A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF THE IMPACT OF DOMESTIC NATURAL GAS MARKET LIBERALISATION POLICY ON MACROECONOMIC AND HOUSEHOLD WELFARE IN NIGERIA

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A Thesis in the Centre for Petroleum, Energy Economics and Law (CPEEL)
Submitted to the Centre for Petroleum, Energy Economics and Law (CPEEL)
in Partial Fulfilment of the requirements for the award of the Degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

JUNE 2019

ABSTRACT

The growth in domestic demand for natural gas and the need to promote market efficiency gave rise to the call for gas sector liberalisation in Nigeria. As of 2017, only about 12% of total natural gas produced in Nigeria were available for domestic consumption, an indication of the underdeveloped domestic gas market. Most studies on gas market liberalisation in Nigeria using the Computable General Equilibrium (CGE) model focused on gas price without examining the economy-wide and household welfare impact of the liberalisation policy. This study, therefore, extends this front by examining the impact of gas price, as well as a third party access policy to natural gas infrastructures on the macroeconomic, sectoral and household welfare in Nigeria.

A recursive-dynamic CGE model, based on the Walrasian theory of market behaviour, and a transhipment optimisation model was used for the study. The model accounted for product and price effects, making it possible to capture the macroeconomic, sectoral and household welfare impact of natural gas market liberalisation policy in Nigeria. The model included production, income and savings, demand, international trade, prices, equilibrium, and dynamic blocks. It was calibrated using data sourced from the modified 2014 Nigerian Social Accounting Matrix (SAM). In the SAM, households were categorised into Rural Core-Poor (RCP), Rural Moderate-Poor (RMP), Rural Non-Poor (RNP), Urban Core-Poor (UCP), Urban Moderate-Poor (UMP) and Urban Non-Poor (UNP) according to 2010 Harmonized Nigerian Living Standard Survey. Capital stocks were considered using investment, while labour supply and the minimum consumption of households were adjusted each period by the population growth rate in order to capture the dynamic adjustment path. The model was simulated for a gradual 10% increment in market liberalisation over a ten-year horizon (2015 - 2025). The transhipment optimisation model was used to analyse the impact of third party access policy.

The simulation scenario exerted negative effects on GDP by 0.74% for the first year, a positive effect of 0.43% for the tenth year; positive effects on inflation, government revenue and investment expenditure by 0.45%, 1.26%, and 1.04% respectively. The simulation scenario precipitated a decline in household welfare at the onset of the policy by 0.26% (RNP), 0.43% (RMP), 0.65 (RCP), 0.32% (UNP), 0.48% (UMP), 0.52% (UCP). However, this was reversed in the tenth year as household welfare increased by 1.27% (RNP), 0.94% (RMP), 0.04 (RCP), 2.18% (UNP), 1.04% (UMP), and 0.06% (UCP) respectively. The transhipment optimisation simulation shows an increase in total market supply (90.27%), gas producers' revenue (141.23%), and gas facility company's revenue (20.73) if the third party policy is utilised.

Domestic natural gas market liberalisation and third-party access policy in Nigeria have favourable long-run impact on macroeconomic, sectoral and household welfare. However, some social safety net measures to ameliorate the envisaged short-run adverse effects are recommended.

Keywords: Gas market liberalisation, Recursive-dynamic computable general equilibrium, Transhipment optimisation model, Third party access, Nigeria.

Word count: 456

DEDICATION

This doctoral thesis is dedicated to:
God Almighty for love and gift of life; and to

Divine Pius and Maria-Faustina - ***my Pride***.

ACKNOWLEDGMENTS

This research work is one of the most significant academic challenges I have had to encounter in life. But it is obvious this would not have been a reality without the contributions, useful ideas, and encouragement that must have come from various directions. I must, therefore, seize this veritable medium to acknowledge some of such contributions that made this journey a reality.

I appreciate and thank Almighty God, the most precious and all sufficient for His infinite mercy over my life, and for making it possible for this work to come to reality. It's all by His grace that I have come thus far.

At the contemplation stage of this journey, little did I know the God in his miraculous ways has strategically positioned destiny helpers on my way to enhance the fulfilment of my destiny. One of this great destiny helper is my mentor, my teacher, my instigator, and eventually my supervisor, Prof. Adeola F. Adenikinju. From my very first contact with you, Sir, I knew there could be no other. This conviction is validated with this work. Sir, your support morally, financially and academically, were the very foundation for this success. Your high standards, and belief in possibilities in all spheres of life have helped reshape my personality for the better. Sir, your time, meticulous guidance, comments and encouragements have indeed brought out the best in me. I shall forever remain grateful.

To my Co-Supervisor, Dr. Oluwatosin Adeniyi - a brother from another mother, words cannot express my profound appreciation to you for all your support, encouragement, advice, and guidance. You were not only my thesis supervisor, but also my academic supervisor and adviser. In all areas of my academic life, you are always available for support. Your mentorship brought out the best in me. Be assured of generational blessings.

My special gratitude goes to the management and staff of the Centre for Petroleum, Energy Economics and Law (The CPEEL Family), for the opportunity given me to pass through her wealth of experience and knowledge in this interesting research area. May the

bond of family keep us united. Specifically, I want to appreciate Professor Akin Iwayemi (Professor of Professors), a worthy teacher and mentor for his advice, encouragement and guidance which help shape the direction of this work. To all my teachers - Dr. P C. Obute, Dr. A O. Falode, Dr. L. Akimkpelu, Dr. O E. Olubusoye, Dr. A. Aminu, Dr. C. Deji, Dr. Mrs. Adenikinju, Dr. Mrs. P. Ajayi, Eng. F. Delano, Dr. D. Busari, I greatly appreciate the value of knowledge you imparted to me. I also appreciate my relationships with the non-teaching staff of CPEEL. Daramola, A. (PO), Femi (APO), Sunday, Olayinka, Dami, Tolu, Yetunde, Bimbo, Bimpe, Esther (CBN), and Blessing for all your assistance throughout the course of this programme. To you all I say a very big thanks.

I am also grateful to my colleagues and friends, especially Dr. Ekundayo (NISER), whose critical contributions against all odds aided the realisation of this dream. Dr. Noble, I appreciate. To my other collegues, Dr. Mrs. Olanrele, Dr. Mrs. Ogunshola-Saliu, Dr. Omoniyi, Dr. Benard, O A, Mr. Afaha, Mr. Jonathan, Dr. Amadi, Eng. Falobi, Mr. Akande and all others. I love you all.

To my immediate family, I appreciate you for your prayers, support, love, Patience, and understanding during these past years. Specifically, I immensely thank Divine Pius, Maria-Faustina and Roseline. You are the rock upon which I stand. To my siblings, Austin, Ann, Rufina, Virginia, Wilfred, and Lillian, I love you all. I appreciate my parents Late Hon. Paul Adama Okeh and Mrs. B. Okeh for believing in me and entrusting in me a sound educational and moral foundation against all odds. I am indeed glad that I have made you proud. For my father who could not live to witness this day, Daddy, may you continue to rest in the bosom of the Lord as your dream for me, today has been realised. I love you all.

PIUS EGBUNU OKEH.

CERTIFICATION

We Certify that this work was carried out by Pius Egbunu Okeh (Matric. No. 177151) in the Centre for Petroleum, Energy Economics and Law (CPEEL), University of Ibadan, Ibadan, under our supervision.

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CHAPTER ONE

INTRODUCTION

1.1 Preamble

Deregulation is not an end in itself, it is one of the options of national energy policy objectives. These objectives are broadly classified into four, namely, economic, social, and environmental as well as inter-generational or sustainability objectives. The economic objectives are to ensure efficiency in the use of energy resources available to the economy – including price stability; cost recovery for energy supply institutions with a fair rate of returns on investment; and economic growth. The social objective, on the other hand, entails equity,[1] balanced regional development, and access to modern energy for the majority of the population, as well as energy security and robustness. However, pollution, biodiversity and, conservation are considered as environmental and inter-generation objectives. The access of future generations to the stock of natural capital endowment of a nation is also an important national energy objective (Bhattachryya, 2011).

Globally the increase in demand and the contemporary need for efficiency in natural gas markets gave rise to the need for liberalisation to protect the consumers and expand competition (Capece et al, 2013). Reasons have been adduced for the replacement of previous energy policy, which seeks the protection of consumers and supply security at the national level is twofold. First, with the emergence of spot markets,[2] security of supply was no more considered a national threat, and secondly, consumer's protection through direct government intervention, was no more considered the best alternative. Hence, the most preferable was a combination of regulation and liberalisation.

[1] Equity is ensuring that the poor are not segrgated against in the consumption of energy products. Hence the three A's of accessibility, availability, and affordability

[2] Traditionally natural gas market is based on long term contracts between suppliers and producers.

The government's role should therefore be, to create a sustainable framework that will ensure efficient production and consumption of energy under a liberalised condition with minimal distortion rather than planning and managing the energy balance between demand and supply or even production and consumption. Hence, the 'Thatcherian principles', which states that 'Business government is not Government business'. Several economists have promoted this new paradigm distinguishing the natural monopolies from the gas value chain segment that should be strictly regulated and those to be opened to competition (see De Paoli, 2000; Thatcher, M. 2007).

Bacon and Besant-Jones (2007) submit that the poor performance of the State-Owned Enterprises (SOE), the government's inability to finance capital expansion of energy supply institutions' (ESI) assets, free up resources for other public programs through subsidy reduction, and need to raise funds for government through a privatisation program necessitated the introduction of reform. Williams and Ghanada (2005) identified other factors that triggered reforms such as national fiscal crises in many developing countries which made the energy sector reforms a conditional part of a macroeconomic reform package, the pressure from international lenders, and chronic under-capitalization of ESI. Similarly, Rein (2003) considered ideology, distributional conflict and path dependence as the main reason for reform. However, Williams and Ghanada (2005), who studied India, China, and Russia, observed that reforms were given birth to as a result of the coalition of interests by private investors and local elite to corner state resources.

Brau et al (2010) notes that the advancement of 'regulatory reform' including network unbundling, privatization, and liberalisation in most countries is often seen as a key tool for promoting economic growth and welfare. Regulations, it is pointed out distorts the allocation of resources between sectors and between firms, thereby affecting the overall economic performance. Hence intense regulated markets entail negative welfare effects.

The consequences of natural gas market liberalisation on developing economies have been a matter of grave concern for academics, researchers, and policymakers since these economies depend heavily on its appropriate use to accelerate its development. This interest is fuelled by the rising tide of globalization, financial integration, and

technological advancement. Thus a large body of literature has been dedicated to understanding how the liberalisation of the natural gas market impact end-users through their impact on price, output, growth and welfare distribution (Hideo, 2009; Adenikinju, 2009; Omisakin, 2011; Smith 2012). The ultimate aim of the gas market liberalisation is to allow the forces of demand and supply of gas determine the market clearing equilibrium price so that there will be an increase in efficiency, a reduction in the price, and consumers' choice and welfare will be enhanced. Since different energy sources are to a certain extent substitute, a certain degree of correlation between the prices of different energy source will always remain in place reflecting the long term ability to substitute between them.[2]

1.2 Statement of the problem

Given the centrality of the energy sector in the Nigerian economy, both as production and consumption inputs, it is evident that any form of reform that will impact on the prices of these products will affect resource allocation and equity in the economy. This works through its effect on production, prices, and demand for both energy and non-energy goods. The reaction of producers and consumers to higher energy prices will be two folds; first, they could reduce expenditure on other commodities – for energy-intensive commodities; or secondly, switch to the alternatives. The first option depends on the pattern of expenditure in the total cost structure of the producers or expenditure outlay of the households. The second option is a function of the degree of substitutability between energy products and other commodities (Hideo, 2009).

Despite Nigeria been the eighth largest holder of natural gas reserves[3] in the world with about 200.79Tcf (Trillion cubic feet) (DPR, 2019), the domestic natural gas market has remained grossly underdeveloped (NGP, 2017). Domestic gas is defined as the gas utilised locally within the shores of Nigeria either for electric power, industrial, and/or home use. Specifically for industrial use, the gas used in value-adding industries such as Petrochemical, fertilizer, methanol, etc. regardless of whether the end product (i.e.,

[3] The latest data released by the Department of Petroleum Resources (DPR) on May 23rd, 2019 shows that Nigeria's oil reserves have risen to 200.79Tcf thereby displacing Venezuela to be the 8th largest reserve holder based on the IEA rankings of 2016.

fertilizer, methanol, etc.) is consumed locally or exported, is considered domestic gas, (Kupolokun, 2006). For instance, out of a total wellhead production of 1.2bcf/d (billion cubic feet per day) of natural gas in 2019, 0.53bcf/d representing 44% was for export, 0.38bcf/d (32%), was for re-injection, 0.13bcf/d (11%) was flared, while only 0.16bcf/d (13%), was consumed by both power and other sectors of the Nigerian economy[4]. Gas export (LNG and pipelines) provides high returns to the government through tax receipts and dividends from equity stake. However, it is recognized that beyond economic rent, there are broader strategic benefits to the economy that may be attained from the increased domestic utilisation and value addition to natural gas. In essence, in addition to exporting natural gas, concerted efforts should be made to develop strategies to ensure increased domestic utilisation and value creation for enhanced domestic economic growth.

The National Gas Master Plan (NGMP 2008), with the strategic theme to: deliver Gas to the domestic market, especially for at least three-fold increase in power generation capacity by 2015; make Nigeria a regional hub for gas-based industries like fertilizer, petrochemical, and methanol,- transform gas sector to value-adding sector; and consolidate Nigeria's position and market share in high value export markets, - regional gas pipeline, - consolidate national footprints and influence, was fashioned as a policy instrument that will drive the Nigerian gas sector from its underdeveloped stage to a fully market-based sector where competition, efficiency, and large scale investment thrive.

Empirical evidence abounds in the literature showing that natural gas market liberalisation did, and in some other economies did not deliver on its anticipated benefits of more output and lower prices at least in the short and medium term (Razavi, 2009; Considine and Mount, 1983; Omisakin, 2015; Ott, M. and Tatom, J., 1982). This shows that liberalisation is not a ‘one-all’ universal solution to natural gas market development.

Knowing that natural gas market liberalisation in Nigeria would have an impact on the economy; the decision about its implementation should be based on an analytic foundation that correctly describes the economic gains and challenges of the policy. Because of this,

[4] See DPR News Letter of 23rd May 2019

this study aims to assess the impact of natural gas market liberalisation to examine its impact on macroeconomic and sectoral performance as well as household welfare in Nigeria. It also seeks to find out whether the Third Party Access (TPA) to gas infrastructures can lead to increased gas supply to the market, and hence increased revenue to gas producers and gas facility owners. The following fundamental research questions are raised to achieve this objective: What is the impact of natural gas market liberalisation on macroeconomic and sectoral performances in Nigeria? What are its welfare implications on households in Nigeria? What is the impact of the Third Party Access (TPA) on pipelines in terms of gas supply to the market and revenue to the gas suppliers and facility owners? This study attempts to answer these questions using the computable general equilibrium (CGE) model framework to capture the macroeconomic effects and feedback levels on the various sectors that uses natural gas on the rest of the economy in Nigeria within the context of the liberalised natural gas market, and optimization model to capture the impact of the Third Party Access (TPA) on gas supply to the market, and revenue of gas producers and facility owners.

1.3 Objectives of the Study

The broad objective of this study is to evaluate the economic and welfare impact of a liberalised natural gas market on the Nigerian economy. Also, to examine whether Third Party Access (TPA), can stimulate supply-side economics of the natural gas value chain in terms of supply and revenue to gas suppliers and gas facility owners.

The specific objectives of this study are to:

1) assess the macroeconomic and sectoral effects of natural gas market liberalisation in Nigeria.

2) evaluate the household welfare consequences of natural gas market liberalisation in Nigeria.

3) to investigate whether the Third Party Access (TPA) policy to the gas facility in gas market liberalisation is efficient.

1.4 Justification of the study

It is estimated that more than 40 percent of Nigeria's energy needs, primarily consumed by the industrial sector can be met with natural gas. The booming profile of the global natural gas market provides a platform for diversified gas based opportunities in Nigeria. The actualization of the gas market potential in both the domestic and export markets has always been a challenge despite the huge endowment. With government renewed interest in the utilisation of natural gas benefits through improved domestic and export markets, liberalisation policy has become one of the cardinal policy issues as enunciated in the GMP (2008) to drive the sector. The basic objective is to encourage domestic utilisation vis-a-viz power utilities (such as the GENCO's[5] and other independent power projects (IPPs); other industrial use such as cement, methanol, and fertilizer plants; and households). This study is motivated to conduct ex-ante simulations of the impact of natural gas market liberalisation policy on the Nigerian economy. This forms the crux of this study.

There exist several empirical studies on the impact of energy sector liberalisation in the economy of most developing countries,[6] however, no study has attempted presently to the best of my knowledge, an economy-wide assessment of the impact of natural gas market liberalisation of the Nigerian economy and households. This study thus tends to extend empirical fronts in this area. Most studies on natural gas market liberalisation have been in other countries, and also did not consider their effects on the household's welfare. For instance, most studies focused on the effects of natural gas market liberalisation on macro-economic activities and security of supply. (See Hideo, 2009). This could be because, until recently, little is thought of, about how natural gas market liberalisation affects households or because it was beyond the objectives of their studies. Although some other country studies have tried to capture the effects of natural gas market liberalisation, there are still considerable debates on its key impact. A few studies emphasize on security of supply (Cavaliere, 2007; Cetin, 201; Hoase, 2009), others accentuate the price effect of

[5] Generation companies (GENCO'S) are the segment responsible for generating electricity in Nigeria.
[6] See Okogu, 1993; Adenikinju, 1994; Iwayemi and Adenikinju, 1996; Husain, 2003; Oktaviani et al, 2005; Coady et al, 2006; Adeniyi, 2010; Omisakin, 2015 among others.

natural gas market liberalisation (Adenikinju, 2009; Omisakin, 2011; Smith, 2012). Thus, analysing the effect as well as identifying the key impact through which natural gas market liberalisation exact influence on the economy and household in Nigeria is imperative, especially if policies geared towards mitigating the adverse impact must be pro-losers.

The CGE model employed by Omisakin (2015) successfully captured the impact of the alternative natural gas price on the economy and household respectively, while being consistent with economic theories and the structural characteristics of the country, the model was simulated for three tiers simultaneous increase in gas price suggesting sectoral price differential for natural gas. This is also evident in the work of Adenikinju (2009). This study accounts for this shortcoming by employing a gradual liberated gas market price for ten years to simulate the model – an attractive point of departure which is characteristic of a liberalised market. Also, while the work of Omisakin (2015) dealt mainly on price which is also a major component of liberalisation, this work examined further other components of liberalisation such as third party access to natural pipelines which is expected to boost competition at upstream, transmission at midstream, and distribution at downstream segments of the gas value chain. This is expected to improve the supply side economics of the natural gas sector, and how this impacts on households and the economy as a whole.

It should be noted, however, that the CGE model employed in this study is a recursive-dynamic, characterized by a sequence of temporary equilibria. Unlike truly dynamic CGE models, the recursive dynamic CGE model assumes that economic agents are myopic (See Wing, 2005). This is inconsistent with the context of developing countries where imperfect information exists (See Adenikinju and Chitiga, 2009). Thus, it has a unique advantage of capturing the time path of adjustment to impact in a recursive sense. Also, a CGE model that is used in this study sheds light on the resulting impact of natural gas liberalisation in a manner that is consistent with economic theory and internally traceable, thus, will enable the results to be of great interest.

1.5 Scope of the Study

The model includes some dynamic features over ten years horizon with the base year of 2015 (i.e. 2015 - 2025). This study is thus an ex-ante analysis. The choice of 2015 base year is because of the availability of the 2014 Nigerian Social Accounting Matrix (SAM), and the need to capture the period marking the beginning of a re-based Nigerian economy. The 2014 Nigerian SAM is appropriate for this study given that it is the latest and there has been no significant change in the structure of the Nigerian economy. The horizon is set for 10 years, to capture the effect of policy responses which are not usually immediate.

This study focused on the implications of natural gas market liberalisation on macroeconomic and households in Nigeria for three reasons; first, natural gas is acclaimed worldwide as a choice fuel in terms of environmental friendliness and highly efficient form of energy, hence its domestic usage will drive the economy and reduce the impact of shocks the economy suffers from crude oil prices. Secondly, from the policy point of view, since natural gas is not the only source of primary energy, whatever policy on its increased domestic usage should not make it more expensive when compared with other alternative sources. Thirdly, energy expenditure represents a major component of most household's budget, since many of the households in Nigeria are poor.[7] Hence, any policy which will create economic problems and cause greater difficulties for many households (especially poor households) who are less able to protect themselves against adverse shocks should be discouraged.

Thus, this study will be useful in understanding the impact of natural gas market liberalisation of the Nigerian economy and households as well as the trade-off of certain policy interventions. It also enhances the knowledge and the factors that should drive policy responses as different outcomes can be expected even within the same country.

1.6 Organization of the study

The study is organized under six chapters and structured as described below. Chapter one consists of the introduction, statement of the problem, objective of the study, and

[7] See the 2010 Harmonized Nigeria living standard survey (HNLSS) by the World Bank.

justification of the study. Chapter two looks at the background of the study. Here we looked at the background information about natural gas in Nigeria, which includes historical, legal and structural background, the current performance of natural gas sub-sector in Nigeria and policies towards its improvement hence the choice of liberalisation by the Nigerian Gas Master Plan. Also, discussions on the liberalisation policy and how it is working in some selected countries was highlighted. Chapter three reviewed the relevant literature. Specifically, the literature was reviewed vis-à-vis theoretical, empirical and methodological fronts of natural gas liberalisation, and how it applies to the study. The focus of this chapter was to highlight how empirical findings in the natural gas market liberalisation are largely driven by methodological approaches as well as theoretical underpinnings. Chapter four looked at the methodological framework that was used for the study, the conceptual issues, structures and simulation procedures of the CGE model used was also discussed. In chapter five, results from different policy-induced simulation analyses are presented and discussed. While chapter six looked at the summary and conclusions, policy lessons emanating from the study, limitations of the study and suggestions for further research.

CHAPTER TWO
BACKGROUND TO THE STUDY

2.1 Preamble

The current restructuring of the natural gas market globally is driven by two main considerations. First, is the unsustainability of government continued funding of the sector, and the second, is the obvious inefficiencies associated with government management of the infrastructures. The policy responses to these challenges are valid: one, open up the sector for private sector participation which naturally involves deregulating the sector and putting in place appropriate pricing mechanism to ensure sustainability and availability; two, is to ensure efficiency in the way natural gas market operates by reviewing the impact of subsidy especially in the context of dwindling fiscal resources; and, three, is the need to free up government investment resource in the energy sector to focus on other important sectors of the economy (Williams and Ghanadan, 2005).

Advanced economies are at the threshold of transiting to full gas price deregulation based on their conviction that market-determined pricing models will yield economies of scale that will guarantee sustainability.[8] On the other hand, emerging markets and developing economies argue that the wholesome transition to market dynamics will hurt the economy in the short run as access will be drastically curtailed based on affordability and sustainability challenges. There is, therefore, the need to incorporate some level of price adjustment to accommodate the low income and vulnerable groups in the society, essential to address the issue of access. Proponents of gas price adjustments further argued that in an environment of income inequality and high energy poverty, a transition to full market dynamics might be suboptimal as energy demand will not be sufficient enough to clear

[8] There is the belief by economic operators that the era of regulation for the security of supply has constrained the development of the sector.

energy waste, therefore, partial price deregulation will ensure equity in energy access without which energy poverty will be on the rise (Nakicenovic N. et al., 1998).

Julius and Mashayekhi (1990) identified three sets of objectives that generally drive government domestic gas pricing policy: first is the efficiency of resource allocation; second, is the satisfaction of specific financial targets; and thirdly is the social equity consideration. While prices need to reflect the real opportunity value of gas development for an economy to send the right signals to consumers and producers, considerations must be given to both the financial viability of utilities and a fair redistribution of resources to the poorest segments of the society. In the case of Nigeria, Adenikinju (1996), acknowledged three factors that have influenced government position: first, it is the desire to protect the interest of the poor members of the society who could be hurt from higher prices. The second is the need to reduce industrial costs as energy products are seen as a critical input into production processes. The third factor relates to the uncertainty surrounding the inflationary impact of higher energy prices. No democratic government can ignore the importance of equity considerations in pricing. Equity concerns stem from the concern that the poorer segment of the population may have a higher proportion of their income spent on energy consumption than the richer segment of the population, and as such are more adversely affected by an increase in energy prices (Grubler, 2008). The goal of equity in most cases has been to minimize the negative impact on poor households.

Availability, accessibility, acceptability, and affordability[9] of energy products are considered a critical input into energy reforms for several reasons: one, widening energy access, that is affordable, is essential for national growth, wealth creation, employment and improvement in the standard of living; two, poor access planning for most energy projects has led to the usage of fuelwood, charcoal, and other unconventional energy sources, even when electricity and natural gas is provided in most rural areas and some urban centres; three, past failures in energy programs in some jurisdictions were mainly

[9] The four A's that drive energy use. These four elements must be critically considered if energy reform policies are to yield positive results

because of the emphasis placed on supply-side driven process without adequate attention paid to the nature and priority of consumers' needs; and finally, the nexus between income levels and ability to pay for energy services has been neglected by energy development experts leading to the excess supply and low demand in most rural areas, especially in developing energy markets such as Nigeria (Iwayemi et al, 1996; Stern, 1997).

A critical and contemporary issue in the natural gas market reform globally is the challenge of appropriate pricing in the context of availability, accessibility, and affordability. Before the recent wave of liberalisation processes in the gas Subsector, especially in the emerging energy markets, gas transmission and distribution was mainly a state monopoly, and pricing models emphasized subsidies and de-emphasized other important economic and investment considerations. This is basically because governments conceptualized energy as welfare, public good and, therefore, was seen as state responsibility (Iwayemi, 1994; Adenikinju, 2010).

However, current reality suggests that subsidized pricing models are no longer sustainable as most emerging economies are facing fiscal crises. It is obvious that a state monopoly model in the natural gas market seems to be undermining access and increasing energy poverty among the poor (William and Ghandan, 2005). Also, state control of gas distribution and transmission is becoming increasingly inefficient and drains available resources that would have been more efficient deployed in other sectors considered relevant for growth and development (Adenikinju, 2010). Reforms are, therefore, required to ensure energy sustainability that will leverage on appropriate pricing that guarantees a return on investment and increasing access by the rural and urban energy poor.

Nigeria is currently vigorously pursuing an ambitious market led natural gas reform, that aims to transit state monopolies in the downstream gas market to private sector controls. One of the contentious issues is how to handle the pricing component of the ongoing reforms to address issues of sustainability and access across several economic classes who, by virtue of their economic status, cannot afford to pay market determined rates. However, without market-led pricing reforms, investment in the sector will remain

constrained as investors focus on the efficiency and profitability of their investments. In this instance, therefore, resolving the tension between reforming the natural gas market to address investment returns and sustained access for development by vulnerable economic units in Nigeria, remains not only contentious but a pragmatic question to comprehend.

2.2 Trend in natural gas market development in Nigeria.

Gas production in Nigeria dates back to the discovery of oil after the exploration license granted to Shell D'Arcy petroleum in 1938 to prospect for oil paid off. However, the initial attempt at commercializing natural gas was initiated by Shell/BP in 1960 when an agreement to supply gas to the then Electricity Corporation of Nigeria (ECN) for electricity generation and to some manufacturing units in Aba, South Eastern Nigeria, was reached, as it was being treated as a nuisance during the exploration of oil and subsequently flared (Charles, 2010). Currently, Nigeria's gas reserves, according to Nigerian gas policy document (2017), is ranked as the ninth largest in the world and the largest in Africa with current reserve at about 180.5 trillion cubic feet (Tcf), with a significant scope for growth to about 600 Tcf level, given appropriate fiscal incentives and funding (BP, 2010). The Nigerian natural gas is of high quality, particularly, it is rich in liquids with low levels of nitrogen oxide and close to zero sulfur-dioxides. It has almost a 50 to 50 percent of associated (AG) and non-associated (NAG) natural gas.

The natural gas production, utilisation, and export in Nigeria can be categorized into three distinct phases in its evolution, namely:

Phase 1: **Demand constrained Era- (***Pre -1999***)**. This period witnessed massive gas flaring, which led to the conception of fiscal incentives to stimulate demand. However focus was on export LNG as the most promising sources of demand, hence the beginning of an export-oriented gas sector. There was also the absence of a gas legal framework which led to a proliferation of fiscal incentives.

Phase 2: **The Nigerian Liquefied Natural Gas (NLNG) Era -** (*1999-2005*). During this period, natural gas export picked up substantially and increased rapidly, mainly due to the

successful gas monetization policy. This fostered the government and the oil companies' commitment to the building of the export gas market infrastructures in the country. This project embarked upon at this stage was for the utilisation of the country's reserve and to reduce gas flaring. Such a project includes Bonny Nigerian liquefied natural gas (NLNG), for export LNG. The West Africa gas pipelines (WAGP) project to export Nigerian natural gas to the Republic of Benin, Togo, and Ghana, Escravos Gas to Liquid (EGTL) project amongst others. This period also marked the beginning of the consolidation of fiscal policies and legal regime – the Downstream Gas Act (DGA), Nigerian Associated Gas Framework Bill (NAGFRA).

Phase 3: **Demand boom/supply constrained Era -** (*Post 2005*). This period witnesses a sudden shift from demand to supply constrained as a result of a demand boom from both the domestic and export sectors. The domestic market boom is a result of power sector reform, increasing awareness, and more usage by households, etc. It was as a result of this that the Nigeria Gas Master Plan (NGMP) was born to articulate ways of driving Nigerian economic growth of 10 percent GDP aspiration with natural gas (Yar'adua,2007; Onyeukwu, 2010; Ndukwe, 2014). These scenarios above highlighted are further illustrated in fig. 2.1.

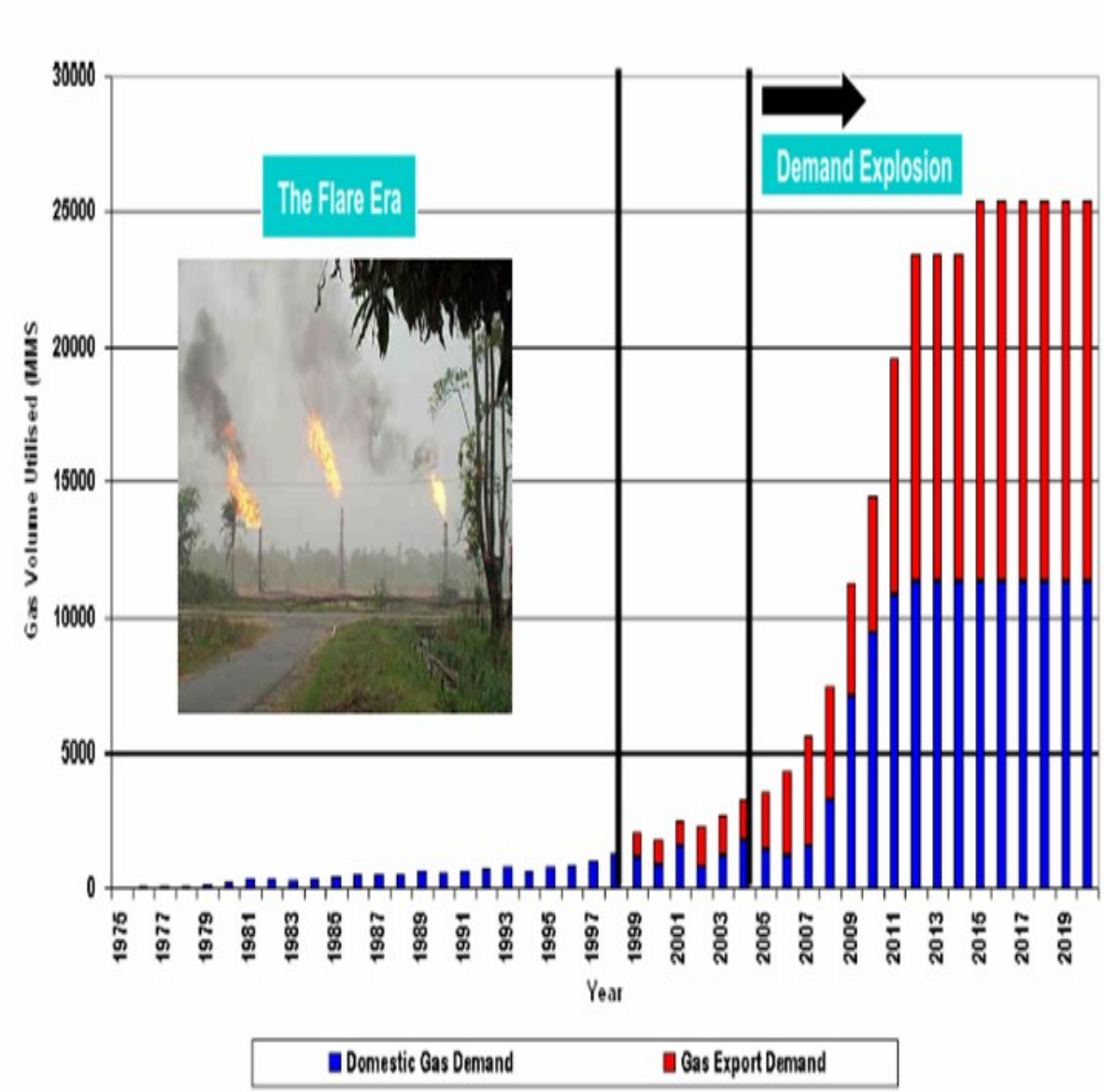

Figure 2.1: Phases of Natural gas development in Nigeria.
Source: Yar'adua 2013.

From the above discussion, it can be observed that domestic natural gas market development, was never given priority in terms of policy and infrastructural facilities as major projects were developed mainly for export revenue. Hence the birth of the export-oriented gas sector in Nigeria.

Due to several reasons ranging from lack of domestic gas infrastructure, regulated and low domestic price, the export orientation of the Nigerian gas sector among others, preference was given to gas export by gas producers to the detriment of the domestic market (Ige, 2014). This can be seen in the illustration (Figure 2.2) showing actual natural gas production and usages in Nigeria as of 2017.

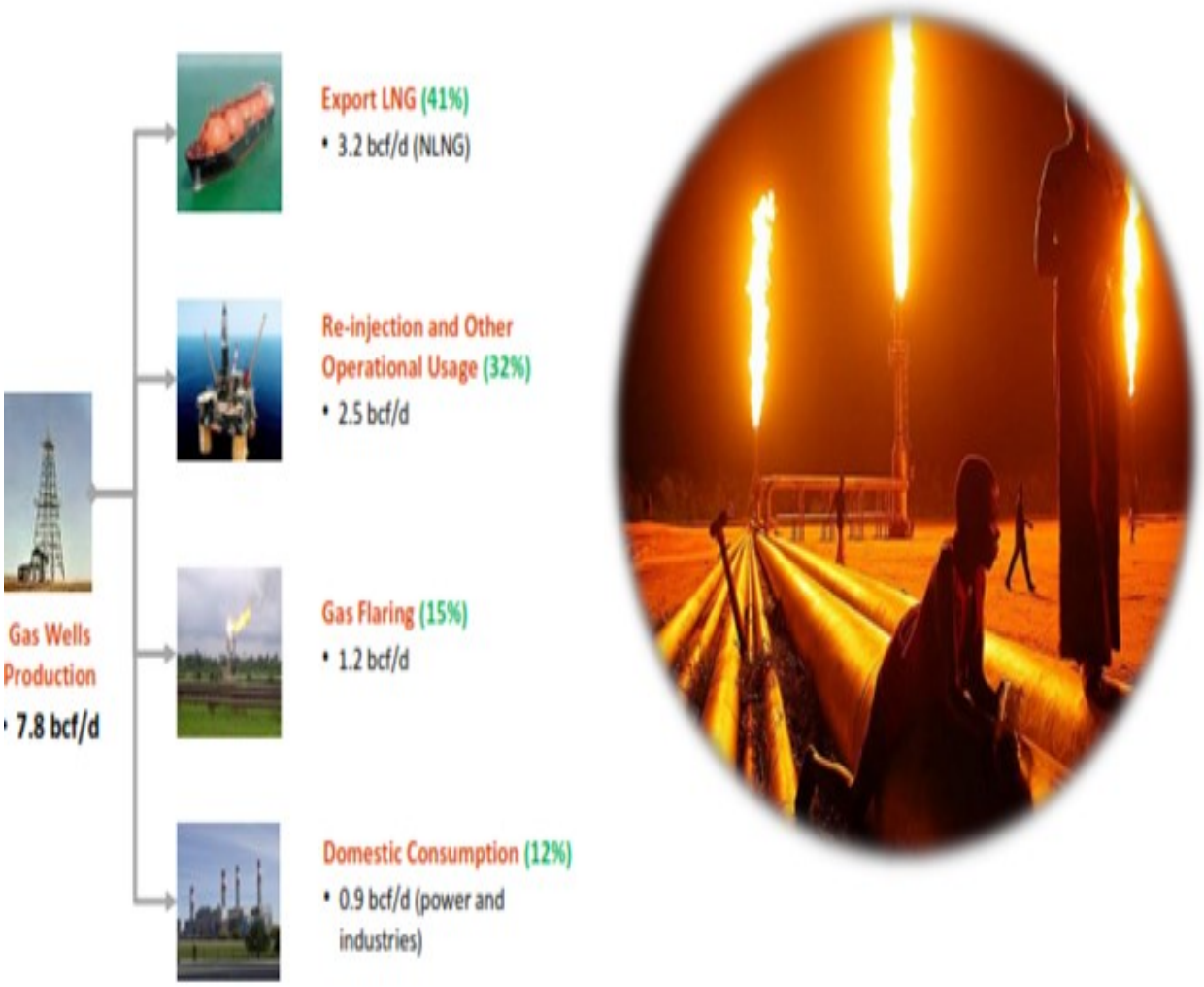

Figure 2.2: Daily gas production and utilisation in Nigeria (2014). Source: NAPIMS 2015.

The above scenario implies that natural gas in Nigeria was primarily for rent-seeking rather than for domestic economic growth through increased domestic consumption. However, in other economies of the world natural gas due to its highly profiled quality among other fossil fuel' is used extensively as a preferred energy source to grow their economy. For instance, in Saudi Arabia with a natural gas reserve of about 294Tcf (NGP, 2017), AL-Naimi (2012),[10]notes that, Saudi Arabia is among the world's leading petrochemical producers, with her vast reserves of associated and non-associated gas, alongside her large reserves of crude oil. Due to its energy policy, gas flaring was outlawed, while more pipelines are being developed both onshore and offshore to increase its production level. The policy mandates the use of these gas reserves to power a historic transformation of the Kingdom, as gas is the preferred fuel for water desalination and power generation, helping them to meet their increasing energy demand and fuelling new industries and creating new jobs, particularly in terms of downstream industrial clusters. Also, gas is needed to help further develop the mineral industry around the kingdom, where they are already strong and see great potential for future growth. Since gas is a fundamental part of their long term development and prosperity, Saudi Arabia has no plans to export its gas or get into the LNG business, not least due to her domestic energy requirement.

Nigeria and the Kingdom of Saudi Arabia shared common trends in term if reserves and flaring, but while Saudis' have been able to find the path by developing policies that ended flaring and converted the gas resource to integrate national development, Nigeria with its export revenue oriented policy is still grasping with issues of gas flaring, lack of domestic gas infrastructure, domestic energy crises amongst others. Hence the policy of domestic market liberalisation to reposition the gas resource, for value addition and national development.

[10] An address presented by Ali AL-Naimi, the petroleum and mineral resources Minister, Kingdom of Saudi Arabia at the 4th IEF-IGU Ministerial Gas Forum captioned Natural Gas: A view from Saudi Arabia. Held in Acapulco, Mexico Nov. 2012.

2.3 Overview of the structure of Nigerian natural gas market

The structure of the gas market in any economy can be said to be either unified or segmented when considering the link between the domestic and export markets. Domestic and export markets are unified if the marginal volume unit of gas not consumed in the domestic market is readily available for consumption in the export market, on the other hand, if the marginal volume units consumed in the domestic market does not have the possibility to be exported, markets are said to be segmented, and hence, no economic rationale to unify the price of natural gas sold domestically or exported. When the domestic and export markets are segmented, the opportunity costs of the domestically sold gas may differ from the export netback value (Adenikinju, 2010).[11]With globalization, technological advancement, and international trade, markets are exposed to competition not only within its own country but also internationally. Hence it is appropriate for a market such as that of natural gas to be unified in terms of price and volume of gas traded. Unified markets, it is believed will bring about competition, free flow of goods and services, efficiency, and economic resource allocation, thereby removing distortions and providing incentives for optimal performance, it is also argued that unified markets lead to uneven opportunity as all the market players are not equal, hence creating opportunity 'for perpetual winners and losers' in the market. Figure 2.3, illustrates further.

[11] If the marginal volume of units consumed in the domestic market cannot be exported, markets are said to be segmented, and hence, no economic rationale to unify the price of natural gas sold domestically or at the export market. When domestic and export markets are segmented, the opportunity costs of the domestically sold gas may differ from the export netback value.

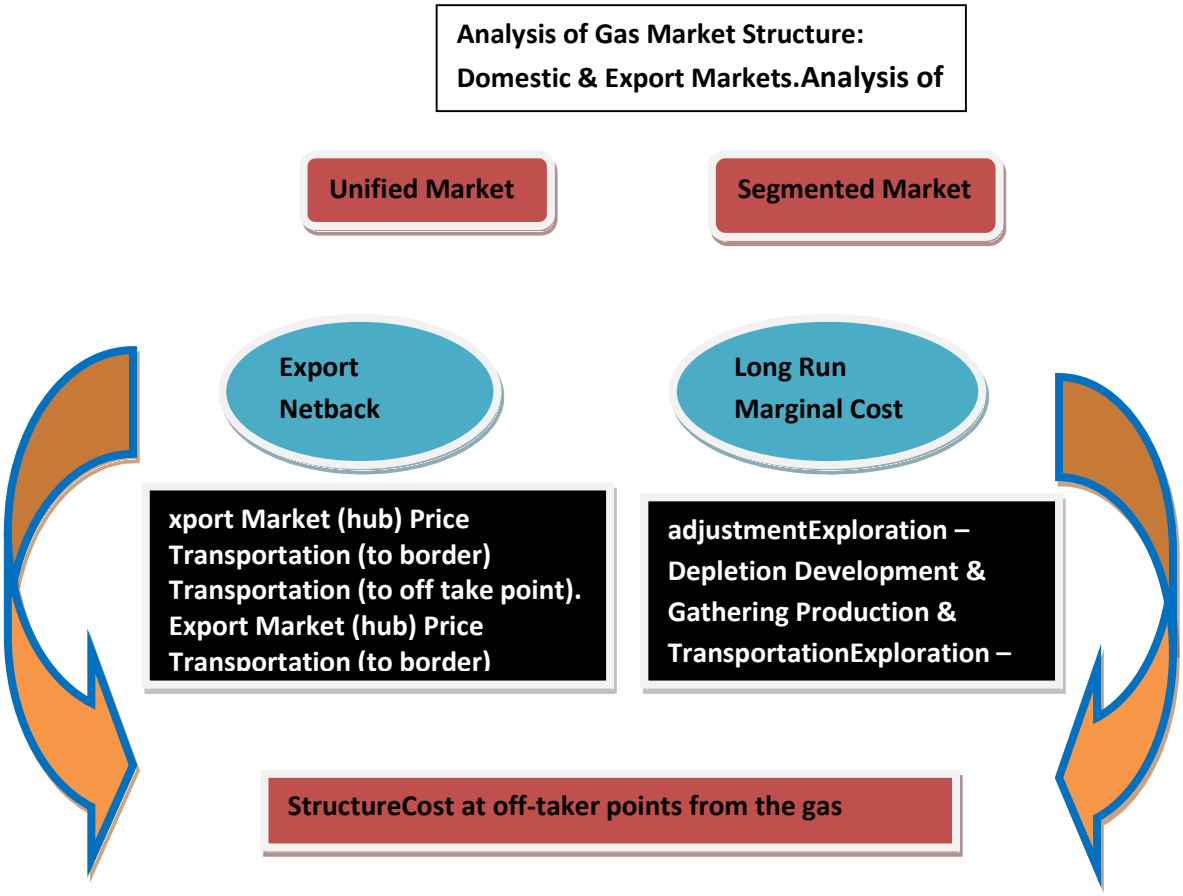

Figure 2.3: Structure of the Nigerian gas market.

Source: Adapted from Omisakin, (2015).

The Nigerian gas market is highly segmented with a regulated domestic price and an unregulated export price. As a result, gas producers in Nigeria prefer to export to the detriment of the domestic market. The domestic price of gas in the local market does not incentivize gas producers to invest in domestic gas infrastructure. This identified deficiency led to the restructuring of the domestic gas pricing framework through deregulation in a bid to attract investment into the Subsector for the development of a gas-driven economy. Hence the liberalisation policy of the Gas Master Plan seeks to advance the domestic natural gas market in Nigeria from segmented markets to a unified market. With this policy, a gas producer will have incentives to sell their product either in the domestic market or for export and yet make normal returns on their investment.

2.4 Overview of the natural gas supply value chain

The geological conditions for hosting gas in the view of Rogner (1989), are much less severe than those for oil. Hence, can be regarded as a different hydrocarbon and not as a byproduct of Oil and its resource base not linked to that of oil. Up to a certain depth, oil in liquid form can be found after that at higher depths oil dissociates into gas, an indication that the gas has no such limits. This also implies that natural gas can be found in conditions different from that of oil (non-associated gas), hence, natural gas is more widespread and abundant than oil.

The natural gas industry comprises of many capital intensive and technically challenging well-designed activities. These consist of production, gathering, pipeline transportation, storage, distribution and supply to end-users. Natural gas development includes a set of operations, such as exploration, drilling, and production, which are prerequisite to delivering natural gas at the wellhead. Production involves considerable start-up costs, most of which is often risky and fixed before natural gas production takes place. This is because of the risks involved in the process as well as the technical nature of exploration (Teece, 1996). Gas production at the upstream is potentially competitive as many firms are involved.

Gas transmission/transportation facilities have limited or no alternative usage as they are high assets specified. They constitute a unique and crucial aspect of the industry as they serve as the linkage between the producers at the upstream and the city gate or LNG at the midstream using high-pressure pipeline (comparable to the high tension electricity transmission network). Investments in gas facility transmission facilities which tend to be enormous and lump-filled are determined by the diameter (size) of the gas facility, which also depends on the distance and peak demand. Consequently, the transportation average cost inclines decrease over a large range of output, signifying that the transmission system has the features of a natural monopoly. (IEA, 2000). The transmission segment with its monopolistic characteristics is the crux of natural gas market liberalisation. This is essential because gas produced will only be economically meaningful if it can find its way to the end users (households, industries, etc.), hence the liberalisation policy encompasses Third Party Access (TPA) which allows owners of produced gas to use available pipelines space which they did not own to transport their gas to the end users.

The distribution segment of the natural gas value chain consists of the delivery of natural gas from the midstream (city gate) to the end-user-costumers using low-pressure pipelines (comparable to electricity distribution networks). It is generally believed that distribution systems bestow both scope and scale economies and as such is considered to have the characteristics of a natural monopoly. Generally, investment in the distribution segment is dependent on the length of peak demand on the system. Hence, depending on the pattern and size demand by customers, the cost would vary (Julius and Mashayekhi 1990).

The supply segment (this is usually at the retail or wholesale level) is a potential competitive trading activity with a limited economy of scale. Suppliers and traders require some investments up-front in this segment; as such the market size comprises the various sizes of individual traders. The gas industry's main concerns are continuity and integrity of supply security [12]as supply disruptions even temporarily and re-establishing it can lead to gas leaks, explosion, and fire. The variation in demand can be addressed by varying the

[12] Due to the concerns of security of supply and continuity, gas supply contracts are usually on the long term ranging from fifteen to twenty-five years.

extraction rate from the wells or through gas storage facilities. Hence, like the electricity sector, the natural gas industry requires close coordination and cooperation of system activities to ensure that the pipelines system operates smoothly. These include load balancing, pressure control, storage, and gas mix, rerouting of gas during line work (see Newbery, 1999, Juris, 1998a, Teece, 1996).

In the case of Nigeria, the upstream players in the natural gas sector include International Oil Companies (IOC's), such as Shell, Chevron, Exxon Mobil, Total, and Eni. Independents include Addax petroleum, ConocoPhillips (Oando), Petrobras, Stat oil, etc. The transmission is The Nigeria Gas Company (NGC). Distributors are Gas link, Shell Nigeria Gas (SNG), Falcon, and Gas land. The end consumers are Power Plants (GENCOS), Petrochemical, Methanol, Fertilizer, Cement & other manufacturing companies, households, etc. The final price of natural gas to pay by the consumer is determined by the different cost curves of the natural gas value chain. Hence the pricing framework takes into consideration the various segments' return on investment and an incentive to enable them to remain in business. The structure of the Nigeria gas value chain is illustrated in figure 2.4 below.

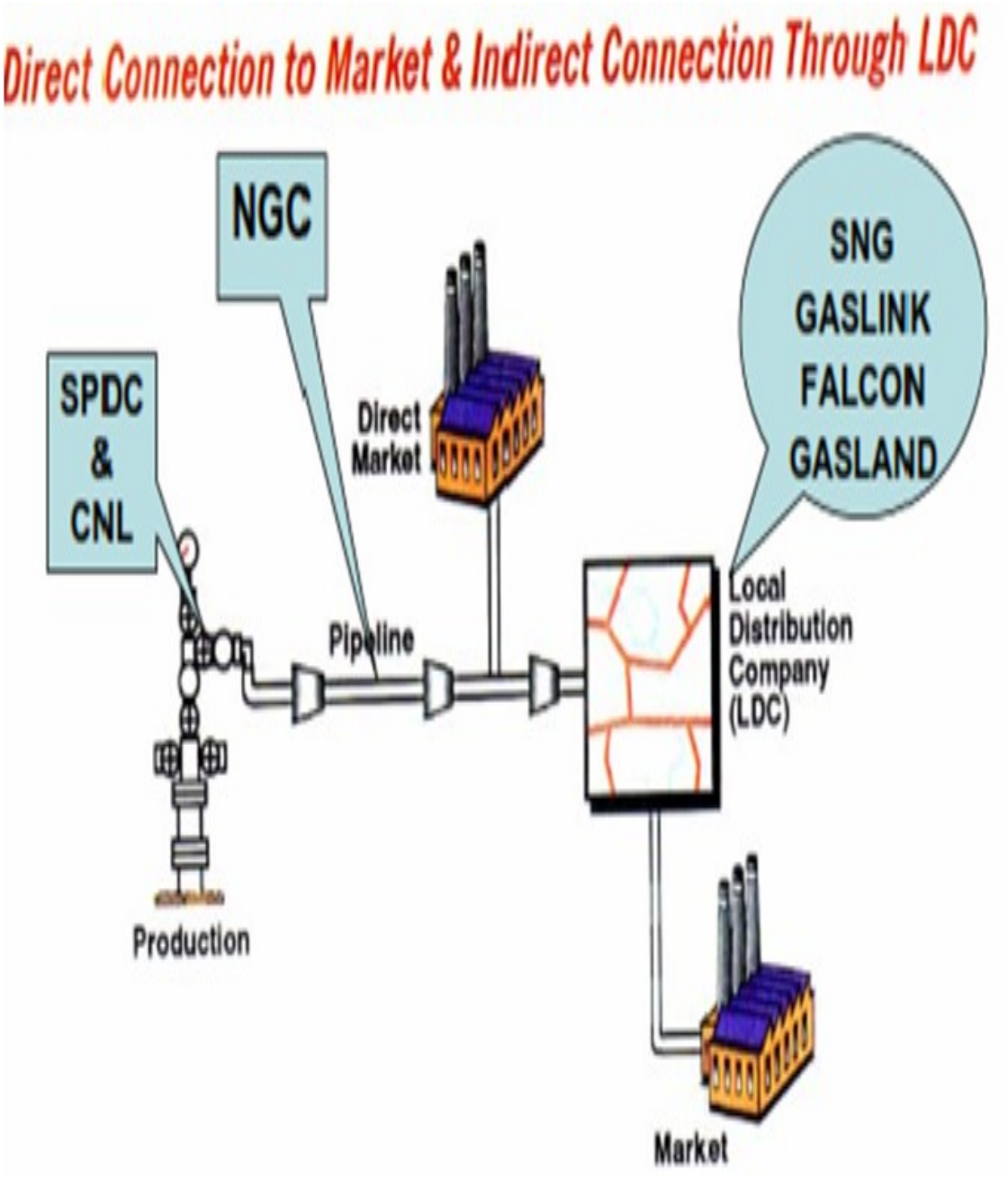

Figure 2.4: Schematic structure of the Nigerian gas value chain.
Source: Adapted from Ndukwe, 2014.

The natural gas export market in Nigeria is mainly through the Bonny NLNG and WAGP. Nigeria through the WAGP commissioned in Nov.2007 supply gas to Benin, Togo, and Ghana, with an initial volume of 133 Million standard cubic feet per day (mmscf/d) and to grow to 400mmscf/d by 2025. The Bonny NLNG which was commissioned in September 1999 has six trains made up of 24 LNG dedicated vessels, 4 LNG tanks, 4 LPG tanks, and 2 condensate tanks with a total capacity of 22mmtpa of LNG, 5mmpta of NGLs. The Brass LNG, Olokola LNG, and Kwandoro floating LNG plants are in various stages of completion. The liberalisation policy will help; it is envisaged, to invigorate all the segments of the value chain for competitive and efficient performance.

2.5 Fiscal incentives and regulatory framework for natural gas utilisation in Nigeria

In a renewed effort to ensure the economic exploitation of her vast natural gas resource, the Nigerian government had offered a series of fiscal incentives, for both upstream and downstream gas utilisation, to potential investors, especially operators and newcomers, as a way of encouraging investment, and also, developing gas utilisation schemes within the gas Subsector. Some of these incentives are discussed below to highlight the policy journey so far in developing the gas resource for economic use.

2.5.1 Natural gas fiscal incentives

2.5.1a. Associated gas utilisation fiscal incentives (AGUFI)

The Associated Gas Utilisation Fiscal Incentives (AGUFI) document sets out policy incentives for any gas producer that will make additional investments in delivering gas that is flared to any interested buyer. These are:

a) All investments made for the purpose of separating oil and gas from the reservoir into utilisable products shall be regarded as part of costs for the development of the field.

b) The proportion of capital investment of gas in usable form, for fiscal purposes, at designated custody transfer points shall be treated as part of the oil development capital investment.[13]

c) The offset of capital depreciation shall be against oil income at a tax rate of 85 percent.

[13] This is to encourage current oil producers to invest in gas transmission and processing facilities.

d) The revenue from gas and gas products and the gas delivery operating expenses for commercial use shall be considered under gas producers fiscal terms. Also, the document sets out the government's unfavourable disposition to unbridled associated gas flaring by penalizing defaulters on an incremental basis. However, this was tied to the price of gas delivered to industrial users.

