FUEL SUBSIDY REMOVAL AND ENVIRONMENTAL QUALITY IN NIGERIA: A DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM APPROACH

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ACCEPTANCE

This is to attest that this thesis is accepted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Economics** in the Department of **Economics and Development Studies,** College of Business and Social Sciences, Covenant University, Ota.

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CERTIFICATION

We certify that the thesis titled "Fuel Subsidy Removal and Environmental Quality in Nigeria: A Dynamic Computable General Equilibrium Approach" is an original work carried out by AKINYEMI Opeyemi Esther, (05AF02008), in the Department of Economics and Development Studies, College of Business and Social Sciences, Covenant University, Ota, Ogun State, Nigeria, under the Supervision of Professor Philip O. Alege and Dr. Oluseyi O. Ajayi. We have examined and found the work acceptable for the award of a degree of Doctor of Philosophy in Economics.

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DEDICATION

This Ph.D thesis is dedicated first and foremost to the Most High God, the Creator of Heaven and Earth. Also, this work is dedicated to my wonderful and loving parent, Dr. and Mrs. Oladunni and Bolaji Akinyemi and my brother, Mr. Peter Akinyemi for their financial support, love, prayers and counsel throughout the period of doing this work.

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LIST OF ABBREVIATIONS

ADR: Africa Development Report

AEO: African Economic Outlook

AfDB: African Development Bank

ADB: Asian Development Bank

AGO: Automotive Gas Oil

APEC: Asian Pacific Economic Co-operation

BAU: Business-as-Usual

CAB: Current Account Balance

CBN: Central Bank of Nigeria

CES: Constant Elasticity of Substitution

CGE: Computable General Equilibrium

CO_2: Carbon Dioxide

CPI: Consumer Price Index

CtGE: Competitive General Equilibrium

DCGE: Dynamic Computable General Equilibrium

DPK: Dual Purpose Kerosene

DSGE: Dynamic Stochastic General Equilibrium

E2: Energy-Environment

ECOWAS: Economic Co-operation for West African State

EFS: Environmentally Friendly Subsidies

EHS: Environmentally Harmful Subsidies

EIA: Energy Information Administration

EKC: Environmental Kuznet Curve

EU: European Union

FGN: Federal Government of Nigeria

FMAWR: Federal Ministry of Agriculture and Water Resources

G-20: Group of 20 Countries

GAMS: General Algebraic Modelling System

GHGs: Green House Gases

GDP: Gross Domestic Product

GSI: Global Subsidies Initiatives

GTAP: Global Trade Analysis Project

IEA: International Energy Agency

IMF: International Monetary Fund

IISD: International Institute for Sustainable Development

ISO: International Standard Organisation

MENA: Middle East and North Africa

MDGs: Millennium Development Goals

MOC: Marginal Opportunity Cost

NBS: National Bureau of Statistics

NNPC: Nigerian National Petroleum Corporation

OECD: Organisation for Economic Co-operation and Development

OPEC: Organisation of Petroleum Exporting Countries

PEP: Partnership for Economic Policy

PIB: Petroleum Industry Bill

PMS: Premium Motor Spirit

ROW: Rest of the World

SAM: Social Accounting Matrix

SAP: Structural Adjustment Programme

SDGs: Sustainable Development Goals

SSA: Sub-Saharan Africa

SURE-P: Subsidy Reinvestment and Empowerment Programme

UAE: United Arab Emirates

UK: United Kingdom

UN: United Nations

UNCTAD: United Nations Centre for Trade and Development

UNDP: United Nations Development Programme

UNEP: United Nations Environment Programme

UNFCCC: United Nations Framework Convention on Climate Change

USA: United States of America

USEPA: United States Environmental Protection Programme

VAR: Vector Autoregressive

VAT: Value Added Tax

WTO: World Trade Organisation

ABSTRACT

Environmental challenges such as climate change continue to threaten human existence globally. This has necessitated renewed focus on some existing policies that by design or otherwise may counter global efforts at addressing these challenges. Various engineering solutions have been championed while economic and social development tools have focused on using various policy instruments to reduce the concentration of emissions in the atmosphere. One of such policies is the fuel subsidy policy and various arguments for and against this policy exists. While some support the policy as it enhances access to energy and promotes welfare, others argue that it places budgetary burden on the economy. More so, studies that have focused on policy instruments have employed different approaches. However, those that focused on addressing environmental questions in terms of promoting green growth are very scarce. This study, thus, investigated the environmental consequences of fuel subsidy removal in Nigeria using an economy-wide modelling approach. It adapted the energy-environment (*E2*) dynamic CGE model of the Nigerian economy that is based on the Partnership and Economic Policy (PEP) recursive dynamic CGE model. Furthermore, the study simulated three scenarios namely the partial removal (Simulation1), gradual removal (Simulation 2) and complete removal (Simulation 3) of import tariff on imported refined oil. It assessed the impact of the various simulation strategies on carbon emissions (as a measure of environmental quality) in Nigeria. The dataset employed is the re-aggregated version of the 2006 Nigerian Social Accounting Matrix (SAM) that specially accounted for petroleum subsidy. The re-aggregation was to make it more compatible with the main objective of the study. This is necessary since the 2006 SAM has different components. The outcome of the simulation analysis showed that reduction in carbon emission occurred only when subsidy was partially removed, but marginally increased with gradual removal and complete removal. This suggests that even though the removal of subsidy can reduce emission, it is not sufficient in the long term especially as there is yet to be a viable "green" alternative to petrol in Nigeria. Therefore, subsidy removal will only make consumers reduce consumption initially and then increases later in order to meet their energy demands since there is no better environmentally friendly alternative to petrol. It is recommended that subsidy on petrol be targeted towards enhancing the commercialisation of renewable energy sources or appropriate technology (such as fuel blending) which are still not affordable for some households. This will further enhance the development of green growth practices and then be supported with relevant financing options in order to make it sufficient for driving environmental quality in Nigeria.

Keywords: Fuel subsidy removal, Environmental quality, Dynamic computable equilibrium model

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The need to ensure environmental sustainability as an integral component of sustainable development has necessitated renewed focus and attention on the interaction between energy consumption and the environment. A key factor attributable to this is the realisation that some existing policies may by design, stand in the way of implementing the three pillars of sustainable development (economic prosperity, social equity and environmental sustainability). This is in addition to the call for a new growth model that will follow a low-carbon growth path ("green growth" as against "brown growth") to ensure that the economy is not growing at the expense of the well-being and health of the populace. Also, the impact of various developmental policies on environmental quality has become an increasingly important concern in public policy agenda globally (Al-Amin, Hamid and Chamhuri, 2008). The inclusion of environmental sustainability in the newly inaugurated Sustainable Development Goals (SDGs) which represents the modified Millennium Development Goals (MDGs) equally reflects the importance of supporting growth strategies that enhances a clean environment.

Moreover, the energy sector is one of the sectors identified to play a key role in driving the environmental sustainability agenda. Other similar sectors include the transport and agricultural sector. The importance of energy in growth and development process makes energy policy an integral component of an economy's plan. Energy services, thus, help to foster economic and social development by increasing productivity and facilitating income generation and employment (Ajayi, 2009; Sambo, 2010). It plays a central role in accelerating growth and development of any nation with its use in communication, transportation, industrialisation, health care delivery and services among others (Sambo, 2010; Akinyemi, Ogundipe and Alege, 2014). In addition, energy is a major source of revenue for many countries particularly, oil-producing nations. In Nigeria, the share of oil in total export peaked at 97 percent in 1984 while its share in Gross Domestic Product (GDP) had been between 25 percent and 30 percent (National Bureau of Statistics (NBS), 2012; Siddig, Aguiar, Grethe, Minor and Walmsley, 2014). This continued to rise until recent times when it began to decline due to the economic recession in 2007 and 2008, conflict in the Niger Delta Region and a number of other factors. Also, the sale of crude oil contributes between 67 percent and 75 percent to government revenue and about 96 percent of foreign exchange earnings in Nigeria while also providing employment (Adenikinju, 2009; CBN Statistical Bulletin, 2014).

Furthermore, given that the energy sector is instrumental to economic growth; it has been identified as a key contributor to increased concentration of Green House Gas (GHG) emission in the atmosphere. This has resulted in environmental concerns such as climate change. This relationship between energy consumption and the environment continues to receive extensive attention in the literature over the years. The emission of carbon dioxide (CO_2) is one of the means through which the energy sector influences the environment. Efforts have been made by policy-makers and industry experts towards addressing the environmental consequences of energy production and consumption. This involves exploring different physical options and use of policy instruments to address the challenge of environmental degradation, particularly climate change. Some of these options and instruments include introduction of energy taxes, carbon taxes, provision of energy subsidies (designed to promote technological innovation and research), substitution of carbon-intensive energy for better alternatives (e.g. renewables), carbon capture, carbon sinks, carbon storage, reform of fossil fuel subsidies, among others (Stavins, 1997; UNEP, 2004; Goulder and Parry, 2008; Adenikinju, Omenka and Omisakin, 2012; Akinyemi, Alege, Ajayi, Amaghionyediwe and Ogundipe, 2015). However, some policies have been identified to be at odds with the achievement of environmental objectives, one of which is the policy of energy subsidy.

Energy subsidy as a pricing policy represents a policy tool that government employs to actualise the objective of enhanced energy access for sustained growth. It is designed to make energy cheaper and more accessible for the people by lowering energy prices, especially for the low-income earners. This policy is aimed at achieving certain economic and welfare objectives such as the strengthening of industrial growth, expanding domestic consumption and supporting energy access for low-income households. This is done by government placing energy price below equilibrium market price and paying the difference so as to protect households from volatile oil price shocks and fluctuations at the international market. The justifications for energy subsidies by policy makers is that it contributes to economic growth, poverty alleviation and the security of energy supply (International Energy Agency (IEA), Organisation of the Petroleum Exporting Countries (OPEC), Organisation for Economic Co-operation and Development (OECD) and World Bank Joint Report, 2010). They are particularly necessary in periods of high oil prices and other economic shocks as they make energy products cheaper. It can also be very helpful in addressing market failures and inadequate redistribution of income to achieve social and welfare objectives. Thus, energy subsidies if well-designed and targeted could be useful in switching from traditional energy sources which are not environmentally friendly, to modern energy sources considered to be more environmentally friendly.

However, despite the advantages presented by the adoption of energy subsidies, they also have some negative effects on the economy. This includes creation of economic and environmental concerns which can alter growth and development processes. These subsidies, which are large payments from government budgets, impose fiscal pressure on government finances, resulting into many countries attempting to reduce these subsidies. Countries such as Egypt and India considered the prospects of reforming energy subsidies as Egypt's energy subsidy was about 14 percent of GDP (The Economist, 2014a). The Economist (2014b) also stated that Indonesia increased fuel price by 44 percent to cut its annual subsidy bill which amounted to US$20 billion (2013 figures). Same scenario was experienced in Malaysia and Nigeria. Furthermore, these subsidies results in deadweight loss, that is, loss of economic efficiency that can be as a result of the equilibrium of a good or service not been pareto optimal (Davies, 2013). Studies such as Jones (2011), Anand, Coady, Mohommad, Thakoor and Walsh (2013) and Umar and Umar (2013) showed empirical evidence that suggests that subsidising fuel products does not necessarily lead to equitable distribution of income. As pointed out by Bao and Sawdon (2011), subsidies on fossil fuel-based energy tend to be regressive in nature with the relatively well-off, who tend to consume larger portions of energy, benefiting disproportionately from the subsidy.

Furthermore, energy subsidies as part of energy policy also affect environmental quality as the continued production, consumption and distribution of fossil fuel leads to increased concentration of GHG emission in the atmosphere. These emissions significantly impact the environment (Alege and Ogundipe, 2013). The argument is that subsidising fuel consumption will lead to higher levels of consumption, since energy prices are cheaper, which increases emission levels thereby having implications for efforts at fighting climate change impact experienced globally (Bao and Sawdon, 2011). This is the channel of transmission. A number of empirical studies analysed the relationship between energy consumption and carbon emissions for different countries and regions and found a positive relationship (Ang, 2007; Apergis and Payne, 2010; Lotfalipur, Falahi and Ashena, 2010; Shahbaz *et al*., 2010; Alam *et al*., 2011; Alege, Adediran and Ogundipe, 2015). The argument is that fossil fuels from energy consumption enhances carbon emissions while clean energy source mitigate atmospheric concentration of CO_2.

According to Oosterhuis (2013), providing support for the production and consumption of fossil fuel is clearly at odd with the objective of reducing GHG emissions. If tackling climate change impact entails reducing emission level, then energy subsidy as a policy is clearly at odd with achieving that objective. Koplow and Dernbach (2001) pointed out that fossil fuel contributes about 90 percent to the concentration of greenhouse gas through emission. These negative influences of energy subsidies has led to a number of institutions, countries and development organisations (OECD, European Union (EU), IEA, OPEC, Asian-Pacific

Economic Co-operation (APEC), G-20, African Development Bank (AfDB), World Bank, among others) conducting researches on the best option towards reforming these Environmentally Harmful Subsidies (EHS). In addition, international agreements such as the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto protocol which aims to stabilise GHG emissions recognise the key role that fossil fuel subsidy reform could play in ensuring energy conservation and efficiency (United Nations Environment Programme (UNEP), 2003). The recommendations of the International Standard Organisation (ISO) standards (ISO/TC207/SC7) represent another international effort toward addressing climate change impacts due to continued concentration of GHGs in the atmosphere. These standards (ISO standards 14064, 14065, 14066, 14067 and 14069) provide an internationally agreed framework for measuring GHG emissions among other activities that countries including Nigeria, should adhere to.

1.2 Statement of the Research Problem

The threat of environmental challenges such as climate change has made it necessary to reform policy-induced distortions such as fuel subsidy policy which have negative consequences for both growth and the environment. Different countries continue to adopt various policy approaches such as switching to renewable energy and introducing carbon/energy tax to tackle the problem of climate change. However, policies such as fuel subsidy and the nature they are introduced have been found to not only be unsustainable but also contribute to increased carbon emissions. Despite the policy's laudable motives, it had been regarded as a blunt policy tool that undermines global efforts at tackling climate change impacts (Bao and Sawdon, 2011; Ballali, 2013; UNEP, 2015). Thus, the link between energy subsidy and the environment rests on how the subsidy encourages increased consumption, thereby increasing carbon emissions in the atmosphere. This historic link had pointed to the fact that these subsidies were responsible for a 20.7 percent of global carbon emissions between 1980 and 2010 (Stefanski, 2014). A number of empirical studies have provided evidence that reducing EHSs such as fossil fuel subsidy can be useful in improving the environment's quality and cutting down global carbon emissions (Larsen and Shah, 1992;

Morgan, 2007; Burnianx, *et* al, 2011; IEA, 2011; Liu and Li, 2011; Ballali, 2013; UNEP, 2015). Also, it was estimated that global energy-related CO_2 will increase by some 50 percent between 2004 and 2030 unless major policy reforms and technologies are introduced to change the manner in which energy is produced and consumed (OECD, 1998; United Nations-Energy, 2008). Scientific evidence such as the study of Koplow (2010) has equally shown that emission levels could reduce by 10 percent in 2050 if fossil fuel subsidies are removed or reformed.

Fuel subsidy as a pricing policy affects environmental quality through the consumption of fossil fuel (mainly petrol). When the cost of fuel is placed below the equilibrium market price, demand and consumption will increase which results in the emission of CO_2 and atmospheric concentration of greenhouse gas. This process had been argued by scientists to be a leading cause of climate change globally. Thus, debate for the reform of fuel subsidy hangs on the fact that the policy acts against global efforts towards tackling climate change. The transmission mechanism is explained by the increased fuel price resulting from the withdrawal of fuel subsidy coupled with the downward adjustment in use and production of non-renewable energy (Abraham, 2013). As the focus of the world is shifted from economic development to sustainable development, it becomes necessary to ensure the adoption of cleaner sources of energy. A number of empirical analyses had explored different measures to achieve energy and economic sustainability, some of which includes uses of taxes (carbon and energy) and driving a low carbon growth strategy.

Also, there are indications that the continued existence of the fuel subsidy could pose a threat to the actualisation of the growth vision of Nigeria. Nigeria intends to become one of the top 20 economies in the world by the year 2020 as projected by its economic growth blueprint called Nigeria Vision 20:2020. This will require enhancing the growth potentials of the economy in a sustainable manner economically, socially and environmentally. The environmental dimension had made a green growth strategy imperative in driving the economy. One of the identified means towards this green growth policy shift is the adoption of low carbon development initiatives which is recognised as one of the key ingredients of green growth. This strategy involves promoting economic growth with minimal carbon emissions and lower carbon intensive production technology (Eleri, Ugwu and Onuvae, 2011). In actualising this, the energy sector will play a strategic role due to both the importance of energy to economic growth and its contribution to carbon emission. Thus, the valid question is, can fuel subsidy reform be a useful tool in achieving a low-carbon emission development strategy?

In year 2011, when fuel subsidy in Nigeria amounted to ₦2.19 trillion, carbon emissions from liquid fuel consumption stood at 34.5 million metric tons (IEA, 2013). This emission level represents the highest among sub-Saharan African countries after South Africa. Despite the fact that Nigeria and many African countries contributes less to climate change; the continent is however, most vulnerable to the effects. Nevertheless, the increasing CO_2 emissions and other gases due to crude oil exploration activities and use of fossil fuel can be abated. Thus, to achieve a low-carbon green growth strategy within the Nigerian Vision 20:2020 blueprint, emission levels can be further cut down.

Despite the fact that a sufficient amount of literature exist on macroeconomic, welfare and political implications of fuel subsidy removal; its environmental assessment remains scarce as limited studies analysing this relationship exist. Two notable studies related to the environmental consequences that focused on Nigeria include Adenikinju, Omenka and Omisakin (2012) and Abraham (2013). While the former examined the prospect of energy (carbon) tax introduction in stabilising CO_2 emissions and the economy-wide effects; the latter used a narrative analysis to assess how the reform of fuel subsidy can serve as a mitigation tool for climate change mitigation in Nigeria. This study fills this existing gap in the literature by examining the prospect of the reform of energy subsidy in driving a green growth agenda in Nigeria, especially towards achieving vision 20:2020 using a modified energy-environment CGE Model. This is done by answering the question, to what extent does the removal of fuel subsidy reduce carbon emissions in Nigeria.

1.3 Research Questions

The issues raised above have provoked series of questions which this study provided answers to. The methodology of the study focuses on analysing the reaction of one sector of the economy to a change in policy in another sector, thus it seeks to ask a “what if” question. This justifies the structure of the research questions presented in this session.

These research questions include;

1. How has fuel subsidy affected the measure of environmental quality in Nigeria?
2. How does the partial and gradual removal of fuel subsidy affect environmental quality in Nigeria?
3. To what extent does a one shot, gradual or complete removal of fuel subsidy influence environmental quality in Nigeria?
4. What threshold can fossil-fuel driven economic growth and environmental quality be compromised for one another?

1.4 Objectives of the Study

The broad objective of this study is to investigate the extent to which fuel subsidy reform as a policy influences environmental quality in Nigeria. The specific objectives include the following, to:

1. examine the extent to which fuel subsidy has impacted the measure of environmental quality in Nigeria;
2. evaluate the implications of partially and gradually removing fuel subsidy on carbon emissions in Nigeria;
3. investigate the effect of a complete removal of fuel subsidy on carbon emissions in Nigeria; and
4. assess the trade-offs between fossil-fuel driven growth and environmental quality in Nigeria.

1.5 Scope of the Study

This study explored the environmental consequences of the economy-wide impact of fuel subsidy as an energy pricing policy and its removal on the Nigerian economy, using a Dynamic Computable General Equilibrium (CGE) model. This was done by modifying the energy-environment CGE model of Adenikinju *et al.* (2012) and incorporating a subsidy component. Analytically, the model, consisting of two factors of production (labour and capital), two categories of households (rural and urban) and eight (8) sectors of the economy form the basis of the analysis which is in line with the objectives of the study. It used carbon emissions (CO_2) as the measure or indicator for capturing environmental quality. Conceptually, the study focused on subsidy provided for petrol and this is because the petrol also known as Premium Motor Spirit (PMS) is identified as the major fossil fuel for which subsidy was reduced in Nigeria as at the time of this study. Given that fuel as a term covers different energy sources such as coal, petrol, diesel, kerosene, biomass, and so on; fuel as used in this study refer to PMS also known as petrol in the Nigerian parlance.

1.6 Significance of the Study

The need to ensure energy security and at the same time, drive environmental sustainability, particularly given the global effect of climate change and increased energy prices; had seen increased call for the reform of subsidies provided for fossil fuels. In the past few years, empirical evidence on the impacts of these categories of subsidies had been increasing, especially for oil producing and oil exporting countries. This impact assessment ranges from economic to welfare (social), political and environmental impacts. Sufficient attention had been given to the analysis of the economic, social and political impacts of the reform of fuel subsidies; however, assessment of its environmental implications remains very limited, especially for Nigeria. This environmental impact assessment is essential especially as there are global efforts to reverse some of the environmental consequences of the activities of the energy sector (such as exploration, extraction, transportation and refining). This is also given Nigeria’s voluntary “non-bidding” commitment under the UNFCCC accord, to reduce atmospheric concentration of greenhouse gases.

Nigeria had been introducing a number of initiatives as part of its commitment through the activities of the Ministry of Environment. This study, thus, investigates the extent to which the removal of fuel subsidy can be used to reduce emission and thereby mitigate against climate change impacts. A key significance of the study is the fact that it used an economy-wide modelling approach such as the dynamic CGE model by developing a unique version that incorporates the environment and energy components. This was done by adapting an existing dynamic CGE model. Findings from the study are useful for policy-makers in understanding the dynamics of energy policy and environmental management interactions while better managing the trade-off. It will also provide insights into the designing of appropriate policy mix needed to complement current efforts at addressing climate change. It is relevant for policy-makers and other decision-makers to understand the role that fuel subsidy removal as a policy can play in addressing environmental concerns and using it as a means to achieving a low-carbon development plan. This is in view of the fact that Nigeria's strategic plan of Vision 20:2020 entails shifting to a low-carbon growth strategy and also been part of international negotiations aimed towards better quality of the environment.

1.7 Outline of the Study

This thesis is organised into six chapters. Following the introductory chapter, chapter two focuses on the review of empirical literature. Specifically, it discusses conceptual, theoretical, empirical and methodological literature relating to fossil fuel subsidies and country experiences. Chapter three presents some stylised facts on the structure of the Nigerian economy and trend facts of fuel subsidy in Nigeria with comparisons to similar country experiences. While chapter four dwells on the theory, model specification and estimation method of the study, the discussion, analysis of results and policy implications are presented in chapter five. Finally, chapter six contains the summary of findings, conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

In assessing the environmental impact of fuel subsidy in Nigeria, there is need to understand the state of knowledge in the area of energy subsidies and its reform. A general consensus in the literature is that energy subsidies, particularly the environmentally harmful ones, are wasteful, inefficient and distorts energy markets, invariably leading to calls for their removal or reform. In analysing the impacts of fuel subsidy on an economy, different studies have examined its economic, welfare, political and environmental implications and how best the reform should be undertaken, most especially for developing countries where consumer energy subsidies are prevalent. This chapter thus, examines the review of the empirical works on energy subsidies, particularly as it relates to its definitional and conceptual issues, theoretical, methodological and empirical review. In addition, the chapter presents identified gaps in the literature in light of the reviewed literature and summary of selected empirical studies.

2.2 Review of Definitional and Conceptual Issues

This section focuses on discussion relating to the concept of subsidies, energy subsidies and environmental quality. It covers the various forms and definitions that exist in the literature on the main concepts of the study (energy subsidy and environmental quality).

2.2.1 The Concept of Energy Subsidy

The IEA, OPEC, OECD and World Bank (2010) joint report described subsidies as one of the many policy instruments employed by governments to achieve economic, social and environmental objectives. Despite the wide usage of the term “subsidy” in economics, it is rarely defined (World Trade Organisation-WTO, 2006). There is no universally adopted definition for subsidy; instead, studies use any of the several definitions that exist depending on the perspective of the study (Steenblik, 2002;

Valsecchi *et al*, 2009). The international community (IEA, OECD, IMF, UN, GSI, G-20, World Trade Organisation, and so on) have attempted to provide different definitions to the term, legally or otherwise. Generally, subsidies are widely used by government as policy tools to achieve certain desired objectives. These various definitions suggest that despite the varying definitions of subsidy in the literature, the common denominator in many of the definitions is that subsidy is any form of government assistance provided to reduce cost of a product to consumer and cost of production to producers. The Global Subsidy Initiative (GSI, 2010) defined subsidy as a form of government action that results in an advantage for consumers and producers in order to supplement their income or reduce their cost. According to Fattouh and El-Katiri (2012), the concept of subsidy is often "too elusive" to define and this is evident in different definitions across empirical research on subsidy. The United State Congress Joint Economic Committee as cited in Fattouh and El-Katiri (2012) viewed subsidy as any type of assistance rendered by government to private sector producers or consumers in which case government receives no equivalent compensation in return, but expects certain level of performance by the recipient.

A more narrow definition is the one provided by Fattouh and El-Katiri (2012), which stated subsidy as any step taken towards keeping prices for consumers below the market price or above for producers or that reduces costs for consumers and producers through direct or indirect support. This definition supports Guiyang (2007)'s argument that the character of subsidy is such that the government support consumers or producers directly or indirectly so as to reduce cost and increase income for various policy targets to be realised. Other definitions include the definition by Whitley (2013), where subsidy was defined as "any financial contribution by a government or agent of a government that confers a benefit on its recipients". Also, the UNEP (2003) presented a simple description of subsidy, as a direct cash payment by a government to a producer or consumer; but this is believed to be just one-way. Subsidies can be in form of cash, credit, tax procurement or what is called in-kind subsidies (Fattouh and El-Katiri, 2012).

Government can equally provide subsidies in different forms. It could be in form of direct cash transfers from government to the recipients, through tax concessions (in terms of preferential tax treatment), assumption of contingent liabilities, through procurement policies at administered prices or by equity injections into businesses (WTO, 2006). Other forms of government intervention that may be classified as subsidy in the energy sector include trade restrictions, energy related services provided by government at less than full price or through the regulation of the energy sector (UNEP, 2008; Ballali, 2013).

Subsidies exist in different sectors of an economy, including agriculture, energy, mining, manufacturing, road transport, and so on. When subsidies are targeted towards the energy industry to achieve certain objectives, such subsidy is called energy subsidy. The IEA (2011) study defined energy subsidy as any act by government centered on the energy sector which reduces the cost of producing energy, increases the price collected by energy producers or reduces price paid by energy consumers. These energy subsidies are employed to alleviate energy poverty, thereby promoting economic development by enabling access to affordable modern energy services (IEA, OPEC, OECD and World Bank, 2010). Thus, energy subsidies are intended to make energy products such as petroleum, kerosene, diesel, amongst others, cheaper and affordable. Policy makers provide justification for energy subsidies with the argument that they enhance economic growth, alleviate poverty and ensure energy security (IEA, OPEC, OECD and World Bank, 2010). However, as stated in International Institute for Sustainable Development-IISD (2012), energy subsidy is often not an efficient tool in achieving these objectives. They are often viewed as an inefficient tool that promotes waste and environmental pollution. In reality, the motivation for energy subsidies is mainly political (IISD, 2012). Energy subsidies are useful in enhancing access to energy for the poorest households, but the consensus in most empirical analysis reflects the fact that the negative impact of fossil fuel subsidies is evident both at country level and at the global level (Ellis, 2010).

There are two categories of energy subsidies identified in literature which are consumer and producer subsidies. The former are designed to reduce cost of consuming energy products while the latter are aimed at supporting the domestic production of energy products thereby reducing the cost of production for producers. Also, the Africa Development Report (ADR, 2012) differentiated between two types of subsidies. This classification depends on the position of the country as either a net importer or net exporter of oil in the foreign market. As an importer, a subsidy represents the difference between foreign price (covering associated costs) and local price. On the other hand, for the exporter, the government derives a difference which is regarded as indirect subsidy by placing the local price below the foreign price (ADR, 2012).

Distinction is also made between subsidies that are considered environmentally harmful and those that are environmentally friendly. According to Valsecchi *et al* (2009), environmentally harmful subsidies represent government action that confers an advantage on consumers and producers aimed at supplementing income or lowering costs, but in doing so discriminate against sound environmental practices. An example is fossil fuel subsidy. On the other hand, environmentally friendly subsidies do not damage the environment as they are designed to enhance its quality. This could be in terms of subsidies to enhance commercialisation and development of clean forms of energy (such as renewables), improvement in research and development or providing incentives to shift from environmentally harmful products to the friendly ones.

Another form of distinction of subsidies relate to the explicit and implicit subsidies. The former refers to the difference between production cost and the selling price while the latter on the other hand is the difference between the opportunity cost of a wasting asset such as crude oil and the present selling price (Nwafor, Ogujiuba and Asogwa, 2006). The implicit subsidy is usually important due to their implications for efficiency as prices must equal their Marginal Opportunity Cost (MOC) for the prices to be efficient.

It also reflects in the difference between the border prices and the domestic prices of the energy products.

2.2.2 The Concept of Environmental Quality

The concept of environmental quality consists of different definitions and interpretations, especially in the sciences and the public policy sphere. According to Kerekes (2011), the concept had been a historically difficult concept to measure and evaluate. However, it essentially entails the set of features and properties that defines the condition of the atmosphere. It represents the measures of the environment in relation to basic human or specie requirements. It could also relate to the potential effects that these features tend to have on general well-being (mental or physical health). In terms of characteristics, it refers to the natural and built environment which includes air, water, land, noise and pollution (Kerekes, 2011).

The built environment is the environment created by humans for themselves while the natural environment is the natural inhabitant occupied by plants, animals and humans. It also includes the surrounding natural resources. The state of health of this environment is what is considered as environmental quality. Similarly, Khattab (1993) defined environmental quality based on two meanings; the physical and the perceived environment. The physical or natural environment entails the material components of the surrounding environment such as the air quality, water quality, pollution, negative effect of overpopulation and noise (Khattab, 1993). On the other hand, the perceived or built environment which is considered the more sophisticated definition by Khattab (1993), consists of man-made environment that provide support or otherwise, the social and cultural structures and institutions related to specific group of people. As stated earlier, common indicators of environmental quality includes the quality or otherwise of air, water, soil, degree of deforestation, amongst others.

Air quality/pollution which is one of the common indicators of environmental quality, is often measured by carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), methane (CH_4), Suspended Particulate Matter (SPM), chlorofluorocarbons (CFCs) and lead (Kerekes, 2011). Carbon dioxide is regarded as the primary greenhouse gas that contributes to environmental degradation. It is emitted through both natural causes and human (anthropogenic) activities. This is either by adding to the carbon emission in the atmosphere or by altering the ability of natural sinks such as forests to remove CO_2 from the atmosphere (United States Environmental Protection Agency-EPA, 2015). A major form of human activity through which this CO_2 is emitted is through the combustion of fossil fuels which includes oil, coal and natural gas. These fossil fuels essentially emit CO_2 through their use for energy, transportation and other processes such as industrial process and some land use changes. The US-EPA (2015) identified the reduction of the consumption of fossil fuel as a most effective method in cutting down CO_2 emissions. Other techniques commonly discussed to be adopted include energy efficiency, energy conservation, fuel switching, carbon capture and sequestration.

Empirical literature had also assessed the relationship between economic growth and environmental quality, especially as it relates to the Environmental Kuznet Curve (EKC). Some of them include Shafik (1994); Johansson (2001); Liu, Heilig, Chen and Heino (2007); Alege and Ogundipe (2013); Awan (2013); Strong (2013); Osabuohein, Efobi and Gitau (2013); Osabuohein *et al.* (2014); Osabuohein *et al.* (2015); among others. Strong (2013), however, opined that this relationship between income and environmental quality is poorly understood as emphasis is often on pollution. Thus, using a simple conceptual model, the study constructed two different aggregates of indicators of environmental quality. These two aggregates are the ecosystem approach and the biodiversity approach. The main idea behind the EKC hypothesis is that at earlier stages of development, the society will be developing at the expense of the environment, thus environmental deterioration is commonly experienced at earlier stages of industralisation.

However, over time, quality of the environment begins to improve with higher levels of income as the income generated are been used to clean-up.

Strong (2013) attempted to expand the frontier of the literature on EKC by not only evaluating the role of emissions but also consider the role of absorptive capacity of the environment. Awan (2013) considered how the sustainable development concept can support environmental quality so as to control the spread of environmental degradation. It supports the link between sustainable development and environmental quality as the latter is one of the pillars of the former (that is, environmental sustainability). The achievement of environmental quality is dependent on efficient and sustainable use of resources as argued by many environmentalists. Another underlining argument in the growth-environment nexus is that there is always a trade-off effect between economic growth and the achievement of environmental quality (in terms of low pollution, minimal depletion of resources, cleaner air, better soil quality, water resources, among others). This is due to the desire to experience high levels of growth through excessive use of resources, which then result to varying environmental challenges (Awan, 2013).

Also, some studies developed environmental models to examine the impact of certain externalities on the environment. The development of these models which are often funded by international organisations such as the World Bank, IMF, OECD, UN, EU, and the African Development Bank, helps in explaining policy strategy directions towards addressing these environmental problems. Other ways the environment had been linked with other concepts includes property rights and regional conflict. The work of Kerekes (2011) exemplified the role of property rights in environmental quality by stating that if these rights are not properly defined, especially property right over air; this can erode the quality of the environment. In the same vein, Kennedy (1998) opined that excessive use of resources in a depleting and unsustainable manner is capable of inciting violent and non-violent regional conflict. These are the various approaches in describing how the quality of the environment can enhance sustainable growth and development.

2.3. Review of Theoretical Literature

A number of economic theories have been used in explaining the theoretical foundation of the impact of fuel subsidy on the economy in general. Economic theory tries to explain theoretical underpinning of the existence of subsidies and how they result in wasteful and unproductive consumption. According to Holton (2012), subsidies change the price of a product and therefore the consumption of that product. This section thus reviews the economic theory relating to subsidies and other theories that explain the justification for subsidies and need for its reform.

2.3.1 Economic Theory of Subsidies

Economic theory suggests that unwarranted subsidies result in inefficiency and a suboptimal allocation of resources which could ultimately have a negative effect on GDP per capita (Holton, 2012). These subsidies make products to be sold at less the economic opportunity cost that "leaves energy firms with inadequate financial resources for investing in productivity, capacity or environmental improvements". This according to Pearse and FinckVon (1999) has the capacity to generate a vicious cycle of poor supply and low investment or none at all. From this standpoint, the argument against subsidies is that they create uncompetitive domestic industries. Subsidies are also often discouraged for the fact that it diverts or redirects government spending from social and investment spending. Unless a subsidy is designed to address a market failure, it is likely to be harmful for economic efficiency (Saunders and Schneider, 2000).

Furthermore, as stated in Adagunodo (2013), subsidies are not efficient because in the absence of market imperfections coupled with a convex indifference curve, the value the subsidy will have, to the consumer will be less than its cost to the government. The report then asserts that consumers do not use resources optimally. Hence, they will be on higher indifference curve if prices were increased to reflect commercial costs with subsidy been returned to consumers in form of cash. This is in addition to economic theory that states that social welfare is maximised at the point where the price of each good and service is determined by the interaction of the willingness of producers to supply and extent to which consumers are willing to pay. As this price shifts from this point of static equilibrium, allocation of resource will be inefficient as benefit to consumers from the last unit of energy consumed are lower than the costs involved in supplying the energy services (Adagunodo, 2013).

Another economic reasoning is that subsidies create deadweight loss by “enabling transactions for which the buyer’s willingness-to-pay is below the opportunity cost” (Davis, 2013). In calculating the deadweight loss of global fuel subsidies, Davis (2013) asserts that it is the short run elasticity of demand and supply for crude oil that is inelastic. However, the economic cost of subsidies depends on the long run elasticity. Gupta *et al.* (2002) stated that most oil exporting countries do not tax domestic fuel consumption and this results in significant economic losses. This deviation from efficient pricing then results in a deadweight welfare loss. Onyemaechi (2012) added that fiscal policies theoretically impact the development of an economy directly or indirectly. The direct effect is usually through its impact on aggregate demand functions while the indirect channel is through effects on endogenous variables of consumption and production functions. Ekong and Akpan (2014) also illustrated deadweight loss as the cost to society as created by market efficiency in social welfare associated with fossil fuel subsidy.

The argument is that given an infinitely elastic supply of fuel (which can be the case for Nigeria, as a price taker since it cannot influence the price of imported fuel as it is determined in the international market), the introduction of subsidy will lower market price and increase quantity demanded. Ekong and Akpan (2014), however, noted that the extent of the overconsumption of the subsidised fuel would depend on the elasticity of demand. Adagunodo (2013) further stressed that income transfers are superior to subsidies and reduce inefficiencies as the income transfers do not result to deadweight loss. While analysing how fuel subsidy removal will have effect on crime in Nigeria, Oladipo (2012) reviewed the classical utilitarianism, traditional and neoclassical welfare theories and considered suitable, the neoclassical welfare theory. This is given that it emphasised more on government responsibility to make the need of the people available without undue stress. In other words, the ideal of the neoclassical welfare theory is that the performance of economic institutions should be judged in relation to whether they provide economic goods in quantities that is in line with consumer's relative desires and at the barest minimum cost (Oladipo, 2012).

Amegashie (2006), however, argued that departures from the competitive equilibrium quantity and price reduce social welfare and do not make economic sense. The question then is if subsidies are distortional and reduces welfare in perfectly competitive markets, are they necessarily so in markets which are not competitive? The answer according to Amegashie (2006) is no. Using the theory of second best, the explanation is that there is no guarantee that the removal of any form of imperfections like subsidy, will improve social welfare.

2.3.2 Public Choice Theory

This is another theory that had been adopted in empirical literature in explaining the behaivour of subsidy. It is majorly employed by authors analysing political dimension for the persistence of subsidies, particularly energy subsidy. As described by Butler (2012) the theory is essentially an approach that uses the methods and tools of economics to explore how politics and government work. It describes the application of the rational choice model to non-market decision making (Hill, 1999). The argument of the public choice theory is that, just as self-interest motivates people's private commercial choices; it can also influence their communal decisions (Butler, 2012). One of the key studies in this category is Israel (2010) who explained the staying power and rigidity of these subsidies or the endurance of the policy with the public choice theory. In terms of how this theory relates to fossil fuel subsidies, it holds that energy subsidies persists due to the commonality of interest that exists among the relatively few who receive these energy subsidies (Israel, 2010).

2.3.3 Neo-liberalism Theory

The “neo-liberal” component entails a modern economic policy with state intervention. The word “neo-liberalism” was originally coined by the German scholar, Alexander Rustow in 1938 at the Colloque Walter Lippmann and the concept entails “the priority of the price mechanism, the free enterprise, the system of competition and a strong and impartial state” (Anyadike, 2013). Other aspects of the Neo-liberalism concept entail economic liberalisation, open markets, free trade, privatisation, deregulation and enhancing the role of the private sector in the economy for efficiency. Other underscoring tenets of neo-liberalism as identified by Anyadike (2013) are sound macroeconomic policy, trade liberalisation, labour market flexibility and export-oriented sectoral policies. Neo-liberalism’s aim is to transfer the control of the economy to the private sector with the assumption that it will bring about efficiency and better working of the economy. Onyishi, Eme and Emeh (2012) equally adopted the neo-liberalism theory in explaining the domestic and international implications of fuel subsidy removal crisis in Nigeria and concluded that the reactions was due to the fact that Nigerians were simply tired of policies that does not increase their purchasing power in the country.

As laudable as this theory may be, opponents have argued that fuel subsidy is not the monster in the oil industry but corruption (Victor, 2009). So the tenability of deregulation of the sector to save the country from truncation is questionable. Anyadike (2013) stated that even as the theory fundamentally recognises the importance of deregulating the petroleum industry, it does not address what happens when liberalism becomes corruption as may be the case for Nigeria. In other words, the theory does not consider who feels the impact of the deregulation.

Many of the policies of neo-liberalism are rooted in the John Williamson "Washington Consensus" which is a list of policy proposals approved between the IMF and World Bank. The three main ideals of the consensus are macroeconomic discipline, development and promotion of a market economy and a general degree of openness to the world (Symoniak, 2011). These are broken down into ten policy points as stated by Williamson (1999) and Symoniak (2011) which are the following:

i. Fiscal Discipline: Government should avoid running large fiscal deficits as they contribute to inflation and capital flight;
ii. Public Expenditure Priorities: Government spending should be directed at key sectors that will enhance growth (sectors such as health, education, and infrastructure). Also, subsidies should be reduced or eliminated, particularly the ones described by neo-liberals as indiscriminate subsidies;
iii. Tax Reform: The tax base "should be broad" and marginal tax rates "should be moderate" so as to encourage innovation and efficiency;
iv. Interest Rates: This should be "market-determined" by the domestic financial markets as positive (real) interest rates will discourage capital flight and increase savings;
v. Exchange Rate: The exchange rate to be adopted by developing countries should be floating exchange rate and one that is "competitive" to boost exports by making the goods produced cheaper abroad;
vi. Trade Liberalisation: There should be liberalisation of imports with minimised tariffs. There should be no tariff on intermediate goods that are used to produce exports;
vii. Foreign Direct Investment: Foreign investment should be encouraged as it brings in the required capital and skills for development. There should be opportunity to invest funds overseas and for foreign funds to be invested in home country;

viii. Privatisation: State-owned enterprises should be privatised to promote the provision of goods and services which the government may not be able to provide in an efficient manner (for example, telecommunication);

ix. Deregulation: This is the removal of restrictions or regulation that impedes market entry or competition as excessive regulation can promote corruption. The only exception should be for industries that are justified on safety, environmental and consumer protection grounds. For financial institutions, there should be prudent oversight; and

x. Property Rights: This must be enforced with legal security for property rights. Weak and poor legal institutions reduce the incentive to save and accumulate wealth.

