MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICAN REGION: INVESTMENT AND REGULATORY APPROACHES

Abertay University

A thesis submitted for the degree of Doctor of Philosophy (PhD)

by

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Declaration

Candidate's declarations:

I, KANYA Williams James, hereby certify that this thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy (PhD), Abertay University, is wholly my own work unless otherwise referenced or acknowledged. This work has not been submitted for any other qualification at any other academic institution.

Signed: [redacted] Date: 26 October 2018.

Supervisor's declaration:

I, Professor Reza Kouhy hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Doctor of Philosophy (PhD) in Abertay University and that the candidate is qualified to submit this thesis in application for that degree.

Signed [Principal Supervisors signature] …………………………………...

Date…………………………………………………………………………….

Certificate of Approval

I certify that this is a true and accurate version of the thesis approved by the examiners, and that all relevant ordinance regulations have been fulfilled.

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Date…………………………………………………………………………….

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Dedication

Dedicated to the African Union and those who share similar concerns for the poor energy condition of sub-Sahara Africa. The learning points herein might be some of the missing enablers to unleashing the potentials of natural gas in Africa.

Dedicated to my family: Asabat, Chafari, Japheth, Jemima and Madaki.

Abstract

The study is modelling a natural gas market for sub-Sahara Africa. The abundance of natural gas amidst energy poverty in sub-Sahara Africa has been a concern. It is this concern that persuades the conduct of this research. Literature review indicates that this case of natural gas abundant resources in sub-Sahara Africa is a case of optimization problem. Although literature documents several researches on the energy condition of Africa, but gas is not sufficiently covered and there is no such document as to a natural gas market model on sub-Sahara Africa gas market in literature. Applying Supply-side Economic Solution through pragmaticism philosophical underpinning derived in the conduct of the research, a market model was attempted. This was by using comparative analysis of four major global natural gas markets to derive lessons for modelling the quantitative part and focus group interviews with key stakeholders of the industry for the qualitative part. The research takes the fundamental market issues in a micro-economic scope comprising investment theories; firm theories; gas price fundamentals; regulatory economics and supply-side economics solution. The concept of economic rent also is included in the literature review.

What emerges from the research is the proposed sub-Sahara Africa Natural Gas Market reflecting all the five issues of market and concept of economic rent considered in literature review from which questions and hypotheses were raised and the research conducted. This is the result of the research on sub-Sahara Natural Gas Market from Regulatory and Investment Approaches.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

What translates into the geo-political region of sub-Sahara Africa, is the entire African continent, comprising forty-nine (Tapon, 2018) sovereign and economic independent states, except for six North Africa Arab countries. The African Union and United Nations however recognize forty-eight from the total fifty-five countries of the continent. This variation and any other in numbers do arise, from disputed territories and inconsistencies regarding some island nations off the coast of the continent. According to the Encyclopedia Britannica on sub-Sahara Africa, the region has an assortment of ecoclimatic and biogeographical zones fostering a variety of biomes formed in response to shared physical climate. These zones include the renowned Sahel Savanah, Kalahari basin, Guinea Savanah, Tropical rain forest, the Eastern Miombo woodlands, Serengeti ecosystem, Bushveld and Karoo ecosystems. The region brandishes a functional delta of sub-regional cooperation tributaries, culminating into the main regional body, the African Union. These tributaries include Economic Community of Central African States; Southern African Development Community; Economic Community of West African States and East African Community. Its noTable cities include, Abuja, Addis Ababa, Lagos, Cape Town, Johannesburg, Dar es Salaam, Kinshasa, Nairobi and Dakar.

In this introduction, the sub-Sahara Africa's natural resource endowment; economic condition and governance issues regarding resource optimization are briefly discussed in analytics. This is hoping to illuminate the problem area of the study if there be any, find justification for the need to undertake the study and if there be any justification to undertake the study, outline the aim and structure of the study as well.

1.2 Research Gap

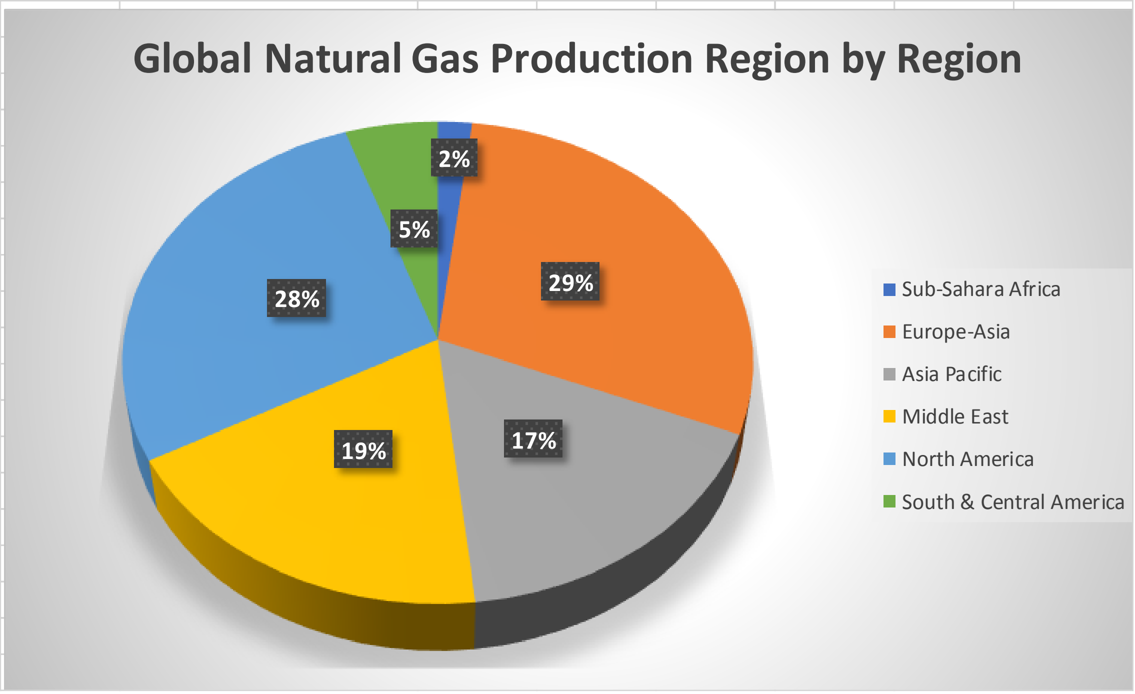
The present energy condition of the region is the research gap this project is about to explore. The World Bank reports contain substantial evidence showing that Sub-Sahara Africa is endowed with a good number of natural resources comprising rich hydro-carbon deposits, enormous biogeographical terrain with upside and large population capable of creating a vibrant domestic productive capacity and market activities that can place its economic position in a place far better than now. In this introduction, this study takes natural gas endowment among those rich hydro-carbon deposits which is the core of the study and ties it to key economic drivers that are gas dependent. Those key economic sectors include agriculture; industry; residential heating and lightnings and electric power.

In terms of its natural gas endowment, the BP Statistical Review of World Energy 2017 reports that sub-Sahara Africa sits on 225.3 trillion[1] cubic feet of proven conventional natural gas resources but produces only a paltry 1.02 per cent of it.

[1] Please note that this does not include recent natural gas findings in Tanzania and Mozambique, nor does it take into account the 600 trillion additional conventional natural gas new geological findings being touted by the Nigerian National Oil Company. Also note that non-conventional gas endowment like shale deposits have not yet being reported in sub-Sahara Africa.

The figure below gives the position of sub-Sahara Africa in the global gas production from its 2017 Statistical Report.

Figure 1 - Global Natural Gas Supply



Source: Constructed by Author from BP 2017 Statistical Report.

Figure 1 above is self-explanatory. It shows the low level of natural gas[2] production in the sub-Sahara Africa region, as well as reflecting the poor investment condition in this important economic sector. Available records on global energy balance flows from International Energy Agency (IEA) 2017 reports that from this paltry 2 per cent production, a massive 58.23 per cent is exported out to the large natural gas producers comprising North America and Euro-Asia, leaving only 41.77 per cent of the commodity for domestic use. The

[2] The comprehensive terminology in practice is Natural Gas Streams, which is the gross gas commodity comprising all other derivatives such as ethane, methane, Propane, butane and the “natural gas” in LNG liquefaction business. However, in all this document – except where it is explicitly stated - natural gas refers to Natural Gas Streams as it is known in commercial practice.

story does not end here as this 41.77 per cent is partly flared, partly used in operation of ageing oil field called re-injection to persuade stagnating crude flow and partly lost during processes. At the end, very little is left for the essential need for gas dependent vital economic sectors. This raises the concern as to why an essential commodity like this is exported amidst a thirsty need for key economic sectors. It also raises the concern that why investment is not encouraged to increase both the export and to create enough domestic supply.

The diverse richness of the region in terms of natural resources includes its biogeographical ecosystems narrated in the opening of this introduction. Each one of the ecosystems is imbued with a variety of riches with good upside, potentially poised to create significant fortunes for the region, if harnessed. The Sahel-Savanah is the largest of the zones stretching 5,400 km from the Atlantic Ocean in the West to the Red Sea in the East according to Terrestrial Ecoregions and 1,000 km wide separating the North Africa from the rest of the continent and covering an area of 3,053km. According to the Terrestrial Ecoregions, this massive belt lies in a topography that is mainly flat with annual rainfall reaching up to 24 inches per annum. According to Rao (2008) the availability of this climatic condition is a great asset for grain farming especially rice and wheat. The flat land topography is an advantage for commercial agro-activities. The Sahel Savanah with its geographical terrain like the lush green Sahelian forest along the Bamako-Kayas road in Mali and the Western Highlands of Ethiopia to mention a few, are areas that can create an agricultural enterprise to satisfy the total food needs of the region and leaves a good volume for export. This researcher learns from Cereal farming in Encyclopedia

Britannica, that this type of biogeography can support a successful agro-enterprise of cereals, especially the major sub-Sahara Africa cereals like sorghum and millets, maize, wheat, rice and barley, if there is availability of chemical fertilizer. It is also a common knowledge that where the grass family thrives, there lies the best breading turf for livestock. Therefore, this zone is a potential livestock producing area as well. Other ecozones equally possess the potentials of successful agro-enterprise for groundnuts/peanuts, soya beans, ginger, sugar cane, tropical fruits and tubals. Although, most of the challenges facing agricultural output in the region like fragmented agro-value chain, poor infrastructure, inadequate policy environment, poor access to finance are being addressed to a certain level but agricultural output remains the same all through the ages to now.

Feeding Africa (2015) presented by the United Nations Economic Commission for Africa (UN-ECA) has identified insufficient fertilizer input as the main reason holding back crop yield in sub-Sahara Africa. In this document, farmers in sub-Sahara Africa can afford only 13kg of fertilizer per hectare of farm which is only 13 per cent of what is available for Asian farmers and only 8.67 per cent of the required standard used by farmers in advanced countries. According to PetroWiki, 95 per cent of ammonia is produced from natural gas. This therefore raises another concern as to why does the region allow a key economic sector to be held back by lack of fertilizer which can be produced from its abundant gas resources.

The poor industrial level of the region reflected by its poor capacity utilization is common knowledge. Key industries directly depending on gas for their feedstock are the chemical industries (apart from ammonia for fertilizer discussed above), heavy and intensive heat users like cement industry and iron, aluminum smelting plants. Electric power generation is in this category. In Kanya et al (2013) gas as a feedstock for electric generation outperforms all other feedstocks including the traditional and agelong hydro-electricity that is associated with electric power generation in sub-Sahara Africa. But the domestic gas industry has not been opened sufficiently to provide raw materials and fuel for these categories of industries.

It is helpful to compare the current economy of sub-Sahara Africa with Japan. This is in order to lay bare the dichotomy between gas-rich sub-Sahara Africa and gas-poor provision for critical sector resulting to its state of the economy. This compares with an Island (Japan) that is the reverse in terms of natural gifts and again further plagued by Hiroshima devastation in the forties and recent nuclear disaster couple with several natural disasters.

The current GDP of sub-Sahara Africa at constant US$ (2010) is US$1.67 trillion with a population of 1.0 billion people according to IEA 2017 Key World Energy Statistics report. In the same report, Japan wields a whooping US$ US$5.99 trillion (2010) and with a population of 127 million people which is only 12 per cent of that of sub-Sahara African population. Many have wondered, including this researcher, how is Japan with no land to farm and no oil and gas commanding such a buoyant economy while sub-Sahara Africa with all its sufficiency in natural resources lagging behind. It is the believe of this researcher that if the region’s natural gas endowment finds itself in the proper place in the economy of the region, and is given the investment level required, the fortunes of the region would be positively different. This believe is based on the statistics provides by the World Bank as in the Table below.

Table 1 - Sub-Sahara Africa Key Economic Data

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GNI in billions (constant 2010 US$)	1141	1191	1229	1300	1353	1407	1454	1549	1605	
Fertilizer consumption (kilograms per hectare of arable land)	13	12	12	15	14	15	16	17	15	
Cereal yield (kg per hectare)	1210	1290	1314	1375	1294	1424	1338	1452	1466	1395
Agriculture, value added (% of GDP)	20	20	21	18	17	18	18	17	17	18
Industry, value added (% of GDP)	31	32	29	27	28	27	26	26	25	24
Natural gas rents (% of GDP)	0.17	0.20	0.25	0.16	0.11	0.19	0.28	0.20	0.21	0.14
Imports of goods and services (% of GDP)	35	36	34	31	33	32	32	31	30	32
Exports of goods and services (% of GDP)	35	38	31	32	34	33	29	28	25	28
Electricity production from natural gas sources (%of total)	5	5	5	7	7	8	8	9		
Food imports bn (current US$)	31	34	32	37	60	56	53	52	0	0

Source: Tabled by Author from World Bank 2017 Statistical Report

Table 1 shows economic indicators relating to fundamental economic sectors that are gas dependent, such as food security, energy sufficiency, residential and industrial heating and chemical industries. According to the Table, sub-Sahara Africa imports food it could produce from its vast natural resources rising from US$31 billion in 2007 to US$52 billion by 2014. The United Nation Economic Commission for Africa (UN-ECA) unbundles this import basket report of the World Bank and states in UN-ECA Feeding Africa (2015) document that the major imports in the list are rice and wheat. According to the UN-ECA feeding Africa, in 2013, wheat import alone is estimated at US$15 billion. In the same cited document, it is reported that while wheat production steadied at an average of 5 million tons per year, sub-Sahara Africa's wheat consumption is said to increases geometrically from 12 million tons in 2007 to more than 45 million tons in 2015. The major reason accounting for inadequate food production mentioned in the beginning of the introduction is fully manifesting in - Table 1 which is the poor supply of fertilizer. While the standard required fertilizer for cereals is 150 kg/hectare in advanced economies, sub-Sahara provides 13 kg/hectare in 2007 with an addition of only 2 kg/hectare in 2017, ten years after. The impressive crop yield exceeding a thousand tons/hectare just proves how fertile sub-Sahara African soil is, responding impressively to the tickle drops of chemicals required. There is no doubt therefore that gas is disposed to change the food situation of the region, save the region an average of US$44.375 billion in food imports, change the disproportionate import-export differential of the region, improve the contribution of Agriculture to the domestic national income and push the GDP of its economy onto the climbing track. It is therefore a concern as to why natural gas fortunes have not been deployed to capitalized upon these agricultural opportunities.

In industry, the contribution to GDP averages 27 per cent as in Table 1 signifying low capacity utilization of resources. The main industrial activities like cement production, smelting plants for infrastructural delivery which are gas-dependent are tied down due to lack of domestic gas supply. The deficiency of infrastructure robs-off on the poor and stagnating gross national income which crawls from

US$1.142 trillion in 2007 to US$1.605 trillion in 10 years for one billion people. It is no surprise that the sub-Sahara African car, ship, even train wagons are yet to arrive. Many of the economic activities that use metals including roofing sheets down to nails depend largely on imports. A shift of direction from import to domestic supply could crank up the engine of the economy and propel its productive motion to fast track. In the abundance of natural gas, one wonders again, why this has not been developed for the benefit of this important economic sector.

To further buttress the poor investment level of natural gas in the region, Table 1 shows that contribution of gas to the gross domestic products of the region has perpetually remain far below one percent in the ten years captured in the Table and contributes only 5% of the total electricity produce in the region. The Organization of Economic Cooperation and Development (OECD) member countries through IEA conducted a research on the cost of generating electricity in 2010. In that report, it is concluded that natural gas technology has low capital cost, short lead time of construction, high efficiency, operational flexibility and low carbon intensity and therefore the best competitive fuel in electric power generation. These attributes are more suitable to the clime and economic condition of sub-Sahara Africa in view of the abundance gas which comes in handy without import cost. It also fits this region in key variables like low capital cost – considering the poverty level of the region – short lead time required and operational flexibility to help reduce high demand for high technical manpower that may not be readily available. The lesson learnt here is that there is a saving of cost in the 95 per cent of cost from the use of comparatively expensive fuel mix in the current electric power generation in the region, if natural gas is used. The question that comes quickly is that why not use the natural gas in the electricity generating mix if not to displace current expensive fuel but to expand the capacity as electricity in this region is again the poorest in the world regional areas?

This situation of sub-Sahara Africa region which is clearly a dichotomy of ubiquitous natural gas resources and poor performance of gas dependent key sectors that are drivers of its economy such as agriculture, industry and electric power should be of a great concern. It is therefore natural to ask the overall question, why has the situation remained like this till now? Cameron and Stanley (2017) encourage us to split this overall question and turn the searchlight for answers to include fundamental areas such as governance issues.

It is the believe of this researcher that this is a situation worthy of an academic research. It is the hope of the researcher, that the reader agrees with the researcher that the gloomy gas situation of sub-Sahara Africa should attract research attention. However, it is noted that wading through the exercise of finding answers requires a bit of stretching out the conduct of the research. Therefore, this research work is planned to take an expanded scope; attempt a new approach; and try a comprehensive engagement of factors and areas tangential to the development of natural gas enterprise in sub-Sahara Africa under the topic:

Modelling Natural Gas Market for sub-Sahara Africa: Investment and Regulatory Approaches.

This research work plans to use deliverables or outcomes of the research issues to propose a model market that represents the ideal market the region needs to adopt to provide the domestic gas needs in strategic sectors to revamp its economy.

1.3 Statement on the research problem

This case of natural gas abundant resources in sub-Sahara Africa is a case of conscious optimization problem, where a critical resource is not used to stimulate and sustain the needed economic development and growth. Conscious in the sense that there are documentary evidences that the economic managers of the region are aware of the poor performance of the key economic sectors. The UN-ECA Feeding Africa (2015) highlights the concerns of the Head of States of the African Union concerning the astronomical growth of wheat consumption and its threat to food security in the region. It is equally known from policy initiatives and drives in some states of the African Union, that natural gas is pivotal to the revolution of the region’s economy through the key critical economic sectors highlighted. However, what might not be known or might be just a perception are market issues specific to the region, that could influence investment decision regarding the region’s gas industry. Those issues could be partly from the side of prospective investors, government policies, market structures or any internal or external stakeholder no matter how remotely tangential. Nevertheless, the overarching optimization need is to produce and provide the needed gas commodity in the critical economic sectors for a regional economic buoyancy. It is therefore expedient to expand current research towards the discovery of such specific market models that might represent a proto-type market for the economic managers of the region to consider and provide information to prospective investors and add to academic literature.

1.4 Objectives of the research

The aim of this research therefore is to provoke a deeper and consistent investment interest in gas business in Sub-Saharan Africa region to provide natural gas to its domestic needs. The main objective of this research project is therefore to attempt a market model for sub-Saharan Africa natural gas market, with the hope that if the model is brought out from the result of the research, its pictures might be able to indicate a useful approach for attracting investment in the domestic gas market of sub-Sahara Africa.

Specifically, this study is:

1. An attempt to reverse the dichotomy between vast natural gas endowment amidst insufficient gas supply in sub-Sahara Africa;
2. To find another mechanism of increasing natural gas market activity through an organized and well-functioning market system in sub-Sahara Africa;
3. To ultimately model a natural gas market to support a well-functioning market system to improve gas supply to gas dependent economic activities in that region.

1.5 Research Questions.

The gas industry in general holds high expectation for investment destination, ceteris paribus. This is an industry, where it is expected that investment from private purse and public treasury will flow readily into, without any incentive or persuasion. But as to why private and public investments have not risen sufficiently to unlock the perceived fortunes of this industry creates several research questions that are worth exploring for answers. For the Sub-Saharan Africa region, questions are pertinent given the fact that the region possesses a large market for gas and has clear domestic needs for it.

The relevant research questions are not different from the concerns raised during discussions on the natural gas condition of the region that represents the research gap above. The general question being, why has the sub-Saharan Africa not developed its gas potentials for domestic opportunities prevailing in key economic sectors that can positively change its economy? This main question covers the entire ramification of market fundamentals such as the market structure; price of the commodity; prices of alternative commodities; rules and regulations of business engagement; risk nature, dimension and impacts on investment decision. Specific questions of the research are:

1. What is the nature of shocks in the market where sub-Sahara Africa natural gas trades?
2. Would natural gas from sub-Sahara Africa follow a pattern in terms of volatility if traded in markets other than current markets?
3. Do the returns of natural gas in these markets which incorporate gas from sub-Sahara Africa generate the right news signals for investors to take decision in terms of leverage, just as in crude oil markets?
4. In the event of market instability, how long do shock last?
5. What effect do shocks have on natural gas returns in markets where sub-Sahara Africa natural gas trades?
6. What factors will investors be looking for to attract them to invest in terrain like sub-Sahara Africa natural gas market, apart from profit motivation?
7. What are the critical successes factors of creating a gas well that the investor will want to see in the sub-Sahara African gas market as elsewhere?

8. Is the perception of gas business risk in sub-Sahara Africa by prospective investors larger than reality on the ground?
9. Do these risks have specific features rather than normal business risks found in literature?
10. How could these specific risk features be addressed to attract investment?
11. How do investors adjust their Rate of Return in new investment to capture perceived or estimated risk?
12. How willing is government to accept the position of prospective investors?
13. Is there any prospect in investing in sub-Sahara Africa gas market in terms of operational profit?
14. Is there an effective demand for natural gas in sub-Sahara Africa?
15. What is the relationship of natural gas price and other energy commodities in the sub-Saharan Africa energy commodity basket?

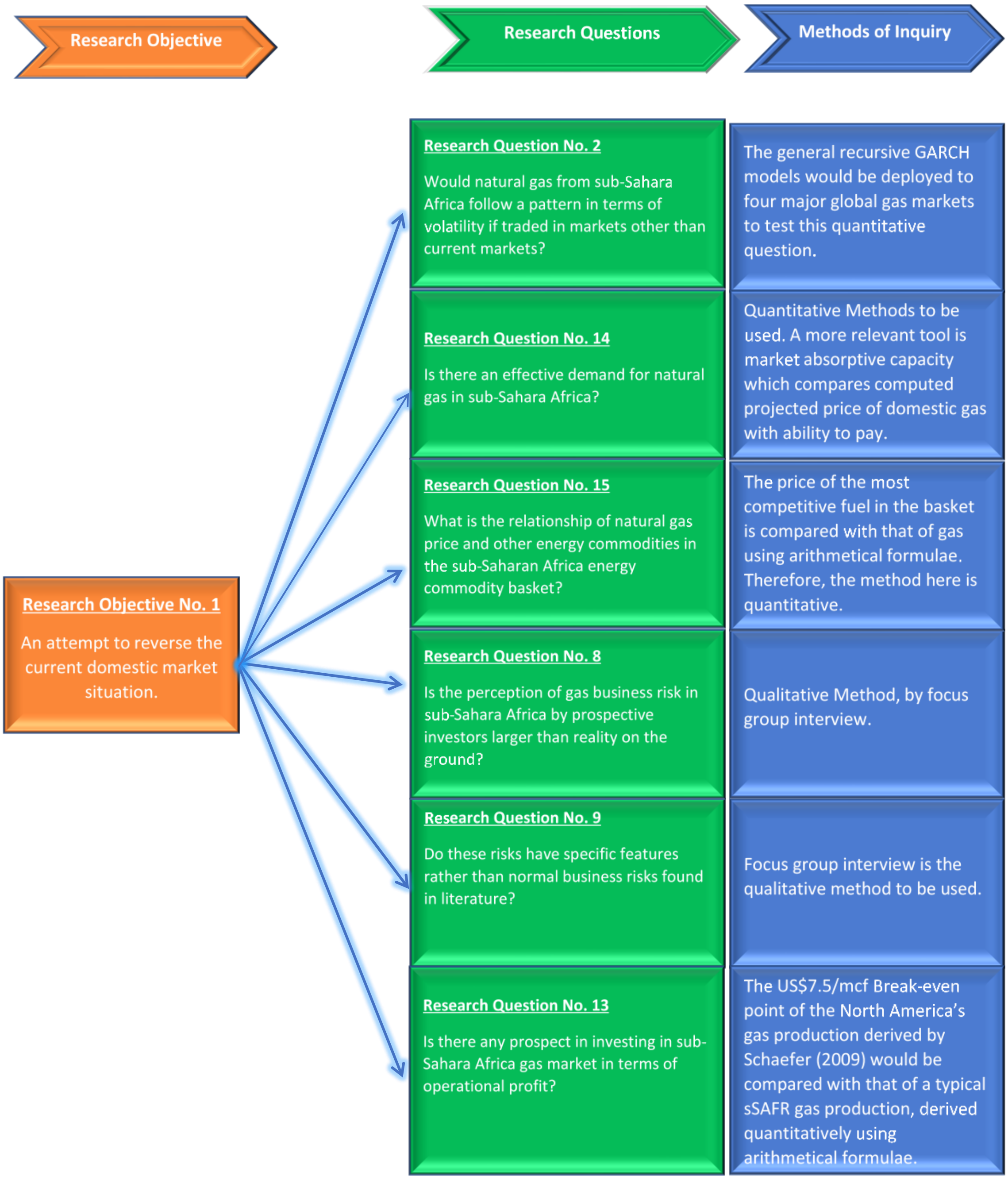
1.6 Mapping of Research Objectives and Questions

The figures presented below are the mappings of research objectives and questions. The methods of investigating the set research questions are also added in the third column to give clarity to the flow.

While the three research objectives are presented sequentially, the numbering of the questions follows no particular order.

Research objective number one is an attempt to reverse the current natural gas situation in the region. In doing so, the current domestic market conditions need to be understood. Domestic issues like effective demand for natural gas, relationship of natural gas with other energy commodities, perception of gas business by potential investors, specific nature of risks and prospect of investment are relevant research issues of interest put in the form of questions to derive objective number one.

Figure 2 - Research Objective one mapping



Constructed and presented by Author

While research objective number one is about digging out information on the current domestic condition of the natural gas market – more like pulling out the market's current practice – research objective two is finding ways of addressing the situation. Research question number six in particular is a generalized question. It is thrown wide covering the entire gamut of the market with theories such as Investment; firm; regulatory economics - which is the same as governance of mineral resources - and market fundamentals. These theories need to be investigated in literature review. Question number twelve is a question that has received broad research interests in the extractive industry under topics such as governance issues or regulatory economics, taxation, economic rent, consumer/supplier surpluses, etc. In this research, it would be grouped under economic rent and regulatory economics. Topic like governance issue sits astride economic rent and regulatory economics depending on what is applicable or what is in search. Therefore, governance issues will not necessary require separate investigation in literature review for this research.

Figure 3 Research Objective number two mapping

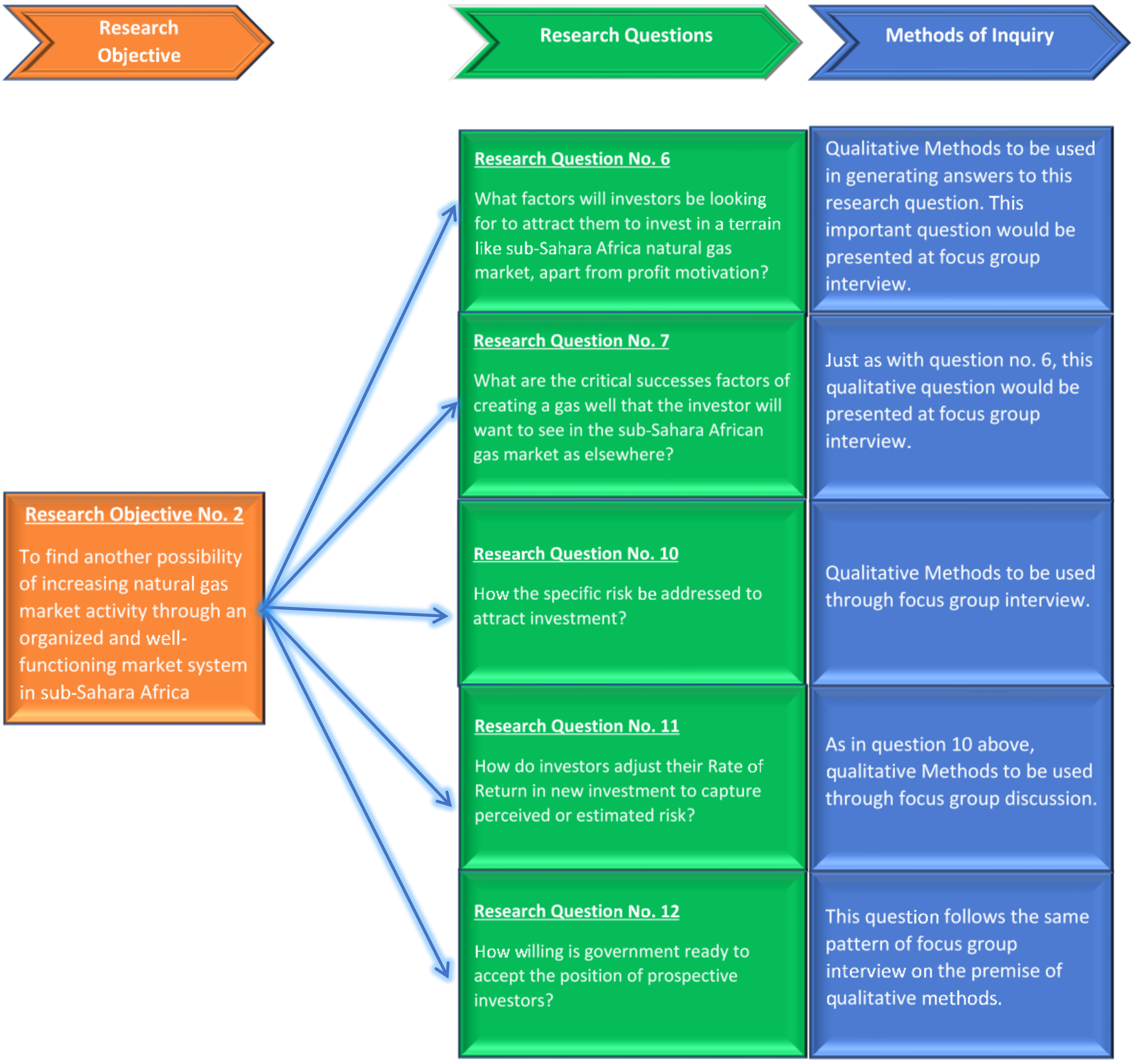


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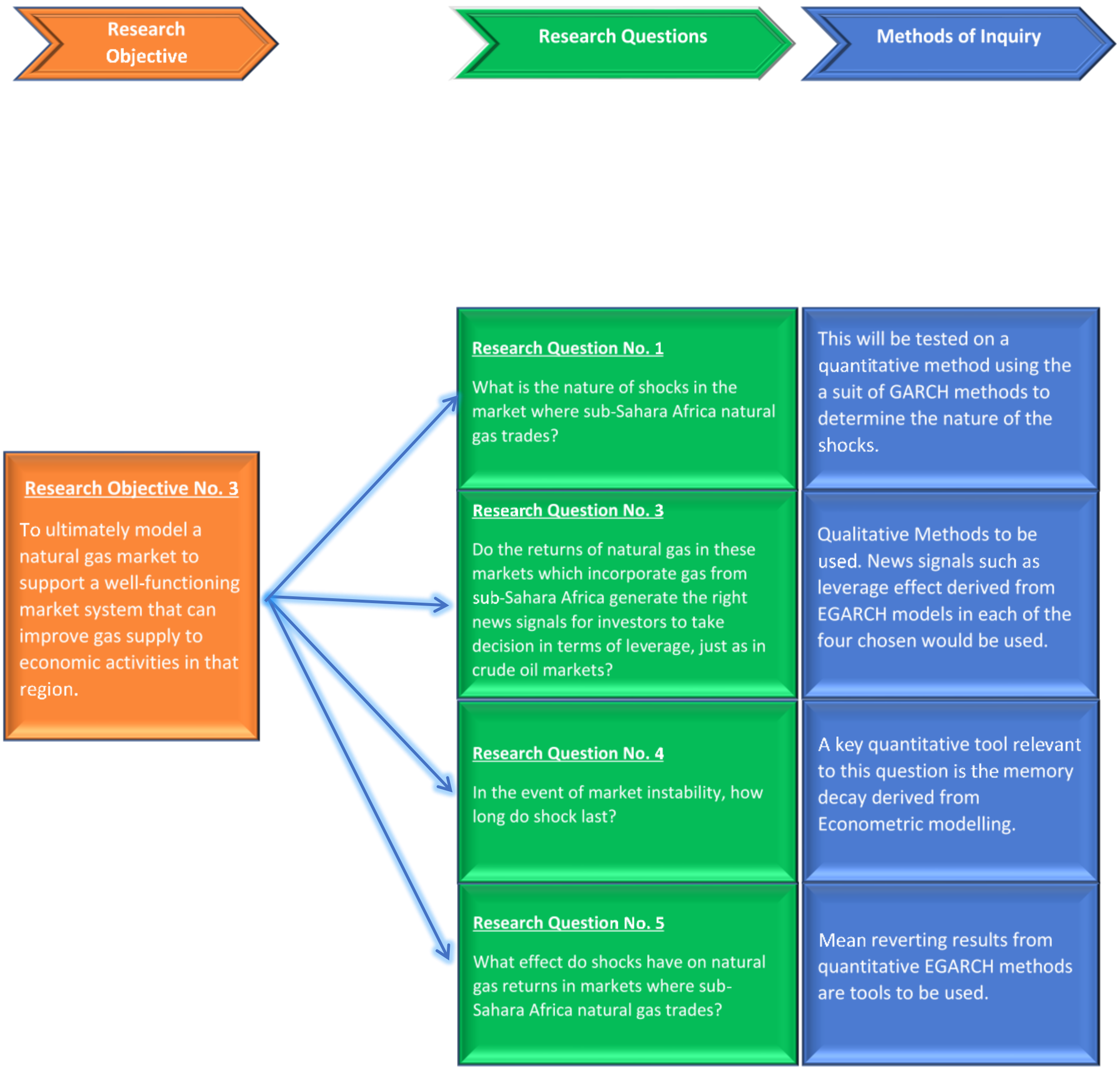
Figure 3 above therefore maps out five questions to generate findings for a well-functioning market using qualitative research methods.

The third research objective in figure 4 below is the ultimate modelling of a natural gas market to bring out and support a well-functioning market system. Parts of proposed market model's attributes are the results of objectives numbers one and two. The remaining attributes are the quantitative lessons to be learnt from matured markets in which the sub-Sahara Natural gas current trades in, using the quantitative research questions. These quantitative research questions aim at achieving research objective three.

Figure 4 Research Objective three mapping



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1.7 Justification of the study and contribution to literature

The core pre-occupation of energy economics is about energy markets and what this discipline across time and space deals with, is the price of energy commodities. Energy prices are among the most volatile prices of visible and invisible tradeable like financial derivatives and foreign currencies in terms of prediction and most of the time are more chaotic than these prices. Most prominent among these energy prices are the prices of crude oil and gas as evidenced many of the literature used in chapter two of this thesis. However, crude oil price has obtained a universal posture trading on Freight on Board basis and therefore is able to have a common price value wherever it comes from. But gas is yet to have this universal price anchor even though it is quoted by market agents like Platts and Argus based on global market, its cargo is contracted to. Mostly, the African natural gas commodity is traded in Henry-Hub[3]. Price is the most effective tool the science of economics uses in performing its core function of scarce resource allocation. In this researcher's understanding, the price of anything is the cardinal and binding mid-point whereby an owner of a commodity accepts to release that commodity in exchange for money. In the same vein, that price is also the same mid-point the owner of money is willing to release the amount of money in exchange for that commodity to the owner in exchange for his money. The futuristic value of money is therefore essential to any business endeavour. Gas investment, being highly capital intensive requires the knowledge of future price direction. It is certain that given the current sub-Saharan Africa gas market condition, this price must be sought for through the investigation of the underpinning economic and market fundamentals. Energy economists therefore owe potential gas investors

[3] Henry Hub is a distribution hub on the natural gas pipeline system in Erath, Louisiana. Records abound in the gas industry that this gas pipeline is owned by Sabine Pipe Line LLC. The name is lent to the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX) and the OTC swaps traded on Intercontinental Exchange (ICE).

in the sub-Saharan gas market the duty to establish a predictable future price and other economic fundamentals to help in their investment decisions. The IEA in its 2014 World Energy Outlook has affirmed that answers to a gas price level acceptable to both consumers and investors are future global desire. In its words “the way that gas will be priced on domestic and international markets, is key uncertainty…” IEA (2014) *World Energy Outlook* (pp. 155). There is therefore no doubt that a study in this direction is in tandem with contemporary world class economic exigency especial when dealing with sub-Sahara Africa where risk of gas business is perceived to be higher than elsewhere.

It is based on this justification that this study is motivated.

Price of energy is a culmination of several economic and regulatory fundamentals. Therefore, searching for economic and regulatory factors to attract investment interest by this study is essentially a useful exercise in investment decision making concerning the vast gas endowment of the sub-Saharan Africa. This is more so as the study looks for those factors that build up to the price of gas in that region more accurately and predictively and then attempts a suggestion on mechanisms whereby these factors would be managed to arrive at a price competitive enough to attract potential investors.

Investors need enough economic and regulatory evidences to help in the difficult investment decisions regarding capital intensive projects like gas production especial in regions like the sub-Saharan Africa with a blur business climate.

Overall, if the result of the research provides cogent and succinct answers to the questions raised, the larger private business world then might have confidence in investing in sub-Saharan Africa gas market. The features that might attract private investors will be the forecasting values of the parameters upon which their business models are built. The sharper the forecasting variables are, the clearer would the investment climate be, and this might attract hitherto unwilling and reluctant investors. The documented outcomes of theoretical examinations are for the academic world to use.

1.8 Theoretical Framework

The aura that seems to describe this project from discussions so far is a market situation with supply problem to satisfy a thirsty demand for a critical commodity. Therefore, the theoretical framework that will help the project will be from those economic theories supporting a functional market system in which gaps between demand and supply are always in equilibrium. One of such theories is the price theory by Leftwich and Eckert (1985) which they established from the classical economic works of Adam Smith's "*invisible hands"* that keeps markets at equilibrium and expanded by classical economists like Say (1821). In their price theory, Leftwich and Eckert (1985) explain that the price theory is essentially the economics interacting subunits of the economic system which involves individual economic agents like consumers, firms and resource owners. In this way it becomes the overall pivot in which market activities are anchored. The price theory therefore provides a good theoretical framework for market analysis. But the structure of the natural gas industry exerts the "normal" market structure, altering its functions by the dominance of government. It is an industry where governance issues play critical roles. Be it as it may, price theory still serves as a critical mechanism in a project like this. The researcher therefore finds it expedient by retaining the price theory in the construct of theoretical framework but incorporates governance to form a composite theoretical framework known as supply-side-economics-solution. Proponents of supply-side-economic theory like Bruce and Timothy (1984) Barth and Joseph (1982) Bartlett (1981), Brunner (1982), Congdon (1982) explain that government policies have a powerful effect in directing economic activities. Therefore, it is reasonable and rightly so, to recognize the power of policy instruments in designing markets that will of necessity have a significant presence of governance. This is what persuades this researcher to consider price theory and government policies in the frame of supply-side-economic-solution as the theoretical framework for this project.