2.5.1b. Associated gas-framework agreement (AGFA) 1992

As a fiscal incentive package to incentivize natural gas utilisation in Nigeria, the Associated Gas–Framework Agreement (AGFA) legislation was introduced in 1992. These incentives include:

a) A three years tax holiday;

b) To henceforth consider all investments necessary to separate gas from oil in reserves appropriate for production as part of the oil field development.

With Associated gas-framework agreement legislation in place, the contractual relationship between the Multinational Oil Companies (MOC's) and Nigeria's National Oil Company (NNPC) will henceforth be dependent on a Memorandum of Understanding (MoU) which is subject to review regularly. Nigeria's realization of the importance of a viable gas sector within this legal framework necessitated the conception of some major gas projects such as the West African Gas pipelines Project (WAGP), Escravos Gas Project, Oso condensate project, NLNG project amongst others. Specifically, the provision of AGFA for the upstream and the downstream segments are discussed below.

(i) Upstream gas utilisation incentives:

The current applicable Fiscal Terms for Upstream Gas development in Nigeria is the AGFA incentives as provided for under Section 10a of the Petroleum Profit Tax Allowance (PPTA) as follows:

a) All capital costs of upstream gas investments (equipment and facilities) for the purpose of delivering associated gas in all forms usable, at utilisation or designated custody transfer points shall, for the purposes of taxation, be treated as part of oil development capital investment.

b) Also to be considered as part of oil field development are the investments required to separate crude oil and gas from the reservoir into usable products.

c) The basis of tax assessment, operating expenses, and capital allowances, shall be subject to the provisions as provided in this act and the tax incentives under the revised MoU.

d) The upstream producer is exempted from payment of petroleum profit tax and royalty on any gas that is dedicated to a downstream project.

e) A ten ear tax holiday was granted the LNG projects.

f) LNG projects are exempted from income tax on services or work provided by non-residents and from withholding tax on the interest and dividends paid to non-residents.

g) Upstream projects also have an additional investment allowance of 20 percent; 35 percent for Natural Gas Liquids (NGLs) extraction and Gas-To-Liquid (GTL) facilities and 15 percent for downstream projects.

(ii) Downstream gas utilisation incentives:

Grant[14] had enumerated some approved incentives for private investors in downstream gas utilisation projects which include but not limited to Tax holidays, competitive pricing of feedstock, guaranteed export earnings, capital allowance, duty exemption on construction materials, full equity participation, to mention just a few. Eromosele (1997) listed some of the areas of downstream gas-related investments to include plants for the production of Methanol and MTBE, Carbon Disulphide, Methyl Chlorides, and Carbon Black.[15]

The current applicable Fiscal Terms for Downstream Gas development in Nigeria is the Companies Income Tax Act (CITA)[16] incentives as contained under Section 28g. CITA Incentives (Act 18, 1998) provides as follows:

a) Initial tax-free period of 3 years with a possible extension for two additional years (Act 30, 1999).

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[14]In a Paper entitled, "*Investment Opportunities in the Gas Sector of the Nigerian Petroleum Industry."* – Presented at the Sub-Saharan Oil and Minerals Conference, Johannesburg, South Africa. 1995.

[15] A Handbook on Nigerian Petroleum Business. Edited by Victor E. Eromosele.

[16]CITA, defined Gas Utilization as: "*the distribution and marketing of natural gas for commercial purpose and include: Liquefied Natural Gas, Power Plant, Fertilizer Plant, Gas-To-Liquid Plant, Gas Transmission and Distribution pipelines."*

b) An additional 35 percent Investment Tax Allowance (ITA), which shall not reduce the value of the asset shall serve as an alternative to the above-stated tax-free periods.

c) The treatment of the Accelerated Capital Allowance after the tax-free period shall be as follows:

i. For investment in plant and machinery, an annual allowance of 90 percent with 10 percent retention (Act 19, 1998).

ii. Also, an additional investment allowance which shall not reduce the value of the asset at 15 percent (Act 30, 1999).

d) During the tax-free period there shall be a tax-free dividend where:

i. The investments in the business were in foreign currency, or

ii. During the period, the acquisition of imported plant and machinery was not less than 30% of the company's equity share capital.

e) Also deductible for tax purposes include interest payable on loans obtained for a gas project, with prior approval of the Minister.

f) The commencement of the tax-free period for a company shall start on the day production commences in the company as certified by the Ministry of Petroleum Resources.

a) Government, in 1998 provided additional incentives for investment in economic utilisation of flared gas. These fiscal incentives included:

b) A reduction of taxes on gas projects to 30 percent as against 85 percent for oil projects.

c) Gas projects, capital expenditures shall be chargeable under Petroleum Profits Tax (PPT).

d) A five (5) to seven (7) year tax holiday.

e) Exemption of customs duties and VAT on gas-related development equipment.

f) A 15% Investment capital allowance.

g) Interest on loans is deductible.

h) During the tax holidays, dividends are tax-free.

As of 2017, there has been no encompassing gas utilisation bill covering the entire gas value chain, viz: gas exploration and production, transportation and distribution as well as flaring. Such a bill is yet to be passed into law! Thus, it may be practically difficult, to end

gas flaring at the year-end of 2008 as mandated by the government. The Government's policy on Clean Development Mechanism (CDM) and its incentives coupled with its encouragement on investment in the natural gas sector as above stated could be one of the options towards end-gas-flaring in Nigeria initiative by the government. The conception of a high-level group known as 'The Presidential Implementation Committee on the Clean Development Mechanism', to, among other goals, support the use of CDM to reduce gas flaring is an indication that the government remains committed to incentivizing financially the reduction of gas flaring (see NNPC the Seven-Big-Wins). The following Tables show summaries of the Nigerian Fiscal Terms for Upstream and Downstream Gas (Pre-AGFA and 1992 AGFA).

Table 2.1 Summary of Nigerian gas fiscal terms pre AGFA

TERMS	UPSTREAM	DOWNSTREAM
Royalty Rate	0%, if transferred to an industrial project	None
G-Factor	16.9% (for load factor 50%) to 13.6 % (for load factor 80%)	None
Tax Rate	85%PPT (65.75% for the first Five years)*	40% CIT (30% from1997)
Tax Holiday	None	None
Treatment of	Deductible	Deductible
Capital Allowances	4 years @ 20%,1year @ 19%, 1% Retention	4years@25%
Tax Credit/ Allowance	5%-15%ofCapitalCosts	None
Consolidation	Terms the same as of Oil	Separated from Upstream operations
VAT	5%, Applicable to all good & Services	5%, Applicable to all good & Services
Import Duties	Averaged 20%, Applicable to all Imports	Averaged 20%, Applicable to all
NDDC Levy	None (Introducedin1999)	None (Introduced in1999)
Dividend Withholding	None	10% of distributed Dividends

* Plus 2% Education Tax

Source: Computed by the Author from various NNPC publications.

Table 2.2 Summary of Nigerian fiscal gas terms AGFA (1992)

TERMS	UPSTREAM	DOWNSTREAM (Up to Utilisation point)
Royalty Rate	5%-7% of Revenue	None
Tax Rate	40% CIT (30% from 1997)*	40% CIT (30% from1997)*
Tax Holiday	None	5Years
Treatment of Interest	Deductible	Deductible
Capital Allowances	4Years@20%,	4Years@20%, 1Year@19%?
Tax	5% of Capital Costs	5% of Capital Costs
Consolidation	Capital can be treated as of oil costs	Separated from upstream oil operations
VAT	5%Applicable to all goods&	5% Applicable to all goods & services
Import Duties	Average 20%, Applicable to all	Average20%, Applicable to all Imports
NDDC Levy	None (Introducedin1999)	None (Introduced in1999)
Dividend Withholding	None	10% of distributed dividends

*Plus 2% Education Tax.

Source: Computed by the Author from NNPC publications.

2.5.1c Incentives for gas on domestic gas operations

Incentives for domestic gas operations already existing include:

a) The exemption of all machinery and equipment meant for the development of gas projects from value-added tax (VAT) and import duties.

b) The harmonization of applicable tax under the Petroleum Profit Tax Act (PPTA) to be at the same rate as the Companies Income Tax Act (CITA) currently at 30 percent.

c) The provision of a 20 percent per annum rate for capital allowance in the first four years, 19 percent in the fifth year and the remaining 1 percent of the books.

d) Harmonizing Investment Tax Credit (ITC) for gas project development with that of oil producing companies at the current PPT rate of 50 percent.

e) Royalty payable on gas production is at the rate of 5 percent offshore and 7% onshore.

f) There is also a pioneer status for a period of five (5) years for companies engaged in gas production, transmission, and distribution.

g) There are a VAT and import duty waiver granted on equipment, plants, and machinery purchased for gas development and utilisation.

h) The pioneer status of five years includes a tax holiday for the same period.

2.5.2 Natural gas regulatory framework

It could be said that Nigeria does not have a single body of law for the gas sector pre - the proposed Petroleum Industry Bill (PIB), however, the sector is governed by several legislations. Some of the existing laws and regulations governing the operations of the natural gas sector in Nigeria include the Petroleum (Drilling and Production) Regulations Act No. 51 of 1969, Associated Gas Re-injection Act of 1979 and 1985 as amended, the Nigerian Liquefied Natural Gas (NLNG) Fiscal Incentives, Guarantees and Assurances Act of 1990, the 1991 and 1992 as amended Associated Gas Framework Agreement (AGFA), the Year 2000 Memorandum of Understanding, amongst others. Below is an exploration of some of the relevant existing laws and regulations:

2.5.2a The petroleum (drilling and production) regulation Act No.51 of 1969

The Petroleum (Drilling and Production) Regulation Act No.51, known as 'The Petroleum Act' of 1969 is the first Nigerian law on oil and gas, it prescribes a legal framework for

petroleum exploration, and defines petroleum to include natural gas. The Act notes that exploration, prospecting and mining of petroleum and natural gas in Nigeria may be carried out only after licenses on oil exploration, prospecting, and mining lease respectively issued by the minister of petroleum resources has been acquired. Section 42 of the Act stipulates that, the licensee or lessee shall submit to the Minister of Petroleum Resources not later than five years after the commencement of production, the relevant feasibility study, program or proposal that they have developed for the utilisation of any natural gas; weather associated with oil or not, which has been discovered in the course of their field development. This Act does not specify any penalty clause, should operators fail to submit any such plan and/or proposal, hence this can be said to account for the operator's lack of strict adherence to the provisions of the Act.

2.5.2b The petroleum amendment Act of 1973

The Petroleum Amendment Act of 1973 stipulates that the Federal Government can take associated gas produced by the licensee or lessee free of cost or at an agreed cost and without payment of royalty where such gas is being flared at the flare by the producer. Hence, interested parties approved by the Department of Petroleum Resources (DPR), can take without payment to the producer for use, any associated gas for which the producer has not programmed for any project. It is essential, therefore, that the DPR is notified formally of the gas producer's associated gas (AG) utilisation projects by submitting their plan or program as soon as they are firmed up.

2.5.2c The associated gas re-injection Act 99 of 1979

The Associated Gas Re-Injection Act No. 99 of 1979 requires field development operators to submit proposals and /or programs on the utilisation of associated gas produced in the course of their field development and end gas flaring by 1st January 1984. Any operator found flaring gas after the above date without the express permission of the Minister of Petroleum Resources forfeits the field amongst other sanctions.

2.5.2d The associated gas re-injection amendment Act 7 of 1985

To give weight to the Associated gas re-injection act of 1979, due to some identified lacuna in the Act, an amendment known as the Associated Gas Re-Injection Amendment Act was enacted in 1985. This Act introduced a penalty fine of 2k/1000 cubic feet of gas flared (equivalent to 4 cents/1000 cubic feet as at that time when crude oil prices ranged between $20 - 28/bbl) in the field where there was no express permission to flare from the Minister for Petroleum Resources. However, to reflect the effect of the exchange rate at the time, the penalty was reviewed to 50kobo/1000 cubic feet of gas flared. This was further reviewed to N10/1000 cubic feet in 1998. As a matter of policy, the Department of Petroleum Resources (DPR) has the powers to disallow, apart from the provision for back-up supplies, the development of non associated gas where associated gas utilisation is feasible.

2.5.2e The Nigerian liquefied natural gas (NLNG) fiscal incentives, guarantee, and assurance Act 1990

With the government's drive to end flaring in addition to the associated gas re-injection Act and its amendment, this Act was enacted to encourage the utilisation of associated gas as liquefied natural gas (LNG) through incentives such as guarantee, assurances, tax holidays, etc. This Act was specifically enacted for the pioneer LNG project in Nigeria - The Nigerian Liquefied Natural Gas (NLNG) project at Bony Island. This Act to some extent has made it impossible for other LNG projects to be developed in Nigeria, a new project such as The Brass LNG, Olokola LNG, and Kwandoro floating LNG are asking for comparable or even better incentives than that granted to the NLNG.

2.5.2f The National Oil and Gas Policy 2004

The National Oil and Gas Policy 2004, is a broad-based policy framework statements aimed at liberalising and repositioning the gas industry in Nigeria, especially with regards to the domestic gas utilisation. The Downstream Gas Bill (DGB), 2005 was projected as a legal tool upon which the implementation of domestic gas market liberalisation will be anchored. The Nigerian Gas Master Plan (NGMP) 2008. Proposes the framework for the development of the domestic gas market in Nigeria in line with the National Energy

Policy and National Oil and Gas Policy. The plan proposes a Domestic Gas Supply Obligation (GSO), to boost the supply of gas to domestic markets; Gas Infrastructure Blue Print, for the development of gas infrastructure in Nigeria and the Gas Pricing Policy, to ensure that all gas consuming sectors are supplied gas at sector's capacity to pay. Also, the National Domestic Gas Supply and Pricing Regulation 2008 and the National Domestic Gas Supply and pricing policy 2008, are all extant legal and policy framework to implement the Nigerian Gas master plan (NGMP).

2.5.2g(i) The Petroleum Industry Bill (PIB)

There was a quest for a comprehensive policy and regulatory framework for exploitation and mining of the petroleum and gas resources in Nigeria. Thus, the oil and gas sector reform implementation committee (OGIC) that came into being in 2000 drafted the National Oil and Gas Policy report in 2017. The policy document was used as the basis for the first executive bill of the PIB 2008 (Onolemhemhen et al, 2017).

However, the PIB witnessed turbulent times and repeated setbacks in the hands of various stakeholders – the Nigerian legislature and the oil and gas operators towards realisation and has therefore been considered in many cycles as the longest legislative bill the world over to be deliberated into becoming a law (NEITI policy brief, 2016). External stakeholders such as the International Monetary Fund (IMF) and the Organisation of Petroleum Exporting Countries (OPEC) did endorse the PIB as a good instrument for the restructuring of the Nigerian Oil and Gas space (Nwaoha & Wood, 2014). The concurrence of the Nigerian legislature and discontent of major oil and gas producers (the IOCs – Shell, Mobil, Chevron, AGIP, and Total) that account for over 85 percent of oil and gas production in Nigeria had stalled its passage. The most controversial issues among the stakeholders include the powers allocated to the Minister, benefits accruable to host communities, ownership, and control of the oil and gas resources and the right fiscal regime (NEITI policy Brief, 2016).

Substantial revenue losses to the Nigerian government amounting to more than US$200 billion as well as multiplier effects on the macro-economy has been attributed to the delay

in the passage of the PIB which is seen as representing the much needed policy and regulatory framework to guide the Oil and Gas industry in Nigeria especially gas exploitation and utilisation. The PIB has been restructured to the Petroleum Industry Reform Bill, in the continued quest for effective policy and regulation of the industry. The new re-structure is considered to contain the most fundamental policy and regulatory requirements of the overall petroleum industry in Nigeria (MPR-7BigWins, 2017) as well as the introduction of key national policies to address the different segments (upstream, downstream, fiscal) of the oil and gas industry.

2.5.2g.(ii) The petroleum industry reform bills (new PIB) and national policies

The new PIB has been restructured into the following four bills – the Petroleum Industry Governance Bill (PIGB), the Petroleum Industry Fiscal Bill (PIFB), the Petroleum Industry Administration Bill (PIAB) and the Petroleum Host and Impacted Communities Development Bill (PHICDB). These bills when enacted into Acts are expected to serve as the regulatory instruments for the operation of the oil and gas industry in Nigeria. Also, new national oil and gas policies have been issued outlining the development strategies in the short, medium and long-term targets of the industry these include: the National Oil Policy (NOP), the National gas Policy (NGP), the Downstream Policy and the Fiscal Reform Policy.

The PIGB which is the first to be passed among the four bills enshrines the establishment of a framework for the creation of profit-oriented governing institutions whose responsibilities have been clearly defined and separated to ensure efficiency, effectiveness, value addition and internalization in the Nigerian oil and gas industry (KPMG newsletter, 2017). The PIAB seeks to provide for the establishment of the administrative and regulatory framework for the petroleum industry in Nigeria is somewhat similar to the functions of the DPR currently. The act in addition to administration of oil mining activities, shall foresee the administration of (i) gas discoveries – mining rights and royalties, (ii) flaring of gas prohibition, (iii) domestic gas supply obligations, (iv) midstream and downstream gas regulation, including bulk gas

storage, gas transportation, gas processing facility, and gas wholesale and retail supply (PIAB draft, 2018).

The PIFB outlines the fiscal policy framework for the Nigerian petroleum industry and other related matters such that substantial and progressive investment is attracted to the oil and gas industry, thereby seeking to increase government revenues from oil and gas operations and enthrone fiscal rules of general applicability so to encourage equity, transparency, and accountability (PIFB draft, 2018).

2.5.2h The national gas policy 2017

As the reform in the gas sector is viewed as the way forward in repositioning the sector to drive the economy, the national gas policy was approved by the Federal Executive Council (FEC), in June 2017. The policy articulates the vision of the Federal Government of Nigeria, which is intended to remove the barriers affecting investment and development of the gas sector by setting goals, strategies and an implementation plan for the introduction of an appropriate institutional, legal, regulatory and commercial framework for the gas sector. The summarized table below highlights other legislation that governs the natural gas sector in Nigeria.

Table 2.3: Gas sector Policy/Law/Regulations

POLICY/REGULATION	MAIN PURPOSE
Petroleum Act of 1969	This Act, which defines petroleum to include natural gas, prescribes a legal framework for petroleum exploration. This is the principal industry legislation. It states that exploration, prospecting, and mining of petroleum and natural gas can only be carried out after a license for oil exploration, prospecting, and mining lease respectively, is issued by the Minister of Petroleum Resources (MPR).
Petroleum (Drilling and production) Regulation 1969.	This regulation was made to regulate oil and gas operation, in pursuant to the Petroleum Act. A prospecting licensee is to submit a feasibility study program or proposal for the utilisation of associated gas not later than five years after the commencement of 'crude oil' production. Since this is not to be done before the license is not granted nor immediately after or before petroleum operation, natural gas can be flared for five years before the proposal is made. The act also did not stipulate any penalty for defaulting operators.
Oil Petroleum Act 1956 and Oil and Gas pipelines Regulations 1995	Regulates transportation and storage regulation for petroleum and natural gas.
Associated Gas-Re-Injection Acts of 1979, Regulations 1985 and Amendment 1995.	Requires operators to prepare a detailed program for gas re-injection or an alternative plan of viable gas utilisation option before the commencement of operation. It prohibits penalties gas flaring beyond Jan. 1, 1985.
Petroleum Profit Tax (PPTA) 2004, and Companies income tax Act (CITA) 2007	These regulate taxation from natural Gas value Chain (upstream & downstream).
The Nigerian LNG Fiscal Incentives, Guarantees and Assurance Act 1990	This Act is specific to the Nigeria liquefied natural Gas project (NLNG) in Bony Island. It specifies certain fiscal incentives such as tax holidays, guarantees and assurance to encourage the utilisation of associated Gas as LNG. This Act created the NLNG
Associated Gas Framework Agreement (AGFA 1991, and 1992.	This document presents fiscal incentives for gas utilisation in the domestic economy to create value addition. These include: gas to liquid (GTL) plants, gas-fired power plants, LNG, fertilizer plants, gas transmission, and distribution pipelines.
National Energy Policy, 2003.	This document proposed an overall energy value chain development policy to ensure adequate, optimal, secure and reliable energy supply and consumption.

National Oil and Gas Policy (NOGP), 2004	This document proposed a broad policy framework statement for the liberalisation of the domestic gas markets, to make it functional.
Downstream Gas Bill (DGB), 2005	The DGB, 2005 Proposed the framework for the implementation of the domestic gas market liberalisation in Nigeria.
Nigerian Gas Master Plan (NGMP) 2008	The NGMP 2008 prescribes an agenda for domestic gas development in line with the National Energy Policy and National Oil and Gas Policy. The key policy target includes Gas infrastructure blueprint, domestic gas supply obligation and gas pricing policy.
National Domestic Gas Supply and Pricing Regulation 2008, and National Domestic Gas Supply and pricing policy 2008	An extant legal and policy framework to implement the Nigerian Gas master plan (NGMP)
The Petroleum Industry Bill (PIB) 2012	The PIB proposes a comprehensive legal framework for the exploration and operation of the petroleum and gas sectors in Nigeria, in pursuant to the oil and gas industry reforms that began in 2000.

Source: (Adapted from Oyewunmi, 2013)

Unlike crude oil, the Government derives value from natural gas development from taxes, royalties, bonuses and a share of production (for production sharing contracts). For royalties, offshore fields attract 5 percent and 7 percent for onshore fields of natural gas production. Companies' income tax (CIT) rate of 30 percent also applies; others include a 2 percent education tax, 3 percent of the total annual budget as a levy for Niger- Delta commission. It is worthy of mention that royalty and petroleum profit tax do not apply to gas transferred from a natural gas liquid facility to a gas-to-liquid facility. The revenue accruing to the NNPC under its joint ventures and production sharing contracts (PSC's) is paid into the Federation Account.

Some notable deficiency of the Gas sector fiscal and Regulatory framework above, include the following:

a. Lack of strict legislation on gas flaring to curtail waste and environmental issues.
b. The existing Associated Gas framework Agreement (AGFA) regime favoured incumbent upstream oil investors, thereby acting as an obstacle to new entrants and non-oil investors in the gas sector.
c. The provision to offset capital costs at a higher marginal rate of 85 percent other than the rate at which gas profits are assessed, does not give effective incentives for containment of cost.
d. The granting of tax relief as an incentive for capital expenditure encourages upstream investors to gold plate capital investments.
e. The low Government share of economic rent is unappealing as gas development is essentially being funded from existing oil tax revenue due to Government (PPT.)
f. There are no infrastructure development incentives likened to that of NLNG to drive domestic gas infrastructural development.
g. There is a need to have a proper commercial, a regulatory framework for the downstream gas sector, including the provision of third-party access, pipelines ownership and tariff structure, gas transportation code, etc., which is not in existence.

These incentives and legal framework above discussed were all aimed at finding a path to the sustainable and economic development of the natural gas resource, but unfortunately,

Nigeria is still far from realizing a developed domestic gas market that will drive the growth of the economy as entrenched elsewhere. Hence the consideration of the liberalisation policy of the sector by the Gas Master Plan.

2.6 The Nigerian natural gas master plan (NGMP) 2008

In order is fully optimise the natural gas assets in Nigeria, the Federal Government introduced the gas master plan (GMP). The plan, which provides a holistic framework for the development of the Nigeria gas sector is designed to be private sector driven; hence 15 companies (3 domestic and 12 foreign (IOC's)), were shortlisted for its implementation. It is aimed to attain a balance between domestic and export gas aspirations and also end gas flaring, thereby leading to the rapid growth of the nations' gross domestic product (GDP) by about 10 percent. The ambition of the Nigerian gas master plan is to within then the shortest possible time transform Nigeria into a regional hub for gas supply with a scalable presence in the domestic, regional and export market simultaneously. Pursuant to this desire, the plan seeks to put in place a fully liberalised domestic gas market in Nigeria underpinned by:

1). Opening up the gas sector in Nigeria, especially the midstream and downstream segments to stimulate competition and attract new participants to achieve efficiency.

2). Creating a scalable, robust and highly interconnected gas infrastructure that supports the domestic, LNG and export markets simultaneously, with cost-effective gas from any source to any market.

3). The repositioning of the domestic natural gas market into a fully commercialized and vibrant market where investment in gas supply is stimulated by gas price and the sustainability of the domestic market complements' the LNG and the other regional export markets thereby enabling for a balanced portfolio (Yar'adua 2007).

The key policy drive of the master plan is summarized by the illustrations on fig. 2.5.

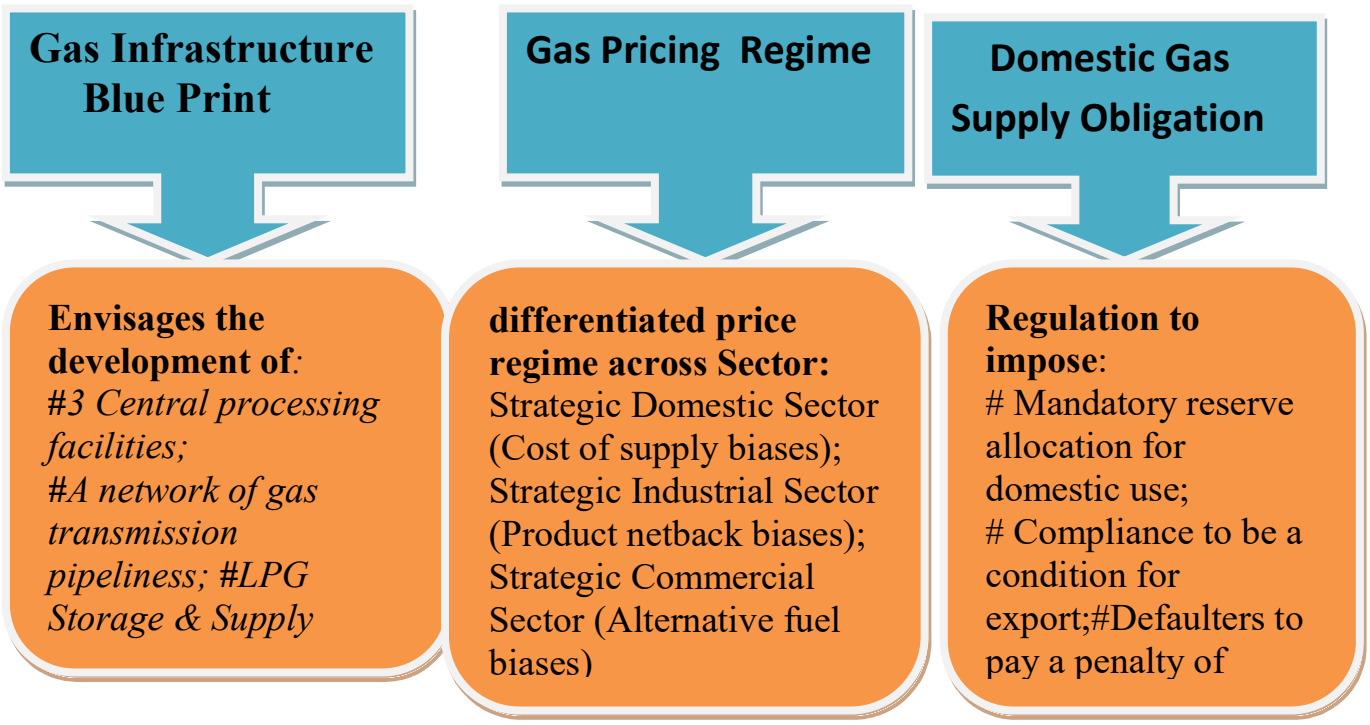

Figure 2.5. Key policy drive of the gas master plan

Source: Sketched by the Author from the gas master plan (GMP, 2008) document.

Sequel to the attainment of its stated objectives, the plan (NGMP, 2008), was categorized into three very important segments. These segments are:

2.6.1 The natural gas pricing framework

The quest for the "correct" or "appropriate" gas price has, for a long time been an issue of contentious debate in Nigeria. Despite the significant scope for growth derivable from Nigeria's gas, which is of high quality, rich in liquids and condensates with relatively low sulfur content, no gas exploration program was put forth as a sole project to harness this vast potential in the country. Consequently, the Gas Sector in Nigeria is synonymous with high domestic under utilisation and flaring of this exhaustible natural resource, which, unfortunately, is a phenomenal waste.

Because of the need for rapid domestic gas sector development as a crucial policy to rapidly grow her GDP, the government in 2008 approved the National Domestic Gas Supply and Pricing Policy. This policy thrust is to ultimately initiate a pricing framework that will maximize the value of Nigeria's vast natural gas resources from both domestic and export markets with a view to ensuring a dynamic balance between domestic and export objectives[17].Figure 2.6 below illustrates the pricing framework for natural gas in Nigeria.

[17]Excerpts of the text of the Ministerial Press Briefing addressed by the Minister of State for Energy (Petroleum), Mr.H. OdeinAjumogobia (SAN) and the Minister of State for Energy (Gas), Chief Emmanuel Odusina at the NICON Luxury Hotel, Abuja, Nigeria on April 15, 2007.

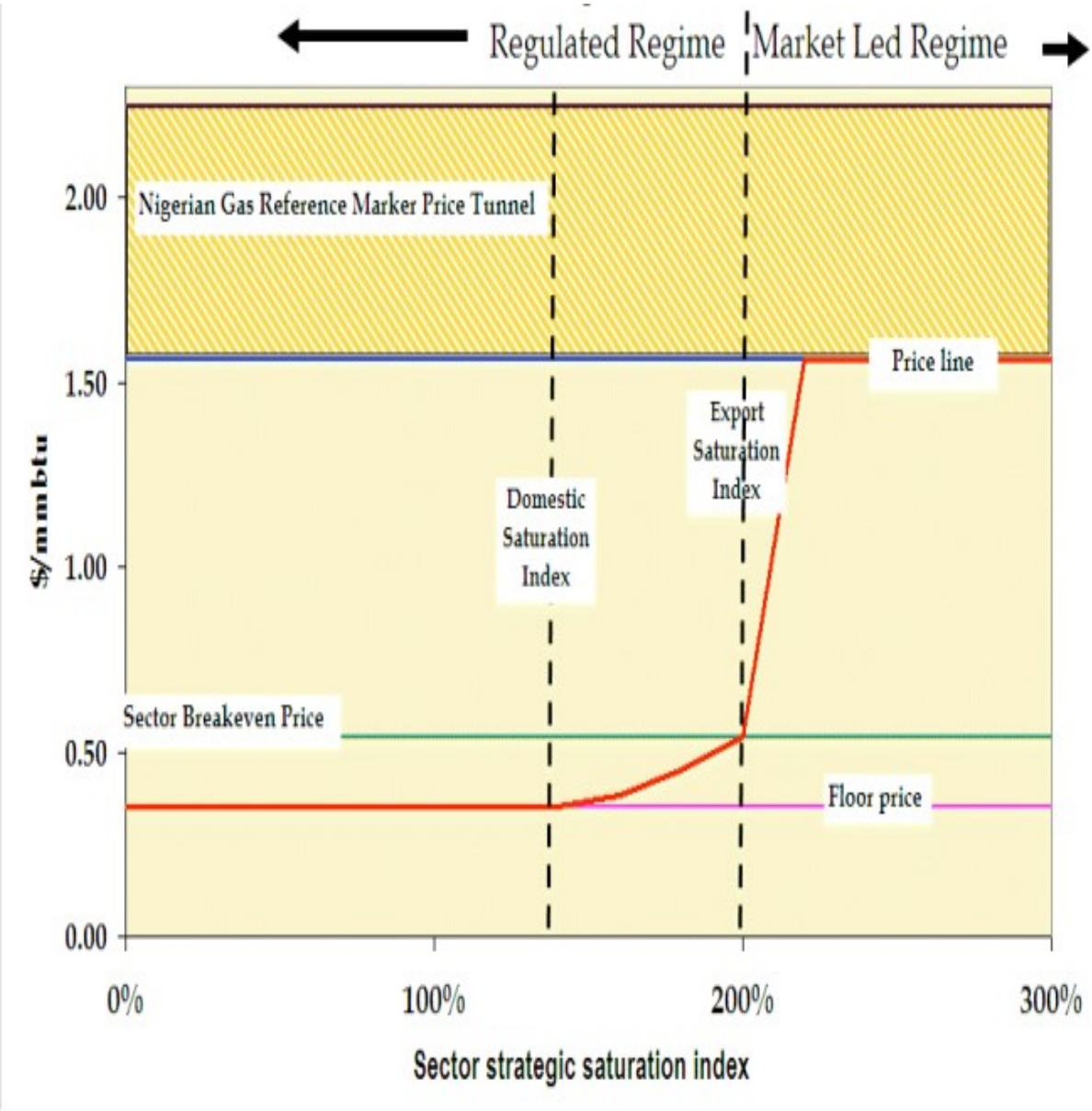

Figure 2.6: Natural gas pricing framework for Nigeria.

Source: NNPC, OPTS (July 2006).

The Gas Pricing Framework as schematically shown in Figure 2.6 is designed to enable GDP growth through affordable pricing to Strategic Sectors as well as ensuring that maximum value is derived from gas by allowing any marginal gas beyond strategic use to compete at a price considered maximum for the Nigerian gas commodity. To guarantee that the current gas sector dynamics, translates into visible economic transformation for Nigeria, three key levers are being employed by the gas industry to fuel the sectors' growth. These are:

a). The necessity to improve government rents through major export gas project delivery;

b). Repositioning the gas sector for higher multiplier effects in the domestic economy;

c). Initiating structural, infrastructural and institutional reforms necessary for a sustained economic impact of the gas sector.

This policy intends to build a planned and transparent structure where gas pricing is determined by market prices. Also, it ensures that all sectors within the domestic market, especially, the power the sector is supplied natural gas at affordable prices that have a considerable multiplier result on the economy of the nation (Ige, 2014). Transitional stratified domestic gas pricing mechanisms to be managed by the Gas Aggregation Company of Nigeria (GACN) was adopted for this policy as listed below.

2.6.1a The strategic domestic sector

This includes the power to residential and light commercial users and other sub-sector that the Minister of Energy (Gas) may from time to time align with. This sector is identified to be the sector with the highest multiplier effect on the economy. Using the pseudo-regulated pricing regime, this sector will be supplied at the cost of a supply basis. This regime allows for a 15% return for the supplier, thereby establishing the lowest cost of supply. The proposed Gas Pricing Formula for the Strategic Domestic (Power) Sector as contained in the Gas Master Plan is as stated hereunder:

$$\mathbf{CP = [PP^* (1+Inflation)]} \quad (2.1)$$

Where:

CP: is the Current applicable Gas Price ($/MCF).

PP: is the Prior Gas Price (presently $0.10/MMBTU).

Inflation: is the prevailing OECD Inflation Rate.

The implementation of this policy in the Strategic Domestic (Gas) Sector as shown in figure 2.7 hereunder reveal the gradual increase of domestic gas price to the power sector from $1.00/scf in 2010 to $2.50/scf in August 2014. However, due to this price rigidity gas producers have under supplied gas to this sector leading to frequent electricity crises. This policy, though a transitional arraignment is not achieving its expected mandate.

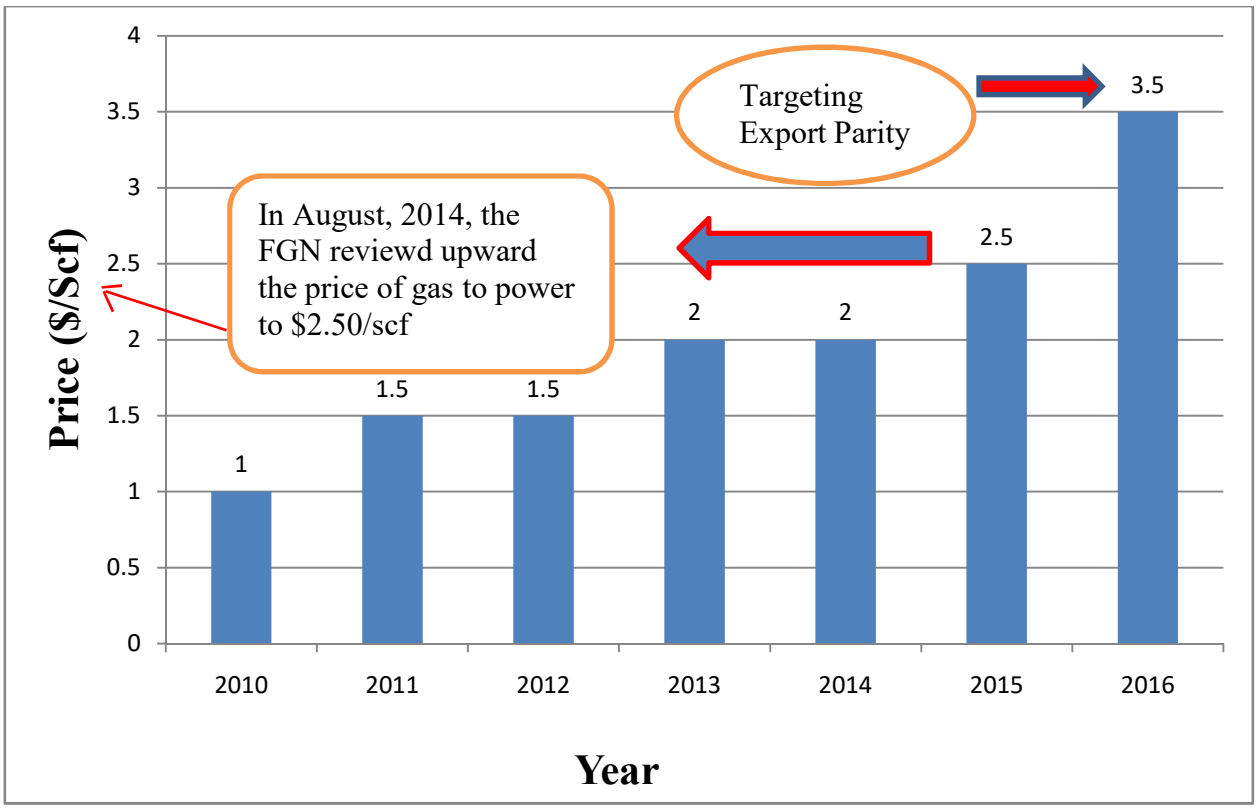

Figure 2.7: Gas to power sector pricing framework

Source: Computed by the author from the NNPC gas master plan team, 2008

2.6.1b The strategic industrial sector

This sector is made up of industries that require gas as their main feedstock in the creation of new products and maybe primarily meant for local consumption or export such as fertilizer, methanol, gas to liquid (GTL), petrochemical plants and LNG. This sector will be supplied on the product Netback basis. The proposed Gas Pricing Formula for the Strategic Industrial Sector as contained in the Gas Master Plan is as stated hereunder:

$$\mathbf{CP = NRP*(1+EPF)} \qquad (2.2)$$

Where:

EPF:	(CMPP – PRP)/PRP
CP:	Applicable Gas Price in $/Mcf
NRP:	National Reference Price for Strategic Industries
NRP:	$0.90/Mcf @ Product Reference Price
PRP:	Product Reference Price
EPF:	End Product Factor, which tracks changes in end product price e.g. Fertilizer End Product Price, etc.
CMPP:	Current Month Average End Product Price.

Fig. 2.16, shows two comparable models concerning the proposed gas pricing formula for the Strategic Industrial Sector in Nigeria.

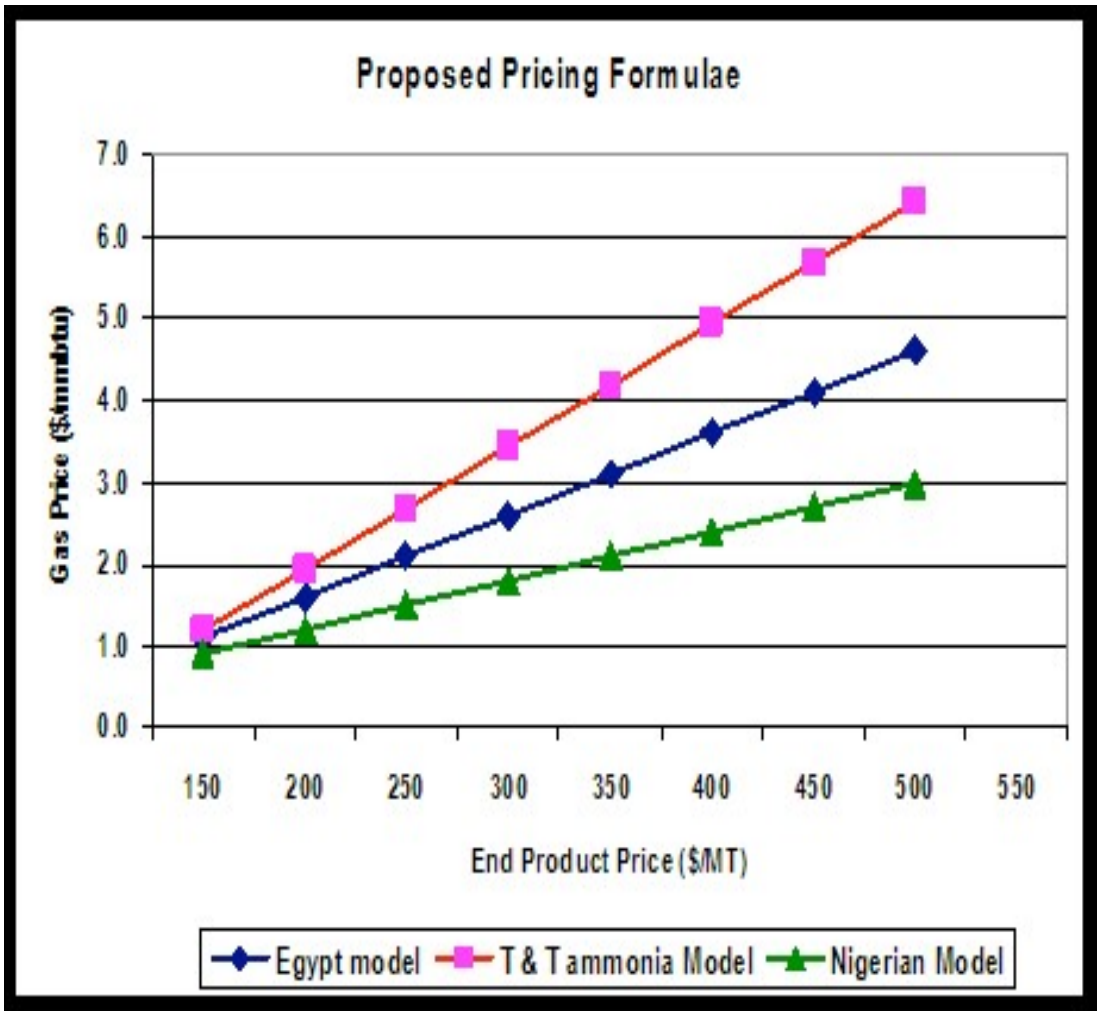

Figure 2.8: Proposed Gas Pricing Formula for the Strategic Industrial Sector

Source*:* NNPC Gas Master Plan Team, 2008

2.6.1c Other commercial sector

This Sector uses Natural Gas as fuel and not as feedstock. Operators employ Gas as direct fuel energy as against Low Pour Fuel Oil (LPFO) or coal. Thus, they have a direct impact on the economy. In arriving at the price this sector will buy gas, two gas pricing formulae were proposed.[18]

i) The basis for this formula is the existing NGC/SNG equation. It is represented as follows:

CP= [Ind_Fac*(FO_Price*1050/38,330)*1000]-T-M (2.3)

Where:

CP: Current Gas Price in Naira/Mscf

Ind_Fac: Applicable Indexation Factor in a Contract Year (YR1 = 60%, YR2 = 70%, YR3 = 80%)

FO_Price: Official Ex-Depot Price of LPFO in Naira/Litre

1050 btu: Heating Value of 1scf of Natural Gas

38,330 btu: Heating Value of 1 Litre of Fuel Oil

1000: Factor to adjust for the pricing in (Mscf)

T: Transportation Tariff

M: the Distributor's Marketing Margin

FO_Price (2007): **N**25.4/litre

CP (1000scf): (25.4*1050/38,330)*1000 = N695.8-T-M

Proposed EQ – Cap CP @ max $4.00 in the event that Subsidy for FO is removed.

ii) The second proposed gas pricing equation is as follows:

CP = [EPP*1.75*(FO_F)] </= 60%*FO </= $4/MMbtu (RT 08) (2.4)

[18] The cost of alternative fuel was arrived at for the price at which other commercial sectors will pay for gas.

Where:

CP: Current Applicable Gas Price in $/MMbtu

EPP: Export Parity Price

FO: Fuel Oil Price

FO_F: Fuel Oil Factor

EPP (2007): $0.72

- **Assuming FO_F =** 1
- **CP (Current Price) = $0.72*1.75*1 = $1.26/MMbtu**

The Cap: 60%*FO = 60%*695/120 = **$3.48/MMbtu**

If the FO price doubles, then the cap is $6.95/MMbtu

- **Where 0.8 < FO_F < 1.3**
- $\boldsymbol{FO\_F = \frac{\text{CurrentF O Price}}{\text{Prior Year Price}}}$

If EPP = $1.44, CP = $2.52 but limited to $3.48 (60% of FO)

They will be supplied with gas at the price of an alternative fuel basis. The Gas Pricing Framework as contained in the Policy document is more of a transitional arrangement, as it does not fix gas prices. The Energy Minister (Gas) will need to monitor the situation to know when the domestic market is fully matured and attained for another pricing methodology

The estimated average domestic price for all the three sectors will be known as the Aggregate Domestic price (that is, the price that all gas supplies will be paid). Figure 2.9below is a schematic diagram showing the summary of gas price calculations for each of the strategic sector classifications in Nigeria as prescribed by the plan (NGMP, 2008).

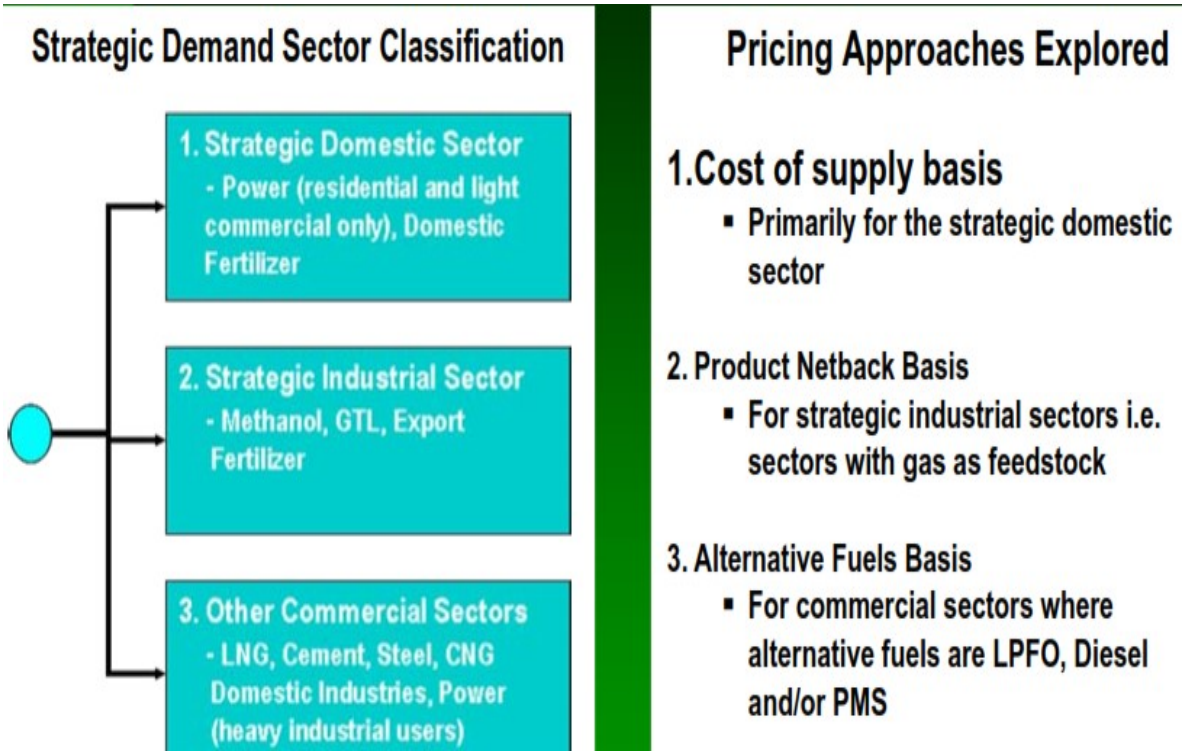

Figure 2.9: Gas Pricing Framework.

Source: Yar'adua 2007

2.6.2 The Domestic Gas Supply Obligation

The National Gas Supply and Pricing Policy (NGSPP, 2008) also introduced the domestic gas supply obligation (GSO), in a bid to ensure the success of the master plan (NGMP, 2008). The regulation requires all gas (associated and non-associated) producers in Nigeria to set aside a predetermined quantity of the produced gas for the domestic market. To ensure its effectiveness, each gas producer is mandated to submit a gas production and supply plan synonymous with the requirement under the domestic supply obligation rule.[19]The penalty for defaulting the order of the gas aggregator by any gas producer as stipulated by the regulation is the payment of compensation for loss suffered to any gas purchaser. Also, the policy sets a $3.50/mscf (Thousand standard cubic feet) penalty for obligations and/or flared and a surcharge of $0.50/mscf of flared gas as environmental fine.

However, the performance of the DSO since inception leaves much to be deserved as shown in table 2.4, and figure 2.10. This shows the extent to which the domestic natural gas market has been impacted by the policy. From these illustrations, there is a clear indication that the DSO policy has not and can not drive natural gas domestic market development. Hence the need to 'look further', if the goal of driving Nigeria's GDP growth by at least 10 percent through natural gas is to be achieved.

[19] There will be periodic reviews to the domestic gas obligation by the minister of energy to reflect the evolving dynamics of the demand and supply environment.

Table 2.4: Domestic market obligation and supply (2008 to 2017)

YEAR	OBLIGATION	SUPPLY	PERFORMANCE (IN PERCENTAGE)
2008	2231	716	32.10 percent
2009	2995	752	25.10 percent
2010	3635	795	21.90 percent
2011	4107	966.4	23.50 percent
2012	4584	1113	24.30 percent
2013	5073	1030.65	20.30 percent
2014	3940.5	1299.27	33 percent
2015	4393	1398.85	31.60 percent
2016	2567.7	980	38.18 percent
2017	2535	1227.7	48.43 percent

Source: DPR Oil and Gas Industry Annual Report, (2017).

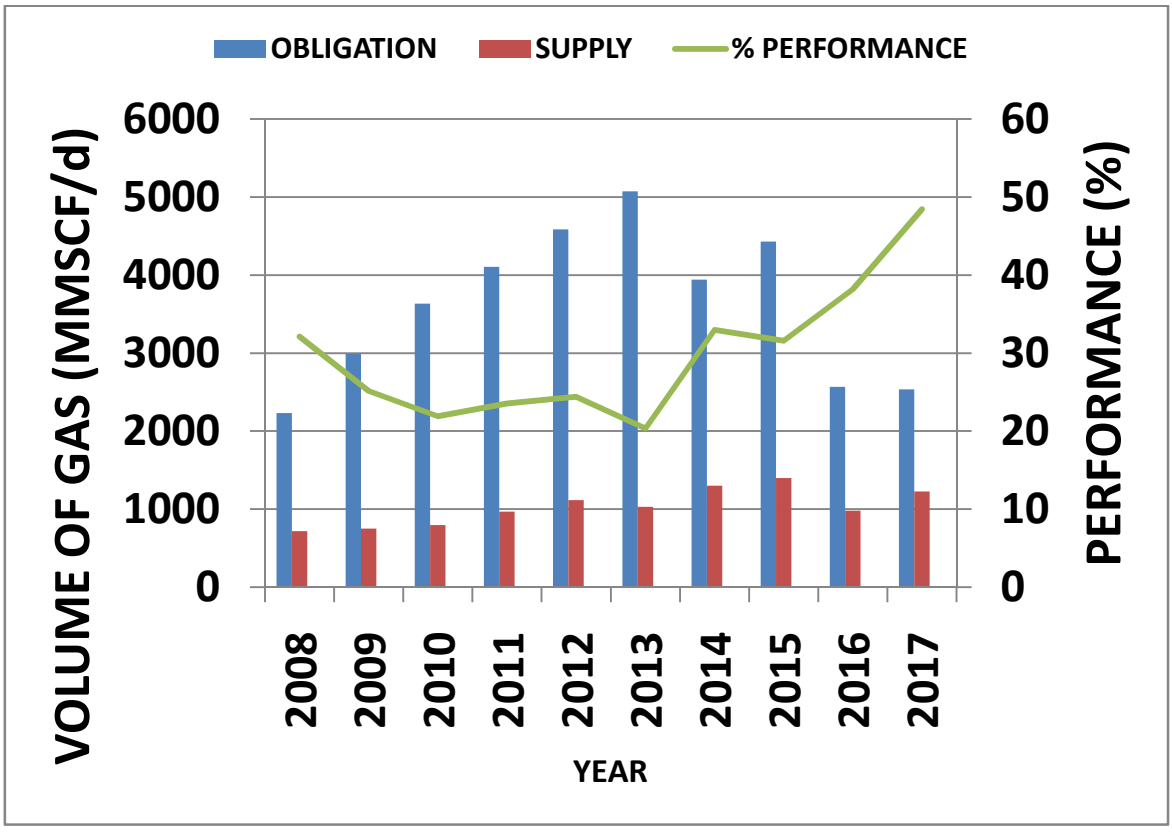

Figure 2.10: Domestic market obligation and supply (2008 to 2017)

Source: Oil and Gas Industry Annual Report, (2017)

From the above, it is clear that the aspiration for the domestic natural gas market development in Nigeria cannot be achieved through this policy. Gas producers, as shown above, have performed abysmally very poorly with an average performance of about 26.5% for the period considered. There is no expectation that as it stands now, the performance can significantly improve. Hence the need to consider a review or an alternative.

2.6.3 The strategic gas aggregator

The domestic gas pricing policy also stipulates the establishment of a Strategic Gas Aggregator known as The Gas Aggregation Company of Nigeria (GACN), which manages the demand and supply of gas in the domestic market and aligns the reserve obligation accordingly. The strategic Aggregator will, after due diligence on the gas buyers (as it will be the first contact point for the gas trade), issue gas purchase orders. Figure 2.11, illustrates in a summary form the operations of the aggregator.

