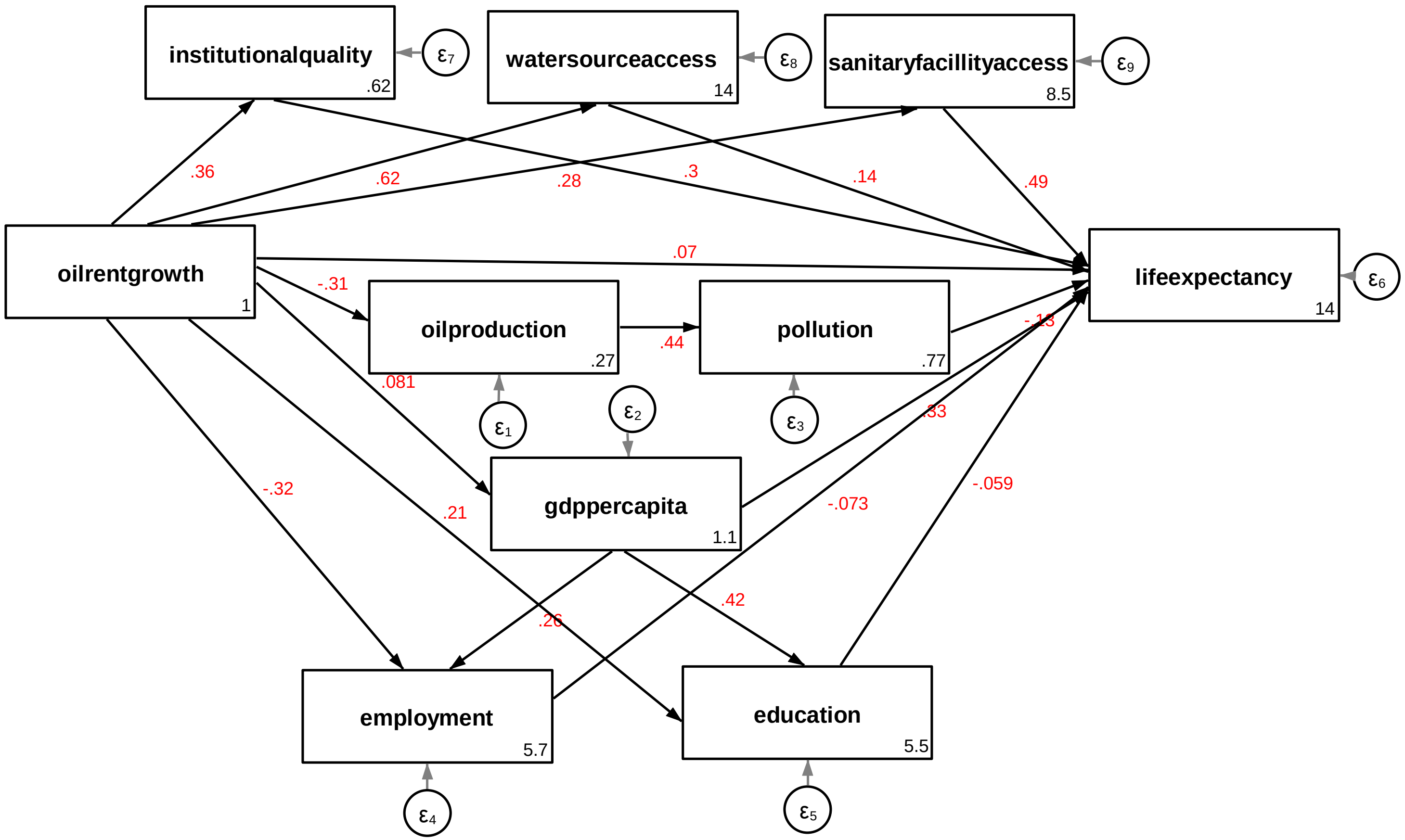


Table 5.15: Disintegration of standardised total effects into direct and indirect effect (life expectancy at birth)

		Lifexp			Accwater			Accsanit			Emp			Instiqual		
	Income group	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total
Oilrent contribution to GDP (Oilrent)	Low	0.03	0.06	0.09	0.04	-	0.04	-0.03	-	-0.03	0.21*	0.03	0.24*	0.20*	-	0.20*
	High	0.07	0.38*	0.45*	0.62*	-	0.62*	0.28	-	0.28	-0.32*	0.02	-0.30*	0.36*	-	0.36*
Access to basic drinking water source (Accwater)	Low	0.23	-	0.23	-	-	-	-	-	-	-	-	-	-	-	-
	High	0.14	-	0.14	-	-	-	-	-	-	-	-	-	-	-	-
Access to basic sanitary facility (Accsanit)	Low	0.61*	-	0.61*	-	-	-	-	-	-	-	-	-	-	-	-
	High	0.49*	-	0.49*	-	-	-	-	-	-	-	-	-	-	-	-
Employment (Emp)	Low	0.21*	-	0.21*	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.07	-	-0.07	-	-	-	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	0.25*	-	0.25*	-	-	-	-	-	-	-	-	-	-	-	-
	High	0.30*	-	0.30*	-	-	-	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	-0.04	-0.04	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-0.06	-0.06	-	-	-	-	-	-	-	-	-	-	-	-
Pollution (Pollu)	Low	-0.17*	-	-0.17*	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.13*	-	-0.13*	-	-	-	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	0.08	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-
	High	-0.06	-	-0.06	-	-	-	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-0.01	-0.05	-0.05	-	-	-	-	-	-	-0.41*	-	-0.41*	-	-	-
	High	0.33*	-0.04	0.29*	-	-	-	-	-	-	0.26*	-	0.26*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance). Ind = Indirect

Table 5.16: Disintegration of standardised total effects into direct and indirect effect (life expectancy at birth)

		Oilprod			Pollu			Educ			GDP		
	Income group	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total	Direct	Ind	Total
Oilrent contribution to GDP (Oilrent)	Low	-0.56	-	-0.56	-	-0.15	-0.15	-0.63*	-0.04	-0.68*	-0.08	-	-0.08
	High	-0.31*	-	-0.31*	-	-0.14	-0.14	0.21*	0.03	0.25*	0.08	-	0.08
Access to basic drinking water source (Accwater)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Access to basic sanitary facility (Accsanit)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Employment (Emp)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Institutional quality (Instiqual)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Oil production (Oilprod)	Low	-	-	-	0.26*	-	0.26*	-	-	-	-	-	-
	High	-	-	-	0.44*	-	0.44*	-	-	-	-	-	-
Pollution (Pollu)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Enrolment in basic education (Educ)	Low	-	-	-	-	-	-	-	-	-	-	-	-
	High	-	-	-	-	-	-	-	-	-	-	-	-
Gross domestic product (GDP)	Low	-	-	-	-	-	-	0.54*	-	0.54*	-	-	-
	High	-	-	-	-	-	-	0.42*	-	0.42*	-	-	-

* represents estimates with p value less than 0.05 (statistical significance). Ind = Indirect

The percentage of variance (R-squared) explained by each indicator and the total variance for model with infant mortality and model with life expectancy at birth is shown in appendix U. In the model with infant mortality, the proportion of variance explained by infant mortality was 55% for low income group and 71% for high income group. In the model with life expectancy at birth, the proportion of variance explained by life expectancy at birth was 53% for low income group and 64% for high income group. The model variances for low and high income group are: model with infant mortality (0.7; 0.6) and model with life expectancy at birth (0.7; 0.5) respectively. The coefficient of determination (CD) shows that model with infant mortality was a good fit to the data (0.6) and model with life expectancy at birth was also a good fit to the data(0.5).

The models with robust standard error had a better fit to the data; based on the AIC and BIC statistics (appendix V). Appendix W tabulated the coefficient of determination for the models that fits crude oil export (% growth) on health and it showed that the model with infant mortality and the model with life expectancy at birth also had a fairly good fit to the data (0.5).

5.2. Phase two study

This study assessed the relationship between crude oil-led economic growth and health as well as its associated determinants in Nigeria. The data used for this study were from 38,522 households in 37 states/federal capital territory. Since the data are hierarchical, the first level comprises household characteristics and state-level characteristics made up the second level. A description of the data is reported in tables 5.17 and 5.18. Missing data were handled using multilevel multiple imputation by chained equations (under missing-at-random assumption), preventing the potential bias that can arise from incomplete data. All predictors were used in the imputation of the missing data.

In this study, all the models were mixed effect models with both fixed effects and random effects, with households nested within states in a random intercept multilevel model. The outcome measures for health determinants were access to drinking water and access to sanitary facilities while the measure for health was household death. Though the final models in this study were fitted using MCMC method, many different estimation techniques were used (as sensitivity checks to test the assumptions of the different models).

Multilevel nominal models were used to model the relationship between oil-led economic growth and health determinants (access to drinking water and access to sanitary facilities), treating each dependent variable as a nominal variable. The models were built systematically, with a null model built first. The null model contained a random intercept for each state but had no explanatory variables. This was used to show the amount of variation that comes from the state-level. A simple random intercept model was fitted with progressive addition of predictors to the null model (reported as model 1 to 3). This allowed the demonstration of the variation that comes from the predictors, gradually exploring the hypothesised relationship.

As with this study, multilevel nominal models fitted on data with small numbers of level 2 units are usually estimated using the restricted maximum likelihood estimation and the most accurate quasi-likelihood estimation method is second order penalised quasi-likelihood (PQL2). However, this method has been reported to be biased, especially when the size of the level 2 units is small. Therefore, a sensitivity test was done between models fitted with quasi-likelihood methods and the model fitted using the Markov Chain Monte Carlo estimation (MCMC) method. The final model was fitted using the MCMC method.

Also, multilevel Poisson and negative binomial models were used to demonstrate the relationship between oil-led economic growth and health (household death), treating the dependent variable as a count variable. The models were built systematically, with progressive addition of predictors (reported as model 1 to 4). Sensitivity analysis was done to compare the model fit to the data, as there was a possibility that there was over-dispersion in the data. A multilevel Poisson without over-dispersion parameter, Poisson with over-dispersion parameter and negative binomial models were compared and the results were similar. This was also compared with the MCMC model and the final model was fitted using the MCMC method. The Deviance Information Criterion (DIC) statistic was used to compare the models and the one with the smallest DIC is estimated to be the model that best predicts a dataset with the same structure as that estimated.

It is important to note that the estimates of all the models were expressed as coefficients as the analysis using imputed data (in the Runmlwin STATA package) did not allow for estimation of rate ratios, which would have been more intuitive to interpret in terms of magnitude of effects.

The estimates and their associated confidence intervals were reported for all the multivariate analysis in the phase two study. The confidence intervals described the precision of the estimates, showing with reasonable certainty the range of values within which the true effect actually lies. A narrow confidence interval indicated that the effect size was known precisely while a fairly wide interval reflected more uncertainty in the estimates but suggested that there may still be enough precision to make decisions about the effect. A very wide Interval indicated that there was uncertainty inherent in the estimates and little was known about the effect. Also, if the confidence intervals did not include the null value of zero, the null hypothesis (which states that the coefficient was zero given that the other predictors were in the model) was rejected but if it included zero, the null hypothesis was not rejected.

5.2.1. Summary of phase two data

Tables 5.17 and 5.18 give a summary of the data in the phase two study. It shows that a large proportion of the household heads were in their middle age (62.9%), male (80.1%) and had no education (34.8%). Of the 38,522 households in this study, a large proportion of the households were rich (44.2%), used pit toilet (44.2%) and had access to well water as their drinking water source (59.7%). Based on Urban-Rural classification, 41.2% of the households were in urban areas and 58.8% in rural areas. The number of household deaths ranged from 0 to 6 but each household is typically made up of between one to forty-three members. Most of the households (94.5%) did not have any deaths in the last twelve months before the survey and a very small percentage (less than 0.1%) of the households had high number of deaths.

Table 5.17: Descriptive statistics (main dependent and independent variables)

	Number (percentage)	Mean (standard deviation)
Measured at household level		
Access to sanitary facility n = 38,481		
Flushed toilet	8252 (21.44)	
Pit toilet	17002 (44.18)	
Bucket and composting toilet	1173 (3.05)	
No facility	12054 (31.32)	
Missing	41 (0.11)	
Access to drinking water n = 38,459		
Piped water	4100 (10.66)	
Tanker and packaged water	3464 (9.01)	
Well water	22942 (59.65)	
Open water	7953 (20.68)	
Missing	63 (0.16)	
Number of household deaths n = 38,475		0.06 (0.27)
0	36361 (94.51)	
1	1905 (4.95)	
2	181 (0.47)	
3	26 (0.07)	
4	1 (< 0.01)	
6	1 (< 0.01)	
Missing	47 (0.12)	
Measured at state level		
Crude oil revenue (% growth) n = 38,522		436.51 (88.24)

Table 5.18: Descriptive statistics (control variables)

	Number (percentage)	Mean (standard deviation)
Measured at household level		
Household wealth index group n = 38,522		
Poor	13043 (33.86)	
Average	8453 (21.94)	
Rich	17026 (44.20)	
Missing	0 (0)	
Gender of household head n = 38,522		
Male	30854 (80.09)	
Female	7668 (19.91)	
Missing	0 (0)	
Educational attainment of household head n = 38,083		
No education	13404 (34.80)	
Incomplete primary	2133 (5.54)	
Complete primary	6294 (16.34)	
Incomplete secondary	3169 (8.23)	
Complete secondary	7515 (19.51)	
Higher	5569 (14.46)	
Missing	438 (1.14)	
Urban-rural classification of residence n = 38,522		
Urban	15859 (41.17)	
Rural	22663 (58.83)	
Missing	0 (0)	
Age of household head n = 38,446		45.40 (16.20)
For descriptive purposes, age categorised:		
Young household head (age ≤ 30yrs)	8428 (21.88)	
Middle aged household head (31-64yrs)	24233 (62.91)	
Elderly household head (age ≥ 65yrs)	5785 (15.02)	
Missing	76 (0.20)	

5.2.2. Household drinking water source

The source of household drinking water is a nominal response variable with clusters and was modelled using the multilevel nominal logistic regression (Anderson et al., 2013). The reference category was open water source. The predictors were wealth index, residential place, age of household head, sex of household head, educational attainment of household head and crude oil-led economic growth. I fitted models progressively with fixed effects and then a random structure, adding predictors that were important to the study.

5.2.2.1. Bivariate analysis

Tables 5.19 to 5.21 show details of the bivariate analysis in this study. There were 38,522 households included in this study. Out of these, those with access to safe drinking water sources were: 10.7% had access to piped water, 9.0% had access to tanker and packaged water. Others had access to unsafe drinking water sources: 59.7% had access to well water and 20.7% had access to open water sources. 0.2% (63) did not report source of drinking water. Tables 5.19 to 5.21 shows a cross tabulation of household drinking water source and the predictors in this study. The table contains chi-square test for independence and frequency for each predictor.

Chi-square test for association showed that the place of residence, wealth index, educational attainment and gender of household head were associated with the sources of drinking water (see table, $p<0.001$). Hence, the sources of drinking water varied across these predictors. Among households that use piped water source, 65% were in urban areas compared to 35% in rural areas. Conversely, in households that use open water source, 15% were in urban areas and 85% in rural areas. Most of the poor households (compared to others) used open water sources (48%) while most of the rich households used piped water sources (68%). Of the households using open water sources, 38% were from households with heads that have no education and 8% were from households with heads that have higher education. Well water is the most used water source in both female and male headed households.

The bivariate analysis suggests that there is statistically significant association between household source of drinking water (piped water, tanker and packaged water, well water and open water source) and place of residence ($p<.0001$), educational attainment of household head ($p<.0001$), wealth index ($p<0.001$) and gender of household head ($p<0.001$). Therefore, further investigation (multivariate analysis) was conducted.

Table 5.19: Distribution of household drinking water source (place of residence and gender of household head)

Variables (Chi-square, p-value)		Piped water	Tanker and packaged water	Well water	Open water source	Total
Place of residence: Chi-square=5500, p< 0.001	Urban	2,649	2,844	9,121	1,226	15,840
		64.61	82.10	39.76	15.42	41.19
		16.72	17.95	57.58	7.74	100.00
	Rural	1,451	620	13,821	6,727	22,619
		35.39	17.90	60.24	84.58	58.81
		6.41	2.74	61.10	29.74	100.00
Gender of household head: Chi-square= 72.14, p< 0.001	Female	3,227	2,659	18,688	6,226	30,800
		78.71	76.76	81.46	78.28	80.09
		10.48	8.63	60.68	20.21	100.00
	Male	873	805	4,254	1,727	7,659
		21.29	23.24	18.54	21.72	19.91
		11.40	10.51	55.54	22.55	100.00

For each variable: row one represents the frequency; row two represents row percentage; and row three represents column percentage.