1.9 Research Methodology

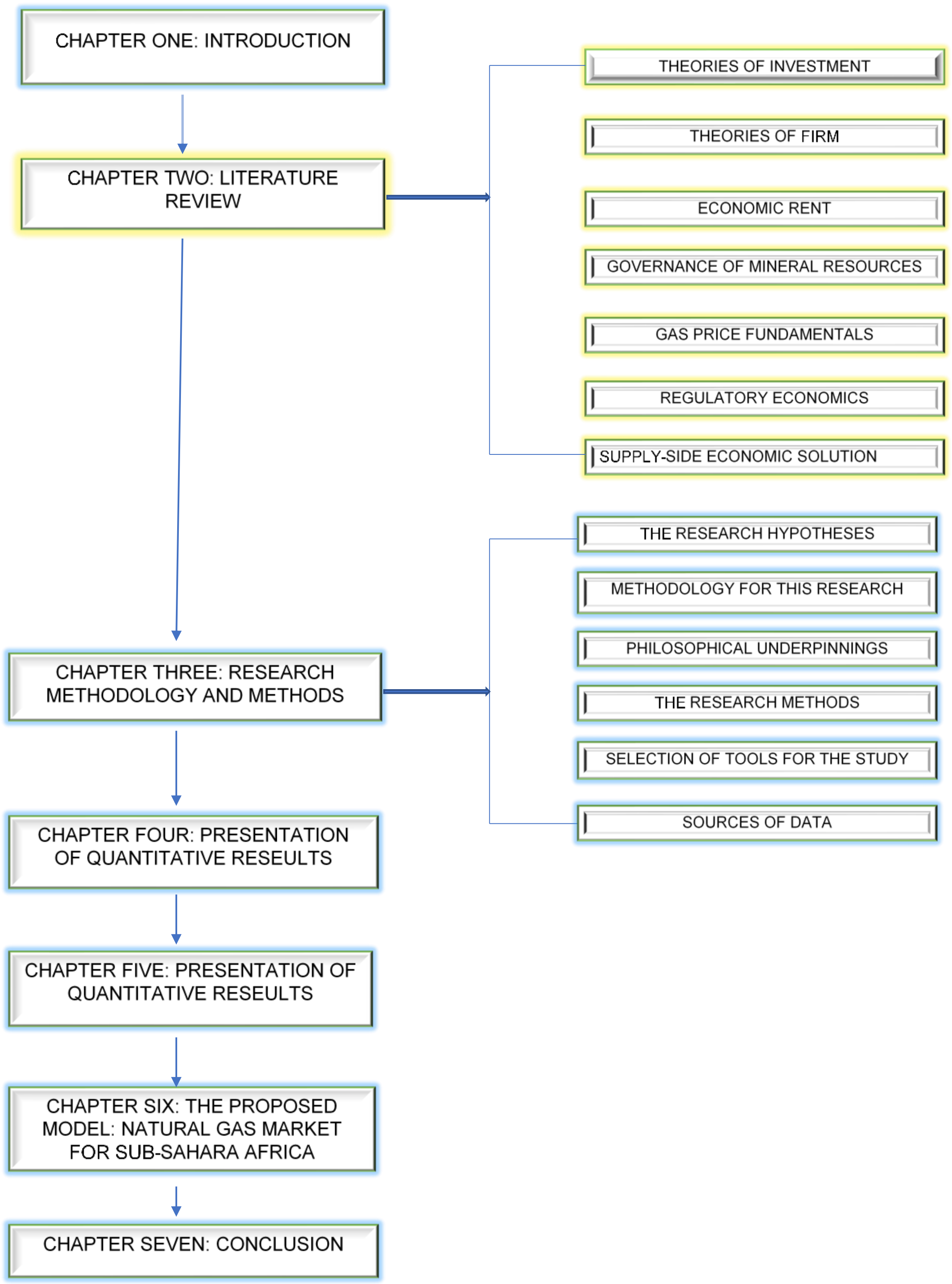
A somewhat dualistic composite theoretical framework as the one in this project suggests the use of a hybrid of research philosophies, paradigms and techniques. The research concerns arising from foregoing discussions seem to have split into quantitative and qualitative spheres. Both the questions in consideration and the theoretical framework tend to show that the research methodology for this project is trending towards dualism for now. The project's methodology will eventually manifest as the research work progresses.

1.10 Structure of the Thesis

This introduction chapter is immediately followed by literature review in chapter two. The study which is the first of its kind for gas dedicated study and in sub-Sahara Africa has no much sources to refer to as there is no such study found in literature, that takes the entire gamut of market in one single document. However, there are well documented relevant literature in all the market components comprising the study. Therefore, literature is picked from these fragments, the analysis of which is presented in chapter two. Chapter three takes on the methodology and derives the philosophical underpinning of the research and structures the research methodology and methods. Quantitative results and analysis are presented in chapter four while chapter five captures the same for the qualitative research. In chapter six, materials distilled from the two research approaches are ingrained to form the proto-type natural gas market model that the research is set out to find. Chapter seven concludes.

The plan is figuratively captured in the flow chart below.

Figure 5 - The Overall Thesis Flowchart



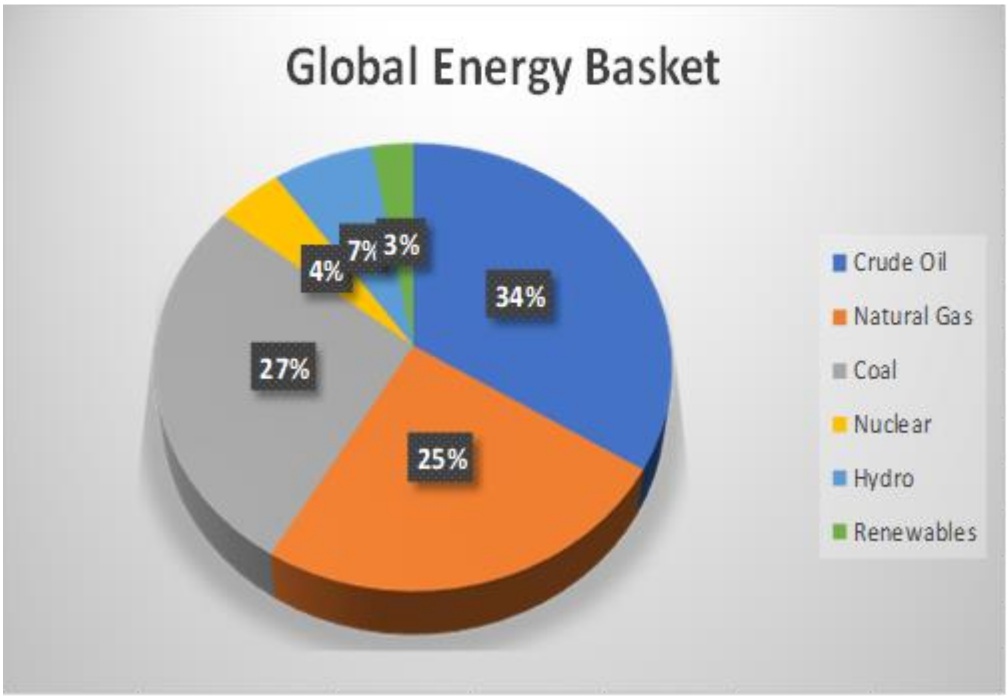
CHAPTER TWO:
LITERATURE REVIEW OF ENERGY MARKET FUNDAMENTALS

2.1 Introduction

Studies on how to unravel factors sustaining the dichotomy between poverty of gas feed-stock to key economic drivers in sub-Sahara Africa, in the midst of its natural gas abundance comprising 25 per cent of total global gas reserves can reasonably be attempted, through gas market models. To this researcher, market approach offers a comprehensive coverage in finding answers to the research questions. This is because the market is the totality of economic activities involving production, sales and consumption of commodities or services as the case may be. In analysing situations of concerns like the case at hand through market models, it is quintessential to comprehensively engage all the fundamental aspects of market to a large extent and these aspects according to Pyndick and Rubinfeld (2009) and Callon (1998) include the price of the commodity; its investment requirement; market structure and regulation. Depending on the political “maturity” of the sovereign area(s) of the study, a fifth aspect to the analysis to be added is availability of strategies to address governance issues and, in this study, it is supply-side economics solution. As we will see later on, a key concept both in theory and practice regarding the extractive industry which is, at this stage referred to simply as “rent’ necessitates the inclusion of this fifth aspect – the supply-side-economics solution

Existing literature show that the heavily-trafficked energy research arena is in fragments of this comprehensive market aspects with commodity prices occupying a significant space. Even in this one aspect of the studies, crude oil enjoys more accommodation than any other commodity, and when crude oil study is associated with gas, the focus on crude oil overshadows that of natural gas in details, contents and at the end, the conclusions, suggestions and recommendations are all or mostly oil-pruned as we shall see from the refences used in the review of literature and methodology. A few gas-focused studies have been attempted but not without the dominance of crude oil. Such studies include the works of Brown and Yucel (2007); Siliverstovs et al. (2005); Apostolos and Rangel-Ruiz (2004); Jose and Joutz (2006); and Bachmeier and Griffin (2000). These studies which are meant to combine natural gas and crude oil, end up with discussions that are more of crude oil than gas. The dominance of crude oil over gas studies can be excused on account of history where in about two decades ago, natural gas was still held as part of the waste to be dispense with in search for oil through flaring by many operators. Currently, the crave for cleaner energy and the abundance of natural gas and its competitiveness has improved the eminence of natural gas in the global energy basket as shown in the figure below.

Figure 6 - Global Energy Basket



Source: Constructed by Author using BP Statistics 2016

In figure 6 above gas position in the world energy basket in 2016 according to the BP Statistics was a quarter of the bulk and third to oil and almost catching up with coal and so should have a fair share of research interest going forward. In any case, a new paradigm shift in the form of an all engaging facet of the market is desirable for the study of any chosen energy commodity or commodities of interest. However, no one single research has been found in literature to have taken such an interest in the wide sub-Sahara African region. Detailed gas market studies have been documented such as the works of Wright (2006). But this is on matured market of UK Oil and Gas industry. This study therefore by taking in one piece, the market elements referred, in search for answers concerning the domestic condition of natural gas in sub-Sahara Africa, is that new paradigm shift in the energy studies and by focussing on gas only, has risen to the call on expanding research interest in the area of gas commodity. The research work therefore takes a critical assessment of literature on each aspect of the market to state weaknesses, gaps and raise questions as they emanate.

A close examination of the global oil and gas industry will reveal that the entire value chain in the market is solely dependent on the up-stream activity. It is incumbent therefore to think of approaching the problem of energy market vibrancy in sub-Sahara Africa region by investment activities in the up-stream. As the dynamics and elements of this gas industry include the behaviour of key economic agents, a complete and in-depth prior work review would of necessity have to include fundamental economic theories on market. The conclusion by Leftwich and Eckert (1985) that it is a necessary requirement to use economic theory when attempting a useful systematic study of an economic activity like a natural gas market, has brought up the need to use economic theory in a study like modelling natural gas market for sub-Saharan Africa in addition to the use of academic journalized literature. It is on this basis that this literature review is structured into five sections starting with investment which is considered by this researcher as the first step in production activities. It follows with firm theories to seek for neglected areas in literature, contributions to this project, disagreement, and convergence of thought, arguments and possible areas where this project could add to knowledge. Investment decisions and firm structures and functions are influenced by price. In this review therefore, the fundamentals of gas price starting from global perspective down to sub-Sahara African specifics in literature are examined in-depth. This is followed by regulatory economics based on the fact that most economic activities, especially the extractive industry in which the gas market belongs is subjected to regulatory economics using the tax instrument. As the research is a market dominated area from supply side, the theory of supply-side solution completes this literature review. Consequently, the review is structured in five sections as follows: investment theories; theories of the firm reflecting investor's inherent interest; gas price fundamentals (volatilities and its drivers); regulatory economics and Supply-side Economic Solution.

2.2 Theories of Investment

Investment literature is as old as the advent of the economics science, dating as far back as 4^{th} century with the work of Chanakya which is considered a forerunner to later times classical economics according to Mabbett (1964) and Jiha and Jha (1998). It is also one of the areas where there is little conceptual difference in economic argument. The precepts, postulates, ideologies, and philosophical underpinnings of investment from leading economic school of thoughts like the Keynesian, Neo-Keynesian, Classical, Neoclassical to mention a few, do not materially differ. Several contributions across time have led to assemblage of a body of knowledge used in supporting investment choices and decision making. This body of theories includes the Modern Portfolio Theory of Markowitz (1952) that earned him Nobel Prize in economics; Capital Asset Prizing Model introduced by Treynor (1961, 1962) and followed by Sharp (1964), Linter (1965), Mossin (1966), building on the work of Markowitz. Other theories include Arbitrage Pricing Theory. The Efficient-Market Hypothesis of Fama in 2012 is one of the recent contributions to theory of investment.

However, these theories are more targeted at financial trade instruments on specific and micro investment activities, many of which are suitable for portfolio-mix choice and risk management. A broader review including reviews of Neoclassical and Keynesian postulates however brought to the surface, how profitability and cost of capital drive investment decision for large scale investments. Contributors including the ground-breaking work of Keynes (1936), Kalecki (1968) Vianello (1986) Kurz (1990), Richardson and Romilly (2008) establish the roles of profitability and price of capital to investment decision. Even though it is not directly stated that profitability is a determinant of investment, Keynes (1936) accepts the identity of his marginal efficiency of capital with Fisherian definition of rate of return over cost of investment. This is however disputed and rejected by Garegnani (1978) based on his findings that the marginal efficiency of capital does not assume full employment of resources and as such, cannot equate to the Fisherian rate of return. The classical economists had already accepted the prominence of profitability in investment decision. What followed were generation of several forms of profitability such as net rate of profit, Kalecki (1968); capital accumulation, Junankar (1972), Sawyer (1985) and Junankar (1972).

The peculiarity of natural resource industry undermines the sufficiency and efficacy of investment tools resulting from above reviewed literature. The mineral industry has a size larger than most investments and a time scale stretched to several years. It faces unpredictable outcomes and is highly variable in nature according to Andrews (1991) and Padmore (1992). An exploration search could produce a zero find, leading to a loss of huge invested fund. Otto (1992) explains that the extractive industry is usually in a fixed or remote location. The existence of gas reservoir therefore dictates the operational site of production activity. In this scenario, investors have no control on where production activities should be based. This denies the investor the strategic ability to change production places after they are created. The business therefore is made to face environmental risk, political risk, risk of resistance from their host, community issues and none of these risks can be covered by any of the elements suggested in this investment literature nor can be transferred by any ingenuous investment theory or method, except by favourable negotiation with host government.

The extractive industry also has high financial expectation from the host country and often occupies a large proportion of the country's GDP. There are issues concerning social environmental impact and restoration. Decision to invest in such an industry therefore goes beyond the traditionally established Time Value of Money; Discount Factors; Discounted Cashflows; Net Present Value; Internal Rate of Return and Payback Period. Brennan and Schwartz (1985) have long identified this gap and suggested the use of stochastic control theory to evaluate these types of projects. A review of the stochastic control theory by this research work however reveals that the stochastic control theory is suitable only for evaluation of assets in project management and not capturing the ramification of issues face by this peculiar industry. This is because the stochastic control theory is like the Linear-Quadratic-Gaussian Control (LQGC). Michael and David (1995) argue that the LQGC does not automatically ensure good robustness of properties. This by extension also translates to the fact that the stochastic control theory shares the same deficiency.

Consequently, more literature is required in this industry to continually discover sharper instruments to aid investment decision making. Economists are making attempts, using econometric tools with some like Bean (1981) and Catinat et al (1987) providing evidence of the significant effect of prices in investment but incapable of rendering a comprehensive package to fill this gap. Some conclusions like the work of Chirinko (1993) refute the effective response of investment to price changes thereby creating a somewhat lacuna on the sufficiency of theories of investment in literature.

The literature reviewed in this section therefore indicates that existing investment literature is not sufficient to suggest a model of natural gas market that could attract investors into a region with natural gas endowment. This is mainly because of the peculiarity of the mineral resource industry which faces market conditions beyond the capacity of investment suggestions in literature. This research project needs a wider frame of theory, incorporating comprehensive investment decisions tools for creation of large-scale entities in unfamiliar and likely untested economic environment. These should recognize the highly technical nature of the industry, the plethora of the high risks it faces which require favourable host government support. Reviewed investment literature falls short of this irreducible minimum requirement.

The review however brought to fore the pre-eminence of price and profitability in investment decision making. While the content and context of profit is understood, price was however restricted to the prices of acquisition of asset creating components without incorporating the price of the commodity itself. That is perhaps, the authors approach the subject in a more general sense. Specific to this research project, the price of natural gas itself is the overriding determinant for venturing into this industry. The review of investment literature covers an important aspect of the research area, yet it was found inadequate to serve as an overriding fundamental to attempt a suggestion of a market model which potency is planned to be tested to show the right approach in attracting investment into sub-Sahara Africa natural gas market. This is because the result of the review has not given sufficient basis for the theoretical framework for this research. Overall, the review discovers that the following questions are left unanswered:

i. What factors are investors looking for to attract them to invest in a terrain like the sub-Sahara Africa natural gas market apart from profit motivation?
ii. What are the critical successes factors of creating a gas well that the investor will want to see in the sub-Sahara Africa gas market as elsewhere?

These questions arising from the gap in investment literature reviewed mandate this research to look at other theories such as the theory of firm to further investigate the possible factors influencing decision to invest beyond the profit motivation.

2.3 Theories of the firm reflecting investors' inherent motivation

Firm theory occupies a significant space in literature, covering a wide spectrum across time. Profitability dominated the theories of firm initially with the works of Coase (1937), Jensen and Meckling (1976) and Philips (1996) playing prominent roles. In contemporary time, firm theory has been expanded to cover various areas, including environmental, social, political and time dimensions. The shores of economic perspective which were restricted solely to profitability issues have also been expanded to cover expectations from stockholders' interests in the form of Return on Investment (RoI) as enumerated by Argadona (1998), Friedman (1970) Boatright (1996), Machlup (1967), Holzl (2005) and Thomas et al (2004).

Recently, Lozano et al (2015) based on Seth and Thomas's (1994) three groups of firm theories and a host of relevant literature, report eleven firm theories under three broad categories covering the business as a unit; its existence and obligations to others.

The view of this researcher is that for an adequate investment to flow into sub-Sahara Africa natural gas market, the overall investment climate has to be such that can guarantee business sustainability, prevent fear and threat to business survival and add no social, political, economic or environmental burdens. This research advocates a type of corporate entity that should be given a supportive operating climate to encourage and compensate adequately for the high risk of business associated with extractive industry.

Firms in the extractive industry normally take the form of Public Liability Companies, Private Liability Companies, state-owned enterprises or special purpose vehicle for joint venture activities between private shareholders and host government. Kumar (1991) observes that the common goals of firms in the extractive industry include maximizing the present value of revenues generated through mining activities. Rutledge and Wright (1998) uphold this goal and add that the oil & gas industry requires higher than average rates of return on capital because of the inherent risk. Johnson (1994) does not differ from these authors on the interest of the firm in the extractive industry rather, he adds that one of the objectives of the firm in this industry are to build equity through wealth maximization using cost reduction strategy. Therefore, it is important to understand how company managers in this industry make investment decision. This research work notes that the primary responsibility of the company is to their shareholders and its main motivation is to make profit wherever the company invests. They therefore use instruments identified in investment theories such as time value of money, discount factor, discounted cash flow net present value internal rate of return payback period as well to estimate their goal. Since these firm theories do not differ from investment theories reviewed in terms of their findings in that they all affirm the supremacy of profitability in investment decision, and as this researcher asserts that profitability is not a sufficient condition in the gas investment decision, the following research questions remain to be answered. These questions are:

ii Is the perception of gas business risk in sub-Sahara Africa by prospective investors larger than reality on the ground?

iii. Do these risks have specific features rather than normal business risks found in literature?

iv. How could they be addressed to attract investment?

From a plethora of firms' theories, the contractual and agency theories by Coase (1937), Demsetz (1988), Boatright (1996) and Yu (1999), Resource based view theory by Penrose (1959), Corner and Prahalad (1996), Sanchez and Heene (1997); the stockholder theory of Machlup (1967), Argadona (1998), White (2004); social contract theory Rousseau (1762) and Hasnas (1998) and the stakeholder of Freeman (1984), Freeman et al (2004) Castca and Prajoko (2013) appear more relevant to the extractive industry.

Digging far back into the seminal article of Coase (1937), this research finds the contractual and agency theories. This body of theories stress that the behaviour of the firm in contracting other economic agents like suppliers of materials, capital and labour, and customers is about cost reduction. This assertion however lacks the sufficient market condition to support or prove it. For an entity to enjoy cost advantages during its engagements in contractual relationship as stipulated in the theories, that entity must be structurally supported by pure monopoly market structure. The science of microeconomic demonstrates that it is only in a pure monopoly type of market that a firm can dictate both factor price, production cost and selling price. The body of these theories therefore cannot be universally applied. However, oil & gas entities do exercise some monopsony over labour and by their capacity as sole owners of technology and huge capital, can by extension enjoy monopolistic power as well in contractual exercises in the market and by this decide input costs with the ultimate goal of cost reduction. This research work however enjoys the contribution of these theories on further proof that profit maximization is important to firms' decision.

The resource-based view of Penrose (1959), Conner and Prahalad (1996), Sanchez and Heene (1997) however gives a better explanation on what could be a firm in the oil & gas industry. The authors see the innate posture of the firm as a collection of production resources. This is more like entities in the energy world. The tanks, pipes, high tech equipment and machineries, natural resource reservoirs that characterize the energy industry are in the list of the items brought out in this theory. Sanchez and Heene (1997) added capabilities and cognition on this list. Barley et al (2001) point out the long gestation period that is a feature of the energy industry. There are learning points from this theory, but they are limited to economic tenets of cost reduction with ultimate profitability boosting.

The last set of firm theories reviewed by this research work however provides more useful points as they cover corporate responsibilities and obligation that could address environmental and host community concerns which are the bane of this industry. These theories include the stockholder (shareholder); stakeholder and the social contract theories. The shareholder theory upholds the pecuniary interest of the stockholders with focus on maximizing profit to make impressive returns to stockholders as point out by Argadona (1998) and Friedman (1970). Hill and Jones (2001) and Thomas et al (2004) highlight the important role of shareholders in provision of seed investment to acquire power over the ownership of the firm with the aim of good Return on Investment. Shareholding interest is sacrosanct in the investment of highly risky industry as the oil and gas. The social contract theory of Rousseau (1962) and White (2004) is not so different with most of the theories already reviewed. The stockholder theory would have been sufficient to serve as a pillar to the theoretical framework of this research project. But as Brook (2001) explains, the theory sidesteps the fundamental aspects of economic, social and cultural needs. This is due to the inherent power of the stockholder in the affairs of the firm where managers cannot react in response to public demand without the consent of the stockholders. Boatright (1996) and Hasnas (1998) highlight the long-term consequences of holding on to this theory on environmental and host community which include eruption of violence, rejection and discontent by host community.

In this context, it is obvious therefore that the short-term view of this theory of firm cannot fit into gas firms that have a life of about thirty years per well.

The failings of the theory of stockholder necessitates a further look at the stakeholder theory proposed by Freeman (1984), Argadona (1998), with contributions from Caska and Prajoro (2013), Linfelt (2002) and McIntosh et al (1998). The stakeholder theory is an expansion of stockholder theory which is extended beyond the responsibilities of the firm to stockholders to include employees, customers, suppliers of capital, material inputs, credits and financial services. Argadona (1998) and Freeman et al (2004) added factors including environment and government influence in the list. Corporations therefore are not only concerned about shareholders, but all the economic, political and social agents that have an influence on or relationship with the company no matter how tangential. Subsequent works on this theory up to 2009 by Kruken and Meroni (2006), King (2007) and Cespesdes-Lorente (2004) cover the remaining areas such as environmental regulation, management and protection. As Kaku (2003) explains, the corporation is obliged to balance the needs of these multiple stakeholders if it is to survive. Putting this conclusion in the context of this research project which is persuading investor shows that the foregoing theory is out of tune with what the investors in sub-Sahara Africa natural gas market will want to see their firms look like. If this balancing demand was coming willingly from the investor, merits would have been drawn from the theory. But in this case of persuading investors into the risky business of extractive industry in sub-Sahara Africa shows a disconnection with this research work in terms of theoretical backing. Additionally, one of the difficulties inherent in this theory that supports the position of this researcher, as Langtry (1994) points out, is ability to meet the expectations of the stakeholders by the investor and lack of concrete tools of forecasting the reaction of the stakeholders to the firm. However deficient the stakeholder theory is, this research project benefits from it in the form of articulation of various dimensions of the stakeholder and the consequences of relying on short term measures.

The works of Lozano et al (2015) would also have served the purpose of this research project. The authors took all the theories analysed above and distilled some points to use in arriving at a new firm theory which they claim to be a complete vision that could be used in providing firms the avenue to complete obligations, opportunities, relationships and processes in the life of the firm. Their conclusion was also interesting. That the firm is a profit generating entity in constant evolution. That it is a system comprised of resources and relationships. That the firm in their new theory holistically addresses the economic, environmental, social, and time dimensions according.

This research has already raised concerns to this conclusion in all of the theories as they were reviewed. But it is pertinent to rehash the general issue of lack of provision of means of discerning what the stakeholders' expectations are and how to meet them. These issues are germane to this research in the sense that investment flows are mostly from foreign organizations who have little knowledge of the host communities and their systems. If one therefore is to subscribe to this conclusion, then the conclusion should include a method that will gauge stakeholders' expectation especially host communities.

This research draws the attention of the reader to industry practice where large entities like Shell, Eni, BP, Chevron, Exxon Mobile and marginal operators mostly require to: make a potential reward which commensurate with the risk (commercial, geological and political); operate in a clear, stable and transparent tax regime; have a high degree of control of the project planning and implementation; desire to have the ability to take any profits out of the host community and restrict burdens to the barest minimum. It is also to be noted that the firm (foreign investors) brings into the host country technology, technical skills, managerial skills and capital otherwise hitherto unavailable in the country. It shares the country's commercial risk, and also provides additional incentives for the enhanced performance of domestic industry through competition by their presence. Firms in the extractive industry especially in economies like sub-Sahara Africa know that they are the main suppliers of foreign exchange according to Otto (1992). Making them to conform to postures of firm theories examined above is somewhat doubtful. Theories of the firm examined above in the context of the interest of the firm in the extractive industry do not fit into the peculiar nature of this industry. Therefore, the search for relevant theories and concepts such as economic rent is desirable. It is also pertinent to state that the essential issue of risk attribute is conspicuously unattended to, a gap that necessitates further review. The theories however provide, confirm and put in proper perspective the application of instruments identified in investment theories.

2.4 Economic Rent

The Concept of Economic Rent is as wide as where the branches of economic of thoughts and economic regulations stretch it to. It also differs in current application of natural resource tax practices. In classical economics, economic rent is considered as the share of produce paid to freeholders of land for allowing production on the land they own and control. This is reflected in the 18th and 19th centuries' works of classical economic thinkers including Adams Smith, Jean-Baptiste Say, Thomas Robert Malthus, David Ricardo and John Stuart Mill. While David Ricardo in Kittrel (1957) is credited with putting the concept of economic rent in clear analysis, Adam Smith's postulate as reported by Canna (1904) is yet to go out of fashion in terms of today's relevance and application, especially for this research in sub-Sahara African Region. Adam Smith asserts that in any country, landowners demand a rent for the use of their land. What constitutes this rent underpins the differing concept of economic rent, with features such as accounting profit, operating surpluses, opportunity cost, economic profit, contract rent and even patent have been sometimes appearing in discussions of economic rent. It is also not abnormal to see some works defining economic rent such as excess earnings over factor cost to keep production in current position as discussed in Shepherd (1970) and Morton and Goodman (2003). Others like Economic A – Z define economic rent as the difference between what a factor of production is paid and how much it would need to be paid to remain in its current use. The Economics A – Z definition is close to Tollison (1982) who defines economic rent as that excess return which is above the normal level of return in a competitive market. George (2006) definition is similar to that of the classical forerunners in that he defines economic rent as the remaining of the produce accruing to the owner of the land.

For the ease of understanding and in recognition of the exigency, practice, economic stage of sub-Sahara Africa and applying a concept in sync with the ultimate goal of modelling a well-functioning market, the concept of economic rent in this research is any payment to the owner of gas area where a gas well is established and commercially operated. In this way, the concept of economic rent in this research is not too distant from the classical school of thought. This definition however differentiates economic rent with other concept such as accounting profit, operating profit, economic profit, producer and consumer surplus etc.

By this definition also, it is easy for the research to see the region as a rentier state in line with Hossein (1970) and so conducts the research in this way.

2.5 Governance of Mineral Resources

It is expedient to mention upfront a vital section of the mineral resource business of which gas is a prominent commodity. The attitude, intentions and ways of securing the economic rent especially by government and their agents can be described as rent seeking behaviour as described in Daha-Norris and Wade (2001) and Tollison (1982). This process alone defines to a large extent the structure, ownership, market type and the entire character of mineral resource business and in our case, the gas business. Literature also documents the works of Cooper and Kovacic (2012), Weijermars (2015) and Abdo (2009) that have provided rich findings in the area of governance of mineral resources of which gas is key. In this research, governance of mineral resources is extensively covered in subsequent sub-topics such as regulatory economics and supply-side-economic solution. However, the focus has been on natural gas resources in sub-Sahara Africa.

As price is fundamental to the research interest, and profitability seems to carry an endorsement, a review of the gas price fundamentals is crucial at this stage.

2.6 Gas Price Fundamentals.

Economic theories of the firm underscore the dominant role price of a product plays in investment decisions. The works of Lozano, et al (2015) articulate various firm theories that prove the significance of price in investment decision making and firm creation. The summation of various arguments in this one piece of work makes the power of price in literature, a more acceptable conclusion. In the extractive industry, price dominance in investment decision making is more pronounce as the core motivation is wealth creation to satisfy shareholders. The imperative of price of natural gas or any energy commodity continues to attract various interests from academicians, market participants, governments, advocacy groups and every stakeholder in the industry no matter how remote the relationship of the stakeholder is to the business.

The review is set in two stages, literature that focus exclusively on sub-Sahara Africa and the general academic interest that have high quality contribution on the market fundamentals of gas elsewhere.

2.7 Sub-Sahara Africa natural gas market.

Before exploring the research materials with related research questions, this research first focused on writers exclusively on the sub-Sahara Africa countries.

While there are not so many academic literatures on gas market model for sub-Saharan Africa typical to this research project, a few of those found including the works of Matthews (2014), Sonibare and Akeredolu (2006), Kanya et al (2012), Egging, Holz and Gabriel (2010), Hoz (2009). Hubert and Ikonnikova (2011), and Tye and Antonio (2007) provide arguments on key areas related to this study.

Matthew (2014) is the closet work to this PhD project in terms of focus area of study. The author looks at the opportunities and challenges for petroleum and liquefied petroleum gas markets in sub-Saharan Africa with the key objective of reducing price differential between imported energy products prices and final market price. Matthew (2014) concerns are on the devaluation impact of high crude oil prices on the disposable income of citizens in the sub-Saharan Africa region that depend on the imported products and the fiscal impact of the government in the case of necessary intervention by way of subsidy. The study concludes that governments of countries studied can save cost from direct import of petroleum products rather than importing crude for local refinery. However, the study did not provide convincing validation of the claims in savings from petroleum products and LPG import-pruned strategy against local refinery. This is not surprising as the study lacks quantitative measurement and optionality techniques for choice of a best option between import and local refinery ventures. As such, it could not materially proffer convincing solution for policy prescription. Apart from the lack of relevance of that study in the area of focus with this PhD project, Matthew (2014) is in the retail end of the industry, while this research is for the upstream investment persuasion. Matthew (2014) however raised vital factors affecting price like the size of petroleum products and Liquefied Petroleum Gas (LPG) markets, economies of scale, market types but missed price elasticity and elasticity of substitution which are key determinants of ability to pay and market power.

In terms of purpose, the work of Sonibare and Akeredolu (2006) comes close to this research project. The authors come out to fix the problem of gas flaring in Nigeria by canvassing for diversification of routine flared gas to consumption in household and electricity generation. In efforts, the authors also come close to this PhD project by looking at natural gas domestic market development which is at the centre of this PhD project even though their work is limited to only one of several countries in sub-Saharan Africa. They also focus on the upstream activity of the gas value chain as this PhD project. Their work also lays bare the poverty of energy supply in the country of study, Nigeria and highlights areas of good investment opportunities especially the gas sub-category in that country and by extension, sub-Saharan Africa region. However, there is a noticeable lack of quantitative tools required for deriving estimated value of cost items and natural gas price for investment decision. In terms of techniques, their work is based only on qualitative methods and do not contemplate areas such as statistically data and the use of quantitative techniques. The study also does not consider the necessity of exploring market theories to gauge the impact of its conclusion that social capital funding should be deployed to the huge infrastructural gas pipelines requirement across the thirty-six states of Nigeria including its capital city. Therefore, it could not provide the opportunity cost of social cost funding for the suggested infrastructural need. Market theories would have guided the authors to the reality that they were suggesting a control market which is at variance with the Nigeria's energy market policy of liberalism at that time.

Other literature reviewed on sub-Saharan Africa region and specific countries within this region also leave various gaps. The work of Kanya, et al (2012) advanced gas production to shore up electricity supply in Nigeria but fail to develop a market structure that will ensure sustainable gas supply even when they attempted a certain level of quantitative techniques. The authors used a two-way regression model and were able to find evidence that electricity power has positive relationship with the country's Gross Domestic Production. However, the essential and necessary effort of creating a market that will attract investment in gas production, which in turn increases gas supply in a chain reaction that will lead to economic development through increase in electric supply, was not their focus. This PhD research project therefore has risen to the need to fill these gaps by taking a study focused on sub-Saharan Africa region, using effective quantitative techniques to model a market that could open the trapped natural gas endowment in the region. It is therefore not surprising that the foregoing reviews find no sufficient answer to the research questions apart from a good attempt from Mathew (2015) that qualitatively explains the relationship of gas and other petroleum liquids in terms of availability.

2.8 Review of literature with similar research questions.

The gaps observed in literature specific to sub-Sahara might have arisen because of the questions they raised. As this research work finds no sufficient answer from the group of the above preceding literature, a further search from elsewhere is necessary. This led to the choice of academic journals with related questions to be reviewed. Such works include that of Hartley, et al (2008); DeVany and Walls (1993, 1999); Siliverstovs et al. (2005); Apostolos and Rangel-Ruiz (2004); Jose and Joutz (2006); Brown and Yucel (2007); Bachmeier and Griffin (2000) among many that are sited. This group of authors have investigated the volatilities of energy carriers; causes of changes in gas prices specifically and oil and gas combined; relationship of gas and other prime energy carriers and products like electricity in different markets at different periods. Their conclusions and suggestions are analysed in the context of answering similar questions in respect of the sub-Sahara Africa natural gas market in line the with goal of this research project

2.8.1 Relationship of natural gas price with other energy commodities.

The interest of Hartley et al (2007) is in the relationship between natural gas and oil prices and the factors that cause short run departures from long run equilibrium relationship. This PhD market model for sub-Saharan Africa gas market is equally interested in both the short and long run equilibria of the market. The relationship between the prices of gas and oil is also of importance to this project because of the way it affects gas suppliers by influencing their incentives to invest. To prove the existence of a long run co-integrating relationship between residual fuel oil prices, natural gas price and technology change in electricity generation, Hartley et al (2007) focus on Western Texas Intermediaries market for crude oil and Henry-Hub for gas prices respective. They used a large size and high frequency data spanning over a period of fifteen years on monthly basis. With the application of vector error correction model, the authors discovered   shocks that caused departure from the co-integrating relationship. Using distillates rather than the gross crude, they assert that the relationship between gas price and crude is indirect. This kind of approach which is searching through distillates has helped in shifting the focus of this research from using the gross crude oil and gas to using their products in estimating the relationship of gas with crude oil prices in sub-Saharan Africa. Mathews (2014) in his work highlights the eminence of petroleum products in sub-Saharan Africa, providing essential information on what is materially useful for this research. In his words, Mathews (2014. p.78) states that petroleum products are the "lifeblood of the economies of all sub-Saharan African countries". Therefore, using petroleum products, rather than crude price in finding the relationship between crude price and gas price in sub-Saharan Africa is a sound logic.

Hartley et al (2007) are not alone in seeking the relationship of various energy prices with gas. Serletis and Herbert (1999) also examine the closeness of the prices of natural gas, electric power and residual fuel using daily frequency data in a systemic equation. Their findings suggest a weak exogeneity of fuel oil. Jose' and Joutz (2006) look at decoupling of the prices of natural gas and crude oil. Their findings contradict that of the evidence of Hartley et al (2007) in the later years in that Jose' and Joutz discover a close relationship between the prices of the two commodities. This is not surprising as they use crude price directly rather than the petroleum products as in Hartley and others. Brown and Yucel (2007) in joining the search for the relationship of the prices of natural gas and petroleum products as the aforementioned authors support Jose' and Joutz, finding. They conclude that there is a relationship between the two prices over the long period used which spans from 1994 to 2006.

These contradictory findings on the question that relates to the relationship of natural gas prices and other energy commodities require a confirmatory test aid the investors in their investment decisions.

2.8.2 Drivers of natural gas prices.

Nick and Thoenes (2014) ask the same question – what drive natural gas prices? Their conclusion is that in the short run, temperature condition and supply shocks affect the price of natural gas. However, the long run behaviour of natural gas as per their findings is decided by prices of other energy commodities, notably, crude oil and coal. Brown and Yucel (2007) ask the same question and hold weather conditions especially hurricanes accountable for driving gas prices. Sam (2006) in answer to the question what drives natural gas prices points at weather. Hulshof et al (2016) taking oil price, changes in concentration of supply, storage and weather condition into account conclude that weather condition and storage have more impact on the behaviour of gas in Europe than the other two variables.

The works of these authors were out of the focus area of this study where weather condition is stable. It is difficult therefore for weather condition to exert an influence on the price behaviour of natural gas in sub-Sahara Africa. Using storage to explain behaviour of gas price may not fit well in sub-Sahara Africa because of the scarce gas situation. In this case of scarcity, there will hardly be enough gas to use and spare requiring storage. Neither storage nor weather are concerns of the region. What could be important influences in this region are inflation, exchange rate and interest rate.

2.8.3 Derivation of Natural Gas Forecast value

One major risk faced by the extractive industry besides the risks of geology, environment and politics earlier mentioned, is price volatility. The dominant role of price in influencing investment decisions in the energy market is reflected by the monumental interest academic researchers, market participants, governments, advocacy groups and other stakeholders have expressed in its behaviour represented by the huge and high-quality literature available. Upholding the evidence presented by a number of authors, including Hartley et al (2008), Hjalmarsson and Osterhol (2009) and Nick and Thoennes (2014) that the behaviour of prices of oil & gas move in the same direction especially in the long-run. Let it suffice here to talk of oil and gas in the same context for the ease of analysis in this discussion. This suggestion is also substantiated by the fact that gas & oil are mostly co-joined products in the business of the oil industry.