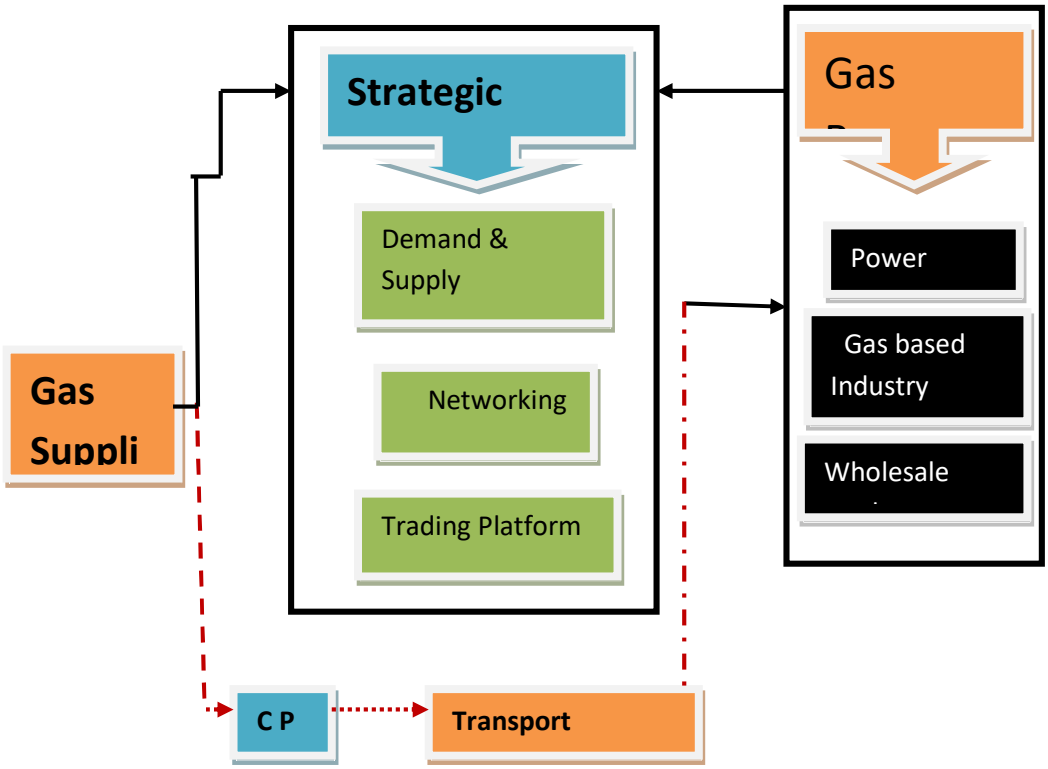

Figure 2.11 Schematic of the Gas Aggregator

Source: GACN, (2010).

The role of the GACN can be summarized thus:

i). It ensures that gas is supplied to the strategic sectors with approved national gas pricing framework as it serves as an intermediary between gas purchasers and suppliers in the domestic market.

ii). It operates an equitable gas production curtailment or nomination and balancing mechanism each time demand and supply expediencies are necessary

iii). It facilitates the execution of securities concerning gas payment default.

iv). It interacts with the regulator on due diligence procedure on buyers, demand rationing criteria, and management of the domestic supply obligation (DSO)

The expected benefits of the aggregate domestic price include the following:

a). It will stimulate the full involvement of all operators, regardless of the gas portfolio as gas price is relatively higher.

b). It will alleviate concerns by gas producers as it provides a more appreciable price of gas to suppliers.

c). It will reduce the price differential between export and domestic markets in terms of sales income and rate of returns (IRR) to gas producers.

d). It bridges the distance, difficulty of some suppliers to export and LNG markets by providing relative, and attractive domestic markets.

e). It provides a single point of contact for buyers and sellers.

This policy as laudable as it seems cannot be fully realized with the under-supply of domestic gas obligations.

2.6.4 The gas infrastructure blueprint

Gas infrastructure in Nigeria is grossly underdeveloped with poor inter-connectedness between the various gas production centres and the various demand centres. Where for pipeline connection exists, there is no optimal use, resulting in duplication of such facility

due to lack of third party access policy. Hence the plan (NGMP, 2008), sets out strategies towards addressing this infrastructural deficiency.

The gas infrastructure development in Nigeria is embedded in the robust gas infrastructure blueprint of the gas master plan (NGMP, 2008). The blueprint provides strategies that aim to reduce the overall cost of infrastructure and to ensure a more flexible supply across Nigeria. This will provide connectivity between the various gas demand centres and gas reserve sources, thereby providing a road map that will serve as a future investment guide in the sector, to ensure efficiency in resource utilisation within the domestic economy's key sectors and export markets. The blueprint is designed in such a way that it maximizes synergies and properly align infrastructure to achieve the objectives of the plan. The domestic gas infrastructure deficit in Nigeria, according to the blueprint will be broadly addressed from the point of gas gathering and pipeline transmission systems.

2.6.4a Gas gathering

The blueprint proposes the establishment of three central processing facilities (CPF) at the following designated areas - Akwa Ibom/Calabar area, Obiafu area North of Port Harcourt and Warri/Forcados area, to serve as gas major hubs for the treatment and processing of wet gas from gas fields for the extraction of liquefied petroleum gas (LPG) and condensates, while the dry gas will be fed into a network of gas transmission lines.

2.6.4b Gas pipeline transmission system

The blueprint proposed a design for construction and operation in Nigeria, grids of pipeline networks that will deliver gas to demand centres across the country. The print specifically focused on three pipeline systems in the country that will serve as the backbone infrastructure that will stimulate the construction of other pipeline networks. These three major backbone systems are:

2.6.4bi ***The western Transmission System***

The expected major market for this network system which includes the existing Escravos Lagos pipelines (ELPS) I and a new ELPS II, with a new offshore extension to Lagos that will run through the Western states and terminates at Jebba in Kwara State, will be industrial feeds and residential demand in the domestic markets, and also the export

market through the West African Gas pipelines (WAGP) which supplies gas to Ghana, Togo and Benin Republic. The expected gas throughput when fully operational is 3250mmscf/d (million standard cubic feet per day). This will boost supplies of gas to domestic and industrial gas users in the Western states up to Jebba.

2.6.4b (ii) ***The South-North Gas Transmission System***

This transmission system will supply dry gas to Ajaokuta, Abuja, Kano, and Katsina from the central gas gathering and processing facility in Akwa Ibom/Calabar. The key markets for this system comprise of the domestic markets of the Eastern States of Imo, Abia, Enugu, Ebonyi, and Anambra, as well as the North African regional markets through the Trans-Sahara pipelines. The expected gas throughput at peak of this system which shall be from the Northern node is 3800mmscf/d of gas.

2.6.4b (iii) ***The Interconnector system***

To increase the resilience of supply to the gas market due to pipeline disruptions, the interconnector pipeline system is planned to connect the Easter gas fields with other transmission systems. This grid system ensures redundancy and multiple access to gas from any source to the market.

The above backbone transmission system provides the bases for the of a liquid and robust gas market in Nigeria. It also unveils numerous investment opportunities in gas transmission for both foreign and local investors. With these systems in place, gas availability, deliverability, as well as commercially in Nigeria will be assured (see Ige 2013, NGMP, 2008). Figure 2.12 shows the outline of the pipeline infrastructure in the master plan.

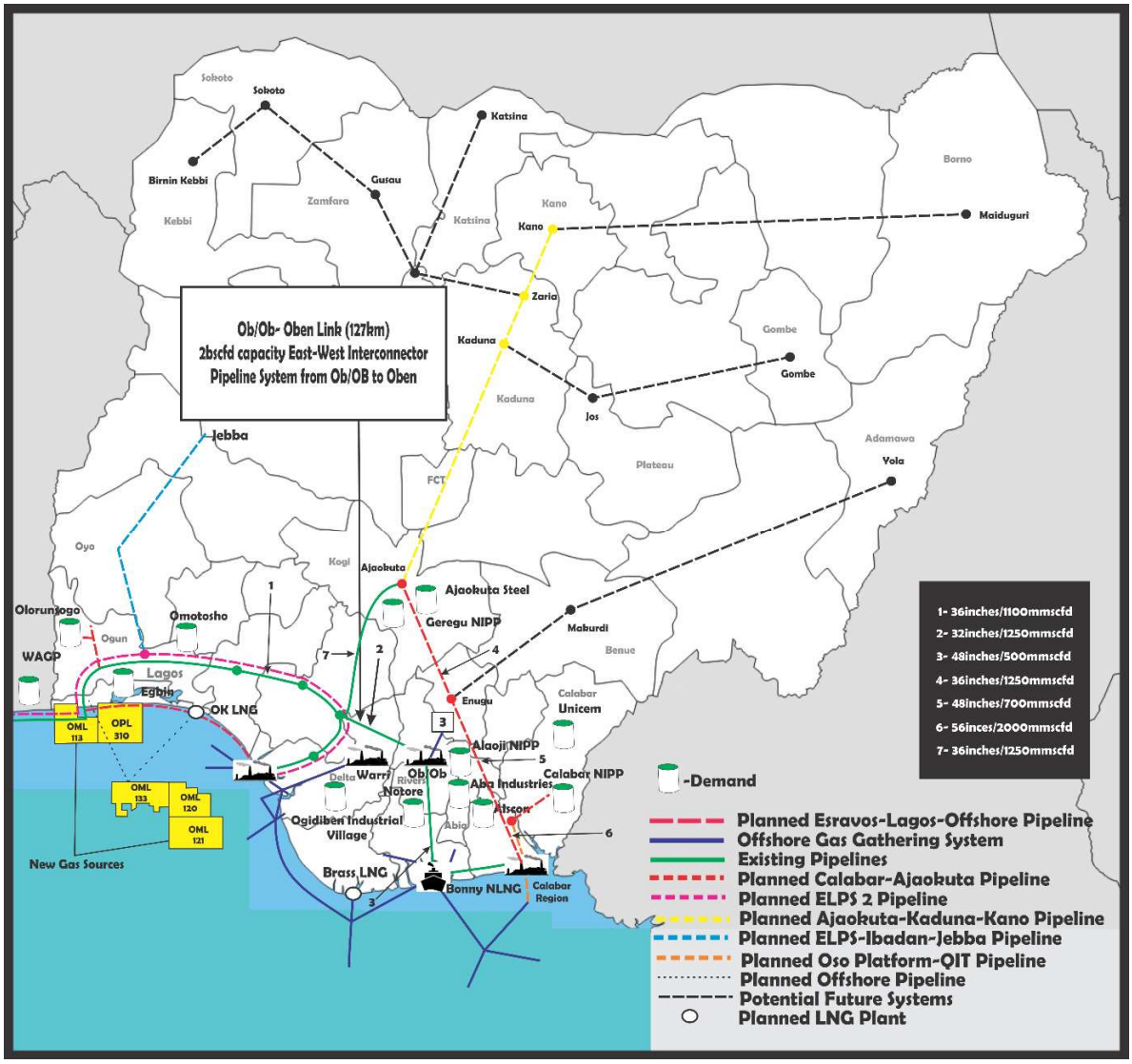

Figure 2.12: Map of Nigeria showing NGP Planned Gas Infrastructure

Source: National Gas Policy (2017).

Because of the above mentioned, the gas sector in Nigeria is being strategically repositioned to capture a considerable market share in key export markets to grow more rent to the government. In this regard, two export initiatives; the Nigerian Liquefied Natural Gas (NLNG) Plant with planned expansion to Train 7; and the two green fields Plants (Olokola (OKLNG) and Brass LNG) enable this strategy. As stated earlier, the 630-kilometre stretch West African Gas pipelines (WAGP)which delivers gas to the Republic of Benin, Togo and Ghana with an initial capacity of 200 MMscf/d, is being projected to grow to 580 MMscf/d of gas. Thus, WAGP has strategically positioned Nigeria to effectively capture the emerging gas markets in the West African sub-region. To complement this effort, there are two other regional pipeline projects currently under evaluation: the Trans-Saharan Gas pipelines Project (TSGP) and the Equatorial Guinea Gas pipelines Project. With the Trans-Saharan Gas pipelines Project, Nigeria intends to capture the satellite markets in North Africa and also, position itself for growth in the European market. Through the Equatorial Guinea supply, Nigeria intends to broaden its value capture in the LNG trade. Thus, efforts to attain the projected LNG capacity of 22 Metric Tons Per Annum (MTPA) from the year 2013 and additional 10MTPA from Brass LNG are progressing steadily.

Apart from the export potentials of Nigeria's natural gas resources, tremendous opportunities abound locally for economic stability and sustainability. Due to the poor state of the gas infrastructure in Nigeria, the domestic gas market remains grossly underdeveloped, thereby constraining domestic gas utilisation. Available records reveal that less than 12 percent of the gas produced in Nigeria is available for domestic value chain creation.

Domestic demand in the areas of power generation, petrochemical and fertilizer plants, cement industries, steel plant, aluminium smelting, and other industrial centres are some initiatives that can bring multiplier effect to the economy. Hence, it is therefore essential that gas to power and other domestic value creation industries ought to as a matter of precedence and urgency, be given the needed attention on the government’s agenda for economic growth, which will then incentivize the domestic market utilisation to make it

sustainable in both the medium and long term. This is envisioned will be realized through the domestic natural gas market liberalisation policy.

2.7 Natural gas markets liberalisation

Globally the growth in demand and the contemporary need for efficiency in natural gas markets gave rise to the need for liberalisation to protect the consumers and develop competition (Capece et al, 2013).

With the evolving dynamics in the energy sector globally, it became eminent to substitute the former energy policy's direct public intervention in energy consumption and supply planning which aimed at consumer protection and guaranteeing national security of supply. The reason for this is because, firstly, consumer protection through public direct intervention has become obsolete and hence no more considered the best means. Secondly, due to the emergence of spot markets, supply security was not considered an obstacle to be tackled at the national level. Hence the emergence of a new paradigm, a mix of regulation and liberalisation (De Paoli, 2000). This new paradigm shift entails the repositioning of the government's role as that which creates a guaranteed framework for efficient energy production and consumption under the market condition with minimal distortions rather than that of managing the balance between demand and supply through planning energy production and consumption. Hence, the notion that 'Government need not participate actively in business' (De Paoli, 2004).[20] This new model was advanced through the efforts of numerous economists, who believed that there should be an unbundling of the various gas value chain segments, so that those with the natural monopoly characteristics should be properly regulated, while those segments that have no such characteristics be opened up to competition [21] through liberalisation.

Generally, liberalisation can be described as the removal of imposed barriers that are negatively hindering competition and obstructing free movement of people, capital, goods,

[20] This principle was nick-named after the then Prime Minister of Britain Mrs. Margaret Thatcher who vigorously pursued the deregulation of the British commanding heights of the economy.
[21] For efficiency in resource allocation and benefits accruing to economies of scale, not all segments of the gas value chain can be open to deregulation.

and services among nations or regions. It involves the outright removal of or reduction in the magnitude of restrictions that will allow businesses to function in a market-driven condition. Regulation, on the other hand, is the placement of restrictions or rules by that state behaviour and pricing of businesses in the market. The ultimate aim of gas market liberalisation is the creation of a competitive market environment where open access to gas infrastructures among participants thrive. Liberalisation leads to a perfectly competitive market model where there exists transparency in information flow, consisting of many sellers and buyers with homogeneous commodities and freedom of entering and exiting the market at will. The perfectly competitive market model is believed by the classical (classical and neoclassical economists) to be the best way to ensure that resources are allocated efficiently which will lead to an overall increase in consumers' welfare. This, according to them is achieved by ensuring that the resource is allocated based on the consumers' desire to obtain economic value for commodities they consume (see Vickers, 1997).

Gas market liberalisation is essential as it will enable the market clearing equilibrium price to be determined by the interaction of demand and supply, thereby resulting in increased efficiency, price reduction and enhancement of the consumer's choice and welfare. There exists a certain degree of correlation between the prices of the different energy sources as they are to some extent substitutes, reflecting the long term ability to substitute between them. However, with liberalisation, it is expected that the price relationship between gas and oil should, over time diminishes or close, as the gas price will be based on gas on gas pricing rather than oil price indexation. The natural gas sector as a network industry will not deliver on its benefits of market liberalisation unless there is the holistic legal unbundling of the distribution system operation (DSOs) and the Transmission System Operation (TSOs). This implies that the activities of gas transmission and distribution should be performed by different network companies - third party access (TPA).[22]

[22] Third Party Access (TPA) is a structure that mandates gas facilities (Pipelines, Storage facilities, etc.) owners to avail access of their facilities to other suppliers to transport their gas for a pre-determined fee. With this in place, gas developers do not have to first build their facility before production, thereby saving some costs. However, this is only applicable to gas transmission lines

Natural gas market liberation was first introduced in the United States of America (USA) in 1978. This was followed by The United Kingdom with the passage of the oil and gas Act of 1982. Other European countries since they are, at the various stages of implementing natural gas market liberalisation following the European Union first, second, and third gas directives. One thing which is clear that distinguished the United States and British gas market that have successfully implemented full market liberalisation is the level of market maturity already attained before liberalisation, and of which substantial domestic source of supply availability then, restricted them from importing all the gas needed for their consumption. While Nigeria has a domestic supply source availability in abundance, her gas market is nowhere near maturity with basic gas infrastructure lacking.

Natural gas market liberalisation, however, has some disadvantages and risks inherent in the policy. One of the most crucial risks is the security of gas supply. Gas supply planning through the institution of long term contracts that guarantees the suppliers development of new fields becomes more difficult in a liberalised market. The long term contract agreement policy provides a guaranty for a stable demand and the basis of the company's investment in production and infrastructure as well as an assurance of security in gas supply has under this new paradigm been considered as an obstacle to liberalisation. The oligopolistic characteristics of the gas upstream; the natural monopoly of gas transmission and distribution segment of the gas value chain; the incumbent monopoly position with the new entrants who will depend on the infrastructure of the incumbent to compete; the incumbents national gas monopolists who will have to open up of their own national markets for potential competitors, with its resultant threats etc., constitute some of these challenges to fully implementing the policy on natural gas market liberalisation. Despite the challenges, it has a variety of benefits some of which include: more new entrants which will increase supply and lead to price reductions; customers' free choice of the service provider, thereby increasing their welfare; mobilization of resources for more investment in the sector; establishment of spot and futures market which will help freeze price rigidity and make gas cheaper; a third party policy that will help increase gas supply; etc.

Liberalisation policy as aforementioned above has some positive aspects as well as negative aspects. The challenge in this perspective is the fact that often aspects which are negative for one group of players might be positive for another group. The question remains can natural gas market liberation brings about the much desired domestic natural gas market development, provide the needed gas infrastructure, and incentivize dedicated natural gas exploration to make natural gas drive the economic growth of the Nigerian economy. The diagram (figure 2.13), shows the sketch of natural gas flow under the traditional and liberalised markets.

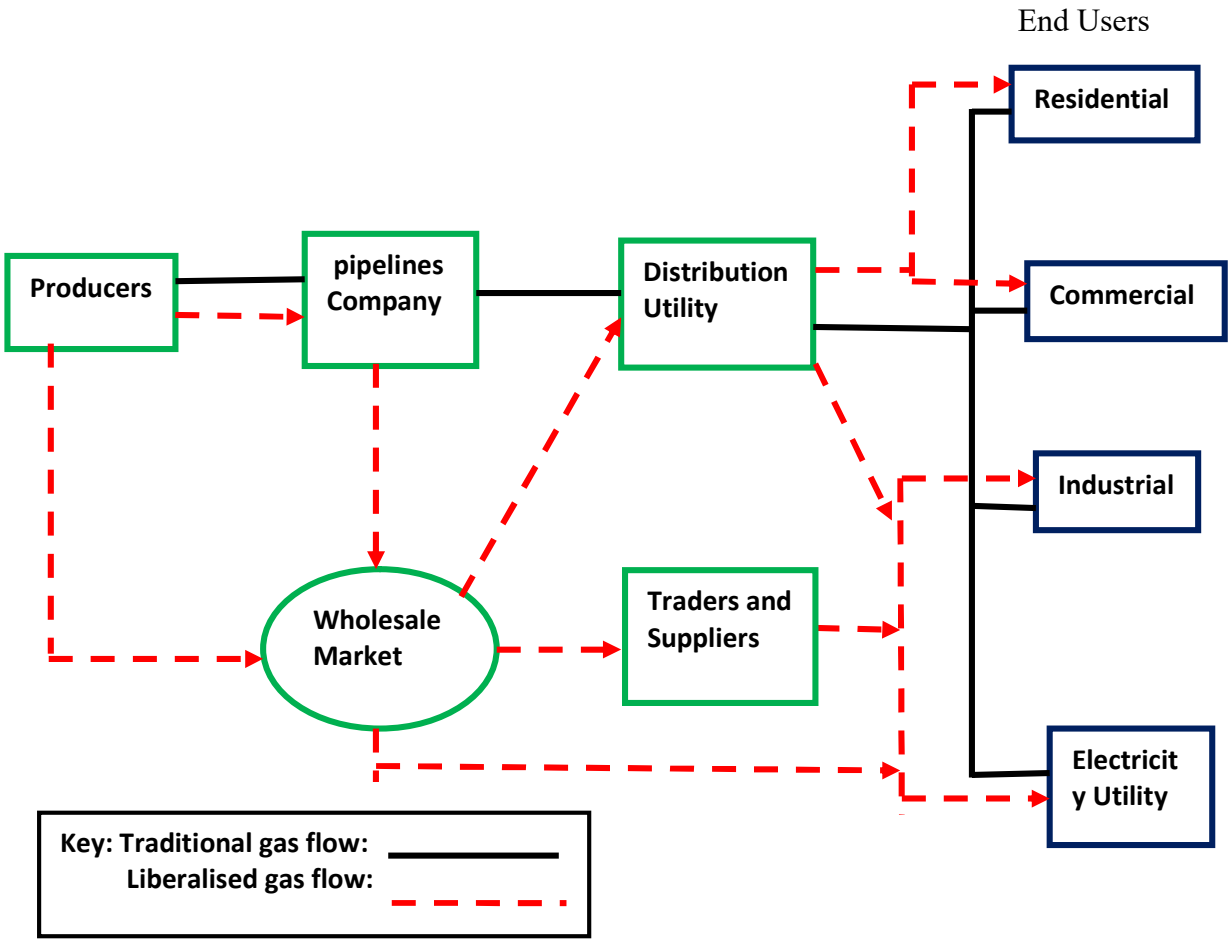

Figure 2.13: Gas flow under the traditional and liberalised markets

Source: Adapted from Juris (1998a).

The above figure shows gas flow in a traditional (monopolistic) value chain and a liberalised value chain. In the traditional system, the gas moves from the producers to the transmission pipelines usually owned by the producers to the distribution companies, and finally to the end users in a vertically integrated way. However, with liberalisation competition and new entrants in the form of wholesalers, suppliers and traders that can purchase gas directly from the producers and, from the pipeline company have been introduced into the market

2.7.1 Stages of development in gas market liberalisation

Stern and Rogers (2014) opined that, for national natural gas markets to evolve into a competitive one from the state public monopoly operations and privileges, it has to go through a dire process of liberalisation. To them, liberalisation is a long process of altering the structure of a regulated domestic market on a national scale into a competitive market. Before the recent evolution of liberalisation of the natural gas markets, the construction of natural gas transmission grids, as well as privileges to import gas were granted to monopoly enterprises that were already managing both transmission and wholesale activities thereby solidifying their power and restricting new entrants and competition in the gas value chain.

In a study conducted on the development of future EU gas markets by Estrada et al (1996), natural gas market liberalisation was described as a four-stage process of development in terms of the organizational structure. These stages as categorized have different significant features. These stages are:

i).Commencement stage;

ii). Growth stage;

iii). Development stage and;

iv). Maturity stage.

These four stages as prescribed by Estrada et'al (1996) above can be used as a framework to examine the process of liberalisation of the natural gas market in Nigeria, as it describes the role of state during these four stages of birth, growth, development, and maturity. It

vividly describes the public sector role during the commencement stage (birth) of the sector during the liberalisation process, through to the infrastructure and demand expansion at the growth stage, as well as the evaluation of the competitiveness of the wholesale market in the development stage displaying its different attributes. The model presumes a progressive development from a pre-existing monopoly to a developed, liberal and competitive gas industry with many suppliers, distributors and consumers. This competitive and liberal market can be achieved through: financially, by privatizing the operational assets; legally, by deregulation; and technically, through infrastructure expansion that induces increased consumption. This will necessitate the transition from long term to short term contracts that enables diversification of supply sources and market dynamic enhancement.

The four stages of the liberalisation process in natural gas markets as proposed by Estrada et al (1996) are described in table 2.14. It describes these stages of birth, growth, development, and maturity under the demand, infrastructure, and wholesale conditions.

Table 2.5: The Matrix of liberalisation process in natural gas markets

	Birth	Growth	Development	Maturity
Demand	- Low demand -Vertical integration -Long term Contracts - Pricing on cost-plus basis -Market conditions, tariffs & pricing are not transparent - Steady demand with a high volume from customers	- Exponential increases in demand - The use of Long-term contracts still exist - Due to different customer's profile, there is a need for flexibility -Market reports condition is provided	-Growth in demand declines -Short-term demand customers start to emerge in the market -Market set prices	- Demand and supply equilibrates - Market completely set prices --Tariffs are formulated transparently -Costumers choose their own supplier -Availability of transparent market data
Infrastructure	- The building of infrastructures is on project level - Monopoly control is low - There are significant economies of scale - Market spread limited geographically - Joint access is Limited	- An increasing number of projects - Transmission and distribution infrastructure expansion for more consumers access - Transmission system third-party policy allowed -Transmission system operator (TSO) monopoly still exists	- Transmission and secondary capacity market are active - High-level third party access to the transmission system - Transmission systems operators focus is on gas flow optimization and system balancing - Enhancement of transmission system infrastructure is crucial for market operation	-Establishment of a developed infrastructure -Developed storage facilities - Availability of trading hub - Accessible third-party access policy - Sophisticated network code is applied - Balance system operators/shippers due to higher penalties
Wholesale	- Few or no market participants - Monopoly control in place - Strict regulation in place - Wholesales market is possible only in theory - None availability of churn rate	- Increasing market participants present - Intensifying competition among market players - Elements of long term contracts still present - Pricing based on oil indexing - The wholesale market is limited - Churn rate available minimally	- Freedom of suppliers choice available to consumers - Dedicated market areas are delimited - Many market players are fully operational - Financial players have a high stake in the gas market - Indexation to other fuels is the basis for price formulation - Churn rate is increased considerably	- Supply chain unbundling - vertical, legally and financially - The number of market players increases substantially - Relatively low-profit margins - Churn rate considerably high -Fully liberalised prices - Availability of short-term contracts -Spot markets available - Ample market liquidity available - Sources of supply are chosen based on short term contracts by tenders

Source: Estrada (1996)

2.7.2 Experiences of other economies

In this section, we highlight natural gas market liberalisation is some selected countries such as Europe, the United States, and the United Kingdom, to find out how well and or otherwise the liberalisation policy performing, and especially, its impact on consumers. The choice of these countries as case studies is because the liberalisation policy has been introduced in these countries for a while.

2.7.2a Gas market liberalisation in the United States of America

The federal laws and status supplemented by state laws where applicable[23] principally govern natural resource conservation and energy policy fields in the United States of America. As a result, each state has its own separate energy agency/department responsible for its development. Natural gas exploration is within the jurisdiction of the state laws and policies which gives room for a high variety of exploration and production activity management. Once planning the land use has been determined, exploration and production activity management is based on competition and open access to available reserves, thereby creating an environment for new entrants into the sector to thrive and enhanced competition even among existing gas producers.

The last century marked the commencement of the natural gas industry in the United States of America with natural monopolies such as in gas transmission exempted from regulation. However, with the report of the Federal Trade Commission, which investigated the activities in the gas sector and reported a high level of abuse of market power and concentration at the exploration and production, as well as the transportation segments of the gas value chain, by vertically integrated companies in 1935, that regulation to curb these excesses was considered. This led to the enactment of The Natural Gas Act of 1938 which established the Federal Power Commission (FPC) to regulate inter-state gas pipeline, while intra-state pipelines were to be regulated by the state agencies. In the 1970s, there was an unprecedented increase in gas demand, as the price of gas remained low due to increased regulation, compared to the prices of alternative oil which rose

[23] Where the federal laws do not address the issues, state laws are used to supplement and clarify situations.

astronomically during that period. This increase in demand created supply shortages at the inter-state levels as the intra-state companies were buying gas from regulated markets. The inability of The Federal Power Commission (FPC) to handle the deteriorating qiotic situation led to the enactment of The Natural Gas Policy Act of 1978. This Act deregulated the wellhead prices for new gas contracts only, exempting existing contracts that were later deregulated by The Natural Gas Wellhead Decontrol Act of 1989. This Act also replaced the Federal Power Commission with The Federal Energy Regulatory Commission (FERC). However, the powers and function of the FERC and that of the FPC remained similar to a great extent (EC, 2009a).

The gas prices, which consistently remained below long term contract prices were however not beneficial to gas buyers since the existing contracts on take-or-pay bases at fixed prices for the supply of gas between vertically integrated gas supply companies and gas producers have locked them into their existing contracts. To remove this obstacle, all long term minimum obligations bill were repealed by Order 380 of The FERC in 1984. In 1985, FERC issued Order 436 which established the third party access to gas pipelines on a voluntary basis, at a regulated transportation tariffs bandwidth. This new regulation which brought about for the first time sole transportation service operation was widely patronized by most interstate pipeline operators even though it was voluntary. In 1992, FERC Oder 636 requiring fully divesting (separation) of storage and transportation services from sales services and offer these capacities (storage and transportation capacities) on an open access base by vertically integrated companies changed the voluntary third-party access and made it obligatory. The establishment of pooling areas and market centres to facilitate a 'common ground' where the gas demand side and supply side can meet, was promoted by FERC Order 636. These spots were aimed at creating market centres that will bring different pipeline operators together to create an inter-pipelines operator's market centres and encourage competition among different gas suppliers.

The establishment of polling centres where different gas suppliers could meet to aggregate their gas deliveries and where pipelines operators balancing could be done on such an

aggregated and pooled bases were demanded by FERC. This required pipelines operator to oblige gas shippers to receive and sell gas at any point in the system provided system constraint does not make deliveries impossible. The utilisation of metering technology by pipeline operators to accurately measure and monitor injections into the system on a timely basis was acknowledged by FERC, in that regard. The New York Mercantile Exchange (NYMEX) at that time commenced the establishment of a futures market on gas deliveries which provided value over time for stored gas. Similarly, motivated by the customer aggregation, portfolio optimization grew to be possible and this led to the appearance of gas entrepreneurs which presented their services of bundled products to customers. These services covered packages of gas procurement, pipeline management, and storage capacities as well as the delivery of gas to the city gate. There are about 29 distinctive buying and selling gas hubs in the United States and nine in Canada as of 2016.

A well-developed policy and regulatory framework, strong and transparent economic signals indicating the state of the market based upon the fundamentals of competition and open access, as well as experienced market participants' characterised. The United States gas markets. As a result of the liberalisation policy in the United States, residential customers can choose their gas suppliers via the 'customer choice' program. This, however, depends on the State, since not all the States have implemented full unbundling - unlike in Europe, where in most countries have implemented full unbundling and market opening. Distribution services are provided by the distribution companies. Also, the long term supply of gas depends primarily on the expectations of future demand and supply, the collective foresight of market participants, and the associated investment in infrastructures to deliver and balance gas supplies (EIA, 2010).

2.7.2b Gas market liberalisation in the United Kingdom

The gas market liberalisation took place in the United Kingdom long before its consideration at the European level. Hence it could be said that the experiences at the UK level served as a reference point for other European countries' gas markets. The history of the United Kingdom’s gas market, which started to develop in the early 1970s reveals

relatively early commencement of liberalisation with the passage of the Oil and Gas Enterprise Act of 1982 (Oxford Institute, 2010).

The UK implemented an open and transparent gas development regime for fields in the upstream sector, while the privatization program for nationalized industries in the late 1970s and 1980s, driven by the then Prime Minister Margaret Thatcher instigated gas market liberalisation in the midstream sector. The desire of this program by the then government was for the newly formed private companies to be self-sustaining and successfully fund their new investments and generate revenue to government through taxation for other governmental activities rather than liberalisation. Before this program, a public utility company - the British Gas Corporation (BGC), has the full and sole rights to buy all produced gas (monopsony) and supply the same to all customers in and around Britain (monopolistic rights). With this exclusive position, the British Gas Corporation negotiated to field specific prices for their supply at the upstream and sell the same at regulated prices, based on an average cost, plus costs of transportation and distribution approach. (Radetzki, M., 1999).

The opening up of the upstream segment of the gas value chain by the Oil and Gas Enterprise Act of 1982 can be regarded as the first step towards liberalisation of the UK gas market. Competition nevertheless remained low because the midstream remained regulated. This condition changed with the privatization of the British Gas Corporation in 1986, leading to the creation of a vertically integrated British Gas PLC (BG PLC). The Gas Act also introduced the third party access policy and made it mandatory at the midstream segment of the gas value chain. This opened up the market for direct participation in large gas customers (consumers of over 25,000 therms {1 therm = 29.3 kWh}). Also, the Office of Gas Supply (Ofgas), - a regulator, to supervise non-discriminatory access, was established by the Act. The gradual market opening that necessitated competition and suppliers' choice by end user-customers was finally decided by the Gas Amendment Act of 1995 which categorized consumers based on the volume of consumption and granted them eligibility rights to switch suppliers based on these categorisations (Simmons, G. 2000; Cameron, P. D. 2002).

The liberalisation policy in the United Kingdom can be said to be highly effective as it has led to the efficient market allocation and also served as a reference point for the European Union liberalisation policy; customer switching is above 50%; a functional spot market (The British Balancing Point - BP) where gas is traded amongst other benefits.

2.7.2c Gas market liberalisation in Europe

The principles of internal markets, where competition in all sectors thrives in an area devoid of internal frontiers and characterized by the free movement of persons, capital, goods, and services, formed the underlying philosophies that established the European Union (IEA, 2012). On the energy fonts, the issuance of 'The Internal Energy Market' document in 1988 by the European Commission (EC), (now European Union {EU}) as the bases for further debate on Energy matters, could be said to have marked the commencement of the liberalisation and market integration process among member states (EC, 1988). The growing concerns about the competitiveness of products from European industries in a globalising market gave rise to the consideration of how to make its energy sector competitive and efficient since energy is a critical input in the production process. The directives of the EU on energy matters have, first to be transposed into national legislation by member countries, adapting it to its peculiarities for ease of implementation. To date, the EU has proposed several of such directives in a bid to facilitate gas market opening among its member states. For instance, directive 94/22/EEC which defines a set of common rules to ensure non-discriminatory access to the activities of prospection, exploration and production of gas and aimed at greater competition and enhanced security of supply in the EU, opened up the exploration and production of natural gas at the upstream segment from 1994 onwards (EC, 1994). In addition to the EU laws, there are also Regulations, which are directly applicable to market participants and enforceable among member states.

The recommendation of the 'Madrid Forum' - a stake holder's forum, formed in 1999, contributed to the adoption of the second directive on gas in 2003 (EC, 2003) and of Regulation 1775/2005 in 2005 (EC, 2005),to further strengthen the market opening process of the natural gas sector. These measures resolved the issues of capacity allocation

between member states, congestion management, and services balancing, with better coordination. The directive mandated the establishment of regulatory authorities in all member states and introduced legal unbundling. It also further improved third-party access requirements. With these changing gas market dynamics, nine out of the fifteen member states were already planning for full market liberalisation by 2008, indicating a high level of acceptance among member states.

'The third package' – the third legislative package on market opening, requiring all member states to domesticate it into their national laws by March 2011, was aimed at further improvement in the quality of effective regulatory oversight, and equally on third-party access between member states. This strengthened the independence of regulators from public or private interests and decided that the least a form of unbundling, legal and functional unbundling, was not effective in attaining the desired target of non-discrimination. On the contrary, it believed that 'ownership unbundling' is the most effective tool by which investments in infrastructure in a non-discriminatory way will be promoted to guarantee fair access to the network for new entrants and transparency in the market. The Directive also allowed for two other forms of unbundling (structural and financial unbundling), the creation of an independent transmission operator (ITO), and the independent system operator (ISO), and allowed the choice of at least one of these unbundling models to be implemented in the hands of member states. To further strengthen security of supply, the directive mandated the introduction of supply obligations on gas producing companies; minimum supply and infrastructure standards; bilateral agreements between member states and greater reporting and information exchange on long term contracts with gas importers and intergovernmental agreements, thereby placing security of supply within the market integration amongst EU member states, to ensure that trade and supply continues uninterrupted even under exceptional emergency conditions (Cameron, P. D. 2002; Cavaliere, A. 2007; EC, 2009a).

Although the primary objective of these Directives was the development of a single European gas market, the extent of market openness across member states differs substantially. Specifically, countries like the United Kingdom, Germany and Finland can

be said to be pioneers in the liberalisation process have pursued strategies that aimed at unbundling activities in the supply market segments and the full domestication of these EU Directives into national legislation have a higher degree of market openings than others. Other countries like France, Denmark, Greece, Luxembourg, Belgium, Spain, and Italy have opted for a gradual market opening leading to market liberalisation. While countries like Latvia and the Czech Republic are still lingering at the initial restructuring stage.

2.7.2d The Lessons to be learned from the experiences of other economies

Nigeria is unlike any of the markets mentioned above in terms of gas resource availability, as most of the countries are not self-sufficient and rely on importation to meet the domestic requirement, consequently, no experience can be applied directly without adapting it locally. Stakeholders in Nigeria can nevertheless draw lessons from experience gained in some ways from the markets discussed above. One critical factor that should be taken into account if the lessons are applicable is the stage of market development and maturity when they started liberalisation in contrast to that in which Nigeria now stands. Despite the underdeveloped stage of its domestic market and its increasing interactions with international gas markets through exports, Nigeria's domestic gas market is nonetheless at a noticeably early stage. Most aspects such as legal and regulatory policies, the development of domestic gas infrastructure, and the building of long-distance pipelines across the country, is beginning to emerge. A high-pressure transmission network for a long distance is still relatively low and still being developed to transport gas from gas producing regions to gas markets. The number of gas consumers in the domestic markets is relatively low, though with power sector reform in Nigeria, the tide has shifted with the power generating sector driving the growth in domestic demand.

The above case study reveals that most of the countries have a well developed natural gas sector for more than a decade before deciding to liberalise the sector. The most outstanding is the United States of America that commenced the liberalisation process in 1978 after several decades of gas sector development with complete or near full amortization of investments in gas infrastructure. As for European countries, most of them

commenced the liberalisation policy in the late 1990s with the existing functional gas transmission, storage, and distribution system efficiently serving a substantial commercial and residential customers that are still growing at a more modest pace over the past decades. From the above review, it can also be learned that liberalisation policy takes time and regular monitoring and 'fine-tuning' if the aim is to be achieved. This is contrary to the Nigerian Gas Master Plan (NGMP 2008), which sets to achieve liberalisation in one policy document over a short span of five years.

It is also worthy of mention that most European countries have seen a more modest growth of their domestic gas consumption since the commencement of liberalisation policy. For instance, while gas consumption in The United Kingdom increased by about 80 percent between 1986 to 2000 period, that of OECD Europe, such as Spain and Turkey only increased by 20 percent over the 2000 - 2010 period, while its market was liberalised. Nigerian domestic gas consumption is expected to reach 250 Bcm by the year 2020 according to NNPC's forecasts. In Nigeria, achieving gas consumption on supply-driven policy is believed will help provide needed incentives to attract investors to develop the domestic market, hence the option of liberalisation. However, over the next few years, the price of gas is expected to increase with this policy, the affordability of gas in key sectors such as the power generation sector will have to be addressed.

2.8 The third party access (TPA) to natural gas infrastructures

The transmission aspect of the natural gas sector is regarded as a natural monopoly due to the huge initial investment (sunk cost), social, and environmental issues involved. Hence it is believed to be economically unviable for multiple transmission pipelines to traverse along the same route. But natural gas has to be wheeled from the wellhead to the end user. Therefore, the constraints of the 'duopolistic' gas market are quite obvious. Each gas company renders, through privately owned and operated pipeline (facilities) services to their various customers. The facility company may be the sole operator in some city-gates with very limited competition. This is much different from “gas-to-gas competition” in a liberalised market where third party access to gas infrastructures is obligatory and competition exit between potential gas suppliers at every city-gate. Third party access can

be quite different depending on the institutional arrangement of the gas market, but in general, it refers to the regulatory arrangement that gas infrastructure (facility) owner is mandated to carry gas for third parties (traders or shippers). It means, the property right over the gas infrastructure (facility) does not guarantee the owner the right to use the infrastructure for just regarding the company's profit. When third party access is not guaranteed, players may act strategically and prevent efficient supply.[24]

Third party access to gas infrastructures implies that an infrastructure company is mandated to allow any gas seller or buyer access to its gas infrastructures, provided there is available capacity at a reasonable tariff. Any two parties concerned in moving natural gas from point A to point B should be allowed to use gas infrastructures that happen to facilitate these two points even if it is owned by yet another party. The expected outcomes would also appear to be clear: competition must increase; the ability of the pipeline company to limit the flow of gas and to maintain high tariffs would become less; the entire provision of gas should increase, and the cost of gas, and not just the transportation tariff (which establish in most cases a high ratio of the final price), should come down (Hannesson. R., 1998).

Specifically, the lack of third party access policy in the natural gas market is associated with two basic problems. First is the problem of guaranteeing efficient gas supplies in the downstream segment. Access restrictions set a barrier to free entry and hence preclude cheaper gas from exerting its cost advantage in the market. Second, it can serve as a hindrance to emerging competitors since they have to build their pipelines and/or facilities before they can operate in the market. Hence, consumers envisaged benefits due to enhanced competition and increased output from new entrants will be lost if fair access to the existing gas infrastructures is lacking, and will not benefit from enhancing competition if gas produced by private firms has no fair access to the existing infrastructures. Also in the LNG market, the surge of spot LNG markets worldwide that are currently improving availability, supply security and competition would yield no result if there is no third party

[24] Worthy of mention here is the importance of having formal rules and regulations that are strictly enforced to guarantee access to third parties. Instances abound where formally legalizing TPA without strict enforcement yielded little or no desired results. See European Commission (2007).

access policy that allows access to the LNG terminal, storage facilities and pipelines of private LNG operators.

Third party access has been introduced in the United States, the United Kingdom, and some European countries, and has had a profound impact on the natural gas market in these countries. The gas oversupply of the early 1980s popularly referred to as the period of gas bubble preceded the introduction of third party access in the United States of America. With the introduction of third-party policy which led to the deregulation of the wellhead prices in addition to the uncompetitiveness of natural gas to alternative fuel, especially crude oil whose price was sliding, some pipeline companies was stuck with gas, which they had to purchase due to the take-or-pay contract terms of the sector which they could not sell. The third party policy brought relief to some of these pipeline companies as their obligation was reduced to transporting purchased gas for buyers who directly purchased their gas from the producers. Most pipeline applied to the Federal Energy Commission (FEC) for the rights to be granted in the open access status - an indication of its wild acceptability by pipeline companies. In the United States, most big pipeline companies have enrolled and have been granted open access status (DeVany and Walls, 1995). Also, the former customers of these pipeline companies that now hold open access status have rights to transport capacity for which they pay only a tariff based on the actual quantity transferred. On a monthly basis, capacity rights holders are required to declare the amount of capacity they intend to use in the coming month. This capacity right can also be transferred to third parties temporarily, leaving the unused capacity for hire in the sports market. Spot markets of gas also developed in the wake of third party access, and since 1990 there has been a futures market of natural gas on the New York Mercantile Exchange (see DeVany and Walls, 1995). The operation of the third party access policy in the United States does not include the local distribution companies; gas must be bought at the "city gate," except for large industrial buyers, some of whom are in a position to buy directly from the trunk lines.

In the United Kingdom, third-party access became operational with the 1986 introduction of the Gas Act, which privatized BGC, leading to the formation of the vertically-integrated

British Gas (BG) PLC. Before this time, third-party buyers in the midstream sector were subject to negotiated access for third parties which hindered the efficient gas market operation. The Act introduced obligatory third-party access to the midstream sector and opened the market for large consumers (consuming over 25 000 therms [1 therm = 29.3 kWh]). At the same time, the Act created a regulator to supervise non-discriminatory access, the Office of Gas Supply (Ofgas).

In Europe, third-party access was the main focus of the third gas directive issued in 2009. This Directive which required all member states of the EU to domesticate it into their national law by March 2011 was aimed at promoting effective regulatory oversight between member states and equally improving third-party access. The directive made provision for the creation of an independent transmission operator (ITO), and the independent system operator (ISO), and allowed the choice of at least one of these unbundling models to be implemented in the hands of member states (EC, 2009a).

There are several models, to permit third party access to natural monopolistic facilities, namely: operational separation, access regulation, and ownership separation. Access regulation is the initial stage of regulatory reform. The incumbents may be allowed to keep on integrating both supply and transmission business. However, either it should open up the transmission and storage facilities for third parties based on the regulation requirement (regulated access) or mutual negotiation (negotiated access), (see Glachant et al., 1998).

2.9. Nigerian domestic natural gas market opportunities

Opportunities for natural gas utilisation domestically in Nigeria are varied. These opportunities abound in the power generation, petrochemical, fertilizer, iron, and steel, cement, and aluminum smelting industries amongst others as well as distribution to industrial centres as a source of energy supply. Currently, the single largest natural gas consumer in Nigeria is the power generation companies (Genco's) which accounts for about 80 percent of domestically consumed natural gas. With the ongoing aggressive

power sector reform more natural gas will be required from the 270mmcf/d in 1999 to about 4900mmcf/d by 2015. (Ukpohor, 2013).

The demand increase in the cement industry is typically restricted by way of the local manufacturing functionality and potential utilisation rates. Non-gas fired cement is no longer price competitive due to the fact this relies on relatively expensive, often unreliable alternative fuel supplies. In the base case, the needs of the cement industry have been estimated to be about 350mmcf/d by 2015. This will be met through a mixture of the plant expansion, grassroots capacity addition and conversion of liquid-fuelled Kilns to the more efficient, gasoline-fired Kilns. The foremost gas client in cement manufacturing in Nigeria is the West African Portland Cement Company, and Dangote Cement Company. Other cement producing companies (Ashaka Cement, Benue Cement, Cement Company of Northern Nigeria Sokoto, etc.) have not yet availed themselves, the use of natural gas as a supply of energy to power their equipment and fire their Kilns notwithstanding the relative cheapness of gas over other sources of energy. This is due to the lack of a natural gas grid, which needs to have delivered gas nearer the plant location for ease of accessibility (Yar'adua, 2007; Ige, 2013).[25]

The suspension of operations at the Ajaokuta and Aladja iron and steel plants has reduced the gas consumption of these plants to near zero, despite the availability of gas infrastructures in these plants for such a long time, thereby heightening the abysmal situation in the iron and steel sector of the Nigerian economy. In the fertilizer and petrochemical industry, opportunities for considerable expansion of fertilizer production above the present level abound. Gas is a major feedstock of the petrochemical industry the demand, therefore, increases in direct proportion to production. Output opportunity exists for the development of gas supply to small industrial layouts and residential customers save for the infrastructural cost to deliver gas to these exceptionally high areas. Currently, gas link, shell Nigerian gas and gas land operate in this market. Nigeria has a large liquefied petroleum gas (LPG) market potential with demand growing from the current

[25] There are several other ways other than pipelines (National grid) that gas can be delivered to these companies, such as through CNG trucks, LNG trucks, Virtual pipelines, etc., but at a much higher cost than the pipelines, hence their use of alternatives.

level of about 2mta to about 10mpta given the necessary infrastructure. Compressed Natural Gas (CNG) constitutes a veritable supply of fuel in the vehicle transportation sector, which can positively grow the consumption of gas domestically. It has the advantages of being less expensive and environmentally friendlier than other alternative fuel. However, the technological know-how is pretty new and most vehicles in Nigeria are not designed to use CNG coupled with the non-availability of refuelling infrastructure. Currently, the Escravos to Lagos pipeline system (ELPS) constructed in the nineties is the major transmission pipeline system dedicated to domestic consumption as well as industrial and utility sectors in the South Western part of the country. Additionally, It also serves as the entry point of supply to the West Africa Gas pipelines. The other major downstream pipeline systems are dedicated to single projects leading to suboptimal pipeline configurations. These pipelines are by and large for export-oriented projects and cover areas already served by other different single project pipelines. There are no pipelines connection between the gas supply fields in the South-South and the Eastern part of the country, and the developing market for gas in the Western and Northern parts of the country.

From the preceding, it can be seen that Nigerian domestic natural gas market is highly characterized by poor gas infrastructure with no inter-connectedness and limited access, lack of real wholesale market, lack of market maturity, large domestic production but lacks supply in the domestic market due to price and infrastructure constraints. The Nigerian Gas Master plan was formerly advanced to concurrently develop the domestic, regional, and export market, thereby addressing these imbalances in the gas sector, through natural gas market liberalisation. The competence of the master plan to reach this goal sufficiently and reliably forms the crux of this study. The proposed commercial framework of the natural gas domestic market in Nigeria is shown in figure 2.15. The diagram shows that produced gas can pass through the Nigeria gas company (formal monopoly), or through wholesale licensed suppliers, or even directly to the end users (gas-based industries, power, commercial), a departure from the old traditional system of producer - NGC - end users.

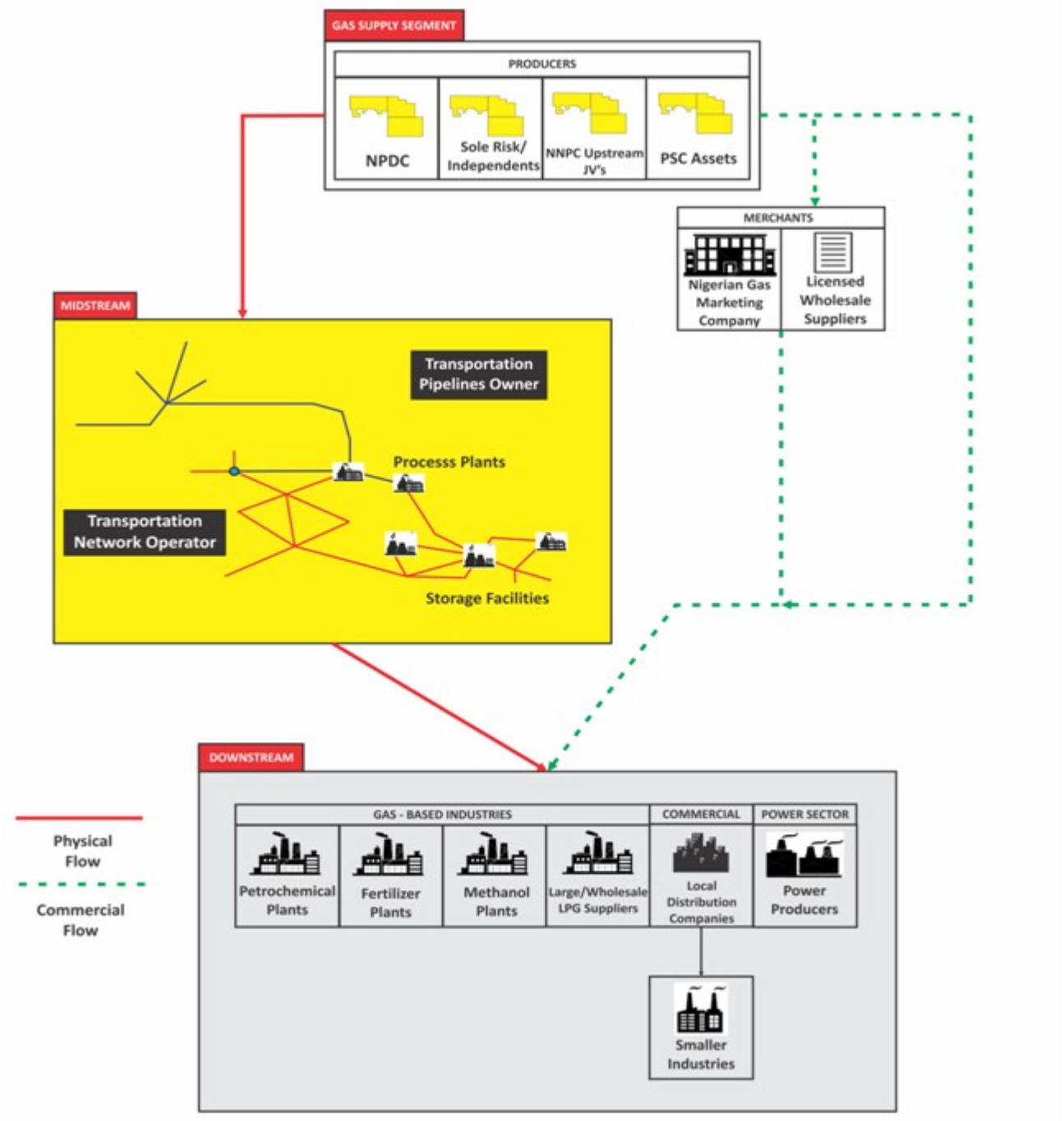

Figure 2.14: Proposed commercial structure for the Nigerian natural gas sector.

Source: National Gas Policy (2017)

CHAPTER THREE
LITERATURE REVIEW

3.0 Preamble

Theoretically, natural gas markets are broadly categorized into deregulated, regulated, or commercialized, as the case may be. Deregulated markets are governed by the forces of demand and supply, and their pricing regime follows market dynamics. Markets that emphasize strict regulation or state monopoly, have fixed pricing regimes and supply are usually capped in tandem with government investment resource capacity, irrespective of demand dynamics. Commercialized markets combine the two in various degrees, but are mainly focused on ensuring profitability and perhaps efficiency within a government regulatory framework.

This section presents a review of the theoretical, empirical and methodological literature on natural gas market liberalisation as well as its implications for the economy. It is made up of three major sections: The first part examines the theoretical aspect; the second part examines the empirical studies, while the third part, reports the methodological reviews for this study. The literature gap is identified at the end of each section.

3.1 Theoretical Review

Stigler (1971), in his theory of Economic Regulations, views regulation as a necessity for industries, as it is specifically designed and operated for its benefits. To him, for industries to operate sufficiently, especially those that are saddled with the responsibility of providing a public good, there is the need for their operations to be regulated as put forward by the theory of public interest. On the other hand, critics of this theory believe that regulations are the results of the political process which neither aims at the majority of society nor has any rational intentions. Hence a wide-ranging assumption that every occupation or industry that has the substantial political power to control state affairs will seek to be in command of entry into the market. Hence, regulation can be seen as producers' protection which imposes the domination of a

small group with a large per capital stake over the larger consumer group with more diffused interest (Pelzman, 1976). This theory, as put forward by Stigler difficult to reconcile with scenarios where regulations act following public interest rather than the preference of few organized economic interests.

Pelzman, (1976), elaborating a more general theory of regulation posits that a rational regulation should be aimed at maximizing its utility function and hence seeks a structure that maximizes returns on his investment based on costs and benefits on investment rather than limiting its operations to a small group of economic interests. Hence, regulation rather than being a tool for producers protection is a more complex exercise. In economics generally, the focus is not the consumer desire and why, but on the quantity of the goods they are willing to purchase from the market, hence considering his preference as given and exogenously determined.