Table 5.20: Distribution of household drinking water source (educational attainment of household head)

Variables (Chi-square, p-value)		Piped water	Tanker and packaged water	Well water	Open water source	Total
Educational attainment of household head: Chi-square= 2900, p< 0.001	No education	1,031	384	9,000	2,955	13,370
		25.60	11.17	39.68	37.52	35.16
		7.71	2.87	67.31	22.10	100.00
	Incomplete primary	159	97	1,140	733	2,129
		3.95	2.82	5.03	9.31	5.60
		7.47	4.56	53.55	34.43	100.00
	Complete primary	628	441	3,648	1,570	6,287
		15.59	12.82	16.09	19.93	16.54
		9.99	7.01	58.02	24.97	100.00
	Incomplete secondary	285	330	1,744	805	3,164
		7.08	9.60	7.69	10.22	8.32
		9.01	10.43	55.12	25.44	100.00
	Complete secondary	953	1,077	4,280	1,200	7,510
		23.66	31.32	18.87	15.24	19.75
		12.69	14.34	56.99	15.98	100.00
	Higher	972	1,110	2,867	613	5,562
		24.13	32.28	12.64	7.78	14.63
		17.48	19.96	51.55	11.02	100.00

For each variable: row one represents the frequency; row two represents row percentage; and row three represents column percentage.

Table 5.21: Distribution of household drinking water source (wealth index)

Variables (Chi-square, p-value)		Piped water	Tanker and packaged water	Well water	Open water source	Total
Wealth index: Chi-square= 5800, p< 0.001	poor	609	119	8,451	3,826	13,005
		14.85	3.44	36.84	48.11	33.82
		4.68	0.92	64.98	29.42	100.00
	average	717	265	4,916	2,542	8,440
		17.49	7.65	21.43	31.96	21.95
		8.50	3.14	58.25	30.12	100.00
	rich	2,774	3,080	9,575	1,585	17,014
		67.66	88.91	41.74	19.93	44.24
		16.30	18.1	56.28	9.32	100.00

For each variable: row one represents the frequency; row two represents row percentage; and row three represents column percentage.

5.2.2.2. Multivariate analysis

The coefficients reported on the tables are the estimated multinomial logistic coefficients. The reference group for the model is open water source. Therefore, a model for piped water relative to open water source, tanker and packaged water relative to open water source and a model for well water relative to open water source are estimated. The parameter estimates are also relative to the reference group. The interpretation of the multinomial logit is that: for a unit change in the predictor, the logit of the response variable (relative to the reference group) is changed by its respective parameter estimate, given other predictors in the model are held constant.

Tables 5.22 and 5.23 shows the influence of different covariates as the model is fitted from the null to the full model (model 3). The addition of different groups of covariates led to some explanation of the variance in model. The relationship between oil-led economic growth and source of drinking water was not attenuated as more variables were included in the model. Due to the very small value of some of the estimates, the results were presented in 3 and 4 decimal places. The magnitude of the estimates in the final model was small but any small difference observed was considered important for Nigeria as a case study.

Table 5.22: Association between household drinking water source and oil-led economic growth

	Null model			Model1			Model2			Model3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
[1] **Piped water relative to open water**												
Oil-led economic growth				-0.001	-0.004	0.001	-0.001	-0.004	0.001	-0.0001	-0.004	0.003
Gender of household head							0.216***	0.133	0.298	0.376***	0.302	0.45
Age of household head							-0.002***	-0.004	0.001	0.007***	0.005	0.009
Place of residence										-2.075***	-2.156	-1.993
Wealth index										1.285***	1.225	1.345
Educational attainment of head										0.074***	0.052	0.097
[2] **Tanker and packaged water relative to open water source**												
Oil-led economic growth				-0.003	-0.007	0.002	-0.003	-0.007	0.001	-0.002	-0.006	0.003
Gender of household head							0.163**	0.07	0.257	0.321**	0.235	0.407
Age of household head							-0.023***	-0.025	-0.02	-0.009***	-0.011	-0.006
Place of residence										-2.372***	-2.483	-2.261
Wealth index										1.683***	1.585	1.781
Educational attainment of head										0.146***	0.119	0.173

Table 5.23: Association between household drinking water source and oil-led economic growth

	Null model			Model1			Model2			Model3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
[3] **Well water relative to open water source**												
Oil-led economic growth				-0.001	-0.003	0.002	-0.001	-0.003	0.001	-0.001	-0.003	0.002
Gender of household head							0.049	-0.004	0.103	0.095**	0.04	0.151
Age of household head							-0.005***	-0.006	-0.003	-0.002*	-0.003	0.001
Place of residence										-1.364*	-1.421	-1.307
Wealth index										0.691***	0.653	0.729
Educational attainment of household head										-0.005	-0.02	0.011
Random effect parameters												
1	0.627***	0.336	0.918	0.595***	0.319	0.871	0.615***	0.33	0.899	0.704***	0.379	1.03
2	1.397***	0.753	2.041	1.31***	0.707	1.913	1.261***	0.681	1.842	1.244***	0.67	1.819
3	0.405***	0.218	0.592	0.403***	0.217	0.588	0.400***	0.216	0.584	0.475***	0.257	0.694

Coeff = coefficients; Lower CI and upper CI = 95% confidence intervals; random effect parameter = between state variance. * p<0.05, ** p<0.01, *** p<0.001. The random effect parameters 1, 2 and 3 represents the random effect for each source of drinking water relative to open water source

As discussed previously, the full model was also fitted using MCMC method (tables 5.24 and 5.25). Recall that the quasi-likelihood estimates become more biased when the sample size of level 2 units are small (as in our phase 2 data), hence, the difference in the random effect output between PQL2 and MCMC models. Estimates reported in the results are based on chains of 50,000 iterations following a burn-in of 5,000.

The outputs for the final model (MCMC model) are interpreted as follows:

5.2.2.2.1. Piped water relative to open water source

The multinomial log-odds for households with piped water relative to open water source (assuming all other variables in the model were held constant) would be expected to decrease by: 0.002 for one unit increase in oil-led economic growth; and 1.878 for rural households compared to urban households. However, it would be expected to increase by: 0.007 for a one unit increase in age of household head; 0.396 for female household head compared to male household head; 0.063 for educated household head compared to household head with no education; and 1.550 for richer households compared to poor households.

All the estimates for households with piped water relative to open water source were precise as the associated confidence intervals for the estimates were narrow. Though all confidence intervals did not include zero, the confidence interval for oil-led economic growth included the null value of zero. Hence, oil-led economic growth did not significantly influence the use of piped water relative to open water source.

Households in rural areas (compared to those in urban areas) were significantly less likely to use piped water relative to open water source. On the contrary, households with older household head (compared to younger head), female household head (compared to male household head), educated household head (compared to household head with no education) and richer households (compared to poorer households) were significantly more likely to use piped water relative to open water source.

5.2.2.2.2. Tanker and packaged water relative to open water source

The multinomial log-odds for households with tanker and packaged water relative to open water source (assuming all other variables in the model were held constant) would be expected to decrease by: 0.002 for one unit increase in oil-led economic growth; 0.013 for a one unit increase in age of household head; and 1.884 for rural households compared to urban households. However, it would be expected to increase by: 0.364 for female household head compared to male household head; 0.151 for educated household head compared to household head with no education; and 1.836 for richer households compared to poorer households.

The estimates for households with tanker and packaged water relative to open water source were precise as the associated confidence intervals for the estimates were all narrow. All but the confidence interval for the estimate for oil-led economic growth included the null value of zero. Again, oil-led economic growth did not significantly influence the use of tanker and packaged water relative to open water source.

Households in rural areas (compared to those in urban areas) and those with older household head (compared to younger head) were significantly less likely to use tanker and packaged water relative to open water source. On the contrary, households with female household head (compared to male household head), educated household head (compared to household head with no education) and richer households (compared to poorer households) were significantly more likely to use tanker and packaged water relative to open water source.

5.2.2.2.3. Well water relative to open water source

The multinomial log-odds for households with well water relative to open water source (assuming all other variables in the model were held constant) would be expected to decrease by: 0.001 for one unit increase in oil-led economic growth; 0.001 for a one unit increase in age of household head; and 1.212 for rural households compared to urban households. However, it would be expected to increase by: 0.133 for female household head compared to male household head; 0.007 for educated household head compared to household head with no education; and 0.814 for richer households compared to poorer households.

The confidence intervals for the estimates for households with well water relative to open water source were all narrow; therefore it is reasonable to say the estimates were precise. All but the confidence intervals for the estimates for oil-led economic growth, age of household head and educational attainment of household head included the null value of zero. Hence, oil-led economic growth, age of household head and educational attainment of household head did not significantly influence the use of well water relative to open water source.

Households in rural areas (compared to those in urban areas) were significantly less likely to use well water relative to open water source. On the other hand, households with female household head (compared to male household head) and richer households (compared to poorer households) were significantly more likely to use well water relative to open water source.

In the random effect parameters in table 5.25 of the output for the final model, the correlations were all positive suggesting that states with high (or low) use of one source of drinking water relative to using open water source also tend to have high (or low) use of other sources of drinking water relative to open water source. The random effect parameters 1, 2 and 3 represent the random effect for each source of drinking water relative to open water source. Random effect parameters: var represents the between state variance and cov represents the correlation between the use of water sources. The highest correlation was between the use of piped and well water. The estimated intraclass correlation (ICC) value showed that the correlation in the source of drinking water between states was 0.145. This indicates that approximately 14.5% of the total variation in the source of drinking water was accounted for by the states. Thus, the remaining 85.5% variability was due to the variation within the households and other factors. There were clearly substantial differences in the source of drinking water between states.

Table 5.24: Analysis of full model using MCMC method (piped water and tanker/packaged sources, relative to open water source)

	Multinomial logistic model (PQL2): model 3			MCMC model		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
1 Piped water relative to open water source						
Oil-led economic growth	-0.001	-0.004	0.003	-0.002	-0.008	0.004
Gender of household head	0.376***	0.302	0.45	0.396***	0.273	0.519
Age of household head	0.007***	0.005	0.009	0.007***	0.004	0.01
Place of residence	-2.075***	-2.156	-1.993	-1.878***	-1.999	-1.757
Wealth index	1.285***	1.225	1.345	1.550***	1.466	1.634
Educational attainment of household head	0.0745***	0.052	0.097	0.063***	0.035	0.092
2 Tanker and packaged water relative to open water source						
Oil-led economic growth	-0.002	-0.006	0.003	-0.002	-0.007	0.003
Gender of household head	0.321***	0.235	0.407	0.364***	0.243	0.486
Age of household head	-0.009***	-0.011	-0.006	-0.013***	-0.016	-0.009
Place of residence	-2.372***	-2.483	-2.261	-1.884***	-2.016	-1.751
Wealth index	1.683***	1.585	1.781	1.836***	1.731	1.942
Educational attainment of household head	0.146***	0.119	0.173	0.151***	0.118	0.183

Table 5.25: Analysis of full model using MCMC method (well water relative to open water source; and random effect parameters)

	Multinomial logistic model (PQL2): model 3			MCMC model		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
3 Well water relative to open water source						
Oil-led economic growth	-0.001	-0.003	0.002	-0.001	-0.006	0.004
Gender of household head	0.095**	0.04	0.151	0.133**	0.051	0.215
Age of household head	-0.002*	-0.003	0.001	-0.001	-0.003	0.001
Place of residence	-1.364***	-1.421	-1.307	-1.212***	-1.299	-1.125
Wealth index	0.691***	0.653	0.729	0.814***	0.767	0.861
Educational attainment of household head	-0.005	-0.02	0.011	0.007	-0.013	0.027
Random effect parameters						
Var 1	0.705***	0.379	1.03	4.170***	2.136	6.203
Var 2	1.244***	0.67	1.819	2.622***	1.322	3.922
Var 3	0.475***	0.257	0.694	2.009***	1.031	2.986
Cov 1_2	-0.567**	-0.924	-0.21	2.191**	0.825	3.557
Cov 1_3	-0.001	-0.19	0.187	2.450***	1.155	3.746
Cov 2_3	-0.561***	-0.87	-0.251	1.433**	0.502	2.364

Coeff = coefficient or multinomial logit estimate; Lower CI and upper CI = 95% confidence intervals. * p<0.05, ** p<0.01, *** p<0.001

5.2.3. Household sanitary facility

Type of household sanitary facility is a nominal response variable with clusters and is modelled using the multilevel nominal logistic regression (Anderson et al., 2013). The reference category is no facility. The predictors were wealth index, residential place, age of household head, sex of household head, educational attainment of household head and crude oil-led economic growth. We fitted models progressively with fixed effects and then a random structure, adding predictors that were important to this study.

5.2.3.1. Bivariate analysis

Tables 5.26 to 5.28 show details of the bivariate analysis in this study. There are 38,522 households included in this study. Out of these, those with access to safe sanitary facilities: 21.4% had access to flushed toilet, 44.2% had access to pit toilet. Others had access to unsafe sanitary facilities: 3.1% had access to bucket and composting toilet, 31.3% do not have access to sanitary facility. 0.1% (41) did not report type of sanitary facility. These tables show a cross tabulation of type of household sanitary facility and the predictors in this study. They also contain chi-square test for independence and frequency for each predictor.

Chi-square test for association shows that the place of residence, wealth index, educational attainment and gender of household head is associated with the type of sanitary facility (see table, $p<0.001$). Hence, the types of sanitary facility vary across these predictors. Among households that use Flush toilet, 79% are in urban areas compared to 21% in rural areas. Conversely, in households that do not use sanitary facilities, 24% are in urban areas and 76% in rural areas. Most of the poor households (compared to others) do not use sanitary facilities (49%) while most of the rich households use flush toilet (96%). Of the households without sanitary facilities, 44% are from households with heads that have no education and 7% are from households with heads that have higher education. Pit toilet is the most used type of sanitary facility in both female and male headed households.

The bivariate analysis suggests that there is statistically significant association between household type of sanitary facility (flush toilet, pit toilet, bucket and composting and no facility) and place of residence ($p<.0001$), educational attainment of household head ($p<.0001$), wealth index ($p<0.001$) and gender of household head ($p<0.001$). Therefore, further investigation (multivariate analysis) is conducted.

Table 5.26: Distribution of household sanitary facility (place of residence and gender of household head)

Variables (Chi-square, p-value)		Flush toilet	Pit toilet	Bucket and composting Toilet	No facility	Total
Place of residence: Chi-square=6500, p< 0.001	Urban	6,493	6,101	357	2,894	15,845
		78.68	35.88	30.43	24.01	41.18
		40.98	38.50	2.25	18.26	100.00
	Rural	1,759	10,901	816	9,160	22,636
		21.32	64.12	69.57	75.99	58.82
		7.77	48.16	3.60	40.47	100.00
Gender of household head: Chi-square= 412.43, p< 0.001	Female	6,359	14,297	767	9,393	30,816
		77.06	84.09	65.39	77.92	80.08
		20.64	46.39	2.49	30.48	100.00
	Male	1,893	2,705	406	2,661	7,665
		22.94	15.91	34.61	22.08	19.92
		24.70	35.29	5.30	34.72	100.00

For each variable: row one represents the frequency; row two represents row percentage; and row three represents column percentage.

Table 5.27: Distribution of household sanitary facility (educational attainment of household head)

Variables (Chi-square, p-value)		Flush toilet	Pit toilet	Bucket and composting Toilet	No facility	Total
Educational attainment of household head: Chi-square= 6600, p< 0.001	No education	712	7,121	257	5,294	13,384
		8.69	42.55	22.10	44.29	35.18
		5.32	53.21	1.92	39.55	100.00
	Incomplete primary	229	951	106	844	2,130
		2.80	5.68	9.11	7.06	5.60
		10.75	44.65	4.98	39.62	100.00
	Complete primary	1,160	2,844	244	2,041	6,289
		14.16	17.00	20.98	17.08	16.53
		18.44	45.22	3.88	32.45	100.00
	Incomplete secondary	619	1,284	148	1,115	3,166
		7.56	7.67	12.73	9.33	8.32
		19.55	40.56	4.67	35.22	100.00
	Complete secondary	2,482	2,852	312	1,863	7,509
		30.30	17.04	26.83	15.59	19.74
		33.05	37.98	4.16	24.81	100.00
	Higher	2,990	1,682	96	796	5,564
		36.50	10.05	8.25	6.66	14.63
		53.74	30.23	1.73	14.31	100.00

For each variable: row one represents the frequency; row two represents row percentage; row three represents column percentage.

Table 5.28: Distribution of household sanitary facility (wealth index)

Variables (Chi-square, p-value)		Flush toilet	Pit toilet	Bucket and composting Toilet	No facility	Total
Wealth index: Chi-square= 12000, p< 0.001	poor	41	6,881	220	5,881	13,023
		0.50	40.47	18.76	48.79	33.84
		0.31	52.84	1.69	45.16	100.00
	average	292	4,158	372	3,621	8,443
		3.54	24.46	31.71	30.04	21.94
		3.46	49.25	4.41	42.89	100.00
	rich	7,919	5,963	581	2,552	17,015
		95.96	35.07	49.53	21.17	44.22
		46.54	35.05	3.41	15.00	100.00

For each variable: row one represents the frequency; row two represents row percentage; and row three represents column percentage.