There have, however, been attempts to revisit and restate these policy instruments by some economic analysts including Symoniak (2011) and John Williamson himself in light of the various debates, oppositions and dispute experienced in the process of its application. Still, the points highlighted above shows that inadequate understanding and implementation of the policies of neo-liberalism, could account for its opposition in Nigeria during the Structural Adjustment Programme (SAP) era. The aim of the policy is to bring about efficiency in the economy and the controversy in its application to the deregulation of the petroleum downstream sector points out difficulties that could arise due to the unique features of a country such as Nigeria.

2.3.4. Competitive General Equilibrium Theory

The Competitive General Equilibrium theory is commonly adopted as the theoretical framework for studies centering on CGE model analysis. The Competitive General Equilibrium theory is a theory that seeks to explain the behavior of demand, supply and prices in an economy having different interacting markets and economic agents. These several markets and agents have several linkages within an economy. General

Equilibrium analysis theoretically looks at the economy as a whole and then takes account of linkages between all markets, including markets for all goods that use energy as input and labour markets (Ellis, 2010). Its initial structure was developed in the second half of the 19^{th} century by neoclassical economists or marginalist school of thought (Decaluwe *et al,* 2000). Sometimes called the Walrasian Competitive General Equilibrium model, it is based on analysis of economic agents' individual choices in response to given prices and other exogenous variables (technology, preferences, and resource endowments). Under this condition, all the markets within a system must balance for equilibrium to exist; in other words the demand for different products in the different markets must equal their supply at prevailing prices.

The theory develops a model that describes interactions and nature of optimising behaviour among the households, the firms, government and other economic agents given the price of goods and services, land, labour and capital. It is suitable for explaining the nature of disturbances caused within an economic system and transmitting to different sectors as a result of an external shock such as policy change. This is due to the nature with which all sectors of the economy are linked to one another. Its main points explains the behaivour of agents (households, producers, government), and other macroeconomic aggregates (capital stock, investment, international trade) with the manner in which adjustments take place when change occur. A recurring idea in general equilibrium analysis, has been that the competitive price mechanism result in outcomes that are efficient in a way that outcomes under other systems such as planned economies are not (Levin, 2006).

2.4. Review of Methodological Issues

In helping policymakers to better understand the trade-off between economic, environmental and social impacts of fossil fuel subsidy, a number of organisations and researchers have attempted to analyse fossil fuel subsidies and their effects using some complex economic models (Ellis, 2010). According to Koplow and Dernbach (2001), these models compare certain factors such as economic activity and projected emissions if subsidies were removed to "business as usual" emissions and economic activity. Two of the common methods used are the partial equilibrium approach and the general equilibrium approach.

2.4.1 Single and Simultaneous Equation Models

These categories of models analyses the direct impact that fuel subsidy has on the economy through regression analysis implemented using either cross sectional, time series, or panel data. Others make use of primary data collected through interviews, focus group discussions or distribution of questionnaires. In simultaneous equation models, set of variables are determined by other set of variables simultaneously (Safdari *et al*., 2012). In other words, this class of model cannot estimate parameters with just one equation unlike the case of the single equation model. Safdari *et* al (2012) used the simultaneous equation system to investigate the effects of energy subsidy on macroeconomic variables in the industrial sector in Iran. Examples of single equation models commonly used are the Johansen co-integration method and VAR Impulse-Response function used to describe existence of long run equilibrium relationship between fuel subsidy and any macroeconomic variable such as poverty, crime, trade, consumption, investment, business development, welfare, among others. This method is popular due to its simplicity, ease of use and minimal data requirement compared to other complex models. Studies such as Olomola (2006), Anwal and Mamman (2012), Holton (2012), Oladipo (2012), Onyemaechi (2012), Charap *et al* (2013), Efobi, Osabuohien and Beecroft (2013), Oriahki and Iyoha (2013), amongst others, employed the use of different single equation models for different countries and form of data, and many of the results reflected evidence that fuel subsidy negatively affects the economy. Thus, policy change should take a systematic approach.

2.4.2 Partial Equilibrium Models

This approach is often used in analysing the impact of energy policy on the economy, especially when policy question focuses on just one sector directly. This category of models consider just the product market where subsidy reform is taking place (for instance, the energy market), and then measure the changes observed in demand, production and price in fossil fuel due to subsidy removal (UNEP, 2003). This is usually done with the aid of some economic assumptions. They are also helpful in providing insights useful in understanding the effect the subsidy reform has on the particular market. Allaire and Brown (2012) adopted the partial equilibrium approach in determining the effects of about 60 categories of energy subsidies on United States of America's energy markets and carbon emissions. Evidence from the study suggests that the expenditure of the US government centered on energy subsidies that increased carbon emissions and those that equally decreased level of emissions. These were mainly focused on tax provisions and other spending programmes.

In Nigeria, Umar and Umar (2013) evaluated the direct welfare effect of fuel subsidy reform in Nigeria with the assumption that consumers do not shift their demand from fuel, despite price change. Cooke *et al* (2014) also assessed the distributional effects of fuel subsidy on the households in Ghana by applying partial equilibrium approach, which according to them is the most suitable approach given the data requirements and the fact that it is less intensive and can be completed within a short time. In partial equilibrium analysis, price of a good is determined by simply focusing on the price of the good while assuming that the prices of other goods are constant. In economic theory, it is adequate if the first-order effects of a shift in the demand curve do not affect the shift of the supply curve.

The study of Ballali (2013) used the same approach to analyse the level of petroleum product subsidy while highlighting its impacts on carbon emissions and the aggregate welfare gains for Nigeria and Venezuela. The study found that a substantial amount of fuel subsidy exists in the two countries and reforming these subsidies can reduce carbon emissions. Despite the strengths of the partial equilibrium models, they also have their short-comings. They are not adequate in answering questions on sectors that employ energy as a significant input (Ellis, 2010). Increase in energy prices leads to higher cost of production in other sectors and thus higher prices of many goods including energy. Another disadvantage of partial-equilibrium models according to Ellis (2010) is that they do not address macroeconomic questions relating to the effects of international competitiveness. To then answer these kinds of questions, general equilibrium models are required.

2.4.3 Computable General Equilibrium (CGE) Model

CGE model is one of the economy-wide analyses that enhance the understanding of how the different sectors in an economy interact. The initial structure of the theoretical underpinning of the model was developed in the second half of the 19th century (Decaluwe *et al,* 2000). CGE models incorporate the fundamental general equilibrium links among production and employment structure, incomes of various groups and the pattern of demand (Falokun and Adenikinju, 2009). They are also known as Applied General Equilibrium (AGE) models and are built on the economic foundations of Adam Smith's invisible hand, Walras law, Edgeworth's contract curve, Arrow-Debreu proof of existence and Leontief's input-output analysis (Chitiga and Adenikinju, 2009).

This category of models is part of a family of multi-sector macro models. As pointed out by Chitiga and Adenikinju (2009), CGE models differ from macro-econometric models. While the latter emphasies time series data analysis, the former focuses on inter-industry analysis. This allows for the analysis of the impacts of policy measure on resource allocation. Having a neo-classical foundation, CGE models usually consist of non-linear simultaneous equations that permits feedback relations from production levels and prices to final demand (Mitra-Kahn, 2008). It has been applied to a number of economic issues ranging from trade, public finance, labour, to energy policy. The method continues to receive considerable attention in the analysis of energy policies and reform. Also, the penetrating role of energy in the economy and different ways energy subsidies can influence allocation of resources, necessitates the use of CGE model (Manzoor, Shahmoradi and Haqiqi, 2012). Even though it is widely used globally, its application to energy and environment research in Nigeria remains limited. Studies such as Nwaobi (2004), Adenikinju (2009), Ajakaiye (2009), Adenikinju and Omenka (2012), Adenikinju *et al.* (2012), Siddig *et al.* (2014), among others, are examples of researchers that have applied CGE modelling in Nigeria.

According to Petersen (1997), the CGE model differ from the traditional General Equilibrium models in that, the former are solved numerically and not analytically where their use is policy driven. One of the advantages of the CGE model is its ability to solve very large models without the need of finding an analytic solution, but the price paid for this is the loss of generality, since the results obtained will be specific to the model and the calibrating parameters (Petersen, 1997). The CGE model is a valuable approach for a number of reasons. Firstly, it provides the framework for the analysis of the total effect (direct and indirect) of policy change in one sector on the rest of the economy (Adenikinju and Falobi, 2009). Secondly, the CGE model is best suited for assessing the multiplier effects of a policy shock (such as subsidy removal) in an economy.

Notwithstanding the numerous advantages of CGE, it also has some limitations. Some of the limitations as stated by Chitiga and Adenikinju (2009) include; firstly, being abstractions from reality, their structures are determined by modeller’s judgments and predispositions, thus it is subjective in nature. Secondly, CGE models are still relatively aggregated given their emphasis on macroeconomic, sectoral and social effects. Thirdly, they use large number of parameters and elasticities which are often borrowed or guessed. This can make it difficult to assess validity and reliability of forms of specification adopted by a modeller. Also, they are not suitable for forecasting. And finally, it demands considerable technical skills to formulate, solve and interpret the results produced by any CGE model. Despite these limitations, they are still useful in analysing economy-wide impacts of policy changes.

Computable General Equilibrium (CGE) models are equally widely used in the analysis of energy policy impact and are particularly useful in examining the economy-wide impact of a change in policy. They are applied to a wide range of issues such as poverty, inequality, trade, environment, among others. Its development was said to have begun in the early 1970s when the World Bank Group showed interest in its application to economic analysis. The CGE model also overcomes one of the criticisms of the partial equilibrium analysis, which according to Baron *et* al (2010), lacks consideration for a general equilibrium important for deadweight loss measures when a change in the price of a subsidised product affects the supply or demand in other markets which are subject to distortions.

The CGE model as a type of macroeconomic model has the capacity to provide quantitative information on the likely effects of some introduced policies on a wide range of macroeconomic and sectoral aggregates (Falokun and Adenikinju, 2009). Also, the CGE model has the capacity to reveal more comprehensive economic relationships than partial equilibrium or econometric models (Lin and Jiang, 2011). Perhaps a more vivid explanation of what the CGE model does is the one given by Adenikinju (2009), where CGE model is stated as providing the framework for analysing the total effect (direct and indirect) of policy change in one sector on the rest of the economy. As put by Kuster, Ingo and Ulrich (2007), CGE modelling provides an established instrument for the quantification of the impacts of energy and environmental policy measure on the economy. They are also useful for the evaluation of feedback effects of policy reforms undertaken in an economy by the government.

The CGE model which is based on the empirical application of the abstract Arrow-Debreu General Equilibrium model, defines the production and consumption functions that reflects the interdependent relationship among multi-sectors and multi-markets (Lin and Jiang, 2011). According to Bacon *et al* (2010), a typical CGE model consists of a number of simultaneous equations that explain the characteristics of the economic actors and sectors considered to be relevant for the analysis, which explains all of the payments across sectors recorded in an economy by means of a Social Accounting Matrix (SAM). They are very helpful in considering policy impact where there are significant market interactions. Basically, the CGE model explains all payments recorded in a SAM and thus, follows the SAM disaggregation of activities, factors, commodities and institutions (Lofgren, Harris and Robinson, 2002). The model is presented as a system of simultaneous equations that are often times nonlinear with no objective function. It composes of three main components, the theoretical, data and shock component. The equations are based on microeconomic assumptions using database of the entire economy and introducing shocks as changes to the economic system under study.

CGE models have both static and dynamic components (Adenikinju and Falobi, 2009). According to Chitiga and Adenikinju (2009), most early applications of CGE models were mainly based on comparative static analyses where time path adjustment to proposed policy changes were usually not considered. In essence, the static CGE models examine the economy at a point in time, due to policy change. The results are often reported as percentage difference in each variable between the base case and the reform case for target year for example year 2015 or 2020 (Ellis, 2010). The process that gives rise to this percentage difference is however, not reported.

The dynamic CGE models on the other hand, trace what happens to each variable from the base year through to the forecast year, usually at annual intervals (Ellis, 2010). They are extremely useful for stimulating the overall economic development path of an economy or an entire region (Chitiga and Adenikinju, 2009). In incorporating dynamics into CGE modeling, there are two approaches as stated by Chitiga and Adenikinju

(2009). There is the recursive and the inter-temporal approach. In the former, economic agents deal with only one period at a time, neglecting the impact of subsequent changes in prices, tastes, and technology or resource endowments. However, in the latter case, each commodity is dated with all economic agents making consistent projections of future prices.

A number of researchers have applied this methodology to the analysis of the impact of various energy policies both for Nigeria and other countries using different variants of the models. This variation covers multi-region models (Larsen and Shah, 1992; Larsen and Shah, 1994; Petersen, 1997; Kuster *et al.,* 2007; Sue, 2011) and single-country models (Nwafor *et al.,* 2006; Al-amin *et al.,* 2008; Bao and Sawdon, 2011; Allaire and Brown, 2012; Adenikinju *et al.,* 2012; Adenikinju and Omenka, 2013; Siddig *et al.*, 2014). These studies have used the CGE model to analyse economic, social and environmental impact of fuel subsidy under varying objectives. For example, Ba and Sawdon (2011) developed a CGE model for the Vietnamese economy in addition to a bottom-up energy accounting approach using the Long-range Energy Alternative Planning system (LEAP) software. The study assessed the overall (economic, social and environmental) impact of change in fossil fuel price due to reduction in subsidy and an imposition of environmental tax. Also, Bahta (2014) used the CGE approach to explore the impact of international oil price increase on the economy of Free State Province in South Africa.

Kuster *et al* (2007) employed the CGE to analyse if upcoming future energy systems will have implication on employment rate in the midst of persistently high unemployment rates in Europe. Lin and Jiang (2011) investigated the economic impacts of energy subsidy reforms using CGE model for China. Liu and Li (2011) established CGE model that contains pollutant and CO_2 emissions account so as to stimulate fossil energy subsidy reform under different scenarios. Abouleinein, El-Laithy and Kheir-El-

Din (2009) evaluated the short and medium-term impact of phasing out subsidies of petroleum products in Egypt using an input-output analysis and the CGE model.

In the case of Indonesia, Dartanto (2012) and Widodo, Sahadewo, Setiastuti and Chaerriyah (2012) used the CGE micro-simulation and CGE model, respectively, to assess fuel subsidy impact. While the former examined the implication of reducing fuel subsidies on poverty, the latter considered how it will affect government spending and fiscal balance. Twimukye and Matovu (2009) applied the CGE model in investigating the macroeconomic and welfare consequences of high energy prices in Uganda. Coffman, Surles and Konan (2007) analysed the impact of petroleum prices on the economy of Hawaii using the CGE model under two scenarios. They applied the static model for price shocks under the first scenarios while a dynamic model was utilised under Energy Information Administration (EIA) scenarios. Also, Petersen (1997) applied the CGE model technique to the analysis of the Europe Agreements between the EU and Hungary, Poland and the former Czechslovakia.

There were also some studies conducted for Nigeria, where Siddig *et al* (2014) evaluated the impacts of removing refined oil import subsidies on poverty using a global general equilibrium model called *MyGTAP* to link the Nigerian economy to the rest of the world. This newly developed *MyGTAP* according to Siddig *et al* (2014) is an extension of the standard GTAP as it augments it by including multiple households, improved government specification and inter-regional transfers such as remittances and foreign capital incomes. Adenikinju (2009) also adopted the CGE model in the analysis of the policy implications of efficient energy prices in Nigeria while equally exploring the impact of a compensatory scheme to cushion the effects of higher energy prices. Employing the CGE model approach and survey method, Adenikinju and Falobi (2006) investigated the macroeconomic and distributional consequences of energy supply shocks in Nigeria

A number of CGE models currently exist, each having a set of complex non-linear equations to be solved, on the basis of assumptions on economic behavior. This includes price elasticity of demand and supply. They are also applied in analysis of energy policy. According to Ellis (2010), the model when applied in fossil fuel subsidy impact are initially run with values that assumes subsidy payment, then it is run with the assumption that the subsidy is removed. This helps to estimate the overall net benefits and costs related with subsidy removal. Data requirements for general equilibrium modelling are usually very large and so the accuracy of the results will be dependent on the accuracy of the assumptions made and data employed. The strategic role of energy as an important input to the production of most goods in the market makes changes in energy prices to affect almost all goods across sectors. Ellis (2010) thus, recommended that energy-intensive industries should be included in the model in a disaggregated manner.

2.5. Review of Empirical Issues

The analysis of fuel subsidies and their impacts have been extensively studied in the literature. In empirical literature, evidence suggests that there is a general agreement that fuel subsidies are increasingly growing and are not sustainable, and their adequate and sequential reform can provide net benefits for the economy. Ellis (2010) reviewed six major studies on fossil-fuel reform undertaken since the early 1990s to determine if there are any common conclusions that can be drawn while identifying areas in need of further research. The study concluded that there exist significant economic and environmental benefits that would result from the reform of fossil fuel subsidy. Thus, the reform of fossil fuel subsidy should be considered as a "key element of a larger overall package for global climate change mitigation" (Ellis, 2010; pp. 8). This corroborates the assertion of Abraham (2012). Studies on the economic, social (welfare), environmental and political dimension of fuel subsidy as a policy are discussed in this section as well as measures for a successful reform of the policy.

2.5.1 Fiscal and Macroeconomic Impact of Fuel Subsidy

Fuel subsidies are increasing by the year and if not eliminated, can pose a threat to sustainable development objectives. The rising energy consumption, energy prices and import dependency coupled with oil price volatility, had made fossil fuel subsidies to represent an increasingly significant drain on public financial resources (Bao and Sawdon, 2011). Also, in many countries, the percentage share of fuel subsidies in GDP is greater than the share of priority sectors such as healthcare, education and infrastructure. Furthermore, the economic consequence of fuel subsidy creates distortive and deadweight loss implications for the economy at large (Cust and Neuloff, 2010). This has generated some concerns among policy-makers and economic analysts over the years on the sustainability of these categories of subsidies. There is a general consensus on the need to analyse the fiscal implications and response of key macroeconomic aggregates of a change in fuel pump price. Empirical studies on economic impact of subsidy reform indicate that these subsidies hamper budgetary balance of government finance and affect key macroeconomic aggregates such as investment, trade, and so on. Their removal or reform will however, have significant benefits on the economy in the long run. The reform process may initially create shock to some economic indicators, but things will begin to normalise in no time.

The IEA (2011) stated that fossil fuel subsidies result in an economically inefficient allocation of resources and market distortions which often fail to meet the intended objectives. The report pointed out that these subsidies can speed up the depletion of resources for oil-producers which can reduce export earnings over the long term. Also, for importers, these subsidies can impose a heavy burden on state budgets. Cust and Neuloff (2010) supported that domestic consumption subsidies do impose high costs and fiscal burden on the economies that provide them. Using Iran as an example, they asserted that consumption fuel subsidies is as high as 10 percent of GDP, thus invariably reducing overall GDP through higher taxes needed to be raised on other economic activities. Also, these subsidies imply large forgone export revenues for fuel-exporting countries (Cust and Neuloff, 2010).

Davis (2013) examined the economic cost of global fuel subsidies and found that using recent data from the World Bank, fuel and diesel subsidies amounted to US$110 billion in 2012. This underpricing of fuel products which results in overconsumption was found to create annual deadweight loss of about US$44 billion worldwide under baseline assumptions about demand and supply elasticity. This study posited that the incorporation of external costs substantially increases the economic costs of these form of subsidies. Lawrey and Pillarisetti (2011) supported the inefficiency argument of energy subsidies by stating that the pricing of energy products below marginal cost results in deadweight loss. This is because consumers are not confronted with the true opportunities cost of energy production and thus have little incentive to conserve.

Plante (2013) investigated the long run macroeconomic impacts of fuel subsidies on the steady state level of macroeconomic aggregates such as consumption, labour supply, and aggregate welfare. The study found that subsidies creates distortionary effects such as the crowding out of non-oil consumption, inefficient inter-sectoral allocations of labour, reduced aggregate welfare and other forms of distortions. Macroeconomic variables such as prices, investment, growth rates of GDP, budget deficit, sectoral value-added, resource gap and welfare were significantly impacted in Egypt using a CGE approach in the study of Abouleinein *et al.* (2009). Their results indicated that subsidy removal will induce a significant increase in Consumer Price Index (CPI) and prices of energy-intensive industries. Also, the price of transport, communications and electricity will rise by about 40-60 percent, budget deficit will turn to a surplus, resource gap will widen, total private consumption falls while GDP achieves about 4.14 percent growth rate under different simulation scenarios. These findings are similar to that of Jiang and Tan (2013) where using an input-output model for China, the removal significantly impacts energy-intensive industries while driving up general price level.

Holton (2012) provided evidence from a panel study that GDP per capita as a measure of growth would be negatively affected with the introduction of energy subsidies. Widodo *et al.,* (2012) studied how fuel subsidy removal will impact government spending in Indonesia using the CGE model and found the removal to affect income distribution of households, firms and government. For Solaymani and Kari (2014), they found that the removal of fuel subsidies in Malaysia resulted in increase in the level of real GDP and real investment but decreases total exports and imports, aggregate energy demand and carbon emissions. On the other hand, Safdari, Nabisheyhakitash, Jafari and Bargharden (2012) employed a simultaneous equation technique for Iran and found that the reduction of energy subsidies will cut down energy demand, increase industrial/sectoral productivity and likewise employment rate.

According to Lin and Jiang (2011), the removal of energy subsidies will result in a significant reduction in energy demand and emissions, but with negative effects on macroeconomic variables. They concluded that offsetting policies could be employed to support other sustainable development measures, which ultimately can reduce energy intensity and favour the environment. Jiang and Tan (2013) corroborated the effect on energy-intensive industries and consequently stated that it will drive up general price level in China. In terms of impact of subsidy on investment, Lawal (2014) analysed the different regimes of fuel increases, subsidy payments and its effectiveness or otherwise in stimulating investment in the petroleum industry in Nigeria, providing recommendations on how best to attract private investment. As asserted by Balouga (2012), without reforms, creating a sound investment climate and promoting economic growth becomes a dream.

The study of Onyemaechi (2012) revealed three major economic implications of petroleum policies in Nigeria suggesting that in the first place, there was a rapid expansion of economic actors in the Nigerian petroleum industry. Secondly, there was increased development of the transport system and finally, there were observed improvements in the country's GDP, FDI and employment levels. However, some other negative consequences their study identified include some economic problems generated ranging from fuel scarcity to loss of man-hours and confusion relating to the actual beneficiaries of the subsidy in Nigeria.

Also, Efobi, Osabuohein and Beecroft (2012) using the VAR technique of estimation, found that the fuel subsidy removal in January 2012 had negative consequences on certain macroeconomic variables with a breakpoint in the trend of the indicators. Their econometric analysis established that there was a sharp reaction of variables such as exchange rate, inflation and money supply to fuel subsidy reduction considering the structural break and the impulse response function. Applying a linear function, Abang, Elufisan and Okwubunne (2012) ascertained how the subsidy removal affects the value of the Nigerian currency (naira) and local production. The study found that the policy will lead to increase in every commercial aspect, thus having negative impact on standard of living of the people. For local production, the removal will drive up transport cost for local manufacturing industries leading to increase in prices of both raw materials and finished products. This will make the local industries suffer at the expense of their foreign counterparts which eventually results in the promotion of large dependence on importation.

The work of Adenikinju and Omenka (2013) analysed the potential benefit-loss and trade-offs associated with a domestic response to a 60 percent increase in international pump price of fuel. Their findings indicated that subsidising local fuel consumption brings about reductions in GDP, government revenue, investment, trade balance and household income by 4.3 percent, 2 percent, 27.2 percent, 2.7 percent, 9.6 percent and 5 percent respectively. They however, pointed out that any negative consequences observed on the macro-economy can be reduced with a gradual reduction of fuel subsidy.

Another key macroeconomic indicator is investment and Morgan (2007) showed how the magnitude of energy subsidies is capable of influencing energy investment, pointing out that direct subsidies such as grants or tax exemptions is a drain on government finances. The study explained that these subsidies can undermine economic efficiency and investment in more efficient and cleaner energy technologies through different ways. This is in addition to incurring some macroeconomic costs as well. Pershing and Mackenzie (2004) equally indicated that the removal or reform of fuel subsidies can help in leveling the playing ground for the development of renewable energy technologies. This is because the subsidy makes fossil fuel cheaper, thereby hampering the commercialisation of alternatives such as renewables. In past years, there had been some improvements in switching to cleaner energy source such as solar and wind power. If the large amounts paid on subsidies are used to further develop the renewables, the demand for fossil fuel can be drastically reduced. Pershing and Mackenzie (2004), however, warned that the political hurdle to enacting this approach is remains very high in many regions.

Energy subsidies can also compete for limited resources which could have otherwise been used to deliver other essential services. This is in addition to widening the scope for rent seeking and commercial malpractices, promotion of non-economic energy consumption, discouragement of both demand and supply side efficiency and make new forms of renewable uncompetitive (Baron *et al.*, 2010). In studying three oil-exporting countries (Iran, Algeria and Nigeria), Birol, Aleagha and Ferroukhi (1995) found that with fuel subsidy reform, these countries will save substantial amounts of oil from domestic consumption which will in turn translate to additional revenue.

Relating to impact of subsidies on trade, Burniaux, Chateau and Sauvage (2011) examined the trade effect of eliminating subsidies provided for fossil fuel by many developing and emerging economies using the OECD's ENV-linkages general equilibrium model and the IEA estimate of consumer subsidies. Their findings indicated that a unified multilateral elimination of these subsidies over the 2013-2022 periods would raise world trade volumes by a very minimal amount (0.1 percent) by 2020. In the same vein, Agbedo and Akaan (2012) presented a critical discourse perspective on how the fuel subsidy debate represents a mind control game between the more powerful group represented by the government and the less powerful group represented by the organised labour union with the Nigerian populace.

The study of Amegashie (2006) provided a unique insight as it argued that the removal of subsidies may not necessarily enhance the economic performance of developing countries as being put forth by the IMF and other empirical studies. The argument of opponents of the subsidy is that any form of departure from the competitive equilibrium price and quantity will result to a fall in social welfare which is not ideal. Thus, if the market is in a perfectly competitive equilibrium, a reduction in the price of the good which serves as a way of subsidy will lead to rises in its consumption beyond the competitive equilibrium quantity. This makes subsidy undesirable. Using the theory of the second-best as showed by Lipsey and Lancaster (1956), Amegashie (2006) concluded that conclusions can not necessarily be made that subsidies reduce social welfare unless the relative magnitude of the costs and benefits are known. The "second-best" theory implies that if there are irremovable disruptions in some sectors of the economy, then behaivour of economic and social indicators may be higher given that lasses-faire pricing doctrines are intentionally violated in other sectors of the economy (Amegashie, 2006).

2.5.2. Welfare Impact of Fuel Subsidy

The welfare impact of fuel subsidy is an important analysis as it is the aspect that creates controversy the most. This is because the policy is considered to protect poor households from oil price shocks and enhance energy access which will ultimately promote growth. Any form of call for its reform is however, met with stiff opposition. This welfare effect on household income will have both direct and indirect effect (Coady *et al.,* 2006;

Granado, Coady and Gillingham, 2012). The direct effect will emanate from higher prices for petroleum products consumed by households while the indirect effect will be in terms of higher prices of other goods and services consumed by households. This is due to the strategic role of fuel/energy in production, thus any increase in energy prices will increase production cost (raw materials, transportation, distribution, etc.) which will increase price of goods and services. The magnitude and distribution of these impacts will depend strongly on the share or value of cooking, lighting, heating and private transportation costs in total household consumption (Granado *et al.*, 2012). This is in addition to the fuel intensity of other goods and services.

In exploring the fiscal and welfare impacts of reforming fuel subsidies in India, Anand *et al* (2013) found that despite the fact that the reform generates substantial fiscal savings; the associated fuel price increase lowers household real incomes for all income groups. Umar and Umar (2013) measured the direct welfare impact of fuel subsidy reform through higher fuel prices, on different socio-economic groups in Nigeria using the Household Expenditure Survey of 2010 and found reduction in welfare to be larger for the middle 40 percent group compared to the top and bottom 20 percent.

Nwafor *et al.* (2006) and Siddig *et al.* (2014) studied how fuel subsidy removal will impact poverty levels in Nigeria. Nwafor *et al.* (2006) stated that national poverty level would increase without the spending of the associated savings as a result of the consequent rise in input costs. Siddig *et al.* (2014) equally asserted that even though GDP would increase, it can have a detrimental impact on household income particularly poor households. However, these negative impacts can be alleviated if the subsidy cut is accompanied with income transfers targeted at poor households. Likewise, Cooke, Hague, Cockburn, El-Lahga and Tiberti (2014) assessed the impact that Ghana’s fuel subsidy reform will have on poverty and the relevant mitigating response. They found that almost 78 percent of fuel subsidies benefitted the wealthiest group while less than 3 percent of the associated benefits reached the poor.

IEA (2011) further confirmed that fossil fuel subsidies continue to remain an inefficient means of helping poor households as statistics revealed that at the global level, only 8 percent of the US$409 billion spent on fuel subsidies in 2010 went to the poorest 20 percent of the population. Gangopadhyay, Ramaswami and Wadhwa (2005) showed that for India, reduction in fuel subsidies will negatively affect the income of poor households. Thus, the removal should be supported with other policies that would limit the adverse impacts. Employing a household budget survey for 5000 households, Adagunodo (2013) found that the marginal social cost for all petroleum products are extremely low which is indicative of the reduction of petroleum subsidies in Nigeria.

2.5.3. Political Economy of Fuel Subsidies

Energy subsidies continue to persist despite their negative effects mainly due to some political issues which affect any attempt at the reform. Governments often find it difficult to institute reform measures as a result of the political economy of fuel subsidies (ADR, 2012). Globally, reform measures in this regard are always confronted with stiff opposition from the public, mainly attributable to the politics that revolves around the policy. This is due to the lack of confidence in the government and since government do not want situations of political and social unrest, most countries often reverse any reform attempt. A number of countries have experienced nationwide protests that threatened economic activities when government attempted to introduce fuel subsidy reform. They include Nigeria, Egypt, Morocco, Iran, among others. This makes the analysis of the political constraints to reforming energy subsidies important. A number of empirical studies exist in understanding the political aspect of the prevalence of subsidies.

Victor (2009) asserted that often times, attempts to reform fuel subsidy could result from the inability of relevant institutions to understand the dynamics of the political dimension of a subsidy policy. As co-ordinated groups tend to gain more from introduction of subsidy, naturally there would be moves against any policy to take it away. Commander (2012) was in support of the notion that fuel subsidy is better understood from a political economy ideology given that political institutions are able to influence the choice of policy instruments. The study also provided a guide to the political economy of reforming energy subsidies by assessing why these subsidies persists and possible channels of overcoming barriers to their reform. Victor (2009) analysed the politics of fossil fuel subsidies by examining the interactions among key fundamental puzzles such as the prevalence of fossil fuel subsidies, the goals of government and the political structure of the fossil fuel industry.

Furthermore, Strand (2013) discusses and models the various political economy aspects of fuel subsidies with particular focus on democratic and autocratic governments. The study designed a political path where promises of low fuel prices are introduced under a democratic system of government to make people vote while also being used as a tool to gather support among essential groups under an autocratic system of government. In Nigeria, Akinwale, Olaopa, Ogundari and Siyanbola (2013) analysed the influences of politics on the operations of subsidy provided for energy. Studies such as Henshaw and Onyeacholem (2012) were able to argue that the problem of corruption also is accountable for the crisis that usually surrounds subsidy and not just a fiscal burden challenge. The study analysed the role of government in allowing illegal and unlawful practices in the payment of subsidy to oil importers.

Thus, in the absence of efforts at addressing the corruption challenge, reform measures may not generate meaningful result but rather continue to lead to agitation. According to Commander (2012) designing an adequate process through which reforms are presented, managed and executed will be a more viable measure to ensure success. This is in addition to due consideration for political and other associated constraints. The study noted that while countries experience the infeasibility of rapid reform, a gradual or systematic approach had been shown to be problematic, often leading to policy reversal.

2.5.4. Environmental Consequences of Fuel Subsidy

The assessment of the environmental implication of fuel subsidy is the key focus of this study. The importance of this analysis lies in the need to reassess some existing policies that could by design or otherwise, hamper global efforts at tackling environmental challenges such as climate change. The study of the link between fossil fuel subsidies and environmental quality is rooted in the three impacts that these categories of subsidies have on climate change as stated by Merrill (2015). In the first place, their presence prevents energy efficiency and cleaner energy alternatives such as renewable energy. Secondly, there reform is capable of reducing demand for fossil fuel based energy and encourage a switch to cleaner sources of energy, thereby causing a fall in carbon emissions. Thirdly, removal and taxation of fossil fuel subsidy can generate and raise domestic revenue that can be invested in the transition to a low-carbon economy (Merrill, 2015). This is further explained by the statistics of Stefanski (2014) that the relationship between fossil fuel subsidies and climate change points to the fact that these subsidies contributed to about 20.7 percent of total global carbon emissions between 1980 and 2010. These and more empirical evidence had thus, resulted to calls to reform these subsidies for a cleaner and more sustainable environment.

This growing international pressure to reduce GHG emissions has necessitated renewed attention on policies that focus on subsidising the consumption or production of fossil fuel, an environmentally harmful source of energy (Koplow and Dernbach, 2001). Though energy is an essential input for economic growth, its production, transformation, transmission, distribution and utilisation exerts negative effects on the environment (Sambo, 2010). This point was supported by Bao and Sawdon (2011; pp. 2) which stated that "environmental impacts occur all along the value chain of fossil subsidies; from the activities of the extractive industries through to the intermediate process (transport, refining and power generation) and then to the final consumption of energy". This realisation had led to some attempts at analysing the implications that fuel subsidy as a policy can have for the environment and also examining the existence of a relationship between subsidies and environmental quality. Studies such as Larsen and Shah (1992); OECD (1998); Koplow and Dernbach (2001); Bao and Sawdon (2011); Allaine and Brown (2012); APEC (2012); UNDP (2012); Ballali (2013); Mukherjee and Chakraborty (2013); Whitley (2013); Douthwaite and Healy (2014), Stefanski (2014); Merrill (2015); UNEP (2015); among others, have analysed how different EHS, majorly fossil fuel, can influence the environment and how their reform can help tackle climate change. This was carried out for different countries and regions.

The study of Mukherjee and Chakraborty (2013) found a positive relationship between subsidies and environmental degradation using a cross-country framework. This relationship could be due to the fact that policies designed to subsidise consumption or production of fossil fuel will inevitably promote increased concentration of GHG and CO_2 emissions in the atmosphere. The argument is that if adequate measures are not put in place, the policy can significantly hamper global efforts at tackling climate change as an environmental concern. Many of these studies that focus on the environmental consequences of fuel subsidy asserts that reductions in GHG emissions can be achieved with the adequate reform fossil fuel subsidy, which will further help in fighting climate change (Burnianx *et al.*, 2009; IEA, 2011; Ellis, 2010; Liu and Li, 2007; Ballali, 2013; UNEP, 2015). This is supported by the assertion of the IEA that the phasing out of energy subsidies is one of the four policies to keep the world on course for the 2-degree global warming target at no net economic cost (Whitley, 2013). This is further re-emphasied by the findings of Bao and Sawdon (2011). Developing a CGE model for the Vietnamese economy, they assessed the environmental impact of reducing fossil fuel subsidy and imposing environmental tax. The study found the reduction of subsidies and tax imposition to result in significant reductions in emissions. This is evident in reductions of about 3 percent of BAU emissions by 2015, rising to over 9 percent by 2020 and remaining at that level by 2030. The subsidies covered subsidy on coal, petrol and electricity.

The work of Larsen and Shah (1992) considered one of the pioneering works on the relationship between fossil fuel subsidies and global carbon emissions, asserts that removing these large subsidies could substantially cut down carbon emissions in some countries. Thus, assuming no change in world fossil fuel prices, global carbon emissions could be reduced by 9 percent and by 5 percent when accounting for estimated changes in world prices. Larsen (1994) applying a simple model with inter-fuel substitution using a detailed sectoral data of a sample of countries found support for this result. In the same vein, Burniaux *et al.*, (2009) provided evidence that overall world CO_2 emissions can fall by 10 percent by 2050 if consumer fossil fuel subsidies in 20 OECD countries were removed. In IEA (2011)'s estimation, growth of these emissions will fall by 6 percent by year 2020. Evidence for Nigeria and Venezuela showed that carbon emissions will average 1.89 and 11.77 million metric tonnes respectively as provided by the work of Ballali (2013). As stated in Whitley (2013), IEA estimates suggest that even a partial phase-out by year 2020 would reduce GHG emissions by 360 million tons, equivalent of 12 percent of the reduction required to achieve the objective of holding temperature rise by 2 degrees. UNDP (2012) estimated benefits of reforming fossil fuel fiscal policies for Vietnam in the context of responding to climate change when GHG emissions are cut.

Also, the reform of fuel subsidy had been argued to be a useful instrument in driving a green growth agenda/strategy. This is in view of the growing consensus that phasing out fossil fuel subsidies is an essential component of the green economy agenda (UNEP, 2015). Furthermore, Merrill (2014) asserted that a growing research, modelling and evidence suggests that reforming fossil fuel subsidies is an important piece of the jigsaw needed if we are to solve the climate change challenge in terms of absolute reductions in GHG emissions. This will help solve not only energy security concerns, but also advance climate change agendas of many countries. Following this line of argument, Whitley (2013) opined that large and increasing fuel subsidies represents obstacles to green investment while seriously undermining attempts to put a price on carbon. That is, in addition to being a drain on national budget, they undermine global efforts at averting climate change. Jones (2011) showed how an economy can drive towards a green economy through fiscal policy reform and public finance (tax), stating that fiscal policies are essential part of a co-ordinated strategy towards improving resource efficiency, reducing environmental risks and scarcities.

However, studies such as Morgan (2007), Liu and Li (2007), Ellis (2010) and Laan, Beaton and Presta (2010) emphasised the issue of switch overs from less polluting fuel to a more polluting fuel as a result of fuel subsidy removal due to increase in energy prices. For instance, an increase in the price of petrol due to the removal of subsidy can drive poor households to using dirty energy such as coal for cooking and other needs. The alternative would be to ensure the switch is to renewable energy sources that are considered to have minimal or no emission. The argument is that government can internalise such externalities, thereby achieving a positive environmental impact through the introduction of the subsidy. The end result will be a stricter form of regulation to guide decision of the switch overs by rational energy consumers. Thus, for fuel subsidy reform to be successful and not create negative consequences, it must be properly planned and executed with adequate consideration.

2.5.5. Energy Subsidy and Environmental Quality

The relationship between energy subsidy and environmental quality stem from how the subsidy results to lower energy prices which increases energy consumption. This, in turn increases the burning of fossil fuel and by extension, increase emission of greenhouse gases into the atmosphere. Through this channel of transmission, the environment deteriorates. Fossil fuel been a non-renewable energy source, has proven to be adequate, however, its byproducts are harmful to both humans and the environment (Ajayi, 2013). The assertion that energy subsidy continues to deteriorate the environment forms an integral aspect of many international and regional debates that tends to be more favourable towards the adoption of alternative sources of energy. In other words, production and generation of energy should be from renewable energy sources such as hydropower, wind, solar, geothermal and biomass (Ajayi and Ajayi, 2013).

The emphasis of government subsidy in the energy sector should be towards supporting technological developments and commercialisation of renewable energy. For instance, government can decide to subsidise technologies for efficient environmentally friendly energy sources to enhance access to electricity in remote areas, diversify energy mix or promote a decentralised generation (UNEP, 2003). Subsidies to enhance these technologies could be in form of research and development (R & D) funding, favourable tax structure, grants, soft loans and favourable regulations.