The quest for near exact forecast value of natural gas or crude oil price to aid investors in investment decision enjoy substantial number of contributions from academicians and other stake holders than any other real sector economic science subject, especially in the recent times. This is understandable because of the pre-eminence of oil and gas in the global economy and the continuous unpredictable behaviours of these prices which affect business in their markets. Ciner (2001), Cologni and Manera (2008) and Lardic and Mignon (2008) provide evidence on how the oil prices and by association natural gas prices have influence on the aggregate economy. All the authors cited in this section explain the risk price volatility presents to the investors in this industry. Some of the authors like Arouri et al (2012) explain that an investor with efficient volatility forecast is in a vintage position to exploit opportunities in the market. All the authors including Arouri et al (2012) therefore canvass for accurate, reliable and powerful forecast of the future behaviour of the prices of these commodities to the help investors take calculated risk in venturing into the business.

Among the host of authors that seek to predict price trends of these prime energy commodities include Hassan and Nassar (2013), Narayan and Narayan (2007), Kang et al (2009), Salisu and Fasanya (2013), Awartani and Corradi (2005), Sadorsky (2006), Hayat and Narayan (2010) and Yang et al (2002). Narayan and Narayan (2007) provide evidence that the behaviour of oil prices is disposed to change over the short term and explain that economic shocks also affect the price of oil.

Hayat and Narayan (2010), discuss that supply and demand fundamentals explain nearly 70% of the US variation in oil shock. Salisu and Fasanya (2013) trace crude price changes to economic fundamentals due to shocks. In Yang et al (2002) the authors conclude that the seed of volatility is contained in switching elasticity. Contributions from cited authors are almost in tandem with the conclusion of the above.

While these contributions are useful elsewhere, they are not connected to the sub-Sahara Africa region which has different market dynamics, structure and functions with the advanced economies these authors cover. However, the authors provide valuable contributions to literature that are essential to this research project especially the works of Salisu and Fasanya (2013), Arouri et al (2012) and Hassan and Nassar (2013). These authors provide the foundation on which this research work builds its methodology and draw the attention of this researcher to usefulness of recognizing memory decay in modern days modelling of energy markets.

2.8.4 Effective demand for gas

What is commonly understood from economic theory about effective demand is the ability and willingness of the customer to pay the asking market price for a commodity. Effective demand could also be extended to choice of, or preference for the commodity among competing substitutes. In this research work, effective demand cannot therefore be isolated from the price forecast, rather, it is the utilizer of the derived value from forecasting exercises. Once the price is determined, various elasticities would now be deployed to test the efficacy of market demand for the product. These elasticity tools are covered in the method selection of the research project.

2.9 Regulatory economics

So far literature has not provided tangible material to construct a theoretical framework for this project. This therefore mandates this research to expand the search to other branches of economics such as the theory of economic regulation.

From the OECD Statistics (2017) regulatory economics or economics of regulation can be described as a system of rules and regulations applied by government and/or their agencies on economic agents for various purposes or intentions. Academic debates on regulatory economics are centred on prescriptions of regulatory interventions and suggestions about the level of interferences. In most cases, the authors provide measurable results to support their arguments. Cooper and Kovacic (2012) used a simple model of a regulator serving as an agent of a political overseer of a particular market. The authors point out the conflict faced by the regulator, between serving the political overseer and the long-term benefit of the industry. Other authors like Armstrong and Huck (2010), Jolls (2007), Knieps and Weib (2007) and Wright and Stone (2011) all bring out the struggle, short comings and biases in regulatory economics in markets. As good as these works may be especially in accessing behavioural responses to regulatory actions, their inadequacy for application to the complicated extractive industry drives this thesis to look beyond this level of their analysis and strive towards the deeper fundamentals of investment behaviours in the extractive industry.

Apart from the inadequacy of the regulatory reviews above, there are four additional reasons why this research project needs to review the regulatory economics further. First is to set the general basis of and reason for regulatory economics. The second reason is the fallout from the preceding review of firm theory; theories of investment; and literature on price forecast that were insufficient to establish a theoretical base for the research. Third is the peculiar nature of the extractive industry from documentary evidences for which the project is to develop a market. Fourth are the essentialities of regulatory economics or the economics of regulation which are needed in this research work as the review so far is showing that regulatory economics could eventually serve as a fundamental pillar in modelling gas market for sub-Saharan Africa. While the second reason has been captured in the summary of each sub-section requiring no further elaboration here, the first, third and fourth reasons need to be explained further in the following sub-topics.

2.9.1 Economic theory of market failure.

Wherever the system of allocation of goods and services is not efficient, that market is said to be an inefficient market, that is, market failure exists. Efficiency in economics as in the Pareto efficiency, productive efficiency and average lowest possible cost concept is a situation of balance in which no further adjustment is desirable. The words “market failure” is said to have first been used in economics science by Bator (1958) in his anatomy of market failure. In Ledyard (2008) and Krugman and Wells (2006) market failure is a situation where an individual (firm) in pursuing its interest operates in a way that is not efficient in the market. Arrow (1969) Hugh and Rees (2004) conclude that the presence of market failure is a justified reason for market intervention, which is the application of regulatory economics. The existence and causes of market failure are usually of concern to micro economists with some like Gregory et al (2002) calling for correction. But David and Vining (2004) point out that interventions like taxes, poor attempt to correct market, subsidies and bailouts could also lead to market inefficiency. Taking this issue of market efficiency from Krugman and Wells in the context of stakeholders’ theory examined earlier, firms in the extractive industry in the pursuit of their core interest of wealth creation for their shareholders might create inefficient market practices. This research considers, the caveat of Krugman Wells (2006) and notices that literature in this area has not offered sufficient solution as to the type of regulatory economics that could be adopted for sub-Sahara Africa region to ensure an efficient market for its natural gas. However, the knowledge of market failure has helped the research in no small measure, in identifying the likelihood of modelling an inefficient market which is undesirable in both economic theory and market practice. This research notes this possibility strongly and has prepared to avoid imbibing elements of market failure as the research work continues.

2.9.2 The peculiar nature of the minerals industry

The extractive industry is a challenging entity. Published books and articles authored by industry experts and academicians like Garnaut and Ross, (1975); Kemp (1996), Van-Meurs (1988), Waelde (1996) and Auty (1998) paint the picture of the extractive business as an industry permeated with complexities in relationship, structure and operation, that are larger than any other industry. Auty (1998) expands the views of these authors by adding that the industry however has the capacity to generate commensurate wealth, larger than any business. This researcher observes one thing that stands out in this industry, that is, its defining capacity to change the economics of any country it gets into. To this researcher, it is such a strong influence that is beyond the power of smaller economic agents to withstand or curtail or control or influence that attracts as a matter of duty, the attention of the government into the operational life of the firms in this business. Allowing the firm to pursue its interests to the fullest might harm the economy by entrenching and sustaining market inefficiency. Government therefore in a call of sovereign and constitutional duty needs to step in, to address this situation in line with the call of economist like Krugman and Wells (2006). As Auty, (1998) and a host of authors cited in preceding review observe, this is an industry that generates a large amount of scarce foreign reserves, provides new technology, challenges poor domestic operators to quality production and best global practices and basically reform the economy. Government therefore is interested in this industry to also serve its interests.

It is the nature of interests of the two parties - the firm and that of government – that differentiates the peculiarities of this industry from any other. There are questions to be asked. But to put them in proper context, these interests need to be further examined using published documents and literature including the works of Johnston (1994), Kumar (1991), Emerson & Gaurnaut (1994) and Mikesell (1987).

2.9.2.1 The Interests (goals) of the investor

In Johnston (1994) the overall interests of the investor in the mineral industry are understood to be building equity and wealth maximization “by producing oil or gas at the lowest possible cost and highest margin” (p.18). This does not distinguish the oil and gas industry from any other industry though, but the investor’s requests for a potential reward to cover commercial, geological and political risk and leave an attractive surplus for him/her as reported by this author and other cited, is what calls for special treatment. This researcher notes that there is no one-fit-all prescription for the treatment of commercial risk, geological risk and political risk for universal application. Commercial activities differ from one country to another and from one region to another just as the geological properties of gas or oil also differ from one geological zone to another. This is evidenced by the product classification as sweet/sour gas and light/heavy gas. And if one is in doubt of the commercial and geological differences, the political difference risk holds substance in the suggestion for treating this industry differently. Kumar (1991) and Emerson and Gaurnaut (1994) go on to add that the investor also requires a clear, stable and transparent tax regime as well as legal system as reported in the opening review in this chapter. In addition, the authors express the strong desire of the investor to have a high degree of control of the project planning and implementation and the ability to take any profits out of the host country. These are the demands the stakeholder theory of the firm finds difficult to treat.

2.9.2.2 The interests of the host government

In economics and social sciences, the objectives of a government are much complex than that of any company. This researcher recognizes this and has therefore narrowed the discussion of government's interest to the context of energy business in which the research project is focused on. However, it should also be noted that regardless of the structure of government or political system, the interest of governments in petroleum exploration are wide-ranging. Johnston (1994) asserts that designing a fiscal system through which economic activities in the extractive industry are acquired is the primary interest of government. This general interest seems to be material, judging from the observation of current practices where governments are wooing investors into their countries for exploration. This researcher accepts this contribution which is interpreted to mean putting the investor first on the scale of preference by the host government in terms of importance. Emmerson and Gaurnaut (1994) also highlight the importance of petroleum taxation in national benefits, while Borges, Szklo and Bucheb (2014) provide evidence on how initiatives of the government of Brazil through local content policies provided windfall profits to the economy.

Other interests of government mention by Mikesell (1987) and Kumar (1991) apart from increases in tax revenues include development of the country's own petroleum industry and related trade; secure energy supply and expansion of foreign exchange earnings. According to these authors, the instrument to achieve these is through a fiscal tax regime or system. Following these interests, it therefore follows that when government officials are evaluating the potential revenues from a gas or oil project, they are most likely to want to obtain the maximum tax revenue possible over the economic life of the project; derive a predictable level of revenue and to some extent may want to invest in the project as well. This last interest has manifested in many oil and gas fields in current practice giving rise to the formation of joint venture arrangements and other purpose vehicles creation. This researcher notes that this interest inherently negates the interest of absolute control by the investor.

Balancing or reconciling the competing interests of these parties provides an attractive avenue for destined investment inflows and allows the formation of an effective and efficient oil or gas market in any region found. Some authors like Moussa et al (2015), Matkin (2010), Andrew-Speed (1998), Cordes (1995) and Garnaut and Ross (1983) have attempted solutions to the balancing of competing interests. They first drew the attention of this researcher to the common ground of interest which is maximisation of revenue. Both sides want to maximize the revenues that come out of production activities using their professional and artisanal tools which are tax, by government targeting petroleum rent and discount rate by the investor which is used in assessing payment required for investment cost and risk rewards. Gaurnaut and Ross

(1998, p.27) define economic rent as “the excess of total revenue derived from some activity over the sum of the supply prices of all capital, labour and other inputs” Cordes (1995, p. 26) defines economic rent as the mark-up margin from “sales and cost of production”. Crowson (1998, p. 22) while accepting the two definitions adds that rent normally accrues “throughout the economic life of the well” - in this case gas well - until the economically usable gas is completely extracted from the well. This definition if put in practice will place a burden on the investor as the cost of abandonment is not captured. Moussa et al (2015) shares the experience of Guinean mining fiscal regime which has undesirable effect on investment inflows. According to these authors, the tax in Guinea is not only targeted to the defined economic rent but incorporates corporate taxes and several indirect mandatory requests that add to the extractive mineral industry investment burdens, rather than lightening it to attract investment inflows. This situation is not restricted to Guinea alone as it is the common practice in existing petroleum business in other countries in sub-Sahara Africa that this project is set to discuss.

Secondly, these authors opine that with a proper understanding of the instrumentalities of economic rent and discount rate, a tax system can be designed to reconcile the competing differences. The most persuasive voices in this debate are Andrew-Speed (1998), Auty (1998) and Crowson (1998). Andrew-Speed (1998) strongly believes in the efficacy of a tax regime to balance the oil & gas producer’s cash requirement flow with government desire for secure revenue. He advocates in terms of cash flow timing, that the government should prepare to wait until the cash flow timing of the investor is satisfied. This addresses the concerns of Kumar (1991, p139) that “the most delicate task has been reconciling efficiency of resource use with fair distribution of economic rent”. Gaurnaut, (1995) supports Andrew-Speed (1998) and other authors cited upholding the possibility of taxing economic rent by government without hurting the economic output.

The concept of economic rent has been clarified in section 2.4 of this chapter However, the issue of discount factor is a valuable material for this researcher especially in the quantitative aspect of the research where volatility forecast modelling is deployed. This research notes that in practice, what seems to be accounting profit appears in the construction and negotiation of economic rent. It is an account profit because it constitutes the subtraction of exploration cost, development cost, operating cost and the discount rate demanded by the operator from total revenue. As early observed, what will count for exploration cost, development cost and operating cost will differ from one region to another depending on the size, grade, ease of extraction; physical location (onshore, off-shore, shallow water, deep water, etc.); available infrastructure; skills and technology; freedom of operation without undue interferences; size and nature of the local market.

While these can be taken as good attempts to address the balancing need, it is evident that the sum total of their suggestion is just a scratch of the surface of what could constitute a satisfactory tax system for sub-Sahara Africa natural gas market. The likely answer is out there to be researched as there is no satisfactory answer from literature. This task therefore forms a core part of this research work.

This gap has led this research work to consider yet another theory, which is the Supply-Side-Economic theory of Robert Alexander Mundell.

2.10 Supply-side Economic Solution: Research Theoretical Framework

The supply-side economics is the most recent macroeconomic thought that maintains that the most effective means of creating economic growth is by investing in capital and lowering barriers on the production of goods and services as discussed by Dwivedi (2010) and Goodwin et al (2015). Although its full application started in the eighties during Ronald Reagan by Mundell (1988), Atkinson (2006) maintains that the term "supply-side" was first used by Herbert Stein during US president Nixon. What was fed into the machinery of capitalism since the advent of John Maynard Keynes was the Keynesianism. By the early eighties, Ronald Reagan displaced the hitherto entrenched Keynesianism by embracing this new economic thought. Supply-side economics is best understood by the Laffer Curve[4] which shows the relationship between tax rates and the government revenue accruing therefrom explicitly, as seen in Tucker (2010). The Keynesianism is about demand side economic management focusing on the relationship between aggregate demand variables while the supply-side economics is about supply economic management. Mundell (1988) presents the two theories in the proper context of their differences to clarify that it is not the exact two sides of a coin as the just concluded statement may seem to connote. According to Mundell (1988), supply-side economics upholds the

[4] The Laffer curve is the work of Arthur Laffer who joins Robert Mundell in the evolution of supply-side economics.

working of fiscal to be consonant with the way markets work. This contrasts the Keynesian postulate which holds that fiscal change should alter demand, hence its focus on demand. In focusing on the marketing dynamics, the supply-side economics can change individual's incentives through change of relative prices. The approach is seen to aim at after-tax rewards for economic endeavours in the form of savings, investment, labour supply and risk taking as Mundell (1998) puts it. It is therefore seen as incentive model that encourages savings, investment, employment and output as individuals are incentivise, to save, invest and employ factors of production.

Mundell (1998) tells the success story of how Ronald Reagan's economic method which is tagged "Reaganomics" arrested and reversed the worrisome inflationary trend he inherited putting, the Keynesian Philips curve to shame. The author states that on account of this, unemployment rate fell 45 per cent, and gross domestic investment grew by 77 per cent, a success Peterson (1998) calls Reagan Revolution. Zhai and He (2008) also tell of the success story of the People Republic of China in using supply-side economics to lift off tax burden on production. They present evidence that the use of supply-side tax system expands output and improves welfare.

Having reviewed the above theories, in this researcher's opinion, the most relevant theoretical framework for the PhD project is the theory of Supply-side Economic Solution. The injection of incentives on case-by-case basis which is the principle of a new tax system from Supply-side Economic Solution could be the solution to the sub-Saharan African situation. The complexities and peculiarities of the energy industry, the type of interests of potential investors for their investment in this high-risk entity and disposition of host government have defied solutions from available literature. Theories of investment from literature could only provide the financial tools for project appraisal. Theory of firm prescribed a type of picture that an oil or gas firm cannot fit in terms of their demands. While there are tools to forecast a future gas price, none however has been tested in the peculiar terrain of natural gas market of sub-Sahara Africa. Literature reviewed form regulatory economics only resulted into bringing out the difficulties in reaching a compromising stance in expectations from contending parties. However, when the Supply-side Economic Solution was reviewed it turned out to be a possible solution to strike a compromise between the requests of the investor and host government in the sub-Sahara Africa natural gas industry. This theory if applied to the tussle in profit sharing using the incentive-based approach as it is, could attract unwilling investors into the market. The theory has proved to work for the US economy and the tax reform of the People’s Republic of China, and it is aimed to be tested through this PhD research project in the African soil, on a special industry.

Supply-side-economic solution is an incentive-based approach to economic solutions such as directing the behaviours of economic agents towards the achievement of aggregate economic goals as in Mundell (1988). This can be applied both at the microeconomic and macroeconomic levels and it is suitable in providing solution to the problem of equitable distribution of disputable economic rent. Supply-side economics solution is therefore chosen as the theoretical framework for this research.

2.10.1 Justification of derived theoretical framework

The justification for using supply-side economics solution in this project is embedded in the mechanics of what holds and dictates the nature, existence and sustenance of a natural resource market from investment perspectives. Answers to key questions like what these mechanics are and how they work help in good measure to support the use of supply-side economics solution as defined above.

Reviewed literature shows that economic gains from mining activities are the centrality and singular axle that defines, holds, and directs the nature, existence of a successful market model for any extractive industry anywhere. Osmulden et al (2013) traces these gains to two domains where they naturally occur. These are socio-economic profits from government, and commercial profits from investors. Each economic entity has its tools which they deploy to realising their main goals. The encompassing system which facilitates the interplay of the tools from each domain constitutes the mechanism that holds the market. It is imperative therefore to once more dig into literature and contemporary practices to examine these instruments from each of the two contending economic agents in the hope of establishing the relevance of supply-side-economics solution as a theoretical framework for the project. Pursuant to this, the works of Garmaut and Ross (1983), Kemp (1987), Waelde (1996), Magne et al (2011), Otto (1995), Weijermars (2015), Ballard (2012) and Osmundsen (2015) provide ground for this exercise.

Starting with the host government, Garmaut and Ross (1983) laid bare the elements that government uses in capturing its target socioeconomic benefits.

These elements of rent tax include Fixed Fee Tax; Specific Tax (in some places called Ad valorem duty); Higher Rate of Income tax; Progressive Profit Tax; Resource Rent Tax; Brown Tax; Product Sharing; Resource Rent with Equity and Carried Interest. Kemp (1987), Waelde (1996) and Otto (1992) while collaborating with Garmaut and Ross (1983) expanded the royalty tax to include production tax, product tax and severance tax and assert that Royalties are much easier to control and collect. They explain that Royalties are not sensitive to cost and yield immediate streams of income as they are payable from the day production starts. However, Kemp (1987) points out that a high level of royalty may result to high-grading or premature abandonment of fields. Other related rent taxes identified by these authors include Signature Bonuses; Bid Auction; Surtax; Petroleum Revenue Tax and Special Tax.

These authors also explain that in the quest for higher socioeconomic benefits, government may want to add to the tax structure, some obligation including foreign exchange regulation; contribution to local government development; fees payable to land owners; investors' participation in joint ventures; obligations to deposit bonds to guarantee investment performance; employment of local man power; utilization of local content; etc. In line with Otto (1992), these taxes may look indirect, but they intrinsically translate into additional cost and additional burden to the investors. When a tax system is perceived unattractive, government   takes one or a combination of the following: tax holidays; tax allowance; tax deduction; tax credits; tax abatement; uplift; flow-through shares; depletion allowance; loss carry-over; cost recovery; expensing; capitalization;

depreciation and tax relief as well according to Parsons (1995), Cordes (1995), Vanblerk (1994) and Kemp (1987).

On the side of the investment, the investor only reacts to the schematic tax offer of the government. This relationship aptly falls into Cooper and Kovacic (2012) model of a principal and agent relationship examined in the literature of economic theory on market failure above. Investment interest therefore is solely dependent on the attractiveness of the tax system. However, the investors' attitude is not as docile as it appears to be in this narrative, but it asserts itself in every business engagement and its actions or inactions do influence the action of the principal. Therefore, a fair tax system has always been the aim of the principal (host government). Weijermars states that tax design could create two reactions that is to incentivise and increase investment or dis-incentivise and deter investment interest.

Recent studies like the works of Emhjellen, et al (2011); Ballard, et al (2012); and Osmundsen, et al (2015) present the position of the investor in making investment decisions in the oil and gas business in recent times. Osmundsen, et al (2015) argue that the multinational (which are the key industry players) have a unique investment decision model across the globe and it is only adjusted to capture country risk. The authors further throw more light on the way these multinationals make their investment decision which is applying the traditional Net Present Value (NPV) with an expectation of high Rate of Return (RoR) as earlier examined in the literature on investment theory. The expectation of RoR connotes the commercial profitability expectation of venturing into investing in the industry in any country. In practice, the authors clarify that investors use stock values of their corporations because they are listed on the stock exchange to calculate their portfolio systematic commercial risk. The value obtained which is denoted by a beta is used in comparing, the viability of specific project intentions to arrive at an objective decision. If the beta of the investment in consideration is higher than the overall beta of the company's global portfolio which indicates a higher risk to the company, then the new investment's RoR must be higher than the RoR of the existing portfolio to qualify for the deployment of fund for the new project. The onus therefore is now left for the host government to strive to meet this high RoR expectation in order to incentivize the investor to carry on with intended investment decision.

The works of James and Noble (1992), Emhjellen et al (2011), Ballard et al (2012) and Osmundsen et al (2015) posit that to incentivize the investor, government needs to aim at a tax system which is efficient, that is the one which collects revenue for government without significantly affecting the behaviour of the prospective investor. They argue that the tax should be equitable, that is a tax that seeks to give the largest satisfaction to both parties. The incentivized tax mechanism should aim at stability in terms of government fiscal policies and flexible to address the vagaries of price fluctuations.

It is then logical therefore to conclude that the effective theory to deploy in order to deal with the problem of best tax regime is the supply-side-economics solution using the various tax allowances mentioned above especially in the context of fairness, neutrality, equity, flexibility and sustainability. In the recent works of Emhjellen et al (2011), Ballard et al (2012) and Osmundsen et al (2015) various considerations are suggested. Osmundsen et al (2015) advocate the use of cash flow tax. Emhjellen et al (2011) advocate for the use of risk-free rate in calculation of the NPV of the cash flow. What is required is the “how” to go about it and it is the opinion of this researcher that the relevance of supply-side economics solution theory aptly applies in terms of theoretical framework.

2.11 Summary

Literature was reviewed in the context of research questions raised. The reviewed covered the five aspects of market including investment theories, firm theories, gas market fundamentals, regulatory economics and Supply-side Economic Solution. The outcome of the review brought economic rent, supply-side-economic solution, regulatory economics and volatility forecasting as key literature for the work of this thesis.

The review therefore made a valuable contribution to this research in terms of direction, provision of tools, derivation of the theoretical framework and identification of problems in order to address the research questions.

CHAPTER THREE:
RESEARCH METHODOLOGY AND METHODS

3.1 Introduction

The approach that outlines and guides the way by which an academic enquiry can be carried out, could be referred to as methodology. Baskerville (1991) confirms this definition by describing methodology as the systematic study of approaches applied in a discipline. Howell (2013) while accepting this definition, adds that methodology includes the methods of data collection and the employment of specific results estimation techniques. Most authors posit that methodology offers the theoretical basis for understanding the method or set of methods. In this manner, methodology becomes a pre-cursor to method. In Irmy and Rose (2005) methodology is said to encompass paradigm, theoretical model, and techniques. Hussey and Hussey (1997) description of methodology does not differ from these authors in reference, as they define methodology as the overall approach in the process of research, starting from the theoretical underpinning to the collection and analysis of data. Methods are however different from methodology in the sense that they are a sub-set of the methodological system. Frankfurter (2007) distinguishes the two by defining methodology as the principles and practices that underlie research works and methods as the tools of enquiry thereby putting the issue in a proper and practical conceptual distinction. This researcher summarizes the relationship between methodology and methods from the aforementioned postulates as follows:

Principles-Tools

House-building materials

Shirts-Clothing materials

It is on the pedestal of this diction that this research work is carried, starting with the quest for the research methodology.

But before delving into methodological and method selection, it is imperative to establish the reason and essence for which the derived methodology and methods are required. Gaps identified, and questions raised together with assumptions made in the form of hypotheses are the reasons for which the selected methodology and methods are required. Key areas identified for further probing and testing to fill the gaps in this research include gas investments; natural gas prices; measures of market instability; behaviour of natural gas price returns on the lags of their past and direction of market information. Although, all the questions raised in literature cannot be answered by quantitative techniques it is however imperative to set the hypothesis for the quantitatively related gaps at the beginning of this chapter.

3.2 The research Hypotheses

This research work is premised on the overall assumption that there is no natural gas market in sub-Saharan Africa. The research asserts that the domestic regional natural gas market in sub-Sahara Africa is dormant and can only be reactivated by domesticating gas activities in the region through a supply-led economic approach in the upstream sub-sector. The research claims that if this is done, the regional energy poverty which is reflected by an estimated energy consumption of 4% of the total global energy consumption according to IEA

(2014) could be increased. To this researcher, the answer to the solution for the current sub-Saharan African regional energy poverty therefore lies in modelling a peculiar market through analyses of, and proffering solutions on the current market components which include investment issues; natural gas price; prices of related energy commodities; effective demand; elasticities of income and regulations. As any of these components can potentially alter the structure and functionality of the market, due diligence is required in constructing the methodology and method section of the research. One of such diligence is to set the hypotheses upfront on the specific quantitative inquiry. This is to clearly demarcate the research work into appropriate approaches and compartments in order to enhance an effective research algorithm. Consequently, the five hypotheses that emanated from the research questions are as follows:

H_{01}: There are no symmetries in the returns of the prices in the four global natural gas markets in which sub-Sahara Africa gas trades in. That is, their joint null hypotheses are: $\Psi_1 = \Psi_2 = \Psi_3 = \Psi_4 = 0$.

This hypothesis is mapped out from the research question 1:

What is the nature of shocks in the market where sub-Sahara Africa natural gas trades?

The above hypothesis tests what drives natural gas prices.

H_{02}: Regional market conditions do not alter fundamental drivers of volatility.

This arises from question number 2 which is:

Would natural gas from sub-Sahara Africa follow a pattern in terms of volatility if traded in markets other than current markets?

This hypothesis tests if volatility will be the same in a hypothetical sub-Sahara natural gas market with the different general conditions.

H_{03} There is no leverage effect in the returns of the price series.

This hypothesis is mapped out from research question number 3 as:

Do the returns of natural gas in these markets which incorporate gas from sub-Sahara Africa generate the right news signals for investors to take decision in terms of leverage, just as in crude oil markets?

The above hypothesis tests news signals which are important to investment decisions.

H_{04}: There is no shock persistence in any of the market. That is, shocks in the market if they ever occur, are transient.

This hypothesis arises from research question number 4 which states:

In the event of market instability, how long do shock last?

Length of decay of shocks are now one of the most important variables in current time energy investment markets.

H_{05}: Shocks in natural gas prices of these markets have no effect.

This hypothesis comes from the research question number 5:

What effect do shocks have on natural gas returns in markets where sub-Sahara Africa natural gas trades?

Table 2 shows the entire mapping of these hypotheses to the questions and investigating tools deployed.

Research questions 6 to 12 are qualitative questions and are to be answered by field surveys and focus group discussions.

Questions 13, 14 and 15 are quantitative in nature, and computation techniques have been used to derive their answers.

3.3 The Methodology for this research

The goal of a typical research is either to produce new knowledge, give good insight into existing knowledge or deepen the understanding of an issue around the research area. Following the definition of method in the introduction, this researcher accepts that methodology is the critical stage in which the philosophical underpinnings of research work are established, its methods designed and the arsenal of the tools of work are organized in a careful and systematic manner for the effective execution of the project. This research is no exception to this format except that it makes a conceptual distinction by limiting the process of methodology to selection of appropriate philosophical underpinning and carries the process of methods in a different section. Again, the project sees methodology as the confluence of what is to be known and how that which is to be known is known. For proper management of the process, the project narrows the scope of analysing research methodologies around business studies so as not to be entangled with a variety of contrasting issues undergoing academic arguments in research methodology.

3.4 The nature of Energy Business Research

The nature of research differs from one discipline to the other. Literature to an extent has sufficiently identified areas defining these differences in research, from one discipline to the other. For business research in general one such common factor of delineation is the goal of the research output which is the need for managerial problems solving. Bryman and Bell (2007) highlighted the problem-solving attribute of most business researches to define the nature of business research. This attribute and the perception of research as an applied field is more pronounced in the energy business where quantity economics seem to be the quintessence of the energy world. But because the practice of business research finds itself in the fabrics of social sciences, its method integrates other practices, and this stretches it beyond the quest for practical issues to imbibing theoretical content in its practice. These processes in business research are therefore, driven by management consultants on the practical problem-solving research type and academicians on the theoretical perspectives. Gummesson (2000) concludes that they all add to knowledge in a complementary manner where the consultant backed by strains of theory contributes to practical knowledge and the scholar armed with elements of practice contributes to theoretical knowledge. This has helped in defining the direction of this research. Burrell (1997) has convinced this researcher to allow the theoretical part to take pre-eminence in the research for building a market model in sub-Saharan from investment and regulatory approaches. This researcher has, therefore, followed this line of thought by taking the scholastic standpoint with strains of practice for the study.

3.5 Philosophical underpinnings of Energy Business Research

Conducting a research requires a philosophical stance to drive the process and this should be derived from the plethora of research philosophies. A good start towards derivation of a philosophical stance is to differentiate the definition, methods, and the derivatives of philosophy as they have confused and convoluted good research propositions. A definition that is commonly made about philosophy by the Strong's Greek Dictionary, Etymology and Oxford English dictionaries is that philosophy is love of wisdom or the quest for wisdom. Webster's New Dictionary adds that philosophy is in addition to the love of knowledge, the search for wisdom is, theory or logical analysis of the principles underlying the conduct, thought, knowledge and the nature of universe. Teichmann and Evans (1999) state that philosophy is the study of problems concerning the nature of existence, knowledge, morality, reason and human purpose. Writers before and after Teichmann and Evans have not departed from this position. Grayling (1998) in explaining the aim of philosophy posits that philosophy is about questions regarding knowledge, truth, reason, reality, meaning, mind and value to gain insight. Critical discussion, rational argument and systematic presentation are commonly identified methods in philosophical inquiry. On the philosophical derivatives, which is the basis of deriving our philosophical underpinnings regarding choice of methodology to conduct this research, this research analyses the core tenets of philosophical approaches mainly ontology and epistemology in detail and briefly talks on axiology and rhetoric.

3.6 Ontological assumptions

In theory, ontology is defined as a formal, explicit specification of shared conceptualization according to Gruber (1993). This definition is found in several literatures depicting ontology as a philosophical discipline concerned with people's views, assumptions and believes about the nature and structure of reality. Initially, it was acknowledged as a discipline exclusively for social sciences after the break-away from the Aristotelian use of ontology in his study of metaphysics[5], but in recent times, ontological approaches feature prominently in study of sciences like computer science. Bryman and Bell (2007) provide an understanding of the two distinctive approaches of ontology using organization and culture of a social entity. The authors postulate that the social entity on the one hand comes across to the actor as external having an almost tangible reality of its own. Following this argument, it behoves that any entity of this semblance portrays the characteristics of an object and as such has an objective reality. On the other hand, the alternative ontology such as the pre-given social external realities postulates that organizational and cultural values, systems, ethos are worked on, that is, human interactions change these elements. Becker (1982) asserts that people create culture. The works of Strauss et al (1973) surmises that the social order is in a constant state of change constructed by the interaction of the individuals. These two deferring approaches are explicitly termed objectivism and constructivism associated with ontology and they are the choices open to this research to choose in line with its view of the entity of study, whether it is objective and external to it or socially constructed and can only be

[5] This is contained in the first books of Aristotle treatise collectively known as "organon". Also note that the term "ontology" was coined only in the seventeenth century

understood by examining the beliefs of the human actors. Hussey and Hussey (1997) pointed out that the research design and its outcome, is influenced by the researcher's beliefs in any of the two paradigms.

The contrasting feature of ontology is its way of inquiry. Questions like what is the nature of reality? what is the economic system made of? what are the constituents of economic reality are complex ontology inquiry in a profound way. This feature of inquiry which has been ignored or subsumed under economic heading and methodologies forms an essential part of philosophical derivation for this dissertation.

Therefore, the ontological stance of this researcher is objectivism in the part that portrays the area of the study as external to the researcher and constructivism in the other part that also represents the gas industry under inquiry as a social construct. The dualistic algorithm employed in the research is an attestation of the ontological stance of this research as stated. This stance also finds credence in Edward (2009).

3.7 Epistemological assumptions

While ontology is about what is out there to be studied, epistemology is concerned with how can that be studied? How would one obtain knowledge about the social reality that is believed to exist? How can a researcher know what exists or how can what exists be known? These are epistemological questions brought out in Hassan (2012). Hussey and Hussey (1997) explain epistemology in terms of relationship between the researcher and what is being researched. Writers generally have concluded that epistemological studies are about the nature of knowledge, the rationality of believe and justification. In leaning towards the “how” approach, epistemology presents itself as a discipline utilising empirical and positivistic means of inquiry. Empirical studies also known as empiricism or empirics according to Bryman and Bell (2007), are approaches of study of reality through experience and sense. Stathis and Martin (2010) emphasize on the observational and experimental tenets of empiricism in acquiring knowledge through evidence. Epistemology is also associated with positivism which states that positive knowledge is based on such natural occurrences as decomposition, germination, etc. in a cause and effect relationship. Positivism therefore affirms the significance of imitating the natural sciences in the study of natural social phenomena by the process of seeking evidence to test assumptions and hypotheses generated from theories. But when the research process takes evidence to build or generate a theory, this approach is called interpretivism. This also represents researchers that are critical of using scientific positivist to the study of social science. They hold strongly that people being the subject matter of social studies are markedly different from core sciences. They therefore advocate the Max Weber’s interpretive epistemological position.

What makes epistemological assumptions stand out is its use of rigorous testing of ideas, assumptions, hypotheses before they can be considered as reality or knowledge on the premise of researcher’s independence from that being researched. This has led epistemology to be associated with deductive process of research conduct and in some cases, inductive approach as well.

Deductive theory underscores the most common view of epistemology for the positivist and inductive approaches for the normative interpretive epistemology.

Set on the domain of theory, the positive researcher deduces a hypothesis which must be subjected to empirical investigation involving the collection and use of hard numerical facts. In this way, the researcher should specify the data required, identify the source, decide the scope and arrange how the data will be collected in relation to the concepts that make up the hypothesis. The interpretivist uses inductive means of inquiry on the basis that, it is not possible for the researcher to disassociate himself from the social entity under study.

The nature of the energy industry is an expansive and complex system pulling global interests together, to an arena of complex and intricate activities. During this process, local customs, and ethos, are beclouded by the supreme external forces. To this researcher, the view of the entity from ontological constructivism and/or epistemological interpretivism is not robust enough for energy study. In this type of study, the suitable option therefore is ontological objectivism and/or epistemological positivism. This research, in looking at the issue from external view detaches itself from the natural gas market modelling being studied. Therefore, the research uses both ontological objectivism to answer, “what is there to be studied” questions and epistemological positivism to organize the “how” to conduct the research on sub-Saharan Africa natural gas market. But because of the dominance of government in the market activities in this type of industry, a dose of interpretivism is necessary to support and or clarify quantitative findings. Consequently, this study has to acquire the pluralistic dualism comprising ontological objectivism and epistemological positivism augmented by normative interpretive epistemology.

The epistemological stance in this study therefore comprises positivism which is conducted and reported in chapter four of the study augmented by normative interpretivism in chapter five.

3.8 Axiology and Rhetoric

It is important to stress that value and language are part of the research methodological components. Axiology is the study of value, seeking to find whether research can be free of value. Scientific approaches like the epistemological empiricism demand that research must be free of value in a manner that the researcher be neutral and objective. The contrast is the interpretivists' approach that argues that biasness of researchers should be expected and tolerated.

Rhetoric is the art of discourse aiming to improve the ability of writers to effectively communicate. Hussey and Hussey (1997) present a quantitative and qualitative dimension of it describing it as formal and informal acceptable quantitative and qualitative words.

The value-free and unbiased axiology and formal use of accepted quantitative words are the choices for this research.

3.9 Pragmatism - Philosophical Underpinning of this research.

The overview of the various ontological and epistemological positions was to derive the philosophical underpinnings of this dissertation and suitable methodology and methods, for conducting the research on modelling natural gas market for sub-Saharan Africa Region using investment and regulatory approaches. For a long time now, economist have remained on the plinth of positive epistemology and objective ontology, rejecting multi-paradigms approaches in conducting economic research like this PhD work. This is quite understandable as most of the constituent economic entities are quantitative in nature and therefore inclined towards the need for a scientific approach. This is not to say that interpretive and constructionism have not been considered in economic research. Hausman (1999), Bhaskar (1978) and Lawson (1999) show that debate centred on ontology by world's leading critics of economic belief has been on-going, bringing scholars to present their various thoughts on ontology of economics. In this evolving opposing argument on paradigm views, this researcher takes a neutral stand, subjecting the research work to the context of the analysed ontological and epistemological positions above to allow the developed questions and hypotheses dictate its philosophical underpinnings.

The pluralistic nature of the philosophical stances discovered for this research work has decidedly created its philosophical underpinning known as pragmatism, which Johnson and Onwuegbuzie (2004) uphold then as the new research paradigm. The works of subsequent scholars like Johnson, and Christensen (2010), Blaike (2010), Terell (2012), Morse & Niehaus (2009), Morgan (2013) and Scott and Briggs (2009) are literally on the tenets of pluralistic paradigms where, convincing arguments have been derived for the dualistic philosophy underpinning the new research frontier.

Pragmatism as a philosophy is not as recent as Johnson and Onwuegbuzie (2004) portend, but dates back to 1870 in the United States with the notable classical pragmatists including Charles Sanders Peirce (1839 – 1914), William James (1842 – 1910) and John Dewey (18 – 1952). As the research journey continued along ages, pragmatism as a philosophy somewhere lost steam. But since its reawakening, noticeable in the 90s, it has been applied as a philosophical and research methodology in all fields including medical informatics with the works of Scot and Briggs (2009). To Morgan (2013), the founding fathers of this philosophy had already set the pivotal underpinning of pragmatism with James (1905 -1995)'s question of why doing research one way instead of doing it another way. A careful consideration of this probing question convinces one to agree with Morgan (2013) as it seems to create an awakening to consider optionality in research philosophies rather than a straight-jacket one-track purist position. Morgan (2013) also upholds the works of Johnson and Onwuegbuzie (2004), Johnson and Christensen, (2010), Blaike (2010), in asserting that the composition and attributes of pragmatism make it a stand-alone paradigm for social research. While Morse & Niehaus (2009) built on Johnson and Onwuegbuzie (2004) work on mixed method research by putting in perspective the range, magnitude, weight classification of the mixed method, Terrell (2012) emphasized on the steps and stages of conducting data collection process.

The major variable in this research work is the composite price of natural gas first in the global markets and then specific to sub-Sahara Africa Region. Therefore, the major component of the dualistic philosophy that led to the choice of pragmatism is the quantitative component. Utilising the postulates of the reviewed scholars especially the works of Johnson and Onwuegbuzie (2004), Terrell (2012) and Morse and Niehaus (2009), the philosophical underpinning of this research is pragmatism with high weight attached to ontological objectivism and epistemological positivism. Its structure consequently describes the methodology in the subsequent sections.