5.2.3.2. Multivariate analysis

The coefficients reported on the tables are the estimated multinomial logistic coefficients. The reference group for the model is no sanitary facility. Therefore, a model for flush toilet relative to no facility, pit toilet relative to no facility and a model for bucket and composting toilet relative to no facility are estimated. The parameter estimates are also relative to the reference group. The interpretation of the multinomial logit is the same as previously described.

Tables 5.29 and 5.30 show the effect of the covariates as the model was fitted from the null to full model (model 3). The addition of different groups of covariates led to significant explanation of the variance in model. The relationship between oil-led economic growth and source of drinking water was attenuated as more variables were included in the model.

The interpretation of the multinomial logit is that: for a unit change in the predictor, the logit of the response variable (relative to the reference group) is changed by its respective parameter estimate, given other predictors in the model are held constant. As in the models for household drinking water source, the results were presented in 3 and 4 decimal places because of the very small value of some of the estimates. The magnitude of the estimates in the final model was small but considered important for Nigeria.

Table 5.29: Association between household sanitary facilities and oil-led economic growth (flush and pit toilet, relative to no facility)

	Null model			Model1			Model2			Model3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
[1] **Flush toilet relative to no facility**												
Oil-led economic growth				0.003	-0.001	0.007	0.003	0.001	0.007	0.005**	0.002	0.008
Gender of household head							-0.075*	-0.141	-0.009	0.382***	0.321	0.443
Age of household head							-0.007***	-0.009	-0.005	0.024***	0.022	0.026
Place of residence										-1.806***	-1.876	-1.736
Wealth index										2.891***	2.782	3
Educational attainment of head										0.409***	0.391	0.427
[2] **Pit toilet relative to no facility**												
Oil-led economic growth				0.005	0.002	0.009	0.005**	0.002	0.009	0.007**	0.002	0.011
Gender of household head							-0.061*	-0.115	-0.008	-0.011	-0.066	0.044
Age of household head							0.001*	0	0.003	0.008***	0.007	0.01
Place of residence										-0.918***	-0.974	-0.863
Wealth index										0.784***	0.747	0.821
Educational attainment of head										0.074***	0.059	0.089

Table 5.30: Association between household sanitary facilities and oil-led economic growth (bucket and composting toilet relative to no facility; and random effect parameters)

	Null model			Model1			Model2			Model3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
[3] **Bucket and composting toilet relative to no facility**												
Oil-led economic growth				0.009	0	0.019	0.01*	0	0.019	0.012*	0.003	0.021
Gender of household head							0.18**	0.071	0.29	-0.06	-0.149	0.028
Age of household head							0.007***	0.004	0.01	0.009***	0.006	0.011
Place of residence										-0.69***	-0.807	-0.572
Wealth index										0.898***	0.83	0.966
Educational attainment of head										-0.186***	-0.218	-0.155
Random effect parameters												
1	1.056***	0.574	1.537	1.065***	0.577	1.553	1.060***	0.574	1.546	0.704***	0.38	1.028
2	0.96***	0.521	1.399	0.952***	0.516	1.388	0.956***	0.519	1.394	1.419***	0.771	2.067
3	10.142***	5.537	14.747	7.067***	3.826	10.308	6.997***	3.788	10.205	6.775***	3.666	9.885

Coeff = coefficients; Lower CI and Upper CI = 95% confidence intervals; random effect parameter = between state variance. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The random effect parameters 1, 2 and 3 represents the random effect for each type of sanitary facility relative to no sanitary facility

Recall that the quasi-likelihood estimates become more biased when the sample size of level 2 units are small (as in our phase 2 data), hence, the difference in the random effect output between PQL2 and MCMC models. This formed the basis of choosing the MCMC model as the final model. The final model was fitted using the MCMC method, with chains of 50,000 iterations following a burn-in of 5,000 (tables 5.31 and 5.32) and the outputs for the final model are interpreted as follows:

5.2.3.2.1. Flush toilet relative to no facility

The multinomial log-odds for households with flush toilet relative to no facility (assuming all other variables in the model were held constant) would be expected to decrease by: 1.752 for rural households compared to urban households. However, it would be expected to increase by: 0.005 for one unit increase in oil-led economic growth; 0.022 for a one unit increase in age of household head; 0.416 for female household head compared to male household head; 0.382 for educated household head compared to household head with no education; and 3.224 for richer households compared to poor households.

All the estimates for households with flush toilet relative to no facility were precise as the associated confidence intervals for the estimates were narrow. The confidence interval for all the estimates did not include the null value of zero. Hence, the results showed that oil-led economic growth significantly influenced access to flush toilet relative to no facility. Households with older household head (compared to younger head), female household head (compared to male household head), educated household head (compared to household head with no education) and richer households (compared to poorer households) were significantly more likely to use flush toilet relative to no facility. On the contrary, households in rural areas (compared to those in urban areas) were significantly less likely to use flush toilet relative to no facility.

5.2.3.2.2. Pit toilet relative to no facility

The multinomial log-odds for households with pit toilet relative to no facility (assuming all other variables in the model were held constant) would be expected to decrease by: 1.108 for rural households compared to urban households. However, it would be expected to increase by: 0.005 for one unit increase in oil-led economic growth; 0.011 for a one unit increase in age of household head; 0.071 for female household head compared to male household head; 0.089 for educated household head compared to household head with no education; and 1.220 for richer households compared to poor households.

The confidence intervals for the estimates for households with pit toilet relative to no facility were all narrow; therefore it is reasonable to say the estimates were precise. All but the confidence intervals for the estimates for gender of household head included the null value of zero. Hence, the gender of household head did not significantly influence the use of pit toilet relative to no facility.

Oil-led economic growth significantly influenced access to pit toilet relative to no facility. Similarly, households with older household head (compared to younger head), educated household head (compared to household head with no education) and richer households (compared to poorer households) were significantly more likely to use pit toilet relative to no facility. On the contrary, households in rural areas (compared to those in urban areas) were significantly less likely to use pit toilet relative to no facility.

5.2.3.2.3. Bucket and composting toilet relative to no facility

The multinomial log-odds for households with bucket and composting toilet relative to no facility (assuming all other variables in the model were held constant) would be expected to decrease by: 0.866 for rural households compared to urban households; and 0.069 for educated household head compared to household head with no education. However, it would be expected to increase by: 0.009 for one unit increase in oil-led economic growth; 0.001 for a one unit increase in age of household head; 0.159 for female household head compared to male household head; and 0.515 for richer households compared to poor households.

The confidence intervals for the estimates for households with bucket and composting toilet relative to no facility were all narrow; therefore the estimates were precise. All but the confidence intervals for the estimates for age of household head and gender of household head included the null value of zero. Hence, the age of household head and gender of household head did not significantly influence the use of bucket and composting toilet relative to no facility.

Oil-led economic growth significantly influenced access to bucket and composting toilet relative to no facility. Similarly, richer households (compared to poorer households) were significantly more likely to use bucket and composting toilet relative to no facility. On the contrary, households with educated household head (compared to household head with no education) and households in rural areas (compared to those in urban areas) were significantly less likely to use bucket and composting toilet relative to no facility.

The random effect parameters 1, 2 and 3 represents the random effect for each type of sanitary facility relative to no facility. Random effect parameter: var represents the between state variance and cov represents the correlation between the use of sanitary facilities. In the random effect parameters in table 5.32 of the output for MCMC models, the correlations are all positive suggesting that states with high (or low) use of one type of sanitary facility relative to using no facility also tend to have high (or low) use of other types of sanitary facilities to no facility. The highest correlation is between the use of flush toilet and pit toilet. The estimated intraclass correlation (ICC) value of 0.241 indicates that approximately 24.1% of the total variation in the type of sanitary facility is accounted for by the states. Thus, the remaining 75.9% variability is due to the variation within the households and other factors. There are clearly substantial differences in the type of sanitary facility between states.

Table 5.31: Analysis of full model using MCMC method (flush and pit toilet, relative to no facility)

	Multinomial logistic model (PQL2): model 3			MCMC model: model 3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
1 Flush toilet relative to no facility						
Oil-led economic growth	0.005**	0.002	0.008	0.005***	0.003	0.007
Gender of household head	0.382***	0.321	0.443	0.416***	0.32	0.513
Age of household head	0.024***	0.022	0.026	0.022***	0.019	0.025
Place of residence	-1.806***	-1.876	-1.736	-1.752***	-1.854	-1.650
Wealth index	2.89***	2.782	3.000	3.224***	3.111	3.338
Educational attainment of household head	0.409***	0.391	0.427	0.382***	0.355	0.409
2 Pit toilet relative to no facility						
Oil-led economic growth	0.007**	0.002	0.011	0.005**	0.003	0.007
Gender of household head	-0.011	-0.066	0.044	0.071	-0.014	0.156
Age of household head	0.008***	0.007	0.01	0.011***	0.009	0.013
Place of residence	-0.919***	-0.974	-0.863	-1.108***	-1.194	-1.022
Wealth index	0.784***	0.747	0.821	1.200***	1.142	1.258
Educational attainment of household head	0.074***	0.059	0.089	0.089***	0.067	0.110

Table 5.32: Analysis of full model using MCMC method (bucket and composting toilet relative to no facility; and random effect parameters)

	Multinomial logistic model (PQL2): model 3			MCMC model: model 3		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
3 Bucket and composting toilet relative to no facility						
Oil-led economic growth	0.012*	0.003	0.021	0.009*	0.001	0.018
Gender of household head	-0.06	-0.149	0.028	0.159	-0.013	0.33
Age of household head	0.009***	0.006	0.011	0.001	-0.004	0.006
Place of residence	-0.690***	-0.807	-0.572	-0.866***	-1.061	-0.67
Wealth index	0.898***	0.83	0.966	0.515***	0.391	0.639
Educational attainment of household head	-0.186***	-0.218	-0.155	-0.069*	-0.128	-0.01
Random effect parameters						
Var 1	0.704***	0.38	1.028	2.198***	1.123	3.272
Var 2	1.419***	0.771	2.067	4.124***	2.13	6.119
Var 3	6.775***	3.666	9.885	6.371**	2.717	10.025
Cov 1_2	-0.855***	-1.281	-0.429	2.445***	1.118	3.773
Cov 1_3	0.482	-0.245	1.208	0.811	-0.562	2.184
Cov 2_3	-1.073*	-2.135	-0.011	0.278	-1.546	2.102

Coeff = coefficients; Lower CI and upper CI = 95% confidence intervals. * p<0.05, ** p<0.01, *** p<0.001

5.2.4. The number of Household deaths

The number of household deaths (in the last twelve months) is a count variable and it is modelled using the multilevel Poisson and negative binomial models. The predictors were wealth index, residential place, age of household head, sex of household head, educational attainment of household head and crude oil-led economic growth. Table 5.33 shows that household death is not a frequent event, where 94.5% of the households had no deaths in the last 12 months.

Table 5.33: Summary of the number of household deaths

	Mean	Standard deviation	Variance	Skewness	Kurtosis
Number of household deaths	0.061	0.268	0.072	5.134	37.392

Count data often follow a Poisson distribution, where the mean and the variance are the same. Table 5.33 gives a summary of the number of household deaths in the last twelve months. The value for skewness is positive and this indicates that the number of household death is skewed to the right. The variance of the number of household deaths is slightly higher than the mean. Therefore, the distribution of the number of household deaths shows though little but signs of over-dispersion. Accounting for over-dispersion is important as it can lead to biased parameter estimates and erroneous conclusion of the presence of significant effect in the variables of interest (Crawley, 2007).

In fitting the models, it is assumed that the estimates conditioned on the predictors, will be approximately the same, based on this slight difference in the mean and variance values. Both models will be reported for the final model (model 4) to compare the results of the models and demonstrate their suitability to this data. The offset used for all the models is the log value for the number of household members.

5.2.4.1. Multivariate analysis

The results for all the models are expressed as coefficients. The data used for this model were from 38,522 households. Tables 5.34 and 5.35 show the effect of the covariates on household death. The addition of covariates explains the variance in the model. The relationship between oil-led economic growth and household death was not attenuated as more variables were included in the model.

Firstly, a negative binomial model is fitted due to the indication of over-dispersion in the data. Model 1 showed the effect of oil-led economic growth on household death without other covariates and the full model (model 4) contains all the covariates mentioned earlier. The full model is also fitted as a Poisson model to see the effect on over-dispersion in the models. The results were presented in 3 and 4 decimal places because of the very small value of some of the estimates.

Table 5.34: Association between number of household deaths and oil-led economic growth

	Model 1			Model 2			Model 3			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Oil-led economic growth	0.0001	-0.003	0.003	0.0001	-0.003	0.003	-0.00004	-0.003	0.003	-0.0001	-0.003	0.003
Gender of head (ref: male)												
Female				0.221***	0.103	0.34	0.22***	0.099	0.342	0.231***	0.11	0.353
Age of household head				0.005**	0.002	0.007	0.004*	0.001	0.007	0.004*	0.0004	0.007
Residential place(ref: urban)												
Rural							0.353***	0.224	0.482	0.318***	0.187	0.449
Educational attainment of head (ref: no education)												
Incomplete primary							0.24*	0.059	0.421	0.231*	0.05	0.413
Complete primary							0.14*	0.001	0.279	0.131	-0.009	0.27
Incomplete secondary							0.044	-0.149	0.238	0.04	-0.154	0.233
Complete secondary							-0.052	-0.22	0.117	-0.048	-0.216	0.12
Higher							-0.157	-0.351	0.037	-0.119	-0.315	0.076

Table 5.35: Association between number of household deaths and oil-led economic growth

	Model 1			Model 2			Model 3			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Wealth index (ref: poor)												
Average							-0.074	-0.206	0.057	-0.077	-0.21	0.056
Rich							-0.252**	-0.411	-0.09	-0.171*	-0.34	-0.002
Access to water (ref: piped water)												
Tanker and packaged water										-0.231	-0.515	0.054
Well water										0.001	-0.171	0.173
Open water source										0.11	-0.088	0.308
Access to sanitary facilities (ref: flush toilet)												
Pit toilet										0.243**	0.07	0.416
Bucket and composting toilet										-0.129	-0.528	0.271
No facility										0.197*	0.005	0.389
Random effect parameter, REP	0.59***	0.306	0.873	0.606***	0.315	0.896	0.468**	0.241	0.695	0.446***	0.229	0.664

Coeff = coefficients; CI = confidence intervals; ref = reference category; REP = between state variance; * p<0.05, ** p<0.01, *** p<0.001

The Coefficients for oil-led economic growth in the models are too small, hence not reported in 3 decimal places. The random effect parameter for the null model was 0.597 ($p<0.001$) with confidence interval of 0.312 to 0.882. There were very little differences in the estimates obtained from both negative binomial and Poisson models (tables 5.36 and 5.37), suggesting that the over-dispersion may not be a significant problem in the data used in this study. Further analyses were done, accounting for over-dispersion and assuming the absence of over-dispersion, to further explore the data.

Table 5.36: Comparison of the estimates of the final model using Poisson and negative binomial

Number of household deaths	Poisson model			Negative binomial model		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Oil-led economic growth	-0.0001	-0.003	0.003	-0.0001	-0.003	0.003
Gender of household head (reference: male)						
Female	0.218***	0.106	0.329	0.231***	0.11	0.353
Age of household head	0.003*	0.001	0.006	0.004*	0.0004	0.007
Residential place (reference: urban)						
Rural	0.324***	0.202	0.447	0.318***	0.187	0.449
Educational attainment of household head (reference: no education)						
Incomplete primary	0.227**	0.062	0.391	0.231*	0.05	0.413
Complete primary	0.131*	0.004	0.259	0.131	-0.009	0.27
Incomplete secondary	0.047	-0.131	0.224	0.04	-0.154	0.233
Complete secondary	-0.043	-0.199	0.112	-0.048	-0.216	0.12
Higher	-0.11	-0.292	0.072	-0.119	-0.315	0.076

Table 5.37: Comparison of the estimates of the final model using Poisson and negative binomial

Number of household deaths	Poisson model			Negative binomial model		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Wealth index (reference: poor)						
Average	-0.072	-0.2	0.05	-0.077	-0.21	0.056
Rich	-0.167*	-0.324	-0.01	-0.171*	-0.34	-0.002
Access to drinking water (ref: piped water)						
Tanker and packaged water	-0.231	-0.502	0.04	-0.231	-0.515	0.054
Well water	-0.006	-0.165	0.153	0.001	-0.171	0.173
Open water source	0.094	-0.089	0.277	0.11	-0.088	0.308
Access to sanitary facilities (ref: flush toilet)						
Pit toilet	0.243**	0.08	0.407	0.243**	0.07	0.416
Bucket and composting toilet	-0.116	-0.493	0.262	-0.129	-0.528	0.271
No facility	0.213*	0.033	0.393	0.197*	0.005	0.389
Random effect parameter, REP	0.451***	0.233	0.67	0.446***	0.229	0.664

Coeff = coefficients; Lower CI and Upper CI = 95% confidence intervals; ref = reference category; REP = between state variance. * p<0.05, ** p<0.01, *** p<0.001.