These global efforts at reforming fossil fuel subsidies stemmed from the need for a renewed focus on existing policies that may encourage consumption or production of fossil fuel. Koplow and Dernbach (2001) showed that fossil fuel contributes about 90 percent to greenhouse gas emission. The impact fossil fuel has on the environment flows from this channel of emission, which subsidies enhance since it leads to overconsumption. These emissions significantly impacts the environment (Alege and Ogundipe, 2013; Akinyemi, Ogundipe and Alege, 2014), and the energy sector is a key contributor. This makes it essential to consider the structure of some policies in the energy sector that may influence the environment negatively. In addition to this, the global drive towards green growth/economy and low-carbon development initiatives has seen many countries and regions seek for necessary avenues to discourage economic activities and production technology that increases carbon intensity. This is essentially through the provision of incentives to support shift towards modern energy sources which are environmentally friendly and sustainable. This will trigger higher growth rates and at the same time with minimal emission levels. Africa is equally making attempt at being part of this global effort and this is reflected in the Africa Development 2012 Report where issues relating to moving towards green growth in the continent are discussed.

The identification of the negative consequences of these forms of subsidies coupled with the corrupt practices surrounding payment of subsidies to fuel importers, led the Federal Government of Nigeria (FGN) to announce the removal of fuel subsidy on January 1st, 2012 (Odoh, 2012). Some of the factors cited for the removal ranges from the huge unsustainable burden of the payments to how it stifles competition and discourage private investment in refinery development. This was, however, met with a stiff opposition from organised labour and civil society which resulted in a mass protest across the country for two weeks. This reaction was partly due to the economic hardship the removal creates and the multiplier effect of an increase in fuel price in the entire economy. Since then, there had been series of debates in support or otherwise for the removal of fuel subsidy in Nigeria.

On one hand are those raising concerns on the fiscal pressure that fuel subsidy payments places on government finances which had been argued to be unsustainable. On the other hand, the civil societies believe the removal of the subsidy will drive up fuel prices and make prices of commodities and services more expensive with attendant multiplier effect. Following the socio-economic crisis the policy shift created in the nation, the then President, Dr. Goodluck Jonathan decided to reverse the decision to a partial removal. This brought the fuel pump price from ₦165 to ₦97 instead of going back to the initial ₦67. Government also inaugurated the Subsidy Reinvestment and Empowerment-Programme (SURE- P) to act as a form of welfare safety net that will absorb the negative impact of the removal on poor households. This programme was to utilise the fuel subsidy savings in infrastructural development projects and designed along the transformation agenda with a life span running from 2012 to 2015. Some of the social safety net programmes by the SURE-P includes vocational training, mass transit system, maternal and child healthcare, community service, women and youth empowerment, HIV/AIDS intervention, polio eradication programme and heart/stroke center (SURE-P, 2013). Other infrastructural development projects include construction of roads and bridges, railways, including Abuja light rail, Niger delta projects and mass housing scheme. The SURE-P team was mandated by the presidency to ensure transparency, accountability and restore the confidence of the people in the government.

2.5.6. Achieving Successful Reform of Fuel Subsidy

Energy subsidies are costly, rising and inequitable making it necessary to reform the policy framework for setting petroleum product prices (Coady *et al.,* 2010). This is to reduce the fiscal burden of these subsidies and tackle environmental challenges such as climate change effectively. Other motivations behind these reforms centers on the desire to reduce fiscal expenditure, improve energy efficiency or minimise pollution and emission levels. However, according to Laan, Beaton and Presta (2010), if poorly planned and executed, the reform can result to adverse economic, social or environmental consequences due to higher energy prices. Friedrichs and Inderwildi (2013) presented an argument for fuel rich countries support for fossil fuel subsidies. They asserted that these categories of countries are most likely doomed with what they termed as "carbon curse". This carbon curse is related to resource curse, in which case the more the fuel endowment of a country, the more their emissions. They identified uneconomic fuel consumption subsidies as one of the causal mechanisms for most fuel rich countries to experience carbon curse. This is because governments in these countries are often under pressure to grant these subsidies which further augments carbon intensity of economic output. Friedrichs and Inderwildi (2013) attributed three reasons why government grants these uneconomical subsidies.

In the first place, political leaders are obliged to accommodate the feeling of entitlement by citizens to the national resource wealth. Secondly, fuel subsidies in most fuel rich countries are opportunity costs rather than fiscal expenditure, since the marginal cost of fuel production is only a fraction of world market prices (Friedrichs and Inderwildi, 2013). Lastly, fuel subsidies are sometimes affordable even in countries where marginal production costs are higher than subsidised fuel prices. The paper concluded that fuel rich countries such as Iraq and Nigeria should focus on addressing energy poverty and infrastructure rather than investing in uneconomic fuel subsidies.

Pearse and Finck Von (1999) emphasised means of advancing subsidy reforms which should be about moving towards a viable policy package. They advocated a gradual approach coupled with adequate public awareness, transparency and accountability as the best method for reform subsidies with success. UNEP (2003) presented the lessons learnt in assessing the impact of energy subsidies and the design of their reforms; while the IEA, OPEC, OECD and World Bank (2010) joint report analysed the scope of energy subsidies and suggestions for the G-20 initiative. Koplow (2012) appraised the commitment of the G20 towards fossil fuel subsidy phase out and highlighted some structural reforms that would increase the likelihood of the phase out being successful. Some of these reforms include separating reporting from reform, establishing an oversight and review board, setting up necessary technical committee, among others. However, despite the need for the reform or removal of these categories of subsidies due to their being inefficient, inequitable and fiscally costly; many developing countries' government still find it politically difficult to reform them (Granado *et al*, 2012).

2.6. Some Regional Experiences and Lessons Learnt

The nature and characteristics of energy subsidies is almost the same in different part of the world, the unique features and peculiarities of some regions only present some differences. Different countries have attempted to reform their fossil fuel subsidies with varying degrees of success (Laan *et al.*, 2010). Studies from a number of the regions supported the view that energy subsidies are costly and require urgent reform. The sequence, timing, pace and politics that play out then determines how profitable the reform process will be. The sub-section below presents energy subsidies for the different regions of the world and lessons learnt from their success or otherwise stories.

2.6.1. Energy Subsidies in the European Union

Different studies (European Environment Agency, 2004; Kovacevic, 2011: GSI, 2012; Alberici *et al*., 2014, among others) have analysed the nature, magnitude and impact of fuel subsidy in the European Union. Kovacevic (2011) assesses fossil fuel subsidies for the Western Balkans, a country close to the South east of Serbia. A GSI (2012) report presented a synthesis of existing knowledge on fossil fuel subsidies through the profiles of some European Union and G20 countries. The goal was to highlight how much could be saved by governments from the reform without applying any subjective judgment to available data. Evidence from the report suggested that countries such as USA, Germany, Australia, Mexico and UK could save between 4 billion and 12 billion Euros a year by the phasing out of government support for fossil fuels. The reform is expected to lead to a significant cut in greenhouse gas emissions and the money saved can be invested in clean alternative energy, green jobs and other public goods. The GSI (2012) report also presented four steps for governments to reform fossil fuels subsidies from the case studies analysed. The steps are as follow;

i. Define plans to phase out fossil fuels by 2015. Countries should agree to eliminate fossil fuel subsidies by 2015;

ii. Increase transparency and Consistency in the reporting of subsidies. A fair and transparent disclosure of the existence and value of subsidies will help to enhance informed and robust plans for reform;

iii. Incorporate assistance and safeguards to developing countries, as well as poor and vulnerable groups. The reform of consumer subsidies for fuel will only be successful if adequate safeguards are incorporated for the poor and the vulnerable. Developing countries should be assisted with financial and technical resources with capacity building; and

iv. Create an international body to enhance the support for subsidy reform. This body will help support the global effort towards the phasing out of fossil fuel subsidies.

2.6.2. Energy Subsidies in OECD Countries

The OECD has been working on reforming and the elimination of support for inefficient consumption and production of fossil fuel subsidies as contained in their numerous reports. This is to help enhance the achievement of economic and fiscal objectives and further tackling of environmental crisis such as climate change. According to the IEA, OPEC, OECD and the World Bank (2010) report, many OECD countries have been raising taxes on energy which represents negative subsidies, majorly fossil fuels transport which are up to US$400 billion (this excludes goods and services tax and VAT) in between the period 2003 and 2008. The report cited examples of Poland's reduced VAT for energy products, Indonesia and Malaysia's reform of direct subsidies for petroleum products including the United States.

Also, the work of Allaire and Brown (2012) assessed the effects of energy subsidies on energy markets and carbon emissions in the United States of America. The study covered about 60 different subsidies targeted towards the increase of energy production, subsidising of energy consumption and increasing energy efficiency. These categories of subsidies cover both tax provisions and spending programmes between the period 2005 and 2009. The major finding of the study using a partial equilibrium approach is that within the period under review; government expenditure shifted from subsidies that increased carbon emissions to those that emphasised its reduction.

According to Allaire and Brown (2012), the US government expenditure on subsidies that increased CO_2 emission in 2005 amounted to US$9.1 billion while expenditures that reduced CO_2 emission stood at US$3.4 billion. In 2009, these figures shifted as expenditures on subsidies that increased and decreased CO_2 emission was given as US$15.4 billion and US$18.5 billion respectively. Examples of subsidies that increased CO_2 emission as indicated in the report includes tax provisions for fossil fuel-based companies, assistance for low-income housing cooling and heating; and alcohol fuel excise tax. On the other hand, subsidies that reduced carbon emission ranges from home weatherisation programmes, tax credits for energy efficient home improvements, renewable energy production and loan guarantees for energy efficient improvements (Allaire and Brown, 2012).

2.6.3. Energy Subsidies in Asia

The Chief Economist of IEA, Dr. Faith Birol asserted in October 2013 that Southeast Asia must remove US$51 billion (2012 estimates) of fossil fuel subsidies which distorts energy markets in the region. The total fossil-fuel subsidies for five Asian countries for 2011 estimates as presented by the IEA showed that Indonesia's subsidies amounted to about US$21.3 billion (2.5 percent of GDP); US$7.2 billion for Malaysia representing 2.6 percent of GDP; US$1.5 billion for Philippines with 0.7 percent of GDP; US$10.3 billion for Thailand with 3.0 percent of GDP and US$4.1 billion for Vietnam representing 3.4 percent of GDP. The argument is that many of the Asian countries such as Malaysia, Indonesia and Thailand who are rich in renewable energy resources (solar, geothermal, biomass, hydro), might remain underdeveloped if the Asian governments continue to spend billions of dollars on subsidising fuel consumption.

Breisinger, Engelke and Ecker (2011) supported the reform of petroleum subsidies for development in Yemen. Attempts towards the removal of these subsidies are often met with angry protests from local communities who are already used to cheap fuel. These unsuccessful attempts are, however, due to their being sensitive and political in many parts of the region. In recent years, there have been some encouraging signs that countries are beginning a gradual phase out of these subsidies. Though Lin and Li (2012) pointed out that for China, subsidy removal would affect competitiveness through the trade channel which would generate negative externalities in china but positive externalities to other regions without subsidy removal. Also, it would generate a rebound effect that would produce positive externalities to areas without subsidy reform which may however hinder global emission reductions (Hong, Liang and Di, 2013).

The fuel price of Indonesia was found to be the lowest in comparison with some selected countries such as Singapore, Philippines, Thailand, Vietnam and Malaysia (Askolani, 2010). Mourougane (2010) asserted that the oil price hike of 2007 and 2008 underlined the vulnerability of Indonesia's energy subsidy policy to oil price volatility. Askolani (2010) suggested that for Indonesia, subsidised fuel should be limited to the households, micro businesses, fishery business, public transportation and public services. Other policy measures include reduction of fossil fuel consumption by introducing new types of bio-fuel, enhancing the development of alternative energy and the monitoring of subsidised fuel distribution and law enforcement for misuse. How practicable these suggestions will be, is another question entirely. GSI (2012) at a workshop with South Asian policy makers on fossil fuel subsidy rise in 2012 stated that three main pillars of implementing reform plans should entail getting energy prices right, managing the impacts of the reform and building support for reform.

2.6.4. Energy Subsidies in Arab Countries

Fattouh and El-Katiri (2012) evaluated the nature, characteristics, financing and reform of energy subsidies in the Arab world and found that despite the negative effects of energy subsidies; they represent a vital social safety net for the poor in many parts of the Arab region. Studying seventeen Arab countries, they asserted that energy subsidies are costly to the Arab world in economic, social and environmental terms. Also, the year 2011 presented the Arab region with difficulties in terms of energy pricing structure as that year witnessed a number of protests and uprisings that resulted to the removal of long serving presidents particularly in Egypt, Libya and Tunisia.

This made government in the region in the coming years who were willing to engage in energy pricing reforms to be faced with tremendous pressure to achieve a delicate balance between necessary but painful economic reform, and the political and economic expectations of their younger generations (Fattouh and El-Katiri, 2012). However, the enormous fiscal burden created by increasing energy subsidies in the Arab countries has thus made its reform essential rather than a matter of choice. Fattouh and El-Katiri (2012) then recommended that despite the serious negative effects the reform will have on the people, the reform programme must be accompanied with focused mitigation measures that will help reduce the impact.

Energy subsidies are prevalent in the Middle East and North Africa (MENA) region as it accounts for about half of the global energy subsidies (IMF, 2013c). The region is made up of the Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, UAE and Yemen. Half of the subsidy on energy is on petroleum products, while the other half is on electricity and gas. In this region, the countries, both energy importers and exporters have had to rely on energy subsidies as a tool to provide social protection and the sharing of hydrocarbon wealth (IMF, 2013c). It is observed that even though these subsidies provide support for the consumers, its benefits basically flow to the upper income group in the society. IMF (2013c) cited the example of Sudan where the poorest 20 percent of the population receives only about 3 percent of fuel subsidies, while the richest 20 percent gets more than 50 percent and this situation is said to be similar in many other countries of the region.

The IMF (2013c) prepared a report on the benefits of energy subsidies in the region, the barriers to reform and the roadmap for an effective policy take-off. Some of the measures for effective reform according to the report include a comprehensive energy sector reform plan and communications strategy; appropriately phased and sequenced price increases; improved efficiency of state-owned enterprises to reduce producer subsidies; and targeted mitigating measures and depoliticised price setting. An important point recognised in reform process is that there should be careful planning in terms of the timing and pace of the reform.

2.6.5. Energy Subsidies in Sub-Saharan Africa (SSA)

The reform of energy subsidies is an important but challenging issue for SSA countries (IMF, 2013a). Analysis on prevalence and persistence of fossil fuel subsidies also exists for the SSA countries. El-said and Leigh (2006) presented the fiscal and distributional cost of fuel price subsidies for Gabon. Despite reform efforts in the region, energy subsidies still represent a large share of the scarce public resource. IMF estimates showed that fiscal cost of fuel subsidies, both direct subsidies and forgone taxes, amounted to 1.4 percent of the region's GDP in 2012; where these subsidies mostly benefit the better off. Then again, their removal will equally hurt the poor. In SSA, energy subsidies mostly benefit the higher income earners as they consume energy products the most. IMF (2013c) suggested the following lessons to be learnt from case studies of SSA countries that have attempted to reduce energy subsidies;

a. Transparency and public communication on the size of energy subsidies and their beneficiaries is essential to kick start the reform process. Like the case of Nigeria, Niger and Ghana where the government used fact sheets to call for the need for reform;
b. There should be careful preparation with public education and wide consultation with key stakeholders. This is critical for success, like in the case of Kenya and the electricity reform and Namibia;
c. A gradual phasing in and sequencing of subsidy reforms seem to work best, which is especially true when subsidies are large or have been in place for a long time;
d. Also, strong institutions are needed to sustain energy subsidy reforms; and
e. The case studies showed that durably reducing electricity subsidies involves much more than tariff increases. There must be an environment that is conducive to seizing the considerable scope for energy gains.

In addition, Laan *et al.* (2010) documented lessons that can be learned from the experiences of Ghana, Senegal and France in reforming their fossil fuel subsidies. They provided in a similar manner, six important strategies towards improving the chances of a sustainable reform. These includes research, establishing reform objectives and parameters, building a coherent reform policy, implementation, monitoring, evaluation and adjustment, and then preventing a backsliding (going forward). These can provide valuable insights for introducing reform measures while considering features specific to the African region.

2.6.6. Energy Subsidies in Nigeria

The nature and the impact of energy subsidies have also been analysed for Nigeria just like other regions. Majority of these studies for Nigeria mostly investigated economic and welfare impacts of energy subsidies on the economy. This is in terms of assessing it both at micro and the macro level, and also how the policy can affect macroeconomic variables. With the exception of Abraham (2012), many ignored the environmental dimension. Abraham (2012) argued that even though the removal of subsidy on fuel may create some welfare implications in the short run; the policy will result to greener growth and the enhancement of sustainable development in the long run. The study Adenikinju (2009) examined the response of energy prices and the private sector to energy sector reform and found that despite the growth in energy prices; significant private sector investment is yet to be stimulated.

Onyeizugbe and Onwuka (2012) attempted to find out if fuel subsidy removal can be an imperative for enhancing business development and wealth creation for the citizenry by adopting the descriptive survey design method. Based on classical economic theory of regulated monopolies with which subsidies are perceived as distorting prices, they found the non-existence of a significant relationship between fuel subsidy removal and job creation in Nigeria. Similarly, Bazilian and Onyeji (2012) observed that as beneficial the removal of fuel subsidy might be, especially in reducing demand; it has the ability to shrink firms' cost competitiveness in severely power-constrained economies. In other words, the removal of fuel subsidy in the face of inadequate public power supply can exert negative influence of performance of businesses.

They emphasised the importance of considering structural features that are peculiar to developing countries when analysing issues of fuel subsidy removal. There should be adequate mechanisms in place while also measuring the tempo of change in order to ensure that increasing access to high-quality energy services is not impeded by non-affordability (Bazilian and Onyeji, 2012). Overall, there should be means by which subsidy removal will promote growth rather than exerting negative influence on the business community. Anyandike (2013) assessed the implication of the full scale deregulation of the downstream oil sector of the Nigerian Economy looking at the neo-liberalism approach. Designing questionnaire for 1,177 respondents in Delta, Rivers and Bayelsa, the study found that the deregulation policy is a good policy but wrongly implemented hence, leaving the existing refineries in a state of comatose.

Chiwetalu (2012) and Ering and Akpan (2012) assessed the socio-economic implications of fuel subsidy in Nigeria, the politics surrounding it and why the populace often put up a resistance towards attempts at its reform. They found out that the subsidy benefited the rulers and multinational companies and not the citizen; thus recommending that government must engage the citizenry at all levels in policies that affect the masses. Balogun (2012) attributed this stiff opposition from the masses to the lack of trust in government which is as a result of failed promises made in the past. In order to ascertain the fallacy or fact claims on the existence of fuel subsidy in Nigeria, Nwachukwu and Chike (2011) found that fuel subsidy is a fact and not a fallacy.

In estimating the effect of the fuel subsidy removal on the real estate industry, Odudu (2013) assessed the effects of fuel subsidy removal on property values in Nigeria and found that the partial removal led to high cost of production and transportation in the real estate sector. The high cost of building materials thus, led some developers resort to using substandard or lesser quantities of materials so as to still be able to maximise profits. In relation to the issue of sustainable development, Lin and Jiang (2010) opined that energy subsidies can have important implications through their impact on efficiency, choice of fuel use and energy use. For Nigeria, Ekong and Akpan (2014) indicated that even though it is knotty issue for government, reforming fossil fuel subsidy in Nigeria offers greater opportunities in placing the country on the path of sustainable development.

Odoh (2012) identified the remote and immediate causes of the oil subsidy removal in Nigeria and asserted that the reform will help curb oil smuggling activities in the country and corruption. In light of all these assertions by the various empirical studies, Isihak and Akpan (2012) designed a "win-win" roadmap for the restructuring of petroleum subsidies in Nigeria, while addressing some of the deficiencies of previous attempts at reforms. Some vital elements identified from the reform process of successful countries as recognised by their study are effective consultation, strong political will coupled with effective communication with relevant stakeholders, in addition to well-targeted compensatory schemes that cushions the reform effects on the most vulnerable group of the population.

2.7. Knowledge Gaps in the Literature

Based on the literature reviewed, it is evident that there have been concerted efforts globally in addressing the challenges posed by large subsidy payments, Nigeria inclusive. The general consensus in the literature is that subsidies create fiscal harm to government budget and inefficient conditions which can hamper sustainable development efforts. In other words, these subsidies, particularly the environmentally harmful ones, should be eradicated or reformed as they often do not achieve the primary objective of enhancing energy access for the poor households. This is evidenced from majority of welfare impact studies that found that the top richest income group in the society often benefits from subsidy payment than the bottom poor 5 percent. Also, these categories of subsidies hamper global efforts at tackling climate change impacts while also eroding investment in the energy sector and development of green energy. A number of these studies have examined how these subsidies impact macroeconomic variables, poverty, environment and welfare. However, studies on Nigeria mostly focus on either macroeconomic implications of fuel subsidy, welfare cost or both, or the impact of its removal. Studies that examine impact of fuel subsidy on environmental quality (carbon emissions) in Nigeria were found to be scarce.

The analysis of the impact of fuel subsidies on environmental quality is important as it has key implications for policy measures put in place to tackle environmental problems such as climate change, pollution and others. An analysis of fuel subsidy impact on the economy can then help to assess how effectively the policy can be useful for climate change mitigation incentive. The rationale is that fuel subsidies increases the production and consumption of fossil fuel, by making fuel prices cheaper, which increases carbon emissions in the atmosphere, thereby hampering environmental quality in general. Thus, if subsidies on fossil fuel are removed, they can be re-invested towards the development of alternative energy sources that are environmentally friendly. This is supported by Ajayi (2013) that stated that the harnessing of renewable energy potentials of ECOWAS countries can spur sustainable development and environmental protection. So by making these alternative sources of energy cheaper and accessible, government can still achieve their objective of enhancing energy access for the poor households.

In terms of methodology, many apply survey design analysis, critical discourse or econometric methods (VAR, multivariate co-integration), only few apply the CGE approach to energy policy analysis, especially relating to the environment. This is supported by Adenikinju and Falobi (2009) that only relatively few applications of multi-sector CGE models to policy making in Nigeria exists compared to other multi-sector macro models. The CGE model as an approach is useful for analysing the economy-wide effects of a policy change as it provides a platform to evaluate policies that have multi-sectoral implications (Adenikinju and Falobi, 2009) just as the fuel subsidy as a policy affects the different sectors of the economy. This is due to the strategic role energy plays as an essential input for all productive sectors. Thus, any price change transmits a multiplier effect throughout the economy as transportation costs and cost of production changes. The framework of the CGE model provides a logically consistent way to look at problems involving more than one economic agent (Adenikinju and Falobi, 2009). This and other earlier discussed advantages, makes CGE model a useful and appropriate methodology for this study.

2.8. Summary of some Empirical Studies

Table 2.1 below present a tabular summary of some selected empirical studies in the area of energy Subsidy impacts showing their objectives, study area, methodology and key findings.

Table 2.1a: Summary of Selected Empirical Studies

S/N	Author/Year	Study Area	Objectives	Methodology	Findings/Critique
1.	Abraham (2013)	Nigeria	Using fuel subsidy removal as a possible policy option for mitigating climate change.	Narrative Method	The policy shift may have welfare implications in the short run, in the long run; it can drive green growth and enhance sustainable development. **It was descriptive in analysis.**
2.	Whitley (2013)	Global study	Examined the relationship between fossil fuel subsidies and the climate.	Descriptive	Cutting down subsidies will help reduce carbon emissions. **Nigeria was not included in study and was descriptive in nature.**
3.	Holton (2012)	Panel study	Assessed the effects of fossil-fuel subsidies on growth, the environment and inequality.	Panel Analysis	Subsidies have negative effect on GDP per capita and income equality while also increasing emissions. **Adopted single equation method of analysis**
4.	Adenikinju and Omenka (2013)	Nigeria	Analysed potential trade-offs associated with domestic response to 60 percent increase in international fuel price.	Recursive Dynamic CGE	Negative impacts of removal on macro-economy are less with gradual reduction with rural poor households been the worst hit. **Focused on economic and welfare impacts.**
5.	Adenikinju *et al.* (2012)	Nigeria	Explored the economy-wide impacts of pursuing a green growth strategy using carbon tax policy.	Energy-Environment CGE	Achieving a green growth strategy will yield economic and social costs, depending on how energy tax revenue is disbursed. **Focused on tax and not subsidy.**
6.	GSI (2012)	Asian-Pacific Economies	Provides an analytical framework on how the reform of fossil fuel subsidies can reduce waste and CO_2 emissions.	Analytical	A framework that will adequately reform these subsidies and at the same time reduce emissions from waste. **Nigeria was not included in the study and was essentially analytical.**

S/N	Author/Year	Study Area	Objectives	Methodology	Findings/Critique
7.	UNDP (2012)	Vietnam	Assessed role of reform of fossil fuels in Vietnam.	Analytical	Analysis will enable transition to a more competitive and greener growth economy. **Focus was on Vietnam**
8.	Mukherjee and Chakraborty (2014)	131 countries	Assessed relationship between fiscal subsidies and CO_2 emissions.	Panel data regression	Higher proportional devolution of budgetary subsidies leads to higher CO2 emissions. **Used single equation modeling**.
9.	Gerlagh and Zwaan (2006)	Global Study	Explored options and instruments for significantly reducing CO_2 emission.	Dynamic top-down economy-energy-environment model.	Recycling of carbon taxes to support renewables was found to be the most cost-efficient way to address the challenge of global climate change. **Nigeria was aggregated with other African countries in the modeling.**
10.	Morgan (2007)	Global Study	Investigates how energy subsidies affect energy investment and GHG emissions.	Descriptive	Reform of these subsidies can play a key role in government efforts at mitigating GHG emissions, with strong political will and compensating measures. **Analysis was Descriptive.**
11.	Ellis (2010)	Reviewed six major studies.	Considers analytical approaches often used to estimate economic, environmental and social impacts of fossil fuel subsidy removal.	Review/ Explanatory	Supports the view that reform of subsidies can achieve significant economic and environmental benefits. **Approach was basically analytical**
12.	Allaire and Brown (2012)	United States	Identified energy subsidies that increases or reduces carbon emissions.	Simulation Procedure	Subsidy on the energy sector influences the level of carbon emissions mainly through the energy markets. **Used partial modeling**
13.	Shafie-Pour and Farsiabi (2007)	Iran	Analysed economic and environmental implications of reducing energy subsidies.	Environmental Cost-benefit Analysis (ECBA) model.	Evidence shows that reducing energy subsidies for each energy form is considerably beneficial. **Focus was on Iran**
14.	Koplow and Dernbach (2010)	United States	Examined previous studies of fuel subsidies within the US and how they influence level of emissions.	Descriptive Analysis	Reforming these subsidies can reduce impact of climate change. **Adopted descriptive analysis and was not based on Nigeria.**
15.	Guiyang (2007)	China	Analysed prospect of energy subsidy reform in providing economic incentives for climate change mitigation.	Descriptive	Suggests that China should emphasise positive impact of subsidy policies which will promote climate change mitigation. **Analysis was descriptive and focused on China.**

S/N	Author/Year	Study Area	Objectives	Methodology	Findings/Critique
16.	Larsen and Shah (1992)	World Study	Provided evidence on fuel subsidies and effect on emissions.	Uses a simple model	Removing these subsidies could cut down CO_2 emissions by 9 % in some countries. **Focus was on the developed economies**
17.	Larsen (1994)	World Study	Extends Larsen & Shah (1992) by incorporating inter-fuel substitution in the model.	Includes inter-fuel substitution in the empirical model.	Removal of the subsidies can reduce global CO_2 emissions by 7 percent. **Focus was on the developed countries**
18.	Umar and Umar (2013)	Nigeria	Measured direct welfare impact of high fuel prices on different socio-economic groups.	Partial equilibrium approach.	Reduction in welfare is larger for the middle 40 percent compared with the top and bottom 20 percent. **Focused on welfare effect.**
19.	Siddig *et al* (2014)	Nigeria	Evaluated impact of removing oil import subsidies on poverty.	CGE (*MyGTAP*).	Accompanying a subsidy reduction with a transfer of income to poor households alleviate some of the negative impacts. **Focus was on poverty.**
20.	Bao and Sawdon (2011)	Vietnam	Assessed environmental implications of changes in fossil fuel pricing policy and imposition of tax.	CGE	Reducing fossil fuel subsidies significantly reduces carbon emissions. **Analysis based on Vietnam.**
21.	Widodo *et al* (2012)	Indonesia	Analysed the impact of fuel subsidy removal on the economy.	CGE	Subsidy reform affects the income spread of firms, government and households. **Study did not cover the environment.**
22.	Jiang and Tan (2013)	China	Analysed how the removal of energy subsidy affects general price level.	Input-output model	Removal has significant impact on energy-intensive industries, consequently pushing up general price level. **Study did not cover the environment.**
23.	Bahta (2014)	Free State Province (South Africa)	Investigated the impact of international oil price increase on the economy.	CGE	Percentage of labour demand of selected industries decreases. GDP equally decreases by 0.01 percent. **Study was not based in Nigeria did not cover the environment.**
24.	Anwal and Mamman (2012)	Nigeria	Investigated the impact of petroleum products supply and domestic prices on domestic distribution.	VAR model and OLS estimation	Domestically refined petroleum and petroleum prices were insensitive to quantity distributed in the long run. **Study did not cover the environment.**
25.	Efobi *et al* (2012)	Nigeria	Effect of change in fuel price on macroeconomic variables such as exchange rate, inflation and money supply.	Chow test and VAR approach	Observed a sharp reaction of the macroeconomic variables to fuel subsidy reduction. **Study did not cover the environment.**

S/N	Author/Year	Study Area	Objectives	Methodology	Findings/Critique
26.	Adagunodo (2013)	Nigeria	Evaluates equity and efficiency implications of Welfare effects of energy (petroleum products pricing) reform.	Marginal social cost Approach	Reduction in price led to reduction in consumption of petrol by households. **Study did not cover the environment.**
27.	Oladipo (2012)	Nigeria	Impact of fuel subsidy removal on crime.	Survey research design (Questionnaire)	Both rate of inflation and crime within Nigeria is still alarming. **Study did not cover the environment.**
28.	Hong *et al* (2013)	China	Analysed how to achieve economic and environmental gains from energy subsidy reform.	Hybrid energy input-output model.	Removal reduces demand in various sectors such as electricity, coal, gas and oil. **Focus was on China.**
29.	Charap *et al* (2013)	60 countries	Explored the degree of responsiveness of energy consumption to changes in energy prices.	Panel analysis of cross-country data	Countries can reap short and long term gains, but the former will be shorter. **Study did not cover the environment.**
30.	Lin and Jiang (2010)	China	Estimated energy subsidies and the impact of its reform.	Price-gap Approach and CGE model	Significant fall in energy demand/emissions. **Study did not cover the environment.**

Source: Compiled by Author

2.9. Summary of Main Issues

The review done was able to show that the analysis of the impact of energy subsidy on the environment is dependent on the definition of the concept of subsidy and the measure of environmental quality. This is in addition to the methodology adopted and the region covered. It was observed that the issue of driving environmental quality (green growth) and tackling climate change is globally recognised and the reduction of carbon emission from fossil fuel is a viable means. The country-specific analysis seemed to be more detailed and in-depth compared to the multi-country analysis. Furthermore, results were based on the region covered, category of subsidy, size and measurement of energy subsidy and the underlying assumptions of the models.

CHAPTER THREE

ENERGY SUBSIDY AND THE NIGERIAN ECONOMY: SOME STYLISED FACTS

3.1 Preamble

This section presents an overview of the structure of the Nigerian economy and the energy sector within the context of the objective of this study. This is important in order to understand the extent to which a change in policy in terms of the removal of fuel subsidy brings about changes in different sectors of the economy. Thus, understanding the features and structure of the Nigerian system is essential. It will also present background information or what can be termed stylised facts on the Nigerian economy especially as it relates to the context of this study. Some of the variables of interest will include fuel price and some measures of environmental quality (carbon emissions). In addition, this chapter examines Nigeria's experience with energy reform, particularly energy pricing while assessing the transmission mechanism through which fuel subsidy impacts the economy (through household effects and the environment).

3.2 The Structure of the Nigerian Economy

The Nigerian economy regarded as the biggest economy in West Africa, was declared the largest in Africa following South Africa after the rebasing of the economy in 2014. In August 2016, South Africa overtook Nigeria as the largest economy in Africa due to falling oil prices and dwindling government revenue in Nigeria. However, the IMF World Economic Outlook for October 2016 calculated Nigeria's GDP to be $415.08 billion from $493.83 billion in 2015 while South Africa's GDP was put at $280.36 from $314.73 billion in 2015 (Vanguard, 2016). The rebasing of the economy involves the re-benchmarking or change of the base year from 1990 to 2010 to give an up-to-date measure of the economy. Also, the rebasing brought about an increase in the number of industries used in the calculation of GDP. Prices and structure of the economy grow over time, thus there is a need to reflect these changes in data and statistics used in economic planning. The rationale is to enhance the reliability and robustness of planning and investment decisions.

According to Masetti (2014), this rebasing process raised the economy by about 75 percent with a nominal GDP of US$451 billion as against South Africa's US$382.3 billion. The rebasing exercise covered the revision of the classifications of economic activity in the National Accounts. It recognised the significant contribution of the telecommunications and entertainment industry. This has shown that the economy is more diversified than what is being reported and the structure of the economy has changed significantly.

In terms of structure before the rebasing, the Nigerian economy was dominated by two main sectors, agriculture and crude oil. Broadly, it was structured into five sectors namely Agriculture, Industry, Building and Construction, Wholesale and Retail trade and Services. Ezirim, Okeke and Ebiringa (2010) also segregated the economy into three main areas namely primary sector (agriculture and mining); secondary sector (manufacturing and construction) and the tertiary sector (made up of mainly service activities ranging from transportation, distribution, wholesale, hospitality, finance, insurance, real estate). With respect to the sectoral classifications, agriculture was the mainstay of the economy in the 1960s and early 1970s and it contributed significantly to the economy in terms of employment and revenue generation.

According to World Bank (1996), in the 90s, the sector provided employment for about 75 percent of the population, contributed about 97 percent of food supply, 68 percent of GDP and 78 percent of foreign export earnings. However, the discovery of oil in Nigeria in 1956 at Oloibiri (Niger Delta) resulted in a decline in the contribution of agriculture and the sector lost its prominent position to the oil industry. This then ushered in the oil boom of the 1970s when oil was discovered in commercial quantity and exported, increasing government revenue. Nigeria been blessed with a vast amount of petroleum resources which is said to be one of the best quality in the world, rapidly prospered from oil earnings. This made the sector play a vital role in the economic and political destiny of the nation (Oyeyemi, 2013). Tables 3.1 and 3.2 show the structure of the contribution of each of the key sectors to real GDP for the period 1981 to 2014.

Table 3.1: Contribution of Sectors to GDP (in percentage) for 1981-2013 (Average*)

Year	Agriculture	Industry	Building & Construction	Wholesale & Retail trade	Services	Total
1981-1989	38.23	32.86	1.63	14.66	12.62	100.00
1990-1999	40.45	31.74	1.35	13.61	12.85	100.00
2000-2005	41.65	29.18	1.42	13.02	14.72	100.00
2006-2013	40.59	20.61	2.00	18.38	18.42	100.00
1981-2013	40.40	26.85	1.67	15.62	15.46	100.00

Source: CBN Statistical Bulletin (2014)
Note: *Based on old classification of 33 activity sectors before the rebasing exercise

Table 3.2: Contribution of Sectors to GDP (in percentage) for 2010-2014 (Rebased*)

Year	Agriculture	Industry	Construction	Trade	Services	Total
2010	23.89	22.03	2.88	16.47	34.73	100.00
2011	23.35	22.39	3.16	16.76	34.34	100.00
2012	23.91	21.74	3.32	16.44	34.59	100.00
2013	23.33	20.59	3.59	16.62	35.87	100.00
2014	22.90	20.54	3.82	16.57	36.17	100.00
2010-2014	23.46	21.41	3.38	16.57	35.18	100.00

Source: Computer by the Author from the CBN Statistical Bulletin (2014)
Note: *Based on new classification of 46 activity sectors after the rebasing exercise.

Table 3.3: Nigeria's Total External Trade (in percentage)

Sector	1981	1990	2000	2003	2005	2009	2010	2011	2012	2013	2014
Oil	45.26	72.43	73.08	65.63	79.00	65.13	64.72	66.20	69.56	67.05	60.52
Non-oil	54.74	27.57	26.92	34.37	21.00	34.87	35.28	33.80	30.44	32.95	39.48

Source: Computed from CBN Statistical Bulletin (2014)

Table 3.4: Trends in Selected Macroeconomic Indicators in Nigeria (1981-2014)

Year	GDP Per capita growth (annual %)	% of oil* in total GDP	% of oil in total revenue	% of non-oil in total revenue
1981	-13.13	29.09	64.41	35.56
1991	-0.62	27.78	81.86	18.14
2000	5.32	25.91	83.50	16.50
2003	10.35	26.53	80.55	19.45
2009	6.93	16.29	65.89	34.11
2010	7.84	15.39*	73.88	26.12
2011	4.89	14.95*	79.87	20.13
2012	4.28	13.64*	75.32	24.67
2013	5.39	11.24*	69.77	30.23
2014	6.31	10.44*	67.47	32.53

Source: WDI (2015), CBN Statistical Bulletin (2014).
Note: Data for GDP per capita growth was from WDI (2015), while other data are from CBN Statistical Bulletin (2014), 2010-2014 figures are rebased
Oil* is crude petroleum and natural gas

As oil was discovered in commercial quantity, it began to dominate the Nigerian economy. Oil accounted for more than 90 percent of exports in Nigeria, contributes 40 percent of GDP, 95 percent of foreign exchange earnings and about 70 percent of government revenues (Ezirim *et al*, 2010). This is evident from the figures in Tables 3.3 and 3.4 which show that the economy is mainly dependent on revenue from crude oil. Percentage of oil revenue in total revenue averaging 70 to 75 percent as against the non-oil sector contribution of about 28 percent average, further reflects the fiscal dependency of the economy. The share of agriculture in total export began to decline continuously from about 89.7 percent in 1960 to about 2.2 percent in 1985 and increased marginally to about 4.1 percent in 2005. The contribution of the oil and gas sector fell in the period 2006 to 2010 from about 25 percent in 2005 to 16 percent in 2010 mainly due to the crisis in the Niger Delta region. It however picked up later in 2011 when normalcy returned to the region. The performance of the manufacturing sector which peaked at 9.89 percent in 1981 reflected government's effort at enhancing productivity through the import substitution policy. However, as stated by Ezirim *et al.* (2010), this policy was unable to sustain growth over time due to the dependence on import of machineries, equipments and raw materials. It rather made the manufacturing sector volatile to external shocks from the international economy.

Nigeria's economic growth has averaged about 7.4 percent annually beginning from the year 2012 driven mainly by the non-oil sector, particularly telecommunications sector, entertainment, construction, wholesale, retail trade, hotel and restaurant services, manufacturing and agriculture (African Economic Outlook, 2012). However, despite this impressive performance (at least in terms of growth), it had been without jobs and with increased poverty, making many term it "jobless growth". According to Ezirim *et al.* (2010), even though the economy had undergone some fundamental structural changes in the last four decades, these changes are yet to bring about appreciable improvements in terms of growth and development. The dualistic nature of the economy where there is the co-existence of the formal and informal sector is also important. The informal sector has been argued to perform a significant role in the economy as it is a huge sector but difficult to measure. Evidence according to Ezirim *et al.* (2010) suggests that the informal sector represents an estimated 40 percent to 50 percent of economic activities in Nigeria.

In an attempt to enhance the strategic competition of the economy especially as it relates to attract FDI, the President Musa Yar' Adua administration introduced the vision 20:2020 in 2009 which serves as the economic transformation blueprint aimed at making Nigeria one of the top 20 economies in the world by year 2020. It involves growing the economy consistently at the rate of 13 percent and the GDP moving from current position of about $170 billion to $900 billion (Ezirim *et al.*, 2010). This was continued by the President Goodluck Jonathan administration as contained in the transformation agenda and continued by the present President Buhari's administration.

3.3 The Nigerian Oil Sector

The oil sector in Nigeria provides a strong fiscal linkage with the rest of the world. According to Cantore *et al.* (2012), oil contributed about 70 percent to government budget in 2011 showing it as a means for implementing public policy. It contributes significantly to the economy in terms of its contribution to GDP, foreign exchange earnings, government revenue, composition in export and employment generation. For example, in 2013, the sector accounted for around 67 percent of government revenue and about 95 percent of foreign earnings (CBN Statistical Bulletin, 2014). Oil being the mainstay of the economy, had played a key role in shaping the economic and political destiny of the country (Odularu, 2008). This sector has contributed to the economy both positively and negatively. On one hand, it provides a stabilising effect on government revenue; while on the other hand, it has created environmental problems and conflicts. This had resulted in deprivation of means of livelihood coupled with other economic and societal factors (Odularu, 2008).

The Nigerian oil sector, which is a major part of the mining and quarrying sector, had three sub-sectors. They are the upstream (exploration), downstream (distribution) and natural gas sub-sectors. The downstream sector had been the most challenging and problematic (Odularu, 2008) as the operations of the sub-sector is always marked with disruption of supply and scarcity of petroleum products. This led the Federal Government to take steps towards its deregulation in 2003. This has, however, been affected by various controversies.