3.10 The Research Methods

In some studies, methodology is used interchangeably with methods. Methods are the tools of scientific investigation. They need to be distinguished from methodology as discussed above. According to Frankfurter (2007), methodology is the sphere of interest and methods by which we discover what is in the sphere. This research joins Frankfurter (2007) in preserving this distinction throughout the research work. From Hussey and Hussey (1997), a method can be defined as the several ways through which data is collected and analysed. This research has no argument against this definition of method but rather, embraces it. The approach however is mixed methods. These approaches are quantitative and qualitative considerations in line with philosophical underpinnings and the array of hypotheses established.

3.10.1 Quantitative/Qualitative Approaches

From references cited above, quantitative methods relate to empirical, positivist and objective system of enquiry using numeric data mostly associated with deductive approach. Qualitative techniques on the other hand is of the interpretivists' stance associated with inductive approach.

As mentioned before, quantitative techniques are the preferences of economic science's enquiry but going by the choices of ontological and epistemological stances above, this dissertation is disposed to the use of both methods. Recent discoveries like the work of Terrel (2012) are persuading many scientists to follow this direction of mixed methods because of the observed robustness of research outcome from mixed methods. The traditional mono-method is fast giving way to this dualistic approach. The argument now therefore is no longer about what methods to use but what weight to attach to a mixed method design. Terrell (2012) presents six types of mixed methods to be considered in answer to this question. This has made the task of choosing a mixed method easy for researchers to choose the preferred mixed method research design strategy fit for their studies. The author arranges these choices in sequence from data collection to analysis and presentation of results.

The six strategies outlines by Terrell (2012) are around the research focus and timing of data survey. Typical researches are either explaining events/phenomena/issues or exploring new ideas or transforming existing systems, beliefs, or ways of doing things as stated in the beginning of this chapter. Quantitative and qualitative data type collection according to Terrell (2012) could be sequential or concurrent. Combining these two issues brings out the six strategies namely: sequential explanatory mixed methods; sequential exploratory mixed methods; sequential transformative mixed methods; concurrent triangulation mixed methods; concurrent nested mixed methods and concurrent transformative mixed methods.

Morse and Niehaus (2009) added a new aspect to complete current mixed methods research designs. These authors provide eight types of mixed methods and explain their mixes and relevance of which the mainly quantitative supplemented by qualitative type is the only one analysed here. They denote this as “QUANT + qual” indicating quantitative component being the core (therefore it is in capital) and the qualitative is just supplementing the core. This method is therefore known as quantitative-driven mixed method design.

In clarifying concerns about the point of interface between the two methods, the two authors present the diagram below which allows the scientist to choose the point at which it is convenient, appropriate and mandatory to interface the two selected methods.

Figure 7 - Anatomy of Mixed-Method Design

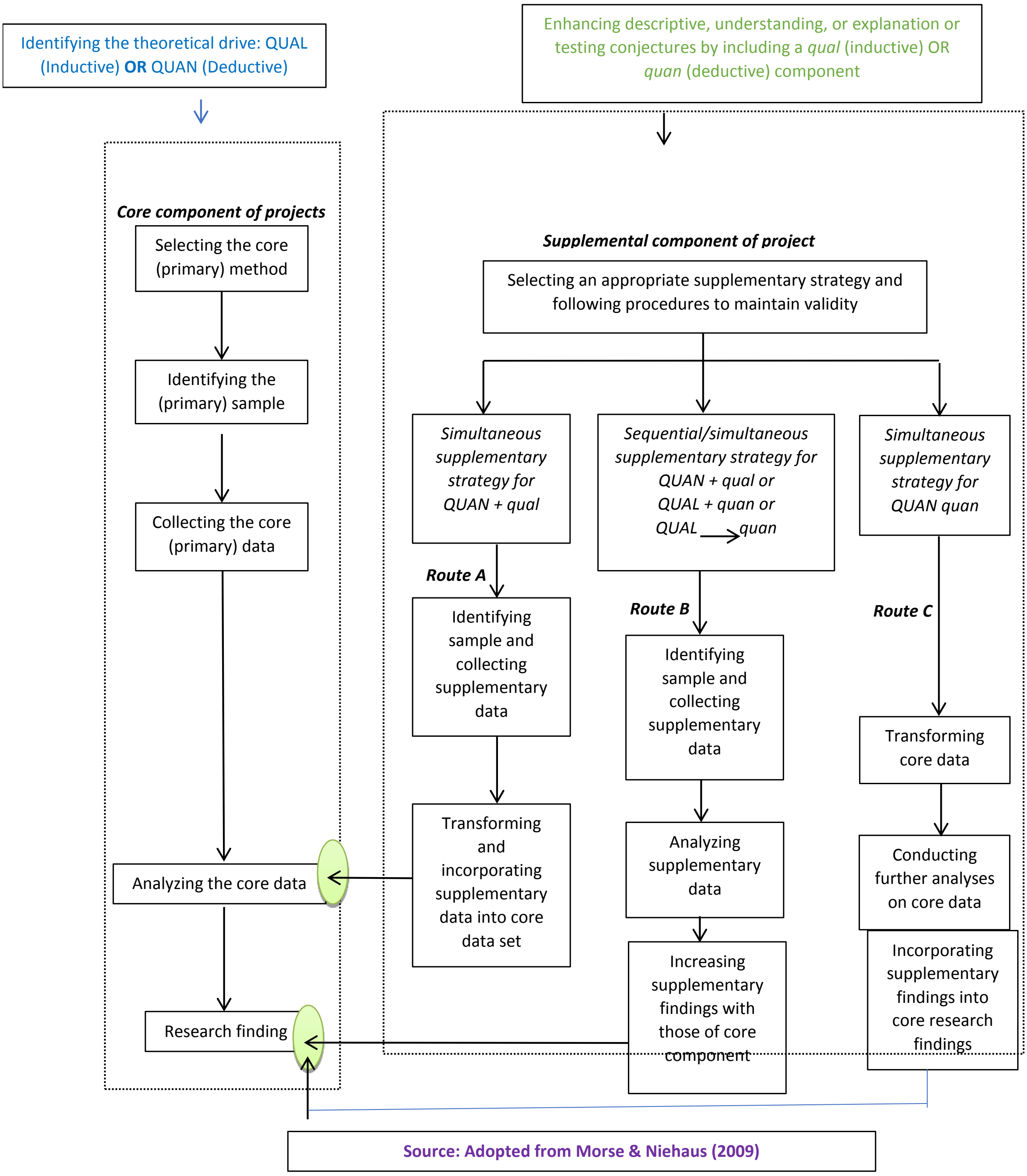


Figure 7 above indicates two points of interface in the two methods. These are the supplementary data analysis stage and the stage of research findings from the core method. In choosing the first stage (*Route A*) the scientist will have to transform the qualitative data to quantitative and incorporate the transformed data into the main set of quantitative data. The second choice (*Route* B) is integrating the supplementary qualitative findings with those of the core quantitative component. The route "C" is one of the eight types of designs flagged up here because it is usually the preference of economic studies.

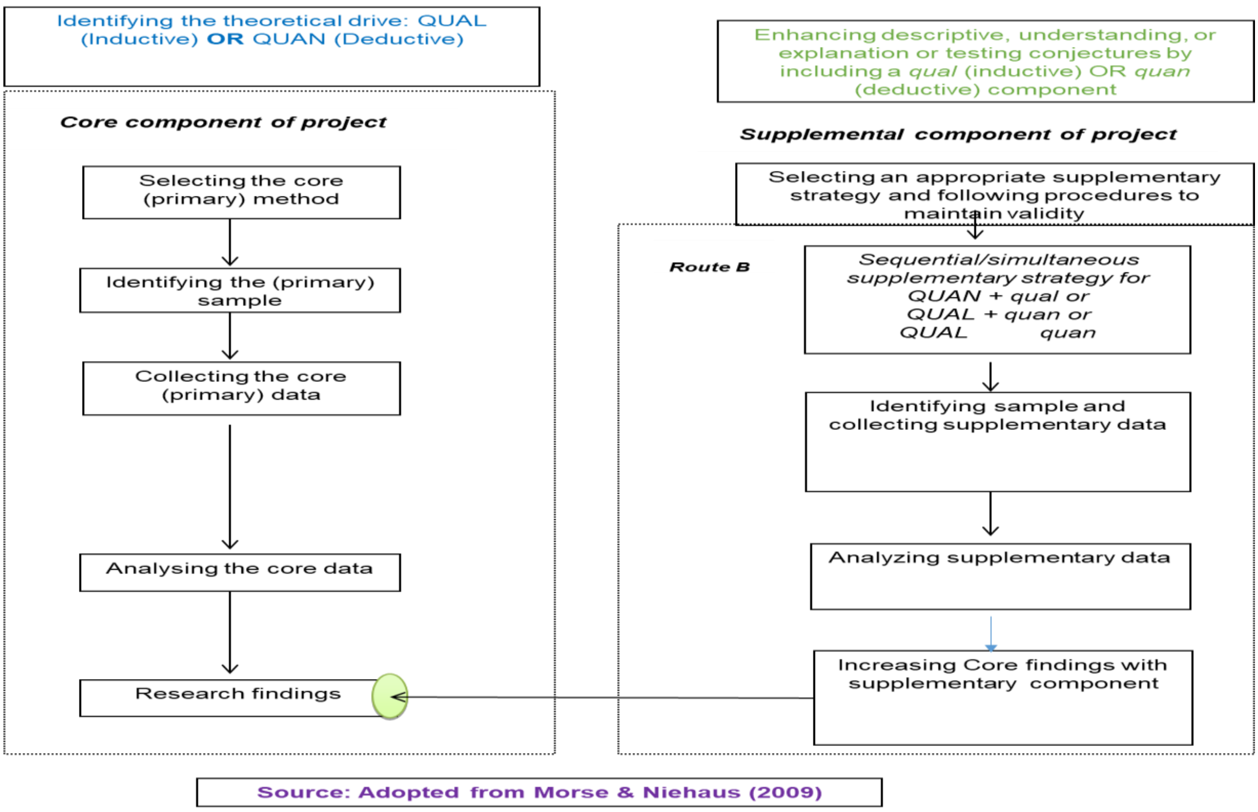
3.10.2 Selection of the Research Approach

The foundational research questions derived from literature review in this research are quantitative-related by order of significance to the project and foundational in the sense of satisfying the *"beta"* requirement which was discovered in literature and current global market practice as the all-embracing and all-engaging criterion for investment decision. This has led to the choice of ontological objectivism and epistemological positivism as the main philosophical underpinnings of the research. The rest of the questions in the literature review are qualitative by nature. This was from the review of regulatory economics and supply-side economics solutions. It is therefore incumbent on this research to also use qualitative means of the epistemological interpretivist to conduct the research. This research therefore is mainly quantitative with complementary qualitative techniques of the QUANT+qual type of Morse and Niehaus (2009). In terms of survey design, Terrell (2012) concurrent transformative strategy amended by interfacing the two strategies at the point of research findings is selected for this study.

This research therefore adopts QUAN+qual mixed method design structure of Morse and Niehaus (2009) route "B". In a summarized statement the research on sub-Saharan Africa gas market is a QUANT+qual mixed method and concurrent transformative strategy (QqCTS) as in Route “B” of the mixed anatomy presented above.

Therefore, the quantitative and qualitative data collection phases will be concurrent, while analysis of the two will be separate, each done on its defined domain. The two results will then be integrated at the sum-total of research findings from both strategies. It is to be noted that this research avoids Route “A” because of transformation techniques of the qualitative data that requires some specialized skills. The anatomy of QqCTS is as the figure below.

Figure 8 - Selected Research Methodological Route



The rest of this research work follows this derived template, starting with the quantitative approach at the left-hand side which begins with method selection and runs through data identification to collection and analysis with its findings presented in chapter four. In the right-hand side is the supplementary component which concurrently follows the same process with the quantitative but in this case, its results of findings are reported in chapter five. In line with the scientific requirement in the chosen route “B” QUNAT+qual system, the results of the two approaches would be distilled and reported in chapter six to see the model that eventual emerges for the sub-Sahara African Natural Gas Market from investment and regulatory approaches.

3.11 Selection of Tools for the Study

In line with the two mixed-method procedures selected for this study, the tools for the analysis of the project are four carefully and systematically chosen approaches comprising three quantitative techniques and one qualitative device. The three quantitative techniques are designed to answer questions raised chapter one to fill quantitative related gaps discovered in the relevant literature and test hypotheses raised. The qualitative device is to supplement quantitative findings.

3.11.1 Quantitative Methods

This research is considering the use of three quantitative tools. This includes high level time series econometric tools, simple profitability determinant mathematical tools and elasticities for cost and price comparison.

3.11.2 Derivation of Times Series Econometric Tools

Literature reviewed underscores the enormous influence of price on key market dynamics and in every area the research considers. Therefore, the main work of the research is in testing the hypotheses on returns by estimating its relationship with its past to derive values that will help in producing a reliable forecast value of the price for investment consideration. It is all about generating a beta reliable for business decision. Investors will need to know the future outlook of the beta of doing business in sub-Sahara Africa and what their intended investment portends. In extant literature, there is a good number of works on estimation of energy price and forecast of the behaviour and nature of the fundamental variables driving prices, using various econometric models. A large number of authors like Nayaran and Narayan (2007) are noted for successful use of time series in similar research works that produce reliable results. In economic-wide market studies relevant variables applied are price of a commodity – in our case, gas; prices of substitute fuels (crude oil and coal specifically) and Per Capita Income. The general inflation level and money inflation; interest rate fluctuation and population growth are also variables that could affect the dynamics of a market structure and its function for a general market study. For the natural gas market model this project attempts, not all the variables would be taken as it is a specific market study in a microeconomic sense. In the microeconomic studies, price is so significant and overarching that economic scholars like Friedman (1976) use the terms interchangeably. In order not to prejudice the eventual outcome of the research by ignoring the effects of other variables tangential to market behaviour, such variables if ever and wherever they manifest will be exogenized and their exogeneity impact tested using specific quantitative techniques such as dummies. In any case, they may be assumed to be a sum of a constant according to the eventualities of initial results. However, this study is exclusive on the price of natural gas from the quantitative view point using its past price values as explainable variables. Taking advantage of the enormous literature available on a more closely related commodity – crude price - this study can afford a choice of the top of the range of suitable methods to choose its quantitative tools of investigation. These include the methods of Hartley, Medlock III and Rosthal (2008), DeVany and Walls (1993 and 1999), Siliverstovs et al. (2005), Apostolos and Rangel-Ruiz (2004), Jose and Joutz (2006) and Brown and Yucel (2007). This group of authors investigate the relationship of price of gas and other prime energy carriers and products like electricity in different markets at different periods using a variety of methods.

The interest of Hartley et al (2008) is in the relationship between natural gas and oil prices and the factors that cause short run departures from long run equilibrium relationship. This project also shares the same aspiration for both the short and long run equilibria of the market. The relationship between the prices of gas and oil is also of importance to this dissertation because of the way it affects gas suppliers by influencing their incentives to invest. To demonstrate the existence of a long run co-integrating relationship between residual fuel oil prices, natural gas price and technology change in electricity generation, Hartley et al (2008) used vector error correction methods, with focus on Western Texas Intermediaries for crude oil and Henry-Hub for gas prices respectively. They analyse large size and high frequency data spanning over a period of fifteen years on monthly basis. With the application of vector error correction model, the authors discovered shocks that caused departure from the co-integrating relationship. Using distillates rather than the gross crude they assert that the relationship between gas price and crude is indirect. Using petroleum products, rather than crude price in finding the relationship between crude price and gas price in sub-Saharan Africa is a sound logic. However, using vector error correction model as in Hartley et al may not generate the desired result of capturing shock persistence and memory loss moments. Hartley et al (2008) is not alone in the examination of the co-integration of various energy prices to draw lessons from. Serletis and Herbert (1999) test for the existence of co-integration in the prices of natural gas and residual fuel using daily frequency data in a systemic equation which suggests a weak exogeneity of fuel oil. Jose' and Joutz (2006) look at decoupling of the prices of natural gas and crude oil. Their findings contradict that of the evidence of Hartley in the later years, in that Jose' and Joutz discovered a co-integration relationship among the two commodities. This is not surprising as they use crude price directly rather than the petroleum products as in Hartley et al (2008). Brown and Yucel (2007) using the same error correction model as the aforementioned authors supported Jose' and Joutz, finding a co-integration between the two, over the long period used which spans from 1994 to 2006. As highlighted in the literature review chapter, the use of some of the explainable variables such as storage levels, weather, hurricanes tagged "market fundamentals" by some of these authors and used by all authors as exogenous, would not apply in a sub-Saharan Africa market setting. Logically, the scarce gas situation which this project is set to address will have no spare gas to store. Storage therefore is not a variable useful in any of the equations in use. Weather condition is obviously not a concern of the region. The application of Johansen co-integration to determine the existence of co-integration between price of oil, price of gas and price of electricity by Hassan and Nassar (2013) produces better results than the vector error correction method. Therefore, it is persuasive to this PhD project, to use the same tool in estimating the relation between sub-Sahara Africa gas price, petroleum products and electricity if the need arises.

The application of different tools by these authors and the fact that all used WTI and Henry-hub trading portals create a departure with this project which uses reference prices of Bonny light of Nigeria, Angolan Girassol and by default, the Henry Hub as benchmark. With the use of different crude prices, different focus area and different objective, the quantitative instruments for modelling a gas market for sub-Saharan Africa are different with those used in the works of these authors reviewed. What this research requires are models that are capable of capturing long memory and volatility asymmetry and persistence and that would exhibit greater forecasting accuracy required for energy price forecasts. The models most also be able to identify structural breaks in order to factor in the impact of economic dislocations, during market modelling. Full disclosure of the parameters affecting the behaviour of gas price in sub-Saharan Africa is what is required.

This PhD project therefore turns to other literature in search of relevant sophisticated econometric models to use in answering the research questions identified in literature as those examined above are not adequate for a project like this. Those that readily come close to the need of this project are the research papers of Narayan and Narayan (2007), Kang et al (2009), Nick and Thoenes (2014), Arouri et al (2012) and Salisu and Fasanya (2013).

The summary of findings from many of these literatures demonstrate that GARCH-class models are known to be suitable in capturing long memory and volatility asymmetry with good forecasting accuracy of time series such as energy price, foreign exchange, interest rate, stock prices, etc. Kang et al (2009) combine many of the GARCH-class models in their search for an effective volatility model for Brent, Dubai and WTI crude markets. Their result is that CGARCH and FGARCH members of GARCH-class are able to capture volatility persistence. In Narayan and Narayan (2007) having found evidence of heteroskedasticity in time series data of oil price from 1991 – 2006 used EGARCH to remedy the presence of the heteroskedasticity. Nick and Thoenes (2014) ask the question – what drive natural gas and use a structural VAR approach to answer their question. Other works that hold some level of substance related to this project include Awartani and Corradi (2005), Sadorsky (2006) and Hayat and Narayan (2010). Awartani and Corradi (2005) perform a pair-wise comparison of various models against the GARCH (1,1) model with emphasis on the predictive content of the asymmetric component and find out that the GARCH (1,1) is inferior to asymmetric GARCH. Sadorsky (2006) uses a five-year rolling window in modelling crude oil volatility. The finding was that non-parametric models were better than parametric models. In Hayat and Narayan (2010), the use of exponential smoothening time series referred to as additive error was employed. They discover that supply and demand fundamentals explain nearly 70% of the US variation in oil shock.

Further examination discovers that the works of Arouri, et al (2012) and Salisu and Fasanya (2013) relate to this project. What persuades this research to join these two set of authors in terms of applied tools is the ability of their model to capture distant past influences on price behaviour. As their methods identify variables affecting prices to an extent, measure volatility, provide full information and generate a good forecast of the future trends of crude prices in their chosen markets, it is likely to also provide a result not less than these studies when applied to the sub-Sahara African natural gas market. Understanding gas price behaviour is a valuable information to a prospective investor's schemes of business ventures anytime particularly in the context of volatile and uncertain markets. In addition, there is the risk of business the prospective investor needs to deal with. A measure of price volatility that will disclose and provide full information with high predictive power of its future direction is what this research work is looking for and it is what Arouri et al (2012) and Salisu and Fasanya (2013) have attempted. They two works were compared and Arouri et al (2012) was selected to model the sub-Sahara hypothetical natural gas market. The superiority of Arouri et al over Salisu and Fasanya are bench-marking the GARCH (1,1), application of long memory which by estimation is easier to measure from observed decay period than the complicated mean reverting estimation of Salisu and Fasanya (2013)

Using Bollerslev's (1986) Generalized Autoregressive Conditional Heteroscedasticity GACH (p, q) as bench-mark, the chosen model of Arouri et al (2012) was considered to suit this project. This resulted to the choice of Exponential General Autoregressive Conditional Heteroskedastic (EGARCH) model for the price forecast of sub-Saharan Africa Natural Gas Market.

The first step in this task of modelling sub-Sahara Africa gas market like in conventional econometric models, is to run diagnostics. This initial stage depicts the homoscedasticity or otherwise and gives the basis and justification to consider the need for GARCH models or not. It then follows that if and only if the null hypothesis is rejected through a test for ARCH and by extension GARCH effects on the gas returns, that the process of estimation and forecasting conditional series for the returns on investment and the risk will then be undertaken using the Nelson (1991).

The model for this research work therefore starts with the implicit introduction of independent variable to help in predicting the volatility of the returns as in Enders (2010). It utilises Engle (1982) as base-case or basic exercise for modelling time series. Engle (1982) suggests the use of regression techniques to obtain the squared estimates of the residuals and sets the squared residual as the term of interest, condition on the past values of the series as:

$$\hat{e}_t^2 = a_0 + a_1\hat{e}_{t-1}^2 + a_2\hat{e}_{t-2}^2 + \cdots + a_g\hat{e}_{t-g}^2$$

Equation 1

Which implies that the conditional variance of the gas returns e_t^2 is dependent on the realised values of $\hat{e}_{t-1}^2$. The relevance of this model is the ability of the conditional forecast to take into account both the known current and past realized values of the returns.

In this model, if the sum values of $\hat{e}_{t-1}^2 \ldots . \hat{e}_{t-g}^2 = 0$

that is if $\sum_{t=1}^{g} \hat{e}_{t-1}^2 = 0$, then there is no ARCH effect even if in depth statistical graphs prove otherwise.

However, in the event that $\sum_{t=1}^{g} \hat{e}_{t-1}^2 \neq 0$, the ARCH process will be deployed using a higher order of Bolerslev (1986):

$$h_t = a_0 + \sum_{i=1}^{q} \alpha_i \hat{e}_{i-1}^2 + \sum_{i=1}^{p} \beta_i h_{t-i}$$

Equation 2

Where h_t is the conditional variance of e_t^2

Bolerslev (1986) is an improvement of Engle (1982) in that it adds a moving average component as in Enders (2010). This is to say that Bolerslev (1986) GARCH model adds a Moving Average to the Autoregressive process in the conditional variance of the error terms sequence.

However, the peculiarity of the oil & gas industry and the scale of this research work which comprises five fundamentals of market variables - investment issues, regulations, effective demand, prices of natural gas and prices of other competing energy commodities - indicate that Engle (1982) and Bolerslev (1986) in equations 1 and 2 need to be re-examined to contend with the demand of forecasting accuracy of market behaviours where sub-Sahara Africa natural gas trades in. This is because of the restriction of some parameters in the two models.

For one, the efficacy of Engle (1982) proposed multiplicative conditional heteroskedastic:

$$e_t = v_t \sqrt{a_{0\,+}} a_1 e_{t-1}^2$$

Equation 3

is based on the circumstances that

$a_0 > 0$ and $0 \leq a_1 \leq 1$

Also, in Bolerslev (1986) model in 2 above,

α_0, α_1 *and* β_i must be positive.

The investors in the oil and gas industry of sub-Sahara Africa region are forward-looking, that is they are only interested in the risk and return on investment over the economic life of the well. Their interest therefore will be in a model that will compute the relationship between the conditional variance of the price series and risk of investment premia to achieve certainty-equivalent like the Von Neumann-Morgensten in the future entire economic life of the asset.

The asset returns model therefore is:

$$R_t = a + bR_{t-1} + c\partial_t^2 + \theta_t$$

Equation 4

Where parameters a, b and c are restricted. They are likely to generate a regression that will have little predictive power.

This is why this research turns to Nelson (1991) with this model:

$$ln(\delta_t^2) = \gamma_t + \sum_{n=1}^{\infty} \beta_n \vartheta(\varphi_t - n)$$

Equation 5

Just like in Nelson (1991), in this project the term $\vartheta(\varphi_t)$ is chosen to be a function of both size and magnitude of the error term so as to address the restrictive imposition of other GARCH family that necessitated the establishment of EGARCH by Nelson (1991). Also, $\vartheta(\varphi_t)$ is defined to allow the conditional variance procedure (δ_t^2) as follows:

$$\vartheta(\varphi_t) \, \Xi \, \lambda\varphi_t \; + \; \omega[\mathrm{I}\varphi_t\mathrm{I} \; - \; \mathrm{EI}\varphi_t I]$$

Equation 6

Where the term ω [Iφ_tI - $\mathrm{EI}\varphi_t I$] represents the effect of magnitude which allows returns to swing positive or negative following the size of φ_t.

3.11.3 Other Quantitative Tools

Research questions numbers 13 to 15 are not subjected to hypotheses testing as they do not qualify for econometrics rigour. Again, simple mathematical techniques as in the following suffice in answering the research questions. Therefore, in other to answer question number 13, *Is there any prospect in investing in sub-Sahara Africa gas market in terms of operational profit?* the LaGrange Multiplier is utilised as follows:

Modified Lagrange Multiplier:

$$\mathrm{V} = \mathrm{pQ} - (\mathrm{wL} + \mathrm{rK}) + \lambda[\mathrm{f}(\mathrm{K}, \mathrm{L}) - \mathrm{Q}]$$

Equation 7

Where:

V is the targeted optimal value in combining factors of production.

P and Q are prices and quantities respectively

I and *K* are labour and capital inputs with wage (w) and price of capital (r) as the price of labour parameters

It takes total revenue represent by P(price) times Q(quantity), deduct factor inputs to fine optimal profitability and minimal cost in line with theory of the firm examined in the literature review.

Research questions numbers 14 and 15 utilizes various elasticity measures. These quantitative questions which asked *are Is there an effective demand for* *natural gas in sub-Sahara Africa? (14) What is the relationship of natural gas price and other energy commodities in the sub-Saharan Africa energy commodity basket? (15)* . These two questions are not subjected to hypotheses testing on the basis that elasticity computation is able to generate answers.

The relevant elasticities are found in microeconomics firm theory as follows:

Price elasticity – $\ell\mathrm{p} = \mathrm{P/Q \; x \; \Delta Q/P}$

Equation 8

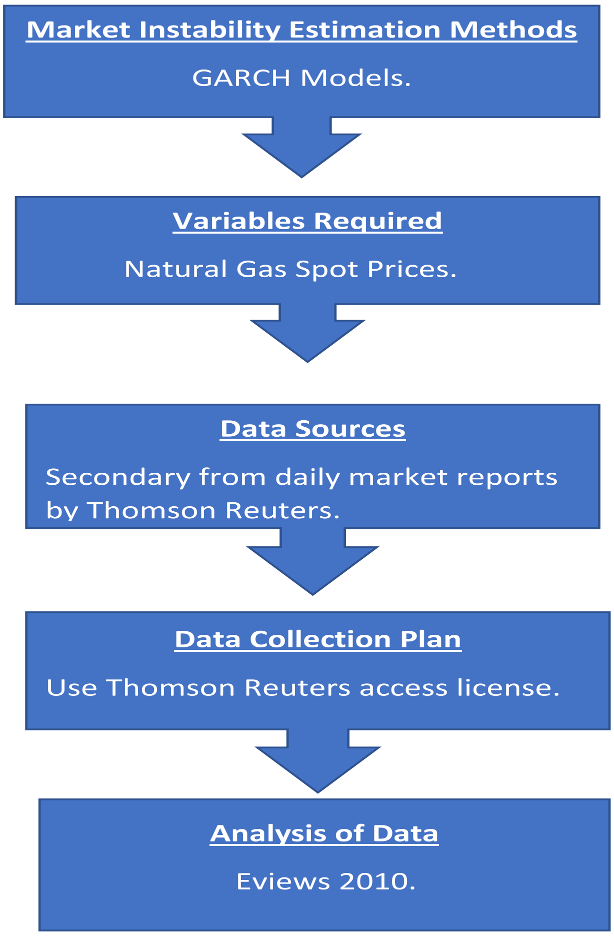
Income elasticity - $\ell\mathrm{Yd} = \mathrm{Yd/Q \; x \; \Delta Q/Yd}$

Equation 9

Elasticity of substitutes – cross elasticity

These are the price elasticity from consumption side of natural gas in the market, disposable income elasticity to assess the wealth and capacity to pay a range of gas prices that the model may bring out and elasticity of substitutes mainly petroleum products.

Figure 9 - Schematic Flow of Conducting the Quantitative Research



Price is the driver of this research. Rightly so because of its centrality in the entire business of natural gas. Price dictates every step, strategy, and action and inaction in the investment consideration. This is why a thorough and expanded literature review on price modelling is carried on in this research and a substantial justification also attempted in arriving at the choice of GARCH models. In the flow chart above, global natural gas prices and domestic gas prices are the target variables. Global natural gas market is divided into four dominant markets comprising the United States/Americas – Henry Hub; United Kingdom – National Balancing Point (NBP) and Continental Europe comprising –

TTF (Title Transfer Facility) and Zeebrugge[6]. The TTF is in Netherlands and Zeebrugge is in Belgium. Every other trade is bench-marked on these markets in line with the proximity of the trading zones. Data choices are of daily frequency and cash traded. The choice of cash traded is to follow price discovery process. a blurred forecast values. However, experience from Nigeria has shown that more than one natural gas price might be ruling in a single country's market. Therefore, part of gas price data will be gathered through primary contact with institutions that are custodians of gas price data for the region.

The need to gain market confidence by the prospective investor, requires the use of elasticities to identify existence of effective demand to support investment confidence. Therefore, the model is directed to income elasticity as a single variable with the functional form as:

$$n(x) = \frac{xf'(x)}{f(x)}$$

Equation 10

where f is the differentiable real valued function of income. Though this is a point elasticity, it is however sufficient in the sense that a point estimate is the only value required. The second elasticity is directed at other energy commodities that could replace gas. This is driven by the substitution function of multivariate to capture substitutes variables like petroleum liquids, electricity, biomass and any other derived close substitutes to gas during the survey. Its function is:

[6] These are found in Thompson Reuters Eikon for Natural Gas spot trade. The trade portal are only available for license holders.

$$\frac{f1(x1,xn)}{fn(x1,xn)} = \frac{x2-kf1(\frac{x1}{xn},1)}{x2k-1fn(\frac{x1}{xn,1})}$$

Equation 11

where *n,* represents numbers of the substitutes to any number beyond 1.

This is suitable as it measures the marginal rate of change in substituting natural gas use for any of the energy product in response to price change.

These variables of the elasticity model are hosted with the African Union under the Division of Africa Energy Council which keeps energy data Bank for the whole of Africa. Access to these data can only be reached by a physical visit to the organization in Ethiopia.

The strategy of using the LaGrange formula is to find the local maxima and/or minima of the objective function of a prospective gas-well subject to its equality constraints. The objective function in this research therefore is a function that will get the maximum profit in every gas well conceived given as $\Pi = TR - TC – pQ – (wL + rk)$ within the constraints of a maximum volume of gas that is expected to be derived from the well in consideration. The maximum volume of gas expected is denoted as Q. the identities in the equation are the factors of production, capital and labour. Profit has been highlighted by reviewed literature to be the main objective of prospective investors in gas business. To attain this objective, a necessary condition set as equality between real cost of capital and marginal productivity of capita must be obtained. According to Renshaw (2012), the LaGrange formula is more suitable for optimization situation like this project than any other, such as direct substitution.

The parameters ***w*** and ***r*** are cost of labour and cost of capital. Although looking so simple, but when unbundled, capital constitutes the whole range of equipment, finances, technology and specialized skills that the investors put in to create a gas production well. The labour input has no hard rule on what qualifies it.

In the elasticity domain, elasticities values would then be compared with this (x) value derived to test capacity to pay the eventual gas price.

The following mapping shows the interlinkages between the theories that decide the questions raised and hypotheses generated, linking these to the data required and the use of the models.

Table 2- Quantitative Mapping

Theoretical Basis	Questions Derived from Literature	Hypotheses
Price Theory	What is the nature of shocks in the market where sub-Sahara Africa natural gas trades? That is to say, what drives natural gas prices?	There are no symmetries in the returns of the prices in the four global natural gas markets in which sub-Sahara Africa gas trades in. That is, their joint null hypotheses is: $\Psi_1 = \Psi_2 = \Psi_3 = \Psi_4 = 0$.
Market Theory	Would natural gas from sub-Sahara Africa follow a pattern in terms of volatility if traded in markets other than current markets? It is the same as asking if volatility will be the same in a hypothetical sub-Sahara natural gas market with different general conditions.	Regional market conditions do not alter fundamental drivers of volatility.
Investment Theory	Could the returns of natural gas in these markets which incorporate gas from sub-Sahara Africa generate the right news signals for investors to take decision in terms of leverage, just as in crude oil markets?	There is no leverage effect in the returns of the gas price series in these markets
Market Theory	In the event of market instability, how long do shock last?	There is no shock persistence in any of the market. That is, shocks in the market if they ever occur, are transient.
Investment Theory	What effect do shocks have on natural gas returns in markets where sub-Sahara Africa natural gas trades?	Shocks in natural gas prices of these markets have no effect.

Source: Constructed and presented by Author

3.11.4 Qualitative Methods

Critical information required to answer the remaining questions raised in literature are contained on textual mode only, and not numeric. For instance, information regarding factors that could attract investors' interest other than profitability and risk perception come only in textual form. This project also needs information on how investors in the extractive industry adjust their Rate of Return and how willing will either government or the investor accept the other party's position regarding rent sharing. The reader will agree with this researcher that these are not quantifiable information. Therefore, the data generating process would have to be by field survey on the primary source and their analysis, interpretive. As explained in the methodology table in the preceding sections of this chapter, information on each question will be interpreted and the result integrated into findings of the quantitative analyses to support an established quantitative result or form a standalone new knowledge position. Where focus group discussion will be required, the procedure will be recorded using permissible recorders in line with research etiquettes. The result would then be transmitted into textual content to be analysed just in the way textual analyses are carried from the survey questionnaires.

As in the quantitative method above, the conduct of this qualitative research is mapped out linking theories that generated questions with the data needs and techniques to be used as in the table below.

Table 3- Qualitative Mapping

Theoretical Basis	Questions Derived from Literature	Investigation	Techniques.	Data Type/Approach
Firm Theory	What factors will investors be looking for to attract them to invest in a terrain like the sub-Sahara Africa natural gas market apart from profit motivation?	An inquiry is made to obtain exact information from the primary source to generate answers to the question.	Interpretive. This is by exploring information obtained to understand factors motivating investment rather than profits.	Qualitative information. Through focus group discussion with key industry participants (BP, Shell) who have long business history and investment appetite in sub-Sahara African region
Supply-side economic theory	What are the critical success factors of creating a gas well that the investor will want to see in the sub-Sahara Africa gas market as elsewhere?	Other factors of interest are regulatory, policies and relationship with host communities. An inquiry needs to be made on all of the factors in investment decision	Interpretive. Information obtained from field survey would be analysed to deduce answers.	Qualitative information. Both government and industry practitioners need to be approached through focus group discussion.
Theory of Investment	Are the perception of gas business risk in sub-Sahara Africa by prospective investors larger than reality on the ground?	Perceptions on risk factors need to be derived to compare with estimated beta of risk of new investment.	This is a comparative analysis. It compares narratives of information gathered from source with estimated betas of risk generated from quantitative methods.	Focus groups discussion with government and selected key industry participants.
Theory of Investment	Do these risks have specific features rather than normal business risks found in literature?	Opinions of global industry practitioners regarding investment risk in sub-Sahara and the understanding of the potential constraint of these risk by government need to be investigated.	Interpretive. Qualitative information gathered from survey will be analysed to find answers	Focus group discussion with industry practitioners.
	How could they be addressed to attract investment?	Answers should come from prospective investors	Narrative.	Focus group discussion with industry practitioners.
Theory of Investment	How do investors adjust their Rate of Return in new investment to capture perceived or estimated risk?	Investigating the power of risk factor in investment decision	Narrative. To support or disproof assumptions made regarding investment behaviour. It is also to clarify some quantitative findings	Focus group discussion. As the extractive industry is based on secrecy, it is only by face-to-face focus group discussion might be answered
Regulatory Economics	How willing is government ready to accept the position of prospective investors and vice versa	This is investigating what could be considered as a fair engagement on the issue of rent sharing	Interpretive. Qualitative information gathered from survey will be analysed to find answers	Focus group discussion with industry practitioners and host governments.

Source: Constructed and presented by Author

Table 4: Mapping for last three research questions

Theoretical Basis	Questions Derived from Literature	Tools for Answering the Question
Investment Theory	Is there any prospect in investing in sub-Sahara Africa gas market in terms of operational profit?	Apply break-even simple mathematics using conservative market practice data
Price Theory	Is there an effective demand for natural gas in sub-Sahara Africa?	In the absence of sufficient information from focus group survey, use world bank data.
Price Theory	What is the relationship of natural gas price and other energy commodities in the sub-Saharan Africa energy commodity basket?	Use comparative analysis

Source: Constructed and presented by Author

The main conduct of the quality filed work is by focus group discussion on the key industry institutions in the region. To make an assurance double-sure, there are focus group discussions with at least three captains of the industry in the domain of sub-Sahara Africa. However, to overcome deficiency noted in literature especially in the works of Berik (1997), Bewley (2002) and Dow (2007) regarding reliability, accuracy, predictive power and credibility, this project identifies respondents that are established global institutions and captains of industries whose experience and deposited knowledge cannot be faulted.

The third mapping in Table 4 part of the questions without answers in literature. Answers to questions raised and eventual decision on hypotheses raised will provide the critical inputs to model Natural Gas Market for sub-Sahara African Region.

3.12 Sources of Data and scope

This project targets secondary data from desk-top survey for its quantitative methods from top four market participants including Thompson Reuters, Argus Media and Platts for gas prices. World Bank and IMF data bank will provide rich statistics on the disposable income from the region for the elasticities measurements. International Energy Agency (IEA) is another renowned world global energy agency with faultless data covering the global energy scene. Yearly and by rotation, IEA undertakes focused studies on continents of interest and updates findings periodically. The African energy focus was done on 2014. This research depends on this institution for provision of statics on other energy commodities such as electricity, petroleum products, biomass, and the commodity in consideration – Natural Gas. But for the domestic prices of these commodities, the African Energy Council under the African Union in Addis Ababa hosts the African energy data.

For the qualitative data, target sources include the African Energy Council in Ethiopia. This is the organization that represents the whole of Africa on energy matters. It centralises data, innovations, and strategy for Africa under the African

Union. This is an important institution as it could provide a spread of statistics for robust analysis.

The West African Gas Pipeline and Nigeria Gas Company are also target sources of the qualitative information. These are two established sub-Saharan African gas entities with depositary of useful information on the market dynamics, government participation and investment statistics.

These are in addition to desk-top survey, Thomson Reuters, Argus Media and Platts are organizations with depository of information on the practice of the industry. They will be useful to this study.

3.13 Summary

Questions and gaps emanating from literature review provide justifications to proceed with a research on the sub-Sahara Africa Natural Gas Market in line with the research objectives. The review suggests the areas on which the research should focus on. Therefore, a methodological architecture needed to be constructed and tools developed to carry on the research on established philosophical underpinning. This is the essence of this chapter.