Also, the final model has to be fitted with MCMC method as discussed earlier. Negative binomial models cannot be fitted by MCMC. However, an alternative model can be used to account for over-dispersion and this is achieved by adding an over-dispersion parameter (extra level) to the equivalent Poisson model. This model can then be fitted the MCMC method. Tables 5.38 and 5.39 shows a Poisson model without an over-dispersion parameter and an equivalent model fitted with MCMC method.

Table 5.38: Analysis of full model (model 4) using Poisson model without over-dispersion parameter and MCMC method

Number of household deaths	Poisson model without over-dispersion parameter			MCMC model 1		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Oil-led economic growth	-0.0002	-0.003	0.002	-0.001	-0.002	0.001
Gender of household head (reference: male)						
Female	0.537***	0.426	0.649	0.536***	0.425	0.646
Age of household head	-0.004***	-0.007	-0.001	-0.004***	-0.007	-0.001
Residential place (reference: urban)						
Rural	0.331***	0.208	0.453	0.329***	0.210	0.448
Educational attainment of household head (reference: no education)						
Incomplete primary	0.136	-0.028	0.300	0.131	-0.031	0.294
Complete primary	-0.020	-0.146	0.106	-0.024	-0.150	0.102
Incomplete secondary	-0.008	-0.184	0.168	-0.013	-0.186	0.160
Complete secondary	-0.056	-0.209	0.097	-0.063	-0.216	0.090
Higher	-0.160	-0.339	0.018	-0.168	-0.348	0.011

Table 5.39: Analysis of full model (model 4) using Poisson model without over-dispersion parameter and MCMC method

Number of household deaths	Poisson model without over-dispersion parameter			MCMC model 1		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Wealth index (reference: poor)						
Average	-0.06	-0.181	0.061	-0.058	-0.178	0.061
Rich	-0.217***	-0.372	-0.062	-0.213***	-0.365	-0.061
Access to drinking water (ref: piped water)						
Tanker and packaged water	-0.053	-0.323	0.218	-0.055	-0.321	0.211
Well water	-0.013	-0.172	0.145	-0.01	-0.161	0.14
Open water source	0.072	-0.111	0.254	0.075	-0.099	0.25
Access to sanitary facilities (ref: flush toilet)						
Pit toilet	0.152	-0.012	0.315	0.154	-0.003	0.31
Bucket and composting toilet	-0.171	-0.547	0.206	-0.179	-0.545	0.187
No facility	0.139	-0.041	0.319	0.141	-0.033	0.315
Random effect parameter	0.383***	0.196	0.569	0.442***	0.195	0.689

Bayesian DIC for MCMC model = 16996.61; Average sample size within level 2 unit = 1,025. Coeff. = coefficients; Lower CI and Upper CI = 95% confidence intervals; ref = reference category; random effect parameter = between state variance. * p<0.05, ** p<0.01, *** p<0.001

The MCMC models were fitted using the Markov chain Monte Carlo method, with chains of 50,000 iterations following a burn-in of 5,000. The DIC was used to demonstrate that the final MCMC model had the best fit to the data, as the model with a lower value of the DIC was being favoured. On comparing the estimates of the Poisson model without over-dispersion parameter and the equivalent MCMC model, differences between the results are rather small. Although, the quasi-likelihood estimates gets biased when the sample sizes within level 2 units (states) are small, the level 2 units in the data used in this study are large (with an average of 1,025 households per states).

Tables 5.40 and 5.41 show a Poisson model with an over-dispersion parameter and an equivalent model fitted with MCMC method. The DIC diagnostic from MCMC model 1 (without over-dispersion parameter) has been reduced by 6 to 16,991 in MCMC model 2 (with over-dispersion parameter), suggesting that the accounting for over-dispersion makes a difference to the estimates but not largely different. This is demonstrated in the estimates for the MCMC models 1 and 2, which are fairly similar. Though the magnitude of the estimates in the models was small, they were considered important and reasonable for Nigeria as a case study.

The coefficients in the final model (MCMC model 2) can be interpreted as follows: for a unit change in the predictor, the difference in the logs of expected counts of the household death is expected to change by the respective coefficient, given the other predictors are held constant in the model. Therefore, the outputs for the final model (MCMC model 2) are interpreted as follows:

The logs of expected counts of household death (assuming all other variables in the model were held constant) would be expected to decrease by: 0.0001 for one unit increase in oil-led economic growth; 0.004 for a one unit increase in age of household head; 0.223 for rich households and 0.069 for households in average wealth bracket compared to poor households; 0.170 for households with bucket and composting toilet compared to households with flush toilet; 0.051 for households with tanker and packaged water and 0.007 for households with well water compared to households with piped water; 0.022 for household head with complete primary, 0.027 for household head with incomplete secondary, 0.065

for household head with complete secondary and 0.178 for household head with higher education when compared to household head with no education.

The logs of expected counts of household death increased by: 0.326 for rural households compared to urban households; 0.557 for female household head compared to male household head; 0.181 for households with pit toilet and 0.151 for households with no facility compared to households with flush toilet; 0.083 for households with open water compared to households with piped water; and 0.144 for household head with incomplete primary education compared to household head with no education.

Most of the confidence intervals for the estimates in the final model were narrow. However, the intervals for the estimates for access to drinking water, access to sanitary facilities and wealth index were fairly wide, reflecting a fair and slightly reasonable precision in the estimates. All but the confidence intervals for the estimates for age of household head, gender of household head and place of household residence did not include the null value of zero. Hence, household deaths were significantly more likely to occur in households headed by females (compared to those headed by males) and in households situated in rural areas (compared to those in urban areas) but less likely to occur in households with older household head (compared to younger household head).

For the results on the effect of type of sanitary facility on household death, households with pit toilet compared to flush toilet significantly experienced more household deaths. Households with other types of sanitary facilities experienced no significant change on the number of household deaths, when compared to those with flush toilet. Also, rich households compared to poor households significantly experienced less household deaths but households in average wealth bracket compared to poor households experienced no significant change on the number of household deaths. Oil-led economic growth, educational attainment of household head and access to improved drinking water did not significantly influence the number of household deaths.

For the random effect, the variation at the level 2 (state level) has decreased from 0.57 (null model) to 0.48 (model three). This reinforces the finding that adding the predictors have a substantial effect on the reduction of the variation of the model. The estimated coefficients of the predictors in the fixed effect part of the models were relatively stable, with minor fluctuations across the model tables.

The estimated intraclass correlation (ICC) value showed that the correlation in the number of household deaths between states is 0.014. This indicates that approximately 1.4% of the total variation in the number of household death is accounted for by the states. Thus, the remaining 98.6% variability is due to the variation within the households and other factors.

Table 5.40: Analysis of full model (model 4) using Poisson model with over-dispersion parameter and MCMC method

Number of household deaths	Poisson model with over-dispersion parameter			MCMC model 2		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Oil-led economic growth	-0.0001	-0.002	0.002	-0.0001	-0.003	0.003
Gender of household head (reference: male)						
Female	0.540***	0.418	0.662	0.557***	0.433	0.681
Age of household head	-0.004*	-0.008	-0.001	-0.004*	-0.008	-0.001
Residential place (reference: urban)						
Rural	0.335***	0.203	0.467	0.326***	0.197	0.455
Educational attainment of household head (reference: no education)						
Incomplete primary	0.147	-0.043	0.337	0.144	-0.039	0.327
Complete primary	-0.015	-0.156	0.126	-0.022	-0.161	0.117
Incomplete secondary	-0.017	-0.211	0.177	-0.027	-0.219	0.165
Complete secondary	-0.055	-0.218	0.108	-0.065	-0.232	0.101
Higher	-0.171	-0.361	0.02	-0.178	-0.371	0.016

Table 5.41: Analysis of full model (model 4) using Poisson model with over-dispersion parameter and MCMC method

Number of household deaths	Poisson model with over-dispersion parameter			MCMC model 2		
	Model 4			Model 4		
	Coeff.	Lower CI	Upper CI	Coeff.	Lower CI	Upper CI
Access to drinking water (ref: piped water)						
Tanker and packaged water	-0.05	-0.309	0.209	-0.051	-0.336	0.235
Well water	-0.015	-0.182	0.153	-0.007	-0.178	0.165
Open water	0.080	-0.113	0.274	0.083	-0.116	0.283
Access to sanitary facilities (ref: flush toilet)						
Pit toilet	0.175*	0.003	0.347	0.181*	0.009	0.354
Bucket and composting toilet	-0.182	-0.551	0.187	-0.170	-0.570	0.230
No facility	0.145	-0.041	0.331	0.151	-0.042	0.345
Wealth index (reference: poor)						
Average	-0.071	-0.204	0.063	-0.069	-0.203	0.065
Rich	-0.222*	-0.391	-0.054	-0.223*	-0.392	-0.054
Random effect parameter	0.317***	0.163	0.471	0.476***	0.211	0.740

Bayesian DIC for MCMC model = 16990.65; Average sample size within level 2 unit = 1,025

Coeff. = coefficients; Lower CI and Upper CI = 95% confidence intervals; ref = reference category; random effect parameter = between state variance; * p<0.05, ** p<0.01, *** p<0.001

6. Discussion

In this chapter, the results from the phase one and two studies are briefly summarized and the research questions 'answered'. The findings are then compared with those of previous studies, in order to identify the similarities or differences across the literature. The contributions of this thesis to the body of knowledge in the field, its strengths and limitations, and the implications of the findings are also considered. The last section in this chapter highlights the recommendations and suggestions for future research.

The aim of the phase one study was to explore the hypothesised pathway between crude oil resources and population health in a sample of countries, whilst the phase two study aimed to determine whether oil-led economic growth is related to population health in Nigeria. To address these aims, the thesis sought to answer three main research questions:

Research question 1: How do crude oil resources influence economic growth and population health?

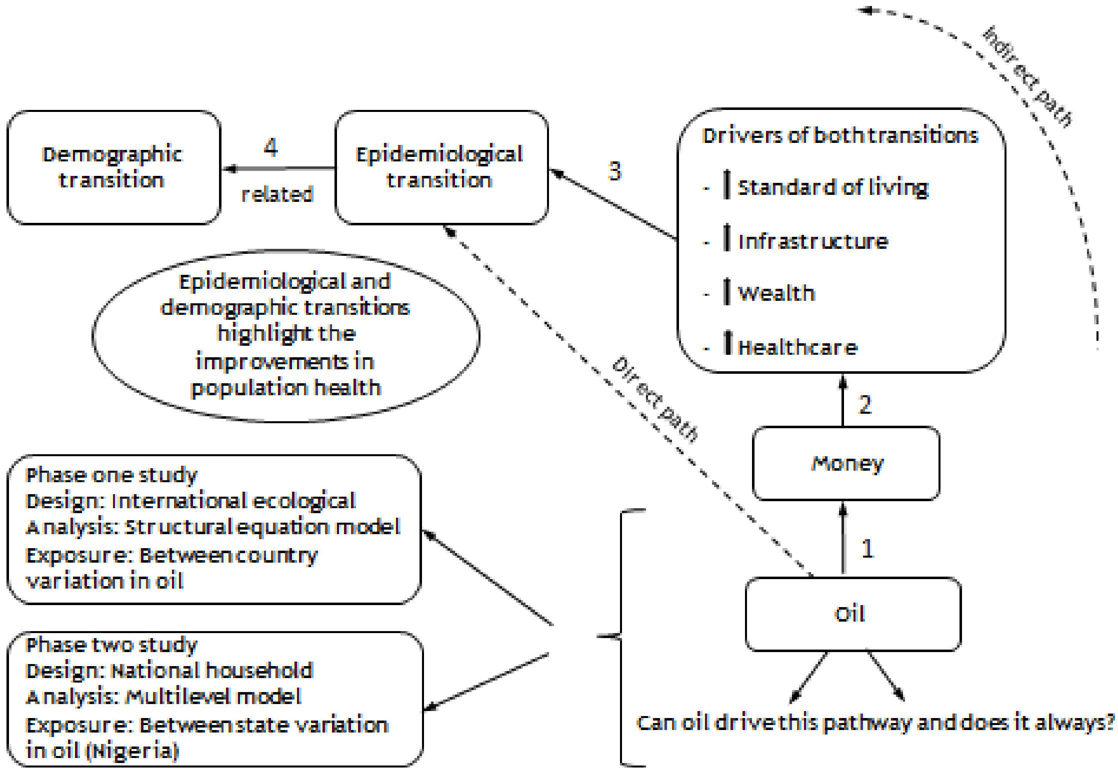
Research question 2: What is the relationship between oil-led economic growth and population health?

Research question 3: Does oil-led economic growth influence population health in Nigeria?

6.1. Summary of empirical studies

Following a review, the phase one study was an ecological, international, study whilst phase two was a household national study. Both were based on a hypothesised pathway from oil resources to economic development and population health improvements (figure 6.1).

Figure 6.1: Thesis map



6.1.1. Phase one study

It is important to note that this was an ecological study and the associations observed here do not translate to individual-level relationship but serve as a lead for future research and also inform policy making decisions at national level.

The result from the longitudinal assessment of the relationship between crude oil resources and population health for low- and high-income countries is summarised in table 6.1. This table highlights the overall relationship between crude oil resources and population health. The results from the hypothesised path model demonstrated that crude oil resources did not display a significant relationship with most indicators of population health. Only crude oil export had a statistically significant (negative) association with access to basic sanitary facilities (highlighted in grey). Income group showed no statistically significant relationship with the markers of population health. Other hypothesised relationships were not statistically significant.

Table 6.1: Summary of the global relationship between crude oil resources and health and its determinants

Measure of crude oil resources	Access to basic drinking water sources	Access to basic sanitary facilities	Infant mortality	Life expectancy
Oil rent contribution to GDP	NOR	NOR	NOR	NOR
Crude oil export	NOR	NR	NOR	NOR

PR= Positive relationship; NR= Negative relationship; NOR= No significant relationship.

The cross-sectional examination of the relationship between oil-led economic growth and population health for low- and high-income countries is summarised in table 6.2. This table highlights whether there was a direct, indirect or overall relationship between oil-led economic growth and population health.

Table 6.2: Summary of the global relationship between oil-led economic growth and health/its determinants (cross-sectional study)

Measure of oil-led economic growth	Observed relationship	Income group	Access to basic drinking water sources	Access to basic sanitary facilities	Infant mortality	Life expectancy
Oil rent contribution to GDP (% growth)	Direct effect	Low	PR	PR	NOR	NOR
		High	PR	NOR	NOR	NOR
	Indirect effect	Low	NR	NR	NOR	NOR
		High	NOR	NOR	NR	PR
	Total effect	Low	NOR	NOR	NOR	NOR
		High	PR	NOR	NR	PR
Crude oil export (% growth)	Direct effect	Low	NOR	NOR	NOR	NR
		High	NOR	NOR	NR	NOR
	Indirect effect	Low	NOR	NOR	PR	NR
		High	NOR	NOR	NOR	NOR
	Total effect	Low	NOR	NOR	PR	NR
		High	NOR	NOR	NOR	NOR

PR= Positive relationship; NR= Negative relationship; NOR= No significant relationship.

In high-income countries, there was evidence of a significant positive association between oil-rent contribution to GDP (% growth) and life expectancy (highlighted in grey) and this seems to be largely operating directly. A negative association was also observed between oil-rent contribution to GDP (% growth) and infant mortality (highlighted in grey). However, crude oil export (% growth) as a measure of oil-led economic growth had no significant association with life expectancy and infant mortality. Generally, the revenue generated from crude oil export should be reflected in oil-rent contribution to GDP, which makes it surprising. Perhaps the disparity between the effect of crude oil-export and the actual contributions of the revenue from crude oil to GDP on health, may be a result of the governance systems in these countries. Institutional quality was represented by an aggregate measure of institutions in this study and mediated the relationship between oil-led economic growth and health. However, inclusion of other measures of institutional quality and the interaction between institutional quality and crude oil on health may be needed to further examine this relationship but for this study, this was the most reliable measure in the dataset and outside my scope. The associations for low-income countries were quite different. There was no significant evidence of an association between oil-rent measure of oil-led economic growth and health. Yet, it was interesting that, in low-income countries, oil-rent was directly and positively associated with access to sanitatary facilities and drinking water sources. This perhaps highlights the inability of low-income countries to channel their oil resources into health improvement, even after controlling for institutional quality. Also, poor-quality data and few markers are available in less developed countries as well as the short time dimension of my analysis may explain the statistically insignificant relationship observed on health, as it may take a long time for oil-led health benefits to manifest.

For the association between oil-rent measure of oil-led economic growth and health determinants, there was only a significant positive relationship with access to drinking water sources in high-income countries (highlighted in grey). There was also no evidence of a significant association between crude oil export

(% growth) as a measure of oil-led economic growth and health determinants in low- and high-income countries. However, crude oil export (% growth) had a significant negative association with health in low income countries. This may reflect the harmful environmental consequences of crude oil exploration and export, coupled with the governance structures in these countries that do not direct policies to curb the harms from oil industries but are rather interested with the inflow of the revenues from oil, irrespective of how it is made.