In terms of production, Nigeria currently has four refineries with a combined capacity of 445,000 barrels per day (bpd). Two of the refineries are located in Port-Harcourt, one in Warri and one in Kaduna. The two refineries in Port-Harcourt established in 1965 and 1989 have a combined capacity of 210,000 bpd. The other two refineries in Warri and Kaduna were established in 1978 and 1980 respectively. The former presently has a capacity of 125,000 bpd while the latter’s production capacity is 110,000 bpd. However, as stated by Odularu (2008), the country still depends on imported refined fuel as the combined capacity of these refineries exceeds domestic consumption. The IMF had estimated that demand for refined oil products in Nigeria is growing in the midst of a booming economy and will likely increase to 7.1 percent from 2013 figure of 6.4 percent. The low performance of these refineries is often attributed to poor funding, lack of maintenance and low level of investment.

3.4 Nigerian Government Policy on Emission Reduction

The Nigerian government had over the years shown commitment towards reducing greenhouse gas emission as a viable means in tackling climate change impacts. The beginning of 1992 marked a strategic step with the establishment of the Federal Environmental Protection Agency (FEPA). There had also been various policies targeted towards the reduction of carbon emission levels especially from the flaring of gas through the exploration of crude oil. This is given the fact that gas flaring is the highest contributor to greenhouse gas emission in Nigeria (IEA, 2014). Furthermore, towards the drive for the achievement of Vision 20:2020, the Nigerian government had articulated a number of policy targets so as to cut down emissions from fossil fuel. This intention was documented in the World Bank report where three key sectors (agriculture, energy and transport) were identified as necessary targets in reducing these emissions. The effort of the government is usually convened by the Department of Climate Change, Federal Ministry of Environment in Abuja.

The department is responsible for the "co-ordination of activities towards the national implementation of the Climate Change convention and the Kyoto Protocol" (Awojuola, 2015). It also serves as a unit of the Federal Ministry of Environment which supports the ministry in carrying out its various activities by working closely with other relevant supporting agencies namely non-governmental organisations, private sector, the academia and other government organisations. This arrangement takes place under the committee known as the Inter-ministerial Committee on Climate Change. According to Awojuola

(2015), the Nigerian government addresses the challenge of carbon emission under three major strategies. These includes strengthening of various institutions, capacity building and the execution of different projects such as CDM projects, GHG inventory system, largest gas gathering programme in Africa and mandatory reduction of emissions by 20 percent by Joint Ventures.

Furthermore, the unit engages in public awareness programmes, training of stakeholders as well as beneficiaries both domestic and internationally. Even though efforts at implementing the expectations of the Kyoto Protocol are at a slow pace, a lot still needs to be done compared to other African countries. According to Ibikunle (2006), government's commitment to reducing carbon emissions in Nigeria is not only related to gas flaring reduction but also through the promotion of the use of cleaner and more environmentally friendly fuel. However, in driving this low-carbon growth strategy, there are usually constraints. One major area of challenge is the issue of finance in achieving the various plans, operations and strategies as set by the stakeholders. This is a similar experience globally in the fight against climate change impacts, especially as it relates to climate financing.

Another aspect of limitation had been technology adoption. This is in terms of localising foreign technology as developed by the industralised countries, especially in the African context. A good example is the "mandatory fuel blending" technology as observed in the Southern African region. This technology entails a blend of renewable energy (for example, ethanol) with fossil fuel. It will reduce the amount of emissions from the burning of fossil fuel especially from motor vehicles. Thus, fuel blend of *E15* will contain 15 percent ethanol and 85 percent fossil fuel. In Nigeria, there were also plans to recreate a variant of the fuel blending. For example, Ibikunle (2006) stated that there is government initiative on the development of renewable energy through the introduction of biomass ethanol programme. This is carried out through the production of fuel grade ethanol which is then blended with gasoline or petrol. The product of this process, which is called "green petrol" is expected to reduce the volume of CO_2 released to the atmosphere. This green fuel or petrol which is also known as biofuel is a type of fuel refined or processed from plants and animal materials and assumed to be more environmentally friendly than the fossil-fuel based energy sources. However, as laudable as this plan is, it had been very challenging for many of the countries to implement and domesticate the technology due mainly to institutional and legal constraints. It is believed that with appropriate policies in place, efforts at reducing emission levels will yield good result.

3.5 Stylised facts on the Energy Sector in Nigeria

From historical facts, it is known that oil was discovered in Nigeria at Oloibiri in Niger Delta in the year 1956 by Shell-British Petroleum. With this, the first exploration took place in 1958 making Nigeria to join the ranks of oil producers producing 5,100 barrels per day (Onyemaechi, 2012). In 1971, Nigeria became a member of OPEC and in 1977; it established the Nigerian National Petroleum Corporation (NNPC). The country was identified as the 12th largest producer of crude oil in the world, producing 2.5 million barrels of sweet light crude oil per day as at 2011 (IEA, 2011). Nigeria is also currently the 4th largest oil exporting country in the world and Africa's biggest oil producer with about 2.2 million bpd (IEA 2013 figures). As at 2009, about 98 percent of its crude oil was exported. In spite of the abundance of oil in the country, Nigeria still largely imports about 80 percent of its refined oil due to lack of adequate capacity to refine (Cantore *et al.,* 2012). Thus, the country still imports a large portion of its petroleum products due mainly to underinvestment in the energy sector and insufficient energy infrastructure. In Nigeria, government had attempted series of reform in the oil and gas industry. Fuel subsidy is a pricing policy issue and government has been involved in regulating fuel prices by allowing households to pay below international oil price.

3.5.1. Stylised fact 1: Gasoline constitutes the highest form of energy consumption

The consumption of petroleum products continued to be on the increase in the past years due to economic growth (Adagunodo, 2013). Four main forms of energy consumed in Nigeria include PMS also known as petrol or gasoline, diesel (AGO), kerosene (DPK) and gas (LPG). Petrol consumption as represented with the sales in the domestic market by PPMC is the highest compared to other forms of energy consumption in Nigeria and this is presented in figure 3.1. Lower prices due to subsidy and lack of alternative for petrol are likely factors for this increase. The 10-year analysis period from figure 3.1 evidently shows that the consumption of petrol was high throughout compared to diesel and kerosene as petroleum products. The refineries are only able to meet about 20 percent of fuel demand, while the balance of 80 percent is imported to avoid scarcity.

According to ADR (2012), Nigeria has been subsidising fuel since the 1970s. Government had been controlling petroleum prices in the domestic market since 1973 when the government took over from the private oil companies (Adagunodo, 2013). The nature of the demand and supply of fuel in Nigeria is such that it is inelastic and subject to a subsidy and price fixing effect (Adagunodo, 2013). This implies that alternatives to the use of gasoline, kerosene and diesel by consumers, is difficult. The Nigerian government instituted some consumption and production related policies and of the consumption-related policies, the fuel subsidy policy stands out. The goal of this policy is to support local consumption of petrol which necessitates the government to make provision for a certain percentage of the marginal cost of supplying the petrol (Onyemaechi, 2012). This was intended to help avoid disruption to the distribution of petrol while also ensuring that the transportation network is as effective as possible.

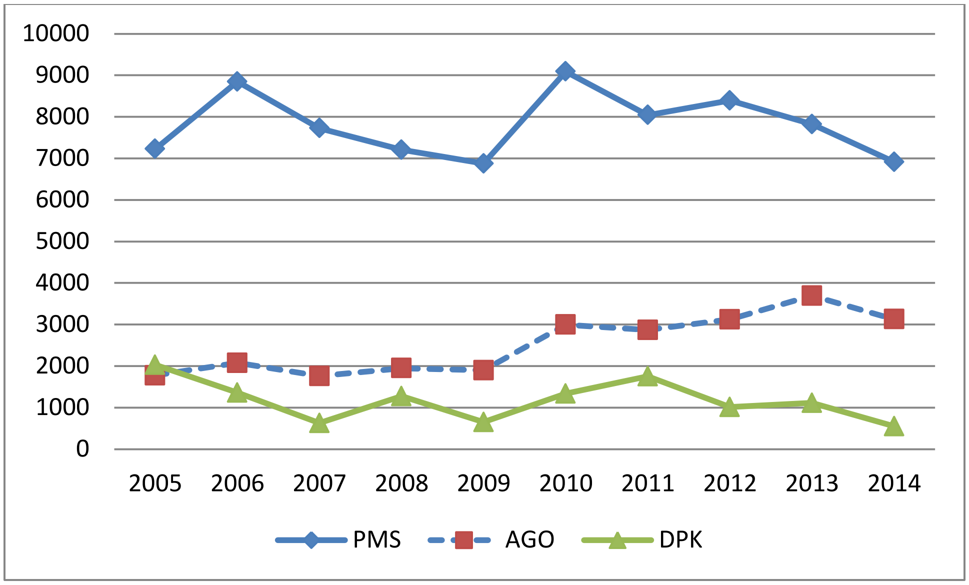

Figure 3.1: 10-Year PPMC Domestic Petroleum Product Sales in Nigeria (‘000,000 litres)
Source: NNPC Bulletin (2014)

3.5.2. Stylised fact 2: Petrol subsidy had been increasing and is unsustainable

Ordinarily, petroleum product prices in Nigeria ought to be theoretically derived from international crude oil prices. In other words, the import price should be reflected (Onyemaechi, 2012). However, this has not always been the case for different reasons such as socio-political reasons. What always happens is that government decides to subsidise price of petrol so as to make it cheaper and pay the difference between international price and domestic price. This subsidy payment by government has, however, on the average been on the increase over the years as shown in Figure 3.2. Thus, the assertion is that, these payments continue to rise yearly and with dwindling government revenue, they are unsustainable. Cantore *et al.* (2012) attributed these increases to be partly due to increasing oil prices in the international market and depreciating exchange rates.

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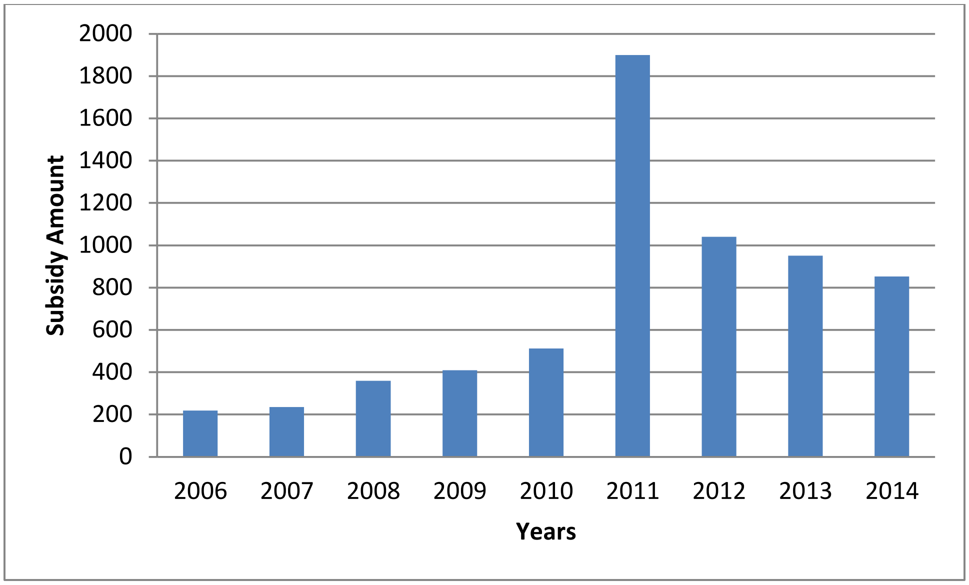


Figure 3.2: Petrol Subsidy in Nigeria (₦billion) 2006-2014

Source: NNPC Bulletin (2014), WDI (2014), Author's Estimate

The payment reached a peak of ₦1.9 trillion in 2011 which was revised from ₦1.3 trillion according to the NNPC Statistical Bulletin (2014). This figure reduced to about ₦1.04 trillion in 2012 and further to ₦951 billion and ₦853 in 2013 and 2014 respectively. It is important to note that these figures are estimates based on the subsidy paid on each litre of petrol and total petrol consumption. This is evident from indications that the amount is likely larger than the reported as there were supplementary payments made to marketers during the year. This has been a critical issue in Nigeria, especially as it relates to the actual amount paid on subsidy. Also, it was observed that different institutions of government provide varying figures.

Furthermore, payment of subsidy had been argued to divert resources from priority sectors such as health, education, infrastructure and communication. An analysis of the 2013 budget showed that provision made for fuel subsidy constituted about 20 percent of the entire budget. The allocation for fuel subsidy was also about 10 times more than the appropriation for agriculture and rural development (₦81.41 billion), thrice the amount for health (₦279.23 billion) and twice the allocation for education (₦426.53 billion).

These are sectors which are expected to propel economic growth. However, government had been making efforts at eliminating these subsidies through strategic reforms of various agencies. The reform agency had helped the PPPRA to eliminate previous manipulation of the bill of laden and generate savings for the government. The reality that the subsidy payment is not sustainable eventually led the government to stop subsidy on petrol in May 2016 which then placed petrol price at ₦145 per litre. This is reflected in the PPPRA revised template as shown in Table 3.5 where provision for fuel subsidy had been removed. This is expected to resolve the problem of scarcity experienced across the country, reduce smuggling to neighbouring countries and attract more investment to the energy sector.

Table 3.5: PPPRA Pricing Template-May 2016

S/N	Cost Element	Naira/litre
1.	C+F	111.30
2.	Lightering Expenses	4.56
3.	NPA	0.84
4.	NIMASA Charge	0.22
5.	Financing	2.51
6.	Jetty Thru'Put Charge	0.60
7.	Storage Charge	2.00
	Total Landing Cost	122.03
	Distribution Margins	
8.	Retailers	6.00
9.	Transportation Allowance (NTA)	3.36
10.	Dealers	2.36
11.	Bridging Fund	6.20
12.	Marine Transport Average (MTA)	0.15
13.	Administrative Charge	0.30
	Total Margins	**18.37**
	Total Cost	**140.40**

Source: PPPRA Website

3.5.3. Stylised fact 3: Prevalence of Petrol subsidies encourages Smuggling activities

In addition to the large fiscal burden of these subsidies, they also encourage smuggling of energy products across the border which is due to the relative low price of petrol in Nigeria. This is evident from figure 3.3. The subsidisation of fuel price reduces the price of petrol compared to neighbouring countries, this result in dealers smuggling fuel at cheap prices from Nigeria to neighbouring countries such as Benin, Cameroun, Chad, Ghana, Mali, Niger, Togo, and others. They are sold at higher prices in those countries thereby creating scarcity in the domestic economy. Table 3.5 compares petrol price in US$ per litre in Nigeria with some selected countries. It is observed that Nigeria has the lowest price for petrol. Interestingly, as pointed out by Isihak and Akpan (2012), Nigeria unlike many other countries, despite subsidies, does not have tax element in their retail price.

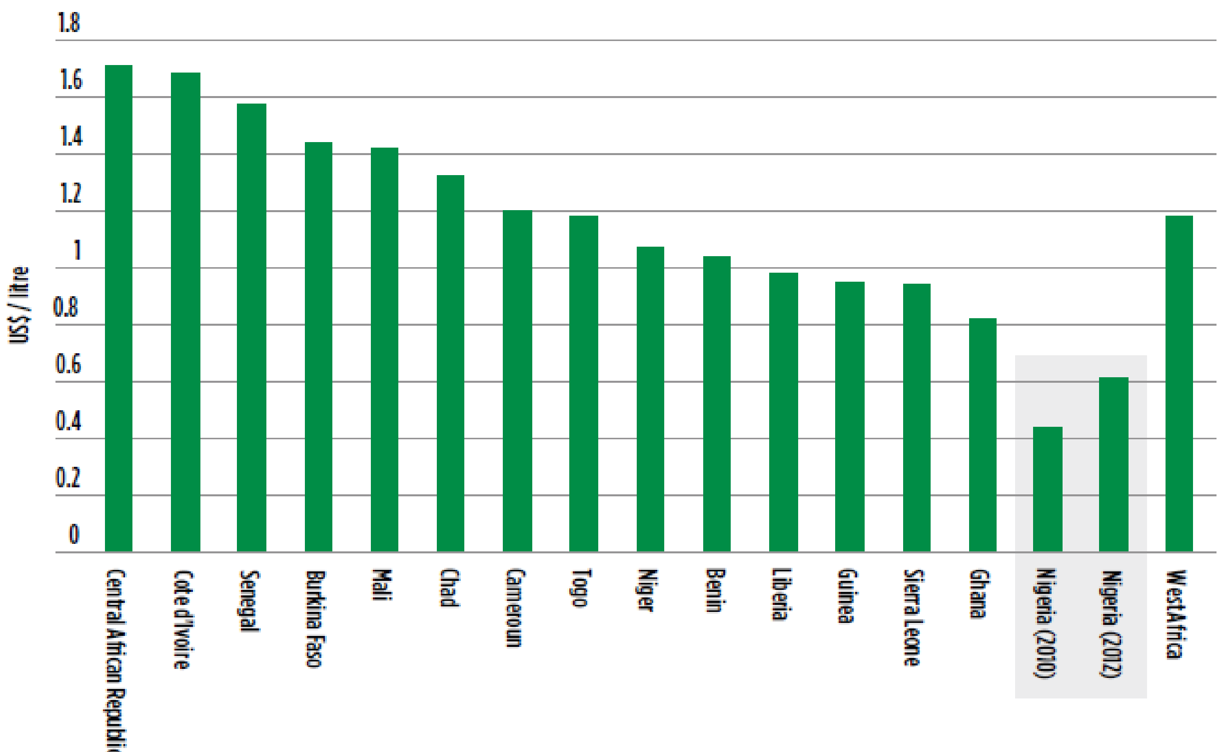


Figure 3.3: Fuel Price in Neighboring Countries and West Africa Region
Source: CPPA and IISD Citizen's Guide to Energy Subsidies in Nigeria

Table 3.6: Petroleum Product Prices in Selected Countries in US$ per litre (2014 Figures)

Country	Retail fuel price	Gasoline	Diesel	Tax as % of Gasoline Retail Price
Cameroon+	Ad-hoc	1.24	1.14	-
Gabon*	Ad-hoc	1.02	0.90	43.2
Ghana+	Automatic	1.06	1.03	47.5
Kenya+	Liberalised	1.21	1.07	26.6
Nigeria*	Ad-hoc	0.56	0.84	None
India+	Ad-hoc	1.10	0.91	55.1
Philippines+	Automatic	1.05	0.82	25.9
Russia*	Liberalised	0.81	0.75	30.8

Source: World Bank Online Database (2014)
Note: +net oil importer and *net oil exporter

3.4.4. Stylised fact 4: Fuel Price had continued to be on the increase despite Subsidy

There have been many attempts to reduce subsidies on petroleum products in Nigeria, and these attempts had at times, resulted in long public protests and policy reversal in the form of cancellation or reduction of the planned price increases. The trends in petroleum product pricing in Nigeria has a long history as indicated in Table 3.6. Adagunodo (2013) described different price increases by different regimes in Nigeria as an attempt towards the removal of fuel subsidy. In 1976, fuel price was raised from 8.45 kobo by General Yakubu Gowon to 9 kobo by the late General Muritala’s Administration. It then became 15.37 kobo on 1st of October, 1978 and this change was made by General Olusegun Obasanjo. There was another hike on April 20, 1982, when the price became 20 kobo.On March 31, 1986, General Ibrahim Babangida increased pump price of fuel to 39.5 kobo and in April 1988, it was increased to 42 kobo per litre. On January 1, 1989, another increase was announced whereby private car were to pay 60 kobo per litre while commercial cars continued paying 42 kobo.

According to Adagunodo (2013), the failure of price discrimination policy led to the announcement of a uniform price of 60 kobo per litre on December 19th, 1989. In March 1991, the retail price of fuel was further increased to ₦0.70 per litre. In November 1993, the pump price became ₦3.25 per litre and in November 1994 it was raised again to ₦11.00 per litre. In December 1998, it increased to ₦30 and reduced again to ₦25. The price was further reduced to ₦22 per litre on June 2000. On January 1st, 2002, it was again hiked to ₦26 per litre from ₦22, later it was increased to ₦40 per litre on June 23, 2003. There was another increase in price on 29th May, 2004 to ₦50. This was later increased to ₦65 in August of the same year and hiked to ₦75 per litre on 27th May, 2007. However, following oppositions, it was reduced to ₦65 per litre in June 2007. This was sustained till January 1, 2012, when the President announced the price increasing to ₦141 per litre. After protests in various parts of the country by organised labor and civil societies that led to a shutdown of the economy making the nation loose close to ₦300 billion in the five days strike; government agreed to lower the price to ₦97 per litre. Furthermore, given the decline in crude oil price, government further reduced fuel price to ₦86 in April 2015, however, under a new administration and the need to attract investment to the energy sector, government eliminated subsidy on petrol and this brought the price of petrol to between ₦140 and ₦145. These are represented in Table 3.6.

The Petroleum Industry Bill (PIB)

Another measure of reform in the energy sector in Nigeria is the Petroleum Industry Bill (PIB) 2012. This bill is the result of several attempts at reforming the energy sector for many years. It represents the harmonised version of the PIB (2008) and previous drafts. The main thrust of the act is to clearly separate the role of government in the oil industry and create a stronger vibrant National Oil company that will be internationally competitive. The objectives of the bill includes ensuring a business-friendly environment for operators; creation of adequate fiscal framework that brings about more investment in the oil sector; supporting the promotion of participation of Nigerians in the industry; creation of efficient and effective regulatory agencies; promotion of transparency and openness in the administration of petroleum resources in Nigeria; and ensure safety, health and protection of the environment in the course of oil operations (The PIB, 2012).

Table 3.7: Trend in Petrol Pump Prices in Nigeria

Date	Prices	% Change
January 1973	0.095	-
September 1978	8.9	8447.2
October 1978	15.5	73.9
April 20 1985	0.20	31.0
March 31, 1986	0.395	97.5
April 10, 1998	0.42	9.0
January 1, 1989	0.40*	43.0
December 19,1989	0.60**	43.0
March 6, 1991	0.70	16.6
November 08, 1993	5.0	614
November 22, 1993	3.25	-35.0
October 2, 1994	15.0	361.5
October 4, 1994	11.0	-26.67
December 20, 1998	25.0	127.0
January 6, 1999	20.0	-20.00
June 1, 20000	30.0	50
June 8, 1999	25.0	-16.67
June 13, 2000	22.0	-12.0
January 1,2002	26.0	18.2
June 20, 2003	40.0	53.0
July 9, 2003	34.0	-2.40
October 1, 2003	38.59 and 42.00	23.53
May 29, 2004	49.90	16.67
September 2004	53.0	8.16
September 2005	65.0	22.64
May 27, 2007	70.0	7.6
June 2007	65.0	-7.6
January 1, 2012	141.0	116.9
January 8, 2012	97.0	-31.2
April 2015	86.0	-11.34
May 2016	145.0	68.60

Source: Author's Computation and Adapted from Adagunodo (2013).
Note: *For commercial users and buyers **For all vehicles

3.6 Trend Analysis of Fuel Subsidy and Environmental Quality

Cantore *et al.* (2012) asserted that from a theoretical point of view, fuel subsidy removal is an appropriate policy tool and also will be better for the environment. However, the study pointed out that the reality is much more complex. Analyses on the impact of fuel subsidy often assess how the policy will affect economic conditions, socio-welfare of households and the environment. The belief is that with the introduction of fuel subsidy, fuel prices become subsidised, enhancing energy access for the people, stimulating growth in the economy but worsening environmental conditions through increased emission from the combustion of fossil fuel. High fluctuations in international oil price in recent years have made this subsidy payment in Nigeria unsustainable for government. As indicated in ADR (2012), fuel subsidies increased by 97 percent from US$4.31 billion in 2010 to US$9.3 billion in 2011. Isihak and Akpan (2012) used the price-gap approach in estimating subsidies on energy products (fuel, diesel and kerosene) in Nigeria and it was observed that subsidies to gasoline (fuel) had the highest amount which runs into billions of US dollars.

The IEA (2011) estimates also showed that fossil-fuel consumption subsidies globally had been on the increase in the past years and will likely continue in the coming decade. They estimated that these subsidies amounted to about US$557 billion in 2008 using the price-gap approach. The report asserted that if these subsidies were phased out by 2020, it would bring about a 5.8 percent reduction in primary energy demand at the global level. In the same vein, there would be a 6.9 percent fall in energy-related CO_2 emissions compared with a baseline in which subsidy rates remain unchanged. This shows that conscious efforts at globally phasing out fossil fuel subsidies and replacing them with more energy efficient technology will bring about economic and environmental gains.

Figure 3.4 shows a graphical representation of amount of fuel subsidy and carbon emissions from liquid fuel consumption in Nigeria from 1971 to 2011. From the graph, it is evident that subsidy payment reached a peak in 2011 with carbon emissions fluctuating in the wake of the millennium. Theoretically, it is expected that subsidy payments increases the level of carbon emissions through lower fuel prices; however, the case of Nigeria had a mixed scenario. This may be attributed to corruption surrounding the payment of the subsidy and fluctuations in environmental policy. Also, it can be explained due to the peculiar characteristics of the Nigerian economy. In effect, the green growth strategy expects the total or partial removal of fuel subsidy to translate to reductions in emission levels from fuel consumption. Emission levels indicated in the graph can still be further stabilised to lower levels if Nigeria intends to drive its green growth strategy. Many African countries such as Nigeria do not contribute much to global emissions compared to the industrialised countries and emerging economies like China. However, they are the most vulnerable to climatic change impacts and this had made it imperative to engage a low carbon economy in the drive towards sustainable development.

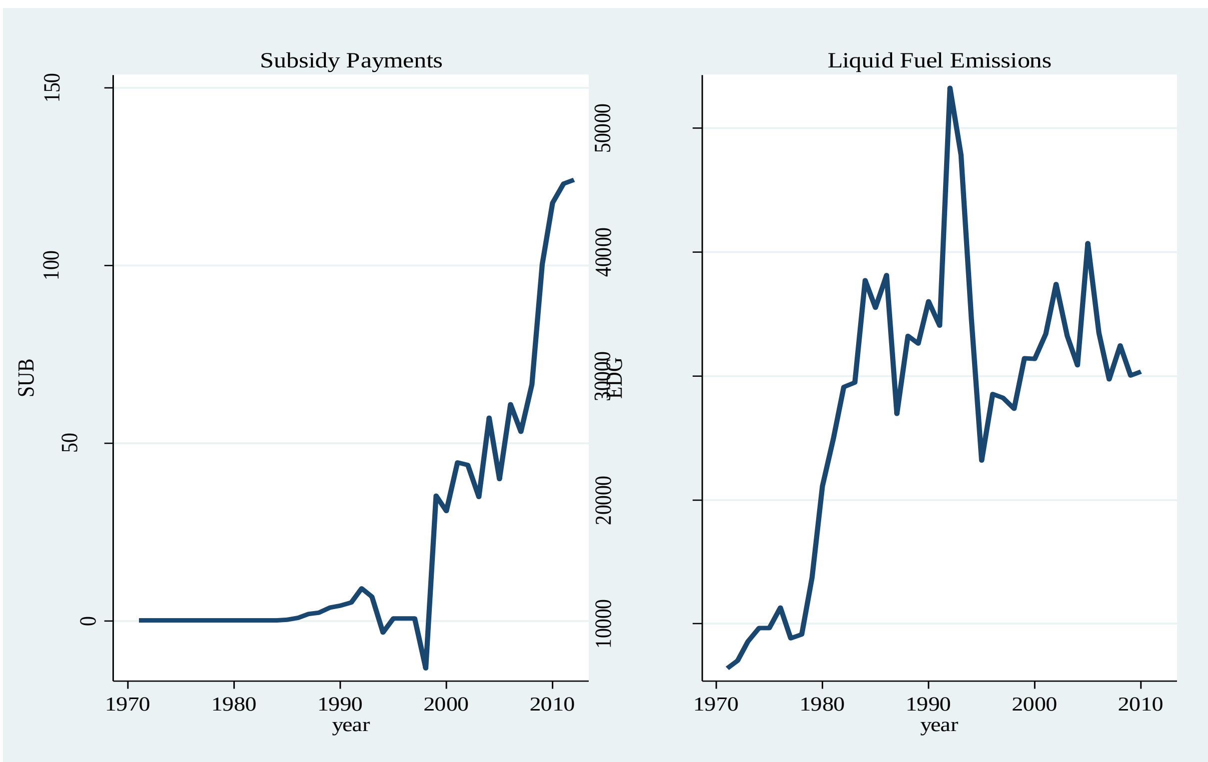


Figure 3.4: Trend Analysis of Fuel Subsidy and Liquid Fuel Emissions.
Source: Author’s Computation using e-views

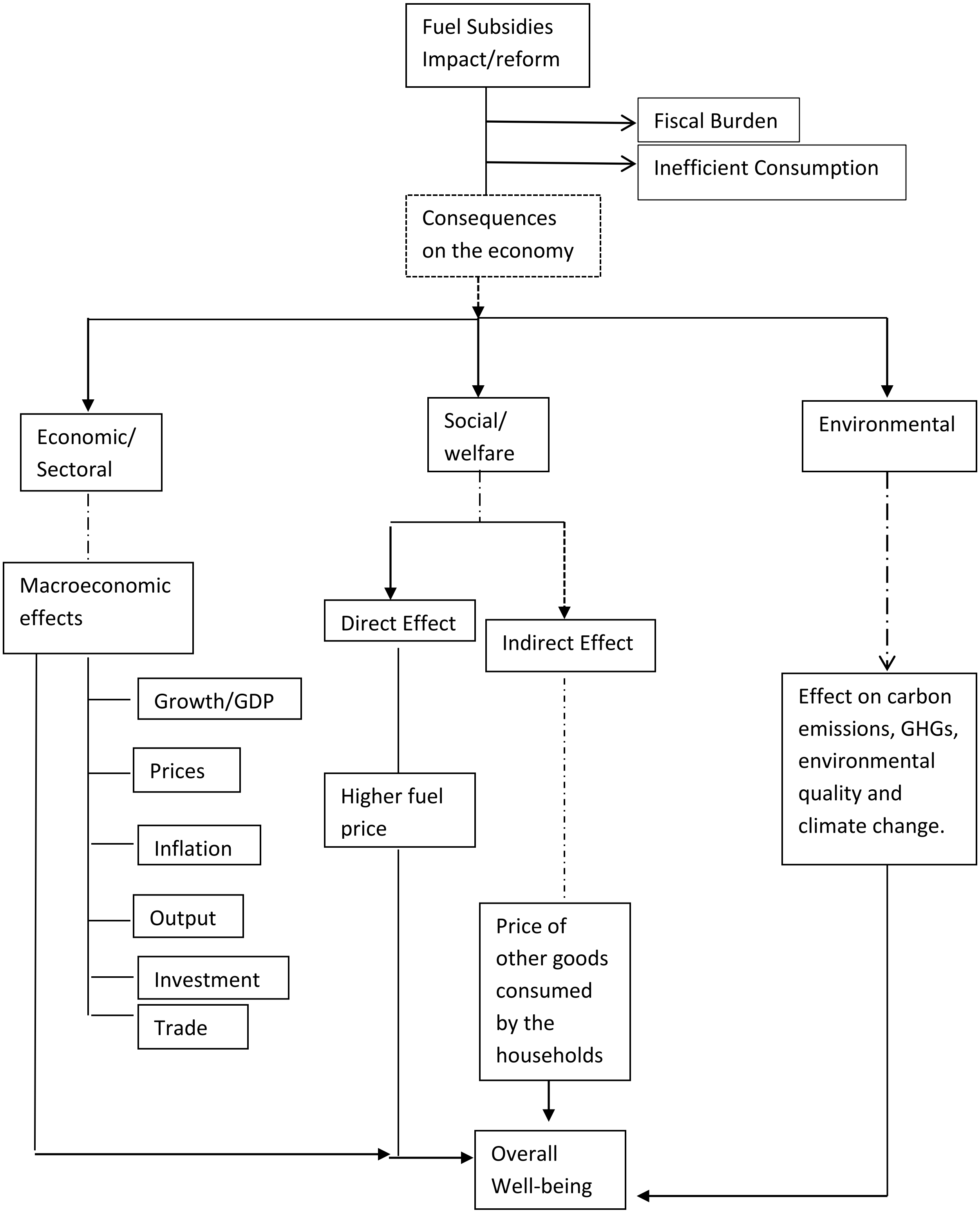


Figure 3.5: Transmission Mechanism/Conceptual Framework of Fuel Subsidy Impact
Designed by Author

Figure 3.5 presents the transmission mechanism which also explains the conceptual framework through which fuel subsidy as a policy impacts the environment. This is in terms of its effects on CO_2 emissions, greenhouse gases, thus creating environmental challenges such as climate change. The figure explains that fuel subsidy as a policy affects the economy in terms of its effects on macroeconomic variables, welfare indicators and the environment. In other words, the policy impacts the economy economically, socially and environmentally. Thus, when fuel subsidy is removed or reformed, macroeconomic variables such as government income, savings, GDP, trade and total investment improves. Also, the removal of the subsidy will improve the quality of the environment and further reduce environmental degradation. However, the effect on welfare of households tends to be negative and the removal will transmit price increases to petroleum products and other household goods. This is the channel of transmission as shown from figure 3.5.

3.7. Green Growth Strategy and Low Carbon Development

Green growth involves the making of growth processes resource efficient, cleaner and more resilient without necessarily reducing the level of economic growth (Hallegatte, Heal, Fay and Treguer, 2011). As a strategy for enhancing economic growth, it is a growth path that does not pollute the environment. An established fact in empirical literature is that the greatest sources of carbon emission are energy production, transportation and consumption (Adenikinju *et al.*, 2012). A green growth strategy as opposed to a "brown growth" must adopt efficient production technology that de-emphasise environmentally harmful source of energy such as fossil fuel. According to Adenikinju *et al.* (2012), a green growth strategy can take any of the following forms; promotion of energy efficiency across sectors, creation of incentives for firms and households to invest in less energy intensive technology or encouragement of substitutability between energy and non-energy capital. In accessing the relationship between fuel subsidy and environmental damage, the contending issue is often how subsidising fuel price contributes to increased carbon emissions. Also, energy and carbon tax are also used to drive energy efficiency towards a green economy.

Africa as a continent had been emphasising on the need to switch to Green growth path for sustainable development. Inclusive and green growth had become a reoccurring theme among African economies in the last three years. Africa's vulnerability to climate change impacts makes it essential to pursue a green growth strategy (ADR, 2012). Green growth and low carbon development involves increase in a country's economic growth with lower carbon emissions. Theoretically, the Environmental Kuznets Curve (EKC) explains that economic and industrial activities of a country would initially be accompanied by high pollution but eventually reach a threshold or breaking point and begin to fall. However, many fuel rich countries have been doomed with what Friedrichs and Inderwildi (2013) termed "carbon curse". The achievement of a low carbon development with high rates of economic growth is essential to actualise the Vision 20:2022 (Cervigni *et al.,* 2013a; Cervigni *et al.,* 2013b; Eleri, Onuvae and Ugwu, 2013) and the fight to tackle climate change impacts. This led the World Bank to present two reports titled Towards a Climate-Resilient Development in Nigeria and Low-Carbon Development Opportunities for Nigeria, to the Nigerian government in June 2013 (Cervigni *et al.,* 2013a; Cervigni *et al.,* 2013c).

The document on low carbon development opportunities provided means of how low carbon technologies and management options can be incorporated into Nigeria's developmental plan. This is to enhance growth and at the same time stabilise carbon emissions. Among the options suggested in the report is the more efficient use of the country's endowment of oil and gas resources. The ADR (2012) stated that the low carbon development can take two forms. It can either be in terms of reducing GHG emissions per unit of energy use through deployment of renewable energy technologies or by increasing output (GDP) per unity of energy input through improvements in efficiency (ADR, 2012). The report however pointed out that fossil fuel subsidies prevalent in many African countries undermine both options highlighted. It essentially does this by reducing the competitiveness of low carbon fuel options and the incentive to improve energy efficiency.

Also the need to cut down emission levels from fuel consumption through fuel subsidy is supported by the result of the study done by Friedrichs and Inderwildi (2013). The study highlighted fossil fuel subsidy as one of the causal mechanism for most fuel rich countries to be doomed with "carbon curse". In other words, governments in these countries are often under considerable pressure to subsidise fuel price so as to ensure the equitable distribution of the wealth of the nations. They presented evidence of a causal connection between fossil fuel endowments, fuel subsidies and carbon intensity. None of the most aggressive "subsidisers" achieved an emission reduction (i.e. stayed in the green growth category). Table 3.8 presents carbon emissions from petroleum consumption for Nigeria and some selected countries/regions, while the CO_2 emission per capita and carbon intensity are presented in Table 3.9.

Table 3.8: CO_2 Emissions from Consumption of Petroleum (Million Metric Tons)

S/N	Country	2011	2010	2009	2008
1	Egypt	101.1847	98.85559	96.03711	96.42497
2	Libya	39.35421	42.43035	40.72797	39.28237
3	Nigeria	34.55169	34.86826	34.50472	41.79489
4	Ghana	9.00539	9.10806	7.48618	7.38905
5	South Africa	85.85094	80.62836	77.56975	78.98331
6	Kenya	12.39526	12.06951	11.3868	10.78335
7	South Sudan	18.46477	18.57161	18.12932	12.10186
8	Africa	481.0129	472.9034	457.2763	446.5188

Source: US Energy Information Agency (2013).

Table 3.9: CO_2 Per capita and *CO_2/GDP (carbon Intensity) using exchange rates

S/N	Country	2011		2010		2009		2008	
		a	b	a	b	a	b	a	b
1	South Africa	7.27	1.23	7.41	1.28	7.39	1.30	7.85	1.34
2	Libya	5.43	1.67	8.74	1.04	8.35	1.00	7.30	0.88
3	Egypt	2.28	1.53	2.20	1.47	2.17	1.50	2.24	1.60
4	**Nigeria**	0.33	0.32	0.33	0.33	0.27	0.29	0.33	0.37
5	Ghana	0.43	0.64	0.42	0.70	0.38	0.66	0.32	0.56
6	Kenya	0.28	0.47	0.28	0.49	0.27	0.48	0.23	0.41
7	South Sudan	0.33	0.36	0.35	0.39	0.35	0.41	0.33	0.40
8	Africa	0.93	0.76	0.95	0.77	0.93	0.77	0.96	0.80
9	Asia	1.51	1.03	1.49	1.06	1.43	1.09	1.36	1.06
10	*China	5.92	1.81	5.42	1.80	5.11	1.86	4.91	1.92
11	Middle East	7.70	1.26	7.58	1.29	7.46	1.30	7.28	1.25
12	OECD Europe	6.75	0.24	7.00	0.25	6.82	0.25	7.38	0.26
13	OECD Americas	13.37	0.41	13.73	0.42	13.26	0.41	14.33	0.43

Source: IEA Statistics (2013).
Note: a- CO_2 per capita b- Carbon intensity. *China includes People's Republic of China and Hong Kong.

CHAPTER FOUR

METHODOLOGY

4.1 Preamble

In this chapter, the theoretical base, analytical framework and research method for the study are examined. In addition, the description of the model suitable to address the stated objectives is presented. The CGE model adopted for the study is a modified Dynamic Energy-Environment CGE (E2CGE) model for the Nigerian economy by Adenikinju *et al.* (2012). It is a modification of the Partnership for Economic Policy (PEP) model. The chapter ends with the data source for the study.

4.2 Theoretical Framework

The theoretical framework points to theories and principles that may have been established and proven by authorities in a field which can be useful in explaining the nature of a specified relationship. It represents the foundation of any research study. It discusses the underlying theory that backs a study. This session describes the competitive general equilibrium theory which represents the underlying framework for any CGE analysis and modelling.

The Competitive General Equilibrium Theory

The competitive general equilibrium theory is usually credited to the French economist, Leon Walras. It is mainly neo-classical in nature and founded strongly on the Walrasian theory of market behaviour. It essentially concerns the interrelationships that exits among economic agents (households and firms) as mediated by interacting markets. The interdependence or interrelationships implies that decisions in one market have effect on all other markets. The interacting markets usually considered under the competitive general equilibrium theory are “competitive” in nature as they take prices as given. The market interacting and interdependence feature of the general equilibrium theory makes it suitable in explaining the economy-wide shocks that will occur at a given time when there is a policy shift such as fuel subsidy reform by the government.

Generally, the theory seeks to explain the behaivour of demand, supply and prices within an economic system on the whole. The resulting effect of this interaction between demand and supply is what is referred to as overall “general equilibrium”. It differs from a partial equilibrium analysis which focuses on individual markets. The theory provides a “bottom-up” approach by using microeconomic foundations, that is, it adopts microeconomic principles in explaining optimisation behaviour of rational economic agent and attempting to derive equilibrium in the whole economic system.