Results show that the general paradigm of inquiry is dualistic dictating reliance on pragmaticism as the philosophical underpinning of the research. Therefore, the exercise is split into two parts comprising quantitative and qualitative approaches. It therefore calls for setting hypotheses on the quantitative and gathering numerical data to conduct the quantitative inquiry as well as collecting textual information for the qualitative part based on derived methods. These methods include the GARCH models for time series of natural gas prices in markets where, sub-Sahara Africa natural gas trades in and field survey for the qualitative. Being a market-based study in a microeconomic sense, the weight of the research method tilted towards main quantitative with a supplementary qualitative method and the conducts of the two are concurrent. This is why the research is code-named QqCTS which is QUANT+qual mixed method and Concurrent Transformative Strategy with value-free and unbiased axiology and formal use of accepted quantitative words.

CHAPTER FOUR: PRESENTATION OF QUANTITATIVE RESULTS

4.1 Introduction

One of the results of the mixed method technique deployed to the study to answer the seven quantitative questions raised from gaps in literature is presented here.

As in all QUANT+qual mixed methods, these quantitative results are the dominant analyses of this project, and they utilize four dominant time series econometric models focusing exclusively on market unpredictability.

The reader will recall that the quantitative questions that emanated from literature relate primarily to market instability and risks to return on investment. According to Osmundsen et al (2015), the oil & gas majors such as Shell, Exxon-Mobil, BP, etc go to the negotiation table in areas of investment interest with a calculated beta (risk return) derived from the performance of their portfolio on the stock market at the time of investment consideration. Cameron and Stanley (2017) state that the derived beta is information managers of natural resources in sub-Sahara Africa are not entirely aware of. They assert that this information regarding the behaviour of markets in which sub-Sahara Africa natural gas trades in is crucial to every stakeholder especially resource managers. The central areas of the quantitative investigation therefore are those that are deem fit to generate the essential market information for policy and investment decision making. These include information regarding:

i. Asymmetry or otherwise between positive and negative shocks. That is, the leverage effect that enables investors and policy makers take informed market decision.
ii. The impact of the asymmetry on conditional variance of the returns.
iii. Shock persistence and Memory decay and mean reverting speed.
iv. Normal volatility pattern across markets.

The null hypotheses upon which the models are built derived in chapter three above are paraphrased as follows:

i. Shocks are not asymmetric.
ii. Regional market conditions do not alter fundamental drivers of volatility.
iii. There is no impact of shock on conditional variance of the returns.
iv. There is no shock persistence.
v. There is no leverage effect.

Vital market information seems to reside primarily in the price of natural gas itself and can only be estimated using the stated econometric tools. Tests for serial correlations and heteroscedasticities on the general null hypotheses that the two situations do not exist form the preliminary hypotheses in conformity with generally required diagnostic tests. These tests are conducted just after the descriptive statistics.

Because the models encountered series of adjustments, it is needful to provide the mathematical computations at every step including the most basic. These models are the GARCH class of models in chapter three.

The overall model selection process is on Akaike (1987), Hannan and Quinn (1979) and Schwarz (1978). Their mathematical derivations are revisited for articulate algorithm in view of their importance to the investigation. A derivation of break-even conventional gas price forms part of the quantitative procedure. This is to ascertain the profitability or otherwise of a proto-type gas-well investment in sub-Sahara Africa. The results are presented accordingly after a note on the data collected.

4.1.1 Data

The importance of data suggests that this report of findings starts with the explanation of the nature and sources of data set collected in order to show the accuracy of the data gathered for the project and to give confidence on the results obtained. One main defect affecting quantitative data's quality, apart from nonexperimental data generating process nature of social science is the practice of aggregation (Gujarati, 2004). It is the belief of this researcher that the use of reference price for natural gas or crude oil as is the practice of some authors may not allow depth of unearthing embedded factors affecting the behaviour of such price in the market. This is because, reference price is likely to overshadow some underlying factors. Bearing in mind that the results obtained can be good, only if the data is good, this research therefore attempts the following remedies:

i. Using natural gas actual daily trading spot prices at close of each business day captured by Thomson Reuters as they are traded in the markets under discussion.

ii. Picking the top four zonal natural gas markets in operation that dominate global gas trade presently. These markets incidentally are the markets that the sub-Sahara African natural gas trades in as its own market is not developed. Unlike crude oil which enjoys unified dynamics, gas is a constrained commodity differing from one region to other, set apart by weather; demographics; economic growth; fuel competition; market structure and level of development; currency in use; storage and export propensity. These differing dynamics necessitate disaggregating the global market into respective zones to gain full knowledge of its price.

iii. Uses the data in each market as they are with all its features unaltered such as currency use; metric of measurement and value in trade which is in line with econometric practice to avoid data mining.

Each market is analysed separately to derive much information contain in the series.

Use data from World Bank and International Energy Agency who are global reputable organisation in data collection

In this way, this researcher departs from the class of GARCH modelers such as Arouri et al (2012), Kang, Kang and Yoon (2009) Kanya et al (2012), Awartani, and Corradi (2005), Hassan (2013), Sadorsky (2006), Narayan and Narayan (200&), Salisu & Timi (2015) Beckers et al (2017) to mention a few, who use aggregated series in their analysis.

A demonstration of aggregation problem especially in the oil and gas industry is necessary here. OPEC basket price is a good example. Unbundling the OPEC basket reveals that it constitutes about fourteen reference prices of different market dynamics including Saharan Blend (Algeria), Girassol (Angola), Oriente (Ecuador), Zafiro (Equatorial Guinea), Rabi Light (Gabon), Iran Heavy (Islamic Republic of Iran), Basra Light (Iraq), Kuwait Export (Kuwait), Es Sider (Libya), Bonny Light (Nigeria), Qatar Marine (Qatar), Arab Light (Saudi Arabia), Murban (UAE) and Merey (Venezuela).   In the next layer of the onion are individual countries with reference prices that are, at this layer aggregated constituting different types of crudes in geological properties and market dynamics.

Taking the two sub-Sahara African countries in the basket together – Angola and Nigeria – they have about twenty-four different types of crude with differing properties in market dynamics, geological properties, production economics, trade destinations and practices compare to their price referenced Bonny light (Nigeria) and Girassol (Angola) Argus media (2015). Should a model of a market in OPEC for one referenced price alone be taken, one can imagine the information loss in using such a series.

Even though gas is not prone to the complexities of oil in terms of geology, refinery configurations, handling, storage and diversity of final products, this researcher still micro-specified each market on its unique zonal basis. These are Henry-Hub Americas), National Balancing Point (UK), Title Transfer Facility (Netherlands) and Zeebrugge (Belgium).

As there is no structured natural gas market in sub-Sahara Africa, it is imperative to use statistics of the markets in which the region's commodity trades in. The dynamics of these markets arguably affect the sub-Sahara African natural gas in many ways. An investor seeking for information regarding sub-Sahara African natural gas will rightly have to analyse these markets. The overarching point however is that modelling a market that is not yet there requires drawing lesson from others and in this case, the model is to draw lesson from the top-four well-established, matured and functional regional markets where it participates.

4.2 Results of Quantitative Analysis

The overall econometric framework was built on the functional relationship between the present gas price on 31st December 2017 with its past prices down to January 1st, 2010 at close of business each trading day. As such, the nature of the models assumes the Stochastic Recurrence Equations (SRE) which captures this functional relationship between the past prices and the present behaviour of time series.

The reader will recall the choice of Exponential General Autoregressive Conditional Heteroskedasticity (EGARCH) over competing Autoregressive Models during the methodology/methods selection stage. Although a slight justification was attempted during that selection stage, a more practical reason for the choice of EGARCH will emerge as the results of findings are presented. However, practice has mandated the submission of data of interest to test and establish, if the series exhibit, stylized facts of time series before assuming the use of any SRE. Consequently, the modelling procedure should start with assumption of workability of Gauss-Markov Least Square until proved otherwise by the presence of ARCH effect and establishment of the stylised facts of log-return data as in Straumann (2005). Accordingly, the presentation of the quantitative process begins with descriptive statistics.

4.2.1 Results from Descriptive Statistics

The first step of generating the statistical properties of gas prices of the selected markets is to compute their risk betas which are captured by the log returns. Consequently, the betas of Henry Hub (HHUBR); National Balancing Point

(NBPR); Title Transfer Facility (TTFR) and Zeebrugge Hub (ZEER) using the log returns formula for each series are as follows:

$$Rt = 100 * Log(\mathrm{Pt}/\mathrm{Pt}-1)$$

Equation 12

Where: $Rt1 \ldots\ldots \mathrm{N} = HHUBRt;\ NBPRt;\ TTFRt\ and\ ZEERt$

therefore, the betas are computed and presented along with the prices of the series as they were captured during the daily trading days at close of each business day as follows:

$HHUBR_t$ = 100*$Log(HHUB_t / HHUB_{t-1})$

$NBPR_t$ = 100*$Log\ (HHUB_t / HHUB_{t-1})$

$TTFR_t$ = 100*$Log(HHUB_t / HHUB_{t-1})$

$ZEER_t$ = 100*$Log\ (HHUB_t / HHUB_{t-1})$

Table 5 - Descriptive statistics

	Henry Hub		Net Balancing Point		Title Transfer Facility		ZEER	
	Returns	Price	Returns	Price	Returns	Price	Returns	Price
Mean	-0.00	3.46	-0.01	49.88	-0.01	20.61	-0.01	49.71
Median	0.06	3.47	0.05	50.80	0.07	21.23	0.00	50.05
Maximu	11.93	6.15	16.86	75.97	10.24	29.35	35.86	73.25
Minimu	-69.31	1.64	-18.23	26.42	-14.90	10.70	-33.48	26.00
Std. Dev.	3.09	0.84	2.33	12.06	1.87	4.66	2.33	11.98
Skewne	-5.86	0.16	-0.78	-0.05	-0.76	-0.29	-0.16	-0.11
Kurtosis	129.87	2.49	13.40	1.88	9.79	2.00	55.74	1.873
J-Bera	*1346.8	29.66	9188.4	103.7	4018.1	111.32	230798.7	109.58
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Obs	2086	2086	2086	2086	2086	2086	2086	2086

*Actual number is 1346759.0 reduced by ‘000 to provide space.

Source: computed and presented by the Author.

The spread between the log return and the series around their mean values indicates the size of volatility of natural gas in each of the markets under consideration as measured by their standard deviation. Equally, the riskiness of returns is measured by the same standard deviation of the dispersal between the real value of its mean on a fitted ordinary least square line using the regression estimator of the data:

$$\hat{y} = \hat{a}1 + \hat{g}1ǫ1 + \hat{u}$$

Equation 13

Equation 13 follows the term structure set in this project as in this table

Table 6 - Term Structure of Regression Line

Ŷ	=	â1 + ĝ1ǫ1	+	Û
Variation in price of gas from January 2010 to December 31st 2017. Ŷ	=	Systematic explained variation of known parameters plaining the behaviour gas prices	+	Random variation or unexplained variation of unknown parameters.

The estimates of â1 and ĝ1 are obtained as in Gujarati (2004):

$$\hat{a}1 = (\Sigma Ǫ2\Sigma Y - \Sigma Ǫ\Sigma ǪY)/n\,\Sigma Ǫ2 - (\Sigma Ǫ)2$$

Equation 14

$$\hat{g}1 = n(\Sigma ǪY) - \Sigma Ǫ\Sigma Y)/n\,\Sigma Ǫ2 - (\Sigma Ǫ)2$$

Equation 15

where *(n)* is our sample size 2073 observations, while ọ represents a factor explaining the behaviour of natural gas price of each market Y being the regressand or predictand of each price. û is unknown.

Equations 14 and 15 are is expanded in this research work to include other factors ranging from geopolitical factors that affect energy prices in the market and some yet to be identified, captured by û to form equation 16 as follows:

$$\hat{y} = \hat{a}1 + \hat{g}1ọ1 + \ldots\ldots + \hat{g}tọt + \hat{u}$$

Equation 16

where: $\hat{a}1 = \bar{Y} - \hat{g}1\bar{Q}1 - \hat{g}t\bar{Q}t$

$\hat{g}1 = (\Sigma ọ1yi)(\Sigma ọ_{ti}^{t}) - (\Sigma ọtiyi)(\Sigma ọ1ọti) / (\Sigma ọ_{1i}^{t})(\Sigma ọ_{ti}^{t}) - (\Sigma ọ1iọti)2$ $\hat{g}t = (\Sigma ọtyi)(\Sigma ọ_{1i}^{t}) - (\Sigma ọ1iyi)(\Sigma ọ1ọti) / (\Sigma ọ_{1i}^{t})(\Sigma ọ_{ti}^{t}) - (\Sigma ọ1iọti)2$

Note that the variables are expressed in deviation term from their means.

The descriptive statistics presented in Table 5 above provides evidence of significant variations in the natural gas prices of the four markets for the eight years covered. This is shown by the wide difference between the minimum and maximum values of the prices in all the markets. Henry Hub's price spread of US$4.51/mmbtu is more than its mean value of US$3.46/mmbtu. In the Net Balancing Point, its spread price of 49.55GBpence/Therm matches its mean value of 49.88 GBpence/Therm, while Title Transfer Facility's price spread of €18.65/MWh is close to its mean price of €20.61/MWh. In ZeeBrudge market, its price spread of 47.25GBpence/Therm, also catches up with its mean price of 49.71/GBpence/Therm. The spread in the prices of the global natural gas market as represented by these key leading market regions is two times the size of its mean value and they are statistically significant at *p*-values of 0.0000. Similar evidence is found in the price returns. All the returns as evidenced from the statistics are highly volatile with Brent exhibiting higher volatility than the rest of them as seen from the standard deviation of 3.09. Title Transfer Facility has the lowest volatility of 1.87 and even at this comparatively low value, it is highly significant exceeding by far the required zero mean of the error term in stationarity value requirement as in:

$$u \sim N(0, \sigma_u^2) = 0 \qquad \mathrm{E(u/X)} = 0$$

Equation 17

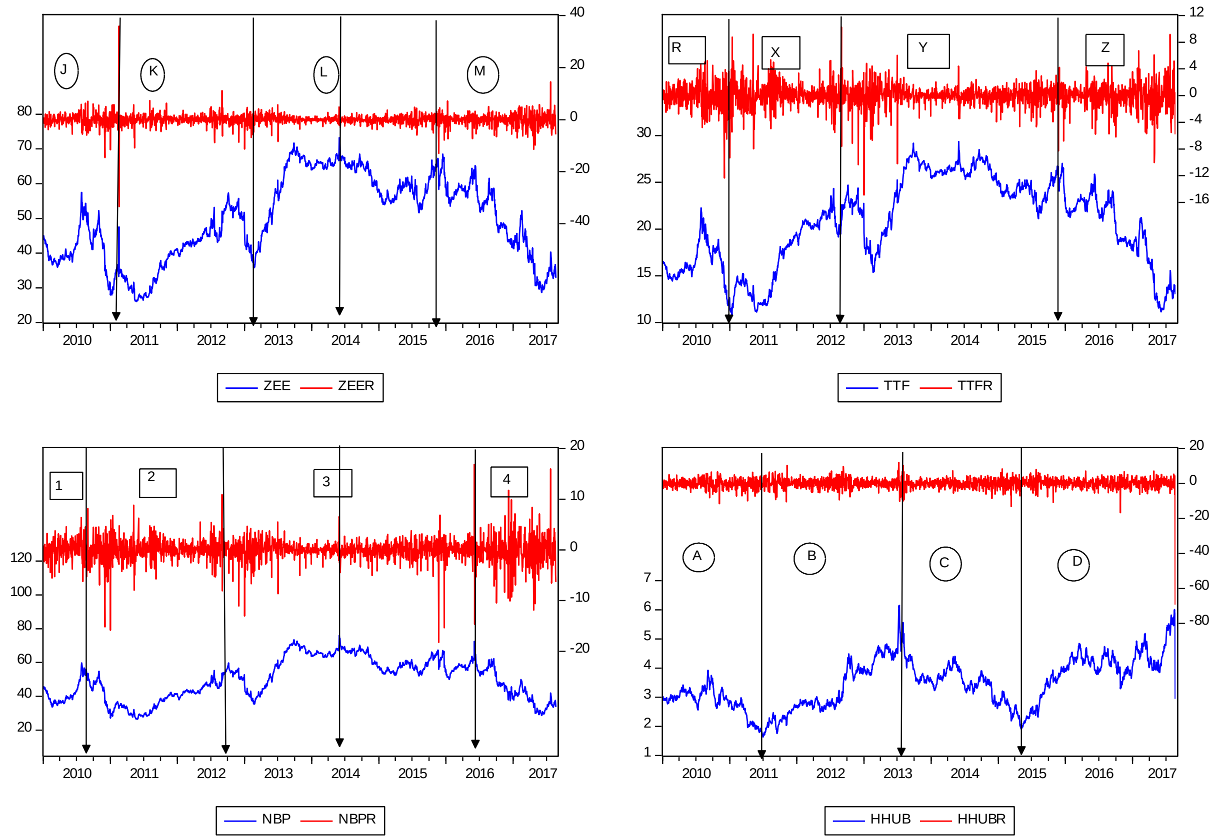
With the standard deviation result showing that the expected values of the mean of the error term in all the series E(u/HHUBr); E(u/NBPr); E(u/TTFr) and E(u/ZEEr) far exceed the Gaussian E(u/X) = 0, a fundamental classical linear assumption has been defied by the returns.

The statistical result also shows the symmetry or otherwise of the distribution of returns around their means using their skewness. The reader will recall that a positive or negative skewness away from zero implies that the distribution has a long tail. Imperatively, as in the zero-mean requirement for the standard deviation, so also it is required that the skewness of a normal distribution be zero. Any value away from zero either positive or negative indicates a long tail. Therefore, going by the statistical properties, returns in the distribution of the series of natural gas in all the markets vitiate the normality requirement of the distribution as they are all negatively away from zero and therefore exhibit the properties of asymmetry.

As for the peakedness or otherwise of the distribution of the returns, all the four markets are leptokurtic as they far exceed the normality value of 3 as measured by their kurtoses. Even Title Transfer Facility which has the list kurtosis of 9.79 exceeds this requirement, three-fold. Additionally, the Jaque-Bera statistics which further tests the normality or otherwise of the distribution in the results of the statistics presented, indicates that neither the series, nor their returns are normally distrusted as confirmed by the significance of their *p-values* = 0.000.

Graphical presentation in figure 7 combining price series and their returns in the four markets illuminate volatility clustering by the spikes of the returns and unstable trends in the price series. The graphs show that the nature of the four markets is volatile revealing conformity to the stylize facts of time series that their volatility is not stationary ergodic. The reader could observe that moments of shocks are followed by moments of tranquillity in all the market

Figure 5 - The dynamics of the four gas markets



Source: Computed and presented by the Author

This research picks four-time periods in each market to establish factors that coincided with these shocks at those periods that could explain the associated volatilities from the graphs. The four periods are chosen (not in any special order or technique) to validate the power of the statistical properties in the various natural gas markets. One conformity to postulates that gas is a constrained commodity is shown by the different timing of occurrences of these major shocks that differ from one market to the other in time space reflecting their differing peculiar domestic factors. A common feature in all the markets is that they exhibit volatility clustering as periods of volatility are followed by periods of tranquillity.

The major spike in Henry Hub in July 2011 in box (A) coincides with first entrance of shale gas in USA. While the spike six months earlier in box (R) of Title Transfer Facility occurred by the sharp drop in prices following the success of the eminence of that market in 2010 that saw massive reduction in LNG coming from other parts of the world to Europe. UK in box (1) had earlier experienced its major shock in the review period later in April 2010 following factors that had to do with depreciation of the pound sterling and consistent fall in production of Brent crude. In box (J), ZeeBrudge experienced the same fate with Title Transfer Facility in the same period showing resemblance of these market in terms of economic and political factors.

More factors could be traced in all the boxes but the most interesting is the serious volatility in UK market in National Balancing Point Box (4). This coincides with Bre-exit that brought several factors central and tangential to its gas market, such as sterling sharp depreciation against major currencies, pass-through effects of volatility in other commodity and financial asset prices, lull in economic activities, threats of inflation and declining GDP.

The statistical properties of natural gas prices in Table 5 and figure 7 convey the inference that the natural gas market is sensitive to social, political and economic factors differing from one region to the other across time-path. Some of the commonly manifesting drivers of gas prices such as weather conditions, storage, seasonality, production disruption and cross-commodity effect like crude oil reflected in the graphs in particular have been raised in literature by Brown and Yucel (2008); Nick and Thoenes (2014) and a host of others examined in literature. This research work has contributed by depicting political influence in the behaviour of gas prices that investors need to watch for and that are fundamental political decisions like the Bre-Exit in Net Balancing Point natural gas market. Stage of the Development of the market also has impact on its price behaviour as observed in Title Transfer and ZeeBrudge natural gas markets. Xunpeng (2016) affirms this result when analysing European natural gas hubs with references to Title Transfer and ZeeBrudge natural gas hubs.

The foregoing descriptive statistics provides the basic stepping stone to proceed with the modelling procedure. Results derived are never satisfactory at this stage as they lack the robustness and sophistry to unravel sufficient reasons behind the behaviour of the market especially for a sensitive market like natural gas. Therefore, this statistical level cannot satisfactorily generate information required for investors or any stake holder in the natural gas market to make accurate decision on. To generate desirable properties, the deployment of econometric models becomes sacrosanct. This is the algorithm of the project with theoretical plausibility, explanatory ability, and estimation of all parameters, simplicity and most importantly forecasting ability as the focus.

4.2.2 Results from Preliminary Diagnostics Tests

In empirical volatility market modelling, it is a mandatory requirement that evidences have to be established first, regarding the homoscedasticity or otherwise of the variable(s) of interest. It is on the basis of the established evidence of the existence of heteroskedasticity that volatility modelling can proceed. In line with this tradition, this market modelling project therefore starts with three diagnostics tests for the presence or otherwise of heteroskedasticity of the price returns of the four markets sub-Sahara natural gas markets are traded.

The results of these tests will form the basis for identifying the relevant model among the GARCH family and use it to suit this project.

These tests include the ARCH test; Correlation Coefficient test and Heteroskedasticity Test.

In this project, the process of the tests begins with taking the original test procedures and subsequent research works related to this project and evaluate each test and refine each to suit the purpose of the project.

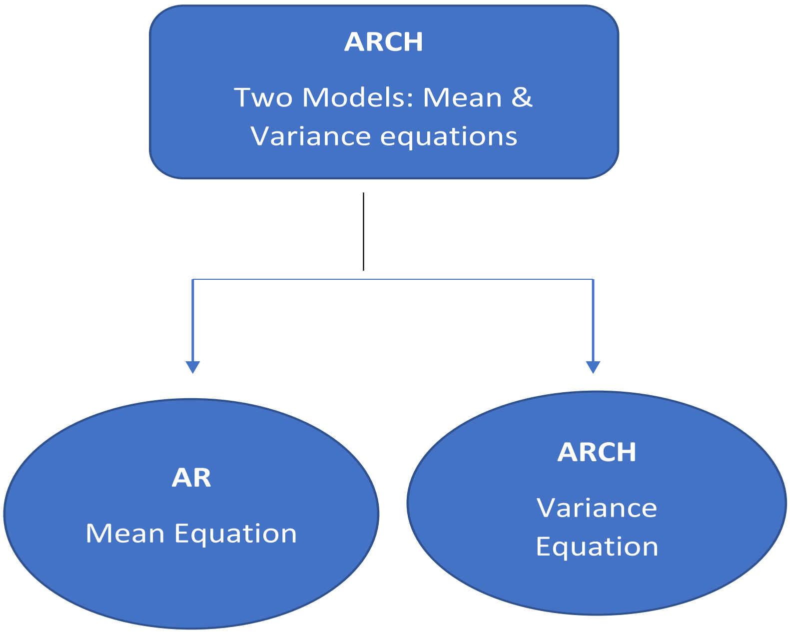
The ARCH test comes first not in any order of arrangement, but it is usually considered as the base of higher order econometric modelling as the reader will see. This is followed by Correlation of Coefficient and then Heteroskedasticity test in line with mandatory diagnostics tests.

i. Result from ARCH Test Analyses

As mentioned earlier, the test for ARCH effect is a mandatory requirement to justify volatility modelling. By Autoregressive it implies that the series depends on its past values. Therefore, the past values stand for the explanatory variable in this project, all through. Conditional Heteroskedasticity means that volatility, that is, the risk returns measured by the standard deviation is not Lipschitz, that is, not uniform or stationary ergodic in the space spectrum of time across the sample period. This is also recognized as the time varying volatility of the returns. In this project as elsewhere, the term Autoregressive describes the feedback mechanism that incorporates past observations into the present and conditionality depicts dependence on immediate past observations that serve as the regressors.

In testing for the ARCH effect on the gas returns, this research starts by the examination of its two terms structure made up of the mean equation (AR), that describes a feedback mechanism which incorporates past observations into the present and the variance equations (ARCH) capturing dependence on the observations of the immediate past as in the Diagram below:

Figure 6 - ARCH Term Structure



Utilizing Engle (1982) the Mean Equation (ωt) for AR (1) is structured as

$$\omega t \ = \ u \ + \ g\omega t - 1 \ + \ et; et \sim \mathrm{IID} \ (0, \partial 2)$$

Equation 18

where the error term of the mean equation (e_t) is independent and identically distributed with a zero mean and a constant variance as in the initial work of

Engle (1982). To attain a higher order model, the AR (1) is re-structured by extending equation (18) to:

$$\mathrm{AR}\ (\mathrm{P})\ = \omega\mathrm{t}\ =\ \mathrm{u}\ +\ \sum_{t=1}^{p} g\omega t - 1 +\ \sigma\mathrm{tet} \sim \mathrm{IID}\ (0, \partial 2)$$

Equation 19

Following the works of Engle (1982) still, it is needful to first obtain the residuals of the error term (e_t) to fit the Ordinary Least Square (OLS) line – the base model. This research obtains these residuals of AR (1) and AR (P) by utilising the following equations:

$\mathrm{et}\ =\ \omega\mathrm{t} - \hat{\mathrm{g}} - \omega\mathrm{tt} - 1$ for AR (p) and

Equation 20

$$\mathrm{et}\ =\ \omega\mathrm{t} - \hat{\mathrm{g}} - \sum_{t=1}^{p} \hat{\mathrm{g}}\ \omega\mathrm{tt} - 1 \text{ for AR (q)}$$

Equation 21

and then uses the squares of equations (20) and (21) to obtain ARCH (1) and ARCH (p) equations as follows:

$$\hat{\mathrm{e}}\mathrm{t}\ =\ \mathrm{u}\ +\ \Phi\hat{\mathrm{e}}\mathrm{t}\,{}_{t-1}^{2} \text{ for ARCH (p) effect}$$

Equation 22

$$\hat{\mathrm{e}}\mathrm{t}\ =\ \mathrm{u}\ +\ \sum_{t-1}^{p} \Phi\hat{\mathrm{e}}\mathrm{t}\,{}_{t-1}^{2} \text{ for ARCH (q) effect}$$

Equation 23

utilising the derived equations (22) and (23), the diagnostic test for ARCH effect is obtained and presented in Table 6 below.

Table 7- Results of ARCH Test

	Henry Hub	Net Balancing Point	Title Transfer	ZeeBrudge
ϕAR (p)	0.2659	0.0805	0.2030	0.0529
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ϕARCH (q)	0.7161	0.9193	0.7978	0.9535
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Source: Computed and presented by author

Following the first null hypotheses which says that there is no ARCH effect in the series, it therefore follows that if:

Φ = 0 for AR (p) and Φ = 0 for ARCH (q) also, then the series conforms to the Gauss-Markov constant variation of the error returns of no ARCH effect and therefore the research should accept the null hypothesis.

But the statistical results presented in Table 7 prove otherwise. All the series are spherically away from zero and are significant at *p*-value values of 0.000 indicating the existence of ARCH effect. The null hypothesis of no ARCH effect is therefore rejected.

ii. Result of Serial Correlation Test

With the rejection of no ARCH effect in the returns, the next stage is test for serial correlation.

Here, this research work employs the use of Box-Jenkins (1996) for the serial correlation test. Methods used in testing for serial correlation however differ almost in every work. Therefore, because of the significance influence of their results in forecasting, the methods in which serial correlation are obtained need to be explained if not deeply but to a certain irreducible minimum level.

One common factor however among econometric works is that going back to basic regression manifests in every work as a mandatory step for establishing the existence or otherwise of correlation in the times series.

We can use the regression estimator in equations 14 and to construct the first order correlation equation generally used as follows:

$$\hat{u}t = \rho\hat{u}t - 1 + \varepsilon t, 0 \leq |\rho| < 1$$

Equation 24

Equation 24 states that for the observation of time *t* the error term $\hat{u}_t$ carries over part of the error from the past period $\rho\hat{u}_{t-1}$ and adds in a new innovation, $\varepsilon_{t.}$ It is this new innovation that is assumed not to be correlated over time period. Note that the correlation of the innovation ε_t comes through $\rho\hat{u}_{t-1}$. This helps in utilising $0 \leq |\rho| < 1$to establish that if $\rho = 0.7$ or more, then 70% or more of the error from the past period (*t-1*) is persistent signifying the existence of serial correlation in the error term. This is because it presents evidence that there are similarities between observations as a function of time lag. However, if $\rho = 0$, the market signifies a zero-serial correlation.

Many of the econometric time series works seen stop at this first order serial correlation test. Part of the reasons could be the first order level suffices in their work. This research however differs from this set of econometricians who are satisfied with employing either AR(1) or MA(1) first level correlation test by utilising a third method which combines AR(1) and MA(1) and at a high order AR(p) MA(q), that is ARMA(p, q).

Therefore, equation 24 is expanded to:

$$\mathrm{AR(p)}\ \hat{u}t = \rho\hat{u}t - 1 + \rho\hat{u}t - 2 \ \ldots.. + \rho\hat{u}t - p + \varepsilon t,$$

Equation 25

$$\mathrm{MA(q)}\ \hat{u}t = \varepsilon t, + \beta 1\varepsilon t - 1 + \cdots. + \beta q\varepsilon t - q$$

Equation 26

and combined to form ARMA (p, q):

$$\hat{u}t = \rho\hat{u}t - p + \varepsilon t + \beta q\varepsilon t - q$$

Equation 27

Equation 27 is therefore the correlation test model used in this project which is consistent with the ARMA term structure introduced at the beginning of the analysis. At this point, the contrasting views of Straumann (2005) regarding the use of ARMA process in log-returns need to be clarified. Straumann (2005) while acknowledging the mathematically tractability and practical relevance of ARMA process in time series cautions on its use for log-returns description. This submission has been well taken in consideration of the overall model, where time series models like EGARCH have been advanced to correct the key concern raised by Starumann (2005). And this is stationary variations of residual values in repeated observations manifesting in the use of ARMA process for a general log-return modelling. However, this research still employs ARMA because as the Straumann also concurs, ARMA process form the back born of time series modelling. This is in addition to the justification provided above, but its use is restricted to diagnostic test only.

The diagnosis of the test of serial correlation is done on the correlation result from equation 27, utilising Ljung-Box (1979) Q-statistic. The reduced form of autocorrelation equation is employed as follows:

$$AC = \sum_{n+1}^{\wedge}(Yt - \bar{Y})((Yt - n - \bar{Y}) / \sum_{i-1}^{T}(Y_t - \bar{Y})2$$

Equation 28

Equation 28 is the simplified autocorrelation (AC) reduced from those in literature to fit into the Eview 10. This is done without prejudice to the values of the result.

The reader will recall that most literature model the autocorrelation as:

$$AC = \{\sum_{i=n+1}^{\wedge}((Yt - \bar{Y})((Yi - n - \bar{Y}i - n) / (T - K)\} / \sum_{i-1}^{T}(Y_t - \bar{Y})2$$

Equation 29

Using the reduced form of autocorrelation in equation 28, the correlograms of correlation tests for the four markets in this research are presented in Table 8 below.

Table 8- Correlogram of Residuals

	Henry Hub	NB-Point	T/Transfer	ZeeBrudge
AC1	-0.466	-0.511	-0.484	-0.541
AC2	0.062	0.002	-0.021	0.027
AC3	-0.029	0.007	0.017	0.044
AC4	0.003	0.016	-0.012	-0.053
PAC1	-0.466	-0.511	-0.484	-0.541
PAC2	-0.198	-0.352	-0.333	-0.375
PAC3	-0.115	-0.266	-0.230	-0.227
PAC4	-0.069	-0.186	-0.188	-0.214
Q-Stat1	432.39	521.06	466.43	582.66
Q-Stat2	440.06	521.06	467.29	584.14
Q-Stat3	441.74	521.16	467.90	588.06
Q-Stat4	441.77	521.67	468.38	593.58
p-value	0.0000	0.0000	0.0000	0.0000

Source: Computed and presented by Author

The values of the correlogram of both Autocorrelation and Partial Autocorrelation at all lags from Table 8 show spikes in returns in all the markets signifying the presence of serial correlation in all.

Observe that the correlation coefficient (AC) in Table 8 derived from equation (28) is nonzero serially correlated in all the markets up to lag four. This gives evidence of serial autocorrelation of the gas returns in all the markets. Another observation is the persistence of the coefficients with none dying off or exhibiting signs of phasing out any time soon, in subsequent lags. Rather, all the returns in the markets show signs of persistence. In Henry Hub for instance, the correlation coefficient zig-zags from -0.466 through 0.062 to -0.029 and back to positive 0.003. Net Balancing Point and ZeeBrudge had one switch directional spikes however, none of the markets shows sign of dying off up to lag four.

Observe in Table 8 that the correlation coefficient does not die off. If the correlation coefficient (AC) dies off less or more geometrically, this would have signified that the returns obey a low-order AR process. In other hand, if AC falls suddenly to zero - let us say from lag two to three - it would have signified the obedience of a low-order MA. However, none of the returns follows such trend. This justified the use of higher ARMA as explained in the beginning of the presentation.

The Partial Autocorrelation (PAC) in this project was regressed on the constant of each return to measure the degree of association between the returns in time path at lag periods down to January 1st January 2010 in all the markets. This therefore removes the effect of any set of controlling random variable. Table 8 presents the PAC of each market which exhibits the same narrative of the AC confirming the nature of serial correlation of the series.

With no other controlling random variable, PAC in all the markets from Henry Hub to ZeeBrudge as in the table displays nonzero serial correlation.

The Q-statistic in this project is reported at lag four and is computed using the Ljung-Box (1979) following the generalized asymptotic ARMA process as follows:

$$\mathrm{Q - stat} = \mathrm{N(N + 2)\Sigma Li = 1\ r2i\ /N - I}$$

Equation 30

where N is (January 1st, 2010 to December 31st, 2017 number of days) and l is lag four. Note that because the series represent the ARMA process, the Q-stat is asymptotically distributed.

In Table 8, the Q-stat of the markets against the hypothesis says that all the correlations from lag one to four equal to zero at 521.16 for Henry Hub, 521.67 for Net Balancing Point, 468.38 for Title Transfer and 593.58 for ZeeBrudge. The probability of getting these statistics by chance is zero as suggested by the corresponding *p*-values.

As observed in Table 8, all the probability values are less than one per cent implying that the null hypothesis of no serial correlation is rejected for all the natural gas prices in all the markets.

iii. Results of Heteroscedasticity Test

There are several heteroskedasticity tests available in literature to serve a variety of econometric needs. The Breusch-Pagan-Godfry (BPG), Harvey, Glejer, ARCH-LM and White's, feature prominently in academic and professional works. For a stochastic recursive equations' mechanism applied in this research, and the fact that this exercise differs from the general space of Markov Chains, the use of ARCH-LM to test for heteroskedasticity in the returns of gas price in the markets under study, is chosen. The choice of ARCH-LM test also is consistent with the ARMA process in use. The fact that the previous tests of ARCH and serial correlation so far indicate that the data in use is of a time varying volatility in nature which could react nervously to geopolitical, economic disorder, social disruption, etc, the use of ARCH-LM is almost indispensable. Note that the essence of heteroscedasticity test is to ensure the validity of the computed standard errors in the ordinary least square. If there be any presence of heteroscedasticity, then the values of the squared errors - a material property of time series - cannot be used for reliable forecast, using OLS. Ignoring heteroscedasticity test therefore could result to loss of forecast efficiency.

In line with the higher order ARMA process, the test statistic is modelled to test the presence or otherwise of heteroscedasticity as follows:

$$\varepsilon_t^2 = \Psi\text{o} + [\textstyle\sum_n^q \Psi\,\text{n}\varepsilon_{k-n}^2] + \vartheta\text{t}$$

Equation 31

Recall that the residual (ε) is from the Engle (1982) estimate derived from equations 18 to 23 during the derivation of the ARCH terms above and it is only extended here as an auxiliary test regression to incorporate elements of LaGrange Multiplier (LM) to follow asymptotic large sample size of the ongoing ARMA process. It is a regression of the returns squared residuals up to lag q. ϑ_t is the white noise as in Engle's model.

After obtaining the squared residuals from equation 31, the result is presented in Table 9 as follows:

Table 9- Result of Heteroscedasticity

Dependent Variable: Gas Price returns (r_t)												
Market:	Henry Hub			Net Balancing Point			Title Transfer Facility			ZeeBrudge		
Model:	F-test	nR^2	p-v	F-test	nR^2	p-v	F-test	nR^2	p-v	F-test	nR^2	p-v
P=5:												
k = 1	16.45	16.33	0.000	43.79	42.89	0.000	10.43	10.39	0.001	21.48	21.27	0.000
K = 2	13.09	25.89	0.000	21.89	42.91	0.000	5.203	10.37	0.005	10.78	21.37	0.000
K = 3	8.737	25.92	0.000	14.67	43.13	0.000	3.596	10.753	0.013	7.732	22.97	0.000
p=10:												
k = 1	9.391	9.356	0.002	26.91	26.58	0.000	72.486	69.99	0.000	469.5	379.8	0.000
k = 2	10.03	19.89	0.000	13.89	27.45	0.000	39.64	79.35	0.000	302.6	463.9	0.000
k = 3	14.37	42.27	0.000	9.557	28.32	0.000	29.29	84.29	0.000	215.4	487.9	0.000
p=15:												
k = 1	48.89	47.76	0.000	30.03	29.66	0.000	64.77	62.77	0.000	414.1	342.6	0.000
k = 2	31.56	61.26	0.000	15.46	30.49	0.000	75.67	140.7	0.000	254.7	405.5	0.000
k = 3	39.96	113.2	0.000	10.65	31.50	0.000	50.77	141.7	0.000	177.5	420.1	0.000

Source: Computed and presented by Author

Table 9 reports two statistics with their associated probability. These are the *F-test* and $nR^{2\cdot}$ Note that the multiplication of the number of observation (n) by the coefficient of determination R^2 produced the F-Test as obtained from equation (31) and it tests the joint significance of all lagged squared residuals. The nR^2 is the number of observations by R-squared statistic of Engle's LM test statistics from the test regression. It is expedient to also mention that this Engle's LM statistic is asymptotically distributed as squared observation to order q with p degrees of freedom, which is consistent with the process of this research.

Results of *F-test* and nR^2 as reported in Table 9 reject the null hypothesis of homoscedasticity at all levels in all the markets up to lag 15 and from k_1 to k_3 in all stages of the lags selected. This result is in tandem with the result derived in Table 1 of the descriptive statistics. In theory and in professional econometric works, the null hypothesis of heteroskedasticity test is rejected if the *p*-value is less than 0.1/0.05/0.01. As we can see from Table 9, the *p*-values are less than 0.001 at all levels of k_i and number of lags. This calls for a resounding rejection of the null hypothesis.