The natural gas sector exhibits features and attributes that enable it to be classified as a public good and a natural monopoly (see Glanchant and Finon, 2000; Wiliamson, 2000 2002). In order to realize scope economics as a way that maximizes the benefits of a natural monopoly, there was the consideration, in order to realize scope economics and achieve optimal gas market structure, that companies in the gas value chain of production or importation, transmission, distribution, storage, wholesale, and retail supply be vertically integrated. This necessitated the consideration of gas companies as an integral part of the state-owned public enterprise which is specifically regulated. However, due to the abysmal performance of public network utilities as a result of stagnant competition, there was a shift in opinions among academics as doubts arose on the suitability or otherwise of the theoretical explanations of natural monopoly and scope economies.

The need for this market structure to be overhauled gradually began to gain recognition (Merjstrk, 2004). With this paradigm shift and its acceptance, there was the need to change the market structure, forms of corporate ownership, and also the legal framework to make the mechanism of competition operational (Glanchant J M,, 2003). To accomplish this, considerations were given to the establishment of a legal framework that will end the monopoly and commercialize supply activities, in addition to breaking the barriers in gas trade between markets, as well as the enforcement of

third party access to gas infrastructures (Glanchant and Finon, 2004). As the paradigm shifts towards liberalisation, the focus was placed on regulatory institutions and the quality of rules and enforcement capacity emanating thereof (Armstrong et' al, 1994; Newbery, 1999).

The Vertically integrated Utility (VIU) model of natural monopoly which was hitherto the structure of the natural gas sector was to a great extent an impediment to the clear-cut attainment of liberalisation. The separation of natural monopolistic activities related to gas infrastructure as well as activities potentially exposable to competition (commercial activities) such as production, wholesale and retail supply was a source of controversy. Economists tend to confer on the positive impact of competition and the negative effects of regulation; however, both concepts indicate arguably that the persistent unbundling of commercial activities from its monopolistic structure, thereby replacing regulation with the competition will bring about efficiency in its operations (Mejstrik, 2004). Contrary to this argument of efficiency is the fact of loss of synergy that the unbundling will bring about on the VIUs. The superiority of this argument will be determined by the benefits accruing to the introduction of competition against the demerits that will ensue due to the loss of synergy. (See Limi, 2003; Bjoerkroth, Groenblom and Willner, 2006).

Glachant and Finon (2004), noted that the divergence economist's opinion on liberalisation is driven by two contemporaneous market theories. These are, first, the virtual competition model propounded by the contestable market theory and secondly, the theory of the standard market. The contestable market theory, propounded by Baumol, Panza and Willig (1982), A market is said to be ‘contestable’ when there are no market entry and/or exit barriers in the form of an economic nature, such as training and know-how costs, high infrastructure sunk costs, as well as other costs that cannot be easily recovered in the short run, or of legal nature such as exclusive rights and concessions. The theory believes that the jurisdictional and technical conditions, rather than the structural conditions, necessitate a credible, competitive threat and virtual competition. With entry barriers in place, potential competitors do not influence the behaviour of incumbents, as they can seize the opportunities of their advantageous position. When such barriers do not exist, potential competition from new entrants has

had the effect of de facto regulating the market as they bring the incumbent(s) into line.

The intervention of public authorities is therefore needed to re-establish contestable market conditions to make the threat of new entrants more likely. Suppressing technical and legal barriers to entry could be a better approach to achieving the goal of the competition. Effective resource allocation can also be achieved through a credible threat of entry exerted by foreign competitors that are incumbents in the adjacent national markets. In other words, industrial structures - and vertical integration of import/production/wholesale and retail supply and horizontal concentration – might be preserved if access to the grid on non-discriminatory biases is guaranteed to the incumbents' potential competitors with a complete unbundling of the networks.

The standard market theory, on the other hand, considers competition at different levels of the natural gas value chain, the number of players that are involved, and then determines the efficiency of the markets through the players' conduct. This suggests that industrial structures, especially those involving commercial activities should be horizontally disintegrated among considerable market participants as the organization of the various activities between different parts along the value chain, will limit the exercise of market power by incumbents. This suggests a clear disintegration of the Transmission System Operation (TSO) from commercial activities. Also, vertical integration between production/wholesale supply and retail supply under a hierarchical structure must be drastically reduced to minimize entry barriers, hence network unbundling is advocated.

Economists believe that as long as the tenets of perfect competition are considered inappropriate to the gas industry due to its natural monopoly characteristics, liberalising the sector would amount to the mere enhancement of public monopoly to a welfare maximizing industry (Willner, 2003; Bjoerkroth, Groenblom, and Willner, 2006). Liberalisation which precedes competition is expected to improve the industry's operation as they make more efforts to shape their competitive edge through efficient allocation of their resources which will cost and price reduction and maximization of consumers' welfare. Liberalising the natural gas industry can be carried out by deepening horizontal integration or by market consolidation, either, of which will

result in the reassignment of strategic decision-making to a small group of large firms resulting in higher prices. This will require more regulation to enhance market opening and provide a level playing ground for both new entrants and the incumbents. In summary, therefore, the tide tends to favour open markets and competition for its perceived efficient resource allocation, lower prices, which will benefit energy-intensive industries and also ensure end-user welfare maximization.

The theory of transaction costs further explains that the structure of the industry has a huge effect on the transaction cost of its economic activities. For instance, assume that economic activity can either be internally carried out within an organization or externally within the market, the choice to be preferred should be the one that minimizes the transaction costs (least cost option). These (transaction) costs include costs associated with negotiations, information, research, contracts conclusions, and the uncertainty in transactions' suitable conclusion. Depending on the transaction cost due to the structure of the industry and the activity in question, vertical integration in most cases is preferred. This is most noticeable when the activity involved cannot be reassigned to another client without an additional cost.

3.2 Methodological Review

In this section, we examine the various models adopted to consider the energy – market liberalisation – economy interactions which have revolved around different development in the global energy market structure.

Recently, due to global energy industry restructuring, analysts have shifted interest in assessing and investigating the impact of these reforms on macroeconomic performance. Also with the computational advancement in the field of applied economics, different empirical models for energy policy analysis subsist. Consequently, different views have been proposed in the economic literature on the classification of energy models (see Bhattacharyya, 1996; Bergman and Lundgren, 1990). Most of these models have been categorized based on some factors such as the model structure, sectoral coverage, analytical approach, and time horizon. The various models that have been used for energy-economy interactions include Single Equation

models; Input-Output models; Partial Equilibrium models; Macro-Econometric models; Computable General Equilibrium models.

The single equation model is the oldest and still, the most commonly used equation to evaluate the direct impact of changes in energy consumption in terms of regression analysis using the ordinary least squares (OLS). Single equation models may be applied to panel, time-series, or cross-section data depending on the objectives. It is simple to use, its interpretation is straightforward and its data requirements are some of the advantages of this model. However, single equation models do not determine the reason for the changes in the model. As a result, it cannot best explain the effects of liberalisation of natural gas markets on the Nigerian economy, hence the need for a more robust tool.

The input-output model is a quantitative economic technique that represents the interdependence between different branches of a national economy (Miller and Blair, 1985). Wassily Leontief is credited with developing this model in the late 1930s and which was based on a system of linear equations that represent the distribution of an industry's product throughout the economy. It shows the nature of interdependency among sectors in the economy both as input suppliers and as output consumers. (Leontief, 1941; Miller and Blair, 1985). The inherent shortcoming of this model is that it assumes the employment of an infinite amount of inputs at constant prices; also the production methods remain constant from year to year. This, in real terms, does not hold (see McDonald, 2002).

The Partial Equilibrium model analysis mainly estimates the impact that directly results from a given policy action in the market(s). The partial equilibrium models are beneficial due to the minimal data requirement. For example, it allows the study of the effects of the liberalisation of LPG imports in Nigeria, a level of aggregation that is neither convenient nor possible in the framework of a general equilibrium model. This model is mainly suited to study industry-specific reforms (see Iwayemi, 1994). The main flaw of the partial equilibrium model is their inability to capture spillovers to other sectors, given their assumption that the sector under study is very small and has only little impact on the rest of the economy.

Macroeconomic models are based on the system of national accounts, which are used to study the impact of a wide range of policy measures. It may be logical, mathematical, and/or computational. It ensures a coherent framework for analysing inter-linkages between variables' sector. Macroeconomic models may also be used to test, compare and quantify different macroeconomic theories to produce ‘what if scenarios' that are used to generate economic forecasts. While the model seems to overcome the shortcomings of partial equilibrium, its inability to capture long-run phenomena, as the equation on which they are based are linked to a given period, is a major weakness of the model. This model is better suited for the ex-post analysis of past energy reforms than the ex-ante analysis of future energy reform (see McDonald, 2002) Since this study is on ex-ante analysis of future energy reform, this model becomes unsuitable.

Computable General Equilibrium (CGE) models are a class of economic models that make use of actual economic data to calculate approximately how an economy might react to changes in policy, technology, or other external factors. It is based on the optimizing behaviour of economic agents. They are heavily built on the macroeconomic theoretical coherence of allowing various spillovers and feedback mechanisms between the market and the economy. The CGE models involve a complex interactions between outcomes and settings of policies that are guided by economic theory described within a well-defined framework, designed to capture both the indirect and direct impact of changes in policy on economic activity.

The CGE model is suitable because it can provide a much-disaggregated view of the economy. This makes a bulk of the sectors to be distinguished, where spillovers and feedbacks between the various sectors are considered. Also, the macroeconomic level of the model is based on the optimizing behaviour of the government, firms, and households, and the resulting macroeconomic outcome is coherent with its foundation because of the social accounting matrix (SAM). These made this model most suitable for studying the long-run impact of crucial policies such as market liberalisation of the economy.

3.2.1. A general equilibrium modelling approach

The difficulty experienced in accounting for the general equilibrium consequences of market liberalisation as well as identifying the transmission mechanism in other empirical methods suggests that a counterfactual analysis within a general equilibrium framework provides an ideal experimental stage. General equilibrium models are economy-wide models that have strong theoretical underpinnings. Following the first general equilibrium model for a developing country by Adelman and Robinson (1978) for Korea and Lysy and Taylor (1980) for Brazil, significant advances have been made to general equilibrium models. The literature is rich in alternative formulations of general equilibrium models some of which have been applied in Nigeria.[26] Among the general equilibrium model that has been developed so far,[27] CGE models remain the most widely used.[28]

CGE models are multi-sector models that provide a macroeconomic general equilibrium link among different activity sectors, economic agents, and external relations.[29]Unlike the methods employed within the partial equilibrium framework, these models incorporate a set of behavioural equations describing the economic behaviour of the agents identified in the model, and the technological and institutional constraints facing them. As a result, they have the advantage of responding to shocks, while fulfilling the optimality conditions of agents' behaviour, technological feasibility, and resource constraint. This subsection presents the variants of CGE models that have been applied in modelling the impact of market liberalisation.

3.2.1a. Static versus dynamic CGE models

Broadly, CGE models can be described as either dynamic or static. Static CGE models consider counterfactual equilibrium analysis based on the comparison of the base year values with changes brought about by the impact of a shock. Some of the static CGE models which have been employed in the study of policy impact include the 123-PRSP

[26] See Adenikinju and AERC (2009) for a survey of the types and variants of CGE models including theoretical developments in CGE modeling and a survey of CGE models applied in Nigeria.
[27] See Essama-Nssah (2005) for a detailed review of some of the modeling approaches used in macroeconomic shocks and policies impact evaluation; and World Bank (2003) for summary information on series of available tools and methods.
[28] Bandra (1991) provides a pretty comprehensive review of CGE models applied to less developed countries.
[29] For definitions of CGE models see Dixon *et al.*, (1992), and Dixon (2006) for distinguishing characteristics of CGE models.

model,[30] Poverty Analysis Macroeconomic Simulator 1 (PAMS I) (Pereira, A.M. and Shoven, J.B., 1988); PAMS II (Essama-Nssah, 2006), as well as other standard CGE models developed by institutions such as the International Food Research Institute (IFPRI), and Partnership for Economic Policy (PEP) network.

The "123-PRSP Model" in Devarajan et al (2002b)[31] simplifies the CGE framework into an aggregate distinction of tradable and non-tradable goods. The model generates a set of sector-specific profits, relative prices and wages that are mutually consistent for a given set of policies.

Another simulation framework analogous to the 123-PRSP is the PAMS. Its design contains three layers: the macroeconomic layer; meso level, based on the idea that each policy impact affects the households, the market (firms), and the government; and the microlayer which deals with household-level information linked to the meso framework. To compute the household effect, the per capita income or expenditure of the household is multiplied by the induced growth rate of the disposable income of the representative group to which the household belongs. A later modification – a reduced form version of PAMS (PAMSII) derives the poverty outcome of shocks by linking recursively an appropriate disaggregated CGE model with poverty and inequality estimator built upon a parameterization of the Lorenz curve (Essama-Nassah, 2006).

Although the various methods can be differentiated by the level of sophistication and information retained in either the macroeconomic or microeconomic component, there still exist some shortcomings. It has been argued that static CGE models contained an analytical inconsistency. Being comparative static, the model does not take into account the adjustment path implied in each scenario nor the associated costs of adjustment. The implication is that the same producer and consumer who optimised their within period decisions, such as allocating expenditures among commodities, stopped optimising when it came to between-period decisions, such as savings and investment (see Devarajan et al 2002b).

[30] This describes a single country with two sectors, and three commodities, this was built into the macroeconomic framework for Poverty Reduction Strategy Study (see Davarajanet'al. , 2003).
[31] See also Daza *et al.,* (2004).

This limitation motivated the development of dynamic CGE models which accounts for the time path of adjustment to shocks or proposed policy changes (based on the premise that some shocks or policy changes require adjustment-time) (Adenikinu and Chitiga, 2009; Annabi et al, 2008). Two approaches – the recursive and intertemporal dynamic CGE models, have been employed in CGE models to capture the time path of adjustment resulting from shocks.

3.2.1b. Recursive – and - intertemporal – dynamic CGE models

Dynamic CGE models can be categorized into sequential dynamic (recursive), and truly dynamic (intertemporal) models (Annabi et al, 2008). The basic distinction between the two is in their treatment of the "dynamics" which draws from the assumption made about the behaviour of economic agents about their foresight. Truly dynamic models assume that economic agents are characterized by perfect foresight (an assumption that has been contested in the literature, especially in the context of developing countries where imperfect information is commonplace; see Cockburn et al, 2010). On the other hand, sequential dynamic CGE models which are a series of static CGE models with a limited number of recursive links from one period to another assumes that economic agents are myopic (Cockburn et al, 2010; Cogneau and Robillard, 2007). This latter approach is, thus, widely used because of its practicability and appropriateness for analysis within the context of developing countries.

There has been a growing development in the application of both standard recursive-dynamic CGE models (see for instance, Lofgren *et al.*, 2013; Annabi, *et al.*, 2008; Decaluwe *et al.*, 2013 – a modified version of 2010), and intertemporal CGE models such as the 123t model (a truly dynamic version of the 123PRSP static model) to the study of a wide range of macro shocks and policy issues.[32] However, irrespective of the type of the CGE model (that is, whether static or dynamic), it provides richer information on the impact of natural gas market liberalisation in Nigeria because of its multi-sectoral treatment.

[32] The Integrated Macroeconomic Framework for Poverty Analysis (see Davarajan and Go 1998; Agenor, 2003; Agenor, *et al.*, 2003, 2005a) is among the class of CGE models developed so far.

3.2.2 Representative households versus microsimulation CGE models

One of the strengths of the CGE model the econometric methods as well as other general equilibrium models is its ability to incorporate detailed information on house households earn and spend their incomes. Two ways this has been done is to make use of representative households (RH, hereafter) (see Lofgren *et al*., 2004) or microsimulation[33](an approach that makes use of more disaggregated household's data from nationally representative household surveys) (see Cockburn et al, 2010; Cogneau and Robillard, 2007; and Decaluwe *et al*., 2010;). Although, the RH approach is based on a very strong theoretical assumption[34] it has been argued that its inability to capture households' heterogeneity or intragroup income distribution limits its analytical power on the poverty impact of external shocks.[35] Thus, the increasing emphasis on microsimulation CGE models.

The microsimulation CGE models, starting with Cogneau and Robillard (2007), combine CGE models with microdata provided by household surveys. They are applied in two distinctive ways: layered or integrated approach. The layered approach first solves the CGE model to capture price, exchange rate, and macro changes; and then combine the results generated with microsimulation information from household surveys (see Bourguignon and Bussolo 2013). This is commonly referred to as the top-bottom approach. The second approach, on the other hand, integrates each household directly into the CGE model (see Cogneau and Robillard, 2007; and Cockburn et al, 2010; Ferreira *et al.*, 2008; Cororation and Cockburn, 2007).

The strength of microsimulation over RH approach lies in its treatment of heterogeneity which is quite explicit in term of consumption preference. However, some issues have been raised along the line of model specification and data reconciliation in a fully integrated microsimulation-CGE model (see Bourguignon *et al.*, 1983, for instance), and feedback effects from the household level analysis (see Savard, 2003).

[33] The idea of microsimulation dates back to Orcutt, (1957) but it was not until the late 1990's that it was used for the analysis of macro-poverty linkages.
[34] - an exogeneity assumption about this,
[35] See Corkburn and Decaluwe (2009) for a discussion on this.

3.3 Empirical Review

Debate continues about the extent to which households are affected by natural gas market liberalisation as empirical studies have yielded different results. The variance in results can be attributed to the method adopted or the context in which the studies were carried out. Nevertheless, three important observations from the review are noteworthy. First, is that the effects of shocks depend on several factors, including the size of the shock (both in terms of the percentage increase and the real price). Second, is the evidence that poorer households and those with the least means to cope are affected more irrespective of the type of shock, country, region, or area (urban/rural) where they live in. Third, is the fact the methodological differences play a significant role in analytical outcomes of the impact of price (liberalisation) shocks. This section presents the main arguments and findings in the literature on the household effects of shocks in gas market liberalisation.

Works of literature on energy sector liberalisation are vast, but leave the question of, what industry structure and regulatory mechanisms are needed to motivate the introduction of competition into one or more segments of prior regulated industries such as the natural gas sector. Most researchers investigate the impact of liberalisation on gas prices, (see Fiorio and Florio, 2007; Slaba and Klimesova, 2013; Kratena, 2011), or on supply security (see Pollitt 2007; Von Hirschhausen 2008); others provide case studies of a single country's process of liberalisation (see Grassini, 2003 in Spain; Stern 1997 in Great Britain; and Certin and Oguz 2007 in Turkey). Some of the authors stress the influence of the country's characteristics on the liberalisation method and outcome. For example, Slaba et al., (2013), emphasised that the individual country's, initial market structure, import dependency, legal and institutional framework determine the result of the country's liberalisation process. In this regard, this study shall review the related empirical literature from both developed and developing economies.

The empirical evidence on the impact of natural gas market liberalisation has evolved over the years. Until recently, the virtual obsession was to analyse the macroeconomic consequences of market liberalisation using different models and theories. Current research has shifted attention beyond the macroeconomic impact to consider microeconomic implications, such as household effects.

Pradhan and Sahoo (2000), constructed a 23-sectors, 3-factor and 9-households categories CGE model to analyse the impact of international oil price shock on the welfare and poverty of households in India. They found that household welfare declined and poverty increased following a 40% increase in international crude oil price. An increase in the elasticity of substitution of demand for imports to domestically produced crude oil increased the welfare loss for household groups.

Bacon (2005), found that for 97 net oil-importing countries (aggregated by per capita income ranges), a persistent US$10 per barrel price increase would deliver a shock equivalent to a loss of 1.47 percent of the GDP for the poorest countries (those with GDP per capita of less than US$300), while the highest income group (over US$9000 per capita GDP) would suffer a loss of 0.44 percent of GDP.

McDonald (2002), using a representative CGE model for South Africa, find that a 20 percent gas price increase in the economy results in a 1 percent drop in GDP. Also unskilled, skilled, and capital, labour income declined by 0.6 percent, 0.9 percent, and 1.1 percent respectively. Consequently, rural households have a slightly smaller decline in incomes than their urban counterparts (-0.76 percent to versus -0.83 percent). It was noted that the choice of factor market closure had a significant effect on the result; allowing scarce capital mobility would generate a small additional welfare loss.

A few studies (IEA, 2000; Löfgren, 2013) have used partial equilibrium models to Analyse the impact of energy subsidy reform. These models consider only the market directly impacted by the subsidy reform and estimates the price, output and demand changes in that market. Lofgren *et al.*, (2013), noted that the magnitude of these changes is determined by the price elasticities of supply and demand. Intuitively, with the rise in price (due to the removal of energy subsidy), demand will likely fall, resulting in a decrease in consumption and a loss of consumer welfare. Although, capable of providing useful insights into the impact of subsidy reform, but as earlier discussed, partial equilibrium models are unable to address questions relating to inter-

sectoral linkages[36] as well as macroeconomic questions relating to international competitiveness.

The variants of CGE models that have been used to the impact of energy subsidy reform include multi-region CGE models (Anderson and McKibben, 2000; IEA, 2000; and Bourguignon et al., 213)[37] and single-country CGE models (Nwafor et al., 2006;, 2008; Bourguignon et al., 1983). While comparison of results with the size of the subsidies is very limited in multi-region CGE models-given the different reference years of studies, the different countries incorporated in each study, and the different approaches to aggregating subsidies, country-specific studies offers more transparency in the modelling of gas price reform. Also, almost all multi-region/country CGE studies focus on economic and environmental impact, while single country studies make extra efforts to capture social/distributional effects.

3.3.1 Evidence from Developed Economies.

Among the early empirical studies conducted on the impact of natural gas market liberalisation on the economy are those of Ott and Tatom, (1982), and Considine and Mount (1983). While they differ in analytical scope, they all focused on the assessment of the impact of domestic gas sector liberalisation to price variability. They were primarily concerned with assessing how liberalisation of the natural gas market may likely affect different economic agents such as consumers, producers, and the economy as a whole. While Bourguignon et al., (1983), concludes that higher natural gas prices will likely cause reduced capital intensive spending on activities, Ott and Tatom (1982), and Considine and Mount (1983), affirm that the influence of higher natural gas prices on output, household real income and inflation is not significant.

Grassini, (2004) examined the dual effects of natural gas price increase in the Texas economy. They found that higher natural gas price creates extra jobs, income, and tax revenue. Dixon, (2014), examined economic development and natural gas prices on the USA economy using a simple regression model. His findings revealed that rising natural gas prices will halt the manufacturing sector and other energy-intensive sectors.

[36]Economic sectors that use energy as a significant input are likely to experience higher production cost (and therefore, higher prices) due to higher energy prices.

[37] With the exception of Anderson and McKibben, 1997 that examined the effects of coal subsidy removal, all over other studies considered a variety of fossil-fuel.

Surprisingly, higher natural gas prices do not predict slower growth for the three industries where expenditures on natural gas are relatively large and used.

Leonard et al (1992), adopted the vector autoregressive (VAR) model using a quarterly data, examined the impact of natural gas price shock on both Canadian and Norway economy as leading natural gas exporting countries. He found out that in both countries, the price increase has a significant impact on their GDP.

The Copenhagen Economics (2005) investigated the determinants of natural gas end-user prices. They developed their indicators capturing regulatory reforms, they also collected market opening index (MOI) for 14 countries in Europe. The indicator was scaled between 0 and 1, with 1 indicating fully applied. They found that liberalisation and competition, tariff structures tend to decrease end-user prices. However, regulation of these prices shows an increasing effect, quite the opposite of what is usually intended.

Brau et al (2010), compared two sources for residential end-user prices in the gas sector in Europe – the International Energy Agency (IEA) and Eurostat as the liberalisation policy was introduced – the study found little or no significant evidence of the beneficial effects of non-regulatory measures on European end-user prices. Instead, liberalisation tends to increase prices. However, Brauet'al neglected two important sub-indicators: the existence of market barriers for entrants and the regime of third-party access (TPA), both of which are crucial for market entry conditions.

Also, Heyendrickk, et' al (2012), presents a framework under which Gazprom maintaining its industrial competitiveness of the energy-intensive sector and expanding stern distributional concern, can generate a substantial investment inflow. This result shows that liberalisation is feasible at a lower economic cost, and will raise investment inflow with both firms and households facing increasing gas prices in comparison to the 2007 levels.

3.3.2. Evidence from Developing Economies

Razavi (2009), presents a measurable structure for deliberating on the liberalisation of the natural gas market in the Middle East and North African (MENA) countries made

up of Algeria, Egypt, Iran, and Qatar where gas prices are highly regulated by governments. The study concludes that the price of gas in most MENA countries are low and below its economic cost resulting in wasteful use of gas, deployment of inefficient technologies and a huge burden on governments' budgets. The finding also reveals that low gas price caused a reduced investors' interest in the upstream and downstream gas sector and at the same time encourages infrastructural development bias in favour of gas export projects in these countries. The study does not go further to show how these conclusions impact the various sectors and households in these economies.

Lekavicius and Galinis (2001), evaluated the economic consequences of natural gas price changes in the Lithuanian case by employing a CGE model to simulate the impact of varying domestic natural gas prices on the economy. The result of the simulations shows that a rise in the prices of natural gas would result in a significant increase in consumers' prices for energy, agricultural products, hence, making a strong influence on the domestic consumption and the economy. The study, however, observed a moderate decrease in natural gas consumption in its conclusion.

Hassan et al., (2013), examined the relationship between natural gas consumption and economic growth in Iran with a multivariate production model. They adopted bound-test over a period of 38 years (1970 - 2007). They found that natural gas price increase has a negative impact on natural gas consumption and economic growth in the long run. They concluded that the Iranian governments' decision for natural gas market liberalisation will have adverse effects on economic growth and policymakers should be cautious in implementing the policy.

The Ministry of Finance India (2013), evaluated a comparative analysis of the economic impact of the revision of natural gas market prices in India. Two scenarios – low and high natural gas prices were considered. For a low price scenario, it was observed that production will stifle, leading to the non-availability of gas and huge losses. For a high gas price scenario, they found that higher gas prices will lead to an increase in the cost of production and higher prices of goods and tariffs and hence inflation in the economy.

For Indonesia, Powell et al., (1993) found, using a Keynesian model, that energy price reform reduces real consumption of households between 2.1 percent and 2.9 percent this decline in real consumption was much larger than the 0.9 percent obtained in their estimation of a non-Keynesian model. They noted that higher-income groups in urban and rural areas were affected because of their relatively high consumption of natural energy (gas products) products. Across all the countries studied they found that a 50% average increase in energy prices resulted, on average, in a 4.6 percent decrease in real incomes. Other studies which found that energy subsidy cut reduces household real income, and thus welfare include Pereira *et al.*, (2005), and Paltsev, (2004).

3.3.3. Evidence from Nigeria

Hunt (2007), in conjunction with the World Bank and Federal Government of Nigeria, researched the appropriate pricing and allocation structure of the upstream gas sector in Nigeria and offers alternative pricing scheme to the current arrangement. The study maintains that the current gas price and allocation arrangement is inherently flawed since, to a considerable extent, it is based on the combination of coercion and an unjustified expectation of producers' future behaviour. The study also considers an alternative approach which is based on long-run marginal cost analysis, where gas investors/producers are faced with a price that will cover the marginal cost of production and over time move towards the LNG netback.

Ogwo, et al (2007), developed a multi-parameter functional model as a framework for assessing the cost of domestic gas at different points of supply. The study concludes, after different simulation scenarios, that the upstream gas sector in Nigeria is not priced appropriately when compared to international market prices.

Adenikinju and Chitiga (2009) confirm *a priori* expectation on the impact of negative oil price shocks on macroeconomic variables and poverty/household welfare in Nigeria. They found that oil shocks slowed down the fates of economic growth. GDP deteriorated cumulatively by 0.96 percent, 4.3 percent, 5.43 percent, and 6.02%, with the shock simulation scenarios under 12.2 percent, 15.2 percent, 63.4 percent, and 69.5

percent, respectively. Also, the results showed a general decline in household income in Nigeria, increasing the level of poverty and worsening household welfare.

Adenikinju, (2010) offers an analytical review and assessment of current and alternative gas pricing methodology and regulation. The study concludes by advocating for a move towards a liberalised efficient market pricing of the gas sector. This submission is also supported by Akinpelu and Iwayemi (2010), as they addressed the problem of how to accomplish cost-effective pricing for natural gas through market-determined pricing mechanism, as the sector transits from a highly regulated, monopolistic (at the transmission segment of the value chain) market structure characterized by high price regulation, to a competitive liberalised structure.

Omisakin (2015) investigated the Economic and Welfare impact of alternative natural gas pricing on the Nigerian economy using CGE modelling. He discovered that an increase in domestic prices stimulates an upward trend in the general price level of domestic commodities, which also negatively impact on real GDP, output, export, and imports; while households experience adverse factor employment and hence fall in total income. However, the study simulated gas price adjustments on uniform and differential basis, suggesting that sectors can purchase gas at different prices. The workability of this assumption leaves much to be desired.

From the various works of literature above reviews, emphases were placed on the impact of a gas price increase as a result of deregulations. This study, however, extends this by proposing a complete gas price liberalization as well as its impacts on total gas supply to market if the TPA policy is implemented.

Considering the significance attributable to natural gas in the economy, the studies reviewed, revealed that natural gas market liberalisation impacts the economy significantly. The studies show that while the liberalisation of the natural gas market will lead to an inflow of investment in the upstream sector, the downstream sector experienced some price increase and hence reduction in consumer welfare.

Despite the huge potential of the Nigerian gas reserve, the strategic importance of the Nigerian Natural Gas Master Plan (NGMP) which intends to usher in a liberalised

natural gas sector, no economy-wide empirical work to the best of my knowledge has been advanced on the impact of improved supply-side economics of the natural gas sector which precedes liberalisation of the economy and households in Nigeria. Hence this study aims to fill the gap by investigating the impact of natural gas market liberalisation on the Nigerian economy. Specifically, this study will employ a gas-focused dynamic CGE methodological framework with detailed characteristics and peculiarity of the Nigerian gas sector. This will help us fully investigate the direct and indirect impact of simulation scenarios of domestic natural gas market liberalisation.

CHAPTER FOUR.

THEORETICAL FRAMEWORK AND METHODOLOGY

4.1 The Competitive General Equilibrium Theory

The basic theoretical framework of this study is the competitive general equilibrium theory strongly founded on the Walrasian theory of market behaviour. The structure of this theory was developed by neoclassical economists, including Menger, and Walras. However, Walras is widely recognized as a major contributor to the design of the framework. The framework was further formalized by the notable works of Arrow and Debreu, and Mckenzie (Omisakin, 2015).

Thus, it is quite suitable for explaining the impact of natural gas market liberalisation in the Nigerian economy, and household effects in particular. The theoretical framework that will guide this study draws from the works of Wing (2005), and Decaluwe et al., (2010). The main points emphasized in the theory and the specific adjustments made to suit the study are discussed below.

4.1.1 Producers and households

The framework begins by describing a finite number of producers (*N*), each producing its own type of commodity (which may be outputs or intermediate consumption inputs), and an unspecified number of households that jointly own an endowment of *F* different types of primary factors. Then, letting the indices $\boldsymbol{j}$ =(1,2,…, N) denotes the set of industry sectors - each producing its own type of commodity, $\boldsymbol{i}$ = (1,2,…,N) denotes the set of commodities, $\boldsymbol{f}$ = (1,2,…, F) denotes the set of primary factors, and $\boldsymbol{d}$ = (1,2,…, D) denote the set of final demands, the behaviour of the agents within the system is described below.

(i) **Producers**

The Production structure of this model entails producers' behaviour in the economy. Each producer $\boldsymbol{j}$ is faced with a set of production possibilities in which outputs have a positive sign and inputs a negative sign. The set of production program has the following properties: production without input is impossible, the scale outputs are non – increasing, and the production process is irreversible. The production procedure is disaggregated into two levels. At the lower level, it is assumed that the composite primary factor (valued added) is produced from capital and labour with the Constant Elasticity of Substitution (CES) type of production technology. At the top level, it is assumed that gross outputs are made from the intermediate inputs and value-added with the Leontief type of production technology. In the Leontief type production technology inputs are used in fixed proportions to the level of output, thus it is characterized by zero substitutability. However, the CES type production technology allows for flexibility in inputs substitutability. (Paltsev, 2004).

Profit π is maximized by each producer when they choose $\boldsymbol{N}$ quantities of intermediate inputs, $\boldsymbol{X_j}$, and composite primary factors (value-added) $\boldsymbol{Y_j}$, to produce output Zj, subject to the production technology constraint facing it.

Thus the $\boldsymbol{j^{th}}$ producer's problem is to:

$$\max_{Z_j, X_{ij}, Y_{fj,}} \boldsymbol{\pi_j} = \sum_{i=1}^{N} \boldsymbol{P_i X_{ij}} - \sum_{f=1}^{F} \boldsymbol{w_f Y_{fj}}$$

Subject to:

$$\boldsymbol{Z_j} = \min\left[\frac{X_{ij}}{a_{oij}}, \frac{Y_{fj}}{a_{1fj}}\right] \qquad (4.1)$$

Where: $\boldsymbol{p_i}$ and w_f are the prices of industrial output, intermediate inputs and value-added respectively; and $\boldsymbol{a_{0ij}}$ and $\boldsymbol{a_{1fj}}$ are input-output coefficients for intermediate inputs and composite factor inputs. Each producer is assumed to have a Leontief production

technology, such that its production function, $\min\left[\frac{X_{ij}}{a_{oij}}, \frac{Y_{fj}}{a_{1fj}}\right]$, is a guide on how inputs of composite primary factors and intermediate goods are combined for optimum result.

By rearranging the constraint in (4.1), the input-output coefficients (parameters) of the Leontief production function are:

$$\boldsymbol{a_{0ij} = \frac{X_{ij}}{Z_j}}, \quad \text{and} \qquad \boldsymbol{a_{1fj} = \frac{Y_{fj}}{Z_j}} \tag{4.2}$$

Resolving the problem in (4.1) yields the producer ***j's*** demand for inputs of intermediate commodities:

$$\boldsymbol{X_{ij} = a_{0ij} Z_j} \tag{4.3}$$

and its demand for composite factor inputs:

$$\boldsymbol{Y_{fj} = a_{1fj} Z_j} \tag{4.4}$$

Rearranging equations (4.3) and (4.4) yields

$\boldsymbol{a_{0ij} = \frac{P_i X_{ij}}{P_j Z_j}}$ and $\boldsymbol{a_{1fj} = \frac{w_f Y_{fj}}{P_j Z_j}}$, respectively, showing that the coefficients of the Leontief production function represent the share of their respective inputs to production in the value of output. However, since equation (4.1) is not differentiable,[38] it is replaced with a zero- profit condition expressed as:

$$\boldsymbol{\pi_j = p_j Z_j - \sum_{i=1}^{N} a_{0ij} p_i Z_j - \sum_{f=1}^{F} a_{1fj} w_f Z_j = 0, \quad \forall_j} \tag{4.5}$$

The assumption that firms cannot earn excess profits, and that all firms are competitive justifies the zero-profit condition.

In the event that some firms can earn an excess profit, there will be entrants of new firms, which eventually reduce the excess profits (per firm). Firms will continue to enter until the

[38] This is due to the Leontief type production function that is not differentiable in the constraint with respect to its inputs. To take a formal derivation of the function, a CES function, which is a generalized function of the Leontief function, the production function is employed. As the elasticity of substitution in a CES function tends to zero, it does to a Leontief function.

excess profit disappears. This condition as expressed in (4.5) can further be simplified into the unit cost function by dividing the zero-profit condition with gross outputs:

$$\mathbf{p_j = \sum_{i=1}^{N} a_{0ij} p_i + \sum_{f=1}^{F} a_{1fj} w_f} \qquad \forall_j \qquad (4.6)$$

(ii) Households

The representative households are assumed to maximize their utility ***U*** by choosing their level of consumption ***C*** of the ***N*** commodities in the economy, subject to their income constraints ***Y*** and prevailing commodity prices ***P***. Their income consists of earnings from its endowment of primary factors, which are in-elastically supplied to industry for production, as well as income in the form of transfers. Thus, the agent's problem is to:

$$\max_{C_1} \; C_1 \, U \, (C_1 \ldots, C_n)$$

subject to:

$$\mathbf{y = \sum_{i=1}^{N} p_1 \, c_1} \qquad (4.7)$$

The representative households are assumed to have Stone-Geary utility function (from which derives the Linear Expenditure System)[39] expressed as:

$$\mathbf{U(c) = \sum_{i=1}^{N} \beta_t In(c_i - \gamma_i)},$$

$$\mathbf{\sum_{i=1}^{N} p_i c_1} \qquad (4.8)$$

[39]Several alternative formulations such as the Rotterdam model by Theil, the linear expenditure system (LES) by Stone, and the Almost Ideal Demand System (AIDS) by Deaton, were used to variously to represent the demand system of households in the literature. However, as noted by Vargas (2004), a theoretical system of demand that is consistent allows for the imposition of classical demand theory's general restrictions, which include: ; (i) homogeneity: demands are homogeneous of degree zero in prices and total expenditure; (ii) adding-up: value of total demand equals total expenditure; (ii) negativity: for the Hicksian demands, direct substitution effects are negative; and (iii) symmetry: the Hicksian demands cross-price derivatives are symmetric. Because it allows the representation of subsistence consumption, in addition to satisfying the above restrictions and also due in part to the convention, the linear expenditure system is the most commonly used.

Where: $\mathbf{c_i}$ is the level of commodity **i**, $\boldsymbol{\beta_i}$ is the marginal budget share of the commodity, and $\boldsymbol{\gamma_i}$ if positive, is subsistence minima as perceived by the consumer.[40]

It is further assumed that only a fixed amount of household disposable income can be allocated to consumption (given that households pay direct taxes to the government and are allowed to save a portion of their income). Therefore, the household constraints in (4.7) can be redefined as:

$$\boldsymbol{d_y = \sum_{i=1}^{N} p_i c_1} \tag{4.9}$$

Where ***dy*** is household consumption budget, derived after deducting taxes and savings.

Solving the first order condition of the Lagrangian equations (4.8) and (4.9) produces:

$$\boldsymbol{\frac{\beta_i}{c_i - \gamma_i} = \lambda p_i} \tag{4.10}$$

$$\boldsymbol{d_y - \sum_{i=1}^{N} p_i c_1 = 0} \tag{4.11}$$

Rearranging the terms in (16), summing across $\boldsymbol{i}$, and solving for the Lagrangian multiplier, yields:

$$\boldsymbol{\lambda = \frac{1}{dy - \sum_{i=1}^{N} p_i c_i}} \tag{4.12}$$

Recall that $\boldsymbol{\sum_{i=1}^{N} \beta_i = 1}$. Substituting (4.12) into (4.10) results in an expression for the commodity ***I*** expenditure by household:

$$\boldsymbol{p_i c_i = p_i \gamma_i + \beta_i (d_y - \sum_{i=1}^{N} p_{ij} \gamma_{ij})} \tag{4.13}$$

The first derivative of equation (4.13) as expected, with respect to household consumption budget $\boldsymbol{d_y}$, is the marginal budget share, $\boldsymbol{\beta_i}$. Dividing equation (4.13) by $\boldsymbol{p_i}$ gives the

[40] This utility function, unlike the wildly acclaimed Cobb-Douglas utility function, imposes neither unit income-elasticity for all goods nor zero cross-price elasticity between all pairs of goods. Hence, it offers some degree of flexibility with respect to substitution possibilities in reaction to relative price changes.

linear expenditure system, equation (4.14), which represents the demand function for the consumption of the i^{th} commodity by the representative agent is:

$$c_1 = \gamma_i + \frac{\beta_i}{p_i}(d_y - \sum_{i=1}^{N} p_{ij}\gamma_{ij}) \quad (4.14)$$

To be estimable, equation (4.14) is implemented in most cases by using a simplified version of the Stone-Geary least expenditure system. Rearranging equation (4.14) yields:

$$\gamma_i - \frac{\beta_i}{p_i}\sum_{i=1}^{N} p_{ij}\gamma_{ij} = \frac{d_y}{p_i}(\frac{p_i c_i}{dy} - \beta_i) \quad (4.15)$$

4.1.2 Government, capital stock and investment

(i) Government

Government is assumed to impose indirect taxes on production (TXp_j) and commodities (TXc_i), and direct taxes on household income (TXh) expressed by:

$$TXp_j = \tau_j Z_j, \qquad \forall_j \quad (4.16a)$$

$$TXc_i = \tau_j Z_j, \qquad \forall_i \quad (4.16b)$$

$$TXh = \upsilon y \quad (4.16c)$$

Where τ and υ represent indirect and direct tax rate respectively.

If the government spends its revenue less savings (S^g) in the consumption of commodities (X_t^g), then government behaviour can be expressed as:

$$X_t^g = \frac{\mu_i}{p_i}(\sum TX - S^g) \quad (4.17)$$

Where $\sum$**TX** is the sum of all tax revenue and μ, is the share of expenditure for the i^{th} commodity ($0 \leq \mu_t \leq 1, \sum_i \mu_i = 1$).

Assuming government receives an income transfer from other agents (tr_o^g) and also transfer income to other agents (tr_g^o); if the government also commits a portion of its

budget on subsidizing the consumption of a particular commodity ($\boldsymbol{B_i}$), then the government budget constraint can be defined as:

$$\boldsymbol{Y^g \equiv \sum TX + tr_0^g = p_i\left(\frac{X_i^g}{\mu_i}\right) + tr_g^o + B_i + S^g} \qquad (4.18)$$

This is just one specification, it can also be assumed that besides its consumption of commodities, the government allocates a fixed portion of its budget on capital expenditure. Thus, equation (4.18) may include an extra variable on the right-hand side (*RHS*). Also, there can be an alternative treatment of the subsidy ($\boldsymbol{B_i}$) in the system. It may be treated as an arbitrary lump-sum payment to producers or consumers or may take the form of price control that set prices below full cost.[41] The latter treatment suggests that $\boldsymbol{B_i}$ depends on the market price and consumption of the specific commodity being subsidized.

(ii) Capital stock and investment

To maintain consistency within the accounting framework, either of two approaches can be applied in the treatment of capital good. The first considers heterogeneous capital, while the second considers one capital aggregate.[42] The latter approach requires aggregating sectoral investment by fixed shares to a composite capital. Implying that, the outputs of the industries combine, according to fixed coefficients, to produce a representative capital aggregate. It should be noted that investment shares are not fixed exogenously; they react to changes in policy shocks as well as in relative terms. Thus, similar to the assumption made about government consumption, investment demand function with constant share parameter can be expressed as:

$$\boldsymbol{X_i^v = \frac{\lambda_i}{p_j}\left(S + S^g + \varepsilon S^f\right)} \qquad \forall \boldsymbol{i} \qquad (4.19)$$

[41] The first possibility is simple and transparent but can involve considerable accounting and transaction cost reality. It also imposes a heavy direct financial burden on the national treasury. The alternative is often preferred if the specific-commodity-producing firm is state-owned.

[42] Farmer and Wender (2001) have argued that dynamic CGE models simulation results are highly sensitive to the various specification of investment and capital aggregation. While recommending using a framework with heterogeneous capital and optimal investment shares (pointing out three great complexities in implementing the framework), they highlighted some circumstances under which the fixed investment shares and capital aggregate appear more justifiable. One includes an analysis in a scenario where capital inputs composition is identical across the sectors.

Where: $\boldsymbol{S}$ is private saving; $\boldsymbol{S^f}$ is foreign savings or current account deficit in the balance of payments (in foreign currency); $\boldsymbol{X_i^v}$ is the investment demand for the $\mathbf{i^{th}}$ commodity; $\boldsymbol{\varepsilon}$ is the exchange rate (local currency per foreign currency); and, $\boldsymbol{\lambda_i}$ is the share of expenditure for the $\mathbf{i^{th}}$ commodity. This investment demand as determined by equation (4.19) is a major demand component. It is realised by the combination of domestic and foreign savings. In a dynamic system, it is made to contribute to capital good. The value of capital good $\mathbf{K_t}$ holds that:

$$\boldsymbol{K_{t+1} = p_{j,t} X_{i,t}^v} \tag{4.20}$$

Total saving in period t equal$\mathbf{K_{t+1}}$. The amount of capital goods, in terms of commodity **i**, is stated as

$\mathbf{k_{t+1} \equiv K_{t+1} / p_{j,t}}$. Recall that investment demand is exogenously determined by fixed (nominal) shares of the total savings, $\boldsymbol{\varsigma}$, so:

$$\boldsymbol{X_{i,j}^v = \varsigma k_{t+1}} \tag{4.21}$$

4.1.3 International trade

(i) The small-country assumption and the balance of payment constraint

The framework, in this subsection, is extended to an open economy model. The small country assumption (that this country is too small to affect international market prices) is employed for simplicity of analysis. Thus, prices of export and import **($\boldsymbol{p_i^{Wm}}$ and $\boldsymbol{p_i^{We}}$,** respectively**)** the country faces are given in foreign currency terms. Given the exchange rate$\boldsymbol{\varepsilon}$, the relationships between import and export prices in local and foreign currency terms are shown in the following equations:

$$\boldsymbol{p_i^e = \varepsilon p_i^{We},} \tag{4.22a}$$

$$\boldsymbol{p_i^m = \varepsilon p_i^{Wm},} \tag{4.22b}$$

Introducing taxes on imports and exports of commodities modifies the relationship between import and export prices to equations (4.23a and b), while the country's balance of payment condition, described in foreign currency, is given by equation (4.24).

$$\boldsymbol{p_i^e = p_i^{We}(1 + t_i^e)\varepsilon} \quad (4.23a)$$

$$\boldsymbol{p_i^m = p_i^{Wm}(1 + t_i^m)\varepsilon} \quad (4.23b)$$

$$\boldsymbol{\sum_t p_i^{We}(1 + t_i^e)E_t + S^f = \sum_t \varepsilon p_i^{Wm}(1 + t_i^m)M_t,} \quad (4.24)$$

Where $\boldsymbol{E_t}$ and $\boldsymbol{M_t}$ are the amounts of exports and imports of the $\mathbf{i^{th}}$ commodity, respectively.

(ii) **The Armington assumption**

With the extension of the framework of an open economy model, some considerations about the substitutability among domestically supplied, exported, and imported goods are needed. If imported goods are perfectly substitutable with exported ones, then the difficulty brought about by two-way trade in actual trade statistics is inescapable.[43] To resolve this problem, exported goods are regarded as imperfect substitutes for imported ones even though, statistically, they are classified into the same category.

A level of aggregation is assumed, to treat domestic goods and imports as different goods, and a disaggregation level for domestic goods and exports. Thus domestically supplied goods and imports are aggregated to be (Armington's) composite goods – used for intermediate inputs and domestic final demand. It is assumed that domestic goods are imperfectly substitutable with imports; that is, the goods are heterogeneous with respect to their origin.[44] The imperfect substitutability between the two is expressed with a CES type production function.

Hence, the profit maximization problem of the i^{th} composite good firms can be stated as:

[43] See Hosoe (2004) for more discussion on this.
[44] This is known as Armington's assumption (1969).

$$\max_{Q_i, M_i, D_i} \pi_i^q = p_i^q Q_i - (p_i^m M_i + p_i D_i),$$

Subject to:

$$Q_i = \varphi_i(\sigma m_i M_i^{\eta i} + \sigma d_i D_i^{\eta i})^{\frac{1}{\eta i}}, \quad \sigma m_i + \sigma d_i = 1, \sigma m_i, \sigma d_i \geq 0 \qquad (4.25)$$

Where π_i^q is the profit of the $\mathbf{i^{th}}$ composite good firm; p_i^q is the price of the ith composite good; Q_i is the output of the $\mathbf{i^{th}}$ composite good; D_i is the input of the i^{th} domestically produced good; φ_i is the productivity parameter of the $\mathbf{i^{th}}$ composite good production function; $\sigma m_i, \sigma d_i$ are the share parameters of the $\mathbf{i^{th}}$ composite good production function; η_i is the parameter related to the elasticity of substitution, ($\eta_i = \frac{\sigma_i - 1}{\sigma_1}, \eta_i \leq 1$); and σ_1 is the elasticity of substitution.[45]

From the first-order conditions of the optimization problem, the following demand functions for domestic goods and imports can thus be obtained.

$$M_i = \left(\frac{\varphi_i^{\eta_i} \delta m_i p_i^q}{p_i^m}\right)^{\frac{1}{1-\eta_i}} Q_i, \qquad (4.26)$$

$$D_i = \left(\frac{\varphi_i^{\eta_i} \delta d_i p_i^q}{p_i^d}\right)^{\frac{1}{1-\eta_i}} Q_i, \qquad (4.27)$$

At another level, producers are considered to transform gross outputs into domestic goods and exports. These exportable goods are also assumed to be imperfectly transformable to domestic goods. This is represented by a constant elasticity of transformation (*CET*) production technology. Thus, the optimization problem of the $\mathbf{i^{th}}$ transformation firm is expressed thus:

$$\max_{Z, E_i, D_i} \pi_i^Z = (p_i^z E_i + p_i^d D_i) - (\tau_i + p_j) Z_i$$

[45] The Elasticity of substitution, which is assumed in the CES function, represents the marginal decrease in the relative amount of inputs under marginal increases in relative prices.

Subject to: $\boldsymbol{Z_i = \theta_i(\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i})^{\frac{1}{\phi_i}},\ \ \xi e_i + \xi d_i = 1,\ \xi e_i, \xi d_i \geq 0}$ (4.28)

Where $\boldsymbol{\pi_i^Z}$ is the profit of the **i**$^{\textbf{th}}$ transformation firm; $\boldsymbol{\theta_i}$ is the productivity parameter of the **i**$^{\textbf{th}}$ firm's transformation function; $\boldsymbol{\xi e_i, \xi d_i}$ are the share parameters of the **i**$^{\textbf{th}}$ firm's transformation function; $\boldsymbol{\phi_i}$ is the parameter related to the elasticity of transformation, $\boldsymbol{\varphi_i = \frac{\psi_i + 1}{\psi_i},\ \phi_i \geq 1}$); and, $\boldsymbol{\psi_i}$ is the elasticity of transformation of the **i**$^{\textbf{th}}$ firm's transformation function.

From the first-order conditions of the optimization problem, the supply functions and the transformation function of domestic goods and export can be obtained as:

$$\boldsymbol{M_i = \left(\frac{\theta_i^{\phi_i} \xi e_i (\tau_i + p_j)}{p_i^e}\right)^{\frac{1}{1-\phi_i}} Z_i,} \quad (4.29)$$

$$\boldsymbol{D_i = \left(\frac{\theta_i^{\phi_i} \xi d_i (\tau_i + p_j)}{p_i^d}\right)^{\frac{1}{1-\phi_i}} Z_i,} \quad (4.30)$$

4.1.4 General equilibrium

To ensure general equilibrium in the system, there is a need for market-clearing conditions in all the markets (for goods and factors). The market clearing implies that the quantity of each commodity demanded as an intermediate input, by the representative agent (households and government) for consumption, or as investment goods must equal the sum of the quantities of that commodity produced. Thus, we have

$$\boldsymbol{Q_t = X_i^p + X_i^g + X_i^v + \sum_j X_{ij},\quad \forall_i} \quad (4.31)$$

Also, the quantities of the primary factors $\boldsymbol{f}$ used by all producers must equal the representative agent's endowment of that factor, $\boldsymbol{Y_f}$. This is given by

$$\boldsymbol{Y_f = \sum_{j=1}^{N} a_{1fj}} \quad (4.32)$$

The zero profit condition implies that the value of output generated by producer $\boldsymbol{j}$ must equal the sum of the values of the inputs of the $\boldsymbol{i^{th}}$ intermediate goods and *f* primary factors

employed in production. This condition is derived by rearranging the *RHS* of equation (4.5):

$$\boldsymbol{p_j Z_j = \sum_{i=1}^{N} a_{0fj} w_f Y_{fj}} \tag{4.33}$$

Income balance implies that the income of the households must equal the value of producers' payment for the use of the primary factors. Thus,

$$\boldsymbol{y = \sum_{f=1}^{F} w_f Y_f} \tag{4.34}$$

These equilibrium conditions, including equation (4.20) form the binding elements in the system of equations which are the building blocks of the model.

4.2 Conceptual framework

The fundamental conceptual starting point for any general equilibrium analysis of the impact of natural gas market liberalisation is an understanding of the linkages in the economy under study and its interactions with the outside world. These linkages and how international price shocks of a liberalised market are possibly transmitted to the households to show the operationalisation of the theoretical framework are described below. This description draws largely from the works of Wing (2004), and Decaluwe, Lemelin, Robichaud, and Maisonnave (2010).

4.2.1 The open economy circular flow

The economy under study is a small open economy. This presupposes that: first, that the country relates to other countries (referred to as the rest of the world – ROW); and secondly, that it cannot influence the international price. The main actors in this economy are : (i) households, who own the factors of production (such as land, labour and capital) and also, are the final consumers of commodities produced; (ii) firms, who rent the factors of production from the households for the purpose of producing goods and services that are in turn consumed by households, government and other firms; (iii) government, that collect taxes from households, firm and rest of the world as revenue and disburses same to households and firms as subsidies and lump-sum transfers, subject to rules of budgetary

balance, and (iv) the rest of the world (ROW), that buys goods from the domestic market and sells to same.

In describing the linkages in this economy, the flow commences from the supply of factor inputs to the firms, and then continue to the supply of goods and services from the firms to the households, who are in turn owners of and suppliers of factor services. Given that the economy is open, the supply of goods and services include those produced domestically and imported. Alternatively, the flow may commence from the payments made to households for services (labour and capital), that they provided to firms. These incomes (labour and capital income), are in turn used by the household to pay the producing sectors for the goods and services that they consume.

The conservation of both value and products in this economic flow result in equilibrium. Product conservation implies that households' endowment of primary factor is fully employed by the firm and that households, fully consume the output of the firm. Hence, the quantity produced for any given commodity must equal the sum of the quantities that are demanded by the households, other firms, and the government in the economy. Similarly, for a given factor, the household's aggregate supply of endowed factors must equal the quantities demanded by firms for the production of goods and services in the economy.

Value conservation, on the other hand, implies that the total sum of all revenue from the activities of production of goods and services in the economy must be allocated either to households as payments for rentals of primary factors, to payments for intermediate inputs by other industries, or as tax income to the government. The unit value of each commodity must then be equal to the sum of all the input values used in its production. That is the cost of the primary factors employed as well as the intermediate inputs used in its production.

Income payments made to households as remuneration for factors supplied to the firm are exhausted in the consumption of goods and services in the economy. If part of this income is saved by the household, then, the amount so saved must be equal to investment which

allows for an increase in productive potential in the economy over time. Investment determines how fast the economy grows, in a dynamic sense where the tracking of equilibria of the economy matter. [46]

Figure 4.1 describes the flow of receipts and payments or goods and services in an open economy. At each economic transaction where the exchange of goods and services are involved, there must be a corresponding receipt and payments. For instance, if a household engages in a transaction involving the purchase of goods from the firm, this implies the flow of both goods and payments. The direction of the flow of goods is from firms to households, while the direction of flow for payments is from households to firms (the opposite direction).