Overall, the phase one study found almost no evidence for a relationship between crude oil resource and population health, within the period studied. The estimates were robustly controlled for additional confounding factors and whilst it is possible that the models missed crucial mediators or moderators, it is reasonable to consider why this relationship was missing. It may be explained by the dynamics of the countries in this study, where the gains on health from crude oil resources through high individual incomes and healthcare funded by oil money (Cotet and Tsui, 2013), are balanced out by the negative impacts from the volatility, conflicts and inappropriate use of funds for national/government activities that do not directly better the lives of the people in oil-dependent countries (Omotor, 2009; Wigley, 2017).

One of the causes of poor health and consequently mortality is from preventable water-borne and sanitation-related diseases (The United Nations International Children's Emergency Fund and World Health Organization, 2015), especially in low-income countries. In 2015, about thirty-two percent of the global population lacked improved sanitary facilities and nine percent of the global population lacked improved drinking water sources, most of which are low-income countries. There was also no evidence of a significant relationship between crude oil resources and health determinants with respect to all measures of health determinants except one, within the period studied. A negative relationship was found between crude oil export and access to basic sanitary facilities. It was a surprising result that is hard to interpret. If it is not spurious, it may be as a result of poor management of revenue generated from crude oil export.

6.1.2. Phase two study

The indicator for oil-led economic growth in this study was crude oil revenue (% growth). Population health was represented by an indicator of health (household death) and determinants of health (access to basic drinking water and access to basic sanitary facilities). Table 6.3 showed the cross-sectional examination of the relationship between oil-led economic growth and population health.

Table 6.3: Summary of the associations between oil-led economic growth and health and its determinants in Nigeria

Health/health determinants	Sub-categories	Oil rent contribution to GDP
Access to basic drinking water	Piped water relative to open water source	NOR
	Tanker and packaged water relative to open water source	NOR
	Well water relative to open water source	NOR
Access to basic sanitary facilities	Flush toilet relative to no facility	PR
	Pit toilet relative to no facility	PR
	Bucket and composting toilet relative to no facility	PR
Household death	Number of household death	NOR

PR= Positive relationship; NR= Negative relationship; NOR= No significant relationship

Oil-led economic growth had no significant association with the likelihood of assessing improved drinking water sources. There was, however, a positive significant association between oil-led economic growth and access to improved sanitary facilities.

Overall, the case study for Nigeria showed that there was no significant association between oil-led economic growth and health. My interpretation of the result is that oil revenue in Nigeria may be ineffectively managed due to the reported weak institutions in the country.

6.2. Research questions

6.2.1. Research question 1: How do crude oil resources influence economic growth and population health?

The systematic review showed that different evidence on the impact of crude oil resource on a nation's economic growth. There are studies that support oil resource curse, and others that support oil resource blessing, especially conditional on several factors. The studies that support oil resource curse documented the role of Dutch disease, rent seeking behaviours and bad economic policies and institutions. For example, Apergis and Payne (2014) documented the presence of oil resource curse, based on the poor state of institutions, where economic activities that deter growth were encouraged. This negative effect of oil resource abundance on economic growth in Middle East and North African countries was shown to significantly reduce on improvement of institutional quality. This interaction between natural resources and economic growth, in the presence of strong institutions, can result in transformation of oil resource curse to blessing (Mehlum et al., 2006a; Nathan and Okon, 2013). Leite and Weidmann (1999) suggest that the existence of weaker policies and political oversight, particularly in less developed countries, hinders growth. Evidence for this perspective is provided by countries with efficient national policies and greater oversight such as Argentina whose crude oil production exceed half a million barrels per day. This nation has recently moved to the high-income groups with their GNI per capita more than US$12,736 (World Bank, 2015b). However, many other researchers found that crude oil resource abundance significantly promotes growth and the reported that several channels can translate oil resource wealth to economic growth. The channels included: good institutional quality or governance structures, human capital investment and development of financial systems. For example, Kurtz and Brooks (2011) demonstrated that countries with high human capital endowment are better able to capture growth-enhancing effects from oil resource, thus avoiding resource curse. However, human capital has to be channelled into productive activities, for it to positively contribute to economic growth. Financial development also plays a role in moderating oil resource curse, by channelling the oil revenues into more productive (Law and Moradbeigi, 2017; Nili and Rastad, 2007). Poor quality of financial institutions translates into poor economic performance, as mismanagement of funds arises within the governance structures. The systematic review showed that there is relatively good information on the impact of oil resource wealth on economic growth. Oil resource abundant nations have the potential to economically benefit from their crude oil wealth, if appropriate systems and institutions are in place.

The weaker evidence on the impact of oil economy on health and its determinants brought about the empirical study in phase one. My empirical finding showed that there was no significant relationship between crude oil resources and population health, except for a weak negative relationship between crude oil export and access to basic sanitary facilities. Though this finding is surprising, Omotor (2009) reported that oil significantly influenced the development of the infrastructural indicators such as housing, roads and water. Omotor found a significant positive result for the impact of oil on these indicators in the era of oil boom and his study was so simplistic that it did not account for factors such as institutional quality and it was a single country study on Nigeria. My study was a more robust cross-country study that accounted for institutional quality and heterogeneity in level of economic growth in the sample of countries included in my study. Unlike Omotor (2009), the phase one study indicated that there was no significant association between oil resource and access to water.

Though my study showed that oil resource is not significantly associated with health in low- and high-income countries, another single country study (Opaleye et al., 2018), demonstrated that revenues from crude oil significantly increased child mortality but their study did not provide a control country within the period of reference. The lack of evidence of a significant association between oil resource and health found in my study may be as a result of the relatively short period of time examined in the phase one study. However, this suggests that the translation from crude oil to health improvement may require time to manifest. On the contrary, a more robust study that accounted for variation in resource abundance and the timing of oil discovery between countries (Cotet and Tsui, 2013), demonstrated that oil wealth was associated with better health. This finding supports the notion that oil resource stimulates health improvements either from improved population income or healthcare programmes in these nations (Lederman and Maloney, 2006; Brunnschweiler and Bulte, 2008).

In summary, these findings indicate that crude oil has the potential for economic and health improvement. The realisation of this potential will depend on political and productive economic processes.

6.2.2. Research question 2: What is the relationship between oil-led economic growth and population health?

Previously, there had been no comprehensive picture on the effect of oil-led economic growth on *population health*. Cotet and Tsui (2013) examined the relationship between oil discovery and health improvement using two health indicators; infant mortality and life expectancy. They demonstrated that oil wealth was associated with significantly lower infant mortality and longer life expectancy, arguing that oil wealth led to better quality of life, especially in less democratic oil-rich nations. The unique contribution of my study is that it highlights the differences in the health outcome from oil-led economic growth between high-income and low-income countries. The findings of this present research are similar to that of previous studies, but it explored a cross-country relationship in countries that were categorised into low- and high-income countries based on their economic performance. I found evidence of oil-led health improvements in high-income countries when the measure using oil-rent was explored. However, a negative association with health was observed for low-income countries when crude oil export measure of oil-led economic growth was used. Therefore, based on the different measures of oil-led economic growth, evidence of oil-led health improvement was found in high-income countries but a negative relationship between oil-led economic growth and health was found in low-income countries. Other scholars have found similar results, where oil wealth was positively associated with child mortality (Wigley, 2017; Opaleye et al., 2018). Wigley (2017) investigated whether oil resource curse affects child health and reported that oil poor countries perform better than oil rich countries in reducing under-five mortality. Opaleye and colleagues examined the effect of oil rent spending on health and several socioeconomic factors in Algeria and Egypt, Nigeria and Cameroon. They demonstrated that revenues from crude oil rent significantly increased child mortality but does not significantly improve socioeconomic factors like education. Alexeeva and Conrad (2011) also reported that oil wealth was associated with poorer health and lower education in transition economies, compared to other oil rich nations. Caselli and Michaels (2013) further explored the increased spending on services, housing, education and health from oil revenues, but this translated into little improvement in these services and health outcomes.

Apart from the grouping of the sample of countries in the phase one study based on their economic performance, my finding may have been different from previous findings because a more robust measure of institutional quality was also used, where an aggregate of institutional indexes was derived for this study. Previous studies included individual measures of institutions, which may have biased the mediation effect of institutions in their study.

My study also suggested that good institutions, infrastructure and education may explain the health improvement effect of oil-rent contribution to GDP (% growth) in high-income countries. A positive mediation channel existed between oil-led economic growth and health via: access to basic drinking water source; education; and institutional quality in the high-income group. This indicates that when this group of countries had more economic growth from the contribution of crude oil, improved access to drinking water source, more enrolment in basic education and good institutions, they had a better health. Though there was no statistically significant health improvement effect of oil-rent contribution to GDP (% growth) in low-income countries, institutional quality positively mediated this relationship. The role of institutional quality was seen previously in the study by Caselli and Michaels (2013), where increased spending on health translated into little improvement in health outcomes. This reflected the existence of poor institutions in these countries. Also, education is related to health improvements because it may result in better jobs, income and resources such as access to health care and information (Cutler and Lleras-Muney, 2006b). The findings indicate the potential for health improvements from oil-led economy, in the presence of these systems.

6.2.3. Research question 3: Does oil-led economic growth influence health and its determinants in Nigeria?

Nigeria is one of the many oil-rich developing countries (Ogunleye, 2008). The findings of the present study demonstrated that oil-led economic growth is positively related to the likelihood of having improved sanitary facility, but no significant association was found for access to improved drinking water. The use of Nigeria's crude oil revenue for the development of basic drivers of economic growth such as health, agriculture, education, investment in infrastructure and national projects has declined or remained at low levels (Ogunleye, 2008). This means that in recent times, the Nigerian government has prioritised the servicing of debt over education which received more inputs from crude oil revenue in the past (12.6% in 1980 and 3.2% in 2004). Furthermore, the inputs from crude oil revenue in national investments fell sharply and contributions to health equally dropped.

Even though crude oil has increasingly contributed to Nigeria's economy over the years (Ogunleye, 2008), the large amount of revenue generated from crude oil activity had provided Nigeria with the resources needed for national investments. Yet this wealth made the country economically dependent on crude oil and in turn faced with socioeconomic problems such as poor infrastructure and rise in poverty. The Nigerian situation captures the phenomenon termed "Dutch Disease" (Gylfason et al., 1997), which describes the decline in the productivity of other sectors of the economy as a result of influx of oil revenue in oil dependent nations as well as its impediment to the growth of the economy due to lack of investment in non-oil sectors. The economy of oil dependent nations is vulnerable to financial crisis due to the volatility of oil prices. This is problematic for national development as such nations tend to go into debt when oil price plummet (Auty, 2004), borrowing more than nations with non-oil revenue (Aluko, 2004) to account for the fall in their national income. Accompanying these disadvantages is the lack of accountability which results in corruption, weak institutions and poor governance.

This present study showed that there is no significant association between oil-led economic growth and health. Previous findings have shown that when properly managed, oil revenue improves the health and wellbeing of its people. Therefore, this present study suggests that oil revenue in Nigeria is not effectively managed and this may be due to the weak institutions in the country. In Nigeria, the ineffective management of its wealth leaves a significant proportion of the population in poverty, poor health and poor living conditions (United Nations Development Programme, 2015). Due to Nigeria's mono-economy, where the country is highly dependent on crude oil, other sectors of the economy are neglected (Gylfason et al., 1997), resulting in an undiversified economy which is not suitable for a sustainable development. Therefore, oil revenue could be invested in other sectors of the economy, potentially increasing the overall gross domestic product of the economy. This economic growth could be channelled appropriately to develop a nation and improve health.

6.3. Strengths and limitations

This section looks at the results of this thesis in the context of its strengths and weaknesses.

6.3.1. Strengths

6.3.1.1. Data

A key strength of this research was that both the phase one and two studies benefited from the use of the most reliable data available for the indicators of interest for this research. The phase one study used longitudinal data from the World Bank's world development and EIA's energy databanks (The World Bank, 2015b; U.S. Department of Energy, 2016). This was a large dataset where 156 countries were selected. This size exceeds the samples used in previous studies that examined the effect of oil economy on health and its determinants (Alexeeva and Conrad, 2011; Cotet and Tsui, 2013; Hong, 2017; Opaleye et al., 2018; Wigley, 2017). The measures used were part of the World Development Indicators gathered from the World Health Organization, United Nations and International Labour Organization (The World Bank, 2017). Each databank reported that data availability, quality and comparability were affected by factors including limited statistical systems in developing nations, variations in statistical methods and incomplete data coverage. Although these data were reported to be from the most reliable sources and underwent extensive standardisation as well as review by the data sources, care was taken when using the data, by comparing the estimates with national updates. Aside the large dataset and international nature of the phase one study, this thesis was further strengthened by the pairing of phase one study with a household-level study in phase two.

The phase two study used cross-sectional data from the Annual Abstract of Statistics, the Nigerian Demographic and Health Survey (NDHS) and the Federal Account Allocation Committee Report. The NDHS is the largest database which provides household-level data on demographics, infrastructure and health indicators in Nigeria. It is a nationally representative survey conducted in Nigeria as part of the Demographic and Health Surveys programme. A total of 38,522 households were included in this study and they were nested in 37 states/federal capital territory in Nigeria.

Previous studies examining the effect of crude oil economy on health and its determinants have relied on the inclusion of data from multiple countries (Alexeeva and Conrad, 2011; Cotet and Tsui, 2013; Hong, 2017; Wigley, 2017), and as our findings in the phase one study, the results can be generalised but interpreted with caution. Like our research, two studies (Caselli and Michaels, 2013; Cotet and Tsui, 2013) examined the effect of oil economy on health using both longitudinal and cross-sectional data analysis, to exploit both the time-series variation and cross-sectional variation. In addition, phase two study controlled for potential country specific omitted factors that were time-invariant, as within country variation was assessed.

The phase one study depended on two commonly used measures of crude oil wealth (Stijns, 2006): oil rent contribution to GDP and crude oil export. Oil rent contribution to GDP has been reported to be a better measure of oil wealth, compared to crude oil production and crude oil export (Ross, 2012; Cotet and Tsui 2013). Crude oil export as a share of GDP and oil production have been criticized for their endogeneity. They are influenced by a nation's political and economic situations, unlike oil-rent contribution to GDP. A sensitivity analysis, where two measures of oil-led economic growth were used in the empirical analysis in phase one study: oil-rent contribution to GDP (% growth) and crude oil export (% growth) was done. Generally, inconsistent results were found between the use of oil-rent contribution to GDP and crude oil export (% growth) as indicators of oil-led economic growth, which aligns with the criticism for the use of crude oil export.

6.3.1.2. Methodology

One of the strengths of this research is the use of structural equation modelling in the phase one study. This technique can assess both direct relationships between variables and indirect effects mediated via another variable. Also, the robustness of the measures of health and its determinants was explored by the use of multiple measures to test the hypothesised relationship. SEM is also equipped to handle missing data based on several assumptions. Multilevel modelling was used in the analysis of phase two data, as it is able to analyse nested data. Missing data were handled by imputation where needed.

Another strength is the control for variables that could confound the relationship between oil-led economic growth and health as there is a possibility that the present findings are related to unmeasured confounders or measurement error in the variables included in this research. A key strength of the phase one study is the simultaneous analysis of the association between the variables in this research model. This technique provided the opportunity to assess the total effects between variables, which were also disintegrated into indirect or direct relationships. Also, missing data was handled efficiently by SEM in this research.

To ensure that my results were not unduly influenced by the imputation methods used, models were also estimated based on the unimputed dataset and the findings were similar to those of the imputed models. This demonstrates that the findings reflect the tested relationship even though the estimations from the imputed models were reported for this research, to prevent selection bias where rich countries are more likely to be included in the research as they have complete data.

There is variation in the economic ability of the countries in phase one study and this heterogeneity was accounted for by considering two different economic status (low- and high-income) in the models.

6.3.2. Limitations

6.3.2.1. Data

A major limitation of phase one study was that the data could only be explored for 15 years (2000-2015), as a lot of data for relevant variables were not captured outside this range. Data spanning from 1960 were available only for a subset of developed countries. Although, the experience of these countries alone would have improved the body of knowledge on oil-health relationship, the availability of data from developing countries would give a more robust information on this relationship. Therefore, it is possible that the most important contributions of oil to the demographic and epidemiological transitions were missed because the data used in this study were comparatively modern. A lot of economies developed their oil industries before this time point and had already improved their public health quite a lot.

Considering the phase two study, data on crude oil from the inception of oil exploration in late 1950s to date would have been appropriate, to capture the development of the oil industry in Nigeria and the health improvements from crude oil. However, the paucity and limited access to data in Nigeria was a major challenge, even when steps were taken to retrieve data from the repository of the Nigerian government, there was no success. Also, the state-level measure of oil-led economic growth which captures the flow of oil money in each area, may not reflect the exact oil contribution of each state, as revenue from crude oil is centrally collected in Nigeria and this is redistributed based on government allocation to the states. The data in the phase two study were authenticated by the National Bureau of Statistics, but the steps taken by them were not published. This study also relied on the inclusion of data from different surveys, therefore their comparability is questionable.