Three stages of test of properties of volatility have been carried on the gas price returns and each stage confirms the instability; asymmetric nature of returns and risk and non-zero serial correlation of the past behaviour of these series. At each stage, most of the desirable properties and some of the 10 (ten) key assumptions of the Guassian classical linear regression model (Gujarati 2006) are violated. These properties comprising the popular Gauss-Markov theorem BLUE – Best Linear Unbiased Estimator – including efficient, consistency and minimum square error (Pindyck and Rubinfeld 1997) are violated by the presence of ARCH effect in all the tests. Therefore, there is sufficient evidence that the standard homoscedasticity of the variance:

$$\mathrm{Var}(\delta i/Pi) = E[\delta i - E(\delta i/Pi)]2 = 0$$

Equation 32

which states that the variance around the average relationship between gas price and risk is the same for all the series of prices from 2010 to 2017 in all of the gas markets does not hold. Consequently, the diagnostic tests call for credible rejection of no ARCH effect, no serial correlation and no homogeneity in natural gas markets under review. This stage completes the mandatory diagnosis tests required on quantitative enquiry and presents the logic to proceed in the search of suitable model for the test of the research hypotheses.

4.2.3 Results of Memory Decay

The question on the length of shock persistent is enshrined in the ARMA modelled in equations 22 and 23 above. The relevance of this question lies in the fact that it is not enough to prove the presence of volatility in the series. Investors are also interested on the how to “go about” the discovered volatility. To do this effectively, information regarding its mortality or immortality is necessary. This is where the issue of memory decay comes in. Initial investigation of the length a shock resides in an observation starts with unbundling the ARMA GARCH terms modified as:

$$y_t = \phi + \rho y_{t-1} + \varepsilon_t + \gamma \varepsilon_{t-1}$$
$$h_t = \omega + \alpha \hat{\varepsilon}_{t-1}^2 + \beta h_{t-1}$$

where:

y_t is the conditional mean of the returns,

ϕ is the constant term for the conditional mean;

ρ is the coefficient of lagged conditional mean – (AR) term,

γ is the coefficient of lagged residual – (MA) term;

h_t is the conditional variances

ω is the constant term for the coefficient of lagged residual

α is the ARCH term coefficient; and

β is the GARCH term coefficient.

Memory decay is then computed by the dividing the log of half and sum of the ARCH and GARCH terms coefficients α and β symbolized as Ψ in equation 22 as:

$\ln|0.5|/\ln(\Psi)$

Equation 33

Depending on the model, Ψ is the convergence or stationarity coefficient and in most models, this is the sum of ARCH and GARCH terms coefficients.

Deploying the ARCH and GARCH term Ψ in all the markets result to the length of the shock in each series reported in Table 9.

Utilizing the half-life formula:

where (α + β) is the sum of ARCH and GARCH term representing the shock persistence (Ψ) in Table 10 in parentheses are the associated squared residuals.

Table 10- Memory Decay of volatility in days

	Henry Hub	NB Point	TTF	ZEE
Ψ	138.62	72.89	115.18	62.49
	(0.0192)	(0.0063)	(0.0131)	(0.0033)
z-Stat	13.8431	12.6738	15.4932	16.1136
P	0.0000	0.0000	0.0000	0.0000
Suitable Model for forecast				
AIC	*4.8906*	*4.3345*	*3.8413*	*4.1843*
SC	4.9045	4.3486	3.8553	4.1984
HQC	4.8957	4.3397	3.8465	4.1895
R2	-0.0090	0.0032	-0.0028	0.0082
γ	0.7	0.7	0.7	0.7

Source: Computed and presented by Author

The p-values relate to all parameters. The result depicts the number of days memory decays. Shocks of Henry Hub take about 138 days to die out. In checking the series and graph in descriptive statistics, it shows price shocks actually stay up to about a quarter of year before they die out in Henry Hub. In ZeeBrudge adjustment is quicker - just about two months - and this is not surprising because ZeeBrudge almost entirely trades in physical spot and is small in size. The small size makes it capable to adjust quicker to shocks than larger markets like Henry Hub and national Valancing Point. Such result could serve as additional knowledge that size and spread of a market affects its adjustment to shock. In terms of model selection criteria, the AIC outperforms the two competing information criteria in that it has the smallest measure of statistical value connoting that it holds more information than the other two.

Answer to the quantitative research question whether a reliable forecast can be obtained demands selection of advanced time series econometric model among competing models and modification of the selected model to be deployed to answer the question. This brings us to the stage of econometric model estimation and selection.

4.2.4 Results of test of research hypotheses from chosen GARCH models

The test of research hypotheses starts with a comprehensive examination of the overarching model selection criteria. For time series, the model selection is based on three criteria: Akaike Information Criterion (AIC); Schwarz Criterion (SC) and Hannan-Quinn Criterion (HQC). The criterion with the least value is considered the best model that fits that particular series well. This is because the quantity of information in a model is the distance from the true model. Therefore, the closer the distance between the true model and the estimated model, the more "loaded" or endowed with information that criterion is for the model and this is measured by the log likelihood. It therefore indicates that the very model with the least value of criterion out-performs all other competing models. The GARCH-type model to be selected among the four competing models will therefore be decided by least value model selection criterion.

AIC is modified from Akaike (1987) as follows:

$$\mathrm{AIC} = -2(\mathrm{l}/\mathrm{T} + 2\mathrm{k}/\mathrm{T}$$

Equation 34

where l is the value of log likelihood k parameters and taking T observation. K is also computed as:

$\mathrm{L} = \mathrm{T}/2(1 + \log 2\text{ʒ}) + \log(\hat{\mathrm{e}}'\hat{\mathrm{e}}/\mathrm{T}))$ and T the smaller the value, the better the fit.

SC is computed from Schwarz (1978) as:

$$SC = -2/T + (k\log T)/T$$

Equation 35

and by this equation imposes a higher penalty to AIC.

HQC is calculated from Hannan and Quinn (1979) as:

$$HQC = -2(l/T) + 2k\log(\log))/T$$

Equation 36

thereby imposing yet another penalty.

The research then moves to specification of the proposed models on which these information criteria are applied. The prominent models considered in this research beginning from the seminal works of Engle in 1982 include ARCH (Engle, 1982), GARCH (Bolerslev, 1986), EGARCH (Nelson, 1992) and GJR-GARCH (Glosten, Jaganathan and Runkle) TGARCH (Zakoian, Glosten and Jaganathan 1994), and PARCH (Taylor 1986 and Schwert 1989).

The research skips the estimation of Engle's ARCH (1982) and Bollerslev's GARCH (1986) which form the basic IGARCH because of the undesirable restrictions of essential parameters that negate the oscillation behaviour of real observations as stated in chapter three. Therefore, the best fit model selection procedure from initially proposed four are reduced to three with the omission of IGARCH. These three models on which the estimation is made include Nelson (1992), Glosten Jaganathan and Runkle (1993), Zakoian, Glosten and Jaganathan (1994) and, Taylor (1986) and Schwert (1989). The researcher presents Engle and Bollerslev (1986) for the sake of mentioning popular GARCH models in use.

As the series have clearly exhibited the presence of heteroscedasticity, it is important to handle these heteroskedastic features appropriately if efficient estimators are to be obtained. Again, the almost-sure way to do this is by employing these GARCH class of models that have served the econometric time series world effectively, like those mentioned above.

The route to generating test results of the research hypotheses is through estimation of the conditional mean, conditional variance and conditional error distribution.

In time series literature, the conditional mean is modelled as:

$$Qt = Nt'\phi + \mathrm{e}t$$

Equation 37

Note that this is written in a functional relationship between the exogenous variable (N) with error term (e). We met this severally in equations 18 - 23.

The conditional variance is also modelled on the same functional relationship premise as:

$$\sigma_t^2 = \zeta + \mu \mathrm{e}_{t-1}^2 + \beta\sigma_{t-1}^2$$

Equation 38

Equation 38 is called conditional variance because the variance(σ_t^2) is conditioned on past information and it is specified in a functional relationship involving the constant (ζ), the ARCH term (e_{t-1}^2) and the GARCH term (σ_{t-1}^2).

The ARCH term (e_{t-1}^2) contains the news, information and insight about volatility that occurred in the past period – in our case natural gas prices in top four global markets form January 1st, 2010 to December 31st, 2017 - as the lag of squared residual from the mean equation 37. The GARCH term (σ_{t-1}^{2}) on the other hand is the lagged forecast variance.

The conditional distribution of the error term (e) completes the specification of ARCH process. Just like the model selection criteria discussed above, the prominent conditional error distribution in time series modelling are three. These are the Normal-Gaussian distribution, Student *t*-distribution and the Generalized Error Distribution.

They are merely mentioned here as their derivation is already computed in all soft-wares in use such as Stata, Win-solve and E-view to mention a few. Therefore, there is no value addition here to recount their equation as any modeller simply utilises them.

Table 11- Results of Hypotheses

	Henry Hub			**Net Balancing Point**		
	TGARCH	EGARCH	PARCH	TGARCH	EGARCH	PARCH
ω	-0.0354	0.0267	-0.033	0.0012	-0.005	-0.0079
	(0.023)	(0.029)	(0.023)	(0.020)	(0.020)	(0.019)
Ψ	0.9135	0.9701	0.9198	0.8900	0.9829	0.9067
	(0.020)	(0.012)	(0.014)	(0.015)	(0.005)	(0.137)
ξ	-0.067	0.0789	-0.223	-0.1370	0.0553	0.0090
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ϕ	138.62 (days)			72.89 (days)		
	Title Transfer			**ZeeBrudge**		
	TGARCH	EGARCH	PARCH	TGARCH	EGARCH	PARCH
ω	0.0366	0.0399	-0.0079	-0.0332	0.0399	-0.009
	(0.022)	(0.022)	(0.019)	(0.016)	(0.000)	(0.000)
Ψ	0.8375	0.9715	0.9067	0.5636	0.9715	0.9067
	(0.019)	(0.007)	(0.013)	(0.177)	(0.007)	(0.013)
ξ	-0.1931	0.0798	0.009	-0.0535	0.0136	-0.0978
[*p*-values]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ϕ	115.18 (days)			62.49 (days)		

Source: Computed and presented by Author

The results of hypotheses testing are derived from equations 39 to 44 in the combined exercise of estimating model selection as well. In parentheses are the associated coefficients of the asymptotic critical values of rejection zone. In per centage terms, none is up to 1% as Table 10 shows. Engle and Victor (1993) set these critical values at 5%, 10% and 15% depending on the sign and magnitude of the news coefficient. The *p*-values relate to all the coefficients showing how statistically significant each of the test results is. The first null hypothesis says that shocks are not symmetric. This is however not the case as there is evidence from error distribution captured by ξ showing shocks asymmetry in all the markets. This further confirms statistical report in figure 8 where strong volatility in 2008 - judging by the spikes - are followed by a less strong volatility in the next round. The reverse is the case in subsequent years as less strong volatility is followed by strong volatility. Rejecting this hypothesis is no near committing types 1 or 2 errors as they all fall in the rejection zone at less than 1% as the Table 11 shows. The differing volatility posture in each market observe in the asymmetry coefficient ξ result also leads to the rejection of the hypotheses that regional markets conditions do not alter fundamental drivers of gas returns. This hypothesis is a strong persuasion of this project. It provides one of the reasons to undertake a study on regional basis as natural gas volatility behaves differently from one zone to the other. This is the case with all the three models examined. Leverage effect is the vogue in each market with differing news. In Henry Hub market, models TARCH and PARCH show that the market is driven by negative news. Table 11 shows the effect in the signs of ξ. Because negative news drive volatility more than positive news, risk averse investors will shy away from investing in markets that portrays such. Leverage effect rules in all the markets as Table 11 shows and it is on this basis that the null hypothesis is rejected. On shocks persistence, all the markets show that there is shock persistence and there is evidence of shocks impact on the returns which are almost permanent. This shows in the coefficient capturing shock persistence Ψ which gets closer to 1.0000 in all the markets and in all the models. Shock persistence is evaluated with the summation of ARCH and GARCH term, $(\alpha + \beta)$ which is (Ψ) in the GARCH-type time series modelling. In the three models in consideration, it is derived from equations 30 to 33. If Ψ is low (approaching 0), the shock is less persistent, implying that it takes less time for the effect of shocks to fade out. If Ψ is high (approaching 1), the shock is highly persistent, implying that it takes long time for the effect of shocks to fade out. If $\Psi \geq 1$, the shock is permanent, implying that the effect of shocks will remain permanent. Shocks with $\Psi < 0.5$ values are considered short-lived and not persistence and otherwise if $\Psi > 0.5$. The results derived is not consistent with the hypotheses that shocks have no market impact and are not persistence. These hypotheses are therefore rejected. The rejection decision gets support from the half-day life cycle in days which shows that there is no shock that is less than 2 months on the daily spot market trading. This also leads to the rejection of the hypothesis that volatility decays are short. The table below shows the summary of test results of the research hypotheses.

Table 12- decision on Hypotheses

No	Research Question	Research Hypothesis	Decision
1	What is the nature of shocks in the markets where sub-Sahara Africa natural gas trades?	The nature of shocks in markets where sub-Sahara Africa natural gas trades are not asymmetric	This hypothesis is rejected on basis of evidence of significant asymmetry within a critical value of less than 1%
2	Would natural gas from sub-Sahara Africa follow a pattern in terms of volatility if traded in markets other than current markets?	Regional market conditions do not alter fundamental drivers of volatility	This hypothesis is rejected on grounds of differing volatility posture observe in the asymmetry coefficient.
3	Do the returns of the price series in current trading market generate the right news signal for investors to take investment decision in terms of leverage effect?	There is no leverage effect in the returns of the price series.	The sings of the asymmetry coefficient provide evidence of the prevalence of significant leverage effect with *p*-value at [0.000] and critical rejection decision at less than 1%. The hypothesis is therefore credibly rejected.
4	In the event of market instability, how long do shock last?	There is no shock persistence	All the markets show shock persistence and in all the models at *p*-value of [0.000]. this hypothesis is therefore rejected on this basis and on the rejection critical value of less than 1%
5	What effect do shocks have on the returns?	Shocks do not have effect on the returns.	The effect of the shocks are almost permanent as ψ is near 1.0000. Therefore, the null hypothesis is rejected.

The test hypotheses also show that the models do not generate the same result. These models with the contents of their results are now subjected to various selection criteria using equations (39 – 44) and on the basis of equations (34 – 36).

iv. Model Estimation and selection

The first of these models is Engle and Bollerslev (1986).

Engle and Bollerslev's (1986) specified their IGARCH model as:

$$\sigma_t^2 = \sum_{j=1}^{q} \varphi\mathrm{j}\, \sigma 2\mathrm{t} - \mathrm{j} + \sum_{i=1}^{p} \vartheta\, \mathrm{i}\varepsilon 2\mathrm{t} - \mathrm{I}$$

Equation 39

In this work, the authors retain their separate initial high order GARCH terms (p, q) of AR and MA models in the conditional variance (σ_t^2). While dropping the constant term (probably because of the effect of integrating Bollerslev's 1986 GARCH) the equality of the sum total AR and MA terms is retained to form the IGARCH model. The equality is the form:

$$\sum_{j=1}^{q} \varphi\, \mathrm{j} + \sum_{i=1}^{p} \vartheta\, \mathrm{i} = 1$$

Equation 40

In Zakoian's (1994), his TGARCH is modelled as:

$$\sigma_t^2 = \alpha + \sum_{j=1}^{q} \varphi j\, \sigma 2t - j + \sum_{i=1}^{p} \vartheta i\, \sigma 2t - i + \sum_{n=1} \lambda k\, \vartheta_{t-n}^2 Zt - n$$

Equation 41

This also bears resemblance to the Glosten, Jaganathan and Runkle (1993) known as GJR-GARCH and is used in most cases interchangeably.

In the conditional variance, Z_t = 1 if ϑ_t <0 and 0 if ϑ_t is more than 0. The Zakoina's TGARCH model defines good news as σ_{t-1} greater than zero (a result of positive integer) and otherwise, bad news. The model further indicates that the signs of σ_{t-l} (+ve and -ve) have different effects on the conditional variance in that good news has impact only on ϑ_i, while bad news affects both $\vartheta_i + \lambda$ and when $\lambda>0$, it is stated that bad news increases volatility depicting a leverage effect for the *i*-th order.

This model has found the interest of several time series modellers like Beckers, Herwartz and Seidel (2016), Arouri et al (2011) who reported successful outcome of their studies, from utilizing the model. Depending on the result of the model selection criteria, the model holds some credible substances in modelling volatility in natural gas markets.

Nelson's (1991) EGARCH centres on the log of the conditional variance. This single persuasion has attracted the interest of many researchers including the works of Arouri et al (2011), Narayan and Narayan (2007), Salisu and Fashanu (2013), who record successful completion of their studies by using the EGARCH model.

In this project, the initial work of Nelson (1991) in equation 42 is reduced to equation 43 so as to allow a choice of the distribution term. Nelson (1991) original specification of conditional variance allows (σ_t) to follow Generalised Error Distribution (GED). From the knowledge of energy market, distribution of oil, gas, electricity, coal series cannot be the same. Therefore, this research chose Nelson (1991) model but allows (σ_t) to follow the three distribution parameters provided in E-view that is, GED, normal and Student's t-distribution in equation 43.

$$\log(\sigma_t^2) = \alpha + \sum_{j=1}^{q} \varphi j \log(\sigma 2t - j) + \sum_{i=1}^{p} \vartheta i \; |\varepsilon t - i/\sigma 2t - j| + \frac{\varepsilon t-n}{\sigma t-n}$$

Equation 42

$$\log(\sigma_t^2) = \alpha + \sum_{j=1}^{q} \varphi j \log(\sigma 2t - j) + \sum_{i=1}^{p} \vartheta i \{|\varepsilon t - i/\sigma 2t - j| - N|\varepsilon t - i/$$

$$\sigma 2t - j|\} + \sum_{n=1}^{?} \lambda n \frac{\varepsilon t-n}{\sigma t-n}$$

Equation 43

The Taylor's (1986) and Schwert's (1989) PARCH is modelled after the standard deviation rather than the variance as in the three models discussed above. Ding et al (1993) specified it as follows:

$$\sigma_t^{\zeta} = \alpha + \sum_{j=1}^{q} \varphi j \, \sigma \zeta t - j + \sum_{i=1}^{p} \vartheta j \, (|\varepsilon t - I| - \lambda i \, \varepsilon t - I)\zeta$$

Equation 44

Where $\zeta > 0$, $|\lambda_i|$ less or equal to 1 for $_I = 1$

Here, the asymmetric effects are present only when (λ) is not equal to zero. Tables 12 - 16 present the results of each of the models in the chosen natural gas markets for selection on the work of modelling the sub-Saharan Gas Market.

Table 13- Model Selection for Henry Hub

	TGARCH	EGARCH	PARCH
ω	-0.0354	0.0267	-0.033
	(0.023)	(0.029)	(0.023)
Ψ	0.9135	0.9701	0.9198
	(0.020)	(0.012)	(0.014)
P-value	0.0000	0.0000	0.0000
ξ	-0.067	0.0789	-0.223
P-value	0.0037	0.0000	0.0443
λ	0.3111	83.5849	37.538
AIC:			
Normal	4.8867	4.8834	4.8814
Student's-t	4.7263	4.7251	4.7260
GED	4.7730	4.7765	4.7705
SIC:			
Normal	4.9036	4.9003	4.9011
Student's t	4.7460	4.7447	4.7488
GED	4.7927	4.7889	4.7930
HQC:			
Normal	4.8929	4.8896	4.8887
Student's-t	4.7335	4.7323	4.7343
GED	4.7802	4.7765	4.7787
ARCH-LM Test			
F-Test	0.2162	0.0509	0.0044
nR2	0.2164	0.0510	0.0044

Source: Computed and presented by Author

The three-stage table presents the key properties of the analyses which are conditional mean (ω), conditional variance (Ψ), conditional distribution (ξ) and their associated *p*-values in the first stage. This is followed by the three model selection parameters and the ARCH-LM test of each model for the four markets in the third and final stage.

In the model selection, recalled that if the specifications of the models in consideration are opened to allow for the choice of the best distribution among the competing distribution techniques – Normal, Student's-*t* and GED. Table 13 above is the selection for Henry-Hub.

The table shows that EGARCH out-performs the two models in all the three model selection criteria and among the best distribution which is the Student's-*t* statistic. In the three model selection criteria, AIC stands out with the least value. For Henry Hub therefore, AIC contains more information than SIC and HQC. As EGARCH, out-performs TGARCH and PARCH judging by AIC, it is therefore the best fit model for forecasting Henry Hub.

Table 14- Model Selection for National Balancing Point

	TGARCH	EGARCH	PARCH
ω	0.0012	-0.005	-0.0079
	(0.020)	(0.020)	(0.0195)
Ψ	0.8900	0.9829	0.9067
	(0.015)	(0.005)	(0.0137)
P-value	0.0000	0.0000	0.0000
ξ	-0.1370	0.0553	-0.0978
P-value	0.000	0.0028	0.009
λ	58.888	177.63	66.352
AIC:			
Normal	4.3202	4.2983	4.300
Student's-t	4.0746	4.060	4.060
GED	4.1005	4.7765	4.7705
SIC:			
Normal	4.3371	4.3151	4.3196
Student's t	4.0942	4.0800	4.082
GED	4.1202	4.7889	4.7930
HQC:			
Normal	4.3264	4.3045	4.3072
Student's-t	4.0818	4.0676	4.0681
GED	4.1077	4.7765	4.7787
ARCH-LM Test			
F-Test	0.0367	0.5355	3.4359
nR2	0.0367	0.5359	3.4334

Source: Computed and presented by Author

For National Balancing Point also, the same scenario plays out where EGARCH outperforms other models and AIC again out-shines other criteria.

Table 15- Model Selection for Title Transfer

	TGARCH	EGARCH	PARCH
ω	0.0366	0.0399	-0.0079
	(0.0223)	(0.022)	(0.0195)
Ψ	0.8375	0.9715	0.9067
	(0.0197)	(0.007)	(0.0137)
P-value	0.0000	0.0000	0.0000
ξ	-0.1931	0.0798	-0.0978
P-value	0.0000	0.0002	0.009
λ	42.389	127.20	66.352
AIC:			
Normal	3.8111	3.8010	4.300
Student's-t	3.6800	3.6719	4.060
GED	3.7004	3.7115	4.7705
SIC:			
Normal	3.8280	3.8179	4.3196
Student's t	3.6997	3.6916	4.082
GED	3.7129	4.7889	4.7930
HQC:			
Normal	3.8173	3.8072	4.3072
Student's-t	3.6873	3.6791	4.0681
GED	3.7004	3.7177	4.7787
ARCH-LM Test			
F-Test	0.3751	1.0049	3.4359
nR2	0.3754	1.0055	3.4334

Source: Computed and presented by Author

Just as in the two markets above, even though TGARCH shows lesser lengths of shock persistence, EGARCH again outshines the other two models by the endowment of information concerning the inbuilt characteristics and behaviours of the markets. This also is consistent with gas market where shock persistence dies slower than that of crude oil. Again, EGARCH proves to be the most suitable model for Title Transfer Facility, just as it is for Henry Hub and National Balancing Point.

Table 16 - Model selection for Title Transfer

	TGARCH	EGARCH	PARCH
ω	-0.0332	0.0399	-0.0079
	(0.016)	(0.022)	(0.0195)
Ψ	0.5636	0.9715	0.9067
	(0.177)	(0.007)	(0.0137)
P-value	0.0015	0.0000	0.0000
ξ	-0.0535	0.0136	-0.0978
P-value	0.0001	0.0001	0.009
λ	3.1708	3.1708	66.352
AIC:			
Normal	4.1740	3.8010	4.300
Student's-t	4.0425	3.6719	4.060
GED	3.9244	3.7115	4.7705
SIC:			
Normal	4.1908	3.8179	4.3196
Student's t	4.0622	3.6916	4.082
GED	3.9440	4.7889	4.7930
HQC:			
Normal	4.1802	3.8072	4.3072
Student's-t	4.0497	3.6791	4.0681
GED	3.9316	3.7177	4.7787
ARCH-LM Test			
F-Test	47.9803	1.0049	3.4359
nR2	46.8961	1.0055	3.4334

Source: Computed and presented by Author

Coming very close to EGARCH is PARCH in all the selection criteria. However, AIC again proves to be the best criterion and in it, EGARCH out-performs all other models. The exaggerated value of shock persistence in TARCH which shows in all the markets especial in ZeeBrudge that shock dies out quickly differs from true observation of the natural gas price which usual shows a drag after-the-events of crude in most volatility examinations and observations.

The superiority of EGARCH is not in doubt as it proves to be the most suitable model in all the four major global gas markets. Therefore, EGARCH is the model of choice for this project.

However, in line with practice, the selected model will also have to be estimated ex-post to prove that it can curtail the serial correlation and cure the heteroskedastic manifests of the returns. To this end, we turn to post estimation procedure.

4.2.5 Result from Model Selected

The same exercise, procedure and equations are used in the post-estimation just as in the pre-estimation, and the aim is to look at the same serial correlation and the presence or absence of heteroscedasticity. The same instruments and measure of judgement also follow.

The result of the post estimation is presented in Table 17 below.

Table 17- Correlogram of EGARCH residuals

	Henry Hub	Balancing Point	Title Transfer	ZeeBrudge
AC1	-0.004	0.022	0.016	-0.013
AC2	0.009	-0.001	-0.005	-0.057
AC3	-0.002	-0.017	-0.030	0.001
AC4	-0.007	-0.009	0.004	-0.019
PAC1	-0.004	0.022	0.016	-0.013
PAC2	0.009	-0.002	-0.006	-0.057
PAC3	-0.002	-0.017	-0.030	-0.001
PAC4	-0.007	-0.009	0.005	-0.022
Q-Stat1	0.0389	0.9731	0.5002	0.3341
Q-Stat2	0.2039	0.9761	0.5566	6.7508
Q-Stat3	0.2091	1.5326	2.3530	6.7522
Q-Stat4	0.3164	1.7077	2.3825	7.4720
p-value	0.989	0.789	0.666	0.113

Source: Computed and presented by Author

The lean values, going almost into insignificance as they are almost nil to the second decimal in both the AC and PAC at all levels demonstrate the absence of serial correlation. Also observe that the value of Q-Stat in Henry Hub for instance against the hypothesis that says that all the correlations from lag one to four equal to zero is 0.3164 compares to 441.77 in the descriptive statistic when there was serial correlation. The *p*-value says it all. Even at 0.113 as in ZeeBrudge market for instance, the null hypothesis that there is no serial correlation in the returns in all the market cannot be rejected. Therefore, EGARCH has completely curtailed the effect of serial correlation and can be used to model global natural gas market effectively and efficiently in any of the markets.

Table 18- Heteroskedasticity of EGARCH

Dependent Variable: Gas Price returns (r_t)												
Market:	Henry Hub			Net Balancing Point			Title Transfer Facility			ZeeBrudge		
Model:	F-test	nR^2	p-v	F-test	nR^2	p-v	F-test	nR^2	p-v	F-test	nR^2	p-v
k = 1	0.53	0.53	0.466	0.97	0.97	0.3242	0.49	0.49	0.48	1.52	15.17	0.13
K = 2	1.31	2.63	0.269	0.49	0.98	0.6117	0.28	0.56	0.75	1.11	16.65	0.34
K = 3	0.88	2.65	0.449	0.51	1.54	0.6728	0.77	2.33	0.50	0.93	18.56	0.55

Source: Computed and presented by Author

Going by the *p*-values, there is no ARCH effect in the EGARCH model.

Having accepted the use of EGARCH and obtaining proofs of no serial correlation and ARCH effect, the whole market returns need to be re-run on this model to fully describe the behaviour and characteristics of each market. The results are presented in Table 19 below.

Table 19: EGARCH Results of the four markets

	Henry Hub	Balancing Point	Title Transfer	ZeeBrudge
ω	0.0267	-0.0293	-0.0150	-0.0264
	(0.029)	(0.0237)	(0.0249)	(0.0219
Ψ	0.9701	0.9795	0.9544	0.9983
	(0.011)	(0.003)	(0.0048)	(0.001)
P-value	0.0000	0.0000	0.0000	0.0000
ξ	0.0789	0.0609	0.1012	0.0491
P-value	0.0000	0.0000	0.0000	0.0000
λ	83.584	389.41	198.28	1058.7
AIC:				
Normal	4.8867	4.2983	3.8023	4.1417

Source: Computed and presented by Author

At a back-cast parameter of seven, the volatility persistence is the sum of ARCH and the GARCH terms in the EGARCH model (Ψ) is captured in C (6) of the equation 43 while the asymmetry coefficient (ξ) is captured in C (5) in the same equation. Recall that if the (Ψ) is close to one, it connotes that the effect of the shock is assumed to have a permanent effect otherwise, the effect of the shock dies out rapidly. Also, if the sign of (ξ) is positive and statistically significant, it portrays that negative shocks increase volatility more than positive shock and if the sign is otherwise, the reverse is the case.

$$\log(\text{garch}) = c(3) + c(4) * \text{abs}(\text{resid}(-1)/@\text{sqrt}(\text{garch}(-1))) + c(5) * \text{resid}(-1)/@\text{sqrt}(\text{garch}(-1)) + c(6) * \log(\text{garch}(-1))$$

Equation 45

Looking at Table 19, all the signs of asymmetry are positive and statistically significant at *p*-value = 0.0000 in the global natural gas market represented by these four leading regional markets. Negative shocks therefore increase volatility more than positive shock. This is consistent with the finding in the descriptive statistics discussed above. A re-visit to the four volatility graphs shows how negative shocks in the four quadrants selected increased volatility more than positive shocks along the periods and in the quadrants. It is pertinent to make emphasize that (ξ) is crucial to the investor because it connotes the leverage effect which is a key signal in investment decision as the impact of bad news in the market differs from the effect of good news.

This brings to an end the use of econometric in analysing the qualitative result from which the following questions have been answered as in the summarized Table 12 above.

4.2.6 Results from analysis of domestic statistics

The question regarding effective demand for gas in the sub-Sahara African region raised in literature was to ascertain if gas business will be profitable in the region in the eyes of an investor. Unlike the popular effective demand theory in economics which deals with utilization of mix factors of production, effective demand here is ability to pay the asking price of gas that will result into profit for the investor. The key to unlock this overarching answer to effective demand question is the break-even price for gas. We will look at it from the point of the investor.

The components of the full gas production cycle costs in no particular order comprise selling, general and administrative expenses; property acquisition costs; finding costs; cost of geological and geophysical work; licensing rounds; signature bonuses and the costs of drilling exploration wells. The cost of acquiring, development, constructing, and installing production facilities and drilling development wells are also part of the gas production cost. There is also the cost of lifting.

This research initially identified the LaGrange multiplier to estimate a profitable operation using the cost items mentioned above as well as use elasticities to estimate competitiveness of gas in the region's energy basket. But Schaefer (2009) has made these exercises unnecessary as he presented a conservative break-even cost at US$7.25/mcf. This single datum suffices in the deriving answers to these questions on effective demand and the relationship of natural gas price and other energy commodities in sub-Sahara African Region. Additional information from a recent conducted focus group discussion with the

Nigerian National Oil Company states that “*Upstream gas development cost could range from $0.3 - $1.5/mcf depending on the terrain, size of field and phase of development (i.e. if there is already presence of adjoining facilities to tie-in) Above stated cost excludes gas processing facility which could range from $1 - $2/mcf.”* Comparing this to Schaefer (2009) estimated cost of US$7.5/mcf translates to a saving of US$4.00/mcf for investing in sub-Sahara Africa. It is therefore a paradox on why the investment inflows have not been commensurate, given this savings in the cost of production. It is this paradox that makes the quantitative research inconclusive, requiring a supplement from qualitative approach.

4.3 Gas competitiveness

Pump price for gasoline is US$1.32 per litre while that of diesel is US$1.17 per litre in sub-Sahara Africa according to World Bank 2018 statistics. Comparing this with Schiefer’s breakeven gas price of US$7.50 in absolute terms seems to put gas in disadvantage in terms of market competitiveness. However, domestic gas production is estimated at US$3.50/mcf. In calorific value, this translates to US$0.45 per litre which generates a saving of US$0.87 per litre making room for absorptive market capacity. Ordinarily, the identified market absorptive capacity serves as an attractive investment signal. But this is not the case for investors out there doing gas business elsewhere. Answers to quantitative questions still leaves gaps on general question why not invest in sub-Sahara Africa?

4.4 Summary

The search for answers to quantitative questions raised in literature for work of modelling natural gas market for sub-Sahara Africa has taken this research work to the four-top global regional markets where the sub-Sahara Africa natural gas is currently trading. An exhaustive modelling exercise is deployed, and results derived for the use in modelling the sub-Saharan market from quantitative approach. Five of the seven quantitative questions raised bordering on volatility and threat to returns were answered by the quantitative techniques through test of hypotheses. Data on the domestic condition of region helped in answering the rest of the remaining two questions on effective gas demand and competitiveness of gas in the commodity basket of the region. Overall results do not fully illuminate the underlying reason why investment inflows are not commensurate with expectation. Quantitative results rather provided the possible models for volatility which could be applied to the region as well as show completeness of gas in its market absorptive capacity. Therefore, resting the research on the conclusion of the quantitative estimation would be a half-done job and is likely to keep current gas production of natural gas in the region which is less than 1 per cent of its endowment in that position perpetually. It is imperative therefore to expand the search for answers to the owner of the constrained natural resource that is, the governments of the region. This is why this research has to turn to qualitative techniques through semi-focus group discussion survey with the key policy bodies in the region to answer the remainder of the questions.

Be as it may, the quantitative results have equipped the research with tools, information to develop a market model for sub-Sahara Africa to be tested.

CHAPTER FIVE: PRESENTATION OF QUALITATIVE RESULTS

5.1 Introduction

Reviewed literature offered a picture of the nature, complexities and peculiarity of the oil and gas industry that differentiate it from other economic entities. However, literature has not exhaustively covered the dynamics of the industry especially gas which not long ago was considered a waste product of the main carbon hydro desirable commodity – crude oil. The dominant dynamic factor which is at the bedrock of the nature of oil & gas industry is regulatory economics born out of policy and varies, not only from country to country but from a gas or oil production well to another well, even in the same terrain. These gaps from literature therefore impelled a search for answers which eventually led to a survey conducted by focus group discussions with the two dominant economic agents in the industry - the investor and the owner of the natural gas resource. These dominant economic agents are represented by government agencies holding these natural assets for the economies of sub-Sahara Africa and operators investing in the industry. The results of the survey are presented here in this chapter and are used as a basis for the modelling of the natural gas market for sub-Sahara Africa.

To conform to best practice of qualitative research process and in line with literature such as the works of Welman and Kruger (1999), Blaxter et al (2006), Van Teijlingen (2001) and De Vos et al (2002) a pre-test was undertaken on the very respondents, by sending them talking points covering the areas of interest in advance. This was to detect in advance, likely flaws in the questions of interest, clear ambiguity and generally avoid any risk of prejudice to the required answers. This was easy to do because, the survey instruments where open-ended questions put in the form of talking points and sent to the respondents in advance before the focus group discussions. This helped in no small measure in clarifying grey areas at the start of the focus group discussion and engendered a seamless and productive discussion that availed the right information required as presented hereafter.

It is pertinent to mention that the entire conduct of this survey follows pattern in literature and professional conduct of qualitative research holding sacrosanct the central issues in qualitative research such as creditability, dependability and validity as in Lincoln and Guba (1985).

The chapter is in five sections after this introduction and it starts with the fundamental issues of the survey in 5.2 which covers seven sub-topics. These sub-topics include sample and sampling techniques; method of data collection techniques; justification of survey method selection; the physiognomics of the respondents; design of survey instruments; the level of participation and method of data analysis. The main research finding is presented in section 5.3 under three thematic areas. Section 5.4 is devoted to the analysis of research findings while section 5.5 concludes the chapter.

5.2 Fundamental issues of the survey

This survey starts with taking the critical issues of qualitative survey upfront, aiming to fulfil the irreducible minimal in the standard requirement of contemporary qualitative research and strives to meet best practice in the field of research as in the sub-sections below.

5.2.1 Sample and Sampling Techniques

In view of the dominant role of regulation and the impact of policy on energy commodities in general and gas in particular, this research project has to take the whole gamut of economic agents that are responsible for energy policies in sub-Sahara Africa, either as policy formulators, regulators, implementers and operators. In one umbrella, the African Union brings all the regional energy issues under its purview. This way, a survey of that institution is by extension the survey of the whole energy landscape of the region as far as regulatory issues are concerned. Nigeria according to BP 2016 statistics is the main driver of gas business in sub-Sahara Africa with almost 80% of its proven reserves and 70% of its supply. Documentary evidence like published accounts of the National Oil Companies of Nigeria and Angola show that Nigeria also has more than 40 decades of oil and gas business experience ahead of all the states of the region with the exception of Angola which has been an active producer of oil. The global oil & gas majors operate in Nigeria and saturate key executive positives in the policy institutions and purpose vehicles that drive policy issues regarding gas business in that country. Therefore, a focus survey on Nigeria as this survey has done is in some way, a survey of the 80% of the market in terms of reserves and 70% in terms of operational experience. It also creates an easy access to the global energy giants like BP, Chevron, Exxon-Mobil, Shell, Eni and a host of marginal operators to get information on policies affecting investment decision. Therefore, the National Oil Company and its three sub-organs specifically carrying its natural gas business are covered in the survey. The only trans-national gas pipeline business in the region, that is, the West African Gas Pipeline was also covered in the survey with the full participation of its regulator.

The necessity of stretching the coverage of the survey over the entire population of policy and regulatory institutions is to harvest a large size and rich pack of information with high quality. Each and every institution is purported to play a different role, has different experience and reflects differing dynamics in the region. Leaving one institution out of the survey by way of sampling may jeopardize the quality, richness and loss of vital information required for modelling the natural gas market for the region, using regulatory approaches. Therefore, sampling techniques such as those offer by Sandelowski (1995), Patton (2002) and host of others are not required. Rather, an all-engaging and comprehensive population coverage of the economic agents are undertaken. What would have qualified for sampling would have been the set of operators' focus group discussion. But given the fact that they appear to speak the same language and have a convergence and common source of knowledge, they are by extension, can be considered as representing the entire population of operators. It is also to be noted that operators are beneficiaries of policy rather than the formulators or implementers.

5.2.2 Method of Data Collection

Several qualitative research methods were considered to arrive at the best fit method for this survey, with the main focus on capturing as much information as possible without prejudice to quality and richness of data. These methods which feature prominently in the works of Brannen (1992), Creswell (2006), Tashakkori and Teddlie (1998), Smith (1988), Lincoln (1994), Bjonholt and Fastad (2012) and Carey (1993) include focus study groups, case studies, participant observation, non-participant observation field notes, reflective journals, structured focus group discussions, semi-structured focus group discussions, unstructured focus group discussions and analysis of documents and materials. Depending on the exigency, convenience, suitability, ease and timing and scope of the research, most of the aforementioned methods are in use.

In this particular research work, the semi-structured focus group discussion is adjudged the best fit as it relates directly to market research, reflecting the attributes of key informant market research survey in Morgan (1988). McNamara (1999), Kerlinger (1970) and Fontana and Frey (2005) uphold the relevance of focus group discussions in a research like this. Justification for the choice of this method amongst various methods mentioned above is explained in the next sub-section.

5.2.3 Basis for Semi-Structured Focus group discussions

In Savin-Baden and Major (2013) focus group discussions (structured, semi-structured and unstructured) and public and official and personal documents and historical items are held as the most common methods used in generating data in qualitative research methods. These are among a plethora of qualitative techniques such as experimental, observational to questionnaire surveys.