The theory is based on the notion that economic agents will maximise some given objectives subject to their constraints, equilibrium is then given by a vector of market clearing prices where only relative prices will matter (referred to as the *numeraire* in modelling). This is what is classified as the foundation of the Walras law. The argument of Leon Walras is that the price system is responsible for the coordinating and equilibrating function (Hosoe, Gasawa and Hashimoto, 2010). The main assumptions of the theory include the following:

-Each economy consists of a finite number of economic agents (households and firms represents agents in a simple framework while further extensions incorporate government and the rest-of-the-world)

-Agents have a strictly continuous concave utility function.

-Agents would have to trade their production to consume other goods.

Based on the above assumptions, a simple case of a small economy can be considered to explain the competitive general equilibrium theory. It consists of two agents (one household and one firm), two factors of production (labour and capital) and two goods (X and Y). The households are represented by their portfolio of factors (land, labour, capital, etc.) and their preferences for final consumption while the firms are represented by the outputs they produce and their production technologies. The economic agents are linked by factor market where households rent their demand for factors of production to firms generating income and commodity markets where firms sell final consumption goods to households, thus generating income for firms.

Mathematically, from the above specifications, one can derive the consumption and production optimisation equations for the economic agents. The equations are presented below:

Max U_h (X_h, Y_h) ………………………..……..……. (4.1)

Subject to: $P_x + P_y = I$ ………………………..……….…….. (4.2)

where U_h: Utility of the representative household derived from consumption of X and Y

P_x, P_y: Price of good X and Y

I: Income of the representative household

h: The representative household

In the above case, equations 4.1 and 4.2 present the maximisation problem of the representative household where utilities from the consumption of goods X and Y are maximised subject to the budget constraints (e.g. income).

Furthermore, the optimisation problem of the firm can be presented where firms maximise profits relative to production technology and inputs mix between factors of production (labour and capital). This is explained by equations 4.3, 4.4 and 4.5 below:

Max X (K_x, L_x) + Y (K_y, L_y) …………………….. (4.3)

Subject to: $K_x + K_y = \overline{K}$, …………………… (4.4)

$L_x + L_y = \overline{L}$ …………………… (4.5)

where K: capital

L: Labour

Here, the optimisation problem involves the maximisation of output subject to inputs (labour and capital) limitations. Thus, the firms make the decision on the quantities of goods X and Y to produce given the factor endowments available. In order to ensure market equilibrium for both factor and commodity markets of the two agents, the following market clearing conditions will be set or imposed.

$DD_x = SS_x$ …………………….. (4.6)

$DD_{l,\,k} = SS_{l,\,k}$ …………………….. (4.7)

$P_x^f = P_x^h$ …………………….. (4.8)

where DD: demand

SS: supply

P: Prices

l: labour

k: capital

f: firm

h: household

While equations 4.6 and 4.7 are classified as the goods and factor markets, equation 8 shows that for the market to clear, the price of good X as supplied by the firm should be equal to the price the household is willing to purchase the commodity. In other words, the demand price must equal the supply price.

The above given specification on how consumers maximises utility subject to their income constraints, forms the basis of the consumer behaviour described in the CGE model (Hosoe *et al.*, 2010). In the same vein, the firm behaivour describes how firms maximise profits subject to their production technology. Thus, all these yield a set of simultaneous equations in the CGE model. There is the demand function derived from the representative household utility maximisation problem; the production (supply) function is derived from the profit maximisation problem of the firm; the factor endowment optimisation and market clearing conditions are also derived and specified.

According to Decaluwe *et al.* (2000), the initiation to CGE modeling requires recalling the major assumptions and properties of the model and so the theoretical framework for the study is drawn from their work. The main points emphasised by the theory are as presented in the model specification section. A standard CGE model has as its framework the points in the competitive general equilibrium theory. Relevant adjustments are only made to suit the peculiar features of each economy. Further extensions of the general equilibrium theory include the welfare and efficiency theorems.

4.3 Analytical Framework

The general framework in any general equilibrium analysis especially in assessing degree of impact of the implementation of a policy begins with the understanding of the linkages that exists within the economy. This is especially through the circular flow of income. A CGE study must be able to establish the various links within the economy as its strength lies in its ability to explicitly show the character and magnitude of the impacts of energy and environmental policies, in the case of this present study. Figure 4.1 explains graphically the circular flow of income within the economy, including the environmental component. This section, thus, describes the nature of linkage within the economy using the circular flow of income of a small open economy such as Nigeria. It starts with the assumption that the country as a small open economy, engages in trade with other economies (external world) and so is unable to influence the international price of fuel. It has the households, firms, government and the rest of the world (ROW) as the main actors. The households own factors of production such as land, labour and capital and represents final consumers of finished goods.

The firms rent these factors of production from the households to produce goods and services consumed by the households, government and other firms. The government on the other hand, collects taxes and distributes its revenue to households and firms in form of subsidies and other transfer payments subject to budgetary constraints. Government also spends revenue on purchase of public goods and amenities such as roads, bridges, and other necessary infrastructure for growth (government consumption). The final actor in the economy which is the rest of the world or the international actors, purchases and at the same time, sell goods and services in the domestic market. This explains the linkage within the economic system. The variable labeled G in the chart reflects the interaction of the economy with the environment. In other words, environmental pollution, such as the emission of carbon through the burning of fossil fuel, is as a result of the activities of households and firms leading to the release of environmental byproducts. See figure 4.1.

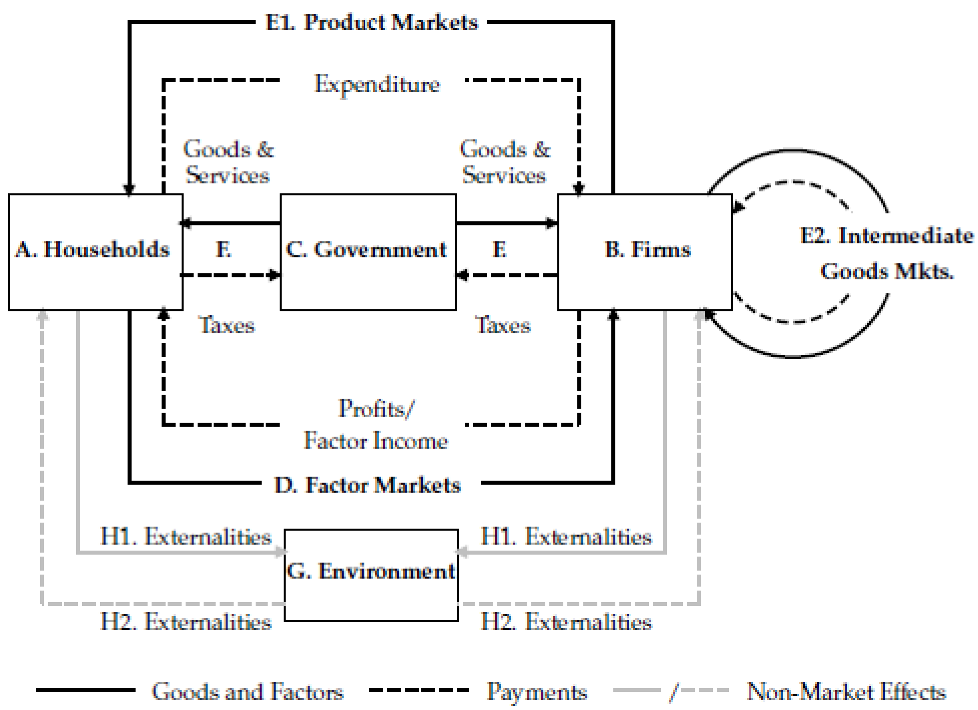


Figure 4.1: Circular Flow of Income (Economy-Environment)
Source: Wing (2011:46)

Figure 4.2 which represent a schematic representation of the model framework, explain further the process of how a policy shock transmits and affects other sectors of the economy in a standard PEP 1-1 CGE model. In the case of the present study, it shows the channel through which a shock to tariff on imported refined oil may be transmitted to influence changes in other sectors of the economy. Energy is used in the production of goods, transport and also at the household level. Thus, if government for example, reduces fuel subsidy by 50 percent, this policy change which represents a shock, will flow through the various sectors of the economy. The nature of the general equilibrium framework is such that any shock in a sector will affect every other sector especially for policies relating to energy issues given that energy is widely used for varying purposes. The Figure 4.2 also demonstrates how closely connected the different sectors are within the general equilibrium framework (Okodua and Alege, 2014).

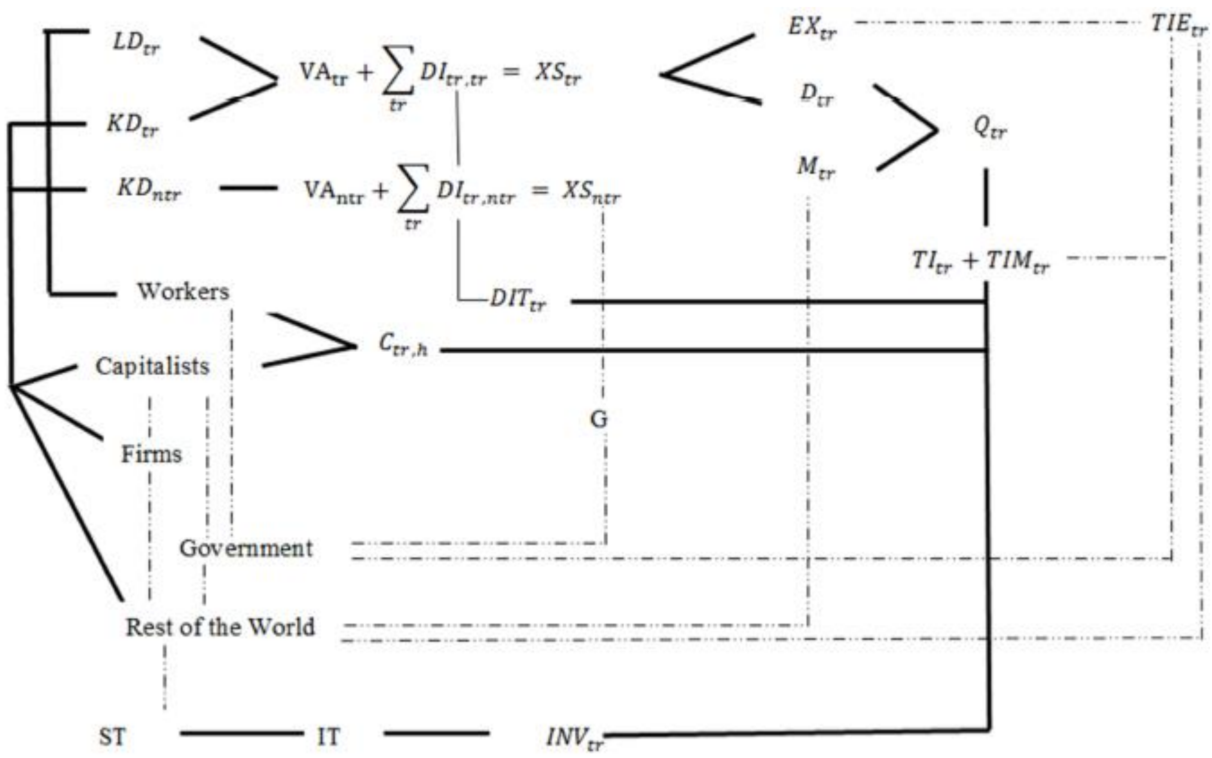


Figure 4.2: Schematic Representation of the Circular Flow in a PEP 1-1 Model
Source: Okodua and Alege (2014:47)

The interrelationships from Figure 4.2 suggest that a positive shock on import tariff (TIM) is expected to reduce imports (IM), especially for import dependent sectors. Thus, these categories of commodities (e.g. refined oil) become more expensive. The implication is that domestic demand will shrink and consumption will fall. Given that imported refined oil is a production input, this increase in price as a result of the positive shock on import tariff, will increase cost of production. Similar effect will occur for producer price. Also, in the different sectors where the refined oil is used, intermediate consumption (DI, output (XS) and value added (VA) will fall, which will invariably influence demand for labour and capital (LD and KD). Depending on the government safety programmes put in place and its effectiveness, the policy shift might result in a fall in household income due to the fall in labour demand. Overall, a policy shock such as the removal of subsidy on refined oil will have varying impact on different sectors of the economy.

4.4 The Method of Analysis

This section discusses the model adapted for achieving the stated objectives of the study. This consists of describing the recursive PEP CGE model for a single country called the PEP-1-t model, the description of the different simultaneous equations that make up the model, the modification made to suit the objectives of the study, their interrelationships and linkages and the SAM structure which is the data set for any CGE analysis. An important aspect is the modification made to the PEP recursive dynamic model in order to adapt the model to the present study. An examination of empirical literature had shown that many studies on energy subsidy analysis often focus on economic and welfare impact evaluation. Only a limited amount of studies carry out environmental assessment of the impact that energy subsidies have on an economy and these studies often adopt a primary or descriptive analysis which are usually regarded as not been too rigorous. This is especially for analysis of policies that generates economy-wide impacts such as the fuel subsidy policy, where a change in this policy transmits shocks in different sectors of the economy. This had made the use of CGE models very useful based on their general equilibrium framework.

These categories of models are well grounded in standard microeconomic theory and use a wide variety of macroeconomic data, making them more desirable to other traditional econometric models. Thus, it finds applications in different areas such as general macroeconomic issues, fiscal policy, international trade, transport, poverty, labour, environment, energy, among others. In the case of Nigeria, using a dynamic recursive CGE model to investigate the impact of fuel subsidy (energy policy) on environmental quality (environmental policy) requires a model that has both energy and environment component. However, many of such environmental CGE models are designed for developed economies and thus, adapting such to a developing economy such as Nigeria becomes computationally and theoretically difficult.

In light of this, this study attempts to address this challenge by adapting a CGE model that follows the features of a developing economy (the PEP model) and introduces the environmental component following the manner in which Adenikinju *et al.* (2012) applied it to their work. This was performed by applying it to the fuel subsidy policy, thereby creating an avenue for further researches requiring this type of modelling. It specifically accounted for carbon co-efficients for all sectors considered in the model using data from the SAM table. The assumption is that these carbon coefficients depends on the energy intensity of the sectors and the energy intensity is given by the ratio of the energy expenditures of each sector to its value added. In addition, the study calculates the subsidy on fuel for the 2006 SAM year and incorporated this into the SAM table to account for the subsidy component. Thus, the general mode of implementing a CGE model is presented which the study follows.

Generally, the implementation of a CGE model usually involves a number of steps. Firstly, the structure of the CGE model is set up. This entails sourcing for the dataset for the economy which is the construction of the SAM for the economy. This study however, intends to adapt an existing dataset, thus, the process would be modified towards verifying the dataset. This results in the benchmark equilibrium dataset. The second step involves selecting a functional form for the production and demand functions which could be of the type, Cobb-Douglas or Constant Elasticity of Substitution (CES). Lastly, the parameter values for the functional forms are derived. This procedure is termed calibration and is one of the most commonly used procedure for deriving parameter values in CGE modeling. The calibration process ensures the model reproduces the initial data as an equilibrium solution after being fed into the software, in the case of this study, the General Algebraic Modelling System (GAMS). This is done with the use of different GAMS codes. The form of the CGE model follows the structure of the SAM for the study where the former provides the mathematical formulations of what is contained in the latter.

4.4.1 The Dynamic Computable General Equilibrium (CGE) Model

CGE models are essentially the mathematical representations of the transactions in the SAM dataset. The model for the study is a modified PEP dynamic recursive model which is for a single country over a period of time as against the static PEP model version. The model does not involve any intertemporal optimisation behavioural assumption, rather, each period is solved as a static equilibrium subject to the values inherited or observed from the preceding period. This makes it possible to separate the within-period and the between-period component. This section provides a description of the mathematical expression of the CGE model and their underlying assumptions as indicated in the PEP model document by Decaluwe *et al.,* (2012).

The CGE model used in this study is based on the modified Energy-Environment CGE (E2CGE) for the Nigerian economy by Adenikinju *et al.* (2012). This model consists of a number of non-linear simultaneous equations modified from the standard PEP CGE model by Decaluwe *et al*. (2012). The equations defined are according to the behaviour of different actors in the economy, just as production and consumption decisions are defined in economic theory by the maximisation of profits and utility respectively. According to Adenikinju *et al*, (2012), the model's unique feature allows for the incorporation of carbon emissions in the equation blocks and the introduction of pollution emission estimation as indicated in Al-Amin *et al.* (2008). However, instead of the numerous tax components of the E2CGE model, this study, in achieving its stated objective, derived the carbon emission co-efficients for each sector and included it in the model for each production process and energy use. Also, the study calculated the amount for fuel subsidy in the year under review and incorporated it into the SAM. This subsidy on refined oil is accounted for in the SAM table as a negative value in the import tariff row.

In terms of structure, the model follows the standard neo-classical assumptions of market clearing condition in all markets, zero excess profits, and a balanced budget for each agent (Adenikinju *et al.*, 2013). The model essentially contains eight (8) blocks of equations. They include production, income and savings, demand, international trade, prices, carbon emissions, equilibrium and the dynamic equation block. The equilibrium block usually contains the equilibrium conditions that are to be satisfied and they cover both for markets and macroeconomic balances. Thus, the system of equations described by the model will show the behavior of various economic agents, the constraints they are confronted with and the equilibrium conditions obtainable in the different markets.

4.4.1.1 Model Description

This section presents the various equations for the different blocks in the model. This follows the standard equations of the PEP dynamic recursive CGE model which was modified to suit the objective of the current study. The following represents the salient features of the E2CGE model showing the structure and linkages in the economy. A complete list of the model sets, variables, parameters and equations are presented in Appendix Two.

i. **Production Block:** The model begins with the assumption that firms operate in a perfectly competitive environment. Thus, firms will maximise profits subject to the firm's production technology. The firm also exhibits a price-taking behaviour as it takes prices of goods, services and factors as given. Also, the production technology follows a nested structure such that it is composed of a multi-level cascading specification of the production process. At the top level, output is produced by each sector from the combination of value added and total intermediate consumption in fixed shares following a Leontief production function. This is represented by equation 4.9 and 4.10 respectively. At the lower level (equation 4.11), each sector's value added consists of both composite labour and capital following a CES specification.

They describe the production technology of the representative firm, various combinations of labour and capital employed by the firm which maximizes profit, and total intermediate consumption for production. In the extractive sectors of the economy namely petroleum (which includes crude oil, gas and other mining sectors) and refined oil, lower substitution of capital and labour is employed to ensure the upward trend in both investment and capital stock growth in the sector (Adenikinju *et al*. 2012). According to Nwafor *et al.* (2006), labour demand will grow at the expense of capital demand without this treatment.

Equation 4.12 shows how firms combine labour and capital inputs to the point where the value of marginal product of each input equals its price thereby ensuring profit maximisation. This follows a Constant Elasticity of Substitution (CES) production function. The bottom level of the value added side reveals the combination of the various categories of capital (land and capital) following a CES function technology assumed to be imperfect substitutes (equations 4.13). Equation 4.14 is the equation for the demand of each type of capital. From the second level, the total intermediate consumption is composed of different commodities and services (inputs) assumed to be perfectly complementary and combined using a Leontief production function. This is given by equation 4.15.

In the case of producers' supply behaviour, they allocate output among products so as to maximise sales revenue, given product prices subject to equation 4.16 and equation 4.17 is the individual product supply functions.

$$VA_{j,t} = v_j \, XST_{j,t} \tag{4.9}$$

$$CI_{j,t} = io_j \, XST_{j,t} \tag{4.10}$$

$$VA_{j,t} = B_j^{VA} \left[\beta_j^{VA} LDC_{j,t}^{-\rho_j^{VA}} + \left(1 - \beta_j^{VA}\right) KDC_{j,t}^{-\rho_j^{VA}}\right]^{\frac{1}{\rho_j^{VA}}} \tag{4.11}$$

$$LD_{j,t} = \left[\frac{\beta_j^{VA}}{1-\beta_j^{VA}} \frac{RC_{j,t}}{WC_{j,t}}\right]^{\sigma_j^{VA}} KDC_{j,t} \tag{4.12}$$

$$KDC_{j,t} = B_j^{KD} \left[\sum_k \beta_{k,j}^{KD} KD_{k,j,t}^{-\rho_j^{KD}}\right]^{-\frac{1}{\rho_j^{KD}}} \tag{4.13}$$

$$KD_{k,j,t} = \left[\frac{\beta_j^{KD} \; RC_{j,t}}{RTI_{k,j,t}}\right]^{\sigma_j^{KD}} \left(B_j^{KD}\right)^{\sigma_j^{KD}-1} KDC_{j,t} \tag{4.14}$$

$$DI_{i,j,t} = aij_{i,j} \; CI_{j,t} \tag{4.15}$$

$$XST_{j,t} = B_j^{XT} \left[\sum_i \beta_{j,i}^{XT} \; XS_{j,i,t}^{\rho_j^{XT}}\right]^{\frac{1}{\rho_j^{XT}}} \tag{4.16}$$

$$XS_{j,i,t} = \frac{XST_{j,t}}{\left(B_j^{XT}\right)^{1+\sigma_j^{XT}}} \left(\frac{P_{j,i,t}}{\beta_{j,i}^{XT} PT_{j,t}}\right)^{\sigma_j^{XT}} \tag{4.17}$$

where;

$VA_{j,t}: Value\ added\ of\ industry\ j$

$XST_{j\ ,i,t}: Total\ aggregate\ output\ of\ industry\ j$

$XS_{j,i,t}: Industry\ j\ production\ of\ commodity\ i$

$CI_{j,t}: Total\ intermediate\ consumption\ of\ industry\ j$

$KDC_{j,t}: Industry\ j\ demand\ for\ composite\ capital$

$RC_{j,t}: Rental\ rate\ of\ industry\ j\ composite\ capital$

$W_{j,t}: Wage\ rate\ of\ industry\ j\ labour$

$KD_{j,t}: Demand\ for\ type\ k\ capital\ by\ industry\ j$

$LD_{j,t}: Demand\ for\ type\ l\ labour\ by\ industry\ j$

$RTI_{k,j,t}: Rental\ rate\ paid\ by\ industry\ j\ for\ type\ k\ capital, including\ capital\ taxes$

$DI_{j,t}: Intermediate\ demand\ for\ commodityi\ by\ business\ j$

$v_{j,}: coefficient\ (Leontief - value - added)$

$io_{j,}: coefficient\ (Leontief - intermediate\ consumption)$

$B_j^{VA}: Scale\ parameter\ (CES - value\ added)$

$\beta_j^{VA}: Share\ parameter\ (CES - value\ added)$

$\beta_{j,i}^{XT}: Share\ parameter\ (CET - total\ output)$

$\rho_j^{VA}: Elasticity\ parameter\ (CES - value\ added);\ -1 < \rho_j^{VA} < \infty$

$\sigma_j^{VA}: Elasticity\ of\ transformation\ (CES - value\ added);\ -1 < \sigma_j^{VA} < \infty$

$B_j^{KD}: Scale\ parameter\ (CES - Composite\ capital)$

$B_j^{XT}: Scale\ parameter\ (CET - Total\ output)$

$\beta_{k,j}^{KD}: Share\ parameter\ (CES - Composite\ capital)$

$\rho_j^{KD}: Elasticity\ parameter\ (CES - Composite\ capital);\ -1 < \rho_j^{KD} < \infty$

$\sigma_j^{KD}: Elasticity\ of\ substitution\ (CES - composite\ capital);\ -1 < \sigma_j^{KD} < \infty$

$\sigma_j^{XT}: Elasticity\ of\ transformation\ (CET - total\ output);\ -1 < \sigma_j^{XT} < \infty$

$aij_{i,j}: Input - output\ coefficient$

ii. **Income and Savings Block:** The second block in the model is composed of equations relating to income and saving behaviour of the economic agents in the economy (households, firms and government) and the rest of the world (ROW). These equations describes the income, taxes, savings and disposable income of the different agents and also transfers received or made from one agent to another. The household agent which is modeled as a representative agent is assumed to have a Stone-Geary type of preference. They derive their income from labour income, capital income and transfers received from other agents (equation 4.18). Likewise, each household category receives a fixed share of their earnings from the labour they provide (equation 4.19). This is also the case for capital income as the total is distributed between all agents in fixed proportions (equation 4.20). Transfers on the other hand represent the sum of all transfers received by the different categories of households (equation 4.21). The disposable income of the type *h* household is given by the difference between the income of the household and direct taxes which is equation 4.22. Equation 4.23 shows the proportion of disposable income that is consumed after saving. The model assumes that households' saving is not a fixed proportion of total income but rather, it is modeled as a linear function of disposable income (equation 4.24). In this manner, the marginal propensity to save is assumed different from the average propensity.

The model also has one representative firm that receives capital income (equation 4.25) which is a share of total returns to capital (equation 4.26). The firm's disposable income given by equation 4.27 is derived by deducting the firm's income taxes from its total income. Government is another agent that receives income from direct taxes from households and firms, indirect taxes on products and imports, and also taxes on production (equation 4.28). Additional income is received from capital income and transfers from the rest of the world (ROW). Equation 4.29 to 4.42 presents the equations of the different revenue sources of the government. The model describes income taxes as a linear function of total income as done for household savings. Thus, whether for households or firm, when a non-zero intercept is employed; the marginal rate of taxation will be different from the average rate and this will be useful in simulating fiscal changes. Government savings shows the difference between government revenue and expenditure (equation 4.43). This equation also shows the current government budget deficit or surplus which could be positive or negative savings.

The rest of the world which describes the domestic economy's interaction with the external world earns income from the payment of goods imported into the domestic economy and capital supplied (equation 4.44). The rest of the world also spends on the domestic economy which is in terms of paying for exports and transfers to domestic agents (e.g. remittances). Therefore, equation 4.45 presents the difference between the revenue of the rest of the world agent and its expenditure which is given as its savings. The value of the savings equals the current account balance (CAB) but opposite in sign (equation 4.46). Finally, transfers in the model consist of transfers by government to households (equation 4.47) and transfers from the ROW to domestic agents made up of households and government (equation 4.48). The transfers are initially set to their SAM values, growing in each period at the same rate n_t as the population index pop_t which is indexed to the consumer price index.

$$YH_{h,t} = YHL_{h,t} + YHK_{h,t} + YHTR_{h,t} \tag{4.18}$$

$$YHL_{h,t} = \sum \lambda_h^{WL} \left(W_t \sum_j LD_{j,t} \right) \tag{4.19}$$

$$YHK_{h,t} = \sum_k \lambda_{h,k}^{RK} \left(\sum_j R_{k,j,t} \, RD_{k,j,t} \right). \tag{4.20}$$

$$YHTR_{h,t} = \sum_{ag} TR_{h,ag,t} \tag{4.21}$$

$$YDH_{h,t} = YH_{h,t} - TDH_{h,t} \tag{4.22}$$

$$CTH_{h,t} = YDH_{h,t} - SH_{h,t} \tag{4.23}$$

$$SH_{h,t} = PIXCON_t^{\eta}\ sh0_{h,t} + sh1_{h,t}\ YDH_{h,t} \tag{4.24}$$

$$YF_t = YFK_t \tag{4.25}$$

$$YFK_t = \sum_k \lambda_{f,k}^{RK} \left(\sum_j R_{k,j,t}\ KD_{k,j,t}\right) \tag{4.26}$$

$$YDF_{f,t} = YF_{f,t} - TDF_{f,t} \tag{4.27}$$

$$YG_t = YGK_t + YGTX_t + YGTR_t \tag{4.28}$$

$$YGK_t = \sum_k \lambda_{gvt,k}^{RK} \left(\sum_j R_{k,j,t}\ KD_{k,j,t}\right) \tag{4.29}$$

$$YGTX_t = TDHT_t + TDFT_t + TPRODN_t + TPRCTS_t \tag{4.30}$$

$$\mathrm{TDHT}_t = \sum_h TDH_{h,t} \tag{4.31}$$

$$\mathrm{TDFT}_t = \sum_f TDFT_{f,t} \tag{4.32}$$

$$TIPT_t = \sum_{l,j} TIP_{l,j,t} \tag{4.33}$$

$$\mathrm{TPRCTS}_t = \mathrm{TICT}_t + \mathrm{TIMT}_t \tag{4.34}$$

$$\mathrm{TICT}_t = \sum_i TIC_{i,t} \tag{4.35}$$

$$\mathrm{TIMT}_t = \sum_m TIM_{m,t} \tag{4.36}$$

$$\mathrm{YGTR}_t = \sum_{agng} TR_{gvt,agng,t} \tag{4.37}$$

$$TDH_{h,t} = PIXCON_t^{\eta}\ ttdh0_{h,t} + ttdh1_{h,t} YH_{h,t} \tag{4.38}$$

$$TDF_{f,t} = PIXCON_t^{\eta}\ ttdf0_{f,t} + ttdf1_{f,t} \sum_k \lambda_k^{RK} \left(\sum_j R_{k,j,t}\ KD_{k,j,t}\right) \tag{4.39}$$

$$TIP_{j,t} = ttip_{j,t}\ PP_{j,t}\ XST_{j,t} \tag{4.40}$$

$$TIC_{i,t} = ttic_{i,t} \left[\left(PL_{i,t} + \sum_{ij} PC_{ij,t}\ tmrg_{ij,i}\right) DD_{i,t} + \left(\left(1 + ttim_{i,t}\right) PWM_{i,t}\ e_t + \sum_{ij} PC_{ij,t}\ tmrg_{ij,i}\right) IM_{i,t}\right] \tag{4.41}$$

$$TIM_{i,t} = ttim_{i,t}\ PWM_{i,t} e_t\ IM_{i,t} \tag{4.42}$$

$$SG_t = YG_t - \sum_h TR_{h,gvt,t} - G_t \tag{4.43}$$

$$\mathrm{YROW}_t = e_t \sum_i PWM_{i,t}\ IM_{i,t} + \sum_k \lambda_{row,k}^{RK} \left(\sum_j R_{k,j.t}\ KD_{k,j,t}\right) \tag{4.44}$$

$$\mathrm{SROW}_t = \mathrm{YROW}_t - \sum_i PE_{i,t}\ EXD_{i,t} - \sum_{agd} TR_{agd,row,t} \tag{4.45}$$

$$SROW_t = -CAB_t \tag{4.46}$$

$$TR_{h\,gvt,t} = PIXCON^{\eta}\, TR^{o}_{h,gvt}\, pop_t \tag{4.47}$$

$$TR_{agd,row,t} = PIXCON^{\eta}\, TR^{o}_{agd,row}\, pop_t \tag{4.48}$$

where;

$YH_{h,t}$: $Total\ income\ of\ type\ h\ households$

$YHK_{h,t}$: $Capital\ income\ of\ type\ h\ households$

$YHL_{h,t}$: $Labour\ income\ of\ type\ h\ households$

$YHTR_{h,t}$: $Transfer\ income\ of\ type\ h\ households$

$R_{k,j,t}$: $Rental\ rate\ of\ type\ k\ capital\ in\ industry\ j$

$TR_{ag,agj,t}$: $Transfers\ from\ agent\ agj\ to\ agent\ ag$

W_t: $Wage\ rate$

$CTH_{h,t}$: $Consumption\ budget\ of\ type\ h\ households$

$PIXCON_t$: $Consumer\ Price\ Index$

$SH_{h,t}$: $Savings\ of\ type\ h\ households$

$TDH_{h,t}$: $Income\ taxes\ of\ type\ h\ households$

$YDH_{h,t}$: $Disposable\ income\ of\ type\ h\ households$

$\lambda^{TR}_{ag,agj}$: $Share\ parameter\ (transfer\ functions)$

λ^{WL}_{h}: $Share\ of\ labour\ income\ received\ by\ type\ h\ households$

η: $Price\ elasticity\ of\ indexed\ transfers\ and\ parameters$

$sh0_{h,t}$: $Intercept\ (type\ h\ household\ savings)$

$sh1_{h,t}$: $Slope\ (type\ h\ household\ savings)$

$agng$: $Index\ of\ non-government\ agents$

YG_t: $Total\ government\ income$

YGK_t: $Government\ capital\ income$

$YGTR_t$: $Government\ transfer\ income$

$TDHT_t$: $Total\ government\ revenue\ from\ household\ income\ taxes$

$TDFT_t$: $Total\ government\ revenue\ from\ firm\ income\ taxes$

TIP_t: $Government\ revenue\ from\ \ taxes\ on\ industry\ j\ production(excluding\ taxes$
$directly\ related\ to\ the\ use\ of\ capital\ and\ labour$

$TIPT_t$: $Total\ government\ revenue\ from\ production\ taxes\ (excluding\ taxes\ directly$
$related\ to\ the\ use\ of\ capital\ and\ labour$

$TPRCTS_t$: $Total\ government\ revenue\ from\ \ taxes\ on\ products\ and\ imports$

$TIC_{i,t}$: $Government\ revenue\ from\ \ indirect\ taxes\ on\ products\ i$

$TICT_{i,t}$: $Total\ government\ receipts\ of\ \ indirect\ taxes\ on\ commodities$

$TIM_{i,t}$: $Government\ revenue\ from\ \ import\ duties\ products\ i$

$TIMT_{i,t}$: $Total\ government\ revenue\ from\ \ import\ duties$

$PP_{j,t}$: $Industry\ j\ unit\ cost, including\ taxes\ directly\ related\ to\ the\ use\ of\ capital$
$and\ labour, but\ excluding\ other\ taxes\ on\ production$

$DD_{i,t}$: $Domestic\ demand\ for\ commodity\ i\ produced\ locally$

e_t: $Exchange\ rate; price\ of\ forein\ currency\ in\ terms\ of\ local\ currency$

$EXD_{i,t}$: $Quantity\ of\ product\ i\ exported$

$IM_{i,t}$: $Quantity\ of\ product\ i\ imported$

$PC_{i,t}$: $Purchaser\ price\ of\ composite\ commodity\ i\ (including\ all\ taxes\ and\ margins)$

$PE_{i,t}$: $Price\ received\ for\ exported\ commodity\ i\ (excluding\ \ export\ taxes\ )$

$PL_{i,t}$: $Price\ of\ local\ product\ i\ (excluding\ \ all\ taxes\ on\ products)$

$PWM_{i,t}$: $World\ price\ of\ imported\ product\ i\ (expressed\ in\ foreign\ currency\ )$

SG_t: $Government\ savings$

G_t: $Current\ government\ expenditure\ on\ goods\ and\ services$

$YROW_t$: $Rest\ ofthe\ world\ income$

$SROW_t$: $Rest\ ofthe\ world\ savings$

CAB_t: $Current\ account\ balance$

$ttdh0_{h,t}$: $Intercept\ (income\ taxes\ of\ type\ h\ households)$

$ttdh1_{h,t}$: $Marginal\ income\ tax\ rate\ of\ type\ h\ households$

$ttdf0\ _t$: $Intercept\ (income\ taxes\ of\ representative\ firm)$

$ttdf1_t: Marginal\ income\ tax\ rate\ of\ representative\ firm$

$ttip_{j,t}: Tax\ rate\ on\ the\ production\ of\ industry\ j$

$ttic_{i,t}: Tax\ rate\ on\ commodity\ i$

$ttim_{i,t}: Rate\ of\ taxes\ and\ duties\ on\ imports\ of\ commodity\ i$

$tmrg_{i,ij}: Rate\ of\ margin\ i\ applied\ to\ commodity\ ij$

$tmrg_{ij,i}^{X}:\ Rate\ of\ margin\ ij\ applied\ to\ export\ i$

$pop_t: Population\ index$

iii. **Demand Block:** The third block explains the different equations relating to the demand for goods and services produced domestically or imported. It consists of demand for intermediate goods, household consumption demand, investment demand (by firms) and government consumption demand. The assumption that households have Stone-Geary utility function where the linear expenditure system is derived allows for a degree of flexibility with respect to substitution possibilities when there is a price change. The specification does not impose a zero cross-price elasticity or unit income elasticity as against the Cobb-Douglas utility function. Thus, the demand of each household type for each good is given by equation 4.49 and is determined by utility maximisation subject to budget constraint. The total of investment expenditure which is made up of both private and public investments is distributed in fixed shares among commodities. This is represented by equation 4.50 and 4.51. In equation 4.52, the final demand for each commodity i for investment purposes which is the sum of the quantity demanded for both private and public investment is presented. Equation 4.53 is government expenditure on goods and services. Finally, given that productive sectors employ inputs in the production of commodities, equation 4.54 shows the intermediate demand for each commodity given by the sum of industry demands.

$$C_{i,h,t}PC_{i,t} = C_{i,h,t}^{MIN}PC_{i,t} + \gamma_{i,h}^{LES}\left(CTH_{h,t} - \sum_{i,j} C_{i\,j,h,t}^{MIN}\,PC_{i\,j,t}\right) \qquad (4.49)$$

$$PC_{i,t}\,INV_{i,t}^{PRI} = \gamma_i^{INVPRI} IT_t^{PRI} \qquad (4.50)$$

$$PC_{i,t}\,INV_{i,t}^{PUB} = \gamma_i^{INVPUB} IT_t^{PUB} \qquad (4.51)$$

$$INV_{i,t} = INV_{i,t}^{PRI} + INV_{i,t}^{PUB} \qquad (4.52)$$

$$PC_{i,t}CG_{i,t} = \gamma_i^{GVT} G_t \qquad (4.53)$$

$$DIT_{i,t} = \sum_j DI_{i,j,t} \qquad (4.54)$$

where;

$C_{i,h,t}$: *Consumption of commodity i by type h households*

$C_{i,h,t}^{MIN}$: *Minimum consumption of commodity i by type h households*

$INV_{i,t}$: *Final demand of commodity i for investment purposes*

$INV_{i,t}^{PRI}$: *Final demand of commodity i for private investment purposes*

$INV_{i,t}^{PUB}$: *Final demand of commodity i for public investment purposes*

IT_t: *Total investment expenditure*

IT_t^{PRI}: *Total private investment expenditure*

IT_t^{PUB}: *Total public investment expenditure*

CG_t: *Public consumption of commodity i (volume)*

$PC_{i,t}$: *Purchaser price of composite commodity i (including all taxes and margins)*

$DIT_{i,t}$: *Total intermediate demand for commodity i*

$\gamma_{i,h,}^{LES}$: *Marginal share of commodity i in type h household consumption budget*

$\gamma_{i,}^{GVT}$: *Share of commodity i in total current public expenditure on goods and services*

$\gamma_{i,}^{INVPRI}$: *Share of commodity i in total private investment expenduture*

$\gamma_{i,}^{INVPUB}$: *Share of commodity i in total public investment expenduture*

iv. **International Trade Block:** This block describes the trade relations of the domestic economy with the rest of the world. It is essentially composed of supply of exports and demand for imports. The equations in this block represent the behaviour of domestic buyers and suppliers. The standard Armington assumption of imperfect substitutions between domestically produced goods and imported goods is assumed for relationship between the domestic economy and the rest of the world. The assumption is that world price of traded goods (imports and exports) is exogenous which is the small-economy hypothesis. Equation 4.55 is the relative supply function which is derived from the first-order conditions of revenue maximisation subject to the Constant Elasticity of Transformation (CET) aggregator function. Equation 4.56 summarises the producers' supply behaviour given by a nested CET function where the upper level shows output been allocated to individual products. At the lower level, supply of each product is distributed between the domestic markets and exports. Equation 4.57 represents the world demand for exports. Equation 4.58 asserts that domestically demanded commodities are a composite combination of both imported goods and domestically produced goods where they are imperfect substitutes. This imperfect substitutability is given by a CET aggregator function. The same manner producers seek to maximise revenue, so also buyers seek to minimise expenses subject to the CES aggregation function. The relative demand for imports or total commodity imported can then be derived to yield equation 4.59.

$$XS_{j,i,t} = B_{j,i}^{X} \left[\beta_{j,i}^{X} EX_{j,i,t}^{\rho_{j,i}^{X}} + \left(1 - \beta_{j,i}^{X}\right) DS_{j,i,t}^{\rho_{j,i}^{X}}\right]^{\frac{1}{\rho_{j,i}^{X}}} \tag{4.55}$$

$$EX_{j,i,t} = \left[\frac{1-\beta_{j,i}^{X}}{\beta_{j,i}^{X}} \frac{PE_{i,t}}{PL_{i,t}}\right]^{\sigma_{j,i}^{X}} DS_{j,i,t} \tag{4.56}$$

$$EXD_{i,t} = EXD_{i}^{o} \; pop_{t} \left(\frac{e_{t} \, PWX_{i,t}}{PE_{i,t}}\right)^{\sigma_{i}^{XD}} \tag{4.57}$$

$$Q_{i,t} = B_i^M \left[\beta_i^M \, IM_{i,t}^{-\rho_i^M} + (1 - \beta_i^M)\, DD_{i,t}^{-\rho_i^M}\right]^{\frac{-1}{\rho_i^M}} \tag{4.58}$$

$$IM_{i,t} = \left[\frac{\beta_i^M}{1-\beta_i^M} \frac{PD_{i,t}}{PM_{i,t}}\right]^{\sigma_i^M} DD_{i,t} \tag{4.59}$$

where;

$XS_{j,i,t}: Industry\ j\ production\ of\ commodity\ i$

$EX_{j,i,t}: Quantity\ of\ product\ i\ by\ sector\ j$

$DS_{j,i,t}: Supply\ of\ commodity\ i\ by\ sector\ j\ to\ the\ domestic\ market$

$EXD_{i,t}: World\ demand\ for\ exports\ of\ product\ i$

$PWX_{i,t}: World\ price\ of\ exported\ product\ i\ (expressed\ in\ foreign\ currency)$

$Q_{i,t}: Quantity\ demanded\ of\ composite\ commodity\ i$

$B_j^X: Scale\ parameter\ (CET - exports\ and\ local\ sales)$

$\beta_j^X: Share\ parameter\ (CET - exports\ and\ local\ sales)$

$\rho_j^X: Elasticity\ parameter\ (CET - exports\ and\ local\ sales); 1 < \rho_j^X < \infty$

$\sigma_j^X: Elasticity\ of\ transformation\ (CET - exports\ and\ local\ sales); 1 < \sigma_j^X < \infty$

$\sigma_i^{XD}: Price - elasticity\ of the\ world\ demand\ for\ exports\ of\ product\ i$

$B_i^M: Scale\ parameter\ (CES - composite\ commodity)$

$\beta_i^M: Share\ parameter\ (CES - composite\ commodity)$

$\rho_i^M: Elasticity\ parameter\ (CES - composite\ commodity); 1 < \rho_j^M < \infty$

$\sigma_i^M: Elasticity\ of\ transformation\ (CES - composite\ commodity); 1 < \sigma_j^M < \infty$

v. **Price Block:** This block defines various price categories as available in the model. It contains prices associated with production, foreign trade and price indices. In all, there are prices for production (price of goods and services, labour and capital), international trade (prices of imported and exported products) and the different price indices. Equation 4.60 represents the unit cost of an industry's output which is a weighted sum of the prices of value added and total intermediate consumption. This is because in aggregation, the price of an aggregate is the weighted sum of the prices of its component. This same principle is applied to other price aggregates (equations 4.61 and 4.62). The basic price of industry j's output obtained from the unit cost by adding taxes on production (other than taxes on labour and capital) is given by equation 4.63. Also, the price of composite capital of an industry given by a weighted sum of the rental rates of the different types of capital used by that industry is presented by equation 4.64. The corresponding equation for wages is not considered as there is only one representative labour in the model.