This research would have benefitted from the exploration of the effects of oil-led economic growth on health and other determinants of health such as health adjusted life expectancy and health expenditure, but these indicators were not captured for many countries or available for this study period, thereby excluded from the analyses.

6.3.2.2. Methodology

The measure of institutional quality used in this study was an aggregate measure of three institutional indexes (the rule of law, corruption control and government effectiveness). It can be argued that the quality of an institution demonstrated by these indexes capture the political environment and governance structure in a country and substantially influence the translation of oil revenue to growth (Akanni, 2007). However, three other dimensions of governance (voice and accountability; political stability and absence of violence; and regulatory quality) which captures democracy, fairness and conflict needs to be assessed. Further studies will benefit from assessing the interaction of oil economy and institutional quality on health, to determine the impact of oil economy on health in either a weak or effective institution.

The cross-sectional study design of the phase two study does suffer from the omitted variable bias. The household level data used in this study was available for few selected years and only cross-sectional study was appropriate for the dataset.

Institutional quality, infrastructure and education were mediators in the relationship between oil-led economic growth and the indicators of health in the phase one study. A test for the interactions with these mediators would have thrown more light on this relationship but this was not done in this research, perhaps, this can be explored in future research.

A further weakness in this research as that many goodness of fit test including standardised root mean square residual, root mean square error of approximation, comparative fit index and chi-squared test were not reported due to the nature of the data and analysis used in this study, which made their test statistics invalid. AIC, BIC and CD were the only valid goodness of fit test in this study.

The empirical analysis was only quantitative. Further work can benefit from qualitative research which could investigate how oil-led economic growth can be channelled for health improvement, explore other factors that facilitate the translation of oil money to health and the views of people on the impact of the oil economy on their health.

6.4. Implications

The interpretations of my results lean towards the idea that institutional quality and infrastructural improvements is important in determining whether oil brings benefits to population health. Although the analyses were able to control for institutional quality to some extent, it is likely that its role was not captured. Institutional quality was also documented in the review in this thesis as a contributing factor to the positive impact of crude oil economy on health. Future studies will benefit from the assessment of the potential for other factors to facilitate the health improvement capacity of oil-led economic growth, as institutional quality did not completely explain this.

This present research suggests that channelling crude oil wealth into health improvement requires more than the pathways through institutional quality but also through education, employment and infrastructure. The activities of crude oil itself have hazardous effect on human life either through disease, conflicts that arise from oil proceeds and even death.

6.5. Further research and recommendation

There are outstanding research questions that need to be addressed in the future to add to the growing body of research. They included:

1. How can the interaction between institutional quality and oil-led economic growth be better understood, and its consequences for population health be clarified?

2. What are the policies that will drive health improvement in oil economies?

3. What are the views and perceptions of people on the effect of oil economy on their health?

6.6. Conclusion

This research suggests that the effect of oil-led economic growth on population health is different for high-income and low-income countries. Oil-led economic growth was associated with improved population health in high-income countries during the time period under study but was not associated with changes to population health in low-income countries. This research also reflects the importance of the quality of national policies and institutions alongside infrastructural improvements, as it explains the health improvement in high-income countries. Therefore, appropriate models of managing oil revenue which will improve the lives of people should be established and most importantly, low-income countries should consider the diversification of their economy to more stable and less harmful ventures like agriculture, to reduce the harmful effect of crude oil activities to life as well as strengthen their institutions.

During the relatively short period of time examined, no significant relationship was observed between crude oil resources and population health for both low- and high-income countries. This may reflect the time-bound translation from crude oil resources to health improvement, suggesting that significant effects require longer time to manifest.

The case study of Nigeria suggests that there is no significant association between oil-led economic growth and health. Previous findings have reported that when properly managed, oil money has the potential to improve health and wellbeing of its people. This study suggests that oil revenue in Nigeria is not effectively managed, probably due to the reported weak institutions in the country. Though oil-led economic growth was positively related to access to improved sanitary facilities, no significant association was documented for access to improved drinking water sources.

Quality of governance and priorities for expenditure are modifiable – they are not set on stone. Countries with high health expenditure, in general, have relatively good population health. The potential for oil to be a fuel for health improvement remains. Whether that potential is realised will depend not on epidemiological processes, but on political and economic ones. The implications of this research can be harnessed by policy makers when making decisions on promoting health and wellbeing in an oil-led economy.

Appendices

Appendix A: Search strategy and terms for electronic databases for review 1

The following search strategy is used in Ovid MEDLINE and is adapted for other databases to search for evidence on the impact of crude oil wealth on economic development.

Search terms	MEDLINE	EMBASE	CINAHL	Web of Science
1. ("oil wealth" OR "oil abundance" OR "oil endowment*" OR "crude oil wealth" OR "crude oil abundance" OR "crude oil endowment*" OR "petrol* wealth" OR "petrol* abundance" OR "petrol* endowment*" OR "peak oil").tw	11	11	21	848
2. ("oil rich" OR "crude oil rich" OR "petrol* rich").tw	929	1,132	82	1,760
3. ("oil revenue*" or "crude oil revenue*" or "petrol* revenue*" or "oil rent*" or "crude oil rent*" or "petrol* rent*").tw	20	18	2	443
4. or/1-3	957	1,157	103	2,989

5. ("economic development" OR "economic growth").tw	10,652	15,659	1,255	101,033
6. ("national development" OR "national growth").tw	156	194	509	3,163
7. (GDP OR "gross domestic product" OR GNI OR "gross national income").tw	15,587	17,640	861	35,680
8. or/4-6	25,751	32,820	2,554	132,314
9. 4 AND 8	13	8	1	214
10. Limit 9 to (English language)	9	7	1	207

Appendix B: Summary of articles included in review 1

Authors	Year	Location	Aims	Study design	Findings	Limitations and Quality Appraisal Score (QAS)
Akanni, O. P.	2007	47 oil exporting countries and 13 non-oil exporting countries	To examine the impact of oil rents on democracy, institutions and growth.	Longitudinal study; Data from 1970 – 2002	Oil rents have failed to promote growth and this failure can be explained by the absence of democratic governments and weak institutions in the oil exporting countries	The panel was unbalanced as data were not available for all the countries for all of the five periods. QAS=8
Alexeeva, M.; Conrad, R.	2009	Organization of the petroleum exporting countries (OPEC) members and major non-OPEC	To examine the effect of a large endowment of oil and other mineral resources on a country's long-	Cross-sectional study	Oil abundance enhances long-term economic growth.	Omitted variable bias. QAS=6

		oil producing nations	term economic growth			
Aimer, N. M.	2018	8 oil exporting countries; Members of organization of the petroleum exporting countries (OPEC)	To know the effect of oil rents on economic growth	Longitudinal study; Data from 1997 – 2015.	There is a positive impact of oil rents on economic growth for OPEC countries. There is one-way strong causality running from oil rents to gross domestic product growth.	The countries used in this study were selected according to the data availability. QAS=8
Apergis, N.; Payne, J. E.	2014	Middle East and North African countries	To re-examine the impact of oil abundance on economic growth	Longitudinal study; Data from 1990 – 2013	Oil abundance has a negative impact on growth but better institutional quality mitigates this negative impact on growth.	Cross-sectional dependence in the data QAS=8

Arin, K. P.; Braunfels, E.	2018	91 countries	To analyse the effects of resources (oil revenues) on economic growth	Two phases: Cross sectional and longitudinal study; Data from1970–2014	There is positive effect of oil rents on growth in the long-run but this growth enhancing effect may possibly depend on good quality of institutions	In the panel analysis, some potential growth determinants were lost due to data availability. Unbalanced panel data. QAS=7
Cavalcanti, T. V.D.V; Mohaddes, K.; Raissi, M.	2011a	53 oil producing countries	To explore whether natural resource abundance is a curse	Longitudinal study; Data from 1980 – 2006	Oil abundance has positive effect on short-run economic growth	There is a substantial heterogeneity among the countries used in the study. QAS=6
Chekouri, S. M.; Chibi, A.; Benbouziane,	2017	Algeria	To examine the association between oil export revenues	Longitudinal study; Data from 1979 –	There is a strong positive association between oil revenue and long-run economic growth but a	Small sample size for identifying long-run relationship and

M.			and economic growth in Algeria	2013	negative relationship between oil revenue volatility and economic growth in Algeria	restriction tests. QAS=7
Cotet, A.M.; Tsui, K.K.	2013	152 countries	To estimate the relationship between oil and growth	Cross-country and longitudinal study; Data from 1960 to 2000.	Cross-country results show that there is a stable positive relationship between oil abundance and long-run economic growth and the panel data methods show no evidence that higher oil rents hinder growth.	The cross-country results introduce omitted variable bias and the panel results increases attenuation bias. QAS=9
Eregha, P. B.; Mesagan,	2016	Algeria, Angola, Egypt, Libya and	To examine the effects of oil resource	Longitudinal study; Data from 1996-	Oil production per capita measure of resource abundance showed a	Omitted variable bias. QAS=8

E. P.		Nigeria	abundance and the quality of institutions on per capita GDP growth	2013	positive effect on growth as against the oil export earning measures which gave evidence for existence of resource curse.	
Fuinhas, J. A.; Marques, A. C.; Couto, A. P.	2015	21 oil producing countries	To examine the effects of the oil rents on economic growth	Longitudinal study; Data from 1970 – 2012	Oil rents depress growth in both the short- and long-run, suggesting that it is more a curse than a blessing for the economies.	Cross-section dependence. QAS=7

Hamdi, H.; Sbia, R.	2013	Kingdom of Bahrain	To examine the dynamic relationships between oil revenues, government spending and economic growth	Time series; Data from 1960 – 2010.	Oil revenue has a positive long-run and short-run relationship with economic growth in the Kingdom of Bahrain.	Gross domestic product is the only proxy for economic growth. QAS=7
Kurtz, M. J.; Brooks, S. M.	2011	Worldwide	To establish a prima facie case for the plausibility that human capital formation is a crucial factor shaping the growth effects of	Longitudinal study; Data from 1979 – 2008	Oil wealth favours economic development under conditions such as those characterized by high human capital endowments.	The findings are preliminary with very basic statistical analysis. QAS=6

			natural resource endowments.			
Law, S. H.; Moradbeigi, M.	2017	Two groups of 63 and 61 oil-producing countries	To examine the impact of oil resource abundance on economic growth, conditional on the level of development in the financial system for oil-endowed countries.	Longitudinal study; Data from 1980 – 2010	Oil resource abundance contributes to economic growth but conditional on financial development. Financial development moderates the negative effects of oil resource abundance on economic growth by channelling the revenues from oil into more productive activities.	Outlier countries were excluded from the empirical analysis. QAS=9
Matallah, S.;	2016	Middle East and	To test the impact of oil rents on	Longitudinal study; Data	Oil rent has a statistically significant positive impact	Gross domestic product per capita growth is the

Matallah, A.		North African countries; 11 oil exporters	economic growth; examine the main symptoms of resource curse in oil-abundant MENA countries; investigate the role of governance in avoiding the resource curse	from 1996 – 2014	on economic growth.	only proxy for economic growth. QAS=8
Mideksa, T. K.	2013	Norway	To explore the economic impact of petroleum endowment	Longitudinal study; Data from 1951 – 2007	Petroleum endowment positively affects annual GDP per capita in Norway	The omission of potential regions from the donor pool for synthetic Norwegian unit due to issues like unavailability of data

						may have affected the estimated impact. QAS=7
Nili, M.; Rastad, M.	2007	12 oil and 132 non-oil economies	To compare the significance of financial development for economic growth for oil and non-oil economies	Longitudinal study; Data from 1960 – 2001	Most of the investment of oil exporting countries can be majorly explained by the oil revenues but financial development has a net inhibitory effect on investment as financial institutions and systems are weaker	Due to data limitations, the sample of oil economies is restricted to a subset of these countries for some statistics. QAS=8
Obafemi, F. N.; Ogbuagu, U. R.;	2013	Nigeria	To investigate the relationship between	Time series; Data from	Petroleum resource abundance may be much less of a curse and more of	Share of oil exports to gross domestic product is the only proxy for

Nathan, E.			petroleum resources, institutions, and economic growth in Nigeria	1970 – 2011	a boom for economic performance if quality institutions are in place	petroleum resource abundance. QAS=7
Ogwumike, F. O.; Ogunleye, E. K.	2008	Nigeria	To examine the long-run relationship between the huge oil revenue that has accrued to Nigeria and its state of development	Time series	There is evidence of long-run relationship between oil revenue and development	The data on oil revenue may not be accurate therefore the actual impact of oil revenue on development may be inaccurate. QAS=7

Torres, N.; Afonso, O.; Soares, I.	2012	48 oil producing countries	To estimate the growth-effects of oil abundance	Longitudinal study; Data from 1980 – 2005	Oil abundance is not significant to economic growth but there is a positive growth effect of oil concentration, which is only significant and increases in the presence of quality institution	Unbalanced panel data. QAS=6

Appendix C: Amended CASP Checklist for Quantitative Research (CASP, 2018)

Section A: Are the results valid?

1. Was there a clear statement of the aims of the research?

Yes ☐
Can't Tell ☐
No ☐

HINT: Consider
- what was the goal of the research
- why it was thought important
- its relevance

Comments:

2. Is the methodology appropriate?

Yes ☐
Can't Tell ☐
No ☐

Hint: Consider
- if research explores the association
- is the methodology appropriate

Comments:

Is it worth continuing?

3. Was the research design appropriate to address the aims of the research?

Yes ☐
Can't Tell ☐
No ☐

HINT: Consider
- if the researcher has justified the research design (e.g. have they discussed how they decided?)

Comments:

4. Was the criteria of selecting countries for inclusion appropriate?

Yes

Can't Tell

No

HINT: Consider
- if the researcher has explained how the countries were selected
- if they explained why the countries selected were appropriate

Comments:

5. Were the variables selected in a way that addressed the research aim?

Yes

Can't Tell

No

HINT: Consider
- if the setting for the variable selection was justified
- was the chosen method justified

Comments:

6. Have the authors taken account of the potential confounders in their design and analysis?

Yes

Can't Tell

No

HINT: Consider
- if the authors considered restrictions in designs and techniques
- if the authors conducted sensitivity analysis to control for confounders

Comments:

Section B: What are the results?

7. Do you believe the results?

Yes

Can't Tell

No

HINT: Consider
- Can it be due to chance, bias, or confounders
- are the design and methods of this study sufficiently flawed to make the results unreliable

Comments:

8. Was the data analysis sufficiently rigorous?

Yes

Can't Tell

No

HINT: Consider
- Have the authors taken account of potential confounders in the design?
- How precise were the estimates?
- If sufficient data are presented to support the findings
- Whether the researcher critically examined their own role/potential bias

Comments:

9. Is there a clear statement of findings?

Yes	
Can't Tell	
No	

HINT: Consider whether

- If the findings are explicit
- If there is adequate discussion of the evidence both for and against the researcher's arguments
- If the researcher has discussed the credibility of their findings
- If findings are discussed in relation to the original research questions and aim

Comments:

Section C: Will the results help locally?