Several factors dictate the choice of semi-structured focus group discussion in this project. Foremost is the ease, platitude and open-ended free flow of discussion focus group discussion provides, especially when it is tailored to a focus group discussion as in this research project. Mack *et at*., (2005) affirm the ability of a focus group discussion to harvest a sizable amount of information in a short period of time, than any other data collection method. The same authors confirm that focus group focus group discussions are effective for accessing views on specific topics. These enable pre - testing to be integrated into the main survey in one frame by sending topic guide on questions to be discussed in advance to focus group discussions before the main focus group discussion session. In this way, ambiguity, misunderstood contents and insufficient rendition as well as a good preparedness are assembled to form the starting point of the discussion. O'Cathan et al (2014) uphold these feats of focus group discussion technique and provides evidence that it leads to added value in qualitative research methods. Secondly, it provides an open-door for receiving additional information in the form of confidential documents and historical items useful to the study that are not in public domain. These documents are not only useful as additional information but serve as essential material to check the trustworthiness of the data generated during the focus group discussion. Ranney et al (2015) use this as practical field work strategy to check threats to data. Thirdly, it allows the use of simple but effective internal validity, accuracy of data and quality control technique known as member check. Creswell (1994) eulogises the potency of member check technique in qualitative research, especially in gaining credible data generating outcome. Number four, the focus group discussion technique engenders a total quick turnaround time and achievement of the high return rate of success. In just about three weeks (travel time excluded), the survey of five corporate organizations spread over a continental territory was complete and 100% target audience achieved.

5.2.4 Physiognomic of Respondents

Following Sekaran (2001), the scope of this survey can be qualified as a population in size as it covers the entire key institutions related to this second part of the research approaches (regulatory approach) in the continent of Africa as far as natural gas fuel is concerned. These institutions include the African Union, Economic Commission for Africa, Nigerian National Petroleum Corporation, Nigeria Gas Company Limited, West Africa Gas Pipeline Authority, Gas Invest Company Limited and Gas Aggregation Company of Nigeria.

i. The African Union

African Union (AU) is the umpire body for energy policy and development in Africa. A study in the African soil without the input of this organization will not be encompassing. AU has the mandate of the continent to integrate the socio-economic aspiration of the continent and deliver a prosperous and sustainable economic blue print in all the sectors of the African economy. Headquartered in Addis Ababa Ethiopia, AU is made up of eleven organs each headed by a designated commissioner at the level of a foreign minister. Each commission is sub-divided into departments. Natural gas business falls into the Department of Energy headed by a Director, in the Infrastructure and Energy Commission. The AU charter states that the organization is responsible for ensuring the development of energy resources at the regional and continental levels. Unbundling its package of services reveals that the roles under its purview include promoting; coordinating; implementing and monitoring programmes and policies on energy. Facilitating private sector initiatives on energy development and advocating among development partners for programme implementation are also among its key roles. It has a symbiotic and collaborative strategic alliance with the African Regional Economic Communities (RECs) and AU specialised institutions and agencies like the African Development Bank. The most attractive features in these clarion roles are promotion of regional policies and facilitating private initiatives on energy development which are clearly understood as promoting investment policies, according to the charter establishing the organization. It is interesting therefore to note that by these functions alone, this institution hosts a veritable source of data that would be useful in modelling natural gas market from regulatory approaches and the use of semi-structured focus group discussion is the best tool among competing techniques to collect the required information. The focus group discussion was held with AU Head of Department of Infrastructure and Energy and his team of experts on natural gas.

ii. *<u>Economic Commission for Africa</u>*

Head Quartered in Addis Ababa Ethiopia also, the Economic Commission for Africa (ECA) is the branch of the global United Nation Economic Commission in charge of the economic affairs of Africa. ECA has eight organs ranging from Macro Economic Policy to Natural Resource Management. A dedicated Statistics organ is among its eight organs. ECA's mandate include promotion of investment in Africa, repositioning ECA to better respond to Africa's priorities, enhancing domestic resource mobilization among other goals. The selection of this institution for focus group discussion was influenced by its roles of promoting private investment and enhancement of domestic resources which includes natural gas resources. In reading its focus on the natural resource management group, this researcher identifies that conducting policy-oriented research aiming to support regulatory framework for proper management of Africa's natural resources in Africa is also a key role of the organisation. Questions therefore regarding attractive policies to investors, risk of doing business, raised in the literature are best tabled to this organization for answers. Consequently, the focus group discussion was held with the Resource Management Group team headed by The Chief, Industrialization and Infrastructure Section under Energy Division is.

iii. *Nigerian National Petroleum Corporation*

Nigerian National Petroleum Corporation (NNPC) is in charge of the Nigeria oil & gas business and it is the largest share of gas in Africa. The oil & gas policies of this African giant Nigeria are the exclusive preserve of the NNPC. The company has demonstrated global capacity in terms of regulatory framework regarding its gas business with landmark policies such as Gas-to Power initiative, gas flaring law and the Nigerian Gas Master Plan. Therefore, this organization qualifies for focus group discussion in search for answers to questions raised regarding effectiveness of current policies in attracting investment. The gas master plan has been in existence for about two decades and none of its set investment objectives has been achieved. It is instructive therefore to hold discussions with this organization in other to understand why such investment goals have not been achieved. The Chief Operating Officer and Group Executive Director Upstream portfolio of the organization raised a team of expert who participated in the focus group discussion.

iv. *Nigerian Gas Company*

The Nigerian Gas company is an operator in the gas business with outreach to international market. It is therefore in position to provide answers from investor’s point of view on issues bothering on investment interest. The company was established in 1988 as one of the eleven (11) subsidiaries of the Nigerian National Petroleum Corporation (NNPC). Initially, its main purview was gas processing and marketing, where it gathers natural gas, treats it and transmit the natural gas processed and its by-products to its customers both domestic and international. Presently, it is charged with the responsibility of developing an efficient gas industry to fully serve Nigeria’s energy and industrial feedstock needs through an integrated gas pipeline network and also to export natural gas to the West African Sub-region. This additional function has made the company a fully diversified entity bearing both private investors’ and government’s interests. These features therefore make Nigerian Gas Company Limited a veritable source of information for a project like this. Its more than three decades experience in the gas industry is also an attractive feature for survey destination. The focus group discussion was attended personally by the Managing Director of the company and a team of gas business experts.

v. *<u>Nigerian Gas Aggregation Company</u>*

The National Gas Aggregation Company (NGAC) is a key market participant in sub-Sahara Natural Gas Market created by the Nigerian government as an operator for its national domestic gas supply and pricing policy. NGAC is a joint venture between the Nigerian Government and the oil majors operating in that country. As a policy establishment, especially price related policy, NGAC is a natural choice for survey on questions and gaps in the project of natural gas market model from policy arena. Discussion with the management of the company therefore was in the right direction in terms of information gathering from policy realm. The acceptance of the MD/CEO of the company and eventual attendance in the focus group discussion was a rare success for the survey outreach.

v. West African Gas Pipeline Regulatory Authority

By treaty, the West African Gas Pipeline Authority (WAGPA) was established to regulate the West African Gas Pipeline (WAGP) Project signed by the Heads of States of the Republic of Benin, the Republic of Ghana, the Federal Republic of Nigeria and the Republic of Togo. Key among such regulatory functions is formulating policies on price of gas, fees and commissions of the pipeline to be managed by the West African Gas Pipeline Company (WAGPCo) which operates the West African Gas Pipeline (WAGP). The WAGP is a creation of a sub-Regional governments of the four countries in West Africa by charter for the transportation of gas from Nigeria’s rich gas region to other economies of the West African Region. Apart from the four sub-Sahara African countries, other shareholders of the company are Chevron, Nigerian National Petroleum Corporation, Shell Overseas Holdings Limited, Takoradi Power Company Limited, Société Togolaise de Gaz, and Société BenGaz S.A. This strategic company therefore is important in the survey for a project on the gas market in sub-Sahara Africa. Its twenty years’ experience in the regional gas business would be useful to this project especially experience on how government policies have affected its operation so far. As in other establishments, the Director General and a team of experts attended to the researcher.

vii GasInvest Limited

GasInvest Company is owned by the immediate past Group Executive Director of Gas to Power Division of Nigerian National Petroleum Corporation. Members of the Board have at one time or the other occupied key top-level positions in Shell, Chevron, Exxon-Mobil to mention a few. This group is deliberately chosen by this researcher for three reasons:

i. To get independent opinion on the gas business environment in sub-Sahara Africa
ii. Their renditions are to serve as a counter check to information received from the current practitioners representing their organization
iii. It is believed that this group will have rich knowledge as seen from their profile.

5.2.5 Design of survey instrument

Saundera et al (2003) emphasised the effect of the design of a survey instrument on the validity and reliability of information collected. Oppenheim (1992) re-echoes the importance of paying crucial attention to designs of survey instruments. Therefore, in designing the survey instruments for this project, a thorough search for guides, pathways and directions was engaged. From this exercise, Mack et al (2005) was found useful supported by suggestions derived from various research works in literature referred to in preceding discussions above. In line with lessons learnt from the guides and best practice discovered, the structure of the design started with ethical issues where ethical problems were identified and resolved to meet the best standard of research ethics required. Next in the structure was the logistics for focus group survey, that is the reality and feasibility of achieving success on the focus group discussion as planned. The entire conduct of the focus group discussion which encapsulates managing the focus group discussion process, engaging participants all through to handling of the information collected concludes the structure of the design instrument which came out as open-ended field notes. Beginning with the ethical issues, this researcher meticulously followed the Abertay's ethical process in the recent 2017 - 18 Research Degrees Student and Supervisor Handbook. A critical ethical issue flagged up in the Handbook and overwhelmingly supported by professional researchers is the consent of the participant when it involves human participation. According to the Handbook and in line with professional research ethics, it is incumbent on the researcher to disclose fully, explain clearly the purpose of the survey, objectives of the research and the role of the participant in the project and reasons why they are selected. The researcher should endeavour to make it clear that participation is voluntary and can be withdrawn at any point of the focus group discussion process. This researcher follows these tenets strictly in the design of the survey instrument where it was explicitly stated that participation is voluntary after disclosures of the purpose of the research and the role of the participants were made clear. Another grave ethical issue in the field that needs to be upheld is confidentiality. The same mechanisms were used in addressing this issue during the design of the survey instrument.

The next stage in the design was an overture to participants which was enshrined in the structure where talking points were sent to the participants seeking their participation. This was followed with official letters introducing the researcher, the research area, the purpose of the study and the benefits to the participant and the sub-Sahara African community. It turned out to be that the subject area was a common concern and of universal interest to all participants.

The final stage of the design takes on the entire conduct of the focus group discussion starting with the researcher's preparedness. Mack et al (2005) recommend the split of roles of moderator and recorder that is taking notes. That is the best focus group discussion outcome that can be achieved when two researchers conduct the research sharing the roles of a moderator and recorder.

However, the role of mediator was taken care of by the advance talking points which were sent to participants upon which the participants' consents were received with some, adjusting and others taking the talking points absolutely without adjustments. This left the researcher taking notes and managing the process easily. These elements constitute the survey instrument that was used in collecting the information from various participating groups. An example is attached in the appendix. This survey instrument was in three sections with first section covering policies that could attract and sustain investment inflows for natural gas in sub-Sahara Africa. The second section was on risks of gas business in the sub-Sahara African region and third, gas tax systems.

5.2.6 Level of participation

All groups participated in the survey without exception. Each organization assembled their team of energy expert and demanded the revised talking points to be re-presented by the researcher. In three organizations, the researcher was made to present a synopsis of the entire project and then, followed by the seventeen talking points. This is a survey in which one hundred per cent success rate was achieved.

5.2.7 Method of Data Analysis

The aim for validity and high quality of data from survey has continued to promote the increasing use of technology in the analysis of qualitative data, especially in complex cases. In most academic exercises it has become a norm that qualitative data analysis be supported by computer programs known in contemporary times as Computer Assisted Qualitative Data Analysis Software.

These include MAXQDA, QDA MINER, ATLAS.ti, Dedoose and NVivo. An examination of these popular softwares indicates that they are suitable in cases where textual data are analysed using statistical parameters. These computer programmes therefore aid significantly in transforming these textual contents into empirically valid data which contain actual value range to be tested against developed hypothesis. There uses are particular applied to coding which hitherto was done manually with poor result in analyst's efficiency. They are also in large cases good for storage and ease of retrieving information with some of them aiding in editing, revision, allow for sharing of work, peer reviews and recursive examination of data. In this research, none of these materials is required. The reasons behind this standpoint are not far-fetched. - The entire approach of the project both from investment and regulatory is price dependent. Price dependent requires specialised and advanced econometric models. Chapter four has analysed and presented the relevant econometric tools to be used in modelling the sub-Sahara Africa Gas Market. In essence the key part of the project which is quantitative has been completed. A re-subjection of information acquired from the focus group discussion survey is an exercise in futility.

The nature of information generated does not require further transformation. Besides they are meant to answer questions raised and fill gaps identified. There are no hypotheses raised that require testing. Therefore, the value addition from the use of computer software programme for transformational purposes is not materially significant. Avoiding such exercise is in no way detrimental to the quality and efficiency of the analysis of the information received.

Information generated fit the questions and gaps aptly. The final content which resulted from various stages of modification, clarification, rigor and confirmation pre-and-post focus group discussion are rich enough for the use of the project without further transformation.

There are operational documents such as charter, agreements, policies, documentary evidences and market practices in the key leading gas economies in the region supplied by the participants to be used as further checks. These are deemed to be more valuable than any computer aided instrument. The analysis is purely interpretive and would entail, matching contents derived from the survey with these documents to make informed decision.

However, the results as presented below are made in such a way that the anonymity and confidentiality of the respondent are preserved. Respondents are only given a number only known to the researcher following the serial sequence of the dates the focus group discussions were held.

5.3 Main Findings

Results of findings are collated and presented in three thematic areas covering the seven research questions raised from literature reviewed. Each section starts with a diagrammatic chevron showing the flow connecting the thematic area of the research interest with the research questions raised in the literature and finally ending with the focus group discussion questions that were discussed. In each section, the discussion is as follows:

a. Brief discussion on the theme followed by a schematic chevron flow of the process.

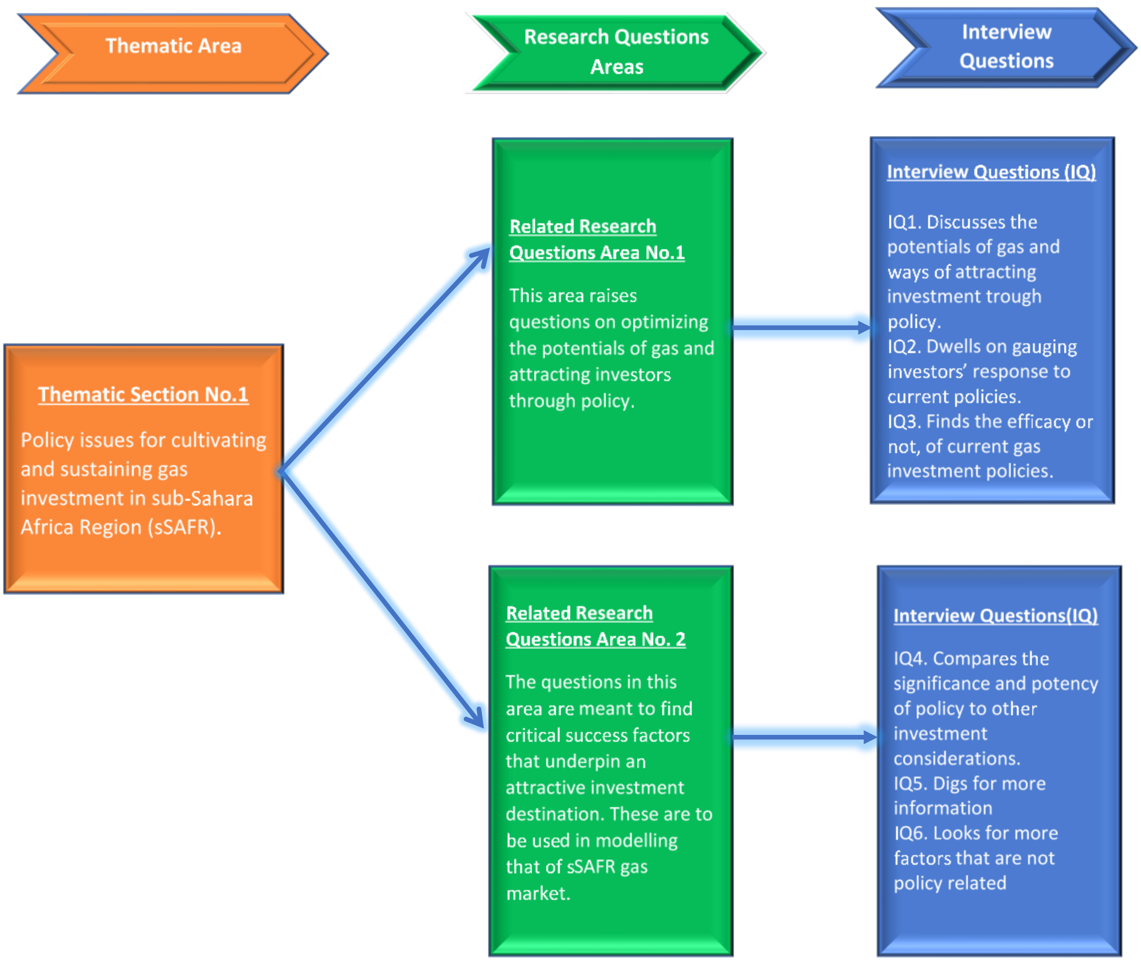
b. Report of findings as they are and as per the approval of the respondent group to be used in this project in the content and context rendered. These are tabled and coded as: *TA* (Thematic Area), *RQA* (Research Question Area) and *FGD* (Focus Group Discussion).

c. A brief synthesis of all the respondent groups in each thematic area to highlight major findings

5.3.1 Theme One – Policy Issues on Cultivating and sustaining interest in natural gas investment in sub-Sahara Africa

This section on cultivating and keeping investment flow is coming from one of the research concerns about the abundant potential opportunities gas enterprise could offer to the domestic economy of the region. Literature reviewed paints the picture of how the success of this industry relies on policy as in Cameron and Stanley (2017). This was the main reason behind selecting the top-level management of the specific policy making institutions in the region for these qualitative questions. The focus group discussion was conducted in teams raised by the respondent institutions, comprising experts and top management of the policy making departments. Below are their views as rendered and approved to be used in this project after this figure.

Figure 7 - Thematic Area One - Policy Issues



Source: From the Result of Focus Group Discussion

Figure 12 shows the flow from the main research concern connecting questions raised in the research that also link to the focus group discussion questions emanating from each question. What follows is the rendition of the focus group discussion.

i. Report of focus group opinion on policy area

Researcher: There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its supposedly huge market opportunities. This is why this research project aims to know the policy issues that could be used to optimize these market opportunities and attract investment into the vast gas endowment of the region.

Kindly therefore assist this research work by discussing the following questions in this regard:

1. ***T1/RQA1/FGD1**. What is your opinion regarding the current state of investment policies to optimize the vast natural gas reserves in sub-Sahara African Region and attract investment?*

Respondent Group 1	Judging by the level of current gas production, investment in the sub-Sahara African region is the poorest compares to the vast gas market opportunities available. Let us use Nigeria as the leading gas country in the region and in specific terms Kaduna, the Northern region of Nigeria where a giant textile industry, which has the capacity to improve the economic condition of the country is made dysfunctional because of lack of gas for industrial uses. In the same country side, there are ample need of gas for fertilizer production. Gas is the only raw material for fertilizer and there are willing private investors in the fertilizer industry but, investment cannot be actualized as there is no access to the critical feed stock, gas. This could also be attributed to lack of policies to drive the process.
Respondent Group 2	Demand for gas is huge, far beyond current production capacity in this region. The energy crisis facing the region can be addressed substantially, by developing the vast natural gas in sub-Sahara Africa. To buttress the point of desperate energy need, Ghana is commencing import of LNG. A sufficient gas supply would have saved this nation the huge cost associated with building a re-gasification facility to receive liquefied natural gas import. Countries as small as Benin Republic are considering the same initiation because of the desperate need of gas that is so vast under the sub-Sahara African soil but substantially under developed. But the policies to promote investment are not there.
Respondent Group 3	Gas investment is just a scratch of the surface in sub-Sahara Africa. Vast discoveries are made in the region, like the Mozambique and Tanzania proven reserves. However, investment to bring the gas out for use is not commensurate. These key industries; Agriculture; Electricity; household and transportation are gas-fed. The main concern is on Agric. The potentials of gas to Agric are enormous through fertilizer revolution. There is the need for the right policies to ensure that investment is commensurate to the gas opportunities in the region.
Respondent Group 4	The abundance of gas resource in sub-Sahara Africa and the potentials it holds for economic bounty of the region is not in doubt and not surprising. But what worries everyone is the current state of gas production which is just a scratch on the surface due to poor policies. Nigeria is known to be the seventh gas nation in terms of endowment having a proven reservoir of 180 trillion cubic meter of gas. Large gas reservoirs have been found in Mozambique and Tanzania and many discoveries are on the way. But the poor state of investment in the region due to

	poor policies is worrisome.
Respondent Group 5	Domestic gas investment opportunities are not in doubt. The fundamental GDP drivers of the African region are gas-driven. Agriculture which is currently the main pre-occupation of the region is potentially driven by gas in fertilizer and agro-processing. All that is required is the right policies. An industrial gas revolution in the region can benefit from its current gas endowment. Gas also holds the potentials to transform the transportation system of the continent. Note strongly that the sub-Sahara Africa natural gas market in summary is completely immature and is likely to remain like this if the proper policy and required enable factors are not put in place.
Respondent Group 6	In this country alone, we have 180 trillion cubic feet of proven gas reserve with upside, best in the world. This is from associated gas reservoirs alone. Our recent geological survey has shown that stand alone dedicated gas reservoirs have a combined total of 600 trillion cubic feet which is almost four times the current proven reserves. This is one side from the supply endowment. From the demand side, we have identified various gas dependent economic activities like agriculture, chemical industry, residential, gas-to-liquids demand, household liquefied petroleum gas, smelting plants and cement production. With the countries current railway initiatives, gas-fired locomotives in the transport segment is another consumer class. The potentials are there but what is lacking is the will power and the right policies to drive both the production side and create the right environment for emancipation of these potential consumer segments.
Respondent Group 7	From our experience as the main operator in the market, we can confirm that current investment in gas is just a tickle in the huge gas potentials of gas in Nigeria alone talk less of the sub-Sahara African region. This assessment is coming from the increasing demand we are facing from the country and the West African Region. As we speak now we have finalized a feasibility report to satisfy a demand for the creation of a 5,875 km pipeline of network and seven compressor stations to increase our services to the West African region. This is an extension of the current 681 km pipeline under the management of West Africa Pipeline. In Nigeria, on daily basis, we have been inundated with demands for gas all over the nation. To say the least, current investment is just a drop in the widening ocean of opportunities in the region.

2. ***T1/RQA1/FGD2.*** *What is your view about sufficiency and stability of policies in respect to investment behaviours in the region?*

Respondent Group 1	There is no evidence of policy sufficiency. The absence of the gas infrastructure policy has been mentioned.
Respondent Group 2	Lack of policies are glaring. Evidences abound that policies are hindrances to prospective investment appetites
Respondent Group 3	Policies are not sufficient. We have cited the recent cases of Tanzania and Mozambique. The Sahara Gas Pipeline between Nigeria and Algeria is another policy defeating project. We can continue with the West African Gas Pipeline which for many decades, has not utilized more than 30% of its installed capacity.
Respondent Group 4	We are in Africa formally to aid in policy insufficiency and our role in this area, for all the economic and social activities of the sub-Sahara African region has been expanding. Specific to energy which includes gas, policy insufficiency has remained the major concern.

Respondent Group 5	There are willing investors. The prevalence of the major oil companies in the continent is a testator to that fact. But gas requires specific policies to attract these investors and these specific policies are not sufficient.
Respondent Group 6	There is a lot to be done in the area of policy sufficiency, especially on the regional basis. If regional states like Nigeria which have been in the gas industry for decades are still far below in terms of policy sufficiency, bigger challenges are likely to be faced by prospective entrants like Mozambique and Tanzania where new gas discoveries are made.
Respondent Group 7	This is one of the constraints facing us – policy gaps.

3. ***T1/RQA1/FGD3.*** *From your experience, how powerful or not will you say about the current policies in keeping and expanding the level of investment in the gas market?*

Respondent Group 1	It seems to us that current gas policies in the region is not a deterrent to investors. This is coming from the prevalence and dominance of global investors like Shell, Chevron, Exxon Mobil, Eni, BP, and several majors and marginal private investors in sub-Sahara Africa in business of oil which share the same policies with gas. Using Nigeria as an example, these global oil giants have a respectful say in the policies of oil & gas in that country. Specific to gas, in responding to policy of domestic gas need by the Nigerian government, Shell, Pan-Ocean, Chevron, Exxon-Mobil and Total asked and were given a permission to create the Nigerian Gas Aggregation Company which is a neutral body to take and sale a domestic obligation of gas supply for them. The Nigerian LNG is also owned significantly by the same group. The only deterrent to gas investment is lack of a domestic market due to lack of infrastructures.
Respondent Group 2	While investment in Gas grows in other areas like the Arab region by the same global oil & gas giants operating in Africa, that of sub-Sahara Africa remains at 0.01% all through the years. Many gas finds are abandoned because of poor policies. The gas discovery and investment initiative in Tanzania has been truncated by poor policies. In West Africa, a noble gas project formed in 1988 by ECOWAS is yet to attain half of the designed capacity almost three decades after the treaty as a result of weak policy to attract investment
Respondent Group 3	We do have cases at hand currently where investors prefer to flare gas rather than investing on its production. In Mozambique for instance, governance issues are keeping investors at bay. The same thing goes for Tanzania
Respondent Group 4	The power of policy to attract investment is not enough. We have reviewed several cases of good investment that could not be actualized because of weak policies.
Respondent Group 5	There are evidences supporting this assertion that poor policy keeps investors away especially for specific gas investment. One of such evidences is clear preference for oil production investment compares to dedicated gas investment. Though oil and gas may be seen as one coin, their fundamental market dynamics differ substantially. Current energy policies in sub-Sahara Africa deters gas investment
Respondent Group 6	A realistic assessment from prevalent evidences points to the fact that current policies are generally weak to attract investment. In percentage terms, only 5% of investors that indicate investment interest eventually implement it and this 5% comprises small, green horns from domestic origin. The bigger tickets are held at bay because of weak policies.

Respondent Group 7	We cannot expand to other gas discoveries in sub-Sahara Africa because of unattractive policies, especially policies that have to do with environmental and communal issues

4. ***T1/RQA2/FGD4*** *Among fundamental investment factors like government policies on gas investment, the country's economic condition, community and environmental factors, which of these factors your organization will put more emphasis to create a strong appeal for investors in natural gas business?*

Respondent Group 1	Government policy is the all-encompassing instrument of attracting investment. Such policies determine the fortune and prospect of the economic condition of a country and by extension the sub-Sahara African Region. Key among such policies is infrastructural policy. Gas infrastructure is the main driver of gas business. First, governments should accept full responsibility of provision of gas infrastructure and accord the same priority to it as it does to railways, roads, airports and other economic entities that are of public provision by nature. Gas infrastructure therefore serves as a strong appeal to investors. We could confirm this with the success of shale gas in UAS where available infrastructure provided an attractive investment environment for shale gas prospecting and development. Key in this gas infrastructure is pipeline. In Nigeria, the construction of Egbim gas pipeline led to establishment of various industries in that cluster. Investment will flow if the right gas infrastructure policy is produced and enforced. Availability of the gas infrastructure keeps the cost of production down and enhances the profitability of investment outlook. It also opens access to domestic market.
Respondent Group 2	We are the regulators. Therefore, we are in the position to say accurately that the major area holding gas resources under the earth in sub-Sahara Africa is poor government approach to attract investment into the natural gas industry in the region. Our attention in terms of strategic priority is policy.
Respondent Group 3	Policy is the key to attracting investment. Policies are preceded by positive and forward-looking progressive governance. Once there is the desire to develop gas, effective policies cannot be in short supply and once there is the strong commitment to implement the derived policies, sub-Sahara Africa becomes the destination for gas investment. Policy continues to be our main focus.
Respondent Group 4	All the factors mentioned are policy dependent and policy driven. Get the right policy, all other factors will fall squarely in square holes. This is why we as a global economic policy institution, are here in the African region.
Respondent Group 5	The gas industry globally is policy dependent. Policy is the redefinition of the scope and magnitude of operation and practice of the industry. Ownership and market structure are purely shaped by the efficacy and sufficiency of policies in the energy market anywhere. So, policy becomes the overarching driver of the industry
Respondent Group 6	Policy is the overall driver of the gas game. Remember, this is a natural resource with so many challenges that only the might of government can control and the instrument for this control is policy.
Respondent Group 7	Although our case has a lot to do with community issues, but these issues are also policy dependent. So, policy is the overall game changer

5. ***T1/RQA2/FGD5** Could you share with us the basis of your answer to question 4?*

Respondent Group 1	For one, there exists regulatory weaknesses. Enforcement and managing policies are huge challenges that if fixed could address other issues like community etc. Second, it is only policies that can address other social concerns like the poverty and gap of technical and operational knowledge in the industry. Such dearth of knowledge are poor signals to investors. Therefore, taking all the issues mentioned, environmental, community, etc., these can be addressed by the right policies. They on their own cannot deter investment if there are good policies to curtail, address and respond to them in the right ways.
Respondent Group 2	Community issues, environmental and other issues related to gas industry are policy dependent. This is why we are harping on the delivery of the right policies and fore runner of policy delivery which is commitment from government. We use the case of West African Pipeline Company for example. Second is the poor pipeline infrastructural facilities. The investment climate generally is opaque. No clear and sustainable investment policy. The political will to enforce commitments is weak. In Nigeria for instance the issue of insecurity acerbates the hostile investment climate. No investor will want to invest in an unstable, unclear climate with weak legal framework and insecurity. The use and application of policies are actually a direct result of managing the issues raised such as environmental, community clashes and restiveness. So, the right policies are the main preoccupation and demand for effective gas investment.
Respondent Group 3	Everything boils down to lack of commitment that will bring in the right policies. The undeveloped vast gas discoveries in Mozambique and Tanzania surfaces again in relation to policy. Economic condition of a country is the direct result of prevailing policies. Concerns on environmental and community issues will naturally be there. But it takes good policies to deal with them so as to create the right environment for investment.
Respondent Group 4	The importance of issues like environment, community are direct input to policy formulation. Their manifestation, nature and features shape the kind of policies governments need to put in place to create a healthy and attractive investment climate. Policy therefore is the major instrument. Economic condition of a country is the direct result of prevailing policies. Concerns on environmental and community issues will naturally be there. But it takes good policies to deal with them so as to create the right environment for investment.
Respondent Group 5	Unlike crude oil, the value chain of gas is interconnected. In oil, crude drilled are taken to any market in the world with ease. For gas, the critical success factor of the business is to get an off-taker. The product is gaseous. It has to be used as soon as it is produced. Therefore, a seamless interconnectivity between producing wells to consuming points are critical. Aside from policies regarding licenses, effective policies regarding this critical artery of infrastructure are required.
Respondent Group 6	From our experience, every prospective investor looks at the prevailing policy. They take the overall policy prevailing, analyze it to formulate investment packages. They use the results against determined risks to take decision whether to invest or decline. Policy therefore is our major focus.
Respondent Group 7	The prevailing policies in every clime is the most important aspect of our investment consideration. It influences every aspect of our gas business and ultimately impacts on the profitability or otherwise of our business. We rely on policy

6. ***T1/RQA2/FGD6.*** *Besides policies, are there other critical success factors that may influence an investor's decision for instance anything to do with investment decision?*

Respondent Group 1	Nothing compares to the right policies. Profit motivation is a given factor, otherwise one would have talked on that. The primary concern of investors is profit and profit. And they will be happy to g*et* all income in the pursuit for higher profits. They are never satisfied with any level of profit. The provision of gas infrastructure serves as a strong appeal. The domestic market is vast, and it provides better business opportunities
Respondent Group 2	The right policies provide the right investment climate. There is no attraction in the face of reality that recouping invested funds is unsure. Second, the right policies drive the process. A factor in operation that holds at bay investment flows is the dominant participating roles government is involved in. Government is seen in several joint ventures. The GACN in Nigeria and LNG have government equity participation. The West African Gas Pipeline is dominated by the Nigerian government. Investors are not always comfortable with the involvement of government into the business. Market interreference in terms of price decision by government rather than market force is a huge set back.
Respondent Group 3	Issue of security is becoming a serious disincentive in investment consideration. We may not be wrong to mention that the implementation of the Trans-Saharan Gas pipeline is being threatened by manifesting security along its planned routes. The case of unwillingness of potential investors to develop the gas potentials of Mozambique due to government request to participate has proved that investment flows can be held at bay by government involvement. Price fixing by government sums up the unwanted market interference that turns investors away. We also note that investors want to have freedom to manage their production output. Lack of this freedom is a great dis-inventive to potential investors. A key issue however cannot be swept under the carpet. This is the issue of subsidy. Issues concerning subsidies are too numerous, we can only mention a few. Revenue leakage comes first followed by abusive behaviours in consumption. In many parts of the region, subsidies breads corruption. As subsidy is threatened by political instability in the region amidst lack of legal system to effect arbitration on breach of commercial contracts, investors shy away from this environment.
Respondent Group 4	We have found market interference in the form of price determination by government, subsidy envelopes, direction of product sales as huge disincentive to investment. No investor will contemplate putting capital in such environment. This is why we are ramping up our private investment programmes to help the governments of the region reduce its interreference in the market to allow the competitive price mechanism to take effect.
Respondent Group 5	Provision of critical infrastructure to serve as a spring board for the development of natural gas market in sub-Sahara Africa is a policy in a different way. This is social investment. This is what should be done to lift the market out of its current unstructured nature. Let us understand the nature of the gas market. The gas market is in three stages. The upstream comprising the exploration, production and processing facilities. The second stage is the mid-stream connectivity infrastructure comprising cross-border pipelines and LNG terminals storages. The final stage is a network of local transmission and distribution pipelines. The gas business is so interconnected in that there must be an off-taker at the third stage to prompt investment at the upstream. The middle is no body's business and it has to be ready to evacuate produce gas to the consumer at the third end before investment interested is elicited. It is this critical second stage that must be provided by the sub-Sahara Africa states in form of policy to attract investment interest. It is the absence of this infrastructure that investors shy away from the African region. Secondly, the off-taker at the end of the African market has creditability issues. The experience of Nigeria is worth sharing. Presently, supply

	of gas for domestic consumption has been experiencing instability because of inability of the off-taker to honour its payment obligation
Respondent Group 6	We recognize the criticism arising from the market about our pricing policy and demands for gas to be sold to some critical areas of national interest. This what the market calls price distortion and undue directives. However, our joint venture policy seems to be addressing these issues
Respondent Group 7	Government interference is a huge challenge. We have limited freedom to ask for gas prices in response to market dictates. We also are directed to sell gas to unviable and unprofitable areas. This has constrained our expansion drive.

ii. *Summary of findings: opinion of focus group on policy area*

In this thematic area regarding policies, all the focus groups decry the poor level of gas supply amidst large and expanding domestic demand for natural gas in agriculture, chemical industries, electricity, household consumption and transportation. They attributed the situation to lack of investment policies. To them, the gas thirsts can only be satisfied by creating a sufficient and sustainable domestic natural gas supply through the policies mentioned. A highlight of the key policies commonly agreed among the respondent groups to be responsible for the poor gas market in sub-Sahara Africa includes:

a. *Wrong policies on optimizing its natural gas resources*

All the focus groups view current gas policy choice of, and over-reliance on foreign exchange from gas and oil as against domestic consumption to fuel its economy as a major setback to a progressive and sustainable gas production specifically and a constraint to regions' economic growth. Respondents assert that policies of foreign exchange dependent distract the region from exploiting the potentials of gas to the domestic economy of the region.

b. *Poor Banking Policies*

Respondents point out that the poverty of banking policies stifles most efforts of investment proposals and operational practices. Respondents cite cases in which banks insufficient capacity, cannot support gas business with large tickets guarantees. They also add the poor banking policies is responsible for the huge debts owed to gas producers in the Nigerian gas industry.

c. *Infrastructural deficit*

All the focus groups harp on the none existence of a regional gas pipeline as it is in Russia, Australia, the US and other regions in which this particular infrastructure enables increasing and sustainable natural gas production. Their explanation is that the success of a domestic gas market, lies on the availability of a regional artery of gas pipeline network.

d. *Market segmentation*

To a majority of the respondents, a regional policy that will enhance market segmentation of the gas industry into clusters in the regional is a policy towards a successful natural gas market revolution. Such clusters according to the respondent groups should be done in a way that gas endowed regions would be grouped together as producer group, while viable and unprofitable gas users be clustered together, and gas pipeline supplied to connect these clusters.

e. *Government dominance in the markets*

All the focus groups decry the presence of government in the market. They raise the issue of pricing, explaining how price mechanisms are distorted by government interferences and unsuitable directives. Interferences in the market through subsidy policies government ownership beclouds private investment and stifle the functioning and maturity of the natural gas market in the region.

f. *Revenue Leakages*
All the respondents decry the huge revenue leakages due to poor policies. The groups assert that this situation is strong enough to deter private investment or any as the primary interest of any investor is security of revenue.

5.3.2 Section Two: Risk Perception on investment in the sub-Sahara African Region Gas Market

Literature review raises spectacular features of risks in gas investment that seem to be more intimidating than normal business risk. This led to the concern that risk may be at the root cause of the lack of investment in the gas endowment of sub-Sahara Africa. As there were no sufficient answers in literature reviewed, this research work had to go in search of answers to questions raised in its literature review on risk perception and its impact on investment decision in this region. As with policies regarding the domain of sub-Sahara Africa, no other person or institution would have the experience and knowledge of these risks than the industry operators themselves. It turned out to be that the same seven institutions selected for the focus group discussion on policy issues have been the risk managers of investment in the region of this continent. This was not surprising to the researcher as policy issues are entirely risk targeted instruments for effective management of their effect on investment. The researcher therefore went ahead with the focus group discussion, which was also conducted in teams raised by the respondent institutions, comprising experts and top management of the risk managers and policy making divisions under energy departments. Below are their views as rendered and approved to be used in this project.