The price charged by producers is a weighted sum of the price obtained from both the domestic and international markets since they are able to sell their products in both markets. The weight, thus, allocated to individual market is proportional to the amount sold in that market (equation 4.65). They, however, differ with respect to relative price changes, which is dependent on the elasticity of transformation. Equation 4.66 shows the basic price of product i by industry j which is derived from the weighted sum of its basic price on the domestic and export market. Given that commodities bought from the domestic market are composites or aggregates, therefore, the price paid for domestically produced commodities is given by the sum of the price received by the producer and indirect taxes (equation 4.67). In the same vein, the price paid for imported commodity will be the world price which is converted to local currency, plus taxes, import duties and domestic indirect taxes (equation 4.68). Equation 4.69 shows the price of the composite which is weighted sum of the price paid for domestically produced and imported. This is for goods facing import competition. Finally the model defines two price indexes namely the GDP deflator (equation 4.70) and the consumer price index (equation 4.71). The former is a Fisher index while the latter is a Laspeyres index.

$$PP_{j,t} = \frac{PVA_{j,t}\, VA_{j,t} + PCI_{j,t}\, CI_{j,t}}{XST_{j,t}} \qquad (4.60)$$

$$PT_{j,t} = \left(1 + ttip_{j,t}\right) PP_{j,t} \qquad (4.61)$$

$$PCI_{j,t} = \frac{\sum_i PC_{i,t} DI_{i,j,t}}{CI_{j,t}} \qquad (4.62)$$

$$PVA_{j,t} = \frac{WC_{j,t} LDC_{j,t} + RC_{j,t} KDC_{j,t}}{VA_{j,t}} \qquad (4.63)$$

$$RC_{j,t} = \frac{\sum_k RTI_{k,j,t}\, KD_{k,j,t}}{KDC_{j,t}} \qquad (4.64)$$

$$PT_{j,t} = \frac{\sum_i P_{j,i,t}\, XS_{j,i,t}}{XST_{j,t}} \qquad (4.65)$$

$$P_{i,j,t} = \frac{PE_{i,t} EX_{i,t} + PL_{i,t} D_{i,t}}{XS_{i,t}} \qquad (4.66)$$

$$PD_{i,t} = \left(1 + ttic_{i,t}\right) \left[PL_{i,t} + \sum_{ij} PC_{ij,t}\; tmrg_{ij,i}\right] \qquad (4.67)$$

$$PM_{i,t} = \left(1 + ttic_{i,t}\right) \left(\left(1 + ttim_{i,t}\right) e_t PWM_{i,t} + \sum_{ij} PC_{ij,t}\; tmrg_{ij,i}\right) \qquad (4.68)$$

$$PC_{i,t} = \frac{PM_{i,t} IM_{i,t} + PD_{i,t} D_{i,t}}{Q_{i,t}} \qquad (4.69)$$

$$PIXGDP_t = \sqrt{\frac{\sum_j PVA_{j,t} VA_j^o\ \sum_j PVA_{j,t} VA_{j,t}}{\sum_j PVA_j^o VA_j^o \sum_j PVA_j^o VA_{j,t}}} \qquad (4.70)$$

$$PIXCON_t = \frac{\sum_i PC_{i,t}\ \sum_h C_{i,h}^o}{\sum_{i,j} PC_{i,j}^o\ \sum_h C_{i\,j,h}^o} \qquad (4.71)$$

where;

$PT_{j,t}: Basic\ price\ of\ industry\ j's\ output$

$PVA_{j,t}: Price\ of\ industry\ j's\ value\ added\ (including\ taxes\ on\ production$

$directly\ related\ to\ the\ use\ of\ capital\ and\ labour$

$PCI_{j,t}: Interediate\ consumption\ price\ index\ of\ industry\ j$

$PIXGDP_t: GDP\ deflator$

vi. **Equilibrium Block:** This block verifies the demand and supply equilibrium of both the goods market and the factor market. Equation 4.72 states the equilibrium condition between demand and supply of each commodity on the domestic market and international market. The equilibrium between the total demand and supply for each factor of production is ensured with equations 4.73 and 4.74. Also, total investment expenditure must be equaled to total savings by the different agents (equation 4.75) while the different forms of investment expenditure equals total investment (equation 4.76). Equation 4.77 show that sum of total goods produced locally that were demanded in the domestic market equal the sum of supplies of all commodities produced by domestic producers. Also, supply to the export market of each good should be the same with its demand (equation 4.78). The GDP is computed not as an equilibrium condition, but rather made up of payments to factors, including taxes on production, products and imports. The GDP equation (equation 4.79) consists of the sum total of income paid to labour and capital including taxes on products and income and other taxes on production.

$$Q_{i,t} = \sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + DIT_{i,t} \tag{4.72}$$

$$\sum_j LD_{l,j,t} = LS_{l,t} \tag{4.73}$$

$$\sum_j KD_{k,j,t} = KS_{k,t} \tag{4.74}$$

$$IT_t = \sum_h SH_{h,t} + SG_t + SROW \quad (4.75)$$

$$IT_t^{PRI} = IT_t - IT_t^{PUB} \quad (4.76)$$

$$\sum_j DS_{j,i,t} = DD_{i,t} \quad (4.77)$$

$$\sum_j EX_{j,i,t} = EXD_{i,t} \quad (4.78)$$

$$GDP_t = \sum_J PVA_{j,t} VA_{j,t} + TIPT_t + TPRCTS_t \quad (4.79)$$

where;

LS_t: $Supply\ of\ labour$

$KS_{k,t}$: $Supply\ of\ k\ type\ capital$

GDP_t: $Gross\ Domestic\ Product$

vii. Dynamic Equations Block: This block links one period to another in the model by showing the between-period relationships. It explains the variables that grow over time for example, population. It is represented in the model by population index pop_t growing each period at a rate n_t such that $pop_t = 1$ for the first period and $pop_t = pop_{t-1}(1 + n_{t-1})$ for other periods. Other constants assumed to grow at the same rate with n_t and pop_t include the household savings function intercept, households' and firms' income tax function intercepts, household transfers to government function intercept, transfers from government and the rest of the world. The variables whose values are assumed to update with time (each growing period) are labour supply, current account balance, minimum consumption of commodities in the LES demand equations, government current expenditures, public investment and changes in inventories.

Capital accumulation in the model is given by equation 4.80 and it shows that the stock of type k capital in industry j in period $t + 1$ equals the stock of the preceding period minus depreciation plus volume of new capital investment in the preceding period. Equation 4.81 describes the amount of public investment expenditures which is determined by the price of public investment. This depends on how much savings are taken up by public investment. The amount left for private (business sector) investment given the price of private investment is presented in equation 4.82. The prices of new private and public capital represent equations 4.83 and 4.84 respectively. The volume of new type *k* capital allocated to industry *bus* (business sector) is proportional to the existing stock of capital (equation 4.85). On the other hand, this proportion varies according to the ratio of the rental rate to the user cost of that capital which may be interpreted as the Tobin's q. (equation 4.86). The user cost of capital is defined as depending on the price of new capital, rate of depreciation and the interest rate.

$$KD_{k,j,t+1} = KD_{k,j,t}\left(1 - \delta_{k,j}\right) + IND_{k,j,t} \quad (4.80)$$

$$IT_t^{PUB} = PK_t^{PUB} \sum_{k,pub} IND_{k,pub,t} \quad (4.81)$$

$$IT_t^{PRI} = PK_t^{PRI} \sum_{k,bus} IND_{k,bus,t} \quad (4.82)$$

$$PK_t^{PRI} = \frac{1}{A^{K\_PRI}} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPRI}}\right]^{\gamma_i^{INVPRI}} \quad (4.83)$$

$$PK_t^{PUB} = \frac{1}{A^{K\_PUB}} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPUB}}\right]^{\gamma_i^{INVPUB}} \quad (4.84)$$

$$IND_{k,bus,t} = \phi_{k,bus} \left[\frac{R_{k,bus,t}}{U_{k,bus,t}}\right]^{\sigma_{k,bus}^{INV}} KD_{k,bus,t} \quad (4.85)$$

$$U_{k,bus,t} = PK_t^{PRI}\left(\delta_{k,bus} + IR_t\right) \; and \; U_{k,pub,t} = PK_t^{PUB}\left(\delta_{k,pub} + IR_t\right) (4.86)$$

where;

$IND_{k,j,t}$: $Volume\ of\ new\ type\ k\ capital\ investment\ to\ sector\ j$

$IND_{k,bus,t}$: $Volume\ of\ new\ type\ k\ capital\ investment\ to\ private\ business$

IT_t^{PUB}: $Price\ of\ new\ public\ capital$

IT_t^{PRI}: $Price\ of\ new\ private\ capital$

PK_t^{PRI}: $Price\ of\ new\ private\ capital$

PK_t^{PUB}: $Price\ of\ new\ public\ capital$

$U_{k,j,t}$: $User\ cost\ of\ type\ k\ capital\ in\ industry\ j$

IR_t: $Interest\ rate$

$\delta_{k,j}$: $Depreciation\ rate\ of\ capital\ k\ used\ in\ industry\ j$

A^{K_PRI}: $Scale\ parameter\ (price\ of\ new\ private\ capital\ )$

A^{K_PUB}: $Scale\ parameter\ (price\ of\ new\ public\ capital\ )$

$\phi_{k,j}$: $Scale\ parameter\ (allocation\ of\ investment\ to\ industries)$

$\delta_{k,j}$: $Depreciation\ rate\ of\ of\ capital\ k\ used\ in\ industry\ j$

$\sigma_{k,bus}^{INV}$: $Elasticity\ of\ private\ investment\ demand\ relative\ to\ Tobin's\ q$

viii. **Carbon Emissions Block:** An additional block is included in the model to achieve the objective of the study. This provides allowance for simulations on CO_2 emissions within the framework of the model. It also establishes links of CO_2 with the production process. These links are established through the energy use of these sectors, that is, the energy intensity of each sector and the carbon co-efficients. This measure of emissions represent fixed co-efficient of energy intensity per sector. Equation 4.87 describes the total carbon emission in the economy from the energy intensive sectors of the model while equation 4.88 is the difference between the total emissions and maximum emission permitted in the economy. The emissions in the model are treated as proportional to the energy inputs used.

$$TQ_{CO_2} = \varphi_{PET}X_{PET} + \varphi_{ROIL}X_{ROIL} + \varphi_{RTRANS}X_{RTRANS} \ or \ TQ_{CO_2} \ \sum_i \varphi_i \ X_i \quad (4.87)$$

$$TQ_{CO_2} - \overline{TQ_{CO_2}} \leq 0 \quad (4.88)$$

where;

pet: Petroleum sector

roil: Refined oil sector

rtrans: Road transport sector

TQ_{CO_2} : Total carbon emission;

$\overline{TQ_{CO_2}}$: Carbon emission limit;

X_i : Total energy type use by sector;

φ_i : Carbon emission coefficient per unit of energy type use by sector;

4.4.1.2 Closure Rules

In a CGE model analysis, equilibrium results, direction of causality and magnitude of change in terms of policy shift depends on the manner in which the model is closed. Empirical literature suggests that closure rule for macroeconomic variables determine how macro-equilibrium is attained after a shock. Mathematically, this process ensures that a “closed” model that derives a square system results to having as many independent equations that explains the endogenous variables. In other words, there are a sufficient number of equations which should equal the number of endogenous variables. According to Decaluwe *et al.* (2013), with respect to decision on choosing macro-closure, consideration should be given to specific nature of the problem and the origin of the shock of interest.

Broadly, CGE models follow different closure rules which could either be based on the Walrasian system where markets are assumed to clear (neo-classical savings-driven characteristics) or the structuralist model that emphasises structural rigidities in markets and institutions. Others include the Johansen and Neo-keynesian closure. Also, the rules on model closure are classified into the microeconomic and the macroeconomic model closure. The micro closure rule focuses on how the capital and labour markets balance; that is, deciding if capital will be mobile or immobile and if the model assumes full employment where labour supply is fixed and wage rate is allowed to adjust.

A CGE model often contain three macro balances which includes government balance, savings and investment, and finally, rest of the world/external balance (current account balance). Generally, common macro closures in standard CGE models are the savings driven by investment or investment driven by savings (Ezaki, 2006). In other words, choice is made between a savings driven and an investment driven closure. In the former, value of savings is determined possibly by a fixed proportion of disposable household income. The balance identity determines the value of investment. On the other hand, in the investment driven macro closure, the value of total investment is determined within the model with the balance identity determining savings. The default closure of PEP-1-t model adopts the nominal exchange rate as the *numeraire*. Also, variables such as government expenditures, volume of public sector investment and the current account balance are assumed fixed in each period. Other variables considered exogenous in the model includes labour supply (assumed to be mobile across sectors), capital stock, minimum consumption, volume of inventory changes, and the world prices of imports and exports. In addition, the model states the equilibrium conditions for the factor and goods markets.

However, the study adopts a neo-classical savings driven macro closure with the full employment assumption. The savings driven closure ensures that savings rate of domestic institutions remain fixed while investment passively adjusts to ensure that savings rate equals investment spending in equilibrium. In the micro closure, labour supply is held fixed and mobile across sectors so that wage is able to adjust to clear the market. Also, capital is held fixed and immobile. The nominal exchange rate is the chosen numeraire with the current account balance held fixed while foreign savings are made to adjust endogenously to ensure external balance. Empirical evidence from literature argue that if the current account is not fixed and allowed to be free, indicators of economic welfare based on household consumption becomes invalid. This is in view of the fact that borrowing of funds increases consumption in the present period, especially as no provision is made in the model to pay back the debt incurred. In the same vein, government expenditure is held fixed in real terms as well as all tax rates. Thus, the balance on government budget adjusts to ensure that public expenditure equals public revenue. The savings driven closure seems appropriate for the Nigerian economy given that many household consumers of imported refined oil are low-income earners and will most likely not increase savings to fund future investment.

4.4.1.3 Description of Simulation Scenarios

The study considers three alternative scenarios to achieve the earlier stated objectives of analysing the implications of changes in imported refined oil subsidies on carbon emissions in Nigeria.

i. Scenario One: This simulation experiment considers a partial removal of subsidy on imported refined oil when there is a 50 percent increase in import tariff on refined oil over the simulation period.

ii. Scenario Two: This simulation experiment considers a gradual elimination of subsidy on imported refined oil over a period of five years and compares the results generated.

iii. Scenario Three: This simulation experiment considers a complete removal of subsidy on imported refined oil. This involves a 100 percent shock to import tariff on refined oil.

4.5 Technique of Estimation/ Model Implementation

The process of implementing a standard CGE model involves a number of steps. Firstly, the structure of the model is set up which ensures that the dataset for the study is verified against the benchmark equilibrium dataset. This is followed by the calibration process of determining the appropriate parameters for the production and demand functions while also deriving the values for the "free" parameters of the model. This calibration process follows the process of choosing the values of a subset of parameters in a way that when combined with the modified SAM and the chosen behavioural parameters, the model reproduces the initial data of the reference year. Following a replication check (the baseline or business-as-usual scenario) that ensures the specified model and calibration exercise were properly done, the data contained in the SAM together with the associated equations of the model are used to solve the model. Once this is completed, the simulation scenarios are then introduced to shock the model and compare simulation results with the baseline or business-as-usual (BAU) scenario. The General Algebraic Modeling System (GAMS) software which is a high level computer modeling programme designed to solve large and complex non-linear system of equations such as the CGE model and the SAM dataset employed to achieve the objectives of the study are discussed in the following sub-section.

4.5.1 The Social Accounting Matrix (SAM) of the Nigerian Economy

The Social Accounting Matrix (SAM) is essentially a square matrix comprising of rows and columns that show different economic activities and transactions that takes place in an economy. It represents a comprehensive economy-wide data framework that shows the economy of a nation (Lofgren *et al*, 2002). It can also be defined conceptually as an accounting system that gives a comprehensive account of all incomes and expenditures by source and destination (Falokun and Adenikinju, 2009). As a matrix, each cell represents the flow of economic activities in monetary terms from a column account to a row account, giving a snapshot of an economy for a given year (Nwafor, Diao and Alpuerto, 2010). These multiple accounts comprise activities, commodities and economic agents.

The design is such that, it brings together aggregated data in a coherent and organized form that can be useful for policy makers in policy making and planning. According to Falokun and Adenikinju (2009), it is the basic building structure for CGE models that serves as the benchmark solution for them. The SAM also represents the database of the CGE model and is designed to capture the microeconomic and macroeconomic structure of the economy (Nwafor *et al*, 2010). In terms of basic philosophy, different variations are often adopted in the construction of the SAM depending on the country or region. However, the most important factor is that there must be accounting consistency at every stage of data generation by modelers. In other words, the data that the modelers supply into their models must be consistent with the national income and the input-output accounting that their equations contain (Falokun and Adenikinju, 2009).

The double-entry accounting principle in a SAM requires that for each account, total revenue (row total) must equal total expenditure (column total). The SAM according to Lofgren *et al* (2002) and Falokun and Adenikinju (2009) is made up of a number of accounts namely, activity account, commodity account, factor account, current account of the domestic institutions, the capital account and the rest of the world account; the subdivision of each account however depends on the objective of the study and data availability. The SAM is useful when trying to identify structure and linkage effects in an economy, analyzing growth and multiplier effects, monitoring of movements of key variables, the tracking of their effects on macroeconomic aggregates and answering "if" situation or policy scenarios especially using a CGE framework (Falokun and Adenikinju, 2009).

The main features/structure of a SAM as described by Nwafor *et al*. (2010) is as follows:

a) Activities and Commodities

This section of the SAM describes the sector responsible for production (such as domestic firms) in the economy and goods and services produced by these production sectors. The former is called activities or sectors while the latter are collectively called commodities, distinction is often made between the two. These production units divided into different sectors combine different factors of production (land, labour, capital) with raw materials used as intermediate inputs to produce different goods and services. In return, for the supply of the factors of production, activities pay economic agents. For instance, households receive wages and rents, government receive profits while the rest of the world collects payments for foreign capital. In a SAM, the "commodities" component also covers total domestic production plus imported supply of goods and services available in an economy at market prices. Also included in this account is tax imposed on commodities (consumption tax, import duties, levies). Other divisions in this category within the SAM include intermediate demand and intermediate inputs for production having their ways of balancing them. They trace the income and expenditure flows of activities and commodities. A SAM consists of different activities and commodities with activities divided majorly into agriculture, manufacturing and services. This can however be disaggregated into other components depending on data availability and the type of sub-sectors aggregated will depend on the nature of the study using it. For example, an agricultural-based study will have large numbers of agricultural sub-sectors like livestock, poultry, maize, beans, rice, and so on; while a manufacturing-based analysis will have the manufacturing sector opened up and other sectors aggregated depending on the objective.

b) Domestic Institutions/Economic Agents

The SAM also records information on various institutional accounts such as households, firms and government (Nwafor *et al*., 2010). The households get their income from payments for use of labor and capital in the form of wages and rent during production process. They also accept profit incomes from firms, social security and transfer payments such as pensions from the government and the rest of the world (usually in form of remittances and gifts). The rest of the world constitutes the external sector that trades with the domestic economy and also make/receive payments. The households spend their income on the purchase of commodities, pay taxes to the government and save the remaining portion or dis-save if expenditure exceeds income. Firms as institutions are treated as intermediate agents who transfer their profits to households and governments (taxes).

c) Savings, Investment and the Foreign Account

According to Nwafor *et al*. (2010), the savings and investment account covers the sources of savings used in financing domestic investments and these savings are divided into domestic (savings from households and government) and foreign (this shows the position of a country's current account balance). The foreign account referred to as "the rest of the world" in the SAM summarizes the economic relations between the country and other economies of the world. Foreign trade is captured in the synergy between the commodities account and the foreign account by trailing the import payments and export earnings. A country can also have interplays between the foreign account and factors account if some capital account employed in domestic production is owned by foreign companies (an example is oil production in Nigeria). The foreign inflows is made up of net remittances from abroad to households and foreign aid/grants received by governments from abroad together with export earnings. Foreign outflows comprise import payment and payments to foreign capital.

The most current SAM for the Nigerian economy is the 2006 SAM representing the economic activities in the economy for the year 2006. It is the most recent year for which sufficient data is available (Nwafor *et al*, 2010). It was built for the Dynamic CGE (DCGE) model that examined the agricultural growth and investment options for reducing poverty in Nigeria (Nwafor *et al*., 2010). This SAM contains 61 sectors/activities, 62 commodities, 12 household groups, 3 factors of production (land, labor and capital) and 4 tax accounts (Nwafor *et al.*, 2010). Each of the sectors were disaggregated to various components; under agriculture, there are 27 crops in cropping sub-sector, 4 livestock and 2 in other agriculture; under manufacturing, there are 13 divisions; under mining, 2 divisions (crude petroleum and natural gas and other mining) while services contains 13 sub-sectors. Agriculture has larger sectors because the study was agricultural-based so the SAM can be re-aggregated based on the nature and purpose of a study.

For the purpose of this study which focuses more on the energy sector, the sectors will be re-aggregated to eight (8) sectors and the details, including each sector's contribution to GDP, are presented in Table 4.1 while the complete re-aggregated is contained in Appendix One. Data used in building the SAM were sourced from publications of Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS), Federal Ministry of Agriculture and Water Resources (FMAWR) including data from the earlier 1995 SAM by UNDP showing Nigeria's economy in 1989. Nwafor *et al.* (2010) noted that the income and expenditures are unlikely to be balanced as a standard SAM make use of information from various sources, however, various methods can be adopted in making the data consistent and balance. It is important to point out some likely limitations associated with the 2006 SAM which emphasises the fact the SAM was built based on the input-output table of 1998. Thus, some of the features of the SAM show characteristics structure of the Nigerian economy as at that period. However, despite this limitation, the SAM is still useful in analysing the objective of the study especially as it is currently the most recent SAM vetted by government institutions such as the National Bureau of Statistics. Notable recent literature on CGE analysis for Nigeria had also used this SAM. Further development of a more recent SAM that considers the new structure of the Nigerian economy is on-going and yet to be completed as at the time of this study.

Table 4.1: Description of the Re-aggregated SAM for the Study

Code Name	**Sector Description**	**Sub-sectors**	**GDP (Current ₦ million)**	**Share in %**
AGR	Agriculture	Rice, Wheat, Maize, Sorghum, Millet, Cassava, Yams, Cocoyam, Irish Potato, Sweet Potato, Banana And Plantain, Beans, Groundnuts, Soya beans, Beniseed, Vegetables, Fruits, Cocoa, Coffee, Cotton, Oil Palm, Sugar and Sugar Cane, Unprocessed Tobacco, Nuts, Cashew, Rubber, Other Crops not Specified, Cattle, Live Goats and Sheep, Live Poultry and Other Livestock, fish, fish meat and forestry	5,913,648	29.70
MFC	Manufacturing	beef, goat, sheep meat, poultry meat, eggs, milk, other meat, beverages, processed food products, textiles, wood, wood products, furniture, transportation and other equipment, other manufacturing	1,315,588	6.61
PET	Crude Petroleum	Crude petroleum, natural gas and other mining.	6.860.390	34.46
ROIL	Refined oil	Refined oil.	58,157	0.29
RTRANS	Road transport	Road transport	446,506	2.24
UTIL	Utility	Electricity and water.	624,578	3.14
SER	Services	Building and Construction, Other transportation, wholesale and retail trade, hotel and restaurants, telecommunications, post, broadcasting, finance and other business services, real estate, education, health, other private services.	3,773,775	18.96
ADM	Non-tradable	Public Administration	915,889	4.60
Total		Total GDP at Factor Cost	19,908,531	100.00

Source: 2006 Nigerian SAM
Note: The original SAM can be downloaded from the following link:
https://dataverse.harvard.edu/dataset.xhtml?persistentId=hdl:1902.1/15648

4.5.2 Solution Technique

CGE models are often solved or formulated through the use of software systems. The major software systems often used are GAMS and GEMPACK, depending on the type of CGE model adopted. Other methods for solving a CGE model include Excel and MATLAB. The PEP model uses GAMS in solving the model and thus will represent the solution technique adopted for this study. The software enables users to implement some form of hybrid algorithms that combines different solvers. It was originally developed by a group of economists from the World Bank and was essentially to facilitate the resolution of large and complex non-linear models on personal computers (Robichaud, 2010). It permits the solving of simultaneous non-linear equations with or without optimization of some objective function (Decaluwe *et al,* 2010). The major strength of GAMS lies in its simplicity, portability, transferability and ease of technicalities. It is essentially user friendly once the codes are well-understood.

According to Robichaud (2010), a typical CGE model programmed in GAMS can be decomposed into three modules. These modules correspond to data entry, model specification and solving procedure. Also, elements in the model must be clearly defined, declared and assigned (that is, sets, parameters, variables and the equations). The first stage (data entry) involves calibration of data and begins with sets and parameter declaration and definition, data assignment and intermediate displays. The benchmark data for a CGE model is usually drawn from the SAM adopted for the study. The second stage (model) entails specifying the model, variables and equations. The third stage (resolution) centers on creating solving statements and display of results.

4.5.3 Simulation Procedure

This section discusses the various steps involved in the simulation procedure that produced the results of the study. Figure 4.3 presents the different steps involved in the implementation of a standard CGE model as described by the WTO and UNCTAD report (2012). Implementing a CGE model begins with obtaining the national data for the concerned economy, region, and world (depending on the nature of analysis). Thus, a country-specific study will use a national SAM data, while a regional study or global study will use a regional SAM or global SAM respectively. The next step will be to aggregate the data in the SAM to suit the objective of the study, where the various sectors are expanded or collapsed.

The completion of the above described process will lead to verifying the dataset with the benchmark equilibrium in the CGE GAMS code. In the gams code, the set of the model including the various variables (real, nominal, price) are presented. Following this is the calibration process where the functional form and elasticity parameters of the model vis-a-viz the SAM data for the economy, are specified. A replication check is then performed to ascertain the validity of the specified parameters. This is closely followed by a pre-simulation procedure that ensures the dataset and components of the model replicate the benchmark equilibrium. The value of the infeasibility input point is usually useful to ascertain this successful replication as the values must be as close to zero as possible. Thus, the stage ensures that there are no specification or calibration errors and thus, shocks can be introduced to the model.

After the initialisation process and policy change, the results of the counterfactual can then be compared to the benchmark. This is usually interpreted in percentage changes. Other policy shock scenarios can be evaluated and necessary sensitivity analyses are carried out. This is the basic simulation procedure for a standard CGE model.

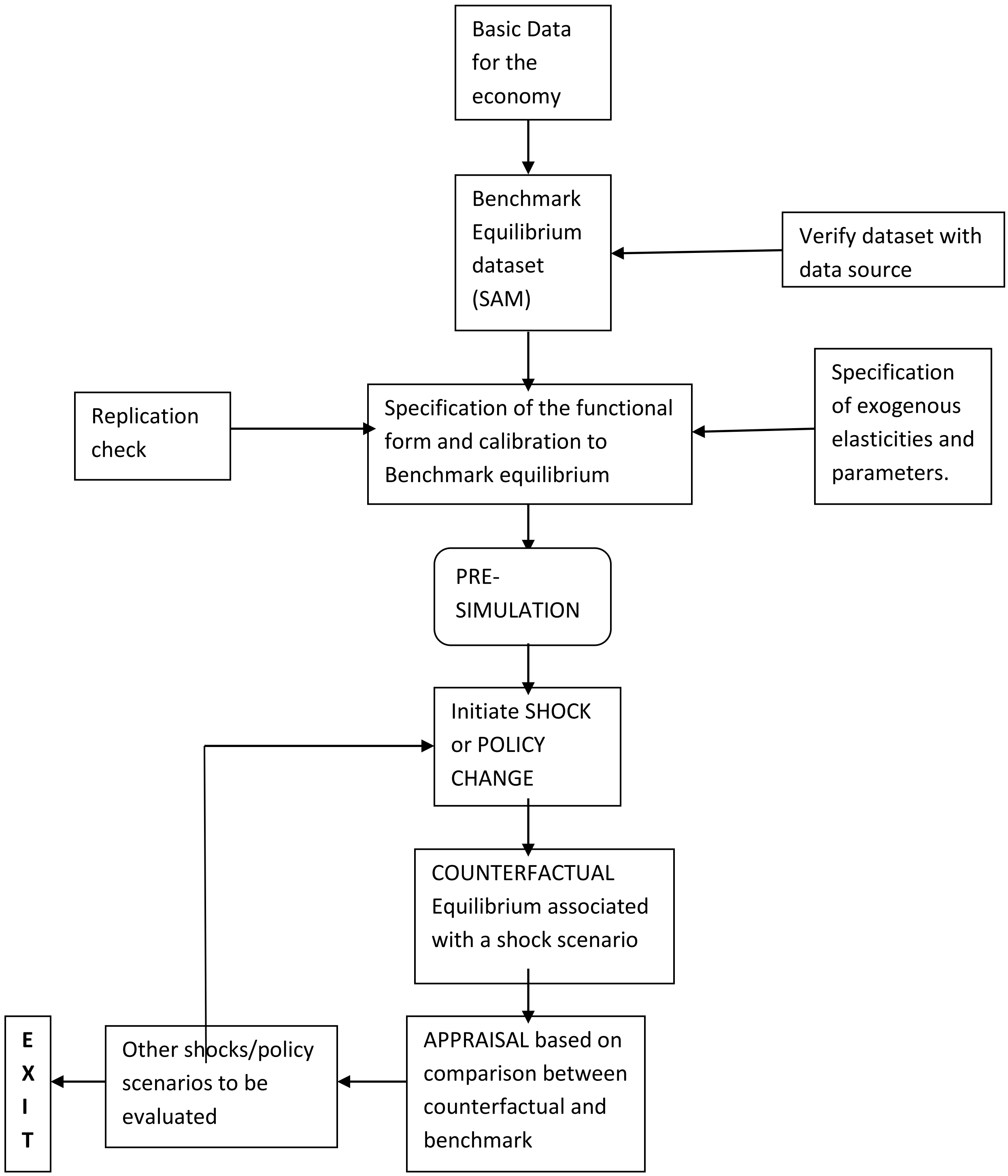


Figure 4.3: Steps in Implementing the CGE model
Source: Adapted from WTO and UNCTAD (2012)

4.5.4. Diagnostic Tests and Sensitivity Analysis

Increasing concern in the literature, especially on the influence of elasticity parameters (demand, supply, price and income) adopted in CGE models, has made it essential to perform robustness checks and the sensitivity of the results obtained. This is especially important as many researchers often "borrow" these elasticity parameter estimates from previous empirical literature. In other words, the rigour involved in CGE model often does not permit the modeller, to directly estimate these parameters. Thus, they depend on econometric studies that focused on determining the values of these elasticities that corresponds with the structure of the economy under study. The values of the parameters determine the magnitude of the result obtained in a CGE analysis. This is why emphasises are often placed on choice of parameters. Therefore, performing some diagnostic checks and sensitivity analysis will help determine the robustness and overall goodness of the model specification.

Further to this, the diagnostic tests helps to ascertain if the model had been able to replicate the benchmark equilibrium as reflected in the SAM data used for the analysis. This is because if the benchmark equilibrium values are not able to replicate the data for the economy as contained in the SAM, then, the results of the model will not be able to adequately explain the changes observed. Invariably, the results cannot be relied upon. One of the commonly used tests of diagnosis is the examination of the values of the infeasibility input point after the running of the model. This value is expected to be as close to zero as possible. The solution of the model must be able to reproduce the initial value of the equilibrium. Also, the verification of the non-violation of the Walras law is another diagnostic test often used in CGE analysis. This law ensures that the last market is in equilibrium. This is referred to as the Leon Walras law. This process involves examining the "level" values of the leon variable to ascertain if it is zero or infinitesimally small (very close to zero) in the baseline and simulation scenarios.

The sensitivity analyses on the other hand are conducted to essentially ascertain the robustness of the stimulation results when different parameter estimates are introduced. Thus, different elasticity parameters can be used in the model and the results under them are compared to check if there are any significant variations in magnitude or otherwise. This is usually performed systematically and then the results are compared. If there are no large deviations or significant variations, then it can be said that the parameter estimates and elasticity values adopted adequately reflect the dynamics of the economy. The result will also show if the model is relatively stable or not, in addition to showing how sensitive the model is to large changes.

4.6 Data Sources and Measurements

The 2006 Nigerian SAM which shows the monetary flows in 2006 is the dataset for the study. It gives detailed information on the flow of goods and services between different sectors, final demand, production inputs and trade for the year 2006. However, the re-aggregation described in Table 4.1 is to adequately capture the feedback effects between the fuel subsidy removal as a policy and the rest of the economy, especially the effect on carbon emission. The re-aggregated SAM contains 8 sectors (6 non-energy and 2 energy sectors); 9 commodities (here, agriculture is divided into food and agriculture to fulfill the Walras Law); 3 factors of production (land, labor and capital); two household groups (rural and urban); 3 tax accounts (firm and government; savings and investment; and rest of the world). This SAM specially accounts for fuel subsidy through the refined oil sector since it is imported refined oil that is subsidised by government. The estimated subsidy on petroleum product for Nigeria from the data of the Federal Ministry of Finance for year 2006 was given as ₦261 billion. However, the computed amount of the subsidy using the Energy Information Administration (EIA) and Central Bank of Nigeria (CBN) data reflected ₦179 billion. This calculation was based on the price of crude oil and retail price for domestic production as opposed to the imported refined oil. It can be attributed to the implicit subsidy of the domestic refineries as the price crude oil is sold to the local refineries is lower than the price sold to the export market. The difference of ₦82 billion is accounted for by this implicit subsidy. The study adopts the ₦179 billion as this reflects the actual value for the imported refined oil, given that this is the sector of interest. The benchmark statistics of this SAM as it relates to the various components are explained in the next chapter.

CHAPTER FIVE
RESULTS AND DISCUSSIONS

5.1 Preamble

This chapter presents the results of the analysis and simulation in line with the objectives set for the study. It begins with the discussion of the benchmark statistics of the model, that is, the state of the economy at *status quo* before simulation scenarios were introduced. The objective of the simulation scenarios as explained in the previous chapter centers on investigating the impacts that removing subsidy provided on petrol have on carbon emission levels in Nigeria. Thus, the results obtained from the simulation experiments are discussed, focusing on how removing fuel subsidy transmits shock to the economy and influence the measure of environmental quality (CO_2).

5.2 Benchmark Statistics

This section presents the overview of the structure of the Nigerian economy especially as it relates to production structure of the different sectors, factor shares, value added, trade pattern (import and export), optimising behaviour of agents (households, firms, government, rest of the world) as indicated in the SAM for the study. These statistics presents the state of the economy before any shock or simulation is introduced. Table 5.1 shows the contribution of each of the re-aggregated sectors to GDP and their respective shares. The information from Table 5.1 as contained in the 2006 Nigerian SAM show that the crude oil (oil and gas and mining activities) has the largest share of GDP in 2006 with ₦6,887,581,000 at 34.60 percent, closely followed by the agricultural sector (29.70 percent). In other words, the energy sector (Petroleum and Refined oil) jointly contributes about 34.89 percent while the non-energy sector contributes the remaining 65.11 percent for the year 2006. This explains the strategic importance of the energy sector in contributing to GDP, foreign exchange as well as government revenue.

Table 5.1: Re-aggregated SAM and their share of GDP

Code Name	Sector Description	GDP(₦'m)	Share of GDP (%)
AGR	Agriculture	5,913,648	29.70
MFC	Manufacturing	1,315,588	6.61
PET	Crude Petroleum	6,887,581	34.60
ROIL	Refined oil	58,157	0.29
RTRANS	Road transport	446,506	2.24
UTIL	Utility	624,578	3.14
SER	Services		18.82
ADM	Non-tradable	915,889	4.60
TOT	**Total GDP at Factor Cost**	**19,908,533**	**100**

Source: Re-calculated by author from the 2006 Nigerian SAM

In terms of trade, data shows that the bulk of imports originates from the manufacturing sector (makes up 52 percent) closely followed by the service sector (21 percent). On the export side, the mining sector holds the largest share with over 90 percent which reflects the economy's dependence on crude oil export. This is presented in Table 5.2. As a result of the huge revenue from oil export (evidenced from high export share of the mining sector), Nigeria had trade surplus in the year 2006. This surplus is estimated at ₦2.87 trillion. Also, it was observed that the net foreign transfer which amounted to ₦0.57 trillion, combined with the trade surplus contributed to the economy experiencing a current account surplus of ₦3.44 trillion. Summarily, the above described relationship in the economy as depicted by the SAM helps to understand the economic linkages and multiplier effects in the CGE model analysis.

Table 5.2: Nigeria Import and Export Share (%), 2001-2005

Sectors	Import shares	Export shares
Agriculture	9.23	0.44
Manufacturing	52.32	1.12
Mining	2.01	93.9
Refined Oil	15.24	-
Services	21.2	4.54
Total	100	100

Source: Computed by Author from the 2006 Nigerian SAM Results

The SAM also contains information on the different tax revenue collected by government from the other economic agents, composed of both direct and indirect taxes. Also, taxes are imposed on activities and commodities (Nwafor *et al*, 2010). The sum of tax revenue for that year in the SAM amounted to ₦2.8 trillion. These taxes ranges from production taxes imposed on the production sectors (excise duties, sales taxes, import tariffs, port levies, and other surcharges), households' personal income taxes, and company taxes (levied on oil companies).

5.3 Simulation Strategies

This section presents the description of the simulation strategies targeted towards providing results of the response of the economy, especially the magnitude of carbon emissions when subsidy of petrol is partially, gradually and completely removed in a dynamic setting. As a first step, a baseline scenario is simulated. The aim of this simulation is to produce a *"business-as-usual"* (BAU) picture of the economy, without the introduction of any policy impact. Once the benchmark statistics as described earlier are replicated, three variant of policy shocks are introduced before running the model. This is then compared with the outcome of the benchmark scenario and the deviations are reported as percentage changes. The simulation considered in the study is based on three scenarios; a partial (50 percent) removal of petrol subsidy, a gradual removal over a period of five years and a full or complete removal.

5.4 Results from Simulation Analysis

The results of the simulation performed to achieve the objective of the study when shocks are introduced to the model are presented. After replicating the baseline scenario of the economy, the policy shocks are expected to bring about macroeconomic and sectoral changes across the economy, including variations in carbon emission level which are reported in percentage changes. In other words, a CGE framework helps to determine the direction and magnitude of change in other sectors of the economy due to policy shift (such as reduction of fuel subsidy) in one sector (refined oil). Table 5.3 shows the simulation results of the changes in different indicators of macroeconomic performance. The aggregate effect is analysed under macroeconomic impacts while how the policy shock influences other sectors is presented under sectoral effects. The discussion follows both analysis of macroeconomic effects and sectoral effects

5.4.1 Macroeconomic Impacts

A policy shock due to a partial, gradual or complete elimination of import tariff on refined oil (fuel subsidy) is expected to bring about some changes in key macroeconomic aggregates in the economy. Such aggregates include Gross Domestic Product (GDP), government income, government savings, total investment, import price and trade. From Table 5.3, it is evident that all the macroeconomic variables produced a positive value in all simulation scenarios except for simulation 1 (partial removal) where the values were negative. Though the direction of change differed, however, the difference in magnitude was marginal. A partial removal of subsidy (SIM1) represented by a 50 percent increase in import tariff on refined oil resulted in a fall in GDP over time with 0.24 percent reduction in the first period and a 1.23 percent fall in the fifth period with an average fall of 0.69 percent over the five-year period.