The domestic economy link with the international sector is captured with the four sets of arrows that indicate the movement in and out of the international sector. Additional goods and services are sourced from the international sector (imports) to the domestic economy. This is matched by a flow of payment from the domestic agents to the international sector. But some of the goods and services the domestic economy produces also go to the international sector as exports. This outward flow of goods and services is matched by an inward flow of payments to domestic producers.

[46] The economy's capital stock is the accumulation of all past investments made by the economy, while, investments at any given time is a flow. Hence, the economy's changes over time occur through the effect that changes in flow have on the stock variable.

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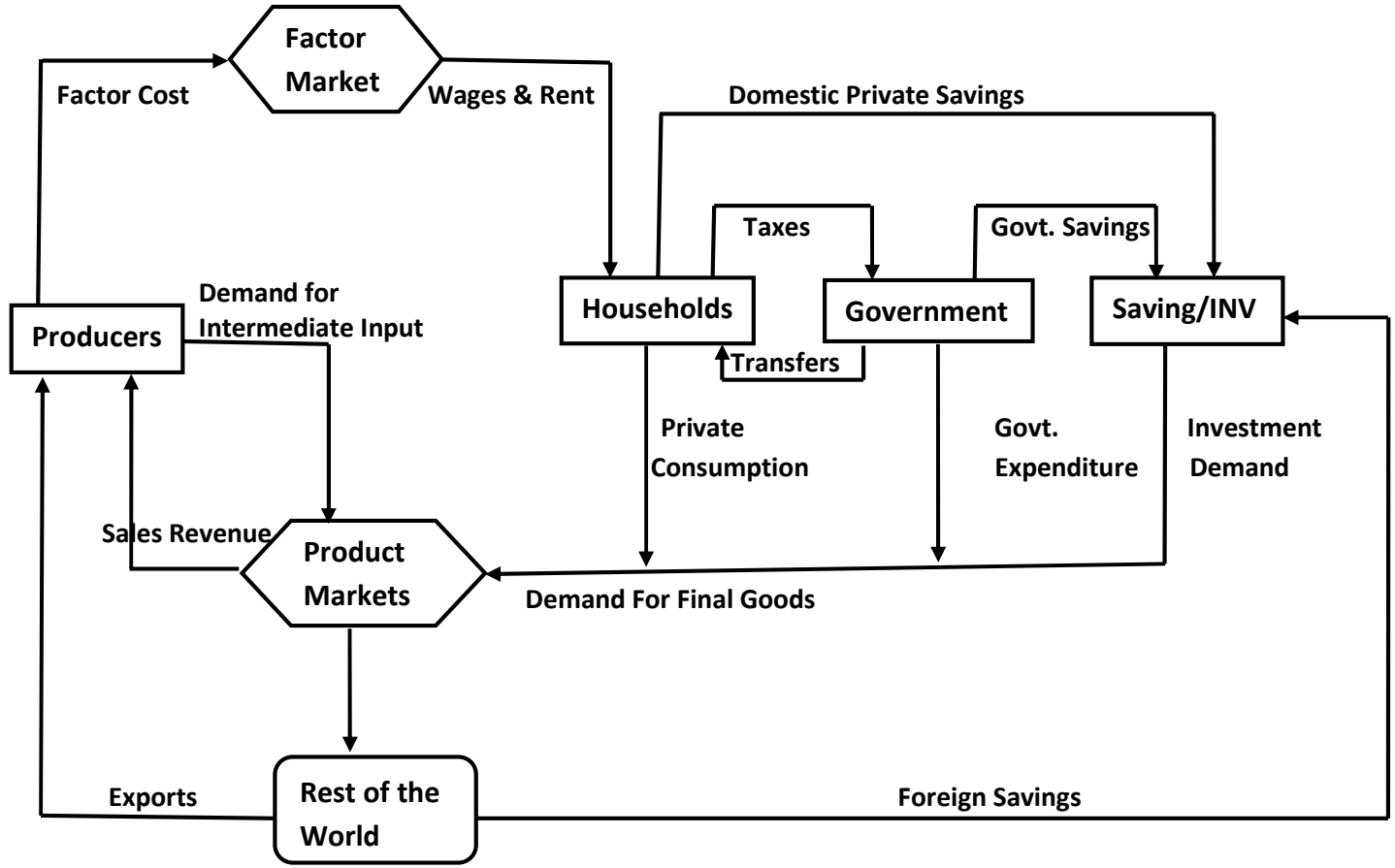

. **Figure 4.1: Circular flow in an open economy.**
Source: Adapted From Khan, 2015.

4.2.2 Impact transmission mechanism

Reviewing the general economic rationale and directions of the economy-wide impact of domestic natural gas market liberalisation as demonstrated in this study. The economic decision making and resource allocation process of institutions, consumers, producers, and other economic actors are expected to be impacted by the liberalisation policy. This impact can be viewed basically from three points viz: the supply-side, demand-side and terms of trade side.

On the production side, while the liberalisation policy is expected to expand the output of the gas sector leading to increased demand for factors and intermediate input, the direct impact on other sectors could be channeled through their use of gas as intermediate inputs.[47] With this increase in the price of natural gas, gas becomes less affordable leading to a decline in the intermediate demand for natural gas by other sectors resulting in lower output and decline in factor and intermediate use. Producers may react to this shock either through production or their pricing behaviour. In terms of the pricing behaviour, they can either buffer the increase in energy prices by diminishing their profit margins, or they can pass through the higher production costs by increasing their selling prices, thereby generating indirect effects on inflation. In terms of their production behaviour, firms react to new market conditions by adjusting the quantities they produced, therefore reducing the amount of energy needed for production. As a result, investment, employment, and wages tend to go down.

The demand-side effects are linked to the impact of the liberalisation policy on real income and consumer prices. As prices increase and disposable income decline, consumption, and savings are reduced. This effect ultimately affects household welfare. Meanwhile, the government might improve its overall performance measured by the level of its income through increased corporate income tax from firm, mining royalties, gas export revenue, and reduction in the subsidy transfer to the domestic gas consuming sectors, especially the electricity sector.

[47] Economic theory postulates an increase in the per-unit cost of output following an increase in the relative price of input.

Although the relative size of gas demand by various sectors is expected to decline, the impact is expected to be more evident in the major gas-consuming sectors since natural gas forms a significant part of the intermediate consumption in these sectors. While the above narrates the general economic *a priori* expectation of the impact of domestic gas market liberalisation, the actual magnitude and direction of an impact critically depend on the degree of change in the domestic gas price (simulation assumptions), the economic structure as represented in the GASAM and the set of assumptions underlying our model. Figure 4.14 shows a schematic overview of the model transmission mechanism.

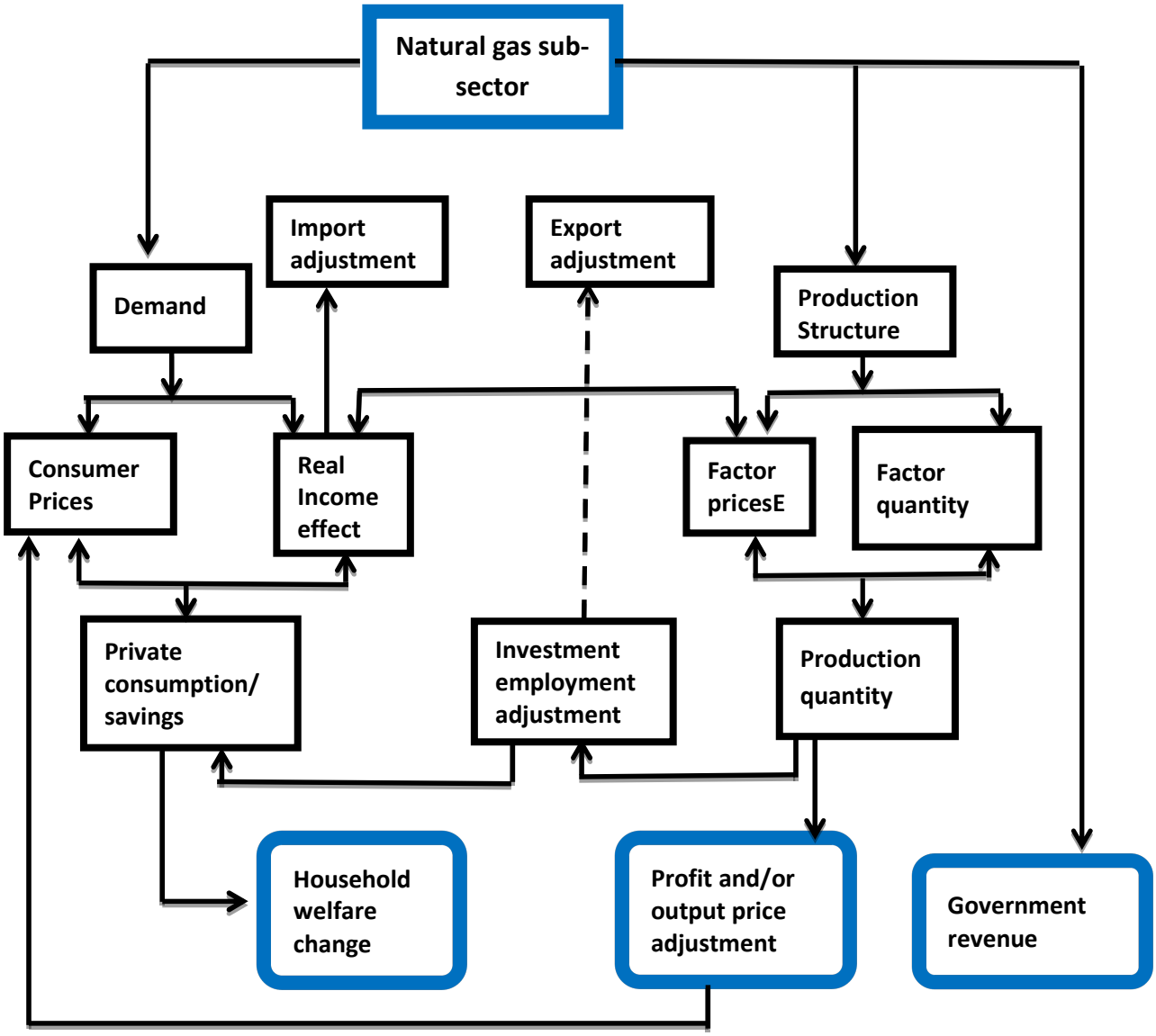

Figure 4.2: **Schematic Overview of the Model Transmission Mechanism.**

Source: The Author.

4.2.3 Welfare measure and specification

The word ‘welfare' is generally seen as a multi-dimensional concept that is much broader than its economic dimension, it has been extensively argued in the economic literature that since the utility function represents the rational preference of a representative household, welfare can, therefore, be proxied by a household utility function (Ng, 1983). This presupposes why the utility function embedded within a CGE model is frequently used as an exact and a convenient valuation of household welfare changes (Martin, 1997). In line with best practices in the literature in the context of the general equilibrium modelling and as a matter of analytical convenience, this study relies on the utility optimization principle to model the economic welfare at the household level.

First, each household's preference is assumed to be represented by a utility function of the quantities of commodities demanded. The optimal behaviour of the household can then be represented by the *indirect utility function*. This is the maximum attainable welfare, given the level of resource and prevailing prices. More specifically, this study adopts and discusses the measure of welfare which is based on the concept of the *money metric indirect utility function* denoted by the following equation:

$$\mu(q,p,Y) \tag{4.35}$$

Equation (4.35) measures how much one would need at prices p to attain the same level of utility, as one would have at a price q while disposing of income Y. When this measure of utility is adopted, we find as a measure of the change in welfare that results from the proposed change as given:

$$\mu(q, p^1, Y^1) - \mu(q, p^0, Y^0) \tag{4.36}$$

From equation (4.36), we have to choose the vector of base prices q. Choosing $q = p^0$, we get the Equivalent Variation (EV) stated below:

$$EV = \mu(p^0, p^1, Y^1) - \mu(p^0, p^0, Y^0) \quad = \mu(p^0, p^1, Y^1) - Y^0 \tag{4.37}$$

Equation (4.37) measures the income change at current prices that would be equivalent to the proposed change in terms of its impact on utility.[48] Consequently, given such a definition of economic welfare, how well off a policy change makes a household, depends on what the change does to its income and prices and, hence, the purchasing power of that income.

4.3 Methodology

In consideration of the overall objectives, the methodological framework of this study is the dynamic multi-sectoral Computable General Equilibrium (CGE) model. In this section, the methodology/analytical procedure is described as well as some conceptual issues and structure of the model.

4.3.1 Computable General Equilibrium (CGE) Model

Policy makers and professionals alike are commonly interested in learning the direct and indirect effects of specific policy measures on economic outcomes. The ubiquitous existence of rich data sets, both at a macro and micro level, combined with abundant computing power, explains the increasing demand for quantitative assessment of the economic impact of actual or eventual policy choices.

Since the beginning of the 1980s, CGE models have become an increasingly popular tool to Analyse the consequences of policy choices and the allocation of resources in developing as well as in developed economies. CGE models are used nowadays not only in Universities and research institutions, but also by governments worldwide in policy formulation.

The CGE model is an analytical system of the nonlinear equation derived from the economic theory of optimizing behaviour of rational economic agents (Kuster et al, 2007). It is the modern version of a multi-sectoral, economy-wide non-linear equilibrium model of the Walrasian model of a competitive economy. The CGE model described the linkages

[48] Alternatively, when we choose $q = p^1$, we get the Compensating Variation (CV) given as:
$CV = \mu(p^1, p^1, Y^1) - \mu(p^1, p^0, Y^0) = Y^1 - \mu(p^1, p^0, Y^0)$. This equation measures the income change that would be necessary to compensate the household for the price change, induced by the 'proposed change'.

between markets, the institution and factor resources that render a numerical equilibrium solution with all markets clearing simultaneously (Grassini, 2004). Numerical CGE models based mainly on the classical analytical equilibrium models upon which a unique general equilibrium solution in competitive markets may arise if three important equilibrium conditions are simultaneously satisfied (Mathesian, 1998; Paltseve, 2004). There equilibrium condition which includes: market clearance condition, zero profit condition, and income balance condition, form the basis upon which the set of prices and the allocation of goods and factors that support general equilibrium in the economy are built.

Johansen (1960) is usually referred to as the first main attempt to use a large CGE model to study a real economy. CGE models have been used in areas as diverse as social policy, energy policy, fiscal and development planning (See Pereira 1988; Powel et al 1993). The development of the CGE model started in the 1960s; it did not receive much fillip until the late 1970's when the World Bank showed interest in its development for economic analysis (Adenikinju and Chitiga 2009). The study of Jorgenson (1984) was one of the works that adopted an AGE model in energy studies. Since then several studies have argued that CGE models are the most appropriate approach to energy-economy policy analysis for a region or a country.

The merits of the CGE model are varied, CGE models are based on established axiom and principles of microeconomics, such as profit, utility maximization and rational behaviour of economic agents hence provides a conceptual consistency for model analysis. CGE model analysis in based on inter-industry or multi-sectoral backward and forward linkages, hence they permit analysis of resource allocation and how policies impact or permeate through the various sectors of the economy. Also, CGE models allow for welfare analysis by evaluating ‘winners' and ‘losers' from policy changes which may provide an avenue to apply compensatory schemes for ‘losers' from economic reforms especially if they belong to the vulnerable groups. Its demerits include the fact that CGE models are relatively aggregated giving the focus on macroeconomic, sectoral and social effects; they require a large number of parameters and elasticity's which often have to be

'borrowed' or 'guesstimated'. Also, it requires considerable technical skill to formulate, solve and interpret the result of a CGE model.

4.3.2 A computable general equilibrium (CGE) model for Nigeria

CGE modelling in developing countries demands considerable efforts due to its extensive data and computational requirements, both of which are luxuries in these countries (Adenikinju 2009). It is particularly more relevant to Nigeria's development effort at this time when the government's development strategy seeks to emphasize the role of the market forces. It's potential for detailed representation of the working of a market economy, including the incorporation of the existing distortions, they offer a convenient Laboratory for evaluating the impact of policy alternatives in the pursuit of growth, efficiency, and equity in the distribution of income. This is a means of achieving sustainable long-term welfare gains in a competitive modern market economy that must be equipped to cope with the demand of the twenty-first century.

A CGE model is often characterized and structured by a detailed specification of major economic agents, the respective behavioural rules for these agents, the equilibrium conditions and, of course, the macroeconomic or institutional characteristics of the economy under consideration. To properly Analyse the policy impact of the domestic natural gas market liberalisation on macroeconomic performance, given the interrelationship between energy and other production sectors, a comprehensive analysis needs to be employed. Such an analysis is expected to explicitly account for the linkages between sectors and consider the responsiveness of producers and consumers to changes in the domestic natural gas market structure. Over time, there have been several CGE models applied on different policy related issues in Nigeria.[49]

The CGE model adopted in this study follows the structure developed by Decaluwe, et al (2010). There are several important distinguishing features of the CGE model used in this study. First, the model identifies the structural feedback mechanism between the natural

[49] See Adenikinju*et al.*, (2009); Taylor *et al.*, (1983); Adenikinju (1994); Iwayemi and Adenikinju (1996); Olaniyan (2000); Aminu (2006); and Oyerenti (2006).

gas sector and the other energy and non-energy sectors. Also, the model assumes three commodities for natural gas sector activity following the strategic domestic product differentiation in the sector.

4.3.3a Model database: Social Accounting Matrix (SAM)

The Social Accounting Matrix (SAM) provides the organizing framework for all the CGE models. It is used to describe the flow-of-funds account of the separate institution or 'actors' in the economy that one may wish to distinguish (See Dervis de Melo and Robinson 1982). A SAM is a square matrix comprising of rows and columns that represent the different activities, commodities, agents, and institutions of an economy. Each cell in the matrix represents the flow of economic activities in monetary terms from a column account to a row account (Nwafor et al., 2010). Given its design, it provides a snapshot of a given economy, usually for a given year. By convention, it is expected that the total revenue (row account) equals total expenditure (column account). Thus, the SAM explicitly represents the initial equilibrium, or market clearing conditions in the economy, and therefore, can be seen as a baseline measurement of the general equilibrium interactions in the economy for a particular year.

Conceptually, a SAM is an accounting system that gives a comprehensive account of all incomes and expenditures by source and destination. It provides a comprehensive and detailed framework for the systematic and integrated recording of transaction flows in an economy. It brings together, into an articulated and coherent system, data ranging in degree of aggregation from consolidated accounts of the nation to detailed input-output data in a way that is useful for macroeconomic analysis and policy planning. It serves as the building structure for CGE models (Adenikinju and Chitiga, 2009).

The 2014 Nigeria's SAM adapted for this study was built for the dynamic CGE model that examined the energy sector growth and reform policies in the country. In its original format, besides other features, the 2014 Nigeria's SAM has forty-six productive sectors and six household types; however, the SAM was modified to suit the current study. The re-aggregation done was motivated by the objectives of the study. Also, given the interest

of this study to Analyse the impact of policy (natural gas market liberalisation), a new feature (natural gas) is added to the original SAM (in the original SAM it was Oil and Gas sector). In sum, the current study's aggregated SAM has nine (9) productive sectors, two factors of production, six household categories, three tax accounts, a firm, government, savings and investment, and the rest of the world (ROW) accounts.[50] The subsections that follow present the structure of the modified SAM for Nigeria used in this study and an analysis of the SAM. Some parameters in the model will be calibrated while other remaining parameters will be adapted from existing literature reflecting reasonable values in the context of this study.

[50] See the appendix for details of the aggregation

Table 4.1. Macro SAM for Nigeria, 2014 (Current trillion Naira).

	Act.	H/H	Firm	GVT	Taxes	Indus.	Com	ROW	S - I	VSTK	Total
Activity						56.775					**56.775**
H/Holds	33.593		8.114	0.005							**41.712**
Firm	14.7502										**14.752**
GVT					7.623						**7.623**
Taxes		2.628	4.436				0.569				**7.623**
Indus.							81.465	14.014			**95.479**
Comm.		38.710		4.832		38.704			7.782	1.378	**91.406**
ROW	8.430		0.738				9.372	14.014			**32.554**
S - I		0.374	1.474	2.786				4.526			**9.160**
VSTK									1.378		**1.378**
Total	**56.775**	**41.712**	**14.752**	**7.623**	**7.623**	**95.479**	**91.406**	**32.554**	**9.160**	**1.378**	**358.462**

4.3.3b Analysis of the SAM

i) Activities and commodities account.

A distinction is made between "activity" and "commodity" accounts. The activity accounts correspond to the output-producing sectors in the economy, while the commodity accounts are those goods and services produced by the activity sector. In aggregate, the commodity accounts combine domestic commodity supply with imports to yield a Total supply to the domestic market or absorption is made up of an aggregate combination of total domestic commodity supply and total imports. In this SAM, export is sold directly to the "rest of the world" (ROW) by the producers (activities), hence, not included in the "commodity" accounts. Thus, there are nine commodities accounts. The total production of the activity sector is derived from the combination of value added (factors of production), and intermediate consumption.

ii) Domestic institutions

The SAM has three domestic institutions, namely: households, firm, and government. The activities (income and expenditure flow) of these institutions are discussed below.

(a) Households

The SAM for this study has six categories. The households were first aggregated into two (urban and rural households), after that, each category was split into non-poor, moderate-poor, and core-poor based on the data obtained from the 2010 Harmonized Nigerian Living Standard Survey (HNLSS). The categories of the households are, thus: Rural Non-Poor (RNP), Rural Moderate-Poor (RMP), Rural Core-Poor (RCP), Urban Non-Poor (UNP), Urban Moderate-Poor (UMP) and Urban Core-Poor (UCP) households. As shown in table 4.1, these households' aggregate income amounting to (N41.712 Trillion) is made up of capital incomes (N8.114), labour income of (N33.593) and transfers from the government (0.005). Households spend their income on consumption of the various goods and services produced (N38.710) direct taxes to the government (N2.628) and savings of (N0.374).

(b) Firms

The "firms" account included in the 2014 Nigerian SAM is aggregated. Their earned income in the form of profits (N14.752), is distributed to households (N8.114), and government (in the form of taxes) (4.426), ROW (0.738) AND savings (1.475). It should be noted that the share of firms' profits received by households is being accounted for in the "capital column".

(c) Government

The government derives its revenue from taxes, profits from the capital, and transfer payments from ROW (such as returns to foreign grants, development assistance, and foreign investments). From the table 4.1 above, the amount derived from the households' direct taxes is (N2.628), from the Firm (N4.426) and from indirect (production) taxes on commodities (N0.569) respectively. Of this lump sum, the share of firm tax (58.06 percent) is the largest. While the least share (7.46 percent) is from indirect (production) taxes from commodities. While observing the different sources of government income and their shares, it is important to understand the government expenditure pattern. The SAM shows that government spends its income on consumption of commodities (N4.832), transfer to households (N0.005), and savings (N2.785).

iii) Rest of the world (ROW) and international trade.

The ROW account, also called foreign account, summarizes the economic interactions between the domestic economy and the other economies of the world. These interactions are in the form of trade (imports and exports), transfers and profits from the capital. In the SAM, the total value of imports is N9.372. On the export side, the total value of export is (N14.014). While the export of crude oil (N1.800) has the largest share in total export, electricity (N0.001) had the least. Besides its earnings from imports, the ROW receives capital income (N8.430) given that some capital employed in domestic production is owned by foreign firms. As regards expenditure, ROW spends their income on the purchase of exported commodities (N14.014) and savings (N4.526).

iv) Savings and investment

The account for "savings and investment" depicts the various sources of savings that are used for domestic investment financing. The total savings in the economy are made up of foreign and domestic savings. Domestic savings include savings from households (N0.374), firm (N1.474) and the government (N2.786). Foreign savings reflect the status of the country's current account balance which is estimated at a surplus of N4.526. This implies that foreign outflows exceed foreign inflow; also, that the country's total expenditure (in terms of investment demand and final consumption) is less than the country's total income.

4.3.4 Model Framework and Structure

This section analyses briefly the basic characteristic/structure and presents the mathematical/analytical framework of the model that will be adopted in this study. The model collapses the economy into six major blocks, namely: (i) the production block; (ii) the demand block; (iii) the commodity supply and international trade block; (iv) the price block; (v) the income and saving block; and (vi) the welfare block. The model will build equations meant to capture the behaviours and interactions between these components. The various model blocks are described briefly below:

(i). The Production Block

The production structure of this model entails producers' behaviour in the economy. Each sector is assumed to behave as a single representative firm producing a single homogeneous product. These outputs of the producers may be consumed domestically (as final good or as intermediate inputs in the production of other goods), or simply exported. Firms are assumed to operate in a perfectly competitive environment. So each industry’s representative firm maximizes profit subject is its production technology, while it considers the price of goods and services, and factors as given (price taken behaviour). This block also defines the production technology, and demand for factors as well as the constant elasticity of transformation (CET) functions. Combining export and domestic sales. The chart below describes, following conventional modelling practice, the specified nested structure of production to be adopted for this study.

At the top level, the sectoral output of each productive activity ***j*** combines value added and total intermediate consumption in fixed shares. In other words, the two aggregate inputs are considered to be strictly complementary, without any possibility of substitution, following a Leontief production function. At the second level, aggregate intermediate consumption consists of various intermediate inputs assumed to be perfectly complementary (with no possibility of substitution) and combined following Leontief technology. On the value-added side, each sectors' value added is a constant elasticity of substitution (CES) combination of labour and composite capital-energy. The bottom level reveals the *CES* combination of the two capital categories (capital and energy input). It is assumed that the capital categories are imperfect substitutes. Energy types – natural gas, crude oil, and electricity are Leontief aggregates. This block defines the production technology and demand for factors as well as a CET function combining export and domestic sales.

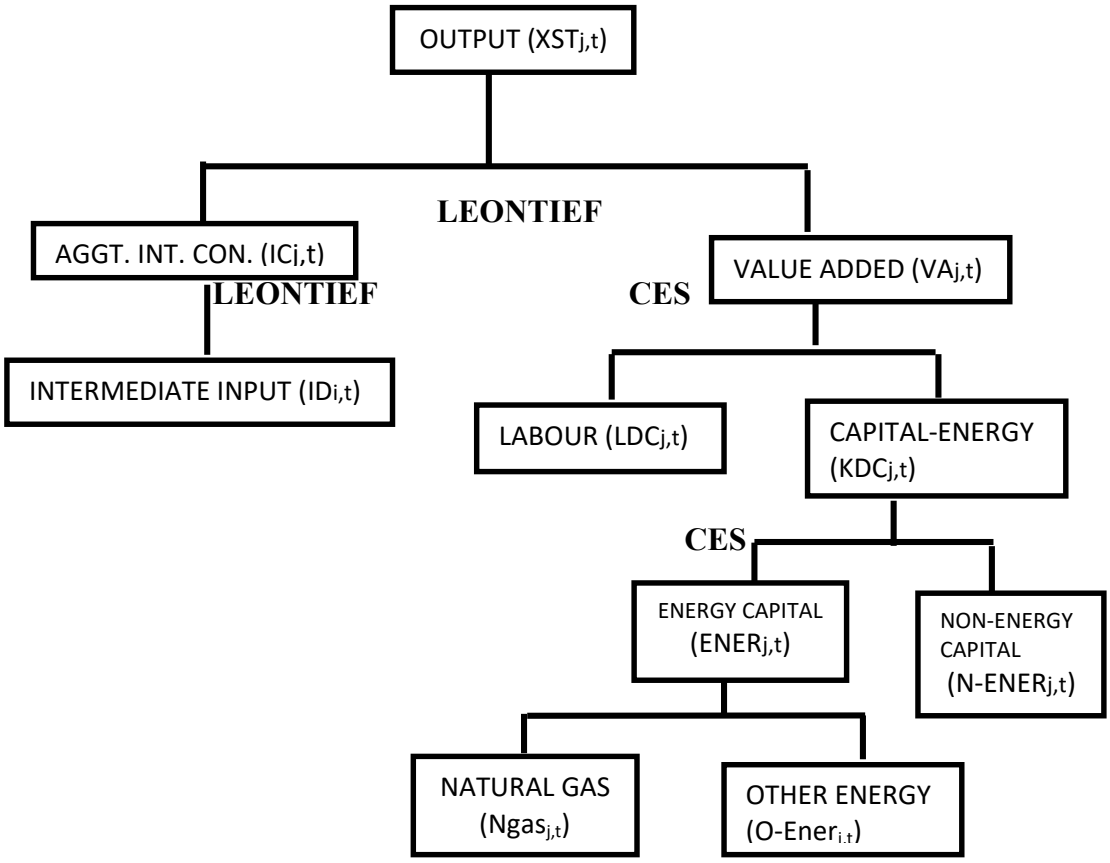

Figure 4.3: Nested production function.

Source: Sketched by author, 2017**.**

(ii). The Demand Block

Domestic demand is made up of the sum of demands for household consumption, government consumption, investment consumption, intermediate inputs, and transaction inputs. The total domestic market demand is for composite commodity made up of imports and domestic output, the demand for which is derived on the assumption that domestic demanders minimize cost subject to imperfect substitutability. Total market demand comprises of total imported commodities that cannot be produced domestically and domestic output for non-imported commodities. This model employs the small open economy assumption, implying that export supply and import demand are infinitely elastic at given world prices. Nigeria, it is assumed, do not command market power in both the export and import markets. The intermediate demand is assumed on a fixed input-output coefficient. The government used tax tools such as tariffs, export taxes/producer fees to raise revenue and inject the same into the economy in the form of government consumption including public investment are assumed to be exogenous. Household demand for each good is characterized by Stone-Geary utility functions subject to a budget constraint. Unlike the conventional Cobb-Douglas utility function, this specification offers a degree of flexibility with respect to substitution possibilities in response to relative price changes. As for investment expenditure, the quantity demanded of each commodity for investment purposes is inversely related to its purchasers' price. The same is assumed of government current expenditure on goods and services.

(iii). The Commodity Supply and International Trade Block

In this section, we considered the trade relations with the rest of the world, that is, the supply for export and the demand for import. This is essential because international trade plays a significant role in the economy. The model is structured to capture the imperfect substitution between domestic goods and imports, and between productions for the domestic market and export market.

The model specified domestic buyers' behaviour with respects to the different supply sources and domestic producers' supply behaviour. The producer's supply behaviour comprises of how composite output translates into the supply of products and how the

supply of each product is directed to destination markets. The small- country hypothesis will be adapted assuming that the world price of traded goods (imports and exports) is exogenous. All commodities (domestic output and imports), except for home-consumed output, enter markets. The domestic output may be sold in the market or consumed at home. Producers make an optimal distribution of their products between export and domestic sales, according to a constant elasticity of transformation (CET) function. The imperfect substitutability between the import and export demand is represented by a constant elasticity of substitution (CES) aggregator function.[51]

[51] See the Armington (1969) assumptions.

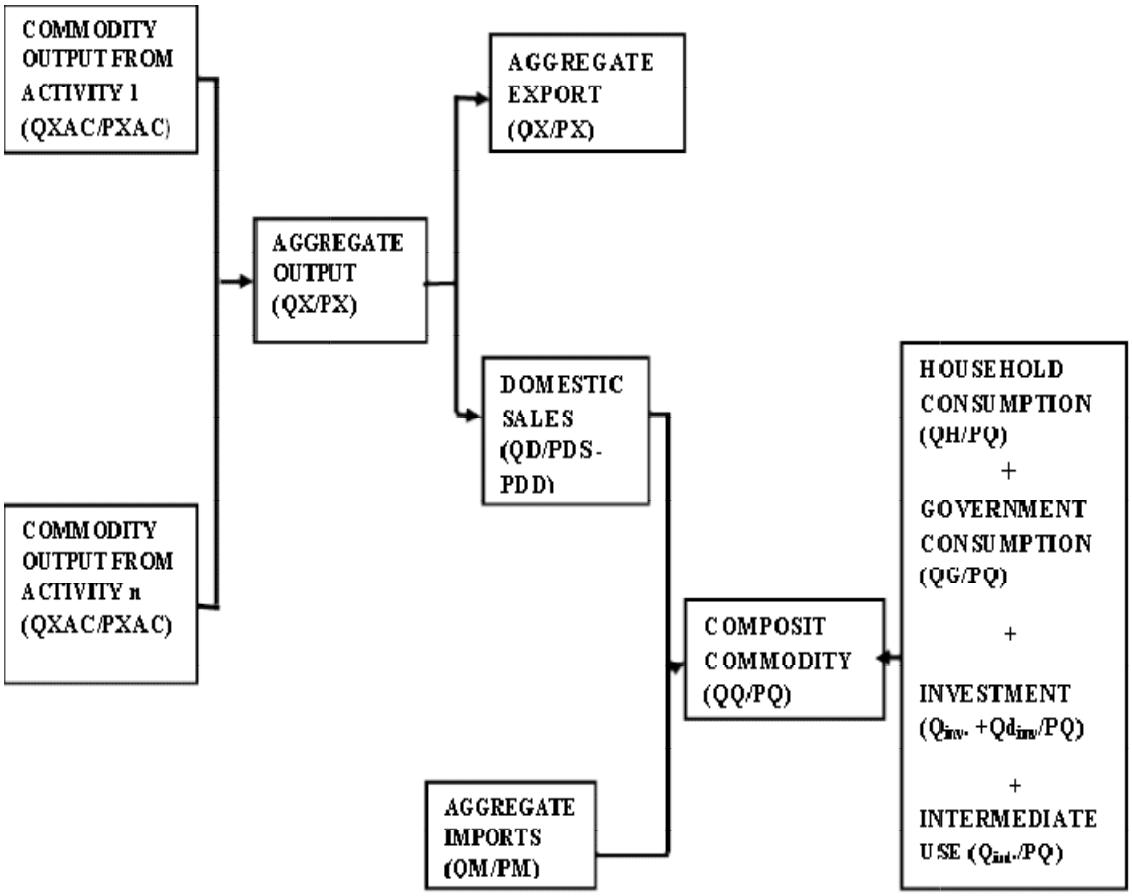

Figure 4.4 Commodity flows.

Source: Adapted from IFPRI (2001).

(iv). The Price Block

Here, the equation relating to prices such as import prices, export prices, output prices will be considered. The different price indexes naturally depend on the hypothesis and the functional form earlier mentioned. In aggregations, the price of an aggregate is a weighted sum of the prices of its components. The weights are determined by equating the value of the aggregator to the sum of the values of its components, given the quantity of the aggregate. The weight assigned to the price of each component is, therefore, the ratio of its volume (or quantity) to the volume (or quantity) of the aggregate. Only in Leontief fixed-proportions aggregations are the weights invariant to relative price changes; in other cases, component proportions, and consequently, component price weight change in response to relative price changes, and they change more or less sharply, depending on the elasticity of substitution or transformation.

(v). The Income and Savings Block

This section highlights the behaviour of the firm, households, government, and the rest of the world (ROW). It is assumed that the households generate their income from the supply of production factors; labour and capital. In return, they receive dividends from enterprises, government transfers, and remittances. Also, the government institution is portrayed as following the specified rule of behaviour. With the government in this model taxes and tariffs are introduced. The Government collects revenue from taxes on factors (direct taxes) and products (indirect taxes), and transfers from other agents which make up its income. Firms' income is made up of the sale of its goods in the domestic and/or export markets.

Lastly, the rest of the world (ROW) brings in the issue of the balance of trade. The theoretical coherent treatment of the balance of trade in CGE models is assumed to be exogenous and the resulting flow is identified as foreign saving (Robinson, 2003). The inclusion of export and imports also raises their concern of how the receipt-expenditure account of the rest of the world (ROW), the current account, is brought into balance. The current account balance expressed in foreign currency imposes equality between the country's earnings and its spending of foreign exchange. Also, household transfer to non-

government agents and firms are proportional to the disposable income of households and firms respectively.

4.4 Model description and linkages: Analytical and mathematical specifications.

The CGE equation specifications were structured in line with the SAM to show the structure and linkages in the economy. The model has seven blocks which include: production, income and savings, demand, international trade, prices, equilibrium, and dynamic equations blocks. It is worth noting that the current model follows closely the standard PEP 1-t model as developed by Decaluwe*et al.*, (2010), save for some few modifications to some equation specifications.

4.4a. Production.

The model identifies nine (9) productive sectors or activities. A multi-level cascading specification of the production process is adopted. At the top level (equations 4.38 and 4.39), the sectoral output of each productive activity ***j*** combines value added and total intermediate consumption in fixed shares. In other words, the two aggregate inputs are considered to be strictly complementary, without any possibility of substitution, following a Leontief production function. At the second level, each industry's value-added consists of composite capital and composite labour, following a constant elasticity of substitution (CES) specification of quantities employed of labour and capital (equation 4.40). It is worth pointing out here that in the extractive sector (including Natural gas, crude oil, and mining sectors), a lower substitution between capital and labour is allowed to capture the upward trend in both investment and capital stock growth in the sector. Without this treatment, labour demand grows at the expense of capital demand. (See Nwafor et al., 2010).

Profit maximization (or cost minimization) by the firms leads them to employ labour and capital to the point where the marginal value product of each is equal to its price (the wage rate and the rental rate of capital respectively) at the bottom level. With a CES production function, such behaviour is described by the demand for labour relative to capital of equation (4.42), and also equation (4.43) which specifies the demand for capital. Again, it

is assumed that, at the bottom level, intermediate inputs are perfectly complementary and are combined following a Leontief production function, no substitution is possible. Producer's, supplier behaviour is represented by the nested constant elasticity of transformation (CET) functions. Producers allocate output among products to maximize sales revenue, given product price, using a CET. Although an industry can recognize its production of goods produced in response to price changes, different products are not perfectly transformable to each other. For individual product supply functions, they are derived from the first-order conditions of revenue-maximizing behaviour.

The resulting equations are:

$$CI_{j,t} = io_j XST_{j,t} \tag{4.38}$$

$$VA_{j,t} = v_j \ XST_{j,t} \tag{4.39}$$

$$VA_{j,t} = B_j^{VA}\left[\beta_j^{VA} LDC_{j,t}^{-p_j^{VA}}\right] + \left(1-\beta_j^{VA}\right) KDC_{j,t}^{-p_j^{VA}} \tag{4.40}$$

$$LD_{l,j,t} = \left[\frac{\beta_{l,j}^{LD} WC_{j,t}}{WTI_{l,j,t}}\right]^{\sigma_j^{LD}} \left(B_j^{LD}\right)^{\sigma_j^{LD}-1} LDC_{j,t} \tag{4.41}$$

$$KD_{k,j,t} = \left[\frac{\beta_{k,j}^{KD} RC_{j,t}}{RTI_{k,j,t}}\right]^{\sigma_j^{KD}} \left(B_j^{KD}\right)^{\sigma_j^{KD}-1} KDC_{j,t} \tag{4.42}$$

$$DI_{i,j,t} = aij_{i,j} CI_{j,t} \tag{4.43}$$

Where:

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

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

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

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

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

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

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

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

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

io_j : Coefficient (Leontief- intermediate consumption)

v_j : Coefficient (Leontief - value added)

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

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

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

$B_{k,j}^{KD}$: Shareparameter (CES-composite capital)

$B_{j,i}^{XT}$: Shareparameter(CET-total output)

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

ρ_j^{VA} : Elasticity parameter (CES - value added) *; —I* $< p_j^{VA} / < \infty$

ρ_j^{KD} : Elasticityparameter(CES-composite capital); $1 < p_j^{KD} < \infty$

σ_j^{VA} : Elasticity of transformation (CES-value added); $0 < \sigma_j^{VA} < \infty$

σ_j^{KD}: Elasticity of substitution (CES-composite capital); $0 < \sigma_j^{KD} < \infty$

σ_j^{XT}: Elasticity of transformation (CET-total output); $0 < \sigma_j^{XT} < \infty$

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

4.4b Income and Savings

(b.1). Households

Households are modelled as representative agents that are assumed to have Stone-Gary type of preferences. Household incomes come from three sources: labour income, capital income, and transfers received from other agents (equation 4.44). Each household category receives a fixed share of the earnings from labour (equation 4.45). Similarly, total capital income is distributed in fixed proportions between all agents, including households, (equation 4.46). Furthermore, transfer income, simply, is the sum of all transfers received by type *h* households (equation 4.47). Subtracting direct taxes and household transfers to government yields the disposable income of the type *h* household (equation 4.48). Our calculations of disposable income are indeed consistent with national

accounts since household transfers to the government are mostly contributions to various social programs. Whatever disposable income is left after savings and transfers to other agents is entirely dedicated to consumption (equation 4.49).

Finally, household savings are a linear function of disposable income rather than a fixed proportion of income. By contrast, (equation 4.50) allows for the average propensity to save to be different from the marginal propensity to save. This choice is motivated by the fact that it is common for certain categories of the household to have negative savings.
The resulting equations are:

$$YH_{h,t} = YH_{h,t,} + YHK_{h,t} + YHTR_{h,t} \quad (4.44)$$

$$YHL_{h,t} = \sum_{l} \lambda_{h,l}^{WL} \left(W_{l,t} \sum_{j} LD_{l,j,t} \right) \quad (4.45)$$

$$YHK_{h,t} = \sum_{k} \lambda_{h,k}^{RK} \left(\sum_{j} R_{k,j,t} KD_{k,j,t} \right) \quad (4.46)$$

$$YHTR_{h,t} = \sum_{ag} TR_{h,ag,t} \quad (4.47)$$

$$YDH_{h,t} = YH_{h,t} - TDH_{h,t} - TR_{gvt,h,t} \quad (4.48)$$

$$CTH_{h,t} = YDH_{h,t} - SH_{h,t} - \sum_{agng} TR_{agng,h,t} \quad (4.49)$$

$$SH_{h,t} = PIXCON^{\eta_t} sh0_{h,t} + sh1_{h,t} YDH_{h,t} \quad (4.50)$$

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_h^{WL} : 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;

$agng \in AGNG \subset AG = H \cup F \cup \{ROW\} = \{H_1,...,H_h,...,F,ROW\}$

(b.2). Firms

Firms' income in this model, is made up of its share of capital income, and transfers received from other agents (equation 4.51). Subtracting the firms' income taxes from the firm's total income yields the disposable income of the firm (equation 4.52). Likewise, firms' savings are the residual that remains after subtracting transfers to other agents from disposable income (equation 4.53).

$$YF_{f,t} = YFK_{f,t} + YFTR_{f,t} \tag{4.51}$$

Given that: $YFK_{f,t} = \sum_k \lambda_{f,k}^{RK} \left(\sum_j R_{k,j,t} KD_{k,j,t} \right)$ and $YFTR_{f,t} = \sum_{ag} TR_{f,ag,t}$

$$YDF_{f,t} = YF_{f,t} - TDF_{f,t} \tag{4.52}$$

$$SF_{f,t} = YDF_{f,t} - \sum_{ag} TR_{ag,f,t} \tag{4.53}$$

Where:

$YF_{f,t}$: Total receipt (income) of type *f* firm

$YFK_{f,t}$: Capital receipt (income) of type *f* firm

$YFTR_{f,t}$ Transfer earnings of type *f* firm

$SF_{f,t}$: Savings of type *f* firm

$TD_{f,t}$: Income taxes of type *f* firm

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

(b.3) Government

The income of government is drawn from direct taxes on household and firms, indirect taxes on products and imports *(TPRCTS),* and other taxes, on production*(TPRODN).* It also earns capital income and receives transfers from the rest of the world (ROW). Equations (4.54 to 4.67) describe different government revenue sources. It should be noted that income taxes (for households – equation 4.68, and firms – equation 4.69) has been modelled as a linear function of total income. With that, the marginal tax rate when a non-zero intercept is applied. This proves useful in simulating scenarios in which fiscal policy changes through time. The government implements two types of taxes on the product in this model. The first shows how these taxes are levied on non-imported and imported products (equations 4.73, and 4.74, respectively), while the second shows government revenue from import duties on commodities (equation 4.75). Government savings (equation 4.76) are given by the difference between its revenue and expenditure, which comprises the consumption of goods and services (taken as fixed) and transfer to other agents, and subsidy.

$$YG_t = YGK_t + TDHT_t + TDFT_t + TPRODN \sum_j R\, R_{k,j,t^t} + TPRCTS_t + YGTR_t \quad (4.54)$$

$$YGK_t = \sum_k \lambda_{gvt,k}^{RK} \left[\sum_j R_{k,j,t} KD_{k,j,t} \right] \quad (4.55)$$

$$TDHT_t = \sum_h TDH_{h,t} \quad (4.56)$$

$$\text{TDFT}_t = \sum_f TDF_{f,t} \quad (4.57)$$

$$TPRODN_t = TIWT_t + TIKT_t + TIPT_t \tag{4.58}$$

$$TIWT_t = \sum_{i,j} TIW_{i,j,t} \tag{4.59}$$

$$TIKT_t = \sum_{k,j} TIK_{k,j,t} \tag{4.60}$$

$$TIPT_t = \sum_{j} TIP_{j,t} \tag{4.61}$$

$$TPRCTS_t = TICT_t + TIMT_t + TIXT_t \tag{4.62}$$

$$TICT_t = \sum_{i} TIC_{i,t} \tag{4.63}$$

$$TIMT_t = \sum_{m} TIM_{m,t} \tag{4.64}$$

$$TIX_t = \sum_{x} TIX_{x,t} \tag{4.65}$$

$$YGTR_t = \sum_{agng} TR_{gvt,agng,t} \tag{4.66}$$

$$TDH_{h,t} = PIXCON_t^{\eta} ttfh0_{h,t} + ttdh1_{h,t} YH_{h,t} \tag{4.67}$$

$$TDF_{f,t} = PIXCON_t^{\eta} ttdf0_{h,t} + ttdh1_{f,t} YFK_{f,t} \tag{4.68}$$

$$TIW_{i,j,t} = ttiw_{i,j,t} W_{i,t} ID_{i,j,k} \tag{4.69}$$

$$TIK_{k,j,t} = ttik_{k,j,t} R_{k,j,t} KD_{k,j,t} \tag{4.70}$$

$$TIP_{j,t} = ttip_{j,t} PP_{j,t} XS_{j,t} \tag{4.71}$$

$$TIC_{nm,t} = ttic_{nm,t} \left(PL_{nm,t} + \sum_i PC_{i,t}^{tmrg_{i,nm}} \right) DD_{nm,t} \tag{4.72}$$

$$TIC_{m,t} = ttic_{m,t} \left[\begin{array}{l} \left(PL_{m,t} + \sum_i PC_{i,t}^{tmrg_{i,m}} \right) DD_{m,t} \\ + \left(\left(1 + ttim_{m,t}\right) PWM_{m,t} e_t + \sum_i PC_{i,t}^{tmrg_{i,m}} \right) \mid IM_{m,t} \end{array} \right] \tag{4.73}$$

$$TIM_{m.t} = ttim_{m,t} PWM_{m,t} e_t IM_{m,t} \tag{4.74}$$

$$TIX_{,t} = ttix_{i,t} \left(PE_{i,t} + \sum_{ij} PC_{ij,t}^{tmrg_{ij,i}^{X}} \right) EXD_{i,t} \tag{4.75}$$

$$SG_t = YG_t - \sum_h TR_{h,gvt,t} - G_t - SUB_t \tag{4.76}$$

Where:

$TDFT_t$:	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 the product *i*
$TICT_t$:	Total government receipts of indirect taxes on commodities
$TIK_{k,j,\ t}$:	Government revenue from taxes on capital
$TIKT_t$:	Total government revenue from taxes on capital
$TIM_{m.t}$:	Government revenue from import duties on product *m*
$TIMT_t$:	Total government revenue from import duties
$TIPT_t$:	Government revenue from taxes on production (excluding taxes directly related to the use of capital and labour)
$TIW_{l,j,\ t}$:	Government revenue from payroll taxes on type I labour.
$TIWT_t$:	Total government revenue from payroll taxes
$TIX_{x,\ t}$:	Government revenue from export taxes on product *x*
$TIXT_t$:	Total government revenue from export taxes
$TPRCTS_t$:	Total government revenue from taxes on products and imports
$TPRODN_t$:	Total government revenue from other taxes on production
YG_t:	Total government revenue
YGK_t:	Government capital income
$YGTR_t$:	Government transfer income
$Ttdf0_{f,t}$:	Intercept (income taxes of firm)
$Ttdf1_f$:	Marginal income tax rate of the firm
$Ttdh0_{h,\ t}$:	Intercept (income taxes of type *h* households)
$Ttdh1_h$:	Marginal income tax rate of type *h* households
$PP_{j,}$ t:	Industry *j* unit cost, including taxes directly related to the use of capital and labour, but excluding other taxes, on production
$ttik_{k,j,\ t}$:	*Tax* rate on type *k* capital used in industry *j*
$ttip_{j,\ t}$:	*Tax* rate for the production of industry *j*
$ttiwl_{j,\ t}$:	Tax rate on type *l* worker compensation in industry *j*
DD. :	Domestic demand for commodity *i* produced locally
e_t:	Exchange rate: the price of foreign currency in terms of local currency

$EXD_{x,t}$: Quantity of product x exported

$IM_{m,t}$: Quantity of product m imported

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

$PE_{x.t}$: Price received for export commodity x (excluding export taxes)

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

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

$ttic_{i,t}$: The tax rate on commodity i

$ttim_{m.t}$: Rate of taxes and duties on imports of commodity m

$ttix_{i.t.}$: Export tax rate on exported commodity i

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

$tmrg^{X}_{i,x}$: Rate of margin i applied to export x

SG_t: Government savings

G_t: Current government expenditures on goods and services

(b.4). Rest of the world (ROW)

The rest of the world (ROW) receives payments for the value of imports, transfers from domestic agents and part of the income of capital, (equation 4.77). Foreign spending in the domestic economy consists of the value of exports and transfers to domestic agents. The difference between foreign spending and receipts is the amount of rest-of-the-world savings (equation 4.78), which are equal in absolute value to the current account balance, but of the opposite sign (equation 4.79).

$$YROW_t = e_t \sum_m PWM_{m.t} IM_{m,t} + \sum_k \lambda^{RK}_{row,k} \left(\sum_j R_{k,j,t} KD_{k,j,t} \right) + \sum_{agd} TR_{row,agd,t} \quad (4.77)$$

$$SROW_t = YROW_t - \sum_x PE_{x,t}^{FOB} EXD_{x,t} - \sum_{agd} TR_{agd,row,t} \quad (4.78)$$

$$SROW_t = CAB_t \quad (4.79)$$

Where:

CAB_t: Current account balance

$PE_{x,t}$: Exported commodity x (in local currency)

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

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

(b.5). Transfers

This model has two transfer equations: governments' transfer to households (equation 4.80), and transfer from ROW to domestic agents (governments and households) (equation 4.81) these transfers are initially set equal to their SAM values, and they grow each period at the same rate $\boldsymbol{n_t}$ as a population index $\boldsymbol{pop_t}$, and are indexed, partially or fully to the consumer price index.

$$TR_{h,gvt,t} = PIXCON^{\eta}{}_t \, TR^{O}{}_{h,gvt,} pop_t \tag{4.80}$$

$$TR_{agd,row,t} = PIXCON^{\eta}{}_t \, TR^{O}{}_{agd,row} \, pop_t \tag{4.81}$$

Where:

pop_t: Population index

4.4c. Demand

The demand for goods and services, whether domestically produced or imported, consists of intermediate demand, household consumption demand, investment demand, demand by public administrations, in this model. It is assumed that households have a Stone-Geary utility function (which derives from the Linear Expenditure System). Type *h* household demand for each good (equation 4.82) is determined by utility maximization subject to the budget constraint.

Investment demand includes both gross fixed capital formation (GFCF) and changes in inventories. GFCF expenditure is obtained by subtracting the cost of changes in inventories from total investment expenditure (equation 4.83). Total investment expenditure which includes both private and public investments are distributed among

commodities in fixed shares (equation 4.84 and 4.85).[52] The final demand for each commodity *i* for investment purposes is the sum of the quantity demanded for private and public investment (equation 4.86). (Equation 4.87) shows government consumption. Finally, in this block, since goods and services are also used as inputs in the production process, activity sectors also demand for investment goods. Hence, the intermediate demand (equation 4.88) for each commodity is given by the sum of industry demand.

$$PC_{i,t}\, C_{i,h,t} = PC_{i,t}\, C^{MIN}{}_{i,h,t} + \gamma^{LES}{}_{i,h}\left(CTH_{h,t} - \sum_{ij} PC_{ij,t} C^{MIN}{}_{ij,h,t} \right) \quad (4.82)$$

$$GFCF_t = IT_t - \sum_i PC_{i,t} VSTK_{i,t} \quad (4.83)$$

$$PC_{i,t} INV_{i,t}{}^{PRI} = \gamma_i^{INVPRI}\, IT_t^{PUB} \quad (4.84)$$

$$PC_{i,t} INV_{i,t}{}^{PUB} = \gamma_i^{INVPUB}\, IT_{i,t}{}^{PUB} \quad (4.85)$$

$$INV_{i,t} = INV_{i,t}{}^{PRI} + INV_{i,t}{}^{PUB} \quad (4.86)$$

$$PC_{i,t} CG_{i,t} = \gamma_i^{GVT} = \gamma_i^{GVT} G_t \quad (4.87)$$

$$DIT_{i,t} = \sum_j DI_{i,j,t} \quad (4.88)$$

Where:

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

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

$GFCF_{\ t}$: Gross fixed capital formation

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

$INV_{\ i.t.}$ Purchaser price of composite commodity *i* (including all taxes and margins)

$INV_{i,t}{}^{PR}\ I$: Final demand for commodity *i* for private investment purposes

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

IT_t: Total investment expenditures

IT_i^{PRI}: Total private investment expenditures

$IT_T{}^{PUB}$: Total public investment expenditures

[52] For the given amount of expenditures (both private and public), the quantity demanded of each commodity *I* for investment purpose is inversely related to its purchaser's price. This also applies to government current expenditure on commodities.

$VSTK_{i.t}$: Inventory change of commodity *i*

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

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

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

γ_t^{INVPRI} : Share of commodity *i* in total private investment expenditure

γ_i^{INVPUB} : Share of commodity *i* in total public investment expenditure

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

4.4d. International trade

In this block, we define the trade relations with the rest of the world, that is, the supply of exports and the demand for imports. This is achieved by specifying domestic buyers' behaviour for the different supply sources, and domestic producers' supply behaviour. The small-country hypothesis is adopted, in the sense that the world price of traded goods (imports and exports) is exogenous. Producers make distribution of their production between export and domestic sales according to a constant elasticity of transformation (CET) function that describes how easily the product-mix .can be adjusted in response to price changes (equation 4.89). For products that are not exported, the total output is equal to supply on the domestic market (equation 4.90). The world demand for export is given by (equation 4.92).