10. How valuable is the research?

HINT: Consider

- If the researcher discusses the contribution the study makes to existing knowledge or understanding (e.g. do they consider the findings in relation to current practice or policy, or relevant research-based literature
- If they identify new areas where research is necessary
- If the researchers have discussed whether or how the findings can be transferred to other populations

Comments:

Appendix D: Search strategy and terms for electronic databases for review 2

The following search strategy is used in Ovid MEDLINE and is adapted for other databases to search for evidence on the impact of crude-oil economy on health and its determinants

Search terms	MEDLINE	EMBASE	CINAHL	Web of Science
1.(oil-led econom* OR oil-based econom*).tw	5	2	7	406
2. (oil econom* OR crude oil econom* OR petrol* econom* OR oil export* econom* OR crude oil export* econom* OR petrol* export* econom*).tw	12	15	582	31,683
3. (oil produc* OR crude oil produc* OR petrol* produc*).tw	3,188	4,151	2,451	171,260
4.(oil-dependen* OR crude oil-dependen* OR petrol* dependen* OR oil rich OR crude oil rich OR petrol* rich).tw	946	1,165	647	27,161
5. (oil growth OR crude oil growth OR petrol* growth).tw	25	37	661	46,866
6. (oil develop* OR crude oil develop* OR petrol* develop*).tw	102	154	1,911	117,211
7. or/1-6	4,247	5,488	4,466	289,998
8. (“human health” OR “animal health” OR “plant health”).tw	40,886	52,081	3,607	68,451

9. ("population health").tw	8,985	10,334	13,702	9,576
10. or/8-9	49,738	62,253	17,245	77,831
11. ("health determinant*").tw	856	984	316	837
12. ("determinant* of health" OR "driver* of health").tw	7,165	9,443	4,305	5,957
13. ("health status indicator*").tw	22,510	3,092	7,479	706
14. or/11-13	29,982	13,182	11,847	7,324
15.7 AND 10	52	69	127	2,300
16.7 AND 14	9	2	18	23
17.15 OR 16	60	70	139	2,320
18. Limit 20 to (English language)	55	67	139	2,265

Appendix E: Summary of articles included in review 2

Authors	Year	Location	Aims	Study design	Findings	Limitations and Quality Appraisal Score (QAS)
Alexeeva, M.; Conrad, R.	2011	Worldwide	To examine the relationship between point-source natural resource abundance and economic growth, institutional quality, investment in human and physical capital,	Cross-sectional study	In the economies in transition, natural resource wealth is associated with lower primary school enrolment and life expectancy and higher infant mortality compared to other resource-rich economies; the net effect of natural resource endowments on these indicators in the economies in transition is insignificant.	Omitted variable bias. QAS=6

			and social welfare.			
Caselli, F.; Michaels, G.	2013	Brazil	To find out whether oil has positive or negative spill-overs on other market activities and investigate the consequences of an oil-related fiscal windfall.	Two phases; cross-sectional and longitudinal study	Oil-related revenues increased reported spending on housing and urban services, transportation, housing, education, health and sanitation; oil revenue translates into little improvement in the provision of public goods or the population's living standards indicating a shortfall termed "missing money".	This study did not fully consider the time lag from revenue spending to manifestation of socioeconomic outcomes which may contribute to the little improvement in the outcomes. QAS= 7

Cotet, A.M.; Tsui, K.K.	2013	152 countries	To provide new evidence of the effect of oil wealth on health improvement.	longitudinal study; Data from 1960 – 2000.	Panel data analysis shows that oil wealth was associated with lower infant mortality and longer life expectancy.	The panel results introduce bias from measurement error. QAS=9
Hong, J. Y.	2017	Worldwide	To examine the effects of natural resource abundance on social spending in dictatorships	Longitudinal study; Data from 1972 and 2008	In authoritarian governments, oil rent has significant negative effect on social expenditures such as government spending on education and health; oil wealth does not significantly affect social expenditure patterns in democratic governments. This implies that the effects may be due to the government structures	Study did not take into account the endogeneity problem of resource wealth being systemically linked to the probability of authoritarian government. QAS=8

Omotor, D. G.	2009	Nigeria	To measure the impact of oil exploration on the inhabitants of the oil producing areas as measured by certain socio-economic indicators	Longitudinal study; Three waves of data around 1964 – 2004.	The overall impact of oil on socio-economic indicators was only significant during the oil boom era; the oil revenue significantly influenced the development of the socio-economic indicators in non-oil producing areas than in oil producing areas, except for power which was less significant in the oil boom era.	The analysis was simplistic and limited and did not account for within country factors; oil exploration revenues were not clearly defined. QAS=7
Opaleye, S.S.; Okowa, W.J.; Ohale, L.	2018	Algeria, Egypt, Nigeria and Cameroon	To investigate the impact of oil rent expenditure on socioeconomic indicators	Longitudinal study; Data from 1995 – 2015.	Oil rent significantly increased child mortality; it did not significantly improve education.	Proxy for education is basic school enrolment which may not have been accurately captured in some countries.

						QAS=7
Wigley, S.	2017	167 countries	To examine whether resource curse extends to the health of children.	Longitudinal study; Data from 1961 –2011.	Oil wealth is positively associated with child mortality; petroleum-poor countries perform better than petroleum-rich countries in reducing under-five mortality, implying that governments in petroleum-rich countries ineffectively use the natural resource revenue to improve child health.	The measure of oil wealth overstates the revenue that each government obtains from natural resources. QAS=8

Appendix F: Countries excluded from phase one study

Excluded countries (61)
Afghanistan, American Samoa, Andorra, Antigua and Barbuda, Aruba, Bermuda, British Virgin Islands, Cayman Islands, Channel Islands, Cuba, Curacao, Democratic People's Republic of Korea, Djibouti, Dominica, Equatorial Guinea, Eritrea, Eswatini, Faroe Islands, Federal States of Micronesia, French Polynesia, Gabon, Gibraltar, Greenland, Grenada, Guam, Haiti, Hong Kong, Iceland, Isle of Man, Kiribati, Kosovo, Liechtenstein, Macau, Marshall Islands, Monaco, Mongolia, Montenegro, Myanmar, Nauru, New Caledonia, Northern Mariana Islands, Palau, Puerto Rico, Republic of Congo, Saint Kitts and Nevis, Saint Martin (French part), San Marino, Sao Tome and Principe, Serbia, Seychelles, Sint Maarten (Dutch part), Somalia, South Sudan, Sudan, Syrian Arab Republic, Timor-Leste, Turks and Caicos Islands, Tuvalu, United States Virgin Islands, Uzbekistan & West Bank and Gaza.

Appendix G: Test for multivariate normality for data in panel models

	Low-income group		High-income group	
Test for multivariate normality	Test statistic	Chi-square	Test statistic	Chi-square
Mardia mSkewness	121.0	2,569.5***	201.5	7,270.2***
Mardia mKurtosis	255.1	700.3***	388.2	7,682.6***
Henze-Zirkler	1.5	3,021.7***	4.0	55,101.9***
Doornik-Hansen	-	2,279.6***	-	4,258.2***

* p<0.05, ** p<0.01, *** p<0.001

Appendix H: Longitudinal assessment of the relationship between crude oil resources and health determinants

Variables	Access to basic drinking water source			Access to basic sanitary facility		
	Estimate	Robust S. E.	z	Estimate	Robust S. E.	z
Lagged effect of health determinant	0.94***	0.01	81.58	0.97***	0.02	53.10
Crude oil export	0.01	0.01	0.26	-0.01*	0.01	-1.85
Employment to population ratio	0.01	0.01	-0.05	0.01	0.01	-0.32
Institutional quality	0.04	0.05	0.72	-0.13	0.08	-1.60
Crude oil production	0.01	0.01	0.53	0.01	0.01	0.16
Pollution	0.01	0.01	1.59	0.01	0.01	1.44
Enrolment in basic education	-0.01	0.01	-1.59	0.01	0.03	-0.05
Income group	-0.27	0.57	-0.47	0.46	0.83	0.56

Robust S.E = robust standard error; z= z-value; * $p<0.05$, ** $p<0.01$, *** $p<0.001$; the coefficient of determination is 0.096 for both models.

Appendix I: AIC and BIC statistics for model with robust and normal standard errors (Longitudinal assessment of the relationship between crude oil resources and health determinants)

	Access to basic drinking water source (oil rent)		Access to basic sanitary facility (oil rent)		Access to basic drinking water source (oil export)		Access to basic sanitary facility (oil export)	
	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Model with robust standard errors	21098.350	21430.780	21285.540	21624.080	24714.930	25068.710	24894.190	25251.020
Model with normal standard error	21264.350	21849.920	21449.540	22038.160	24884.930	25497.950	25062.190	25675.210

Appendix J: Longitudinal assessment of the relationship between crude oil resources and health

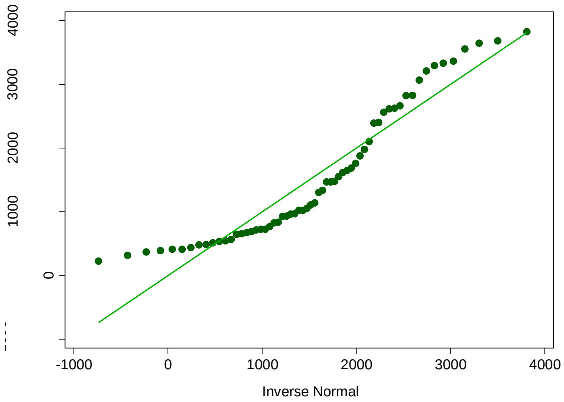
Variables	Infant mortality			Life expectancy		
	Estimate	Robust S. E.	z	Estimate	Robust S. E.	z
Lagged effect of health	0.84***	0.07	11.89	0.84***	0.02	35.73
Crude oil export	0.01	0.01	0.54	0.01	0.01	0.02
Employment to population ratio	-0.06*	0.03	-2.04	0.01	0.01	1.19
Institutional quality	0.10	1.27	0.08	0.13***	0.03	4.04
Access to basic drinking water source	0.08	0.35	0.22	-0.02	0.01	-1.65
Access to basic sanitary facility	-0.06	0.08	-0.79	0.01	0.01	1.24
Crude oil production	0.01	0.01	-0.52	0.01	0.01	-0.61
Pollution	0.01	0.01	0.69	-0.01**	0.00	-3.23
Enrolment in basic education	0.00	0.51	-0.01	0.01	0.01	0.98
Income group	0.25	5.23	0.05	0.17	0.21	0.77

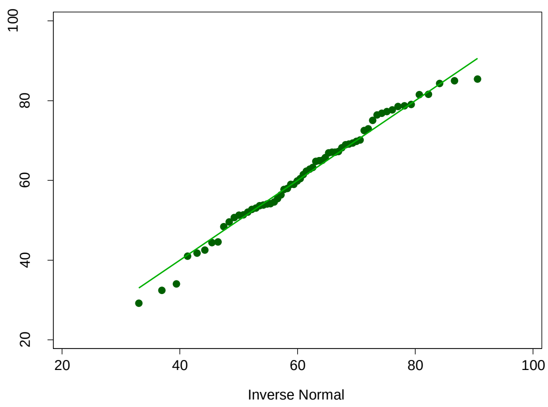
Robust S.E = robust standard error; z= z-value; * $p<0.05$, ** $p<0.01$, *** $p<0.001$; The coefficient of determination is 1.0 and 0.997 model with infant mortality and model with life expectancy respectively.

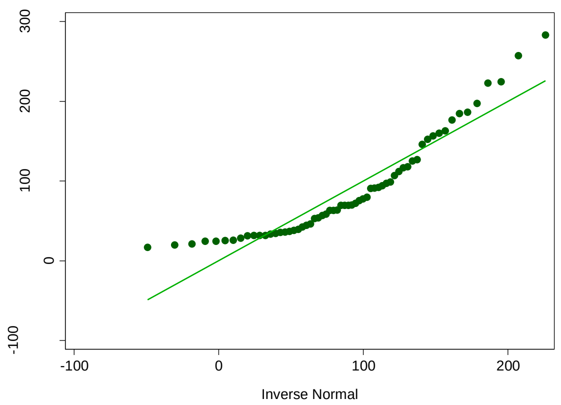
Appendix K: AIC and BIC statistics for model with robust and normal standard errors (Longitudinal assessment of the relationship between crude oil resources and health)

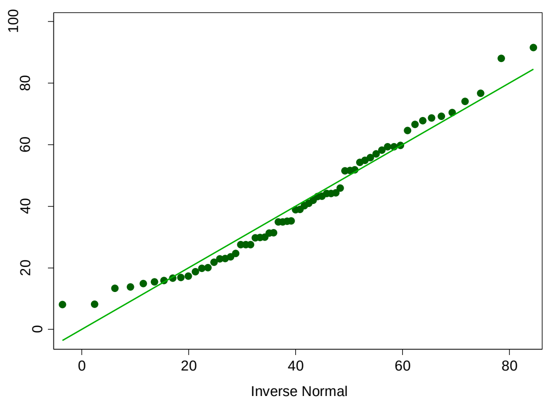
	Infant mortality (oil rent)		Life expectancy (oil rent)		Infant mortality (oil export)		Life expectancy (oil export)	
	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Model with robust standard errors	22125.080	22460.570	20818.090	21144.430	26014.290	26383.320	24430.940	24778.620
Model with normal standard error	22299.080	22899.910	20984.090	21563.560	26180.290	26802.460	24596.940	25197.760

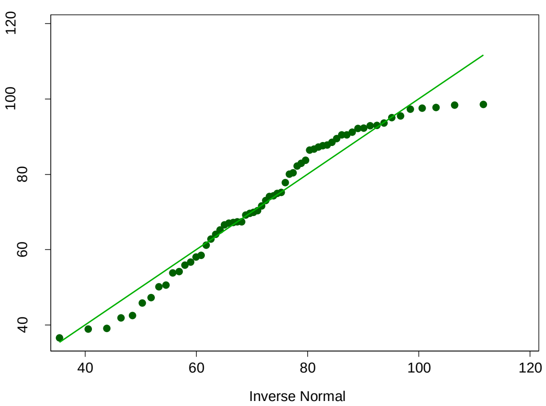
Appendix L: Q-Q plot for low-income group data