Table 5.3: Simulation Results of Macroeconomic Effects (Full Employment)

Year	GDP			YG			SG			IT		
	SIM1	SIM2	SIM3	SIM1	SIM2	SIM3	SIM1	SIM2	SIM3	SIM1	SIM2	SIM3
1	-0.24	0.25	0.39	-1.89	2.05	3.33	-6.20	6.75	10.96	-10.18	10.63	17.14
2	-0.42	0.48	0.69	-2.23	2.75	3.85	-7.32	8.96	12.61	-12.75	15.55	22.30
3	-0.65	0.78	1.06	-2.61	3.43	4.35	-8.56	11.24	14.23	-15.61	20.37	26.36
4	-0.92	1.15	1.49	-3.03	4.18	4.89	-9.93	13.69	16.00	-18.78	25.56	30.59
5	-1.23	1.59	1.98	-3.51	4.99	5.48	-11.47	16.38	17.95	-22.33	31.22	35.14
Ave.	-0.69	0.85	1.12	-2.65	3.48	4.38	-8.69	11.40	14.35	-15.93	20.67	26.31

Source: Author's Computation based on simulation results from GAMS
GDP: Gross Domestic Product, YG: Government Income, SG: Government Savings, IT: Total Investment

This can be expected as one of the negative effects of subsidy is the fact that the policy results to diversion of fund from priority sectors which can reduce productivity over time. Thus, given that under this scenario, the subsidy still persist even though at a lower level, the influence is still evident as government continues to earmark a portion of the budget to fuel subsidy payment. In terms of government income and savings, a similar scenario is observed as income reduced by 1.89 percent in the first year and 3.51 percent in the fifth year with an overall average of 2.65 percent over the five-year period. Government savings likewise fell by 6.20 percent in the first period and by 11.47 percent in the fifth year, with 8.69 percent on the average. In the same vein, total investment declined by 10.18 percent in the first period, 22.33 percent in the fifth period and an average decline of 15.93 percent. The decline in investment could be attributed to the decline experienced in government income and savings which sidelined fund available to investment purposes overall.

In simulation 2 (gradual elimination of import tariff) and simulation 3 (complete removal of import tariff), the scenario is different as all the macroeconomic variables showed positive changes. In simulation 2, the value of GDP increased by 0.25 percent in the first year and 1.59 percent in the fifth year with an overall year average of 0.85 percent; for government income (YG) and government savings (SG), percentage increase recorded 2.05 and 6.75 respectively in the first year. This increased continued until it climatised at 4.99 and 16.38 percent respectively in the fifth year with an overall average of 3.48 and 11.40 percent. Also, the simulation procedure showed an increase in total investment (IT) as against the experience in simulation 1 since the variable reflected an increase of 10.63 percent in the first period and 31.22 percent in the fifth period with an overall average of 20.67 percent.

Similarly, the macroeconomic aggregates increased in the simulation 3 given that GDP, YG, SG and IT increased by 0.39, 3.33, 10.96 and 17.14 percent respectively in the first period. These increases can be attributed to the fact that with the complete removal of the fuel subsidy, funds are freed up immediately for investment purposes while in the partial removal, the funds through savings slowly accumulates for investment over the period. For all the macroeconomic variables, the rise peaked in the fifth year with percentage change of 1.98 percent for GDP, 5.38 percent for YG, 17.95 percent for SG and 35.14 percent for total investment. On the average, the variables recorded 1.12, 4.38, 14.35 and 26.31 positive percentage variation. It is important to note that the complete elimination scenario (SIM3) recorded the largest increase as the magnitude of government savings and total investment increased significantly compared to simulation 1 and simulation 2.

Another interesting picture is painted in Table 5.4 with a mixed result from wages and imports of refined oil variables. Across the different simulation scenarios, import of refined oil fell as expected. This can be due to a fiscal policy change that attempted to achieve an upward effect on import tariff, given that it was targeted at the refined oil sector. However, despite the fact that the direction of change is the same across all simulation scenarios (SIM1, SIM2 and SIM3), it was observed that the magnitude slightly differ. In simulation 1, import of refined oil declined by 5.67 percent while simulation 2 and simulation 3 showed a decline of 3.66 percent and 5.67 percent respectively in the first period. The magnitude of change in the simulation 1 and simulation 3 over the five year period appears to be almost the same and grew over the years in the same manner unlike the case of the simulation 2. In other words, a partial elimination and complete elimination achieves the same effect in terms of reduction in import of refined oil. A slightly similar occurrence was observed with the variable wage as negative values were presented in all the simulation scenarios. While there was a fall in wages in the first and second year for simulation 2 and simulation 3, an increase in wages was experienced for simulation 1 given that the latter produces a partial removal of fuel subsidy.

Table 5.4: Results for other Macroeconomic Variables

Year	**Import***			**Wage**		
	SIM1	SIM2	SIM3	SIM1	SIM2	SIM3
1	-5.67	-3.66	-5.67	0.53	-0.73	-1.25
2	-13.39	-8.17	-13.39	0.18	-0.24	-0.11
3	-15.06	-10.75	-15.06	-0.17	0.11	0.42
4	-15.70	-12.68	-15.70	-0.54	0.44	0.87
5	-15.93	-14.31	-15.94	-0.94	0.80	1.29
Ave.	-13.15	-9.91	-13.15	-0.19	0.076	0.24

Source: Author’s Computation based on simulation results from GAMS
Note:*Import is of Refined Oil

5.4.2 Sectoral Impacts

The simulation procedure under the different scenarios in addition to the macroeconomic effects also produced sectoral effects. One of the strongest advantages of the CGE model is that it enables the analysis of the impact of a policy change in one sector on other sectors of the economy. Thus, when government introduces a policy shock in one sector, in this case, an increase in import tariff on refined oil sector, the impact of this policy shift can be assessed on the other sectors of the economy. This section presents the percentage change in the sectoral aggregates of total output, imports and exports after the introduction of a policy shock.

Sectoral Output

As shown in Table 5.5, output for virtually all the sectors was negative except for the non-tradable (public administration) and road transport that were positive under a partial removal scenario. Though road transport declined over the five-year period with an overall year average of 2.05 percent; utility only declined in the fourth and fifth year with an average of 0.11 percent. The output of the refined oil sector equally declined even as the magnitude was greater for the later years.

Table 5.5: Sectoral Output-SIM1

Year	agr	mfc	pet	roil	util	rtrans	ser	adm
1	-0.05	-0.47	-0.01	-1.19	0.41	2.18	-0.33	1.09
2	-0.16	-0.78	-0.49	-5.61	0.28	2.14	-0.51	1.24
3	-0.29	-1.17	-1.08	-9.25	0.12	2.07	-0.74	1.39
4	-0.48	-1.64	-1.79	-12.18	-0.04	1.99	-1.00	1.57
5	-0.69	-2.19	-2.62	-14.54	-0.22	1.89	-1.30	1.75
Ave.	-0.33	-1.25	-1.19	-8.55	0.11	2.05	0.78	1.41

Source: Author's Computation based on simulation results from GAMS
Note: agr-agriculture, mfc-manufacturing, pet-crude oil and natural gas, roil-refined oil, util-utility, rtrans-road transportation, ser-services, adm-public administration

Table 5.6: Sectoral Output-SIM2

Year	agr	mfc	pet	roil	util	rtrans	ser	adm
1	0.07	0.52	0.02	1.06	-0.49	-2.46	0.34	-1.20
2	0.16	0.89	0.48	12.55	-0.29	-2.63	0.59	-1.53
3	0.35	1.41	1.16	19.46	-0.14	-2.84	0.89	-1.84
4	0.61	2.07	2.02	24.92	0.03	-3.02	1.25	-2.16
5	0.95	2.85	3.05	29.88	0.23	-3.17	1.67	-2.49
Ave.	0.43	1.55	1.35	17.57	-0.13	2.82	0.95	-1.84

Source: Author's Computation based on simulation results from GAMS

Table 5.7: Sectoral Output-SIM3

Year	agr	mfc	pet	roil	util	rtrans	ser	adm
1	0.13	0.86	0.01	1.66	-0.80	-4.02	0.54	-1.96
2	0.22	1.28	0.75	24.48	-0.28	-3.52	0.86	-2.13
3	0.49	1.91	1.71	30.78	-6.67	-3.31	1.20	-2.29
4	0.85	2.66	2.80	34.10	0.26	-3.13	1.59	-2.46
5	1.26	3.51	4.00	36.29	0.52	-2.93	2.02	-2.64
Ave.	0.59	2.04	1.85	25.46	-1.39	-3.38	1.24	2.29

Source: Author's Computation based on simulation results from GAMS

In simulating a gradual and complete removal, the opposite was the case as the agricultural, manufacturing, petroleum, refined oil and services had a positive change with an overall magnitude average of 0.43 percent, 1.55 percent, 1.35 percent, 17.57 percent and 0.95 percent. These are presented in Tables 5.5, 5.6 and 5.7. On the other hand, output in road transport and public administration fell all through the years while utility only declined for the initial three years. The above description and table of results shows generally the response of the other sectors of the economy when a policy shock such as simulation 1, simulation 2 and simulation 3 are introduced to the refined oil sector.

Evidently, the results suggest that on the average, despite the increase in the price of refined oil due to either a gradual or one shot removal; output eventually increased. This particularly stood out for the petroleum, refined oil and service sectors. At the initial period, output was low but at latter years, there is an increase in their total output. This sectoral analysis provides important policy pointers to the energy-intensive and non-energy intensive sectors. This is in terms of the design of policies for these identified sectors. An examination of the agricultural and manufacturing sector show that output declined with a partial removal, however, it experienced positive changes in the gradual and complete removal (even though magnitude of change was not as large as other sectors).

Intermediate Consumption

Overall, the intermediate consumption for all sectors declined under simulation 1 with the exception of road transportation and public administration. This is very similar to the results obtained earlier under total output. It is observed that a partial removal of subsidy reduced intermediate consumption of refined oil and petroleum sectors though with varying magnitude. Also, for utility, the intermediate consumption was only positive for the earlier years before declining. However, with a gradual and complete removal, the consumption pattern showed an increase across the sectors that recorded negative change under SIM1; though marginal for a few sectors. These results are presented in Tables 5.8 and 5.9.

Table 5.8: Total Intermediate Consumption by Industry j

Year	agı			mfc			pet			roil			util		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
1	-0.05	0.07	0.13	-0.47	0.53	0.86	-0.01	0.002	0.004	-1.19	1.06	1.66	0.41	-0.49	-0.80
2	-0.16	0.16	0.22	-0.78	0.89	1.28	-0.49	0.48	0.75	-5.61	12.55	24.48	0.28	-0.29	-0.28
3	-0.29	0.35	0.49	-1.17	1.41	1.91	-1.08	1.16	1.71	-9.25	19.46	30.78	0.12	-0.14	-6.67
4	-0.48	0.61	0.84	-1.64	2.07	2.66	-1.79	2.02	2.80	-12.18	24.92	34.10	-0.04	0.03	0.26
5	-0.69	0.95	1.26	-2.19	2.85	3.51	-2.62	3.05	4.00	-14.54	29.88	36.29	-0.22	0.23	0.52

Source: Author's Computation based on simulation results from GAMS
Note: S1-Simulation 1, S2-Simulation 2 and S3-Simulation 3

Table 5.9: Total Intermediate Consumption by Industry j (contd.)

Year	rtrans			ser			adm		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
1	2.18	-2.46	-4.02	-0.33	0.34	0.54	1.09	-1.20	-1.96
2	2.14	-2.63	-3.52	-0.52	0.59	0.86	1.24	-1.53	-2.13
3	2.08	-2.84	-3.31	-0.74	0.89	1.20	1.39	-1.84	-2.29
4	1.99	-3.02	-3.13	-1.00	1.25	1.59	1.57	-2.16	-2.46
5	1.89	-3.17	-2.93	-1.30	1.67	2.02	1.75	-2.49	-2.64

Source: Author's Computation based on simulation results from GAMS

Imports

Table 5.4 discussed earlier highlighted the import characteristics of the refined oil sector and thus, the impact of the policy change on the imports of other sectors are presented herein. Based on the Armington assumption which implies that the elasticity of demand between imported commodities and locally produced goods is 2, a 50 percent increase in import tariff on imported refined oil will reduce demand for imported goods in agricultural, manufacturing, petroleum, road transport and services over the five year period. Only import for food commodities increased in the first two years, though it began declining in the following years (Tables 5.10 and 5.11). However, with a gradual and complete removal, imports for all the sectors increased except for the food sectors which only increased in the latter years.

Table 5.10: Sectoral Imports

	agr			mfc			pet		
Year	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**
1	0.19	-0.41	-0.74	-0.57	0.45	0.66	-0.97	0.87	1.36
2	-0.32	0.36	0.78	-1.27	1.57	2.52	-4.17	9.69	19.12
3	-0.87	0.95	1.53	-2.01	2.54	3.61	-6.72	14.85	23.68
4	-1.44	1.52	2.18	-2.81	3.55	4.65	-8.68	18.77	25.75
5	-2.06	2.13	2.81	-3.68	4.66	5.72	-10.15	22.19	26.84

Source: Author’s Computation based on simulation results from GAMS

Table 5.11: Sectoral Imports (contd.)

	rtrans			ser			food		
Year	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**
1	-1.72	1.99	3.30	-0.96	0.93	1.47	0.89	-1.22	-2.09
2	-1.89	2.42	3.37	-1.58	1.96	3.01	0.41	-0.51	-0.36
3	-2.08	2.91	3.63	-2.24	2.88	3.95	-0.07	-0.09	0.27
4	-2.27	3.45	3.93	-2.94	3.85	4.87	-0.55	0.25	0.74
5	-2.49	4.02	4.26	-3.71	4.90	5.82	-1.03	0.58	1.14

Source: Author's Computation based on simulation results from GAMS

Exports

This section presents the results of the percentage change in exported commodities for the economy when there is a partial, gradual and full removal of subsidy in the economy. From Table 5.12, it is evident that exports declined the highest when there is a partial removal of subsidy, especially for agricultural (including food), manufacturing and petroleum, though the magnitude fluctuated. However, there was an increase in exported commodities of the services and road transportation sectors over the entire period. In these two sectors, a gradual and complete removal reduced the volume of exports where the greatest reduction was recorded for the road transportation sector. On the contrary, exports for the other commodities were positive even though the magnitude declined over five years on the average. The various simulations are with the assumption that the current account is held fixed within the model as described in the closure rules.

Table 5.12: Sectoral Exports

	Agr			mfc			pet		
Year	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**
1	-0.95	1.33	2.29	-0.19	0.31	0.55	0.006	-0.005	-0.008
2	-0.65	0.75	0.69	-0.16	0.13	0.05	-0.46	0.39	0.59
3	-0.43	0.68	0.58	-0.18	0.18	0.16	-1.03	1.03	1.51
4	-0.29	1.83	0.79	-0.25	0.34	0.41	-1.72	1.86	2.58
5	-0.21	1.14	1.18	-0.39	0.59	0.74	-2.54	2.86	3.77

Source: Author's Computation based on simulation results from GAMS

Table 5.13: Sectoral Exports (contd.)

	rtrans			ser		
Year	**SIM1**	**SIM2**	**SIM3**	**SIM1**	**SIM2**	**SIM3**
1	2.89	-3.23	-5.26	0.17	-0.14	-0.21
2	2.92	-3.56	-4.79	0.30	-0.42	-0.68
3	2.94	-3.95	-4.69	0.43	-0.58	-0.81
4	2.93	-4.33	-4.62	0.54	-0.71	-0.88
5	2.92	-4.69	-4.55	0.64	-0.82	-0.92

Source: Author's Computation based on simulation results from GAMS

5.4.3 Household Impact

The change in policy as a result of attempt to reform fuel subsidy is expected to impact the different household categories in the model. The model differentiated between two categories of households namely rural and urban households. The results of the various channels through which the different households are impacted are presented in Tables 5.14-5.17 and the discussion follows therein.

Income

Household income was found to have increased due to a partial removal of subsidy (SIM1) only in the first two years after which it began to fall. However, with a gradual and a one shot removal, income only declined in the first two years and experienced an increase in the following years. On the average, values of income across all household categories were positive under simulation 2 and simulation 3 while negative under simulation 1. The largest increase in income was recorded for urban households under simulation 3.

Table 5.14: Household Income

Year	**SIM1**		**SIM2**		**SIM2**	
	HR	HU	HR	HU	HR	HU
1	0.44	0.30	-0.62	-0.43	-1.06	-0.75
2	0.93	0.01	-0.13	-0.02	0.02	0.13
3	-0.27	-0.32	0.24	0.31	0.57	0.61
4	-0.66	-0.66	0.62	0.66	1.07	1.65
5	-1.08	-1.04	1.03	1.04	1.56	1.49
Ave.	-0.13	-0.34	0.23	0.31	0.43	0.63

Source: Author's Computation based on simulation results from GAMS

In the case of labour and capital income, a similar scenario is observed as across all households, labour income only increased for the first and second period in simulation 1 while it fell for the remaining periods, with a negative overall average of 0.19 percent. In simulation 2 and simulation 3, labour income was found to increase for most of the years under review and only fell in the first two years with an overall average of 0.08 percent and 0.24 percent respectively. This may be attributed to the absorption of labour in the refined oil sector as is equally evident from the changes observed in wages. It is important to note that labour income for both rural and urban households were the same under the different simulation scenarios (Table 5.15). This is due to the assumption that each category of households obtains a fixed share of the total labour income.

Furthermore, capital income only accrues to rural households as they are the only household category that own land which is a component of capital. As shown in the SAM re-aggregated for the study, urban households do not get income from capital. Table 5.16 shows that the highest capital income accrues to the rural household when fuel subsidy is completely eliminated in one shot. This is evident with an average increase of 0.67 percent. On the other hand, it declined for the same category of household when subsidy was partially removed by 0.44 percent. On the average, the highest transfer income went to urban households with an increase of 0.95 percent when subsidy is completely removed while it only fell for rural households in the first year and increased thereafter. On the other hand, a consistent decline was observed for rural and urban households in the case of a partial removal.

Table 5.15: Labour Income of Households

	SIM1		SIM2		SIM3	
Year	hr.	hu.	hr.	hu.	hr.	hu.
1	0.53	0.53	-0.73	-0.73	-1.25	-1.25
2	0.18	0.18	-0.24	-0.24	-0.11	-0.11
3	-0.17	-0.17	0.11	0.11	0.42	0.42
4	-0.54	-0.54	0.44	0.44	0.87	0.87
5	-0.94	-0.94	0.80	0.80	1.29	1.29

Source: Author’s Computation based on simulation results from GAMS

Table 5.16: Capital Income of Households

	SIM1		SIM2		SIM3	
Year	hr.	hu.	hr.	hu.	hr.	hu.
1	0.47	-	-0.65	-	-1.11	-
2	0.06	-	-0.11	-	0.05	-
3	-0.39	-	0.36	-	0.77	-
4	-0.89	-	0.88	-	1.46	-
5	-1.44	-	1.48	-	2.18	-

Source: Author's Computation based on simulation results from GAMS
Note: Urban households do not on land which is a component of capital

Table 5.17: Transfer Income of Households

	SIM1		SIM2		SIM3	
Year	hr.	hu.	hr.	hu.	hr.	hu.
1	-0.03	-0.09	-0.03	0.08	-0.07	0.12
2	-0.19	-0.31	0.25	0.35	0.45	0.54
3	-0.36	-0.57	0.44	0.66	0.66	0.93
4	-0.53	-0.87	0.61	1.02	0.81	1.36
5	-0.70	-1.22	0.78	1.44	0.95	1.82

Source: Author's Computation based on simulation results from GAMS

Consumption

Across all households, consumption of agricultural and manufacturing products only increased in the first two years and declined in the following years with an average of 0.09 percent (rural) and 0.26 percent (urban) for agriculture and 0.17 percent (rural) and 0.10 percent (urban) for manufacturing under simulation 1. This is evident from Table 5.18. In the consumption of refined oil, there was an increase for all households even though the magnitude of the decrease declined over the five-year period. Also, a partial removal of subsidy resulted in an increase in the consumption of road transportation and services, though it fell in the fifth year. This may be attributed to the vital role that refined oil plays in supporting households domestic and business' energy needs. It is commonly used to power generators and vehicles used for transportation services, thus the increase in the two commodities, except when it fell for the rural households for road transport in the fifth year and for both households for services. However, consumption of food commodities fell across all the households with the partial removal of subsidy.

Table 5.18: Consumption of Commodities by Households-SIM1

Year	agr		mfc		roil		util		rtrans		ser		food	
	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu
1	0.14	0.11	0.63	0.53	13.49	13.10	0.49	0.44	0.35	0.33	0.48	0.43	0.09	0.05
2	0.04	0.04	0.28	0.26	12.25	11.95	0.35	0.34	0.27	0.26	0.36	0.35	-0.04	-0.05
3	-0.07	-0.05	-0.12	-0.05	11.14	10.92	0.18	0.21	0.17	0.18	0.22	0.25	-0.22	-0.18
4	-0.20	-1.15	-0.57	-0.42	10.13	10.00	-0.03	0.03	0.07	0.09	0.06	0.13	-0.42	-0.34
5	-0.35	-0.27	-1.07	-0.84	9.21	9.16	-0.27	-0.17	-0.04	0.01	-0.12	-0.01	-0.67	-0.54

Source: Author's Computation based on simulation results from GAMS

The results for simulation 2 and simulation 3 shows a different scenario from that of simulation 1 as consumption of refined oil declined significantly with an average magnitude of 12.02 percent (rural) and 11.78 percent (urban) with a gradual removal and 13.77 percent (rural) and 13.52 percent (urban) when there is a complete removal. These are presented in Tables 5.19 and 20. This differs from the intermediate demand of the sectors for refined oil which increased under simulation 2 and simulation 3. Therefore, with a gradual and complete removal of subsidy, consumption for road transport and service commodities declined but increased when the subsidy was partially removed. The above described scenario may be connected to the fall in import and local price of refined oil in simulation 1. As the price fell, consumption increased while under simulation 2 and simulation 3 when the prices rose and household consumption of refined oil declined.

Overall, a policy change in fuel subsidy brings about a positive response in quantity demanded of composite commodity even though the magnitude was found to decline under simulation 1. On the other hand, the response was negative under simulation 2 and simulation 3.

Table 5.19: Consumption of Commodities by Households-SIM2

Year	agr		mfc		roil		util		rtrans		ser		food	
	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu
1	-0.17	-0.12	-0.79	-0.66	-11.90	-11.54	-0.59	-0.52	-0.42	-0.38	-0.58	-0.50	-0.12	-0.05
2	-0.07	-0.06	-0.39	-0.38	-11.48	-11.20	-0.50	-0.49	-0.33	-0.33	-0.47	-0.46	0.03	0.03
3	0.06	0.03	-0.04	-0.08	-11.78	-11.55	-0.38	-0.40	-0.27	-0.28	-0.36	-0.39	0.23	0.18
4	0.21	0.15	-0.45	0.28	-12.25	-12.05	-0.20	-0.27	-0.20	-0.23	-0.23	-0.31	0.49	0.39
5	0.39	0.30	0.99	0.72	-12.71	-12.56	0.02	-0.09	-0.12	-0.17	-0.07	-0.19	0.83	0.67

Source: Author's Computation based on simulation results from GAMS

Table 5.20: Consumption of Commodities by Households-SIM3

Year	agr		mfc		roil		util		rtrans		ser		food	
	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu	hr	hu
1	-0.28	-0.20	-1.34	-1.10	-18.08	-17.53	-0.98	-0.86	-0.69	-0.64	-0.96	-0.83	-0.21	-0.09
2	-0.05	-0.07	-0.38	-0.42	-14.26	-13.94	-0.66	-0.66	-0.41	-0.41	-0.58	-0.59	0.08	0.05
3	0.15	0.09	0.28	0.11	-12.98	-12.77	-0.36	-0.42	-0.25	-0.28	-0.33	-0.41	0.39	0.29
4	0.37	0.26	0.95	0.65	-12.13	-12.00	-0.03	-0.15	-0.11	-0.16	-0.08	-0.22	0.76	0.59
5	0.61	0.47	1.66	1.24	-11.41	-11.38	0.33	0.15	0.03	-0.04	0.19	-0.01	1.18	0.94

Source: Author's Computation based on simulation results from GAMS

5.4.4 Carbon Emission

In the simulation of the consequences of subsidy removal on carbon emissions in Nigeria, the carbon co-efficients for each of the sectors were derived. This is to achieve the environmental objective of the study. In other words, the model specially accounts for carbon co-efficients to ensure the derivation of both total carbon emissions in the economy and sectoral carbon emissions. This is one of the key features of the *E2* model. The study calculates the energy intensity of each sector and the assumption is that the amount of carbon emissions emitted by the sectors is dependent on their energy intensity. Thus, how clean or dirty the different sector's production technology is will depend on the amount of energy been used as inputs. This energy intensity is derived by calculating the ratio of energy expenditures of each sector relative to their respective value added. Therefore, the estimated carbon emission co-efficients consistent with the emissions (obtained from energy intensity) of each sector is presented in Table 5.21. The estimation is based on the value added and energy expenditure values of each of the sectors from the re-aggregated 2006 SAM for Nigeria. This is presented in percentage values.

Table 5.21: Estimated Sectoral Carbon Co-efficients

S/N	Sector	Carbon Co-efficient (%)
1	Agriculture	0.04
2	Manufacturing	2.62
3	Petroleum	1.10
4	Refined Oil	21.11
5	Utility	9.10
6	Road Transport	30.90
7	Services	6.02
8	Public Administration	22.78

Source: Calculated by Author from the 2006 Nigerian SAM

In the dynamic simulation of an increase in import tariff on refined oil, overall total carbon emission declined for simulation 1 while it was found to surprisingly increase under simulation 2 and simulation 3. These results are presented in Table 5.22. Despite the fact that most of the macroeconomic variables analysed under simulation 1 showed a decline (though the magnitude was marginal), the scenario showed the greatest fall in total carbon emissions for the economy. This implies that with a partial (50 percent) elimination of import tariff on refined oil, overall carbon emission in the economy fell while it increased with a gradual and complete elimination. This is despite the fact that the simulation 2 and 3 recorded the highest increase in macroeconomic variables. This further confirms the assertion of empirical literature that driving a sustainable low-carbon growth path comes with inherent trade-offs between ensuring environmental sustainability and economic prosperity.

Table 5.22: Total Carbon Emissions for the Economy

Year	SIM1	SIM2	SIM3
2	-0.65	1.02	1.89
3	-1.38	1.98	3.08
4	-2.19	3.04	4.24
5	-3.09	4.24	5.46

Source: Author's Computation based on simulation results from GAMS

In addition, the result further provided evidence that the removal of subsidy on petrol is not sufficient in cutting down emission. The justification for this could be due to the fact that in Nigeria, there is no alternative to using petrol to run cars and generating sets. Therefore, with increase in petrol price, consumers will initially reduce their consumption but with time, they will have to increase it so as to satisfy their various energy needs. This eventually resulted to the increase in emission observed in the latter years, even though on the average the increase marginal. The conclusion is that for the removal of fuel subsidy to be effective in reducing carbon emissions, there must be adequate development and supply of appropriate alternatives to fossil fuel based petrol.

The above discussed trend was equally observed in the sectoral carbon emission with the highest emission level from the refined oil sector in the three simulation scenarios, though the magnitude was much lesser in simulation 1.

Sectoral Carbon Emission Results under various Simulation Scenarios

As observed from Table 5.23, carbon emissions by all the sectors fell with a partial removal of import tariff on refined oil for the Nigerian economy. On the average, the sector with the lowest emission level was the road transport sector with 0.88 percent followed by utility and agriculture sectors with 1.35 percent and 1.47 percent respectively. This tends to show an interesting image considering the fact that the road transport sector had a high carbon co-efficient when compared to other sectors such as manufacturing and services. This result further reiterates the results from the output of the sectors as explained previously (See Tables 5.5-5.7). In the case of the road transport and manufacturing sector, even though emissions only fell in the simulation 1 scenario, there outputs increased when subsidy was completely phased out in one shot (SIM 3 scenario).

Table 5.23: Sectoral Carbon Emission-SIM1

Period	**agr**	**mfc**	**pet**	**roil**	**util**	**rtrans**	**ser**
2	-0.46	-0.52	-0.49	-4.79	-0.40	-0.19	-0.48
3	-1.04	-1.17	-1.09	-8.70	-0.94	-0.55	-1.10
4	-1.76	-1.97	-1.79	-11.83	-1.61	-1.06	-1.87
5	-2.61	-2.92	-2.63	-14.33	-2.43	-1.73	-2.80
Ave.	**-1.47**	**-1.65**	**-1.50**	**-9.91**	**-1.35**	**-0.88**	**-1.56**

Source: Author’s Computation based on simulation results from GAMS

On the contrary, however, emissions from all sectors were found to increase with a gradual and complete removal even though the magnitude increased only marginally. These results are presented in Tables 5.24 and 5.25. Overall, it is evident from results analysed that emission increased on the average in sectors where output increased and likewise carbon emissions declined in the sectors where output fell at the aggregate level under the various scenarios simulated in the study.

Table 5.24: Sectoral Carbon Emission-SIM2

Period	**agr**	**mfc**	**pet**	**roil**	**util**	**rtrans**	**ser**
2	0.43	0.49	0.48	11.88	0.35	0.09	0.45
3	1.09	1.27	1.17	18.97	0.95	0.41	1.17
4	1.96	2.27	2.03	24.54	1.75	0.90	2.11
5	3.01	3.50	3.06	29.56	2.73	1.56	3.29
Ave.	**1.62**	**1.88**	**1.69**	**21.24**	**1.45**	**0.74**	**1.76**

Source: Author's Computation based on simulation results from GAMS

Table 5.25: Sectoral Carbon Emission-SIM3

Period	**agr**	**mfc**	**pet**	**roil**	**util**	**rtrans**	**ser**
2	0.65	0.77	0.75	23.89	0.51	0.08	0.69
3	1.61	1.88	1.72	30.56	1.41	0.57	1.73
4	2.73	3.18	2.81	34.07	2.47	1.26	2.97
5	3.99	4.67	4.02	36.37	3.66	2.12	4.39
Ave.	**2.25**	**2.63**	**2.33**	**31.22**	**2.01**	**1.01**	**2.45**

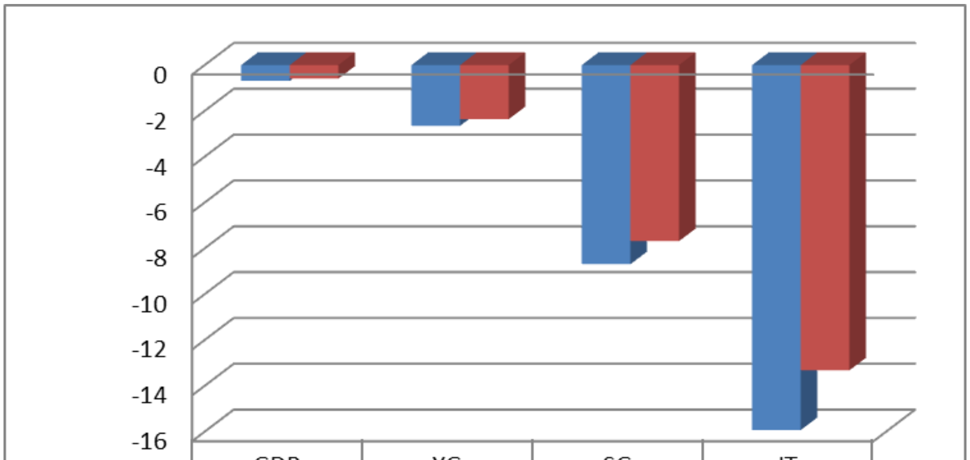
Source: Author's Computation based on simulation results from GAMS

5.5 Unemployment Assumption in the Labour Market

The study under the closure rule, made an assumption of unemployment where it is assumed that a certain level of unemployment exists in the economy. This was done by adjusting the labour equilibrium of equation 65 of the model equations by setting labour supply to equal labour demand plus unemployment. This becomes $\sum_j LD_{j,t} + UE_t = LS_t$.

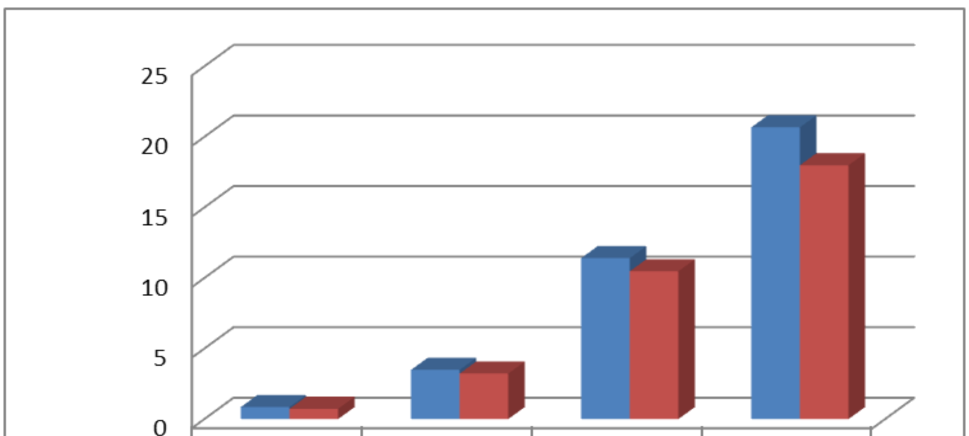
Under the full employment assumption which are the results earlier presented above, equation 65 equated labour supply to labour demand without unemployment. This section thus presents the macroeconomic and sectoral results from the model after equation 65 was adjusted to assume that a level of unemployment exists in the economy. To maintain equilibrium in the labour market under this specification, wage is held fixed in the model.

Figures 5.2-5.4 presents the graphical representation of the comparison between results of macroeconomic aggregates under the full employment assumption and the unemployment assumption. It reflects the extent to which unemployment may influence macroeconomic results. It is evident from the figures that the effect of the shock, especially in terms of direction is the same with the full employment assumption. However, the two scenarios differ in magnitude, though slightly, except for total investment. This deviation in total investment could be attributed to the change observed in government savings as compared to the case of full employment where it was slightly higher. Overall, from the three figures, the impact of subsidy removal on macroeconomic variables under the three scenarios was less in the unemployment assumption compared to the full employment assumption.



	GDP	YG	SG	IT
SIM1	-0.69	-2.65	-8.69	-15.93
SIM1+U	-0.59	-2.36	-7.68	-13.32

Figure 5.1: Macroeconomic Effects under Unemployment (SIM1)
Source: Author's Computation using excel
Note: SIM1+U indicates simulation one under the unemployment assumption



	GDP	YG	SG	IT
SIM2	0.85	3.48	11.4	20.67
SIM2+U	0.72	3.22	10.47	17.98

Figure 5.2: Macroeconomic Effects under Unemployment (SIM2)
Source: Author's Computation using excel
Note: SIM2+U indicates simulation two under the unemployment assumption

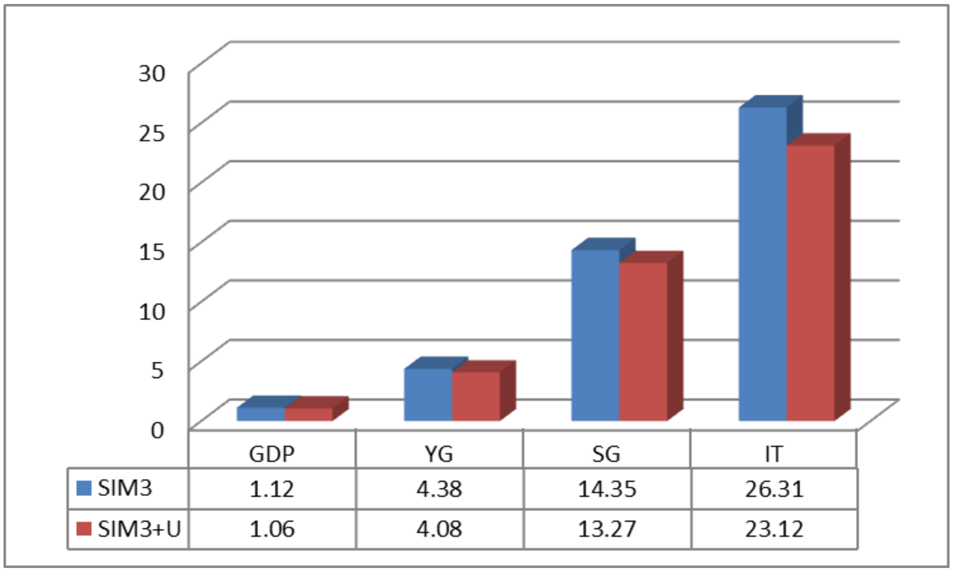


Figure 5.3: Macroeconomic Effects under Unemployment (SIM3)
Source: Author's Computation using excel
Note: SIM3+U indicates simulation three under the unemployment assumption

5.6 Diagnostic Tests and Sensitivity Analysis

A number of diagnostic checks and sensitivity analysis were performed to ascertain the overall goodness of the model specification and confirm the robustness and reliability of the simulation results using different elasticity parameter values. The former is referred to as diagnostic checks while the latter is the sensitivity analysis component. The diagnostic test carried out involves the verification of the baseline simulation which confirms that the solution to the model in the absence of policy shocks, replicates the initial benchmark equilibrium statistics. One way this was done was to examine the magnitude of the infeasibility at the input point from the output (.lst) file. The results shows that the input point for all simulation exercises were infinitesimally small. This is presented in Table 5.26. It suggests that the highest deviation of the simulation value from the benchmark initial equilibrium value is minimal and negligible, as close to zero as possible. In other words, it does not lead to the explosion or bloating of the simulation results. Also, it is expected that the various simulation scenarios are solved without any iteration. This was performed within the modeling framework, showing absence of any iteration beyond "After-scaling".

Table 5.26: Diagnostic 1- Baseline Simulation Check

Inter	Phase	Ninf.	Infes.	RGmax	NSB	StepInter	MX	OK
0	0		1.7838834324E+07	(Input Point)				
				Pre-triangular equations:		461		
				Post-triangular equations:		140		
1	0		1.4260580680E-06	(After pre-processing)				
2	0		7.1501849851E-13	(After scaling)				

Source: Author's Computation based on simulation results from GAMS

The second diagnostic test that was performed relates to checking the *Leon* variable to confirm that the last market is in equilibrium which verifies that the Walras law is not violated. This is done by examining the "level" value of the variable both in the baseline scenario and under the various simulation procedures. The expectation is that the values are as close to zero as possible, that is infinitesimally small and this is confirmed from the Table 5.27. It shows that under the simulations and baseline column, the values are approximately zero.

Table 5.27: Diagnostic 2- Leon Walras Check (VAR LEON)

--------VAR LEON Excess Supply on the last Market						
	LOWER	LEVEL	LEVEL			UPPER
		Baseline	SIM1	SIM2	SIM3	
1	-INF	-4.66E-10	-4.729E-7	-2.785E-8	3.6357E-7	+INF
2	-INF	-4.66E-10	1.3278E-6	4.622E-10	-1.683E-6	+INF
3	-INF	-6.99E-10	-1.191E-6	-1.343E-8	-4.113E-6	+INF
4	-INF	-4.65E-10	5.1532E-8	1.1584E-8	-7.655E-6	+INF
5	-INF	-6.99E-10	3.4562E-8	1.2219E-8	-1.343E-5	+INF

Source: Author's Computation based on simulation results from GAMS

The sensitivity analysis which is the other component of the robustness check for the model employed for the study, involves running the model with varying Constant Elasticity of Substitution values and confirming that they are not significantly different from the earlier results obtained. This is performed systematically and results are consequently compared. A common procedure for carrying out this exercise is to double the parameter values, run the model; then reduce the values and then compare the different results to confirm if there is any significant deviation from the previous results obtained. The purpose of this procedure is to investigate how sensitive the results obtained from the model are, to large changes. The result of the sensitivity analysis conducted with simulation one (a partial removal) is presented in Figure 5.4. The results generally reflect minimal deviation from previous simulation after the Constant Elasticity of Substitution values were changed. This is particularly evident with the macroeconomic and emission aggregates. From the figure presented, all the variables did not show any significant deviation. The savings and investment variables that appeared to change as only changed slightly as the magnitude of deviation was very minimal and insignificant. It is important to point out that the CES value investigated concerns the values arbitrarily obtained from the literature and does not include those calibrated within the model. This includes labour and capital demand, imports and value added.