As with the producer, on the demand side, the relationship between the rest of the world (ROW) and the domestic economy is based on the standard *Armington* assumption of imperfect substitution between imports and domestically produced goods. Therefore, buyers assume that local products are imperfect substitutes for imports. This, however, does not hold true for the demand for natural gas (LPG) and refined oil – where no perfect distinction is made between imports and domestic refined oil. The commodities demanded in the domestic market are combinations of locally produced goods and imports. This assumption is represented by a constant elasticity of transformation (CET) aggregator function (equation 4.93). However, for goods with no competition for imports, the demand

for the composite commodity is the demand for the domestically produced good (equation 4.94). Finally, buyers maximize expenses, subject to the CET aggregation function; thus, the quantity of product *m* imported is given by equation 4.95.

$$XS_{j,x,t} = B_{j,x}{}^{X}\left[\beta_{j,x} EX_{j,x,t}{}^{p_{j,x}{}^{x}} + \left(1-\beta_{j,x}{}^{X}\right) DS_{j,x,t}{}^{p_{j,x}{}^{x}}\right]^{\frac{1}{p_{i,x}{}^{x}}} \tag{4.89}$$

$$XS_{j,nx,t} = DS_{j,nx,t} \tag{4.90}$$

$$EX_{j,x,t} = \left[\frac{1-\beta^{X}{}_{j,x}}{\beta^{X}{}_{j,x}} \frac{PE_{x,t}}{PL_{x,t}}\right]^{\sigma^{X}{}_{j,x}} DS_{j,x,i} \tag{4.91}$$

$$EXD_{x,t} = EXD_{x}{}^{O} pop_{t} \left[\frac{e_t PWX_{x,t}}{PE_{x,t}}\right]^{\sigma_{x}{}^{XD}} \tag{4.92}$$

$$Q_{m,t} = B_{m}{}^{M}\left[\beta_{m}{}^{M} IM_{m.t}{}^{-p_{m}{}^{M}} + \left(1-\beta_{m}{}^{M}\right) DD_{m,t}{}^{-p_{\frac{M}{m,i}}}\right]^{-p\ \frac{-1}{M}} \tag{4.93}$$

$$Q_{nm,t} = DD_{nm,t} \tag{4.94}$$

$$\mathrm{IM_{i,t}} = \left[\frac{\beta_{i}{}^{M}}{1-\beta_{i}{}^{M}} \frac{PD_{i,t}}{PM_{i,t}}\right]^{\sigma_{i}{}^{M}} DD_{i.t} \tag{4.95}$$

Where:

$XS_{j,I,t}$:	Industry *j* production of commodity *i*
B_{j}^{XT} :	Scale parameter (CET - total output)
$\mathrm{B_{j,i}{}^{xt}}$	Share parameter (CET - total output) '
P_{j}^{XT}:	Elasticity parameter (CET - total output) ; $1 < p_{j}^{XT} < \infty$
$\mathrm{p_{j,i,t}}$:	Basic price of industry *j's* production of commodity *i*
$\mathrm{DS_{j,i,t}}$:	Supply of commodity *i* by sector *j* to the domestic market
$\mathrm{EX_{j,I,t}}$:	Quantity of product *I* exported by sector *j*
$\mathrm{PM_{m,t:}}$	Price received for export commodity x (excluding all taxes and tariffs)
$\mathrm{B_{j,x}{}^{X}}$:	Scale parameter (CET-exports and local sales)
$\mathrm{B_{j,x}{}^{X}}$:	Share parameter (CET-exports and local scales)
$\mathrm{p_{j,x}{}^{X}}$:	Elasticity parameter (GET - exports and local sales) ; $1 < p_{j,x}{}^{X} < \infty$
$\sigma_{j}{}^{XT}$:	Elasticity of transformation (CET - total output) ; $0 < \sigma_{j}{}^{XT} < \infty$

$\sigma^{X}_{j,x}$: Elasticity of transformation (CET-exports and local sales); $0 < \sigma^{X}_{j,i} < \infty$

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

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

σ_x^{XD} : Price-elasticity of the world demand for exports of product *x*

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

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

σ_m^{M} Elasticity of substitution (CES-composite commodity); $0 < \sigma_m^{M} < \infty$.

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

B_m^{M}: Share parameter (CES - composite commodity)

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

p_m^{M} : Elasticity parameter (CES — composite commodity); $-1 < p_m^{M} < \infty$

4.4e. Prices

In this block, there three categories under which the price equations will be discussed. These include prices related to production, international trade, and price indexes.

(e.1). Production

In aggregation, the price of an aggregate is the weighted sum of the prices of its component. Thus, the unit cost of an industry's output is a weighted sum of the prices of value-added and aggregate intermediate consumption (equation 4.96). The same principle applies to the prices of other aggregates (equation 4.98 and 4.99). The price of the composite capital of the industry is given by equation 4.100. The basic price of production is obtained from the unit cost by adding taxes on production (equation4.97).

$$PP_{j,t} = \frac{PVA_{j,t}VA_{j,t} + PCI_{j,t}CI_{j,t}}{XST_{j,t}} \tag{4.96}$$

$$PT_{j,t}\left(1 + ttip_{j,t}\right)PP_{j,t} \tag{4.97}$$

$$PCI_{j,t} = \frac{\sum_{i} PC_{i,t} DI_{l,j,t}}{CI_{j,t}} \quad (4.98)$$

$$PVA_{j,t} = \frac{WC_{j,t} LDC_{j,t} + RC_{j,t} KDC_{j,t}}{VA_{j,t}} \quad (4.99)$$

$$RC_{j.t} = \frac{\sum_{k} RTI_{k,j,t} KD_{k,j,t}}{KDC_{j,t}} \quad (4.100)$$

Where:

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

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

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

(e.2). International trade

Exporting industries have the possibility of selling their output on the domestic market or the international market. So the price of their aggregate production is a weighted sum of the price obtained in each market, following the price aggregation principle. The weight assigned each market is proportional to the quantity sold in that market (equation4.102); these weights vary in response to relative price changes, more or less sharply, depending on the elasticity of transformation in the CET. The basic price obtained by industry′ ***j*** for the product ***i*** is a weighted sum of its basic price on the domestic market and its basic price on the export market (equation 4.103).

$$PT_{j,t} = \frac{\sum_{i} P_{j,i,t} XS_{j,i,t}}{XST_{j,t}} \quad (4.101)$$

$$P_{j,i,t} = \frac{PE_{i,t} EX_{j,i,t} + PL_{i,t} DS_{j,i,t}}{XS_{j,i,t}} \quad (4.102)$$

$$P_{nx,t} = PL_{nx,t} \quad (4.103)$$

$$PD_{i,t} = \left(1 + ttic_{i,t}\right)\left(PL_{i,t} + \sum_{ij} PC_{ij,t} tmrg_{ij,t}\right) \quad (4.104)$$

$$PM_{m,t} = \left(1 + ttic_{m,t}\right)\left[\left(1 + ttim_{m,t}\right)e_t PWM_{m,t} + \sum_m PC_{m,t} tmrg_{m,t}\right] \quad (4.105)$$

$$PC_{m,t} = \frac{PM_{m,t} IM_{m,t} PD_{m,t} DD_{m,t}}{Q_{m,t}} \quad (4.106)$$

$$PC_{nm,t} = PD_{nm,t} \quad (4.107)$$

(e.3). Price indexes

Finally, the price indexes are, the GDP deflator (Fisher index) (equation 4.108), and the consumer price index (Laspeyres index) (equation 4.109)

$$\text{PIXGDP}\sqrt{\frac{\left(PVA_{j,t} + \frac{TIP_{j,t}}{VA_{j,t}}\right)VA_j{}^O}{\sum_j \left(PVA_j{}^O VA_j{}^O + TIP_j{}^O\right)}} \frac{\sum_j \left(PVA_{j,t} VA_{j,t} + TIP_{j,t}\right)}{\sum_j \left[PVA_j{}^O + \frac{TIP_{j,t}{}^O}{VA_j{}^O}\right]VA_{j,t}} \quad (4.108)$$

$$PIXCON_t = \frac{\sum_i PC_{i,t} \sum_h C_{i,h}{}^O}{\sum_{ij} PC_{ij}{}^O \sum_h C_{ij,h}{}^O} \quad (4.109)$$

Where:

$PIXGDP_t$: GDP deflator

4.4f. Equilibrium

This block presents the equations that describe equilibrium in the different markets. Whether it be for the goods and services market or the factor market, supply and demand equilibrium must be verified. Thus, equation (4.110) defines the equilibrium between the supply and demand of each commodity on the domestic market. This equation aids the verification of Walras law which states that if *n-1* markets are in equilibrium, then the last market is also in equilibrium. Equations (4.111 and 4.112)ensure the equilibrium between total demand for each factor and available supply of labour and capital respectively. Likewise, the total investment expenditure must be equal to the sum of agents' savings

(equation 4.113). Also, the sum of the different forms of investment expenditure must be equal to the total investment (equation 4.114). The sum of supplies of every commodity by local producers must be equal to domestic demand for that commodity produced locally (equation 4.115). And finally, supply to the export market of each good must be matched by demand (equation 4.116).

$$Q_{i,t} = \sum_{h} C_{i,h,t} + CG_{i,t} + INV_{i,t} + VSTK_{i,t} + DIT_{i,t} \quad (4.110)$$

$$\sum_{j} LD_{j,t} = LS_{t} \quad (4.111)$$

$$\sum_{j} KD_{k,j,t} = KS_{k,t} \quad (4.112)$$

$$IT_{t=\sum_{h} SH_{h,t}} + \sum_{f} SF_{f,t} + SG_{t} + SROW_{t} \quad (4.113)$$

$$IT_{t}^{PRI} = IT_{t} - IT_{t}^{PUB} - \sum_{i} PC_{i,t} VSTK_{i,t} \quad (4.114)$$

$$\sum_{j} DS_{j,i,t} = DD_{i.t} \quad (4.115)$$

$$\sum_{j} EX_{j,x,t} = DD_{x,t`} \quad (4.116)$$

Where:

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

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

IT_{t} : Total investment expenditure

GDP (equation 4.117) computed is not an equilibrium condition. It is made up of payments to factors, plus taxes on production, and taxes on products and imports.

$$GDP_{t}^{MP} = GDP_{r}^{MP} = GDP_{t}^{BP} + TPRCTS_{t} + TPRCTS_{t} \quad (4.117)$$

Where:

GDP_{t}: Gross Domestic Product

4.4g. Dynamic Equations

The dynamic equations describe the between-period relationships in the model. Two key drivers have been identified at the heart of CGE modelling. The first driver in the model is 'population' captured by a population index $pop_{t,}$ assumed to grow each period at a rate n_t thus, we have $pop = pop_{t-1}(1+n_{t-1})$. This is used in the model to update the values of variables and parameters that are assumed to grow at that rate. The variables include labour supply, current account balance, minimum consumption of commodities in the LES demand system, government current expenditures, and public investment. The parameters assumed to grow at the same rate n_t are household savings function intercept, the households' and firm income tax function intercepts, and transfers from government and the rest of the world (see Decaluwe*et al.,* 2010).

The second driver of dynamics in the model is capital accumulation (equation 4.118) which shows that the stock of type k capital in industry j in period $t + 1$ is equal to the stock of the preceding period minus depreciation plus the volume of new capital investment in the preceding period. Equation (4.119) describes the amount of public investment expenditures. The equation determines how much savings are utilised for public investment, and given the price of private investment; the volume of new private capital investment is constrained by equation (4.120). Equations (4.121 and 4.122) give the prices of new private and public capital. Finally, the volume of new type k capital allocated to the private l business-sector industry *bus* is proportional to the existing stock of capital (equation 4.123). This proportion varies from the ratio of the rental rate to the user cost of that capital (equation 4.124), which is interpreted as Tobin's *q.* The user cost of capital depends on the price of new capital, the rate of depreciation, and the rate of interest.

$$KD_{k,j,t+1} = KD_{k,j,t}\left(1-\delta_{k,j}\right)+ IND_{k,j,t} \tag{4.118}$$

$$IT_t^{PUB} = PK_t^{PUB} \sum_{k,pub} IND_{k,pub,t} \tag{4.119}$$

$$IT_t^{PRI} = PK_t^{PRI} \sum_{k,bus} IND_{k,bus,t} \tag{4.120}$$

$$PK_t^{PRI} = \frac{1}{A^K - PRI}\prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPRI}}\right]^{\gamma_i^{INVPRI}} \quad (4.121)$$

$$PK_t^{PUB} = \frac{1}{A^K - PUB}\prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPUB}}\right]^{\gamma_i^{INVPUB}} \quad (4.122)$$

$$IND_{k,bus,t} = \phi_{k,bus}\left[\frac{R_{k,bus,t}}{U_{k,bus,t}}\right]^{\sigma^{INV_{k,bus}}} \quad (4.123)$$

$$U_{k,bus,t} = PK_t^{PRI}\left(\delta_{k,bus} + IR_t\right) and\ U_{k,pub,t} = PK_t^{PUB}\left(\delta_{k,pub} + IR_t\right) \quad (4.124)$$

Where:

$IND_{k,j,t}$: The volume of new type *k* capital investment to sector/ (whether public or private)

$\delta_{k,j}$: The depreciation rate of capital *k* used in industry *j*

PK_t^{PRI} : Price of new private capital

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

A^k_{PRI}: Scale parameter (the price of new private capital)

A^k_{PUB}: Scale parameter (the price of new public capital)

IR_t: Interest rate

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

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

$\Sigma^{INVk,bus}$: Elasticity of private investment demand relative to Tobin's

4.5 Closure rule

The closure defines the way the financial flows are reconciled to satisfy the Walras' law governing a closed model. As highlighted in the closure rule subsection of the literature review, the equilibrium results of the model and their implementation for policy analysis depend on the closure rule adopted for the study (that is how the model is closed). Thus, deciding which prices and quantities to be made exogenous, to derive a square system in

the model is important as it defines the direction of causality in the model.[53] The choice of closure in this study is informed by economic consideration as well as the context of the analysis. The underlying assumptions and implemented the closure rule applied in the model include:

Factor market closure

Labour supply is held fixed, and assumed to be mobile across sectors; thus, it is allowed to adjust to clear the market (neoclassical closure). On the other hand, capital is fixed in the first period, but mobile afterward; thus, return to capital is determined endogenously in the model to clear the market for capital supply.

Goods market closure

Equilibrium in the goods market requires that the demand for commodities equal to supply. This equilibrium is attained through the endogenous interaction of domestic and foreign prices, the effects that shifts in relative prices have on sectoral production and employment, and hence institutional incomes and demand.

Macroeconomic closures

Macro closures determine how macro-equilibrium is reached after a shock; therefore, it is necessary to specify a set of 'macro-closure' rules. The model includes three broad macroeconomic accounts: the current account, the government balance, and the savings and investment account.

In the model, the nominal exchange rate is chosen as '*numeraire'*. Thus, changes in domestic price indices can be interpreted as changes in domestic prices relative to international prices which have been fixed in the model. Given that the nominal exchange rate is treated as exogenous, the current account is fixed directly, and foreign savings are allowed to adjust endogenously to ensure external balance. It has been argued that measures of economic welfare based on household consumption become invalid if the

[53] Mathematically, ensuring that a model is 'closed' or deriving a square system amounts to ensuring that there are as many independent equations to explain the endogenous variables.

current account is free (since borrowing funds increases consumption in the current period, and no provision is made in the model for paying the debt back).In the government account, the government expenditure is fixed in real terms, as well as all tax rates. As a result, the balance of the government budget is assumed to adjust to ensure that the public expenditure equals revenue.

As regards savings-investment closure, the model adopts a savings-driven closure, in which the savings rates of domestic institutions are fixed and investment, passively adjusts to ensure that the savings rate equals investment spending in equilibrium. This is unlike the more Keynesian view which reverses the causality found in neoclassical theory by arguing that investment is exogenous and that savings adjust to clear the market. Arguably, as most households in Nigeria are poor and more unlikely to increase savings to fund future investment, a savings-driven closure appears more appropriate for this study.

4.6 Calibration and implementation of the CGE model

The implementation of the CGE model involves several steps. The first step required setting up the structure of the model. To do this, the required data set for the economy had to be collected. However, given that the current study adapted an existing dataset, the process was modified to verifying the data source, leading to the benchmark equilibrium dataset. After that, a functional form was chosen for production and demand functions. This final stage in operationalizing the CGE model required deriving parameter values for the functional forms. The most commonly used procedure to determine the parameter values is calibration. Calibration involves choosing the values of a subset of the parameters in such a way that, together with the assembled SAM and the values of the behavioural parameters, the model reproduces the initial data set of the reference year. An alternative is to estimate such parameters empirically. However, besides the high-level sophistication of econometric techniques required, most of the required time-series or even cross-sectional series data are rarely available. Therefore, to obtain the model parameter estimates, the information contained in the SAM itself was utilised. The parameters that were calibrated are share and scale parameters. It was supplemented with elasticity parameters (which describes the curvature of various structural functions like

production, utility, export supply, import demand function) obtained from additional sources such as Decaluwe et al, 2013; Nwafor et al., 2010.

After the replication check which verifies that the model specification and the calibration exercise are correct, turned out the exact data set as the reference year, the data of the SAM together with the characterizing equations of the model was taken to be a solution of the model. Once the replication check is done, the simulation experiments (as described in the previous section) were executed. All simulations of the CGE model were based on a comparison with the baseline. Figure 4.2, provides a schematic representation of the steps followed in implementing the model.

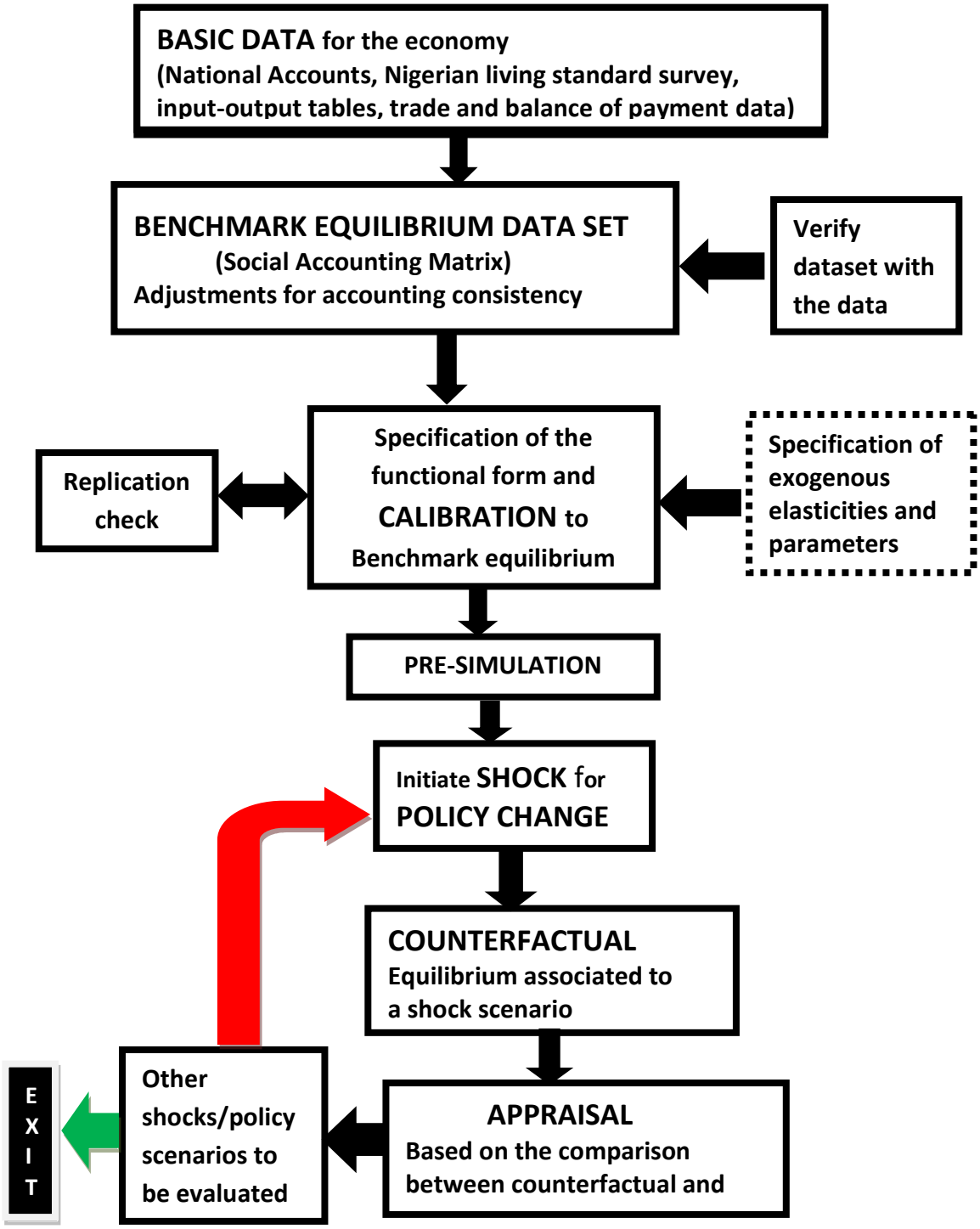

Figure 4.5: Steps followed in implementing the CGE Model.

Source: Adapted from UNCTAD, 2012.

4.7 Modelling Third Party Access (TPA).

The optimization model for gas transportation (TPA) in Nigeria is developed in this section. A linear transshipment modelling approach similar to Lennon et al (1996) was adopted. An optimisation scheme was constructed with centres of activities represented by nodes. These nodes include source, process, and destination (market) nodes.

4.7a Model assumptions

Some of the assumptions upon which the model was derived include the following:

1). The Model is a transshipment model, and as such it has only one source node that will feed (supply) many processes and destination nodes. The source node in this description indicates that it does not receive inflow and a destination node does not have an outflow. A process node, however, has both inflow and outflow.

2). Market indices, such as price and costs were used in deriving the model. Such other factors as social and political factors were not considered. Thus implying the optimal decision from this model is not influenced by political or social factors.

3. The model assumes a zero loss in the process of moving the gas from source to destination nodes.

4. Linearity and proportionality between the constant and the variable in the objective function and constraints as well as all other assumptions inherent in a linear programming model are also applicable.

5. There is no time lag at each of the nodes do not have a time lag as gas transshipped from a particular node immediately proceeds to the next node.

6. The gas produced is either utilised via the market or flared.

Following the general format of LP formulation, both an objective function and sets of constraints are required. A constrained optimization model is adopted for this study. A seven (7) node natural gas transshipment model was developed, which is made up of a source (originating) node, intermediate (process) node and a final destination (termination) node. A summary of the different paths in the optimization scheme is presented in fig. 4.8 below.

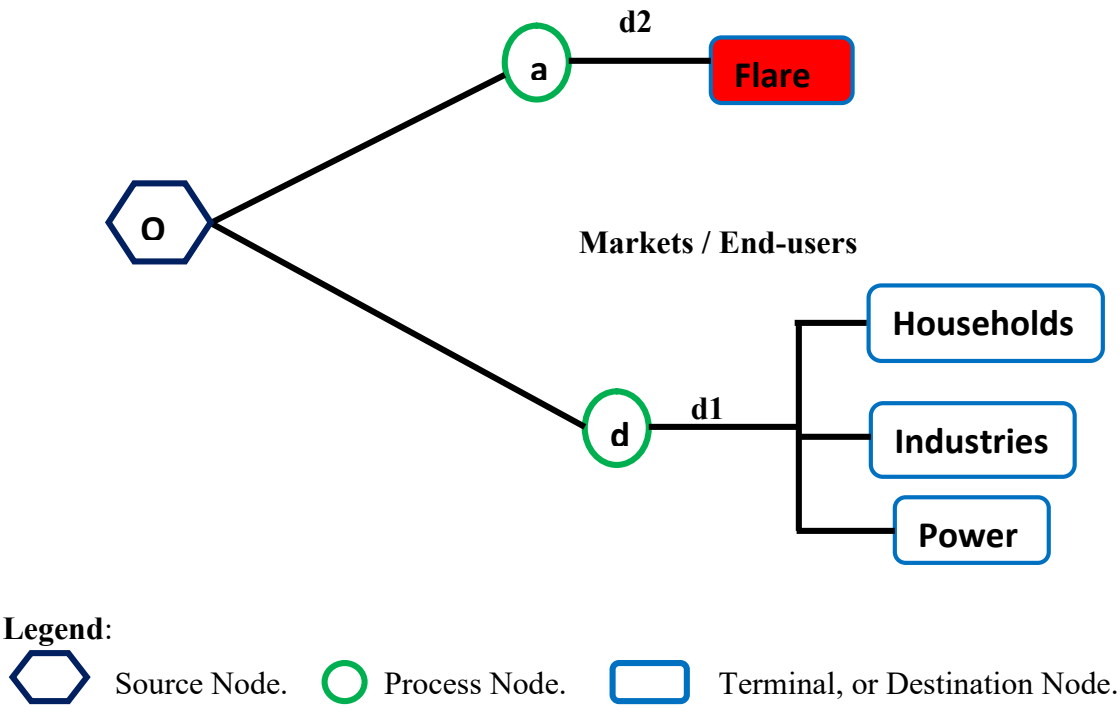

Figure 4.6: **Process path for optimization**.

Source: Authors' Sketch

4.7b Objective Function

The net income or profit function which is the objective to be maximised is expressed thus:

J: [Yields] – [Fixed Costs] – [Variable Costs] 4.125a

Expressing this node in the model yields:

$$\Sigma_i\Sigma_j \ (B_{ij}\chi_{ij}-VC_{ij}\chi_{ij}- FC_{ij}) \quad 4.125b$$

Where;

i,j: node indices that show the through path flow from **i** → **j** as expressed in Fig. 4.8.

Xij: quantity of transported gas from a node 'i' to 'j' in MMscf.

Yij: a coefficient which determines whether third-party access should be applied (yij is between '0' and '1')

Bij: benefits (revenues) arrived at a on the destination node in $/MMscf, j is strictly 1, 2,3... 9.

VCij: associated variable costs for transporting a given quantity of natural gas at the j-th node in $/MMscf

FCij: associated fixed costs for transporting a given quantity of natural gas at the j-th node in $/MMscf.

4.7c. Constraints

Net income in the optimization model is maximized subject to these constraints below:

i). Gas Volume Constraints;

The amount of gas available for transportation to destination nodes is limited by the following two material balances:

(a) Source node material balance.

$$\Sigma_i X_{oi} \leq G \quad 4.126$$

Where;

G: amount of gas available at the source node, "0", for transportation.

Xoi: amount of gas leaving the source node,“0”, to nodes “ d1", "d2 ” through “ a ”.

(b) Destination node material balance.

$$\Sigma_j X_{jt} - \Sigma_i X_{oi} = 0 \qquad 4.127$$

Where:

Xjt: quantity of natural gas inflowing to the terminal or destination nodes " d1" or "d2" through "a" in the model.

Xoi: quantity of natural gas outflowing from the source node, " 0", to nodes " d1", "d2 " through " a ".

ii) Node Storage Constraints;

Another set of constraints adopted in the model is the prohibition of natural gas storage or/and its by-products at a process node. The constraint for this node material balance can be expressed thus:

[Inflow into node] - [Outflow from node] = 0 4.128a

Or explicitly expressed in variable terms, yields

$$\Sigma_i X_{ij} - \Sigma_k X_{jk} = 0 \qquad 4.128b$$

Where:

Xij: quantity of natural gas inflowing to the j-th node from other nodes, i, (i = process or source nodes)

Xjk: quantity of natural gas departing from the j-th node to other nodes, k (k= destination or process nodes).

iii) Constraints on the Fixed Cost.

In formulating the model, and to ensure that nodes that are involved in transporting natural from one node to another, a fixed cost is applied. These constraints are stated as: a set of constraints was defined to ensure that a fixed cost is applied to any node that involves the transportation of natural gas. These constraints take the following form:

$$y_{ij} - \frac{Xij}{M} \geq 0 \qquad 4.129$$

Where:

Xij: amount of gas received by the j-th node from other nodes, i, (where i = source or process nodes)

Yij: a coefficient switch that determines when a fixed cost should be applied

(yij = 0 or 1)

M: a large volume of gas, that significantly drives the value of yi to unity in the maximization function if xij has a positive, non-zero value.

iv) Gas Deliverability Constraints; This constraint limits the amount of gas transported by each gas producer to the available infrastructure capacity. This constraint is expressed as:

$$X_{jt} \leq 365 Q_{jt}\, t \qquad 4.130$$

Where:

Xjt: quantity of gas moving from node "i" to a destination node "t" in MMscf.

Qjt: gas throughput or quantity delivered at the final destination node in units of MMscf/d.

T: the third party access contract/utilisation time (for this study 10years).

4.7d Model data

The model adopted for his study requires some data set in order to obtain the optimum of the objective function for the gas suppliers and the gas facilities company. The model used the data from Lagos-Escravos pipelines operated by the Nigerian Gas Company (NGC), and gas production of Chevron, NNPC, Neconde, and Seplat (DPR 2016; Chevron 2017) as a hypothetical case study. The TheEscravos–Lagos pipeline System (ELPS) is 439 kilometres, and a 36-inch diameter pipeline with a maximum capacity of 800MMcf/d of natural gas pipeline built in 1989 to supply gas from the Escravos region of Niger-Delta to Lagos and also WAGP. The source gas is from Escravos gas plants (EGP) operated by Chevron (215 MMcf/d), the Utorogu gas plant operated by NNPC (360 MMcf/d), Oben gas plants operated by Seplat (300 MMcf/d), and Odidi gas plants operated by Nconde (40 MMcf/d). The total gas volume produced by each producer is shown in table 4.2.

Table 4.2. Gas volume from producers

Producer	The volume of Gas (mmscf/d)	Gas Supplied to Market (mmscf/d)	Gas Flared (mmscf/d)
A	215	210	5
B	360	300	60
C	300	260	40
D	40	30	10
Total	**915**	**800**	**115**

Source: NGC, 2018

1.Total volume of gas Produced = 115mmscf/d

2. Fixed Cost: $600 Million.

3. Variable cost: $0.20/mmscf

4. Transportation Cost: $0.3/mmscf

5. Gas Selling Price: $4.45/mmscf

6. Cost of Flaring gas (Penalty): $3.50/mmscf

7. pipelines Capacity: 810mmscf/d

4.7e. Model Implementation

The model was implemented using LINDO optimization software. It is a comprehensive tool designed to make building and solving Linear, Quadratic, Stochastic, and Integer programming models faster, easier and more efficient. It provides a completely integrated package that includes a powerful language for expressing optimization models, a full-featured environment for building and editing problems, and a set of fast built-in solvers. The solution to the model equations is provided by LINDO using the "branch and bound" algorithm for integer programming. The branch and bound algorithm employ a Linear programming relaxation of the Integer Programming problem and solving iteratively until the solution outputs an integer (0 or 1 in the case of a BLP). The model was executed for the case of a base study and after that, the executions were repeated at some increase or decrease in the parameters such as the level of TPA granted.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Preamble

This chapter presents and discusses the sets of results obtained from the simulation experiments. The discussions centered on aggregate, key sectoral, and household impact of the shocks.[54] Consequently, this chapter is organized as follows. Section 5.2 presents information relating to the benchmark statistics (*the status quo situation*), used in experimenting with the model. Section 5.3 deals with the definition and description of the various simulations carried out. Section 5.4 discusses the simulation results, while section 5.5 presents the model diagnostic check and sensitivity analysis, and section 5.6 is the chapters' concluding remarks.

[54] For ease of interpretation and clarity of data presented, only variables of interest are reported.

5.2 Benchmark statistics

Table 5.1: Production structure, value added composition and trade in GASAM

(in percentages)

Sector	Value Added	Prod. & Share of QVA & INT			Export Share	Export as	Import Share	Import Share
		Prod	QVA	INT				
Agric	23.89	19.49	75.16	24.84	3.38	2.59	7.71	6.84
CPet	8.15	8.06	86.55	13.45	54.65	98.95	0.00	0.00
NGas	7.23	9.02	63.97	36.03	11.66	42.65	0.00	0.00
Manu	6.18	11.15	55.67	44.19	23.82	31.34	17.07	64.23
Pet	0.47	1.00	55.81	44.33	2.39	35.05	59.43	89.73
Elec	0.33	0.51	67.34	32.66	0.05	1.39	0.00	0.00
Trans	1.24	2.86	63.75	36.25	3.44	17.66	4.84	7.45
Serv	48.84	44.66	47.78	52.22	0.61	0.20	11.93	61.36
NTR	3.66	3.59	57.22	42.78	0.00	0.00	0.00	0.00
Total	**100**	**100**	**59.6**	**40.4**	**100**		**100**	

Source: Authors' calculation based on GASAM 2014.

Table 5.2 Sectoral factor shares.

Sectors	Factor Across	Shares Sectors	Value Added	Factor Within	Shares Sectors	Total
	Lab	Capital		Lab.	Capital	
Agric	12.74	7.35	23.89	65.79	34.21	**100**
CPet	4.27	19.78	8.15	20.64	79.36	**100**
NGas	3.75	18.34	7.23	26.50	73.50	**100**
Manu	17.65	11.09	6.18	31.27	68.73	**100**
Pet	4.77	8.05	0.47	21.11	78.89	**100**
Elec	2.79	6.74	0.33	28.53	71.47	**100**
Trans	11.67	3.55	1.24	46.06	53.94	**100**
Serv	20.27	21.18	48.84	31.01	68.99	**100**
NTR	22.09	3.92	3.66	71.62	28.38	**100**
Total	**100**	**100**	**100**			

Source: Authors' calculation based on GASAM 2014.

Shares within Households.						
Households	**Factors**		**Institutions**			
	Labour	Capital	Firm	Govt	Row	Total
RNP	25.30	62.60	12.0	0.1	0.0	**100**
RMP	52.70	42.00	19.2	0.1	0.0	**100**
RCP	55.60	29.00	15.3	0.1	0.0	**100**
UNP	34.40	54.2	11.4	0.0	0.0	**100**
UMP	47.90	33.1	18.1	0.0	0.0	**100**
UCP	51.60	26.7	21.7	0.0	0.0	**100**

Source: Authors' calculation based on GASAM 2014.

Legend:

RNP: Rural-Non Poor

RMP: Rural-Moderate Poor

RCP: Rural-Core Poor

UNP: Urban-Non Poor

UMP: Urban-Moderate Poor

UCP: Urban-Core Poor

Table 5.3. Factors and institutions' shares of household ncome.

RNP	18.1	15.8	21.7	6.4	0.0	17.7
RMP	15.0	11.4	18.8	43	0.0	19.4
RCP	13.2	6.9	13.5	50.6	0.0	19.5
UNP	17.6	29.6	25.9	0.0	0.0	20.4
UMP	25.8	23.8	12.4	0.0	0.0	15.3
UCP	10.3	12.5	7.7	0.0	0.0	7.9
TOTAL	**100**	**100**	**100**	**100**	**0.0**	**100**

Source: Authors' calculation based on GASAM 2014.

Legend:

RNP: Rural-Non Poor

RMP: Rural-Moderate Poor

RCP: Rural-Core Poor

UNP: Urban-Non Poor

UMP: Urban-Moderate Poor

UCP: Urban-Core Poor

5.3 Definition and description of the model simulations.

The base run solution (business as usual BAU) of the dynamic multi-sector CGE model is the steady-state solution of the model corresponding to the calibrated set of values for the parameters, endogenous and exogenous variables of the model. Having replicated the baseline statistics of the model, some scenarios indicating the relevant policy outcome are simulated, and its outcome compared with the baseline scenarios are reported as percentage deviations. The policy simulation strategies performed and reported in this study are basically for the gradual price increment (adjustment) of the domestic natural gas price as proposed by the Nigerian Gas Master Plan (NGMP)[55], for a period of ten years. Attempts are made to access the macroeconomic, sectoral, and household income and welfare consequences of natural gas market liberalisation policy in Nigeria. The Third Party Access (TPA) model, was also simulated to find out the optimum decision of the gas producers as well as the gas facilities company. First, we simulated for a no third party access which is the base case scenario for both the gas producers and the gas facility company. We then simulated a 10%, 50% and 100% openness (following the European Union model) of the access to compare results for both the producer and the gas facilities company.

5.4 Simulation results and discussion.

Primarily, the domestic natural gas market liberalisation policy is expected to have some economy-wide ripple effects. In this section, we address these impacts with a specific focus on macroeconomic, sectoral, household income and welfare incidences.

The policy is expected to impact on the entire structure of the Nigerian economy through the production, price, demand, factor returns, and government transaction structures. The interpretation style of policy simulations adopted here follows the steps earlier demonstrated in the overview of the model simulation transmission mechanism. The macroeconomic, sectoral, household income distribution and welfare impact of domestic natural gas market liberalisation are forthwith reported and discussed with reference to the baseline values of the selected variables. Also, the dynamic path of the simulation

[55]See the revised domestic gas price of the gas master plan (GMP) document 2008.

scenarios for the next 10 years is reported and discussed with reference to the baseline scenario.

5.5 Macroeconomic impacts.

The policy of domestic natural gas liberalisation, which implies the removal of price ceiling regulation of the domestic gas market, is expected to have some significant impact at the macro level of the economy. Some key macroeconomic indicators as real GDP, price index, exports, imports, total output, total investment expenditure, and the institution's (government, firm and household) income were selected to show how the policy impact on the economy's aggregates.

Table 5.4 shows the results of the macroeconomic implications of the policy over a period of ten years. As envisaged, an increase in the domestic gas price is seen to have stimulated an upward trend in other prices in the economy as reflected in an increase in the consumer price index of 0.13 percent, 0.25 percent and 0.43 percent for the first, fifth, and tenth year respectively. This is due to the fact of the role of natural gas as a critical input in most sectors of the economy, especially in the electricity, manufacturing and transport sectors. Theoretically, an increase in the price of intermediate inputs leads to an increase in the implicit cost of production and most likely a decrease in output. The real GDP in our analysis reflected this through a decline of 0.74 percent, 0.18 percent in the first and fifth year. This can be linked to the domestic gas price increase, which theoretically reduces aggregate demand and hence aggregate output[53]. However, in the tenth year, the GDP appreciated by 0.24 percent. Export increased by 0.92 percent, 0.37 percent, and 0.59 percent for the period of study. As domestic demand falls due to increase in price, gas producers export more gas. However, as the policy progressed towards export parity price, export reduced as gas producer's preference skewed in favour of the domestic market. Gas importation progressively declined from 1.07 percent to 0.26 percent and -0.14 percent respectively for the period of simulation.

On the other hand, the total investment expenditure continued to show an increase of 0.36 percent, 0.64 percent, and 1.04 percent for the first, fifth, and tenth year respectively. This

indicates that the domestic natural gas price rigidity has since stifled investment. Hence its removal coupled with other factors such as increased firm's and government income brings about an increase in total investment expenditure.

On institution's (government, firm, household) income, a higher domestic natural gas price shows a fall in income. For the household, since labour income represents a larger proportion of household income, a fall in labour, employment due to reduced sectoral output, especially in the labour intensive activities leads to a fall in household income. On the firm's income, a higher domestic natural gas price shows an increase in the firm's income. This could partly be due to an increase in profit. Government income also increased from 0.05 percent to 0.89 percent, and 1.56 percent for the ten years of the simulation, as a higher natural gas price is expected to generate more tax and royalty income in addition to other income to the government. This increase in the firm's and the government's income theoretically leads to increased savings which eventually increases investment expenditure.

The aggregate effect of domestic natural gas market liberalisation in Nigeria shows the severe impact at the onset (first year), reduces as the policy progressed (at the fifth year), and stabilizes and positively impact on the aggregate variables of the economy (at the tenth year). Even those variables that are negatively impacted such as household income, the negative impact eases (reduced) as the policy progressed.

Table 5.4. Percentage change in macroeconomic variables.

	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Price Index	1	0.13	1	0.25	1	0.43
Real GDP	57899040	-0.74	65165879	-0.18	75545114	0.24
Imports	0.208422	1.07	0.23458	0.26	0.271943	-0.14
Exports	1634456	0.92	1839594	0.37	2132594	0.59
Total Inv. Exp.	10125357	0.36	11396178	0.64	13211294	1.04
INSTITUTIONS INCOME						
Govt. Income	7622627	0.56	8579334	0.89	9945799	1.26
Firms Income	14752012	0.41	16603520	0.67	19248030	0.93
Household Income:						
RNP	1377464	-0.33	1550348	-0.19	1797278	0.23
RMP	7932559	-0.54	8928165	-0.35	10350191	0.15
RCP	9404768	-0.42	10585149	-0.37	12271089	0.13
UNP	2251346	-0.36	2533909	-0.15	2937495	0.28
UMP	13610709	-0.51	15318973	-0.43	17758888	0.17
UCP	8101534	-0.48	9118348	-0.39	10570664	0.15

Source: Extracted by the author from the simulation result.

5.6. Sectoral impact.

This section delves into sectoral results from the simulation experiments. This is aimed at assessing the plausible sectoral factors that drive the macroeconomic shifts earlier discussed. The impact on each sector will depend on the amount of natural gas in the sector's intermediate input cost structure. The simulation results for the ten years are reported as a percentage change from the baseline values for intermediate consumption, domestic supply, domestic demand, export, and sectoral output.

5.6.1 Total Intermediate Consumption.

As earlier discussed, the higher domestic price of gas basically impacts on other sectors. First, the impact is directly passed to the gas consuming sectors which primarily consume gas as an intermediate input in their respective production activities. Second, the impact is also felt indirectly by other sectors through their interactions with these gas consuming sectors. In both ways, due to the increased cost of intermediate consumption, a decrease is experienced. Table 5.6, show how higher domestic gas price impact on sectoral aggregate intermediate input consumption in different sectors. The immediate impact can be felt in the gas sector through an increase in its intermediate consumption. This is of course expected following the increase in its domestic price leading to increased output. The opposite is the case regarding the intermediate demand for natural gas, which is now relatively expensive by other sectors.

The electricity sector, being directly affected due to its relatively higher gas dependence, clearly has the worst of it with the largest fall in its intermediate consumption. All other sectors which depend on gas and electricity sectors are also affected. Specifically, a closer look at the results shows that while intermediate consumption of the gas sector increased to 5.88%, that of electricity declined by about 5.18 percent and transport, by 3.08 percent. This negative trend can also be seen in other sectors, especially in the manufacturing and agriculture sector by 0.41 percent and 0.32 percent. The impact, even though severely at the onset Dyn1 reduced as the policy progressed Dyn5 and Dyn10. The implication of this as earlier mentioned is a fall in output, which will result in a fall in income, and welfare.

Table 5.5: Average percentage change in sectoral intermediate consumption.

Sector	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Agric	2999.956	-0.32	3376.477	-0.13	3914.262	-0.09
Crude Petroleum	426514.3	-0.15	480045.6	-1.07	556504.4	-1.05
Natural Gas	1279543	1.31	1440137	2.05	1669513	5.88
Manufacturing	357308.2	-0.41	402153.5	-0.34	466206.1	-0.22
Electricity	115358.8	-5.18	129837.3	-3.98	150517	-1.05
Transport	409434.3	-3.08	460821.9	-2.19	534218.9	-1.14
Services	5077539	-0.02	5714815	-0.08	6625037	-0.17

Source: Extracted by the author from the simulation result.

5.6.2 Sectoral domestic supply.

One of the core objectives of the gas master plan is to attain a balance between the export and domestic market for gas in Nigeria. From the simulation results obtained, there is an increase in the domestic supply of gas from -0.35 percent, to 0.62 percent, and 1.42 percent for the first, fifth and tenth year respectively. The increase in the domestic supply could be the result of the policy drive of attaining export parity price, which results in gas producer's preference for the export market due to price disparity, amongst other shortcomings been addressed. It is worth noting that this increase in domestic supply is not necessarily due to an increase in output, but primarily balancing available output between the domestic and export market. This is also synonymous with the basic supply law which states that producers will take advantage of higher market price by increasing their supply. Table 5.6 shows how higher domestic gas price impact on sectoral aggregate domestic supply.

Table 5.6 Average percentage change in sectoral domestic supply.

Sector	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Agric	17804699	-0.12	20039346	-0.29	23231094	-0.03
Crude Petroleum	80895.04	0.08	91048.08	0.12	105549.7	0.18
Natural Gas	6996212	-0.35	7874299	0.62	9128470	1.42
Refined Petroleum	620921.7	0.15	698852.8	0.17	810161.9	0.18
Manufacturing	7322479	0.22	8241515	0.31	9554174	0.23
Electricity	483466.5	-0.02	544145.8	0.07	630814.1	0.09
Transport	2255528	-0.08	2538616	-0.13	2942952	0.25
Services	42592822	0.02	47938597	0.06	55573972	0.17
NTR	3466435	-0.04	3901503	-0.09	4522911	-0.11

Source: Extracted by the author from the simulation result.

5.6.3 Domestic demand.

The reported domestic demand represents the change in the relative demand for goods and services at the new equilibrium compared with the baseline. The increase in domestic natural gas prices as a result of the liberalisation policy will significantly affect the domestic demand system of the economy as a whole. It is expected, however, that the sector with a higher domestic consumption rate for gas will be affected more. Based on the reported simulation, it is obvious that the increase in domestic natural gas price has the largest impact on consumer demand for gas and electricity. On the other hand, manufacturing experienced an increase in demand primarily because the price increase in the real term does not impact the sector as the price of gas to the manufacturing sector has already been liberalised.

In the case of the electricity sector, this result is not surprising as about 80 percent of domestic natural demand is attributed to the sector. Also, the electricity sector has the least pricing composition in the aggregated price structure. Hence the decline in demand from 1.46 percent in (Dyn1), to 1.34 percent in (Dyn5), and 0.98 percent in (Dyn10). As a result of these perturbations, the energy-intensive sectors will have (higher cost) lower demand due to higher gas prices than the less energy intensive sectors. The decrease in agricultural products can be explained by the increase in gas prices for fertilizers and other chemical products demanded, as intermediate consumption in this sector. The simulation result is depicted in table 5.7.

Table 5.7 Average percentage change in sectoral domestic demand.

Sector	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Agric	17804699	-0.12	20039346	-1.29	23231094	-0.95
Crude Petroleum	80895.04	0.26	91048.08	0.28	105549.7	0.21
Natural Gas	6996212	-0.35	7874299	0.26	9128470	0.34
Refined Petroleum	620921.7	0.15	698852.8	0.41	810161.9	0.58
Manufacturing	7322479	0.22	8241515	0.36	9554174	0.47
Electricity	483466.5	-1.42	544145.8	-1.34	630814.1	-0.88
Transport	2255528	-0.28	2538616	-0.13	2942952	-0.08
Services	42592822	-0.02	47938597	0.08	55573972	0.16
NTR	3466435	-0.04	3901503	-0.01	4522911	-0.08

Source: Extracted by the author from the simulation result.

5.6.4 Sectoral export.

Table 5.8, illustrates the impact of the liberalisation policy on sectoral export. The policy which leads to a significant increase in the domestic prices of gas with the consequent effect of a fall in domestic coupled with an output contraction at the early stage of the policy (Dyn1 and Dyn10), ultimately, leads to a decline in export. Of course, this is expected following the negative output effect of the high domestic gas price on all sectors of the economy except natural gas and manufacturing.

While the natural gas sector experience a significant decline from 2.29 percent to 0.85 percent in Dyn1 and Dyn10, following an increase in the domestic gas price which could be attributed to gas producer's renewed preference to the domestic market due to an appropriate price. However, the manufacturing and electricity sector's exports progressively improved for Dyn1, Dyn5, and Dyn10 as its exports increased. On average, the negative average response of all other exporting sectors to higher domestic natural gas prices is minimal at Dyn1 and became positive in Dyn10.

Table 5.8 Average percentage change in sectoral export.

Sector	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Agric	473116.3	-0.06	532496.6	-0.04	617309.5	0.47
Crude Petroleum	7658617	0.38	8619841	0.43	9992758	1.04
Natural Gas	1634456	2.29	1839594	1.37	2132594	0.05
Refined Petroleum	335119.5	0.07	377180	0.31	437255	0.49
Manufacturing	3337631	1.07	3756533	1.73	4354851	2.12
Electricity	6792.919	-0.01	7645.49	-0.49	8863.218	0.61
Transport	482355.3	-0.44	542895.1	-1.75	629364.2	0.63
Services	85753.43	0.01	96516.24	0.04	111888.8	0.08

Source: Extracted by the author from the simulation result.

5.6.5 Sectoral output

Following the conditions of perfect competition as in the CGE model as earlier demonstrated, increases in production in production costs will force producers to either increase their output prices or reduce output. In other words, it is expected that the output will inversely be affected given the increase in implicit production cost. Therefore, the contraction of an industry is a rational response to bolster prices and maintain revenue given a cost increase or a drop in demand as originally induced by higher domestic gas prices. Meanwhile, the impact of higher domestic gas prices on sectoral production activities depends primarily on their gas input intensity. An industry with high gas intensity is more likely to be adversely affected by higher gas prices. As shown in table 5.9, all activity levels decline except that of natural gas and manufacturing sectors. The electricity, transport, agriculture, in that order are the worst affected. Accordingly, since gas share in the input cost of electricity is very high, activity in the electricity sector declines more.

Table 5.9. Average percentage change in sectoral output.

Sector	BAU	Dyn1	BAU	Dyn5	BAU	Dyn10
Agric	18277815	-0.41	20571842	-0.38	23848403	-0.24
Crude Petroleum	7739512	0.14	8710889	0.11	10098308	0.05
Natural Gas	8630668	0.08	9713893	0.15	11261064	0.28
Refined Petroleum	956041.2	-0.01	1076033	-0.06	1247417	0.04
Manufacturing	10660110	0.12	11998047	0.13	13909025	0.18
Electricity	490259.4	-1.07	551791.3	-0.64	639677.3	-0.22
Transport	2737883	-0.05	3081511	-0.06	3572316	0.03
Services	42678576	-0.02	48035113	-0.03	55685861	0.02
NTR	3466435	-0.03	3901503	-0.02	4522911	0.01

Source: Extracted by the author from the simulation result.

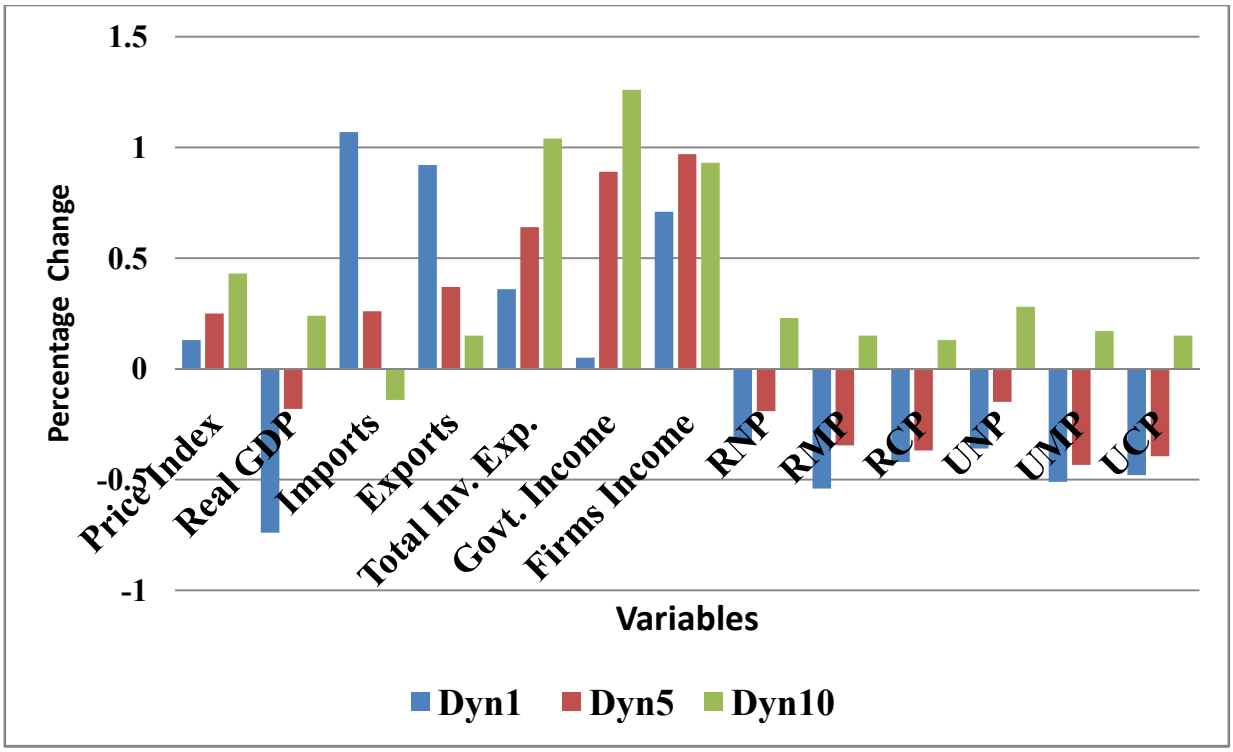

Figure 5.1 Graphical presentation of Macroeconomic variables.

Source: Extracted by the author from the simulation result.

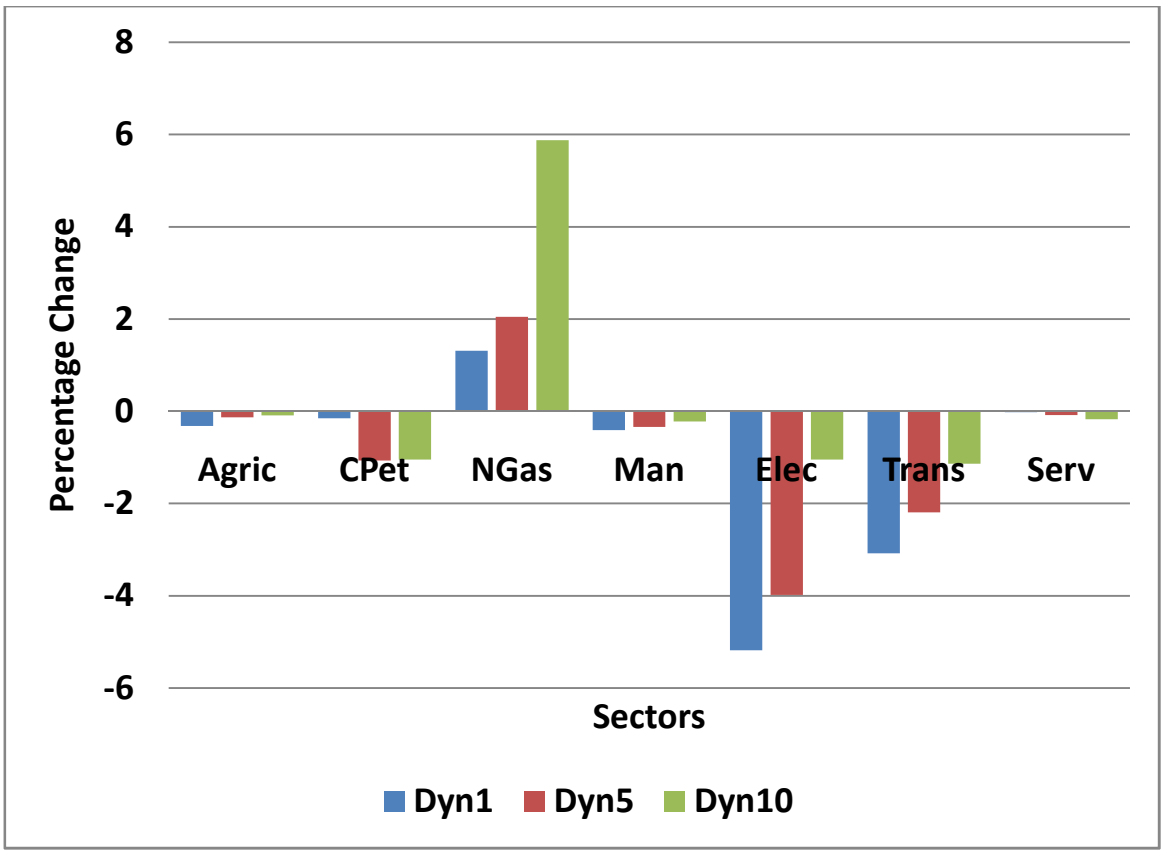

Figure 5.2 Graphical presentation of sectoral intermediate consumption.