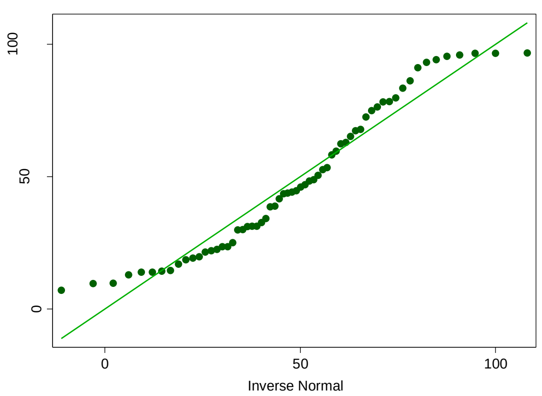


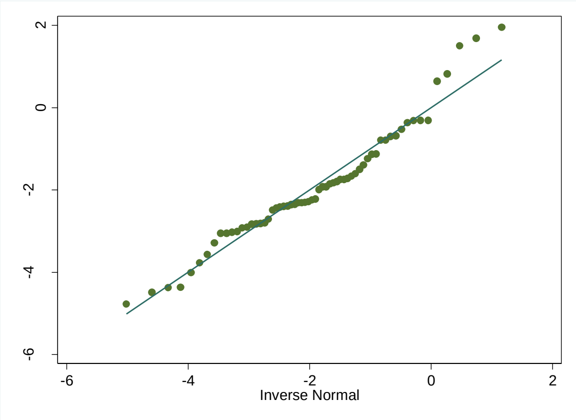








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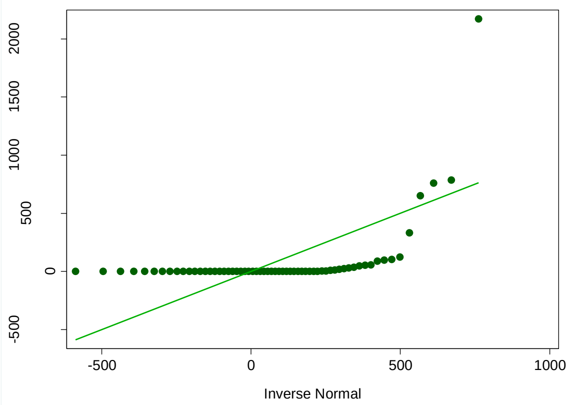
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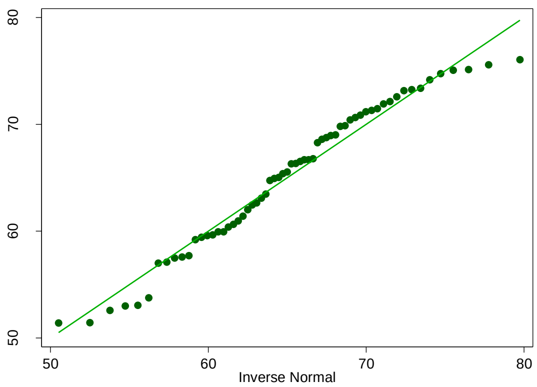
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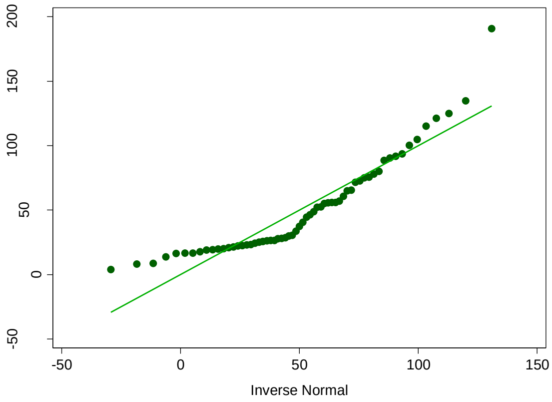
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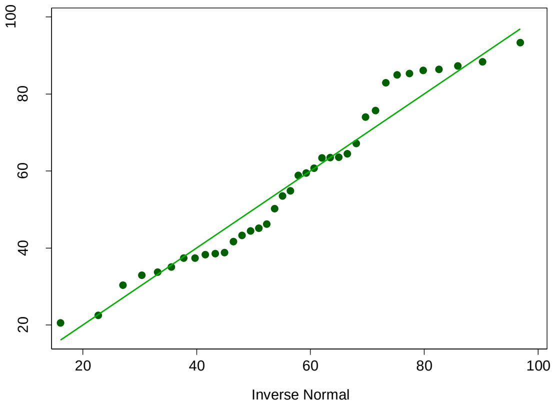
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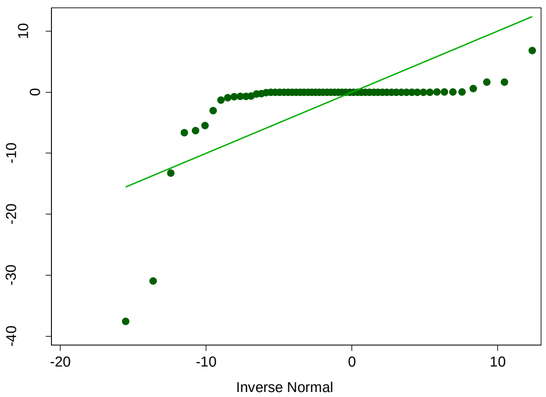
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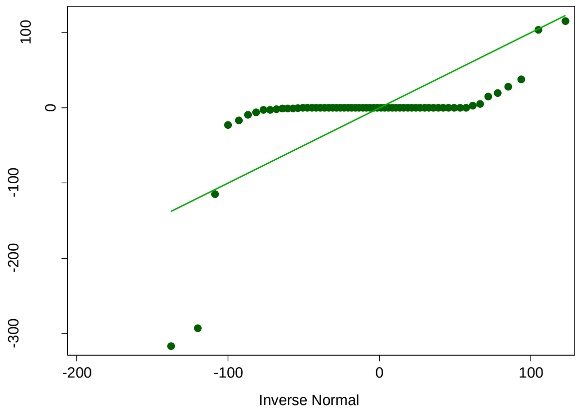
Inverse Normal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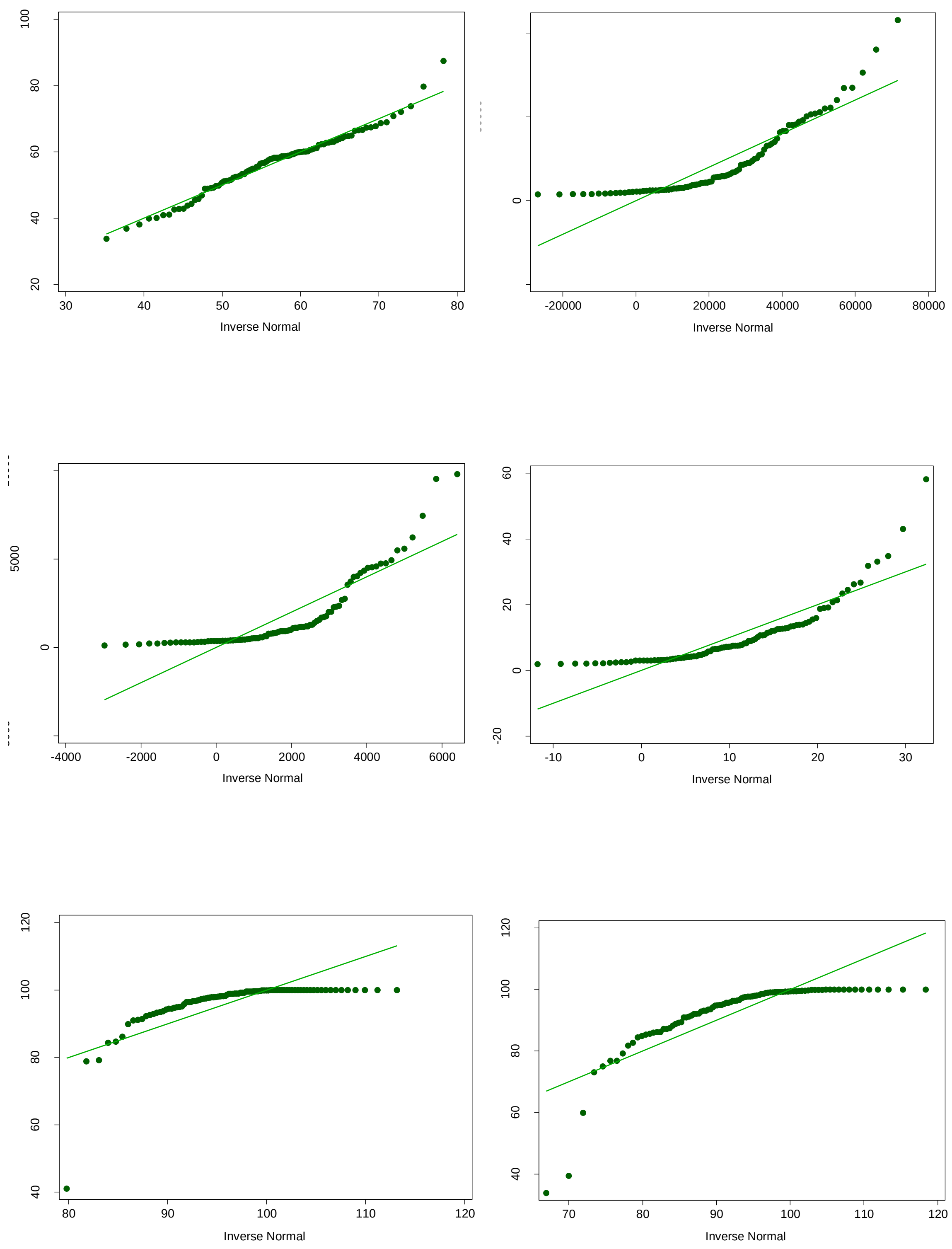
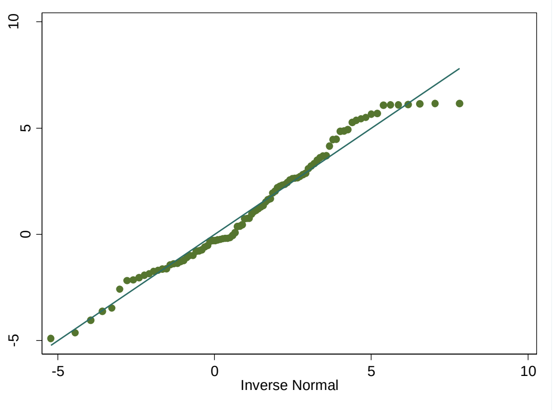
0
100
Inverse Normal

Appendix M: Q-Q plot for high-income group data

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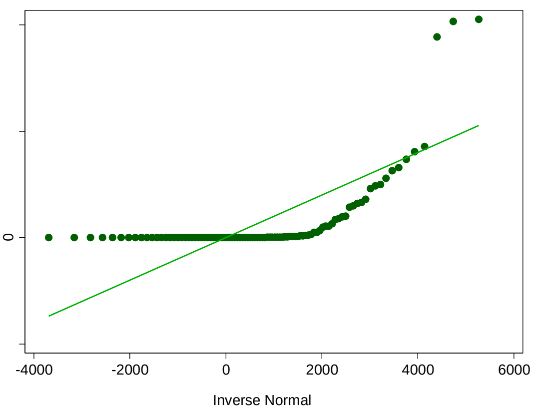
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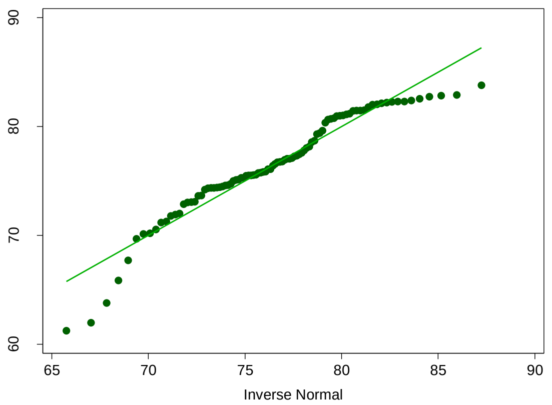
Inverse Normal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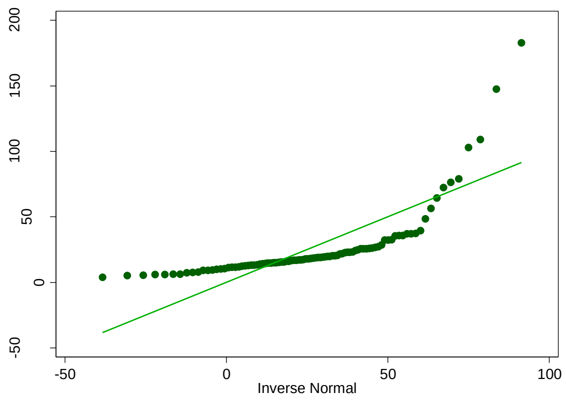
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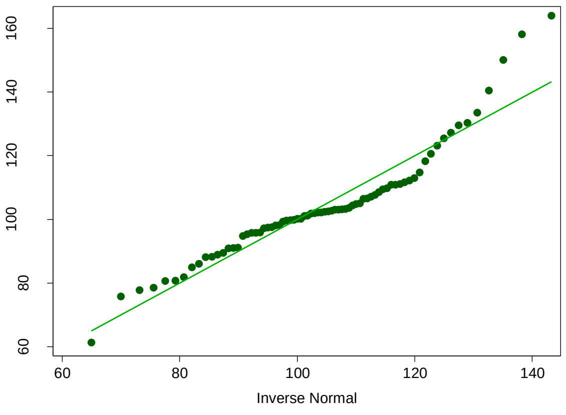
Inverse Normal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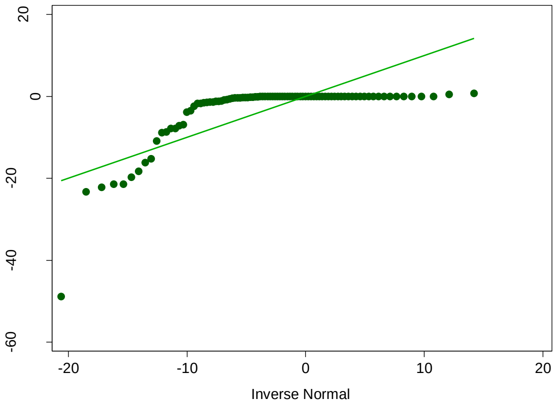
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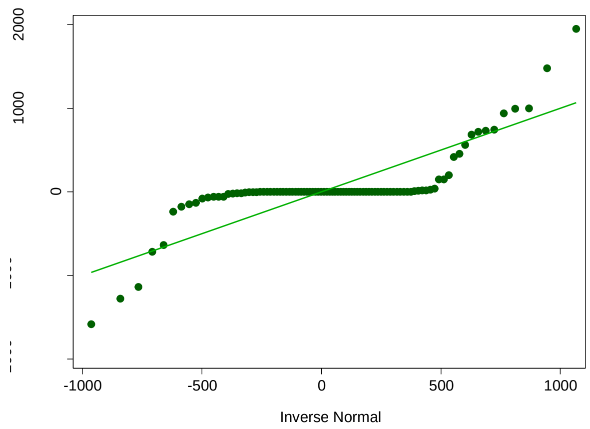
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Inverse Normal

Appendix N: Test for joint univariate normality for cross-sectional models

Variables	Low-income group	High-income group
	Adjusted chi-square	Adjusted chi-square
Employment to population ratio	1.000	5.350
GDP per capita	4.640	19.51***
Health expenditure	9.74**	24.15***
Infant mortality rate	4.450	26.41***
People with basic drinking water services	5.760	27.85***
People with basic sanitation services	3.070	15.65***
Institutional quality	5.05	14.93***
Crude oil production	38.8***	67.81***
Life expectancy at birth	4.280	11.69**
Air pollution	11.88**	61.1***
Enrolment in basic education	5.650	14.38**
Oil rent contribution to GDP (% growth)	13.2**	42.43***
Crude oil export (% growth)	41.07***	20.94***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Appendix O: Test for multivariate normality for cross-sectional models

	Low-income group		High-income group	
Test for multivariate normality	Test statistic	Chi-square	Test statistic	Chi-square
Mardia mSkewness	119.1	803.3***	144.6	1866.2***
Mardia mKurtosis	215.7	10.2**	299.4	517.0***
Henze-Zirkler	1.0	8.0**	1.7	8227.1***
Doornik-Hansen	-	312.8***	-	955.0***

* p<0.05, ** p<0.01, *** p<0.001

Appendix P: Direct, indirect and total relationships between crude oil export (% growth) and health determinants

Structural model	Access to basic drinking water source	Access to basic sanitary facility
	Std. Coeff.	Std. Coeff.
Direct relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.14	-0.01
High-income group	-0.02	-0.06
Indirect relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.02	0.10
High-income group	-0.08	-0.03
Total relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.15	0.10
High-income group	-0.10	-0.09

Std. Coeff. = standardised coefficient. p<0.05, ** p<0.01, *** p<0.001

Appendix Q: R-squared and Coefficient of determination (relationship between oil-rent contribution to GDP (% growth) and health determinants)

Dependent variables	Access to basic drinking water source		Access to basic sanitary facility	
	R-squared (low income)	R-squared (high income)	R-squared (low income)	R-squared (high income)
Crude oil production	0.317	0.099	0.317	0.093
Air pollution	0.067	0.194	0.067	0.194
GDP per capita	0.007	0.007	0.007	0.006
Employment to population ratio	0.225	0.151	0.225	0.160
Enrolment in basic education	0.635	0.340	0.697	0.278
Health determinant	0.696	0.666	0.580	0.445
Institutional quality	0.023	0.114	0.023	0.104
Overall CD	0.593		0.544	

Appendix R: AIC and BIC statistics for models with robust and normal standard errors (relationship between oil-led economic growth and health determinants)

	Access to drinking water (oil rent)		Access to sanitary facility (oil rent)		Access to drinking water (oil export)		Access to sanitary facility (oil export)	
	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Model with robust standard errors	12962.57	13014.39	11871.58	11929.53	11690.22	11742.06	12828.04	12879.68
Model with normal standard error	12962.63	13014.44	11877.58	11944.68	11696.22	11757.21	12828.24	12879.88

Health determinant as response variable: model 1 = access to basic drinking water; model 2 = access to basic sanitary facility

Appendix S: R-squared and Coefficient of determination (relationship between crude oil export (% growth) and health determinants)

Dependent variables	Access to basic drinking water source		Access to basic sanitary facility	
	R-squared (low income)	R-squared (high income)	R-squared (low income)	R-squared (high income)
Crude oil production	0.013	0.240	0.013	0.240
Air pollution	0.067	0.194	0.067	0.194
GDP per capita	0.009	0.017	0.009	0.017
Employment to population ratio	0.196	0.101	0.196	0.101
Enrolment in basic education	0.490	0.175	0.557	0.193
Health determinant	0.680	0.255	0.590	0.320
Institutional quality	0.000	0.021	0.000	0.021
Overall CD	0.510		0.494	

Appendix T: Direct, indirect and total relationship between crude oil export (% growth) and health

Structural model	Infant mortality	Life expectancy at birth
	Std. Coeff.	Std. Coeff.
Direct relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.19	-0.20*
High-income group	-0.10*	0.04
Indirect relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.33*	-0.34*
High-income group	0.16	-0.18
Total relationship: Crude oil export (% growth) and health determinant		
Low-income group	0.51*	-0.54*
High-income group	0.06	-0.15

Std. Coeff = standardised coefficient. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Appendix U: R-squared and Coefficient of determination (relationship between oil-rent contribution to GDP (% growth) and health)

Dependent variables	Infant mortality		Life expectancy	
	R-squared (low income)	R-squared (high income)	R-squared (low income)	R-squared (high income)
Crude oil production	0.317	0.099	0.317	0.097
Air pollution	0.067	0.194	0.067	0.194
GDP per capita	0.007	0.007	0.007	0.006
Employment to population ratio	0.225	0.155	0.225	0.155
Enrolment in basic education	0.752	0.260	0.746	0.235
Health	0.551	0.706	0.530	0.635
Government effectiveness	0.023	0.109	0.023	0.108
Access to basic drinking water source	0.001	0.381	0.001	0.380
Access to basic sanitary facility	0.001	0.080	0.001	0.079
Model R2	0.692	0.564	0.680	0.530
Overall CD	0.567		0.532	

Appendix V: AIC and BIC statistics for models with robust and normal standard errors (relationship between oil-led economic growth and health)

	Infant mortality (oil rent)		Life expectancy (oil rent)		Infant mortality (oil export)		Life expectancy (oil export)	
	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Model with robust standard errors	14973.04	15025.03	14973.04	15025.03	14114.90	14181.99	13847.63	13905.57
Model with normal standard error	14973.24	15025.09	14973.24	15025.09	14116.90	14187.04	13849.63	13910.62

Appendix W: R-squared and Coefficient of determination (relationship between crude oil export (% growth) and health)

Dependent variables	Infant mortality		Life expectancy	
	R-squared (low income)	R-squared (high income)	R-squared (low income)	R-squared (high income)
Crude oil production	0.013	0.240	0.013	0.240
Air pollution	0.067	0.194	0.067	0.194
GDP per capita	0.009	0.017	0.009	0.017
Employment to population ratio	0.196	0.101	0.196	0.101
Enrolment in basic education	0.544	0.182	0.546	0.180
Health/health determinant	0.547	0.634	0.536	0.595
Institutional quality	0.000	0.021	0.000	0.021
Access to basic drinking water source	0.012	0.061	0.012	0.061
Access to basic sanitary facility	0.033	0.017	0.033	0.017
Overall CD	0.529		0.531	

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