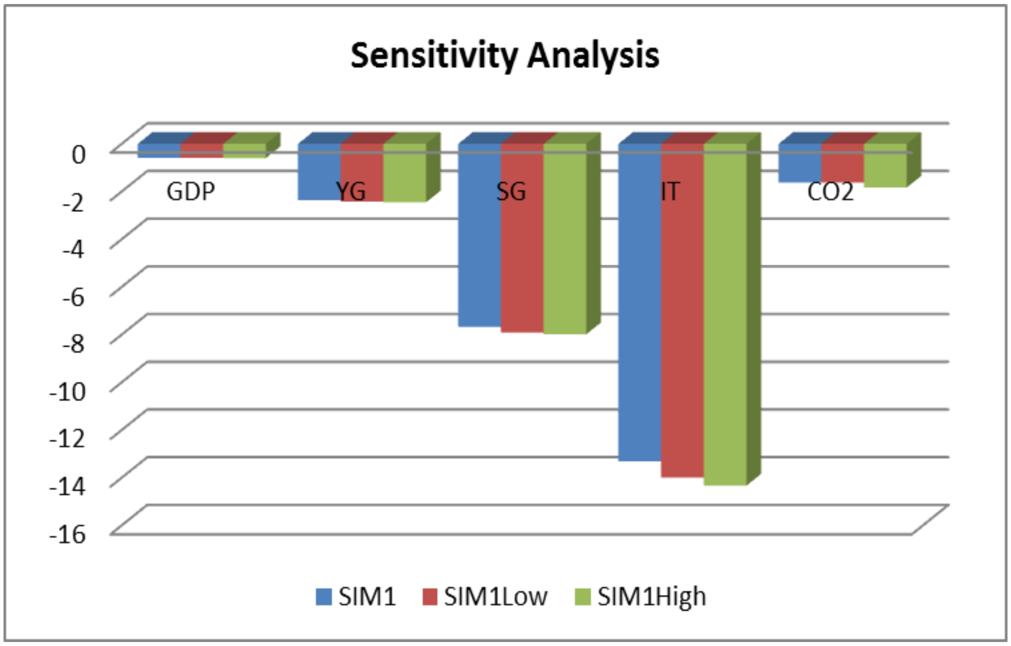


Figure 5.4: Sensitivity Analysis of Macroeconomic and Carbon emission Variables (average)
Source: Author's Computation using excel

5.7 Policy Implications

The results presented and discussed have some policy implications. They include:

1. It was found that carbon emissions declined only in the first simulation where import tariff on refined oil were decreased by 50 percent and it was also the only simulation that recorded decline in key macroeconomic aggregates and welfare of households. This suggests that the drive to minimise emission levels through fuel subsidy removal comes with an additional cost of loss in economic value. This explains the trade-off between a fossil fuel driven growth (brown growth) and environmental sustainability (green growth). It reflect issues usually raised on driving sustainable development in developing economies as pointed out in UNEP and IEA (2001). Even though household's income fell, the fall was marginal. Given the fact that domestic demand fell with domestic supply, a local content strategy might be able to generate a more rewarding outcome. This local content strategy entails developing the local refineries to increase the percentage of domestic production of petroleum. Thus, rather than allocating fund towards subsidising petrol, these financial resources can be redirected

towards further development of the petroleum sector. The savings from the subsidy when targeted on the development of the capacity of the refineries can increase domestic supply which will minimise dependence on import of refined oil. This is especially as a significant proportion of the fuel consumed locally is imported and only a small percentage is produced by the local refineries.

2. Also, given that government savings, income and total investment increased the greatest when fuel subsidy was gradually eliminated and when it was completely eliminated with increased emission; alternative mix of energy can be a viable policy option. Government can develop support programmes that enhance technology in production to minimise fossil emission from fuel consumption. Such can be the "fuel blending" technology used in the Southern African region (Mukonza, 2015) which can be enhanced and adapted to the Nigerian context. This "fuel blending" technology involves developing an energy type that minimises the composition of fossil fuel. A variant of this can be developed for Nigeria. In Zimbabwe for example, there are fuel blending of *ethanol15* which implies that the fuel is made up of 85 percent petrol and 15 percent ethanol (a more environmentally friendly energy) and by this, carbon emission from the consumption of the fuel is minimal as the fossil fuel content is reduced. Even though the study of Mukonza (2015) noted that there are implementation challenges for the case of Zimbabwe; however, with appropriate policy design, these challenges can be navigated with time. The "green petrol" idea as documented in Ibikunle (2006) could have been a viable substitute to gasoline as it will reduce the volume of emissions from the petrol.

5.8 Concluding Remarks

This chapter has presented and discussed the results obtained from the simulation exercise of a partial, gradual and complete removal of import tariff on imported refined oil in Nigeria. This process has helped to shed light on the economic, social and environmental implications of the policy shift on different sectors of the economy. It presents how the various sectors response to attempt to remove the fuel subsidy policy under varying simulation procedures. Generally, the results obtained produced a mixed picture which further reinforced the trade-off often associated with achieving a sustainable development especially for developing countries such as Nigeria. This implies that any attempt to cut down emission levels such as the removal of subsidy results to lower productivity, output and a decline in household welfare while enhancing economic prosperity will come at a cost of increased emission. The results also showed that removing subsidies on petrol may not be sufficient to ensure lower carbon emissions, especially given that there is no cleaner alternative to fossil fuel based petrol to power vehicles. Thus, even if removal of fuel subsidy reduces emission initially through price increases, it may rise in future years since there is no better alternative to switch to. Though the results are slight deviation from other empirical studies but its arguments are similar to that of Allaire and Brown (2012) and Ballali (2012). The latter argued that degree of changes in response will depend on the cross price elasticities of the products. Finally, the results of the various diagnostic and sensitivity analysis performed were presented which indicated the robustness of the model specification of the study and reliability of the results therein obtained.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Recent years had witnessed renewed interest at ensuring environmental sustainability in driving higher levels of economic growth globally. One of the measures often advocated is adopting green growth strategies as against a brown growth. Nigeria as part of Africa's strategy on voluntary emission reduction had been making efforts at combating environmental challenges through different initiatives, especially given its commitment under the UNFCCC accord. This commitment which is a voluntary "non-bidding" one to reduce atmospheric concentrations of greenhouse gases, represents a global effort towards mitigating the impacts of climate change. This is despite the fact that the country contributes minimally to climate change but is most vulnerable to its impact. For example, the Clean Energy Initiatives by the Ministry of Environment is to ensure all sectors of the economy switch to cleaner sources of energy. The study, thus, investigates how effective the removal of subsidy on fuel can be a viable tool in achieving environmental quality. This was done by analysing the environmental consequences of fuel subsidy removal using an economy-wide modelling approach such as the dynamic CGE. It is based on the premise that cheap energy pricing policy such the fuel subsidy policy enhances inefficient consumption of energy among economic agents as supported by empirical literature. It used a modified energy-environment recursive dynamic CGE over a five-year period.

In the core analysis of this study, it was revealed from simulation experiments, that removing subsidy through increases in import tariff as a means of cutting down emission levels provides mixed results. In the three simulation scenarios, simulation 1 which involves a 50 percent increase in imports tariff on refined oil recorded the highest decline in carbon emissions for the economy and in sectoral analysis, even though it also recorded a decline in key macroeconomic variables. In the other two simulations simulation 2 (gradual elimination) and simulation 3 (complete elimination), carbon emissions were found to increase even though sectoral output and other indicators of macroeconomic aggregates also increased. This is despite the fact that the increase in carbon emissions in the two simulations was marginal. It invariably points to the fact that removing subsidies on petroleum is not sufficient enough in reducing carbon emissions, it needs to be complemented with relevant policies that will result to environmental sustainability. Examples of such policies include adoption of green growth practices, further development and commercialisation of renewable energy options, technological advancement that will result to use of machineries that use less of fossil fuel, among others. In other words, the result showed that even though initially when subsidies are introduced and fuel price increases, individuals reduce their consumption of fuel, they however with time increase their energy consumption given that there are currently no alternatives to petroleum use in Nigeria. Thus, consumers will have no choice than to consume to satisfy their energy needs for their cars and to power their generators. This is evident from the observed trend in the result analysis where even though emissions declined in earlier years, they began to increase in the latter years.

Furthermore, this result support empirical evidence that policies to cut down emission levels often comes at a cost especially in driving the achievement of the green growth agenda. This result is supported by the works of Abraham (2013). It is especially the case for many developing countries due to weak institutional framework, insufficient financing and low technological development. This implies that attempts to reduce emissions generate low economic progress while increasing economic prospects drives up carbon emission levels. This is also as a result of the central role of the key energy input of fuel in production. The high carbon coefficients of some of the sectors, calculated from their energy expenditures as a ratio of their value added suggested that this category of fuel use is very significant and high in the production process, thus, given that it is a fossil fuel, its increased consumption will result to increased emission of carbon which contributes to climate change impact. The issues analysed in this study are relevant to economic and environmental management in Nigeria.

6.2 Recommendations

The major findings obtained from the simulation analysis of the study makes it necessary to point out a number of policy recommendations. They are presented below:

1. In the first place, the complete or one shot removal of subsidy on refined fuel was found to be the most favourable for the Nigerian economy. This is given that this scenario produced the most favourable outlook for the performance of macroeconomic aggregates, and thus, measure of economic prosperity.

2. Secondly, complimentary policies can be useful in tackling the observed trade-off relationship between economic prosperity and environmental sustainability. It was evident from the results that at earlier years, carbon emissions declined as consumption of fossil fuel fell. However, carbon emission levels increased at later years due to the fact that there was no alternative to petrol and since people must meet their energy demands, they simply re-adjust their budget spending to accommodate the increase in price. These complimentary policies will enhance and support innovation that will bring about the emergence of better energy efficiency model.

3. Thirdly, a switch from a fossil-based production process to cleaner alternatives is also recommended. Through the appropriate application and adoption of relevant technology, clean alternatives to fossil-fuel can be developed through the local content framework. This will ensure the creation of alternative energy mix that will be more sustainable that fossil fuel. For example, a variation of the Southern Africa “fuel blending” can be implemented for Nigeria. When adequate finance is provided, entrepreneurial start-up companies can develop and commercialise a different

component of ethanol blend. This will be composed of a certain percentage of fuel and ethanol where the latter is more environmentally friendly.

4. Finally, it is recommended that subsidies within the energy sector should be focused on supporting the commercialization of cleaner alternatives to energy rather than subsidise fossil-fuel based energy. In other words, subsidies to be encouraged by policy-makers should be environmentally friendly subsidies as against environmentally harmful subsidies.

6.3 Contributions to Knowledge

This study made some contributions to knowledge and are presented as follow:

1. This study developed a novel energy-environment CGE model that specifically accounted for the impact of petroleum subsidy on carbon emissions (measure of environmental quality). It modified the E2 energy-environment model by Adenikinju *et al.* (2012) which focused on the economy wide impact of the introduction of energy tax on carbon emissions, to incorporate subsidy on petrol. The model by the present study was able to model the environmental consequences of removing fuel subsidy for Nigeria and assess the extent to which the policy can be useful in driving a low-carbon growth strategy.

2. The study also contributes to the field of energy and environmental economics by establishing a policy framework that showed that removing subsidies on petroleum was not sufficient in ensuring the reduction of carbon emissions, but must rather be supported with complementary policies. This was evident from the fact that a gradual and one shot removal did not lead to a fall in emissions. It goes to show that if necessary policies such as encouragement of green growth practices and technological advancements of renewable energy are not introduced, increase in energy prices due to subsidy removal will only temporarily reduce emissions. This is

because once consumers are unable to access alternatives to fossil fuel, they will in time increase consumption to satisfy their energy demands. In doing this, they will adjust their energy expenditures upwards.

3. It further contributed to knowledge by providing empirical facts on the inter relationship between fuel subsidy removal and environmental quality in Nigeria. It specifically showed an innovative way to economic investigation of environmental sustainability in Nigeria. This was done by addressing issues relevant to economic and environmental management in Nigeria through the help of the Computable General Equilibrium model.

6.4 Suggestions for Further Studies

The study has a number of opportunities for other studies to further advance the frontier of knowledge in the field of energy and environmental policy as well as dynamic CGE modelling. In the first place, it will be useful for further studies in the area of the study of the interaction of the energy sector through energy policy, with the environment to adopt an updated SAM that includes energy and carbon emission data. It would be appropriate to divert necessary resources, effort and time towards simulation with more recent database such as the 2010 SAM been currently developed that can also incorporate the financial sector and reflect the role of financing for the achievement of the green growth agenda. This will help to ensure output of more result in the analysis of the impact of energy policy shift on key variables in the economy.

In the same vein, further studies can incorporate micro-simulation in modeling fuel subsidy policy impact especially at the household level as primary data for micro analysis can be useful for analytical purposes. For example, primary data could be used to gather information on energy consumption from generators and the level of emission at that level, be incorporated into the energy-economy-environment CGE model. This, together with further aggregation of the different sectors and commodities will be most useful in explaining industry-household linkages and the transmission mechanism as embedded.

Finally, the various elasticity parameters often used in the energy-economy-environment for the Nigerian economy model can be econometrically determined through further studies and research as against the arbitrary selection obtained. Parameters relating to elasticity of capital demand, labour demand, value added, among others, can be determined by conducting econometric analysis of them and thus obtaining more robust and reliable estimates.

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APPENDICES

Appendix One: The Re-aggregated Nigerian SAM (In Millions of Naira)

Re-aggregated 2006 Nigerian SAM (Left Panel)

		L LAB	K CAP	K Land	AG HR	AG HU	AG Firm	AG Gvt.	AG TD	AG TM	AG TI	AG ROW
L	LAB											
K	CAP											
K	Land											
AG	HR	3317904		2190043			119371					661776
AG	HU	5781750					2513105	171781				697465
AG	Firm		4865843									
AG	Gvt.		2760884						2358771	6584	51599	206333
AG	TD					125405	233366					
AG	TM											
AG	TI											
AG	ROW		992105									
J	agr											
J	mfc											
J	pet											
J	roil											
J	util											
J	rtrans											
J	ser											
J	adm											
I	food				3619134	2380589						
I	agr				445327	399238						
I	mfc				1477186	1851278						
I	pet											
I	roil				39478	78832						
I	util				162228	265229						
I	rtrans				74670	124775						
I	ser				412143	1457901		607729				
I	adm							310896				
X	food											5380
X	agr											28857
X	mfc											87889
X	pet											7359051
X	rtrans											152278
X	ser											203213
OTH	INV				58928	2480851		1700047				-3263718
OTH	VSTK											
OTH	TOT	9099655	8618833	2190043	6289097	9164102	4865843	5588517	2358771	6584	51599	6138528

Re-aggregated 2006 Nigerian SAM (in Millions of Naira Right Panel)

		J agr	J mfc	J pet	J roil	J util	J rtrans	J ser	J adm	I food	I agr	I mfc
L	LAB	3511888	720967	20867	689	357092	272684	3300582	914883			
K	CAP	211717	594620	6866714	57467	267485	173821	446000	1005			
K	Land	2190043										
AG	HR											
AG	HU											
AG	Firm											
AG	Gvt.	7545	11526	12418	3283	18760	9009	82544				
AG	TD											
AG	TM									181830	20663	33646
AG	TI									4980	46619	
AG	ROW									221465	253629	2692373
J	agr									5359290	1100374	
J	mfc											2481012
J	pet											
J	roil											
J	util											
J	rtrans											
J	ser											
J	adm											
I	food	92086	54632					15193				
I	agr	14800	653718				825	9536				
I	mfc	190730	181150	288987	35435	25244	133162	389882	284275			
I	pet		46640	2113	13910	30488	3993	22432				
I	roil	2281	34497	76085	12275	56850	137984	225460	208602			
I	util	9073	1826	1275	12593	2927	1342	158000	180252			
I	rtrans	10093	32259	165327	7402	3822	3640	190665	432418			
I	ser	253643	237060	53079	6988	32077	24504	538501	1087522	394068	118169	160283
I	adm											
X	food											
X	agr											
X	mfc											
X	pet											
X	rtrans											
X	ser											
OTH	INV											
OTH	VSTK											
OTH	TOT	6493903	2568901	7486869	275236	794749	760969	53788	310896	6161635	1539456	5367315

Re-aggregated 2006 Nigerian SAM (in Millions of Naira Right Panel contd.)

		I pet	I roil	I util	I rtrans	I ser	I adm	X food	X agr	X mfc	X pet	X rtran	X ser	OTH INV	OTH VSTK	OTH TOT
L	LAB															9099655
K	CAP															8618833
K	Land															2190043
AG	HR															6289097
AG	HU															9164102
AG	Firm															4865843
AG	Gvt.															5588517
AG	TD															2358771
AG	TM	9059	-179359													65840
AG	TI															51599
AG	ROW	103349	784233		436384	654986										6138528
J	agr							538	28857							6493903
J	mfc									87889						2568901
J	pet	127817									735905					7486869
J	roil		275236													275236
J	util			794749												794749
J	rtrans				60869							152278				760969
J	ser					5175587							203213			53788
J	adm						310896									310896
I	food															6161635
I	agr													16009		1539456
I	mfc													5099	1.00	5367315
I	pet															244769
I	roil													7849		880199
I	util															794749
I	rtrans															1045075
I	ser	4542	89			6771								4422		6507728
I	adm															310896
X	food															538
X	agr															28857
X	mfc															87889
X	pet															735905
X	rtrans															152278
X	ser															203213
OTH	INV															976108
OTH	VSTK														1.00	1.00
OTH	TOT	244769	880199	794749	1045075	6507728	310896	538	28857	87889	735905	152278	203213	976108	1.00	

Appendix Two: Description of the Model

SETS

$All\ industries: j, jj \in J = \{J_1, \dots, J_j\}$

$All\ commodities: i, jj \in I = \{I_1, \dots, I_i\}$

$Imported\ commodities: m \in M \subset I = \{M_1, \dots, M_m\}$

$Non\ imported\ commodities: nm \in NM \subset I = \{NM_1, \dots, NM_{nm}\};\ \ NM \cap M = \phi$

$Exported\ commodities: x \in X \subset I = \{X_1, \dots, X_x\}$

$Non\ exported\ commodities: nx \in NX \subset I = \{NX_1, \dots, NX_{nx}\};\ \ NX \cap X = \phi$

PRODUCTION FACTORS

$Labour\ categories:\ l \epsilon L = \{L\} \quad Note: only\ one\ type\ of\ labour$

$Capital\ categories:\ k \epsilon K = \{K_1, \dots, K_k, \dots,\}\ Note: only\ one\ category\ of\ capital$

AGENTS

$All\ agents: ag, agj \epsilon AG = H \cup F \cup \{GVT, ROW\} = \{H_1, \dots, H_h, \dots, F_1, \dots, F_f, \dots, GVT, ROW\}$

$Household\ categories: h, hj \epsilon H \subset AG = \{H_1, \dots, H_h, \dots,\}$

$Firm\ categories: f, fj \epsilon F \subset AG = \{F_1, \dots, F_h, \dots,\}$

$Non\ governmental\ agent:$

$agng \epsilon AGNG \subset AG = H \cup F \cup \{ROW\} = \{H_1, \dots, H_h, \dots, F_1, \dots, F_f, \dots, ROW\}$

$Domestic\ agents: agd \epsilon AGD \subset AG = H \cup F \cup \{GVT\} = \{H_1, \dots, H_h, \dots, F_1, \dots, F_f, \dots, GVT\}$

MODEL EQUATIONS

Production Block

$$VA_{j,t} = v_j \, XST_{j,t}$$

$$CI_{j,t} = io_j \, XST_{j,t}$$

$$VA_{j,t} = B_j^{VA} \left[\beta_j^{VA} LDC_{j,t}^{-\rho_j^{VA}} + \left(1 - \beta_j^{VA}\right) KDC_{j,t}^{-\rho_j^{VA}} \right]^{\frac{1}{\rho_j^{VA}}}$$

$$LD_{j,t} = \left[\frac{\beta_j^{VA}}{1 - \beta_j^{VA}} \frac{RC_{j,t}}{WC_{j,t}} \right]^{\sigma_j^{VA}} KDC_{j,t}$$

$$LDC_{j,t} = B_j^{LD} \left[\sum_l \beta_{l,j}^{LD} LD_{l,j,t}^{-\rho_j^{LD}} \right]^{-\frac{1}{\rho_j^{LD}}}$$

$$LD_{l,j,t} = \left[\frac{\beta_{l,j}^{LD} WC_{j,t}}{WTI_{l,j,t}} \right]^{\sigma_j^{LD}} \left(B_j^{LD}\right)^{\sigma_j^{LD} - 1} LDC_{j,t}$$

$$KDC_{j,t} = B_j^{KD} \left[\sum_k \beta_{k,j}^{KD} KD_{k,j,t}^{-\rho_j^{KD}} \right]^{-\frac{1}{\rho_j^{KD}}}$$

$$KD_{k,j,t} = \left[\frac{\beta_j^{KD} \; RC_{j,t}}{RTI_{k,j,t}} \right]^{\sigma_j^{KD}} \left(B_j^{KD}\right)^{\sigma_j^{KD} - 1} KDC_{j,t}$$

$$DI_{i,j,t} = aij_{i,j} \; CI_{j,t}$$

$$XST_{j,t} = B_j^{XT} \left[\sum_i \beta_{j,i}^{XT} \; XS_{j,i,t}^{\rho_j^{XT}} \right]^{\frac{1}{\rho_j^{XT}}}$$

$$XS_{j,i,t} = \frac{XST_{j,t}}{\left(B_j^{XT}\right)^{1+\sigma_j^{XT}}} \left(\frac{P_{j,i,t}}{\beta_{j,i}^{XT} PT_{j,t}} \right)^{\sigma_j^{XT}}$$

Income and Savings Block

Households

$$YH_{h,t} = YHL_{h,t} + YHK_{h,t} + YHTR_{h,t}$$

$$YHL_{h,t} = \sum_l \lambda_{h,l}^{WL} \left(W_{l,t} \sum_j LD_{l,j,t}\right)$$

$$YHK_{h,t} = \sum_k \lambda_{h,k}^{RK} \left(\sum_j R_{k,j,t}\ KD_{k,j,t}\right)$$

$$YHTR_{h,t} = \sum_{ag} TR_{h,ag,t}$$

$$YDH_{h,t} = YH_{h,t} - TDH_{h,t}$$

$$CTH_{h,t} = YDH_{h,t} - SH_{h,t}$$

$$SH_{h,t} = PIXCON_t^{\eta}\ sh0_{h,t} + sh1_{h,t}\ YDH_{h,t}$$

Firms

$$YF_t = YFK_t$$

$$YFK_t = \sum_k \lambda_{f,k}^{RK} \left(\sum_j R_{k,j,t}\ KD_{k,j,t}\right)$$

$$YDF_{f,t} = YF_{f,t} - TDF_{f,t}$$

Government

$$YG_t = YGK_t + YGTX_t + YGTR_t$$

$$YGK_t = \sum_k \lambda_{gvt,k}^{RK} \left(\sum_j R_{k,j,t}\, KD_{k,j,t}\right)$$

$$YGTX_t = TDHT_t + TDFT_t + TIPT_t + TPRCTS_t$$

$$\mathrm{TDHT}_t = \sum_h TDH_{h,t}$$

$$\mathrm{TDFT}_t = \sum_f TDFT_{f,t}$$

$$TIPT_t = \sum_{l,j} TIP_{l,j,t}$$

$$\mathrm{TPRCTS}_t = \mathrm{TICT}_t + \mathrm{TIMT}_t$$

$$\text{TICT}_t = \sum_i TIC_{i,t}$$

$$\text{TIMT}_t = \sum_m TIM_{m,t}$$

$$\text{YGTR}_t = \sum_{agng} TR_{gvt,agng,t}$$

$$TDH_{h,t} = PIXCON_t^{\eta}\ ttdh0_{h,t} + ttdh1_{h,t} YH_{h,t}$$

$$TDF_{f,t} = PIXCON_t^{\eta}\ ttdf0_{f,t} + ttdf1_{f,t} YFK_{f,t}$$

$$TIP_{j,t} = ttip_{j,t}\, PP_{j,t}\, XST_{j,t}$$

$$TIC_{i,t} = ttic_{i,t}\ \Big[\big(PL_{i,t} + \textstyle\sum_{ij} PC_{ij\,,t}\ tmrg_{ij,i}\big) DD_{i,t} + \Big(\big(1 + ttim_{i,t}\big) PWM_{i,t}\, e_t + \textstyle\sum_{ij} PC_{ij,t}\, tmrg_{ij,i}\Big)\ IM_{i,t}\Big]$$

$$TIM_{i,t} = ttim_{i,t}\ PWM_{i,t} e_t\ IM_{i,t}$$

$$SG_t = YG_t - \sum_h TR_{h,gvt,t} - G_t$$

Rest of the World

$$\text{YROW}_t = e_t \textstyle\sum_i PWM_{i,t}\ IM_{i,t} + \sum_k \lambda_{row,k}^{RK} \left(\sum_j R_{k,j.t}\ KD_{k,j,t}\right)$$

$$\text{SROW}_t = \text{YROW}_t - \textstyle\sum_i PE_{i,t}\, EXD_{i,t} - \sum_{agd} TR_{agd,row,t}$$

$$SROW_t = -CAB_t$$

Transfers

$$TR_{agng\ gvt,t} = PIXCON^{\eta}\ TR_{agng,gvt}^{o}\ pop_t$$

$$TR_{agd,row,t} = PIXCON^{\eta}\ TR_{agd,row}^{o}\ pop_t$$

Demand Block

$$C_{i,h,t}PC_{i,t} = C_{i,h,t}^{MIN}PC_{i,t} + \gamma_{i,h}^{LES}\left(CTH_{h,t} - \sum_{i,j} C_{i\,j,h,t}^{MIN}\,PC_{i\,j,t}\right)$$

$$PC_{i,t}\,INV_{i,t}^{PRI} = \gamma_i^{INVPRI}IT_t^{PRI}$$

$$PC_{i,t}\,INV_{i,t}^{PUB} = \gamma_i^{INVPUB}IT_t^{PUB}$$

$$INV_{i,t} = INV_{i,t}^{PRI} + INV_{i,t}^{PUB}$$

$$PC_{i,t}CG_{i,t} = \gamma_i^{GVT}G_t$$

$$DIT_{i,t} = \sum_j DI_{i,j,t}$$

Producer Supplies and International Trade Block

$$XS_{j,i,t} = B_{j,i}^X\left[\beta_{j,i}^X\,EX_{j,i,t}^{\rho_{j,i}^X} + \left(1 - \beta_{j,i}^X\right)DS_{j,i,t}^{\rho_{j,i}^X}\right]^{\rho_{j,i}^{\frac{1}{x}}}$$

$$EX_{j,i,t} = \left[\frac{1-\beta_{j,i}^X}{\beta_{j,i}^X}\;\frac{PE_{i,t}}{PL_{i,t}}\right]^{\sigma_{j,i}^X} DS_{j,i,t}$$

$$EXD_{i,t} = EXD_i^o\;\;pop_t\left(\frac{e_t\,PWX_{i,t}}{PE_{i,t}}\right)^{\sigma_i^{XD}}$$

$$Q_{i,t} = B_i^M\left[\beta_i^M\,IM_{i,t}^{-\rho_i^M} + (1 - \beta_i^M)\,DD_{i,t}^{-\rho_i^M}\right]^{\frac{-1}{\rho_i^M}}$$

$$IM_{i,t} = \left[\frac{\beta_i^M}{1-\beta_i^M}\;\frac{PD_{i,t}}{PM_{i,t}}\right]^{\sigma_i^M}\;DD_{i,t}$$

Price Block

$$PP_{j,t} = \frac{PVA_{j,t}\, VA_{j,t} + PCI_{j,t}\, CI_{j,t}}{XST_{j,t}}$$

$$PT_{j,t} = (1 + ttip_{j,t}) PP_{j,t}$$

$$PCI_{j,t} = \frac{\sum_i PC_{i,t} DI_{i,j,t}}{CI_{j,t}}$$

$$PVA_{j,t} = \frac{WC_{j,t} LDC_{j,t} + RC_{j,t} KDC_{j,t}}{VA_{j,t}}$$

$$RC_{j,t} = \frac{\sum_k RTI_{k,j,t}\, KD_{k,j,t}}{KDC_{j,t}}$$

$$PT_{j,t} = \frac{\sum_i P_{j,i,t}\, XS_{j,i,t}}{XST_{j,t}}$$

$$P_{i,j,t} = \frac{PE_{i,t} EX_{i,t} + PL_{i,t} D_{i,t}}{XS_{i,t}}$$

$$PD_{i,t} = (1 + ttic_{i,t}) \left[PL_{i,t} + \sum_{ij} PC_{ij,t}\ tmrg_{ij,i} \right]$$

$$PM_{i,t} = (1 + ttic_{i,t}) \left((1 + ttim_{i,t})\, e_t PWM_{i,t} + \sum_{ij} PC_{ij,t}\ tmrg_{ij,i} \right)$$

$$PC_{i,t} = \frac{PM_{i,t} IM_{i,t} + PD_{i,t} D_{i,t}}{Q_{i,t}}$$

Price indexes

$$PIXGDP_t = \sqrt{\frac{\sum_j PVA_{j,t}VA_j^o \ \sum_j PVA_{j,t}VA_{j,t}}{\sum_j PVA_j^o VA_j^o \sum_j PVA_j^o VA_{j,t}}}$$

$$PIXCON_t = \frac{\sum_i PC_{i,t} \ \sum_h C_{i,h}^o}{\sum_{i,j} PC_{i,j}^o \ \sum_h C_{i\ j,h}^o}$$

Equilibrium

$$Q_{i,t} = \sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + DIT_{i,t}$$

$$\sum_j LD_{l,j,t} = LS_{l,t}$$

$$\sum_j KD_{k,j,t} = KS_{k,t}$$

$$IT_t = \sum_h SH_{h,t} + SG_t + SROW$$

$$IT_t^{PRI} = IT_t - IT_t^{PUB}$$

$$\sum_j DS_{j,i,t} = DD_{i,t}$$

$$\sum_j EX_{j,x,t} = EXD_x, t$$

$$GDP_t = \sum_J PVA_{j,t}\, VA_{j,t} + TIPT_t + TPRCTS_t$$

Dynamic Equations Block

$$KD_{k,j,t+1} = KD_{k,j,t}\left(1 - \delta_{k,j}\right) + IND_{k,j,t}$$

$$IT_t^{PUB} = PK_t^{PUB} \sum_{k,PUB} IND_{k,pub,t}$$

$$IT_t^{PRI} = PK_t^{PRI} \sum_{k,bus} IND_{k,bus,t}$$

$$PK_t^{PRI} = \frac{1}{A_{bus}^k} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPRI}} \right]^{\gamma_i^{INVPRI}}$$

$$PK_t^{PUB} = \frac{1}{A_{pub}^k} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPUB}} \right]^{\gamma_i^{INVPUB}}$$

$$IND_{k,bus,t} = \emptyset_{k,bus} \left[\frac{R_{k,bus,t}}{U_{k,bus,t}} \right]^{\sigma_{k,bus}^{INV}} KD_{k,bus,t}$$

$$U_{k,bus,t} = PK_t^{PRI}\left(\delta_{k,bus} + IR_t\right) \text{ and } U_{k,pub,t} = PK_t^{PUB}\left(\delta_{k,pub} + IR_t\right)$$

This carbon emission component is adapted from Adenikinju *et al* (2012).

Carbon Emissions Block

$$TQ_{CO_2} = \varphi_{PET} X_{PET} + \varphi_{ROIL} X_{ROIL} + \varphi_{RTRANS} X_{RTRANS} \text{ or } TQ_{CO_2} \sum_i \varphi_i \; X_i$$

$$TQ_{CO_2} - \overline{TQ_{CO_2}} \leq 0$$

$$T_{CO_2} = \sum_i t_i^d . PD_i . D_i + \sum_i t_i^m . PD_i . D_i$$

$$t_i = P_{CO_2} \psi_i \omega_i$$

$$P_{CO_2} \geq 0$$

Description of Variables and Parameters (Legend)

Volume Variables

$VA_{j,t}$: Value added of industry *j*

$CI_{j,t}$: Total intermediate consumption of industry *j*

$XST_{j,t}$: Total aggregate output of industry *j*

$LD_{l,j,t}$: Demand for type *l* labor by industry *j*

$LDC_{j,t}$: Industry *j* demand for composite labor

$KD_{k,j,t}$:Demand for type *k* capital by industry *j*

$KDC_{j,t}$:Industry *j* demand for composite capital

$DI_{i,j,t}$:Intermediate demand for commodity *i* by business *j*

$YH_{h,t}$:Total income of type *h* households

$YHK_{h,t}$: capital income of type *h* households

$YHL_{h,t}$:Labor income of type *h* households

$YHTR_{h,t}$:Transfer income of type *h* households

$YDH_{h,t}$:Disposable income of type *h* households

$YF_{f,t}$:Total income of type *f* businesses

$YFK_{f,t}$: Capital income of type *f* businesses

$YFTR_{f,t}$: Transfer income of type *f* businesses

$YDF_{f,t}$: Disposable income of type *f* businesses

YG_t: Total government income

YGK_t: Government capital income

$YGTR_t$: Government transfer income

$TDFT_t$: Total government revenue from business income taxes

$TDHT_t$: Total government revenue from household income taxes

$TIC_{i,t}$: Government revenue from indirect taxes on product *i*

$TICT_{i,t}$:Total government receipts of indirect taxes on commodities

$TIM_{i,t}$: Government revenue from import duties on product m

$TIMT_t$: Total government revenue from imports duties

$TIP_{j,t}$: Government revenue from taxes on industry j production (excluding taxes directly related to the use of capital and labor)

$TPRCTS_t$: Total government revenue from taxes on products and imports

$TIPT_t$: Total government revenue from production taxes (excluding taxes directly related to the use of capital and labour.

$TR_{ag,agj,t}$: Transfers from agent *agj* to agent *ag*

$C_{i,h,t}$: Consumption of commodity *i* by type h households

$C_{i,h,t}^{MIN}$: Minimum consumption of commodity *i* by type h households

$CG_{i,t}$: Public consumption of commodity *i* (volume)

$DIT_{i,t}$:Total intermediate demand for commodity *i*

$PC_{i,t}$: Purchaser price of composite commodity *i* (including all taxes and margins)

$ID_{i,j,t}$: Industry j demand for good *i*

$XS_{j,i,t}$: Industry j production of commodity *i*

$DS_{j,i,t}$: Supply of commodity *i* by sector j to the domestic market

$EXD_{i,t}$:World demand for exports of product *x*

IT_t^{PRI}: Total private investment expenditure

IT_t^{PUB}: Total public investment expenditure

$INV_{i,t}^{PRI}$: Final demand of commodity *i* for private investment purposes

$INV_{i,t}^{PUB}$: Final demand of commodity *i* for public investment purposes

$KS_{k,t}$:Supply of type *k* capital

$LS_{l,t}$:Supply of type *l* labor

IT_t : Total Investment Expenditure

GDP_t : Gross Domestic Product

Price Variables

e_t : Exchange rate: price of foreign currency in terms of local currency

$P_{j,i,t}$: Basic price of industry *j*'s production of commodity *i*

$PC_{i,t}$: Purchaser price of composite commodity *i* (including all taxes and margins)

$PCI_{j,t}$: Intermediate consumption price index of industry *j*

$PD_{i,t}$: Price of local product *i* sold on the domestic market (including all taxes and margins)

$PE_{i,t}$: Price received for exported commodity *x* (excluding export taxes)

$PIXCON_t$: Consumer price index

$PIXGDP_t$: GDP deflator

$PIXINV_t$: Investment price index

$PL_{i,t}$: Price of local product *i* (excluding all taxes on products)

$PM_{i,t}$: Price of imported product *m* (including all taxes and tariffs)

$PP_{j,t}$: Industry *j* unit cost, including taxes directly related to the use of capital and labor, but excluding other taxes on production

$PVA_{j,t}$: Price of industry *j* value added (including taxes on production directly related to the use of capital and labor)

$PWM_{i,t}$: World price of imported product *m* (expressed in foreign currency)

$PWX_{i,t}$:World price of exported product *x* (expressed in foreign currency)

$R_{k,j,t}$: Rental rate of type *k* capital in industry *j*

$W_{l,t}$: Wage rate of type l labor

Nominal (Value) Variables

CAB_t: Current account balance

G_t: Current government expenditure on goods and services

GDP_t^{BP}: GDP at basic prices

GDP_t^{MP}: GDP at market price

$GFCF_t$: Gross fixed capital formation

$SF_{f,t}$: Savings of type f business

$SH_{h,t}$: Savings of type h households

SG_t: Government savings

$SROW_t$: Rest-of-the-world savings

$YROW_t$: Rest-of-the-world income

Parameters

io_j : Coefficient (Leontief-intermediate consumption)

v_j : Coefficient (Leontief-value added)

$aij_{i,j}$: Input-output coefficient

B_j^{KD} : Scale parameter (CES-composite capital)

B_j^{LD} : Scale parameter (CES-composite labour)

B_m^M : Scale parameter (CES-composite commodity)

B_j^{VA} : Scale parameter (CES-value added)

$B_{j,x}^X$: Scale parameter (CET-exports and local sales)

B_j^{XT} : Scale parameter (CET-total output)

$\beta_{k,j}^{KD}$: Share parameter (CES-composite capital)

$\beta_{l,j}^{LD}$: Share parameter (CES-composite labor)

β_m^M : Share parameter (CES-composite commodity)

β_j^{VA} : Share parameter (CES-value added)

$\beta_{j,x}^X$: Share parameter (CET-exports and local sales)

$\beta_{j,i}^{XT}$: Share parameter (CET-total output)

$\delta_{k,j}$: Depreciation rate of capital k used in industry j

η : Price elasticity of indexed transfers and parameters

γ_i^{GVT} : Share of commodity i in total current public expenditures on goods and services

γ_i^{INVPRI} : Share of commodity i in total private investment expenditure

γ_i^{INVPUB} : Share of commodity i in total public investment expenditure

γ_i^{LES} : Marginal share of commodity i in type h household consumption budget

$\lambda_{ag,k}^{RK}$: Share of type k capital income received by agent ag

$\lambda_{ag,agj}^{TR}$: Share parameter (transfer functions)

$\lambda_{h,l}^{WL}$: Share of type *l* labor income received by type *h* households

η_t : Population growth rate

$\phi_{k,j}$: Scale parameter (allocation of investment to industries)

pop_t : Population index

ρ_j^{KD} : Elasticity parameter (CES-composite capital); $-1 < \rho_j^{KD} < \infty$

ρ_j^{LD} : Elasticity parameter (CES-composite labor); $-1 < \rho_j^{LD} < \infty$

ρ_m^{M} : Elasticity parameter (CES-composite commodity); $-1 < \rho_m^{M} < \infty$

ρ_j^{VA} : Elasticity parameter (CES-value added); $-1 < \rho_j^{VA} < \infty$

$\rho_{j,x}^{X}$: Elasticity parameter (CET-exports and local sales); $-1 < \rho_{j,x}^{X} < \infty$

ρ_j^{XT} : Elasticity parameter (CET-total output); $-1 < \rho_j^{XT} < \infty$

$\sigma_{k,j}^{INV}$: Elasticity (allocation of investment to industries)

σ_j^{KD} : Elasticity of substitution (CES-composite capital); $0 < \sigma_j^{KD} < \infty$

σ_j^{LD} : Elasticity of substitution (CES-composite labor); $0 < \sigma_j^{LD} < \infty$

σ_m^{M} : Elasticity of substitution (CES-composite commodity); $0 < \sigma_m^{M} < \infty$

σ_j^{VA} : Elasticity of transformation (CES-value added); $0 < \sigma_j^{VA} < \infty$

$\sigma_{j,x}^{X}$: Elasticity of transformation (CET-exports and local sales); $0 < \sigma_{j,x}^{X} < \infty$

σ_x^{XD} : Price-elasticity of the world demand for exports of product x

σ_j^{XT} : Elasticity of transformation (CET-total output); $0 < \sigma_j^{XT} < \infty$

$sh0_{h,t}$: Intercept (type *h* household savings)

$sh1_h$: Slope (type *h* household savings)

$tmrg_{i,ij}$: Rate of margin *i* applied to commodity *ij*

$tmrg_{i,x}^{X}$: Rate of margin *i* applied to exported commodity *x*

$ttdf0_f$: Intercept (income taxes of type *f* business)

$ttdf1_f$: Marginal income tax rate of type *f* businesses

$ttdh0_h$: Intercept (income taxes of type *h* households)

$ttdh1_h$: Marginal income tax rate of type *h* households

$ttic_{i,t}$: Tax rate of commodity *i*

$ttim_{m,t}$: Rate of taxes and duties on imports of commodity *m*

$ttip_{j,t}$: Tax rate on the production of industry *j*

Carbon Emission Variables

TQ_{CO_2} : Total carbon emission;

$\overline{TQ_{CO_2}}$: Carbon emission limit;

X_i : Total energy type use by sector;

φ_i : Carbon emission coefficient per unit of energy type use by sector;