Source: Extracted by the author from the simulation result.

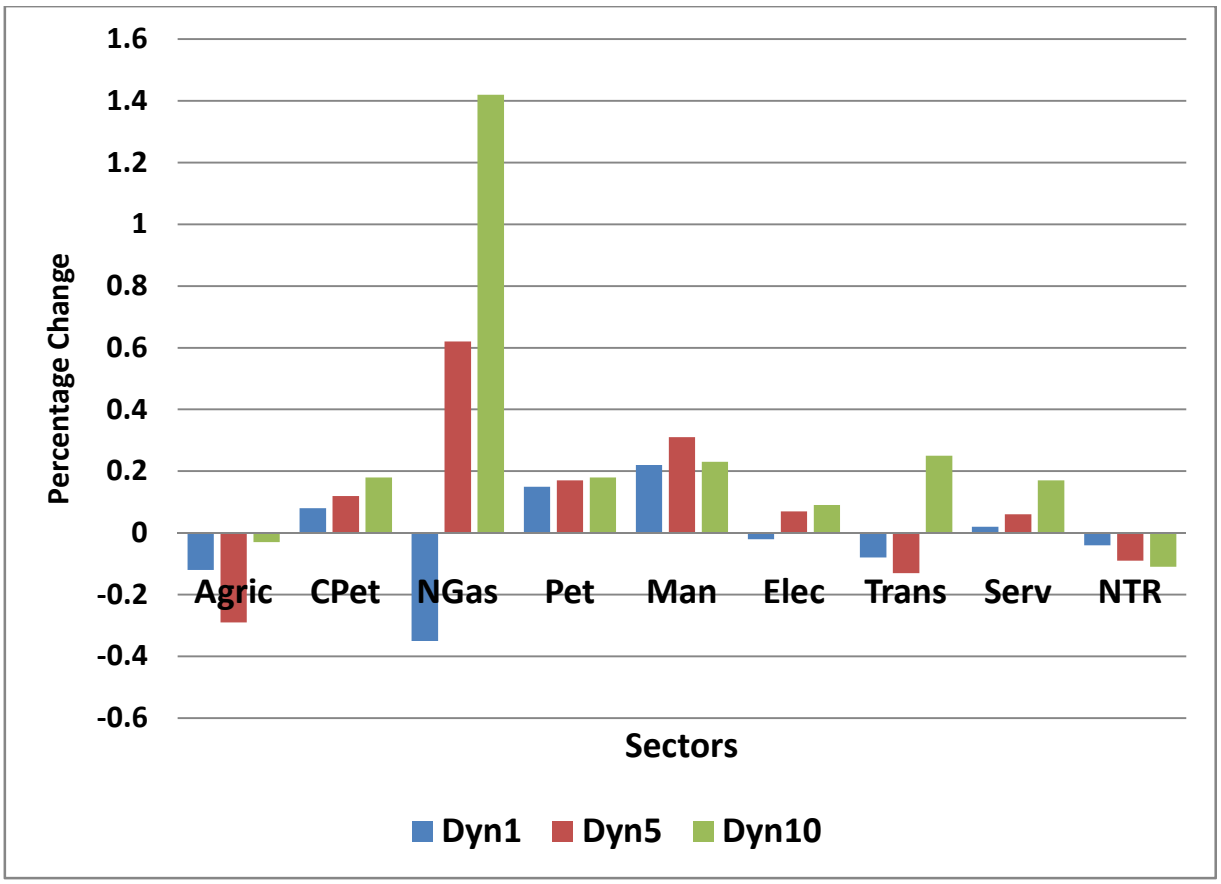

Figure 5.3 Graphical presentation of sectoral domestic supply.

Source: Extracted by the author from the simulation result.

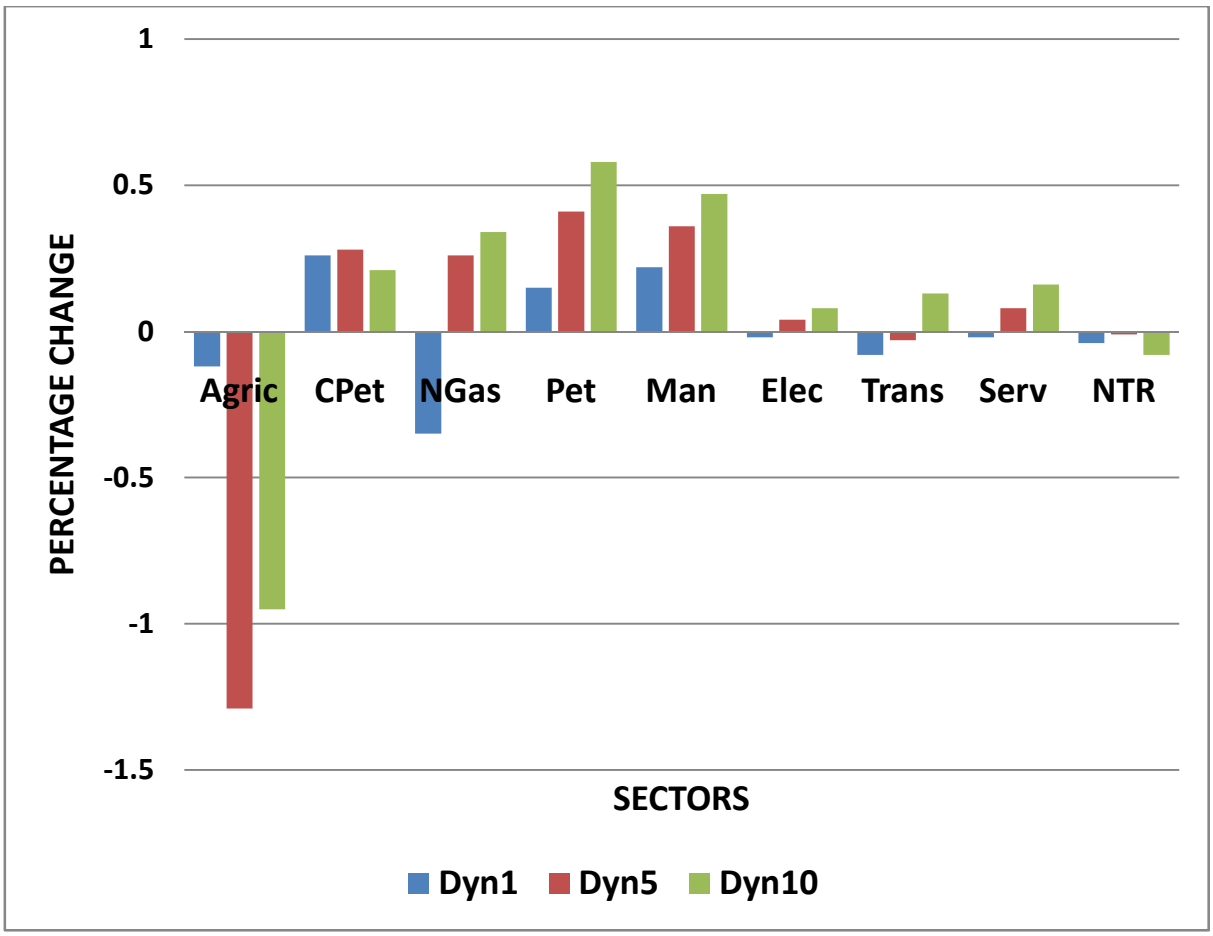

Figure 5.4 Graphical presentation of sectoral domestic demand.

Source: Extracted by the author from the simulation result.

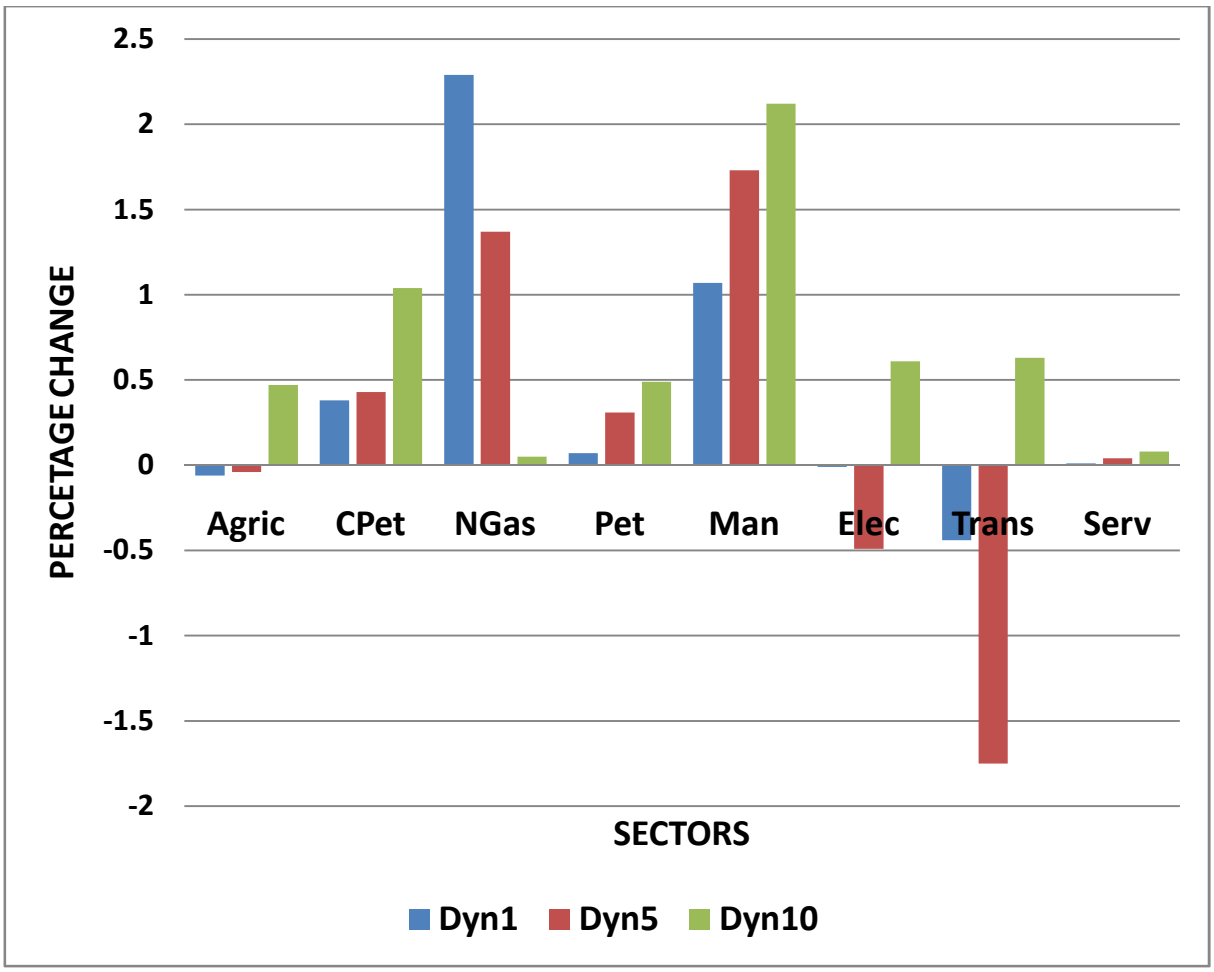

Figure 5.5 Graphical presentation of sectoral export.

Source: Extracted by the author from the simulation result.

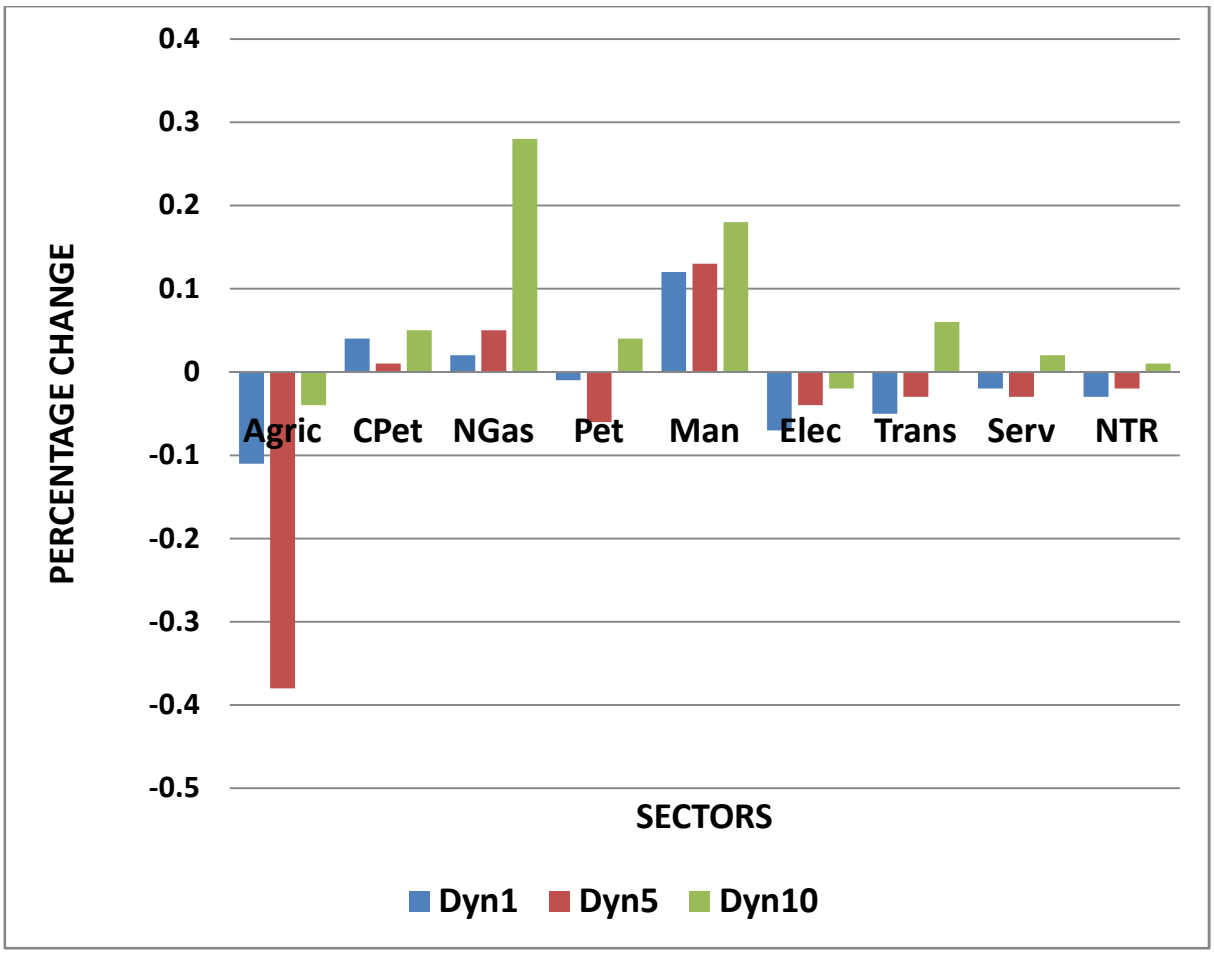

Figure 5.6 Graphical presentation of sectoral output.

Source: Extracted by the author from the simulation result.

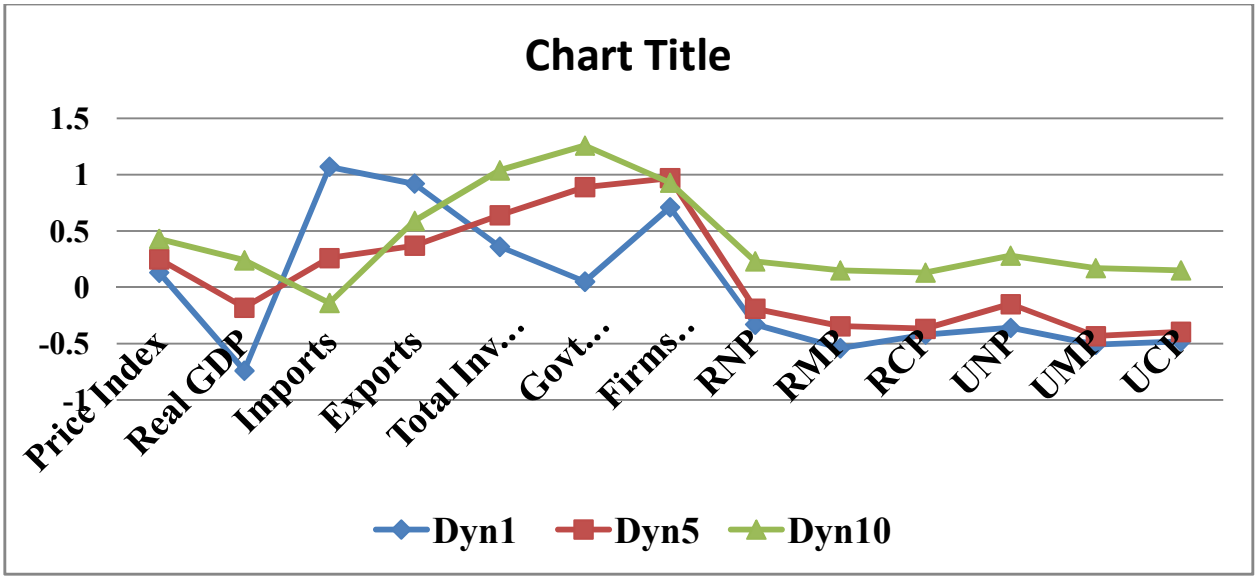

Figure 5.1 **Graphical presentation of Macroeconomic variables.**

Source: Extracted by the author from the simulation result.

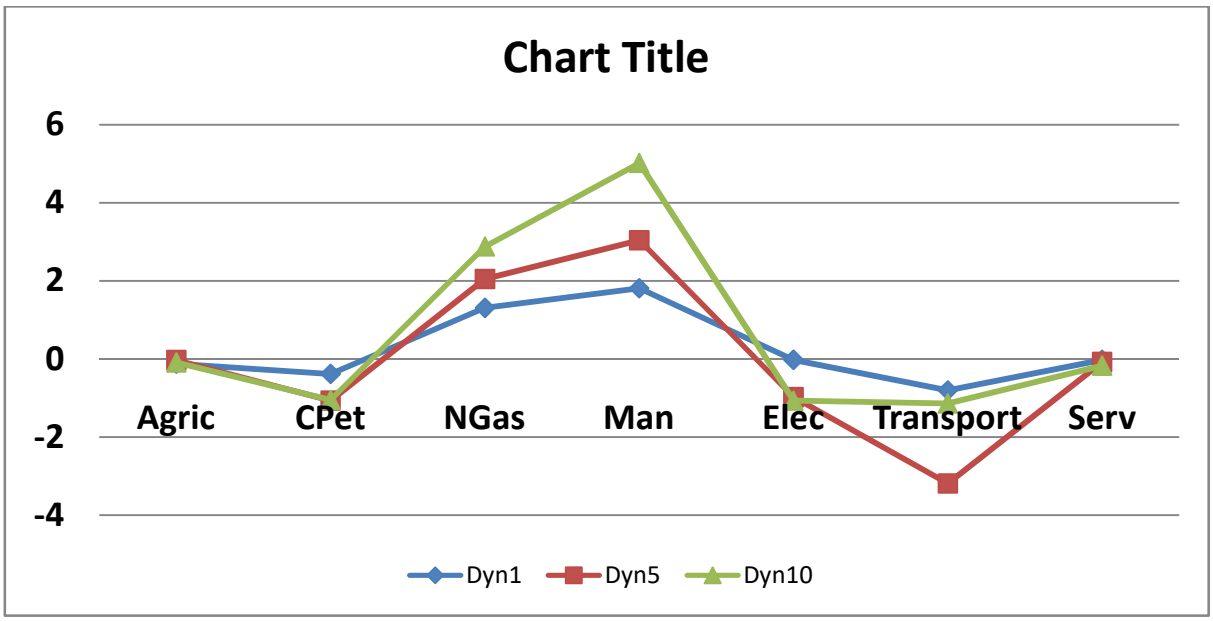

Figure 5.2 **Graphical presentation of sectoral intermediate consumption.**

Source: Extracted by the author from the simulation result.

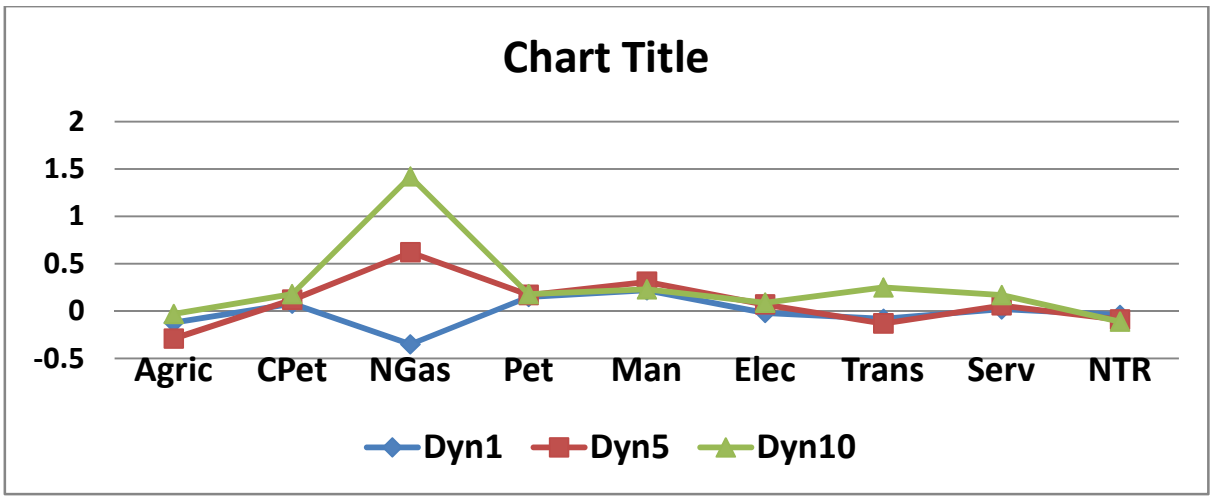

Figure 5.3 Graphical presentation of sectoral domestic supply.

Source: Extracted by the author from the simulation result.

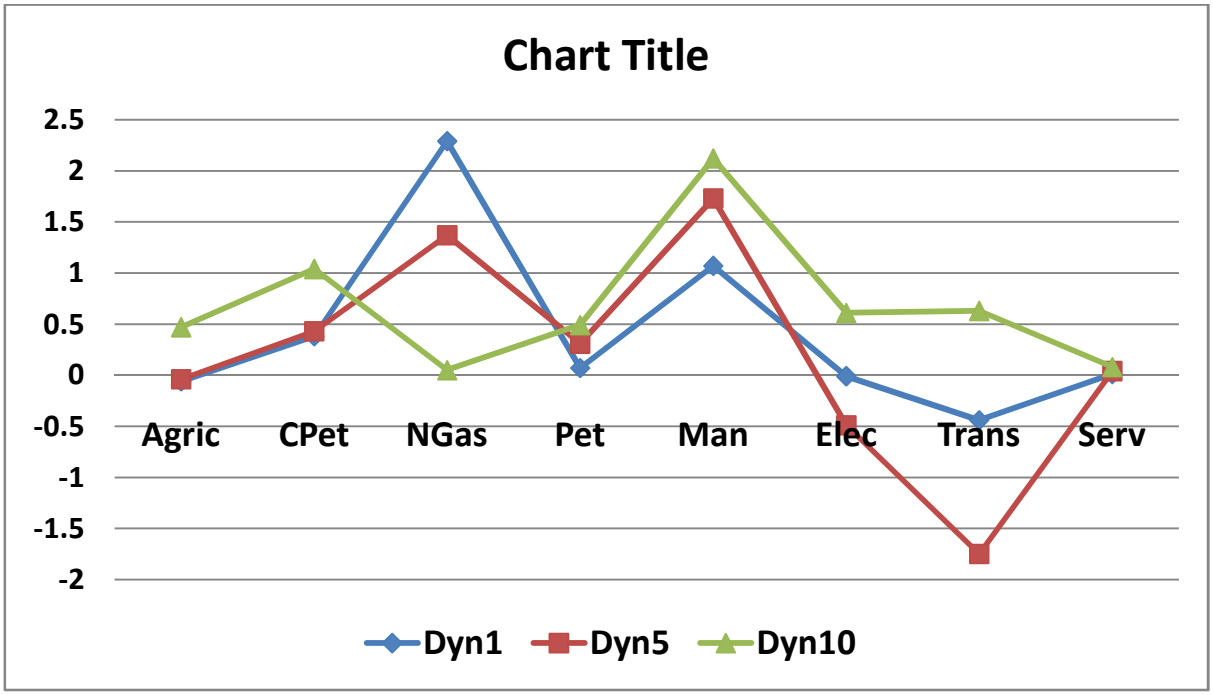

Figure 5.4 Graphical presentation sectoral domestic demand.

Source: Extracted by the author from the simulation result.

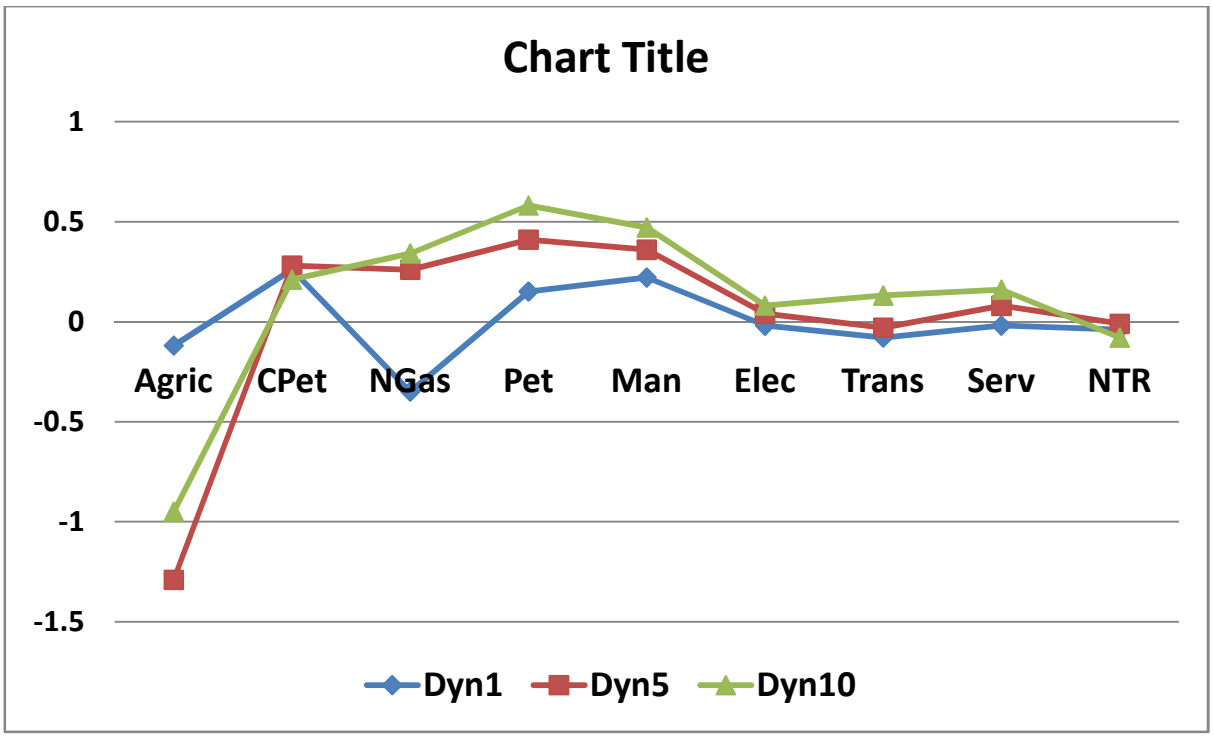

Figure 5.5 Graphical presentation of sectoral export.

Source: Extracted by the author from the simulation result.

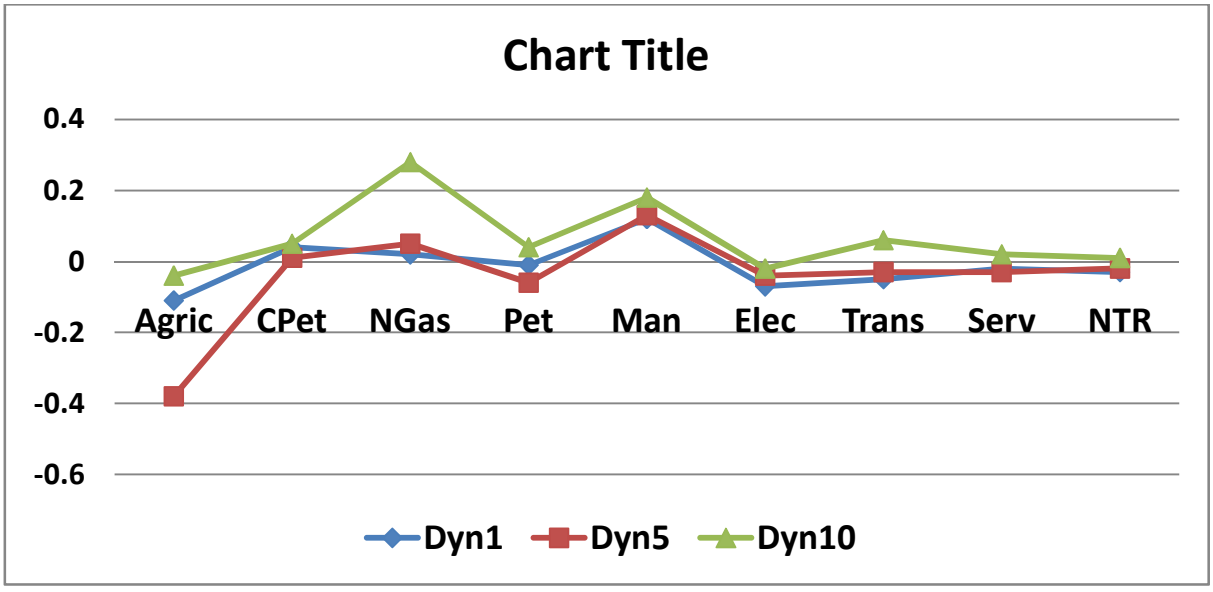

Figure 5.6 Graphical presentation of sectoral output.

Source: Extracted by the author from the simulation result.

5.7 Household income distribution and welfare.

This section focuses on the simulation assessment results of the impact of the domestic natural gas market liberalisation on the household income distribution and welfare. The inter-market price and quantity adjustments ultimately result in income redistribution for all households' categories. While the domestic gas price liberalisation influences household welfare altering consumer prices, the extent of household income redistribution depends primarily on the relative returns on the factors of production they own. The household level results as shown in table 5.10 to 5.14, therefore, represent a logical culmination of sectoral effects of a higher gas price on factor employment, value-added and welfare.

A cursory view of these effects indicates that all household's categories experienced adverse factor employment and hence income effects at the early stage of the policy (Dyn1, and Dyn5) and later at (Dyn10) experienced positive factor employment. The non-poor and the moderate-poor households experienced a larger fall in their factor income than the core-poor households. The reason could be attributed to the fact that non-poor and moderate-poor contributes a larger proportion of factor employment in the production process, also, because they spend a larger part of their income on marketed commodities whose relative price changes are largest (as evident in the SAM). In addition to the household income distribution effect and to get a deeper insight into the actual losses or gains in the household welfare resulting from the policy shocks, this study also evaluates the welfare implications of the domestic gas market liberalisation on the household. As earlier articulated, welfare change measured by Hicksian Equivalent Variation (EV) in millions of naira, with zero welfare change in the baseline, represents the total lump-sum transfer that is equivalent to the policy change.

All categories of households experience a loss in their welfare at the Dyn1, and Dyn5, and gain in Dyn10. Table 5.10, presents household capital income, table 5.11, presents a household's labour income; table 5.12 presents a household's total income; while table 5.13 presents households total savings and table 5.14 presents the equivalent variation calculations.

. **Table 5.10: Household Capital Income.**

	Dyn 1		Dyn 5		Dyn 10	
	BAU	GPSIM	BAU	GPSIM	BAU	GPSIM
RNP	671273.2	-0.23	755523.9	0.02	875859.2	0.45
RMP	3133527	-0.14	3526813	0.03	4088543	0.32
RCP	3647560	-0.05	4105360	-0.02	4759238	0.13
UNP	1221777	-0.02	1375121	0.07	1594142	0.53
UMP	7075368	-0.01	7963389	0.05	9231750	0.48
UCP	4183184	-0.06	4708211	0.01	5458106	0.16

Source: Extracted by the author from the simulation result.

Table 5.11: Household Labour Income.

Dyn 1			Dyn 5		Dyn 10	
	BAU	GPSIM	BAU	GPSIM	BAU	GPSIM
RNP	486773.8	-0.21	547868.2	-0.04	635129.4	0.26
RMP	3270511	-0.27	3680989	-0.05	4267276	0.15
RCP	3848555	-0.27	4331583	-0.23	5021492	0.12
UNP	547620.5	-0.08	616351.7	0.12	714520.6	0.35
UMP	4072050	-0.24	4583128	-0.12	5313102	0.26
UCP	2401105	-0.21	2702465	-0.17	3132898	0.14

Source: Extracted by the author from the simulation result.

Table 5.12: Household total income.

	Dyn1		Dyn5		Dyn10	
	BAU	GPSIM	BAU	GPSIM	BAU	GPSIM
RNP	1377464	-0.33	1550348	0.19	1797278	0.21
RMP	7932559	-0.54	8928165	-0.35	10350191	0.15
RCP	9404768	-0.42	10585149	-0.37	12271089	0.13
UNP	2251346	-0.36	2533909	-0.15	2937495	0.23
UMP	13610709	-0.51	15318973	-0.43	17758888	0.29
UCP	8101534	-0.48	9118348	-0.39	10570664	0.18

Source: Extracted by the author from the simulation result

Table 5.13: Household Savings.

	Dyn 1		Dyn 5		Dyn 10	
	BAU	GPSIM	BAU	GPSIM	BAU	GPSIM
RNP	416844.6	-0.12	469162.3	-0.05	543887.7	0.17
RMP	186641.1	-0.18	210066.2	-0.04	243524.3	0.09
RCP	137387.8	-0.25	154631.2	-0.13	179259.9	0.05
UNP	404535.5	-0.09	455308.2	-0.05	527827	0.22
UMP	169781.4	-0.07	191090.5	-0.03	221526.2	0.14
UCP	107446.3	-0.21	120931.7	-0.05	140193	0.09

Source: Extracted by the author from the simulation result.

Table 5.14: Household Welfare.

		RNP	**RMP**	**RCP**	**UNP**	**UMP**	**UCP**
Equivalent Variation	Dyn 1	-0.26	-0.43	-0.65	-0.32	-0.48	-0.52
Equivalent Variation	Dyn 5	-0.12	-0.18	-0.23	-0.06	-0.14	-0.16
Equivalent Variation	Dyn 10	1.27	0.94	0.04	2.18	1.04	0.06

Source: Extracted by the author from the simulation result

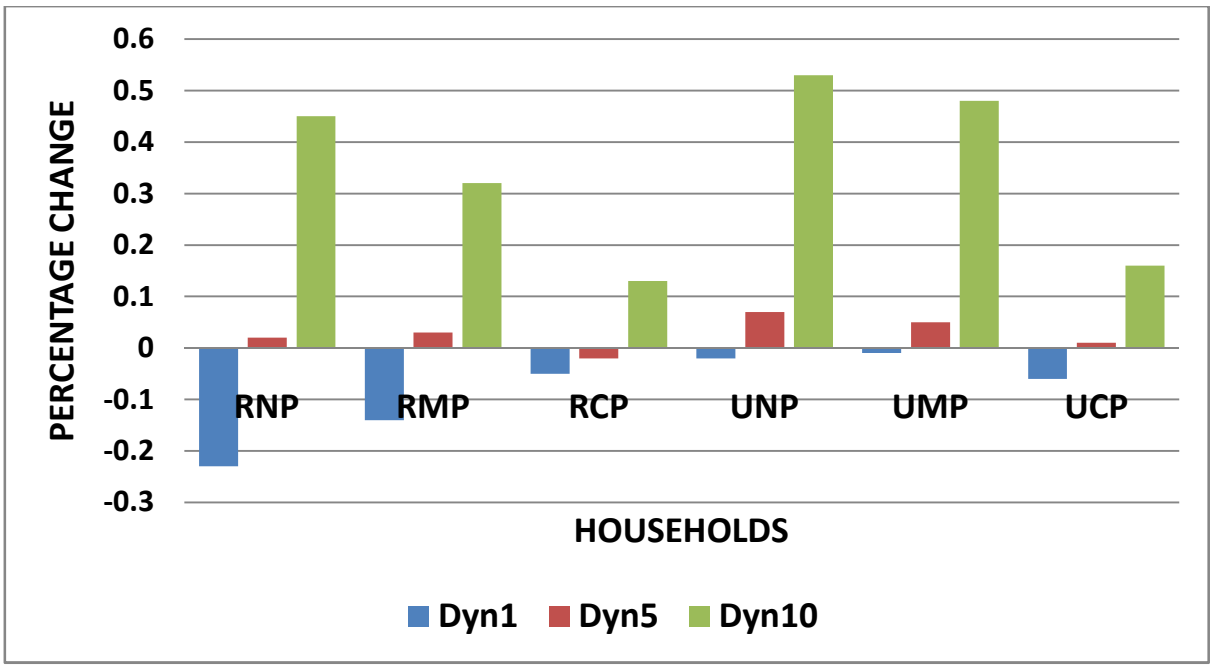

Figure 5.7 **Graphical presentation of Household Capital Income.**

Source: Extracted by the author from the simulation result

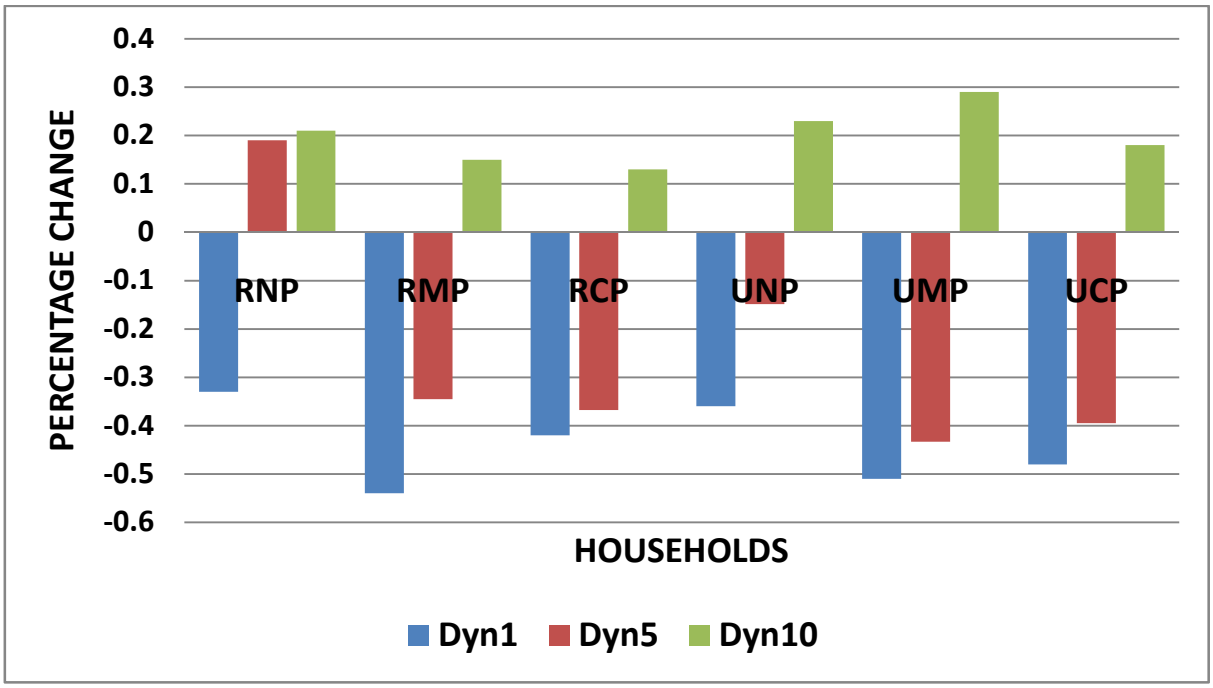

Figure 5.8 **Graphical presentation of Household total income:**

Source: Extracted by the author from the simulation result.

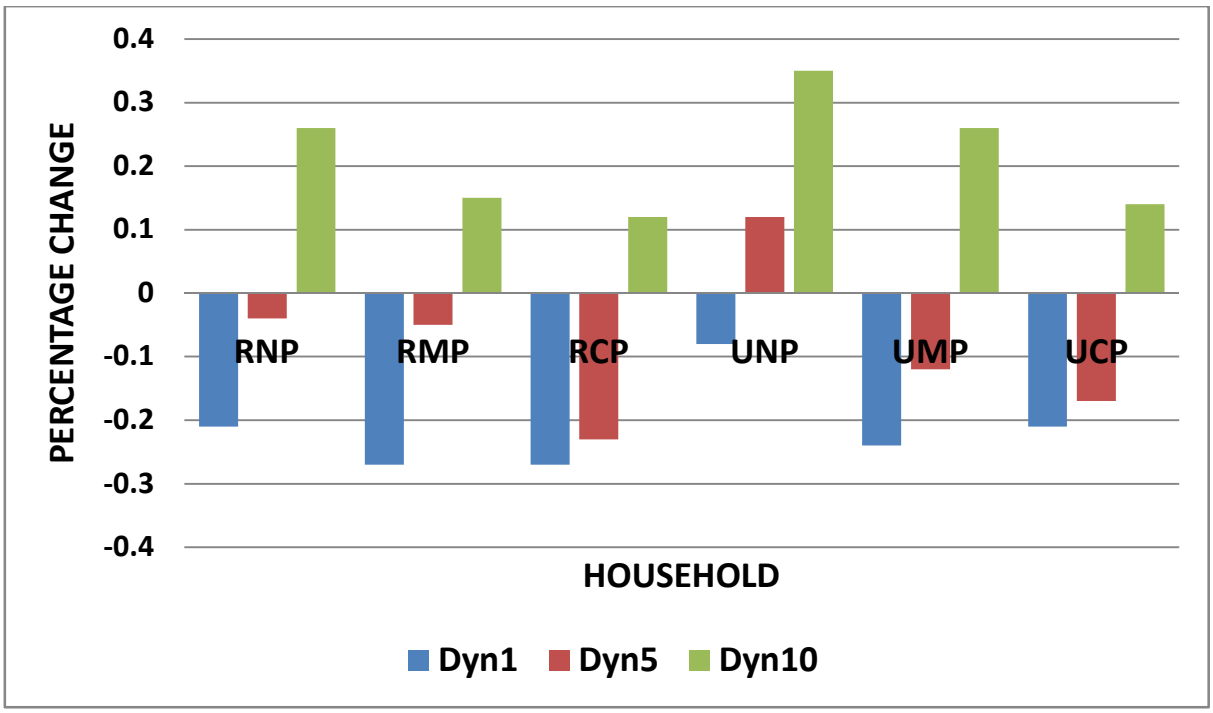

Figure 5.9 **Graphical presentation of Household Labour Income.**

Source: Extracted by the author from the simulation result

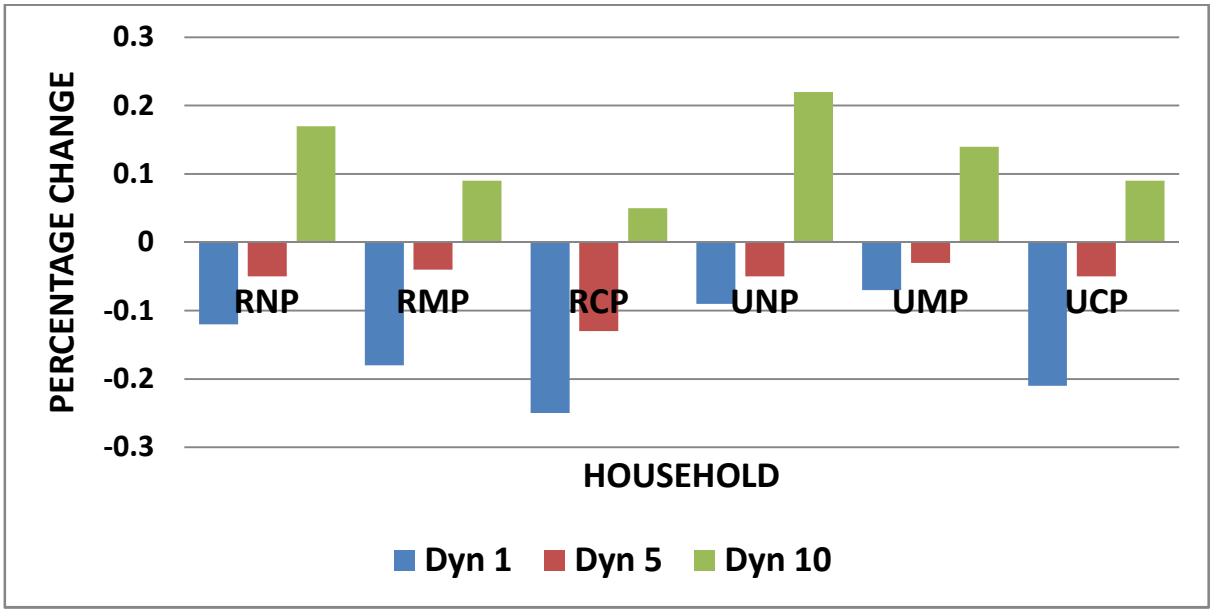

Figure 5.10 **Graphical presentation of Household Savings**

Source: Extracted by the author from the simulation result

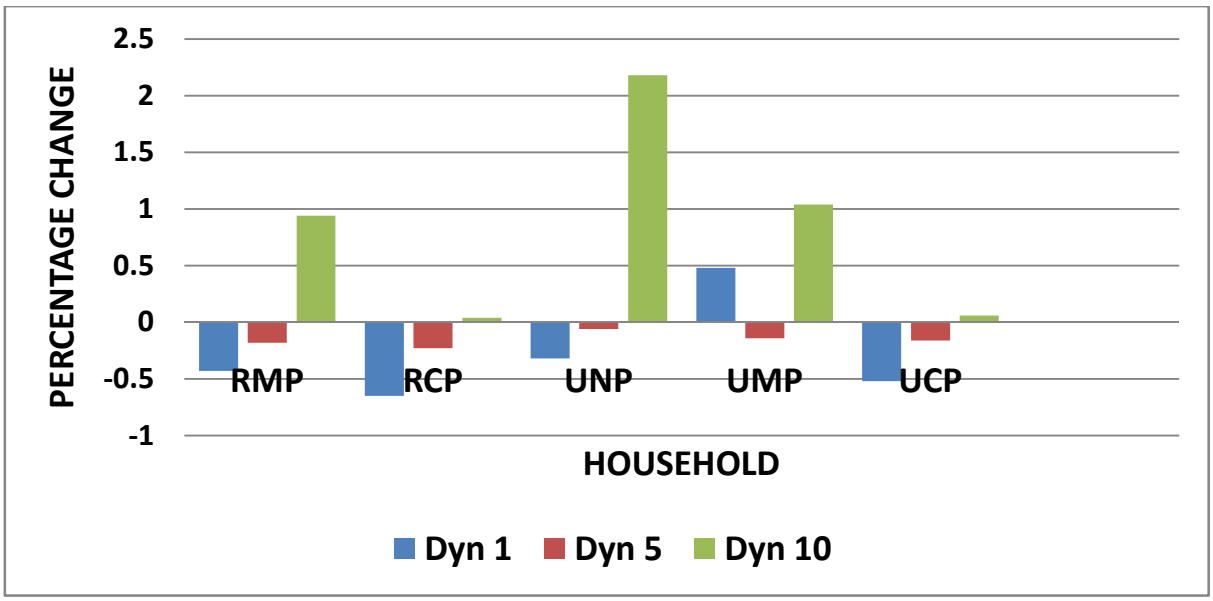

Figure 5.11 **Graphical presentation of Household welfare (EquivalentVariation).**

Source: Extracted by the author from the simulation result

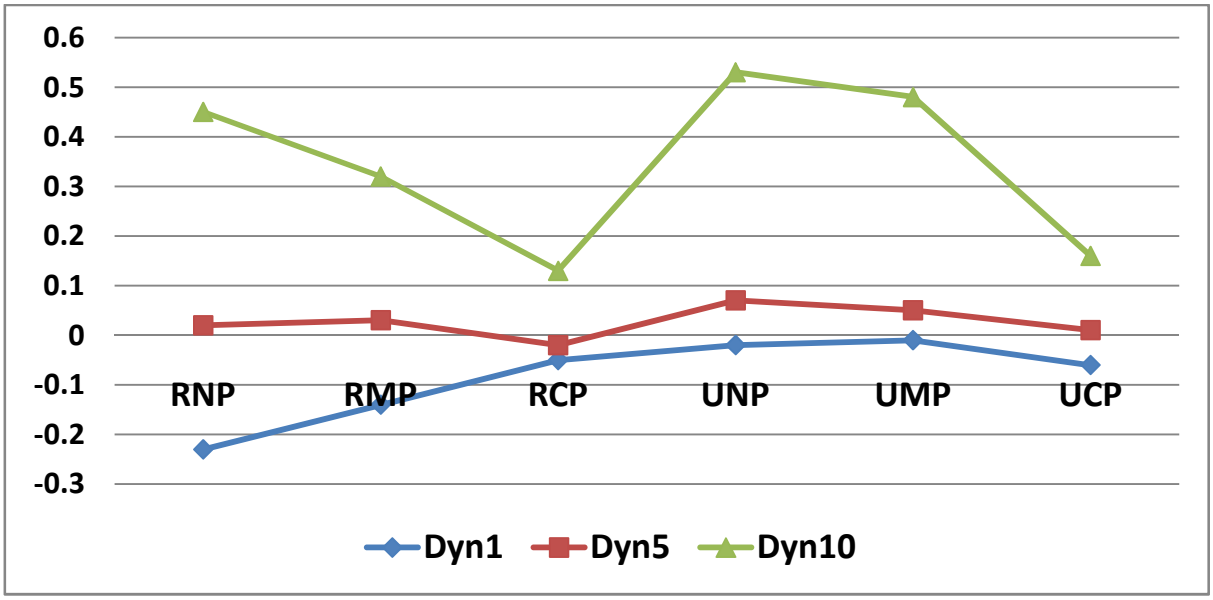

Figure 5.7 **Graphical presentation of Household Capital Income.**

Source: Extracted by the author from the simulation result

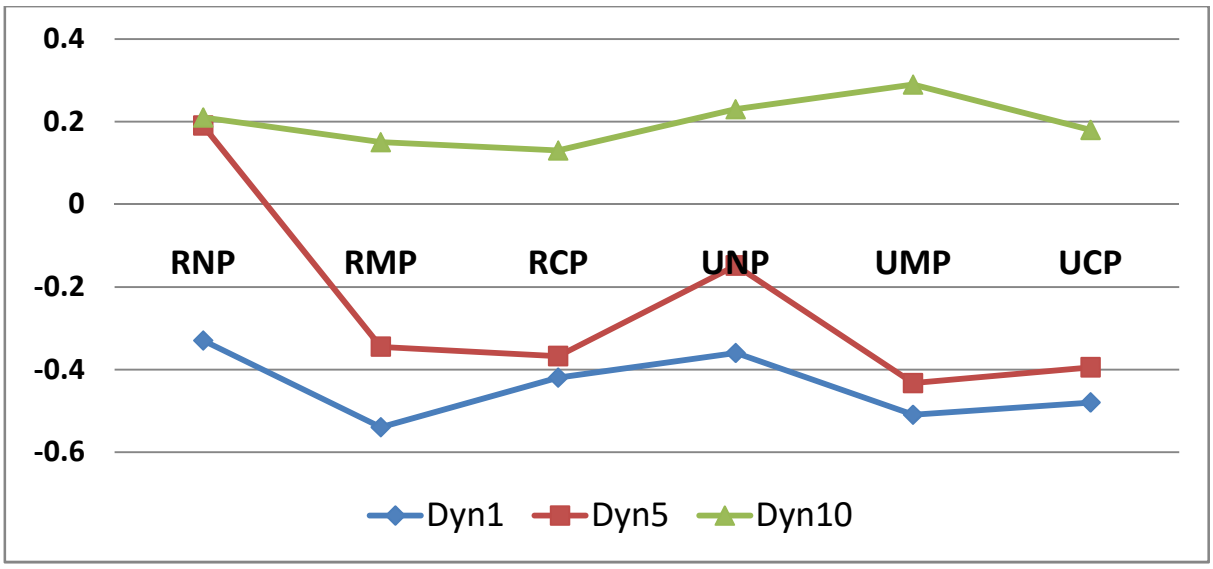

Figure 5.8 **Graphical presentation of Household total income**

Source: Extracted by the author from the simulation result

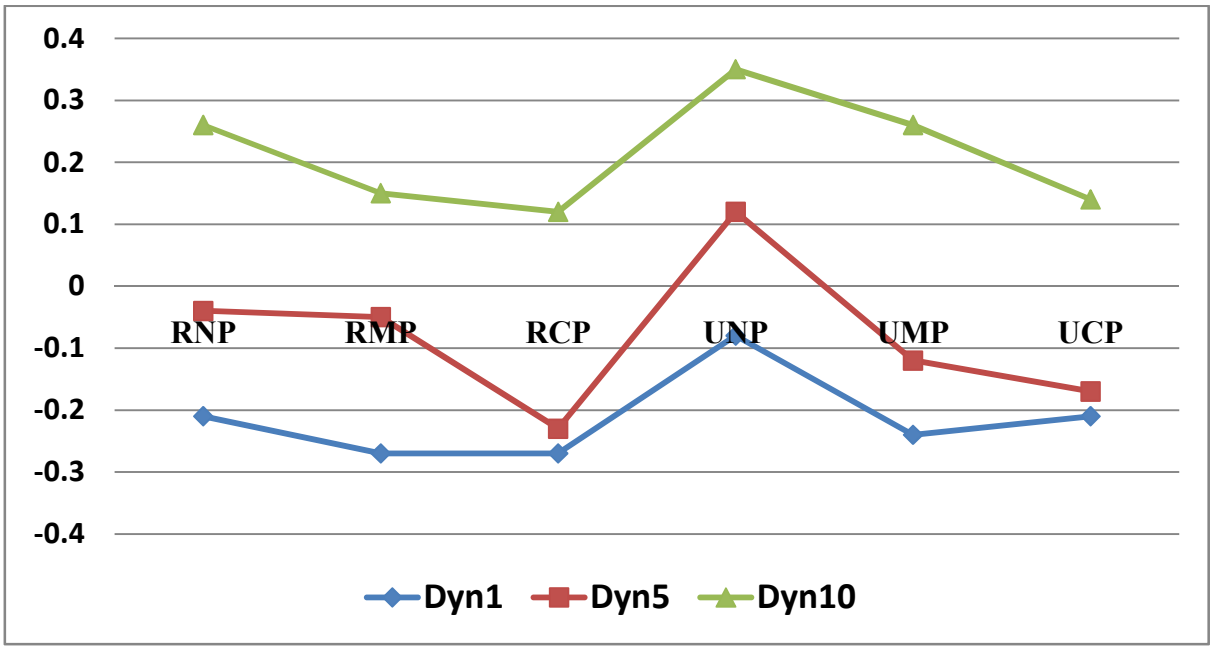

Figure 5.9 **Graphical presentation of Household Labour Income.**

Source: Extracted by the author from the simulation result

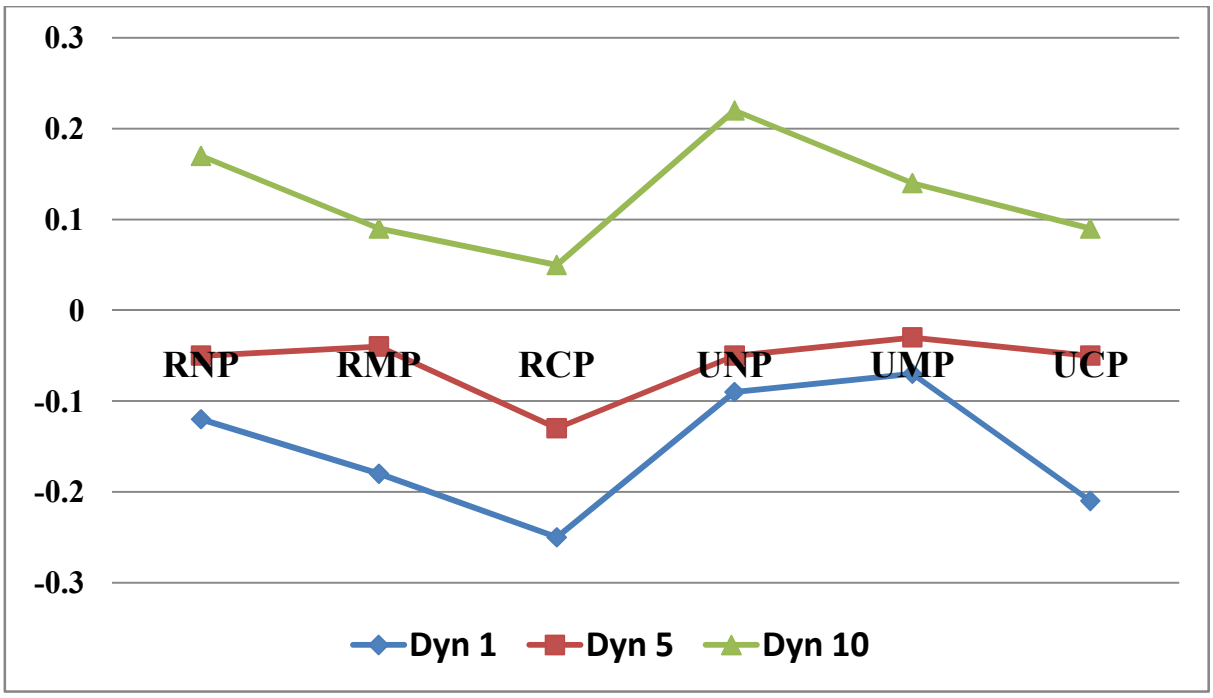

Figure 5.10 Graphical presentation of Household Savings.

Source: Extracted by the author from the simulation result

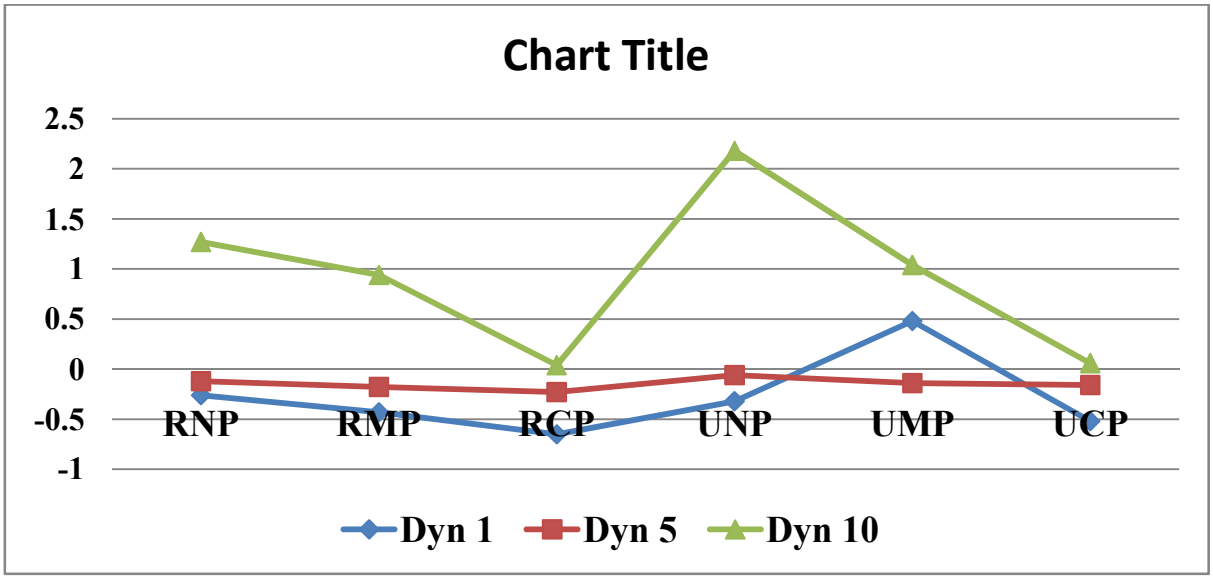

Figure 5.11 Graphical presentation of House Welfare (Equivalent Variation)

Source: Extracted by the author from the simulation result

5.8 Diagnostic checks and sensitivity analysis.

Some diagnostic checks were carried out to determine the goodness of the overall model specification. Also, a sensitivity analysis (SA) was conducted to check the robustness of simulation results under different parameter values, particularly the CES.

Diagnostic 1 - *Baseline simulation*, to check that the solution to the model (without any shock) reproduces the initial equilibrium value. This was done by comparing the output of the baseline simulation with the database. Also, an alternative was to check the magnitude of infeasibility at the input point from the output file. The result shows that the input point for the GPRICE is infinitesimally small (see table 5.13). This means that the highest deviation of the baseline simulation value from the initial equilibrium value is negligible, and does not bloat the simulation result. Also, it is expected that the baseline simulation should be solved without any iteration. This was also achieved in the experiment. As can be seen, in table 5.13, there was no iteration beyond 'after scaling'.

Diagnostic 2 - *Leon*, to check that the last market is in equilibrium. The check verifies that the Walras law[100] is not violated. This requires investigating the "level" value of the Leon variable in the baseline simulation and the shocked simulation. It is expected that the Leon value is zero or tending towards zero (that is, infinitesimally small). The check shows that the values of the Leon at the baseline simulation as well as the simulated gas price shock were approximately zero (see table 2 of Appendix E).

5.8.1 Sensitivity analysis.

The sensitivity analysis was carried out by varying the CES values systematically and investigating the results[102] First, the initial value of CES was doubled, and then reduced by half. This was intended to Analyse how sensitive the results were to these larger changes. For verification, the results for macroeconomic, sectoral and household variables are presented. The results generally show that the model is relatively stable as changes in the CES do not influence the simulation results significantly. For instance, most macro variables of interest such as GDP, Price, Total investment expenditure and Government

income showed no deviation from the original simulation, when CES was doubled as well as when CES was reduced. The firm's income, import and export variables show some deviation above 0.01 (but less than 0.05) from the original simulation. Household income did not also show any significant deviation from the results obtained when the standard assumption made about the CES was employed. The sensitivity analysis is shown on the graph below

Figure 5.12 Result of sensitivity analysis on macroeconomic variables.

Source: Extracted by the author from the simulation result

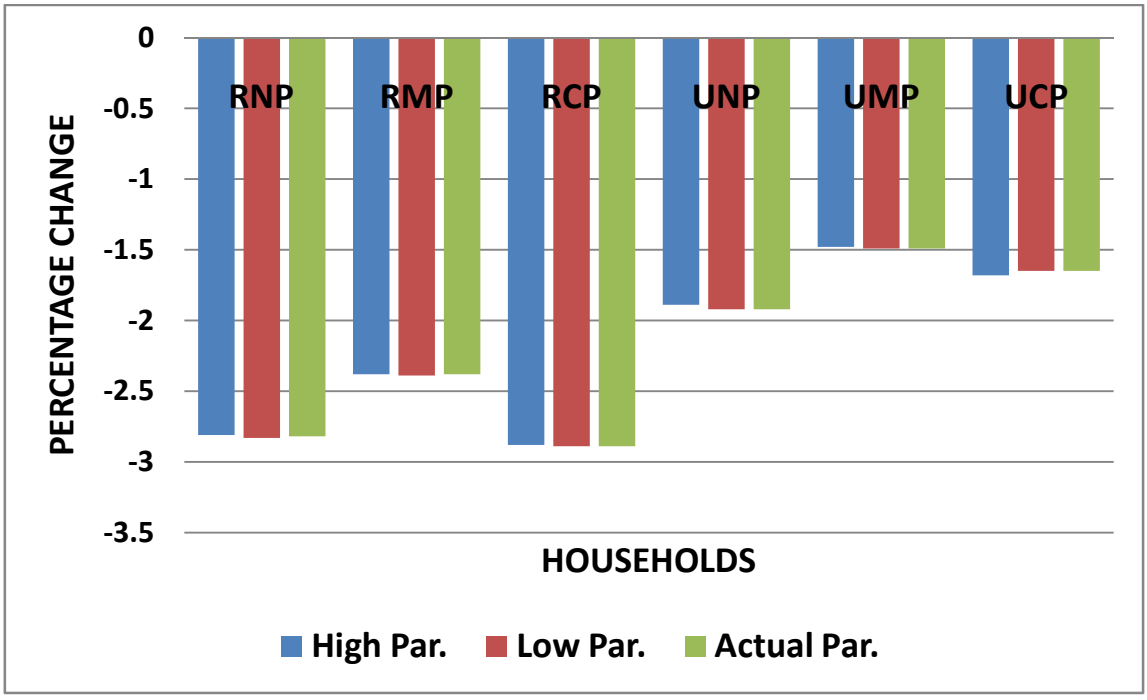

Figure 5.13 Sensitivity analysis on Household categories

Source: Extracted by the author from the simulation result

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5.9 Empirical results from the third party access model

The simulation results from the third party access model are discussed in the tables below. The tables show the deviation from the base case scenario of the various degrees of TPA implemented in percentages following the two path process (to supply or flare). From the results below the introduction of third-party access (i.e. the gradual implementation of TPA by 10%, 50% and 100%, following the European Union model) will lead to increase in the volume of gas delivered to the market, gas producers' revenue, and pipelines owners' revenue as shown in the tables 5.16 to 5.18 and also shown in the graphs figure 5.25 to 5.27 below.

Table 5.15. Results of the volume of gas supplied to the market.

Rout	Base Case	10%	50%	100%
o-a-d-1	28.96	41.23	65.77	90.3
o-a-d-2	28.96	16.7	8.2	4.36

Source: Extracted by the Author from the simulation result.

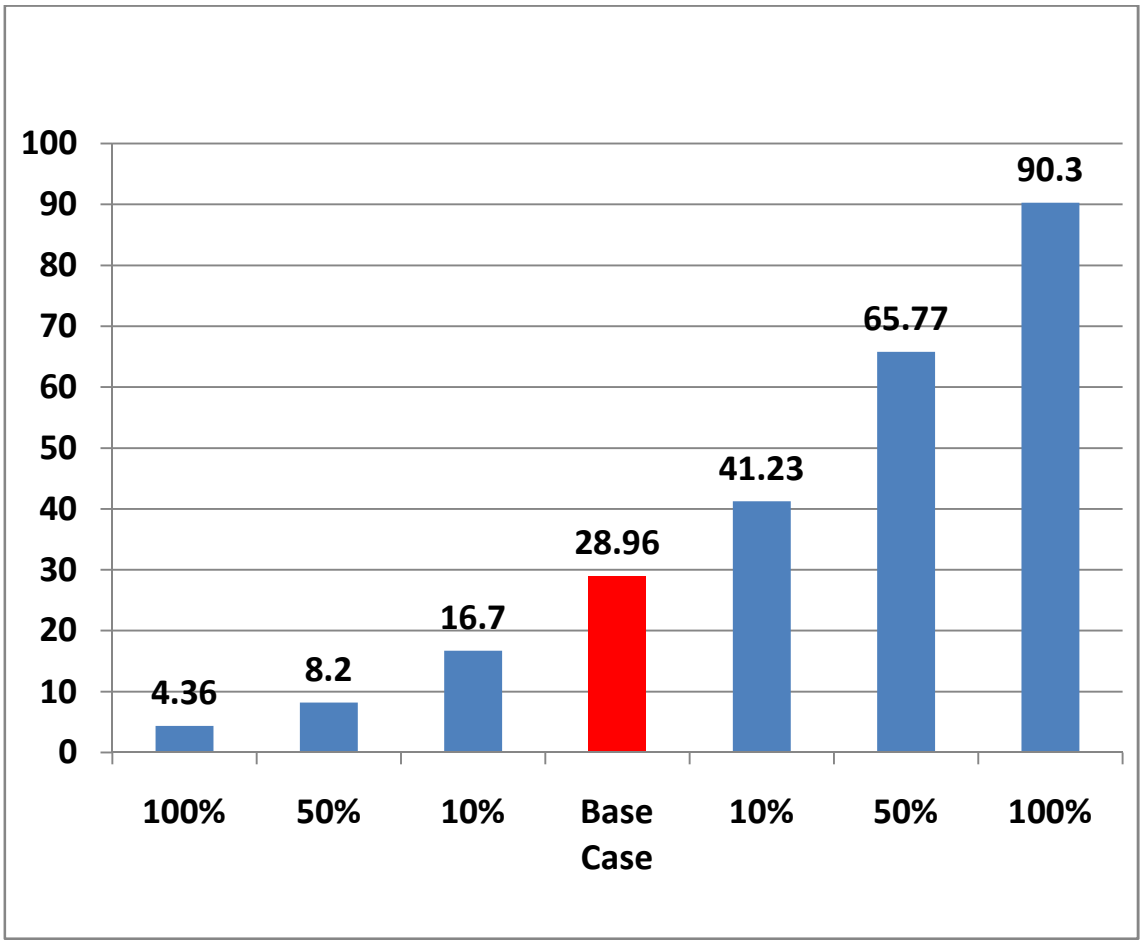

Figure 5.14 Volume of gas supplied to Market.

Source: Extracted by the Author from the simulation result.

Table 5.16 Gas Producers Revenue.

	Base Case	10%	50%	100%
o-a-d-1	28.96	48.24	86.8	141.23
o-a-d-2	28.96	1.02	5.33	10.43

Source: Extracted by the Author from the simulation result.

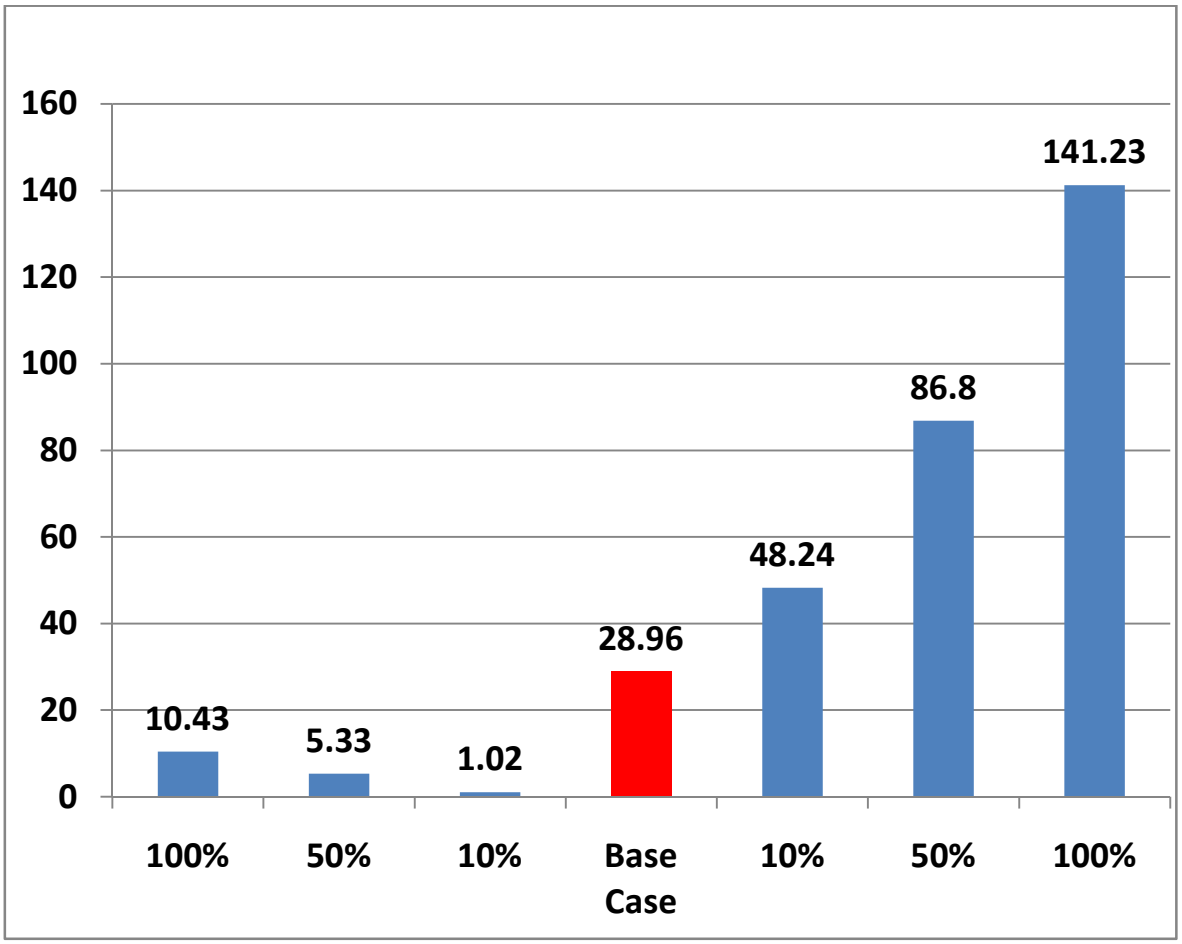

Figure 5.15 Gas Producers Revenue

Source: Extracted by the Author from the simulation result.

Table 5.17 gas facility Company's Revenue.

Scenarios	Base Case	10%	50%	100%
% Deviation	15.77	16.82	17.57	20.73

Source: Extracted by the Author from the simulation result.

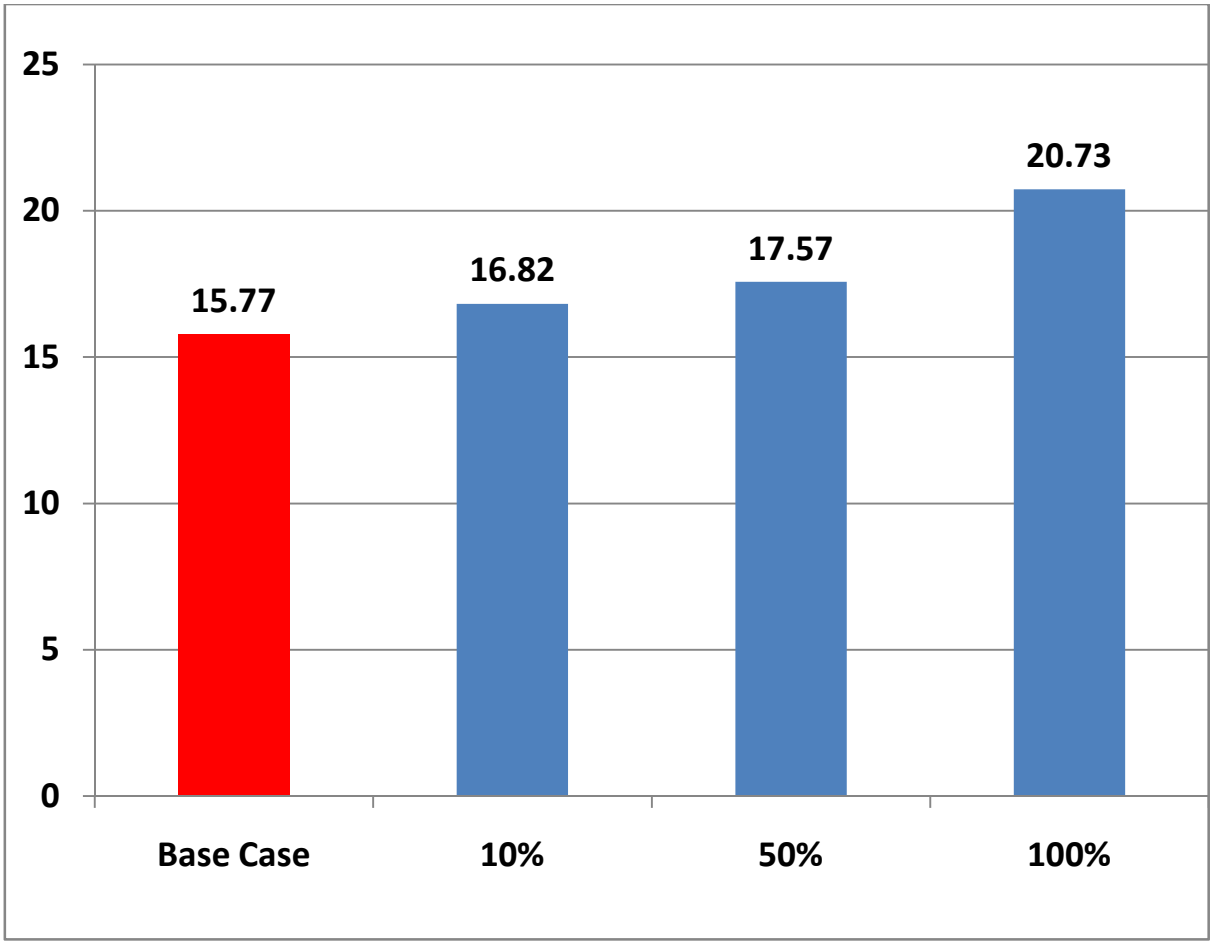

Figure 5.16 pipelines Company Revenue.

Source: Extracted by the Author from the simulation result.

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

6.1 Preamble.

The chapter summarizes the main findings of this study, offers some direction for policy, highlights the limitations of this study and shed some light on the future direction of the research. The chapter is structured as follows. Section 6.2 presents a summary of the research findings. Some policy recommendations are presented in section 6.3. While limitations of the study are discussed in section 7.4, and section 6.5 highlights suggestions for further research.

6.2 Summary of research findings.

This study provided a simulation experiment of domestic natural gas market liberalisation in Nigeria's economy through the exploration of forty six (46) sectors (aggregated to nine sectors) energy focused CGE modeling which incorporates key features of the Nigerian energy sector. The simulation was guided by a graduated price liberalisation as outlined in the Nigerian gas master plan. The model conveniently reproduced the economic situation at the baseline of the 2014 GASAM used. The results of the impact analysis as presented in this study can be grouped into four categories viz: the macroeconomic, sectoral, household income and welfare impact.

An increase in gas price as a result of the domestic natural gas market liberalisation stimulates an upward trend in the general price level as reflected in the consumer price index. It also negatively influences the real GDP, output, export, and import in the early stages of the policy (Dyn 1 and Dyn5), but stabilizes for a positive impact of these variables at a later stage of the policy (dyn10). This invigorates the empirical evidence that dynamic adjustments to policy changes often recoup the long run benefit of policy shock.

At the sectoral level, the results which closely follow the trend observed in the macroeconomic level show negative responses of sectors to higher gas prices in terms of intermediate consumption, output, export, domestic supply, and domestic demand. These variables like the macro variables showed a negative impact at the beginning but became positive at a later stage of the simulation experiment (Dyn10).

While all household categories experienced adverse factor employment and hence fall in factor income. The non-poor and moderate-poor households experience the worst loss in welfare. The core-poor households are comparatively least affected. This result further reinforces the greater vulnerability of non-poor and moderate-poor households to higher domestic energy prices. However, in the tenth year (dyn10), all household categories experience positive welfare.

1.3 Conclusion

Finally, a few conclusions can be drawn from our simulation results. First, the simulation evidence revealed that the impact of domestic market liberalisation of natural gas on the Nigerian economy is minimal, though not negligible. This indicates the lower economic cost, on the average term. Secondly, the gas sector policy of liberalisation record higher price levels, government and firm's income. It also records a fall in real GDP, output, and factor employment at the earliest stage of the policy (Dyn1 and Dyn5), and after that records a positive impact (Dyn10). Thirdly, it reveals that the generation in investment flows is feasible when the domestic gas market liberalisation policy is implemented. Fourthly, although, all household categories are adversely affected at the early stage of the policy (Dyn1 to Dyn5), the simulation evidence reveals that the core-poor are more vulnerable to higher gas prices in the case of income distribution and welfare. Finally, the simulation experiment reveals that the electricity and transport sectors of the economy are worst affected, while the natural gas and manufacturing sectors comparatively experienced growth.

In pursuance of its set objectives, the study shows that in the long run, the liberalisation of domestic natural gas market reform can be realized in Nigeria at low economic and

welfare costs. Hence, in the context of policy formulation, the results of this study can be reasonably relied upon as a starting point in establishing the impact of the domestic natural gas market liberalisation in Nigeria. However, when interpreting and using these results, it is imperative to be aware of several limitations inherent in the methodological approach, analytical assumptions, and the study time frame.

Drawn from the empirical evidence of the simulation experiment, it is evident that the principal benefit of the domestic gas market liberalization policy is that, it will encourage and incentivize gas producers to supply gas to the domestic market. Once producers have a reasonable assurance that they will recover their costs(including an appropriate return on investment), a key barrier to investment and increased supply to the domestic will be removed. Second, the need for any form of coercion will be eliminated and the requirement for domestic gas supply obligation (DGSO), will disappear. Lastly, a social adverse effect that may arise from the implementation of this policy at the early stage, should be ameliorated through various government safety net programs, to reduce the adverse effects of the policy at the early stage on households.

6.4 Recommendations

Based on the research findings obtained from this study, a few recommendations for policy are suggested. There is an urgent need to tackle the factors that have impeded the development of the domestic natural gas market in Nigeria, and to promote reforms that would position the gas sector to drive her economy. In line with this, there is the need for some interventions to be taken, including increased investment in gas infrastructure (which should be private sector driven), improvement in the quality and effectiveness of regulations/laws, and adoption of modern technology and best practices in the natural gas sector.

The need for these interventions is further supported by the result obtained from simulating a higher price of gas as a result of the liberalisation policy. Rather than implement a general one-time price liberalisation, (one-time price adjustment), the results have highlighted the need for a gradual adjustment approach, that has both short and long

term benefits/ impact. Also, it has highlighted the need for targeting policy response, giving that some household category is more affected by the shock than others.

There is the need for the government to ensure that a good time planned liberalisation program of the domestic gas sector is implemented rather than unplanned price adjustment currently be implemented. Being a very capital-intensive sector (with most of the capital owned by IOC's), there is the need to introduce a policy that will help develop local capacities to participate through partnership / shareholding to own capital at the various levels of the sector's value chain, so that returns to capital would be retained in the economy. To this end, the Local Content Act, and the quick passage of the petroleum industry governance bill (PIGB) will be a step in the right direction.

These suggestions if implemented would position the economy and households, in particular, to reap the gains from the importance of natural gas as the fuel of choice to drive national development and reduce over-dependence in crude oil.

6.5 Contribution to Knowledge

The level of energy utilisation rather than the amount of rent accruable from its sale is a critical indices in determining the level of development of any economy. It is on this premise that the Natural Gas Master Plan (NGMP, 2008) seeks to address the low level of domestic natural gas consumption in Nigeria through market liberalisation. Thus, analysing, as well as identifying the key impact through which this policy will exact influence on the economy and household welfare in Nigeria using a Computable General Equilibrium (CGE) Model is imperative, especially as the analysis is based on inter-industry or multi-sectoral backward and forward linkage, and how policies impact or permeate through the various sectors of the economy.

This study, therefore, has been able to extend the Competitive General Equilibrium Theory founded on the Walrasian theory of market behaviour to explain the dynamics of natural gas market liberalisation policy on macroeconomic, sectoral and household welfare in Nigeria. Also, this study has strived to produce a suitable measure to ascertain

the efficiency of the Third Party Access Policy (TPA) to natural gas infrastructure in Nigeria - a component of gas market liberalisation. To the best of the researchers' knowledge, this study signifies the first attempt to generate a set of domestic natural gas market liberalisation index for Nigeria. This index would serve as a useful tool to better understand the magnitude of the domestic natural gas market reform that is being implemented in Nigeria. Again, this study also contributes to the literature by revealing that the domestic natural gas market liberalisation policy is potent in increasing domestic utilization of natural gas than any other policy such as the domestic gas supply obligations. Importantly, the results from the analysis carried out in this study will provide critical input into the formulation of a policy framework that would address the challenges facing the natural gas sub sector and by extension the oil and gas sector in Nigeria. Moreover, this study will be of immense benefit to policy makers, energy regulators, industries, especially power utility companies, the academia and other interested stakeholders in the natural gas sector reforms.

6.6 Limitations of the study.

This study like many empirical studies was constrained by several factors that could be considered as limitations.

First, the CGE model used in this study focuses on the real side of the economy, since the Nigerian SAM does not include features of the financial sector. The implication of this is that the effects of the shocks depended only on changes in relative prices, thus downplaying the role of financial markets on economic agents' behaviour.

The uniqueness, suitability and overall usefulness of the application of CGE in economic and welfare analyses of policy change are unarguably obvious, but also, its methodological and analytical drawbacks cannot be denied. Methodological issues surrounding the choice of elasticity parameters in the model were not econometrically estimated using Nigerian data, but have been 'adopted' from other studies. However, a reasonable level of confidence can be placed on the results from the model simulations, as the results were robust with different parameters.

Another limitation of this study was that, as the current model simulated the impact of gas liberalisation on representative households, it ignored the heterogeneous components of households. More information may be provided with a microsimulation CGE model because of its ability to track the inter-household effects of shocks. However, the construction of a recursive dynamic microsimulation CGE model for Nigeria is not only severely constrained by data, but also computationally challenging.

Despite the limitations mentioned above, the current model along with the modified SAM generated plausible empirical results. Thus, the analysis carried out still proves useful in understanding the impact of the domestic natural gas market liberalisation in Nigeria.

6.7 Suggestions for further research.

The current debate on energy sector reforms and specifically natural gas market liberalisation globally and in Nigeria and its attendant consequences on the economy still poses considerable potential for further research.

First, it would be appropriate to undertake a study on the analysis of the distribution and welfare impact of domestic natural gas market liberalisation using microsimulation CGE. This will offer the opportunity for an in-depth impact assessment on say, poverty, welfare, income, and employment.

It would also be appropriate to carry out research in the area of constructing a comprehensive database for a recent base year that would include activities of the financial sector. This would prove useful in studying how access to credit and possession of financial assets of households can help cushion the effects of the shocks as they may help households smoothing their consumption path in the face of shocks. Also, although the level of confidence attached to the conclusion of the model simulations is reasonable, there is still the need for elasticity parameters used in the model to be econometrically estimated using Nigerian data.

It is ideal also, to extend the current CGE model to incorporate features of microsimulations to account for household heterogeneity. This will better capture the household impact with respect to the shocks they face. Further, the disaggregation of the number of sectors and commodities may prove more useful in understanding the industry level linkages, and the transmission of shocks to households.

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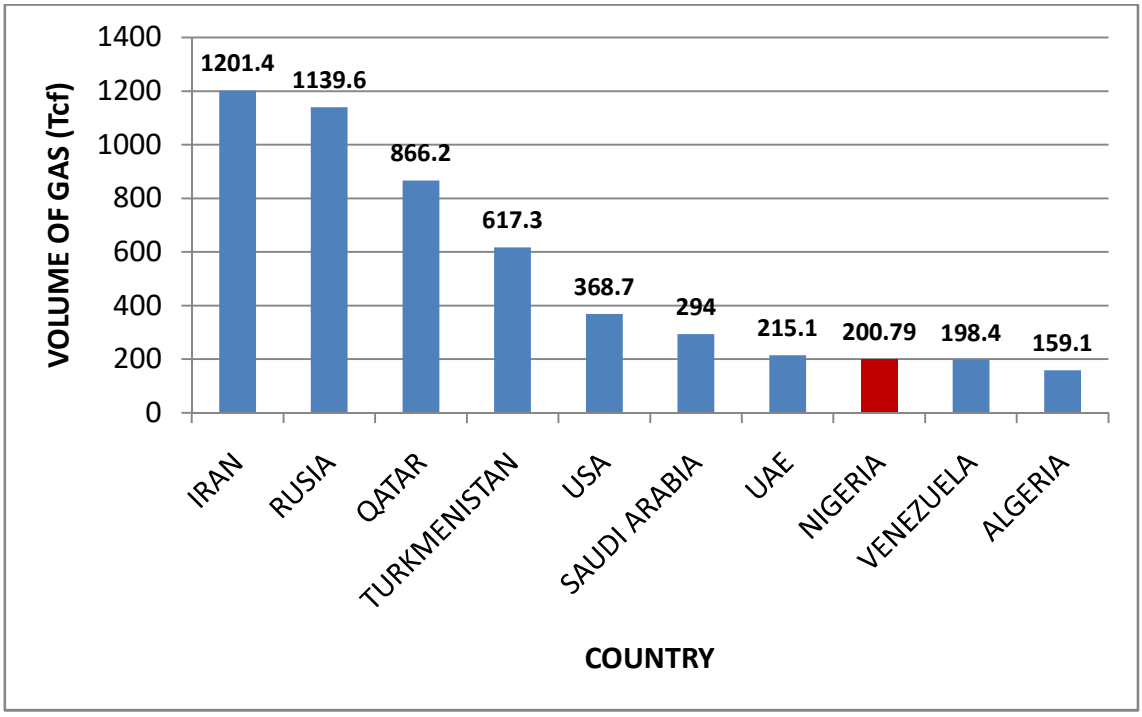
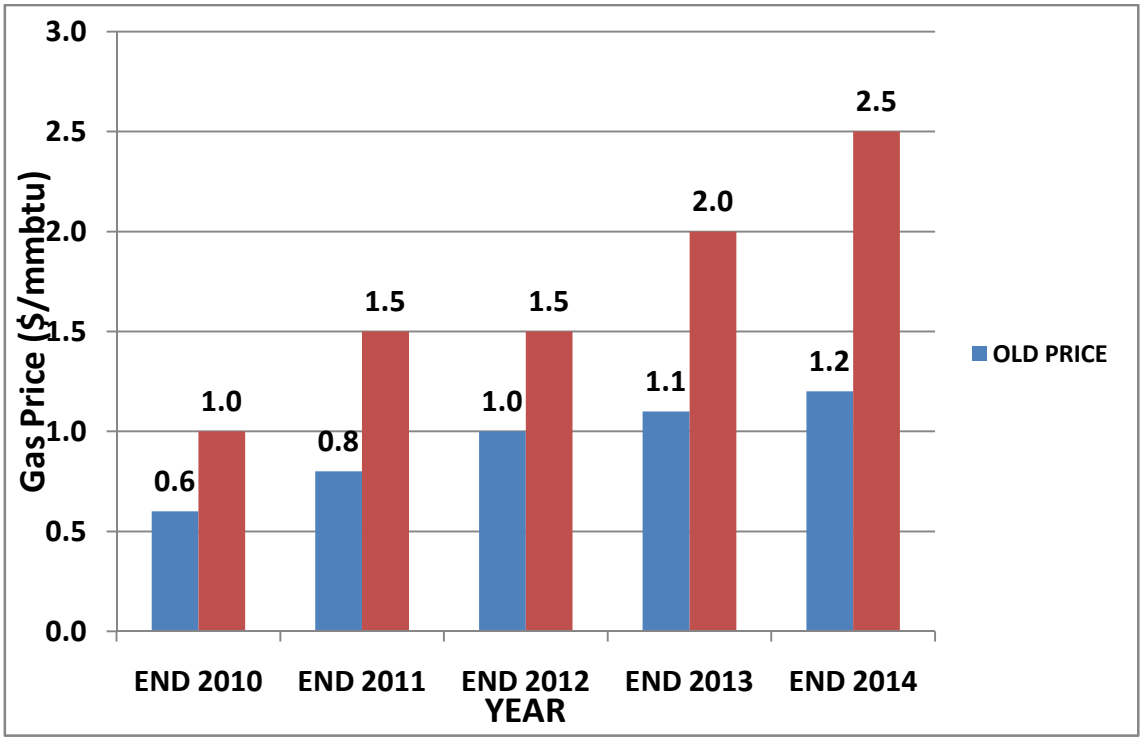
APPENDIX

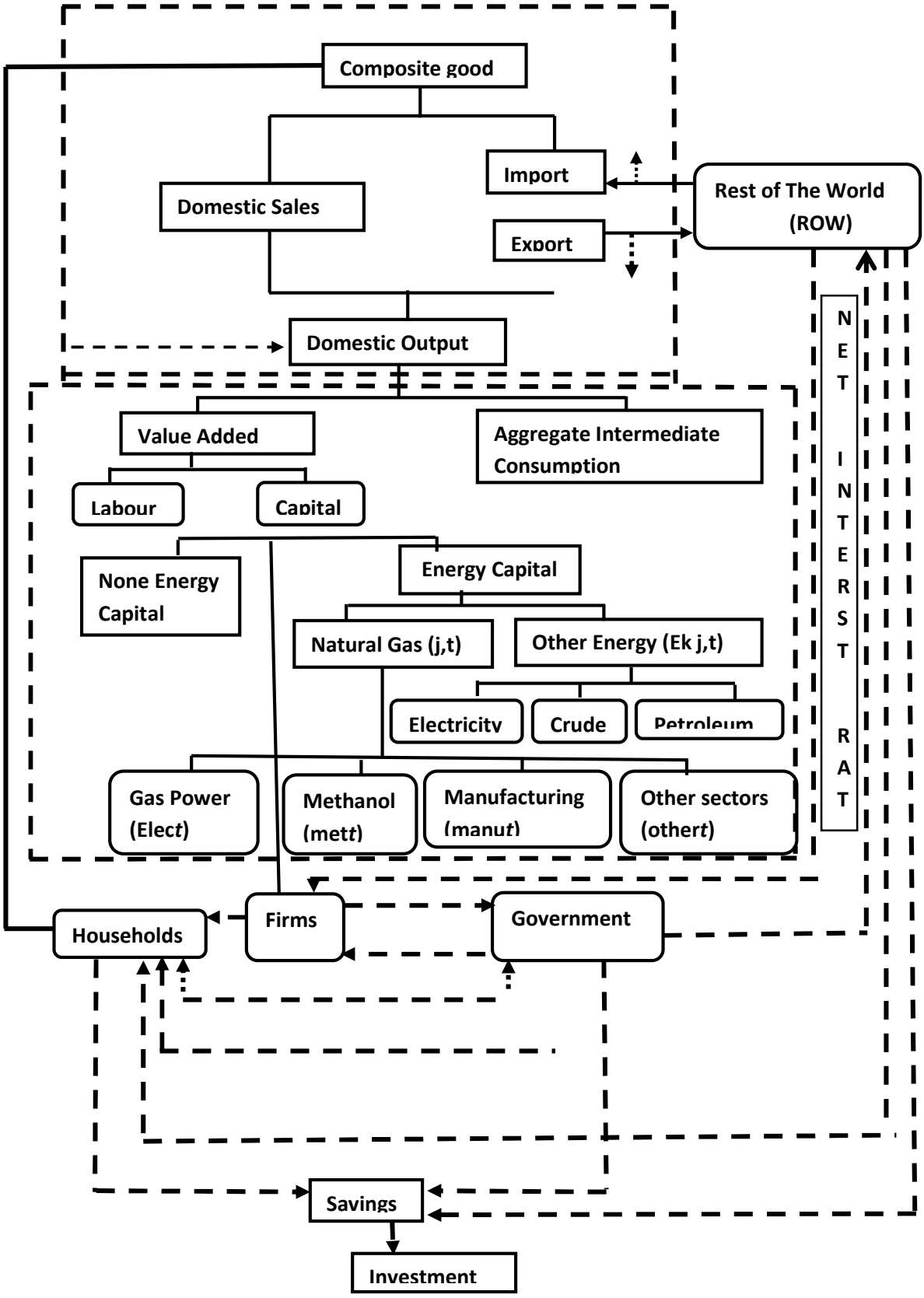
A World Proved Natural Gas Reserve Ranking (2019).



A2 Revised Gas Price NGMP 2008.



B. CGE Model structure.



C1. SETS

C2.1 INDUSTRIES AND COMMODITIES

All industries: $j,Jj \in J = (J_1...,J_j.,...\}$

All commodities: $i,ij \in I = \{I_{1...},I...,.\}$

Public sectors: $pub \in PUB \subset J = \{PUB_1,...,PUB_{pub},...\}$

Private sectors: $bus \in BUS \subset = \{BUS_r...,BUS_{bus},...],BUS \cap$ PU B $= \theta$

C2.2 PRODUCTION FACTORS

Labour categories: $l \in L = \{L_1...,..., L_l,,...\}$

Capital categories: $k \in K = \{K_1.,...,K_k,...\}$

C2.3 AGENTS

All agents: $ag,agj \in AG = H \cup F \cup \{GVT,ROW\} = \{H_l,...,H_h,-..,F_l,...,F_f ...,GVT,ROW\}$

Household categories: $h,hj \in H \subset A$G = $\{H_1 \ldots,H_h,...,F_{1...},\}$

Firm categories: $f, fj \in F \subset AG = \{F_1...,F f...,.\}$

Non-governmental agent:

agng $\in$ AGTVG $\subset$ AG = H $\cup$F $\cup$ {ROW} = $\backslash H_l,...,H_h,...,F_l,...,F_f,...,ROW\}$

Domestic agents:

$agd \in AGD \subset AG = H \cup F \cup [GVT] = \{H_1,...,H_h,...,F_1,...,F_f,...,GVT\backslash$

C2.4 PERIODS

Periods: t $\in$ $T = \{T_1....,T_t...,,\}$

A3. Variables

C3.1 VOLUME VARIABLES

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

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

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

$CI_{j,t:}$	Total intermediate consumption of industry y
$CTH_{h,t}^{REAL}$:	Real consumption expenditures of household *h*
$DD_{i,t}$:	Domestic demand for commodity z produced locally
$DI_{i,j,t}$:	Intermediate consumption of commodity z by industry y
$DIT_{i,t}$:	Total intermediate demand for commodity *i*
$DS_{j,i}$:	Supply of commodity z by sectary to the domestic market
$EX_{j,i,t}$:	Quantity of product z exported by sectary
$EXD_{i,t}$:	World demand for exports of product z
G_t^{REAL} :	Real government expenditures
$GDPt^{BP\_REAL}$:	Real GDP at basic prices
$GDP_t^{MP\_REAL}$:	Real GDP at market prices
$GFCF_t^{PRI\_REAL}$:	Real private gross fixed capital formation
$GFCF^{PUB\_REAL}$:	Real public gross fixed capital formation
$IM_{i,t}$:	Quantity of product z imported
$IND_{k,j,}$:	Volume of new type *k* capital investment to sector *j*
$INV_{i,t}$:	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
$KD_{k,j,t}$:	Demand for type *k* capital by industry *j*
$KDC_{j,t:}$	Industry *j* demand for composite capital
$KS_{k,t}$:	*S*upply of type *k* capital

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

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

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

$MRGN_{i,t}$: Demand for commodity *i* as a trade or transport margin

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

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

$VSTK_{i,t}$: Inventory change of commodity *i*

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

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

C3.2 PRICE VARIABLES

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

IR_t : Interest rate

$P_{j,i,t}$: 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*

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

$PE_{i,t}$ ∴.	Price received for exported commodity *i* (excluding export taxes)
$PE_{i,t}^{FOB}$:	FOB price of exported commodity z (in local currency)
$PIXCON_t$:	Consumer price index
$PIXGDP_t$:	GDP deflator
$PIXGVT_t$:	Public expenditures price index
$PIXINV_t^{PR}$:	Private investment price index
$PIXINV_t^{PUB}$:	Public investment price index
PK_t^{PRI}:	Price of new private capital
PK_t^{PUB}:	Price of new public capital
$PL_{i,t}$:	Price of local product *i* (excluding all taxes on products)
$PM_{.i.t:}$	Price of imported product *i* (including all taxes and tariffs)
$PP_{j,t}$:	Industry *j* unit cost, including taxes directly related to the use of capital and labour, but excluding other taxes on production
PT_j:	Basic price of industry *fs* output
$PVA_{j,t}$.:	Price of industry/ value added (including taxes on production directly related to the use of capital and labour)
$PWM_{i,t}$:	World price of imported product *i* (expressed in foreign currency)
$PWX_{i,t}$:	World price of exported product *i* (expressed in foreign currency)
$R_{k,j,t}$:	Rental rate of type *k* capital in industry *j*
$RC_{j,t}$:	Rental rate of industry *j* composite capital

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

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

$W_{l,t}$: Wage rate of type *j* labour

$WC_{j,t}$: Wage rate of industry *j* composite labour

$WTI_{l,j,t}$: Wage rate paid by industry *j* for type *j* labour, including payroll taxes

C3.3 NOMINAL (VALUE) VARIABLES

CAB_t: Current account balance

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

G_t : Current government expenditures on goods and services

GDP_t^{BP}: GDP at basic prices

GDP_t^{FD}: GDP at purchasers' prices from the perspective of final demand

GDP_t^{IB}: GDP at market prices (income-based)

GDP_t^{MP} : GDP at market prices

$GFCF_t$: Gross fixed capital formation

IT_t : Total investment expenditures

IT_t^{PRI}: Total private investment expenditures

IT_t^{PUB}: Total public investment expenditures

$SF_{f,t}$: Savings of type *f* businesses

SG_t: Government savings

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

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

$TDF_{f,t}$: Income taxes of type *f* businesses

$TDFT_t$: Total government revenue from business income taxes

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

$TDHT_t$: Total government revenue from household income taxes

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

$TICT_t$: Total government receipts of indirect taxes on commodities

$TIK_{k,j,t}$: Government revenue from taxes on type *k* capital used by industry *j*

$TIKT_t$: Total government revenue from from taxes on capital

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

$TIMT_t$: Total government revenue from import duties

$TIP_{j,t}$: 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)

$TIW_{l,j,t}$: Government revenue from payroll taxes on type *l* labour in industry *j*

$TIWT_t$: Total government revenue from payroll taxes

$TIX_{i,t}$: Government revenue from export taxes on product *i*

$TIXT_t$: Total government revenue from export taxes

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

$TPRODN$: Total government revenue from other taxes on production

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

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

$YDH_{h,t}$: 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

YG_t: Total government income

YGK_t : Government capital income

$YGTR_t$: Government transfer income

$YH_{h,t}$: 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

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

C3.4 RATES, INTERCEPTS AND OTHER VARIABLE PARAMETERS

$Sh0_{h,t}$: Slope (type *h* household savings)

$Sh1h,t$: Intercept (transfers by type *h* households to government)

$tr0_{h,t}$,: Marginal rate of transfers by type *h* households to government

$ttdf0_{f,t}$: Intercept (income taxes of type *f* businesses)

$ttdf1_{f,t}$: Marginal income tax rate of type *f* businesses

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

$ttdhl_{h,t}$.: Marginal income tax rate of type *h* households

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

$ttik_{k,j,t}$: Tax rate on type *k* capital used in industry *j*

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

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

$ttiw_{l,j,t}$.: Tax rate on type *l* worker compensation in industry *j*

$ttix_{i,t}$: Export tax rate on exported commodity i

C4. Parameters

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

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

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

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

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

B_i^{M} : Scale parameter (CES - composite commodity)

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

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

B_j^{XT}: Scale parameter (GET — total output)

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

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

βi^{M} : Share parameter (CES - composite commodity)

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

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

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

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

Л: 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}^{IvNPRI} : Share of commodity *i* in total private investment expenditure

γ_{i}^{INVPUB} : Share of commodity *i* in total public investment expenditure

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

io_{j}.: Coefficient (Leontief— intermediate consumption)

$\lambda_{ag,k}^{RK}$: Share of type *k* capital income received by agent *ag*

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

$\lambda_{h,l}^{WL}$ Share of type *l* labour income received by type *h* households

n_t: Population growth rate

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

pop_t : Population index

p_j^{KD} : Elasticity parameter (CES - composite capital) ; - 1 < p^{KD} < ∞

p_j^{LD}: Elasticity parameter (CES - composite labour) ; - 1 < $_P^{LD}$ < ∞

p_i^M: Elasticity parameter (CES - composite commodity); -*1*<$_P^M$, ∞ .

P_j^{VA}: Elasticity parameter (CES - value added) ; *1* < p^{VA} < ∞

$p_{j,i}^X$: *Elasticity* paramyer (CET-total ouput); 1 < p_j^{XT} < ∞

p_j^{XT} : Elasticity parameter (GET - total output) ; *1* < p_j^{XT} < ∞

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

σ_j^{KD} : Elasticity of substitution (CES - composite capital) ; 0 < σ_j^{KD} < ∞

σ_j^{LD} : Elasticity of substitution (CES - composite labour) ; 0 < a^{LD} < ∞

σ_i^M : Elasticity of substitution (CES - composite commodity); 0 < σ_i^M < ∞

a_j^{VA} : Elasticity of transformation (CES - value added) ; *0* < σ_i^{VA} < ∞

$\sigma_{j,i}^X$: Elasticity of transformation (GET - exports and local sales); *0* < $\sigma_{j,i}^X$ < ∞

σ_i^{XD} : Price-elasticity of the world demand for exports of product *i*

σ_j^{XT} : Elasticity of transformation (GET - total output) ; 0 < σ_i^{XT} < ∞

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

v_j : Coefficient (Leontief - value added)

D

D1.1 GSAM Sectoral Disaggregation.

Category	Disaggregation
Activities (46)	**Agriculture (4)** Crop Production Livestock Forestry Fishery **Crude Petroleum (1)** **Natural Gas (1)** **Oil Refining (1)** **Manufacturing (15)** Coal Mining Metal Ores Quarrying and Other Minerals Cement Food Beverage and Tobacco Textile, Apparel and Footwear Wood and wood products Pulp, Paper and Paper products Chemical,Chemical products and Pharmaceutical products Non Metallic Products Plastic and Rubber Products Electrical and Electronics Basic Metal, Iron and Steel Motor vehicle and assembly Other Manufacturing

	Electricity (1) **Transport (5)** Road transport Rail transport and pipeliness Water transport Air transport Transport services **Services (18)** Water supply and waste management Construction Trade Accommodation and food services Telecommunications Motion pictures, sound recording and music production Publishing Post Broadcasting Arts, entertainment and recreation Financial institutions Insurance Real estate Professional, scientific and technical services Administrative and support services Education Human health and social services Other services **Public Administration (1)**

Commodities (46)	**Agriculture (4)** Crop Production Livestock Forestry Fishery **Crude Petroleum (1)** **Natural Gas (1)** **Refined Petroleum (1)** **Manufacturing (15)** Coal Mining Metal Ores Quarrying and Other Minerals Cement Food Beverage and Tobacco Textile, Apparel and Footwear Wood and wood products Pulp, Paper and Paper products Chemical,Chemical products and Pharmaceutical products Non Metallic Products Plastic and Rubber Products Electrical and Electronics Basic Metal, Iron and Steel Motor vehicle and assembly Other Manufacturing **Electricity (1)**

	Transport (5) Road transport Rail transport and pipeliness Water transport Air transport Transport services **Services (18)** Water supply and waste management Construction Trade Accommodation and food services Telecommunications Motion pictures, sound recording and music production Publishing Post Broadcasting Arts, entertainment and recreation Financial institutions Insurance Real estate Professional, scientific and technical services Administration and support services Education Human health and social services Other services **Public Administration (1)**
Factors (2)	Labour

	Capital
Institutions (9)	**Households (6)** Rural core poor Rural moderately poor Rural non poor Urban core poor Urban moderately poor Urban non poor **Firms** **Government** **Rest of the world**

D1.2 Activity Sectors in the modified Nigerian 2014 SAM.

Sector Description	Code Name	Subsectors
Agriculture	**AGRIC**	- Crop Production - Livestock - Forestry - Fishery
Crude Petroleum	**CPET**	- Crude Petroleum
Natural Gas	**NGAS**	- Natural Gas
Manufacturing	**MAN**	- Coal Mining - Metal Ores - Quarrying and Other Minerals - Cement - Food Beverage and Tobacco - Textile, Apparel and Footwear - Wood and wood products - Pulp, Paper and Paper products - Chemical, Chemical products and Pharmaceutical products - Non Metallic Products - Plastic and Rubber Products - Electrical and Electronics - Basic Metal, Iron and Steel - Motor vehicle and assembly - Other Manufacturing
Refined Petroleum	**PET**	- Refined Petroleum
Electricity	**ELEC**	- Electricity
Transportation	**TRANS**	- Road transport - Rail transport and pipeliness - Water transport - Air transport - Transport services

Services	**SER**	- Water supply and waste management - Construction - Trade - Accommodation and food services - Telecommunications - Motion pictures, sound recording and music production - Publishing - Post - Broadcasting - Arts, entertainment and recreation - Financial institutions - Insurance - Real estate - Professional, scientific and technical services - Administration and support services - Education - Human health and social services - Other services
Non Tradable	**NTR**	- Public Administration

E

E1 Sensitivity Analysis.

Macroeconomic Variables	**Low Parameter**	**High Parameter**	**Actual Parameter**
Price Index	0.47	0.61	0.53
Real GDP	-0.12	-0.14	-0.10
Exports	-0.62	-0.67	-0.66
Imports	0.10	0.07	0.05
Total Investment Expenditure	0.05	0.06	0.07
WELFARE MEASURE	**Low**	**High**	**Actual**
Equivalent Variation: RCP	0.09	0.07	0.08
RMP	0.07	0.12	0.09
RNP	0.09	0.16	0.12
Equivalent Variation: UCP	0.02	0.04	0.03
UMP	0.03	0.06	0.05
UNP	0.05	0.08	0.06