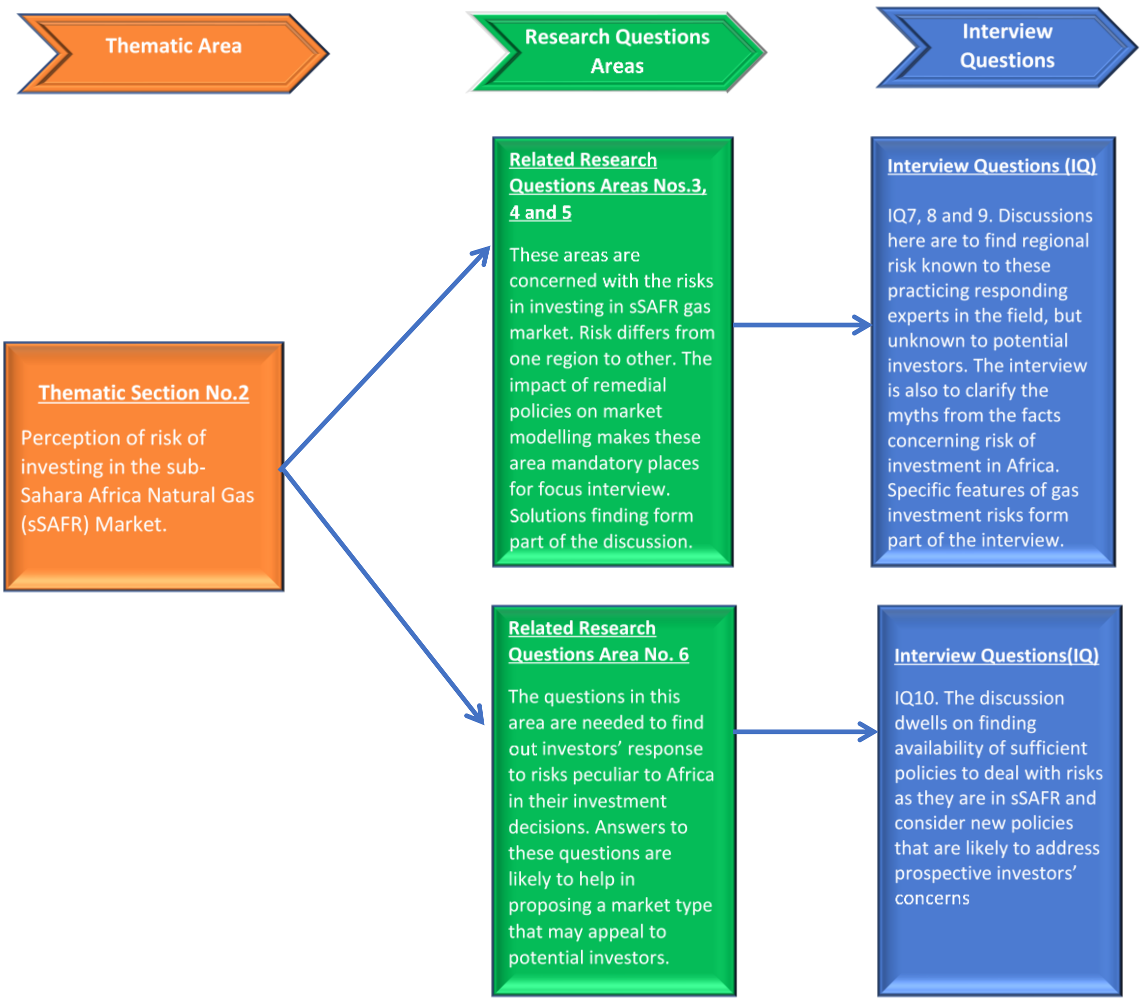


Figure 8 - Thematic Area Two - Risk Perception

Source: From the Result of Focus Group Discussion

The figure shows the flow from the main research concern connecting questions raised in the research that also link to the focus group discussion questions emanating from each question. What follows is the rendition of the focus group discussion.

i. **Focus Group Discussions - Risk Perception**

***Researcher*.** One of the peculiarities of the oil & gas industry, which differentiates it with other industries, is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

Kindly therefore assist this research work by discussing the following questions:

7. ***T2/RQA3/FGD7.*** *From your experience in the industry, what is the risk of investing in sub-Sahara Africa compare to gas business in other regions?*

Respondent Group 1	There is no risk-free endeavor anywhere. It is just a matter of magnitude and risk differs from one area to the other even within the same country. However, issue of risk is guided, controlled and executed by the reward outcome. If the reward is high, risk becomes less worrisome and vice versa. Risk could be perceived to be larger in the African continent because of lower profitability profile
Respondent Group 2	Gas investment risks in sub-Sahara Africa can be intimidating and daunting. The risk of insecurity, the risk of instability in policies and poor legal framework are risks that could be daunting. A case in hand in Nigeria is gas supplied owed by electricity generating companies of US$1.6 billion that was pruned to loss because of inability to enforce the agreement due to weak legal system. That scenario alone is likely to be a major reason why we have not seen additional investment in the domestic Nigerian natural gas market because the major reason for investment is threatened. By extension, the same situation could also be responsible for the poor investment outlook of the entire region
Respondent Group 3	Increasing security challenges facing potential investors from prospecting to development where companies' staff are lost to death and kidnapping is ushering a new kind of risk in Africa. This alone puts off investment consideration in some notable areas of the region. These risks of kidnapping and killing are no longer perception but reality. There are also the risks of security to infrastructure such as vandalism and theft which are peculiar to this region.
Respondent Group 4	Risks of investment in this region are definitely larger than anywhere else. This has to do with the peculiarity of the energy industry which is more difficult here in Africa than other regions. For instance, the African governments depend on gas and oil almost 100% in their fiscal receipts. This is why government's presence permeates the operation of the industry. This presence alone is a risk to private investment
Respondent Group 5	Compare to global gas market, the African market has risks that are larger.
Respondent Group 6	Our presence in the operation of the industry is perceived as a risk by the private investors. They keep reminding us that "this is not the way things are done in so,

	so, and so places". The fear of profit repartition has also been mentioned by some of applicants for oil & gas blocks. In general, risks in this continent is considered larger than in places like the UK, even Russia according to responses gathered in our engagement with prospective investors.
Respondent Group 7	Our experience in Africa regarding risk of business is different from other regions. Attacks on pipelines infrastructures in Nigeria for instance is second to none. The community issues are enlarging themselves as communities confront us with unreasonable and unrealistic demands. We do not have these experiences elsewhere.

8. ***T2/RQA4/FGD8.*** *Do these risks have specific features rather than normal business risks found in literature and in some practices?*

Respondent Group 1	The legal system in the region is not effective enough to secure investment. Litigations from our experience have been dragging on for decades. Defaulters of contractual gas obligation are walking the streets free while gas suppliers are being owed substantial amount of money. This discourages expansion of gas investment in the region.
Respondent Group 2	Risk peculiar to the region are regulatory weaknesses and infrastructural deficits.
Respondent Group 3	Vandalism, kidnapping, governance issues and institutional weaknesses are risk features almost unique to sub-Sahara Africa.
Respondent Group 4	Weak institutions, especially the legal system, regulatory flaws, lack of enforcement of policies are peculiar risk parameters to the region from our global experience. This has dragged back investment not only in natural gas but in most key economic activities like mechanized farming, etc. There is also the lack of capacity from the domestic market to honour obligations.
Respondent Group 5	Risk features particular to gas investment in sub-Sahara Africa market include creditability issue, institutional weaknesses, insufficient bank services and access to transmission network.
Respondent Group 6	Lacks enforcement, inadequate legality, and poor banking policies add to the normal risks of energy market in the region. The banks do not have the financial muscle to help entrepreneur implement gas business proposal with good feasibility reports.
Respondent Group 7	The market structure and practice exert additional risks to us. You are asked to take a price that may not correspond to ruling gas price in the global market such as the Henry Hub that is our reference price. You are also required to sell to an economic agent that has no feasible capacity to pay. This has increased the risk to sales receivable and cash flows. This risk can only be found in this region.

9. ***T2/RQA5/FGD9.*** *How could they be addressed to attract investment?*

Respondent Group 1	From our experience and engagement, current investors have solution to the answer. They are experts in managing these risks and they have been succeeding to a large extent.
Respondent Group 2	An independent arbitration body where dispute can easily be resolved, and agreements entirely enforced is desirable. A regional gas network will serve as a huge incentive as this will reduce the cost of investment and make gas business competitive with global markets in the region
Respondent Group 3	Protection of live and property has to be on the top of the region's agenda
Respondent Group 4	The issue of institutional weaknesses and openness of the market to free forces of demand and supplier are irreducible decimals. It will also be useful for the region to start charting a course towards a regional single market.

Respondent Group 5	For one, the banking policies regarding gas investment should be improved. The current banking practice in sub-Sahara Africa is that letters of credit for equipment importation most be fully funded unlike in the advanced economies where just transaction fees are paid for such. The second is to address the issue of legal system. Third is the need for an independent pipeline regulator to help create access to available pipeline facilities. For example, in Nigeria, the available gas pipelines are not accessible to the operators. Nigerian Gas Company has the sole discretion to allow or deny usage. Fourth, payment guarantees should be raised to improve the credibility in the market. Currently there is about N320 billion Naira6debts owed by local consumers of gas in the Nigerian gas market. This kind of situation is behind the unstable gas supply in that country.
Respondent Group 6	We recommend a regional synergy to form a common system for the region. This will overcome several challenges such as regulations and open up the regional market
Respondent Group 7	With the establishment of a regional gas pipeline, most of the issues would be resolved

10. ***T2/RQA6/FGD10.*** *Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?*

Respondent Group 1	Well, the key variables are known to all such as 1) Rate of interest on invested fund, 2) cost elements per field and 3) the market price as shown in the trading portals of Thompson Reuters
Respondent Group 2	At every forum, investors never shy away from demands of tax allowances to reduce their risk of investment. Investors have a common platform in assessment and sharing of risks. These risks are adjusted towards a set profit objective. Each talks the same language in terms of expectations and assurances of a safe operating climate in a sustainable manner.
Respondent Group 3	Organizations from our experience have a target rate of return to compensate estimated risks. Where the risk of investment is beyond estimation or is not understood, outright rejection of investment consideration is exercised by the prospective investors. One thing that stands out is that they have a common platform. Their voice is one.
Respondent Group 4	We do not engage with investors directly, but we have opportunity to see their proposal when we engage with regional governments. One thing we see in those documents is that investors speak the same voice and have one primary goal – a positive return on their investment.
Respondent Group 5	This is not an issue to either party. There are some risks that rate of return cannot cover. The fundamental problems are those highlighted earlier
Respondent Group 6	This particular aspect is what we go through almost every day. Return on investment and its security and assurance are the preoccupation of every engagement we have with the investors. This can be termed as our preoccupation
Respondent Group 7	This is the hallmark of the business negotiation, rate of return. This is the primary negotiable instrument in all our investment preparation and presentations to the government bodies in our bid for investments.

ii. Summary of findings: Risk issues

In the second thematic area regarding risk of investment, respondents while rendering submission on risk attest that the risk of investing in the natural gas market of the region is not a perception but reality. The issues that were commonly discussed and agreed by majority of respondents are summarized as follows:

a. *Financial Risks*
   A majority of the respondent groups demonstrate how the weak banking environment as a policy deficiency serves as a serious risk for investing in the region. They explain that since there would be no financial support in terms of availability of financial instruments required to create confidence in trade, close financial gaps that could arise from unforeseen timing discrepancy along the value chain, this financial risk could be daunting especially for local prospective investors and start-ups businesses in the natural gas market. The groups cite the power industry in Nigeria which owes gas suppliers a monumental amount of debt.

b. *Risks from institutional weaknesses*
   Comparing the legal and regulatory from work to regions of successful gas operation, all respondents agree that the deficiencies in these key areas have altered the risk of gas business in sub-Sahara Africa than its peers.

c. *Insecurity*
   The issue of insecurity involving pipelines vandalism, ruptures and kidnapping and killing of expatriates and local staff was identified by majority of the groups as a new potential threat that may discourage investment interest especially as no visible solution has been found to eradicate or curtail its menace presently.

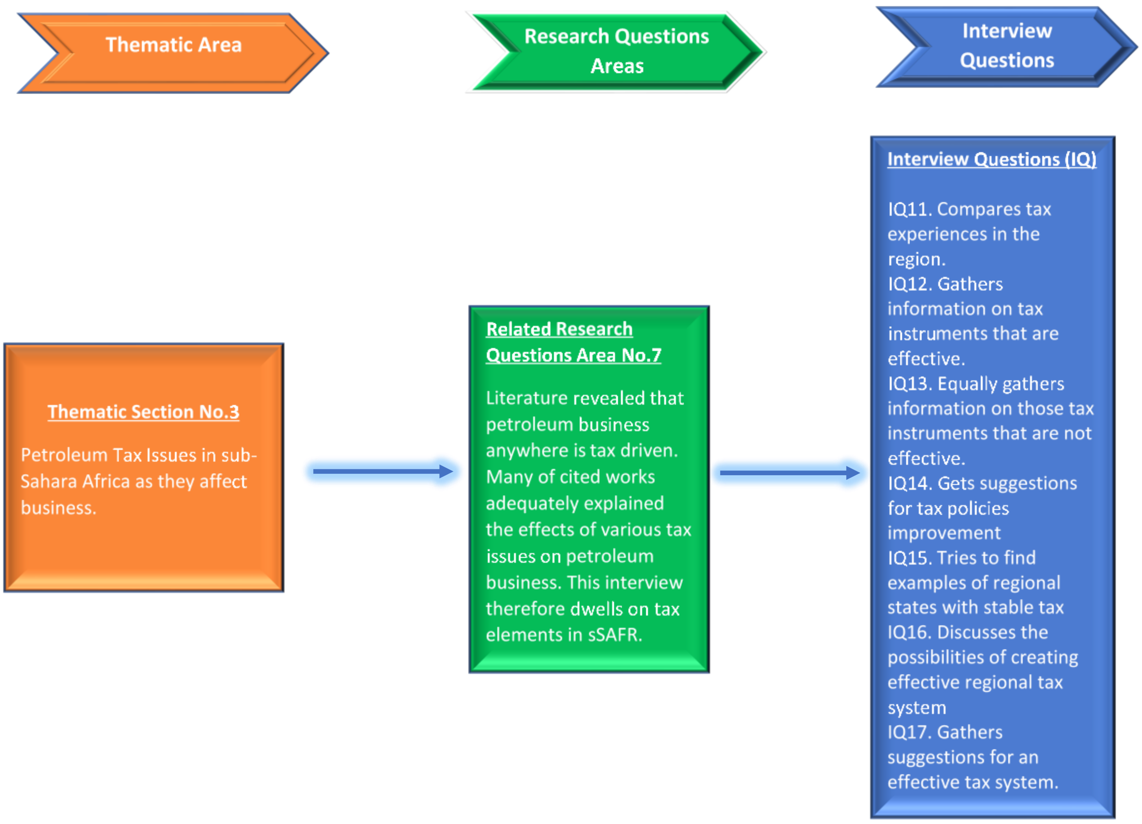
d. *Risk impact on potential investment*

Citing successful operations in the crude oil sub-category, all respondents agree that to some extent, the oil majors have capacity to manage the risks as they are in sub-Sahara Africa. The impact of the risks mentioned is potentially heavy on new entrants, local hopefuls and start-ups.

5.2.3 Thematic Area Three: Tax System in the sub-Sahara Africa Natural Gas Market

Tax system is the overarching issue both in practice and literature when it comes to gas and oil businesses. This third and final section is therefore vital for this research work. As a fundamental pillar in the construction of a market model for sub-Sahara Africa, this research work had to give substantial consideration to task issues. Literature review also supports this significant attention to task matters, as they come out to show how influential they are to investment decision. In order not to leave any useful information out, the participation of the regional experts on this matter have to be obtained. Interestingly, these tax experts turned out to be the same respondent groups. This is not surprising, as policy issues are tax-embedded and risk breeders depending on their structure and elements of operation. Therefore, the top-level management of the respondent groups participated in the focus group discussion on tax matters with their teams comprising management staff from their tax offices. Below are their views as rendered and approved to be used in this project.

Figure 9 - Thematic Area Three - Tax Systems



Source: From the Result of Focus Group Discussion

The figure shows the flow from the main research concern connecting questions raised in the research that also link to the focus group discussion questions emanating from each question. What follows is the rendition of the focus group discussion.

i. Focus Groups Discussions: Tax Matters

Researcher - Another area important to this research work is the tax system for gas industry. Kindly therefore help this research work by discussing the following questions:

11. ***T3/RQA7/FGD11.*** *Taking dominant countries in terms of contribution to the regional gas business, is there any country that has a tax system appealing to investors?*

Respondent Group 1	Tax issues are negotiable contractual agreements. By our experience, no group is ever satisfied with a tax package no matter how liberal it is. But judging by the involvement of the major world IOCs in the region especially in Nigeria which is the leading gas domain in the region, one can reliable conclude that the Nigerian oil & gas taxation is better placed.
Respondent Group 2	Nigeria is the trail blazer in the region. Its policies and operation reflect the region's position. However, tax system is not the issue from our experience as they have capacity to negotiate a tax commensurate to their risk. But the risk of safety, instability in policies, lack of infrastructure and weak legal system are far beyond the compensation of a supposedly good tax system.
Respondent Group 3	That dominant country is Nigeria. Nigeria has the largest gas endowment and is the largest supplier of gas in the region. The prevalence of the main global oil & gas firms and their keen participation in gas export business is an indication of successful policies. We are also aware that these companies which have been operating in that country for ages have influence on the direction of energy policies in the country.
Respondent Group 4	Our assessment shows that Nigeria comprises almost 95% of the gas business in the region. So, the basis of comparison is not there. But as their oil & gas industry seems to have the presence of notable global IOCs, it will not be wrong to conclude that their system is good
Respondent Group 5	The International Oil Companies which are the dominant investors have a key influence in tax issue in the leading countries like Nigeria and Angola. Judging from their investment in the export component of the natural gas, one can conclude that the current tax system in these two countries is good.
Respondent Group 6	Following several years of experience, refinements of tax laws, our tax system is not bad. This conclusion has been supported by the responses we get from operators when discussing continental tax laws
Respondent Group 7	Comparatively, we can say that the Nigerian tax laws are better but there is still room for improvements.

12 ***T3/RQA7/FCD12.*** *Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?*

Respondent Group 1	We will not be wrong to refer to joint venture arrangement and service contracts that have been successful in Nigeria.
Respondent Group 2	Investors can manage the rate of return to compensate for their investment. But the peculiar natures of risk in sub-Sahara Africa are beyond tax elements.
Respondent Group 3	The keen participation of foreign and domestic investors in production sharing4contract can be said to be an attractive tax feature
Respondent Group 4	Our comparative analysis reveals that the joint venture and service contracts tax systems seem to work for the dominant country which is Nigeria. But on a larger scale, there is still enough room to improve the entire tax system
Respondent Group 5	Perhaps the production sharing system seems to work well
Respondent Group 6	We pride ourselves on the production sharing contract which works in Nigeria better and this is on global comparative basis
Respondent	The production sharing contract would have been the best. But the issue of

Group 7	delays in cash calls messes it up. However, the service contract fits us well as we have no hindrance in lifting our service payments from gas produced.

13 ***T3/RQA7/FGD13.*** *Could you also share with the researcher those elements that are bad?*

Respondent Group 1	Bad tax cannot be categorically said to be operation as far as there is an investor operating within the context of subsisting tax structure
Respondent Group 2	It is difficult to categorically point at a tax element that is bad. However, issues of community and corporate social responsibility are burdens to the operators.
Respondent Group 3	Not in specific terms. But additional tax elements such education levy and corporate social responsibility are additional tax burdens. These elements might serve as bad tax practice.
Respondent Group 4	Additional demands such as levy out of gas profit tax are bitter pills and as such bad tax elements.
Respondent Group 5	Cannot say precisely as tax is not the dominant investment criterion especially in the critical mid-stream of the value chain comprising an artery of gas pipeline network.
Respondent Group 6	Once a contract is accepted, there is invariably nothing wrong with it because both parties ab-initio signed that with their eyes opened. It is a conscious, calculated and deliberate action of the two parties that is put into practice. What would have emanated as bad tax practice has been thrown into the dustbin in the agreements rejected on the negotiating Table. So, we cannot say that there are bad elements of tax in operation.
Respondent Group 7	Corporate responsibility and additional levies.

14 ***T3/RQA7/FGD14.*** *What do you think should be done to improve the defects stated?*

Respondent Group 1	A publicly funded effective artery of gas pipeline is the answer.
Respondent Group 2	The region should strive to make the investment climate more attractive.
Respondent Group 3	First there must be the will of the region to create an effective domestic gas enterprise. Second, the appropriate investment policies should be designed and implemented. Third, the operational environment must be made attractive.
Respondent Group 4	Removal of some of the levies stated might pave a good way for tolerable tax system. This can be achieved through a regional single tax system to help unify difficulties in trans-border investment
Respondent Group 5	Think of tax that reflects risk particular to the downstream activities. Regional cooperation and synergy could help unify a single tax system that can work for the region.
Respondent Group 6	The system has a way of dealing with any bad practice that manifests. This is by simple rejecting the proposal.
Respondent Group 7	If the issue of corporate responsibility is taken off our necks and additional levies, we will be happy with the current tax system.

15 ***T3/RQA7/FGD15.*** *How stable are petroleum tax regimes in the key participating countries of the region?*

Respondent Group 1	Policies are pruned to changes. But if these changes happen when subsisting operation are ongoing, this becomes a problem. As far as we know, we cannot recollect a time where subsisting tax instruments were tempered with.
Respondent Group 2	Instability in policy is one of the peculiarities we raised during the discussion on risk
Respondent Group 3	Governance in the region is unstable and this affects stability of tax systems.
Respondent Group 4	There are instabilities in governance in the region. But because of the importance of gas and oil in the region, every successive government pays attention to the policy of the industry. Changes or instabilities in gas and oil industry are more stable than policies in other sectors of the economies.
Respondent Group 5	Because of the long contractual arrangement and tax like production sharing instabilities in policies are well managed to the barest level.
Respondent Group 6	Contracts are of long-term range and outlive successive governments. There is no room for change in policies.
Respondent Group 7	We have no experience of instabilities especially on already established businesses

16 ***T3/RQA7/FGD16.*** *Tax systems are likely to be different from one country to the other. What do you see from your experience and knowledge could be an effective tax system for the region?*

Respondent Group 1	Taxes are different even within a nation and these differences are a restraint to quick business decision as prospective investors would have to study one tax system to another. If a regional tax system is put in place, this will speed up investment as investors won't have to consider several tax systems but a single tax system. The region can do this. It is time in our view that a regional tax system be considered to speed up investment. After all, it is even the current trend in regional energy policies across the globe.
Respondent Group 2	There are differences in tax as there are differences in types of government across the region as elsewhere. On a continental basis, it is usually a huge task for investors to scan all these tax systems for investment. A region would be benefit from a single tax system as this helps investors make quick decision. The prevalence of charters in global regions that have created successful common platforms in tax and other regulatory values are ready made suggestions for the sub-Saharan African region. A common tax system therefore is a critical success factor in the region if implemented and sub-Sahara Africa can achieve this. The benefits of a single tax regime are many. For one it leads to harmonization of commodities and creation of an effective single market. It creates regional cooperation and could bring about a revolution in the trapped market. It leads to the creation of a domestic gas hub and this will arrest the flight of monetary values in the sale commission, delays, losses in differential due to trading on index of other markets like Henry Hub.
Respondent Group 3	A single regional tax regime in today's global business of symbiotic collaboration is easier than single state's tax especially in implementation. There are several charters that ensure successful regional tax system. A single tax system for the region's gas industry is likely to be the key to unlocking the gas potentials that have been trapped for ages. Sub-Sahara Africa can achieve this feat.
Respondent Group 4	We monitor the evolution of tax laws in the region and realize that the trend is towards the same system in that new discoveries like Tanzania and Mozambique want to replicate the Nigerian tax system. To us, this is good and is feasible. However, the region will benefit more by considering a single tax system. The benefits of such a single tax system are many, comprising ease of doing business, risk reduction and openness of the market

Respondent Group 5	Disparities in tax system are there except now that we see Tanzania and Mozambique trying to replicate the Nigerian tax system. This is understandable. But the question is why not move it to a regional level where a single tax system can be put in place? A single regional tax system simply translates into a single regional market. This we think is the best initiative that could unlock the gas potentials of sub-Sahara Africa. A single tax system will also create the capacity to put in place the much desirable regional interconnected artery of Trans-Border gas pipelines we talked about. If member states agree to a single tax system, other operational arrangements will follow, and this will make it easier for a single functional regional market. The mid-stream market is an essential area that cans an only be provided by social capital – public funded. African states should approach the gas market in a holistic strategic manner beginning with provision of the mid-stream infrastructure. This should be followed by clustering strategies where; the entire sub-Sahara Africa region should be clustered in line with the potentials of each zone and policies reflecting the peculiarities of those areas dished out. In this region, it is possible
Respondent Group 6	Tax differs even from one well to another. An all-encompassing regional approach could be a good way to bring an attractive tax system. There is a lot of economic savings, risk reduction, turn around in investment decision economy of scale with a single regional market. This is also to tow in line with the global hue for single market everywhere and remove hindrances of trade agreements on investment and in the African case, it is doable.
Respondent Group 7	We are in position to say that there are different tax systems in the region, and this restricts our business in many ways. One of the best ways to go about it is to have one single tax system. Imagine a situation where you do not have to look at several tax systems. Your investment decision will be quick and less expensive and less time consuming. We do not see the difficulties in sub-Sahara Africa coming together to create a single tax system

17 ***T3/RQA7/FGD17.*** *Kindly explain your answer to question 16*

Respondent Group 1	The simplicity of a regional single tax system in Africa lies in creation of a charter or a licensed regional purpose vehicle to run the entire gas industry and Africa already has established institutions such as the African Union, African Energy Commission, Africa Development Bank to help.
Respondent Group 2	There is the African Union that superintends development activities of the region. With a strong political will and purposeful intention, a charter could be created through this institution to lead the regional gas business. In this way, formulation, implementation and running single rules, which include tax applicable to the entire industry can be achieved.
Respondent Group 3	The sub-Sahara African region can come under the umbrella of the African union and make this happened. Why this has not be done is because the focus of the region has always been in export-oriented business to satisfy its thirst for foreign exchange earnings, ignoring the domestic potentials its gas endowment holds.
Respondent Group 4	The answer lies in a charter. There are already few such purpose vehicles in operation like the West African Gas Pipeline Authority. The region can use this as a pedestal to create a regional charter for a single tax system which is a single market.
Respondent Group 5	A charter such as European gas market, Organization of Gas Exporting Countries, etc can provide a platform where a single tax system is made for the region. This is not only doable but desirable as a single tax system will unify the regions operation and enhance development. Trans-Border gas pipeline network also sponsored by the regional states is easier than individual states sponsor, especially when it is drawn in a strategy of clustering states into their sub-regional potentials connecting gas rich sub-sets with gas-poor sub-region in a supply-demand chain. The clustering simple means passing the gas pipeline along

	areas of economic viability from resource rich areas. The large reticulation of regional gas pipeline network also enjoys economies of scale.
Respondent Group 6	Synergistic collaboration that produced the West African Gas Pipeline need to be considered at this point.
Respondent Group 7	Nothing is impossible with serious intention. After all, we know of the West African Gas Pipeline which is in operation. The same concept can be expanded to the entire regional level.

ii Summary of findings – Tax Issues

The summary of the outcome on the discussions of tax matters is as follows:

A single regional Tax System

All groups in unison suggested a single regional tax system and confirm the practical possibility of this single tax system and offered a solution on the instrument by which it will work. Such instruments according to each group is the establishment of a charter through the African Union for a single sub-Sahara gas market. A majority of the groups further state that a single tax system is the current global practice. All the groups express confidence that the single tax system will generate the capacity and ease of actualizing the regional gas infrastructure and effective gas mid-stream effective operation.

5.4 Research Analysis of findings

5.4.1 Policy area.

The clarion summation from the survey on policy is that the right attitude and policy instruments to cultivate, attract and keep investment inflows into the region's vast gas endowment are in short supply. This translates to saying that the wrong attitude and lack of sufficient policy instruments are part of the investment dilemma of the sub-Sahara African Natural Gas market. This research takes this attitudinal deficiency; insufficient banking policies; price policies and infrastructural gap from the focus group discussions for further analysis to derive appropriate policies and develop strategies for the sub-Sahara African gas market model.

i. *Regional states attitudes on their gas potentials*

Information from annual budgetary planning and execution and statutory economic enactments provide evidence of the wrong focus sub-Sahara Africa region places on optimization of its natural resource endowments. It is quite easy to tell a nation's economic interest and what defines that nation by simply looking at the fundamental pillars that make up the statutory budget documents. Therefore, to prove the point raised in discussing governments' attitudes, focus and priorities, it helps to refer to this document. Here, we can use one reference country and that country is Nigeria as it has been pointed out from the survey discussion. This research takes budget documents from this reference country covering an eight-year period which falls between 2010 and 2018 in line with the period the quantitative analysis is analysed. The self-explanatory evidence of the attitude of heavy foreign exchange preference to domestication of natural resources of which gas is primary, is tabulated and presented in the table below:

Table 20 - Major Macro Economic Budgetary Assumptions of sub-Sahara Africa (Nigeria as case study)

Year	Oil Price (US$)	Production (mbpd)	₦/US$
2010	67pb	2.35	₦150/1US$
2011	65pb	2.3	₦150/1US$
2012	70pb	2.48	₦155/1US$
2013	79pb	2.526	₦160/1US$
2014	77.5pb	2.3883	₦160/1US$
2015	65p	2.2782	₦165/1US$
2016	38pb	2.2	₦197/1US$
2017	42.5pb	2.2	₦305/1US$
2018	45pb	2.3	₦305/1US$

Source: Budget Office of the Federation Federal Republic of Nigeria

Space is not enough here to demonstrate how dependent this economy is on oil & gas in all its statutory engagement. Information from the documents indicates that efforts are placed on studying the external economic fundamentals that drive oil behaviours in order to derive price and production information for the purpose of their economic survival. This supports the assertion that this drive and orientation distracts government and resource managers of the region from focusing on domestic gas resource potentials.

In all the years under consideration and so many before now, the key economic fundamentals and drivers of that economy have been built on prices of oil & gas, exchange rates and production forecast of crude oil & gas. These statutory documents are bereft of such policy as tax revenues drives from domestic gas consumption. This scene plays out in all the states of the region like Angola, Ghana, Congo Brazzaville, Cameroun, Gabon were these three economic indicators are made the supreme drivers of the economy. It is interesting to note that before the Jubilee crude came to surface, the Ghanaian government was already recognizing foreign exchange expectations from off-shore sale of the commodity. The cumulated effect of this attitude is recorded in the statistics of International Energy Agency (IEA) showing that 20.78 million tonnes out of Nigeria's total 35.68 million tonnes of net calorific value of gas produced in 2015 was exported. The OPEC 2016 annual statistical bulletin further sheds light, bringing out the fact that out of the remaining 14.90 million tonnes of calorific value supposedly left for domestic consumption, 47.02% of it is wasted in flaring, re-injection and shrinkages due to poor attention to domestic management of gas output. In the formation of a sub-Sahara African Natural Gas Market model, the examined government focus regarding resource optimization would have to occupy a significant space.

ii. Banking Policies

Suffice to say that gas businesses are heavy-ticket businesses in every stage of the value chain. Recall what is found in literature concerning the oil & gas industry such as its large size, international connectivity, long gestation period, huge financial demand and high risk. For an effective natural gas market to function therefore, the right banking environment is a necessary condition and this “right banking system” must be saturated with institutional banks that have capacity for big risk, large and long-term credit capability and high global rating. Banking institutional weakness in the context of natural gas enterprise financing as highlighted by the respondent is, in sub-Sahara Africa to some extent part of the problems of the gas industry. Going by the report of 2017 top 1000 Banker, it is evident that the banking industry in sub-Sahara Africa lacks capacity to support a domestic market gas enterprise. The Banker in its 2017 top 1000 World Banker, reports that African bank’s return on assets (ROA) and Return on Equity are on the top second rank list, next to Latin America in global rating. However, these do not translate into a sufficient and robust capital-to-asset ratio required to provide a sufficient financial backing to a commensurate size of gas enterprise in Africa, nor do they translate to an amiable global rating in balance sheet size. Taking south Africa out, the big banks in sub-Sahara Africa are ranked from 10 in Africa and 430 in the world down to 24 in Africa and 881 in the world in tier 1 capital adequacy and balance sheet size. Respondent groups give instances in which banks in our reference country cannot handle financial transaction that are critical to the successful operation of the gas industry. It is in record that the Central Bank of that country had to intervene with US$1.8 billion in its local currency equivalent to free overhang commitments that threatened the supply of power in that country through huge debts owed to gas suppliers. The poverty of banking policies to actualization of investment intentions in the vast gas endowment of sub-Sahara Africa region is a gap that should be considered in modelling the sub-Sahara Africa Natural Gas Market Model.

iii. Price Policies.

To fully understand the level of government interference in the market and how it affects investment appeal is to review the operation of the only gas market in the region, the Nigerian Gas Market. This market is dominated by a vertically structured monopoly owned 100% by the government called Nigerian Gas Company (NGC) Limited. NGC was established in 1988 as one of the eleven National Oil Company's subsidiaries to fully serve Nigeria's energy and industrial feedstock needs, through an integrated gas pipeline network as well as export natural gas and its derivatives to the West African Sub-region. Prior to the establishment of NGC, the NNPC was fraught with challenges relating to bad debts from the defunct Nigeria Electric Power Authority (NEPA) for gas supplied to its thermal plants. Similarly, the continued supply of gas by the NGC to NEPA and the newly created Independent Power Project (IPPs) increased the debt stock of NGC, leading to a balloon of the legacy debt that necessitated an intervention from the Central Bank of Nigeria.

NGC is the sole seller of gas to all the consumers of gas in that country, dictating the volume, pricing and transportation of gas between the producers and the buyers. The company operates, using instruments called Gas Transmission Agreements designed and enforced by government and charges a transport fee of US$0.8/MMBtu from receiving terminals to discharge points from the buyers. NGC owns and operates 1,250-kilometre pipelines, ranging between 43” to 46” with an overall design capacity of more than 2.5 billion standard cubic feet of gas per day (bscf/d), 16 compressor stations and 18 metering stations. This is the only gas infrastructure in that country.

NGC runs the country’s gas industry in the following market structure as tabulated below:

Table 21- The Nigerian Gas Market Structure

	Consumer	**Price/MMBtu**	**Share of Market**
1	Electric Power Generating Plant (EPGP)	US$2.50	14%
2	Commercial (retail arm)	US$7.35	3%
3	Industries	US$4.00	6%
4	Export	US$3.50	77%

Source: Figures from focus group discussion with NGC January 2018

Using the powers confers on it, NGC mandates suppliers to sale their gas on this price template. This power was introduced in 2008 which provides for the imposition of a Domestic Supply Obligation (DSO) on all gas producers, requiring them to set aside a predetermined portion of their gas production for supply to the domestic market. The Policy is the instrument that categorized the present domestic gas market into the above customer classes. The Policy also provides for the NGC to be responsible for: determining aggregated gas prices to be paid to gas producers for gas supplied to the domestic market; managing the operationalization of the DSOs by ensuring the allocation of gas supplied under the DSO regime to the various sectors of the domestic market and ensuring that a minimum aggregate domestic gas price that tracks the transition to export parity is achieved; serving as an intermediary between domestic off-takers and gas producers, by managing the receipt of revenues, effecting the payment of the aggregate domestic gas price and managing the implementation of all revenue securitization arrangements. The non-compliance of the obligations imposed on gas producers, which has been in place since 2008, attracts a penalty of US$3.5/mcf.

To draw realistic inference from this price template on the background of investment appeal, we need to draw a parallel line with the cost structure to see the feasibility of a viable operation. This is as in Table 8 below.

Table 22- Cost of producing 100SCF of gas

S/No.	Activity	Amount in US$ million
1	Wells Construction (3 in number)	US$165 million @US$55 million/well
2	Treatment for Condensates	20per cent of volume
3	Distribution/km	US$1 million/km
4	Distribution line Non-Associated Gas	US$100 million

Source: focus group discussion with Nigeria Gas Company December 2017

Table 22 above shows that the total cost of producing 100 million standard cubic feet of natural gas to a destination of a 100 km discharge point is US$266 million, treatment for gas cost yet to be applied. This represents a US$2.66 million/1mscf. Using the conversion factor of MMBtu to mscf, gas production therefore costs an average of US$1.99/MMBtu. This shows that gas production in this reference country is cheaper than estimates of US$7.35/MMBtu of average shale gas estimates which literally portends a good omen for investment. The interference does not stop at the gas market, it extends to the electricity market which is the main domestic buyer of natural gas for now. In the electricity market, prices are regulated all through the entire stages of the value chain from generation all through transmission, distribution to retailing. At the retail end, customers are classified into five bands for the purpose of further price regulation.

The foregoing analyses reveal that this is a government market, highly regulated with no option of effective market mechanism that will attract investment. No investor will want to operate in a market where, prices, quantity to sell, who to sell to and distribution are all controlled with a harsh penalty of US$3.00/MMBtu in the event of default. This scenario supports the assertion that government interference in the market is a deterrent to prospective investment into the gas potentials of the region. Therefore, a market model that will break the jinx would have to opine a market structure that will take a dramatic difference if investment interest is to be earned.

The conclusion of this section therefore highlights the key areas to look for in modelling natural gas market for region which are:

a. Export de-oriented policies to create domestic market.
b. Establishment of financial policies specifically to create liquidity in the financial system.
c. Policy reversal on government dominance.

5.4.2 Analysis of findings: Risk Questions

Risk analysis is a natural occurrence in business studies like this research work. Risk analysis becomes more demanding in this study as literature reviewed brought out a dimension of risks related to the gas industry different from other businesses. In modelling the sub-Sahara African Natural Gas Market, the submission of respondents' experiences regarding the risks that were presented during the survey need to be analysed to draw substance in producing the targeted model market. This again, is done along the lines synthesized above.

Starting with the issue of insecurity involving kidnapping, killing, and pipelines vandalism as mentioned during the focus group discussion, there are quite evidences of such occurrences. In our reference country for example, it is stated that a certain reticulated area of the gas network is constantly under attack. These security concerns are in the view of this research, the reflection of the economic situation of the region. Experts have asserted that these vices normally reduce correspondently with improvement in economic conditions such as employment and wellbeing. This project does not have the ability to model solution to this menace. This has to do with state capacity. It is however the researcher's opinion that an active and effective natural gas market in the region is going to absorb a substantial number of unemployed resources including human capital, and if this happen, these particular social vices might melt away in line with the prediction of security experts. Managers of natural gas resources in the region therefore should embrace and push through, the establishment of a natural gas market to take care of these menaces.

For institutional weaknesses, it is not difficult to discern the impact of such, on investment attractiveness. The case of the banking institution has been analysed and the results obtained can be applied to all institutions that have direct or tangential relationship with the gas industry. What needs to be done here is to investigate the evidence provided by focus groups in support of their stance that the oil majors in the sub-Sahara African Natural Gas Market possess the ability to defy investment risks in the region as they are. This requires analysing Nigerian LNG Limited (NLNG) which is the export segment of the gas market in our reference country.

While the domestic market under the control of NGC has not seen any appreciable investment inflow, the NLNG has been receiving substantial investment inflows year-in-year-out from the same global giants that shy away from domestic gas market investment in the region. From 1999 when NLGN began operation, its 2017 published accounts show that the company has received investment amounting to US$16.57 billion through a consistent yearly investment of US$920.56 million on average. In less than 20 years of operation, the company has expanded its capacity to six trains facilities with a seventh train ready for commission. By imperative, a yearly investment inflow of almost a billion US dollars on average, consistently for nearly two decades makes the conjectures of high and daunting operational risk immaterial. This goes to support the respondent that asserts that investors have ways of dealing with risk. This consistent and huge investment inflow in a single country and in one segment of the market has also made an important contribution to this study that risk as at this juncture is not generally responsible for the 0.032% gas production from the vast African gas endowment of 225.9 trillion standard cubic feet. One could attribute the attraction of investors to this segment of the market to its profitability in which it has consistently generated a yearly average of US$913.89 million to the investors in eighteen years totalling US$16.45 billion in dividends alone. One could also conclude that the success in return on investment and earnings signifies absence of risk. But figures alone might not help in clarifying the status of risk in the entire market comprising both this export segment and the domestic segment. It has to be established in some other way, whether there be risks in this segment of the market. In the event of any risk manifestation, lessons need to be derived on how the investors are able to overcome the identified risk(s) to achieve a yearly average dividend of almost US$1 billion. The way to go about the identification is by examining the commercial operation of the export market segment, just as answers were derived from the same examination of the commercial operation of the domestic market.

From the company's 2017 published accounts, NLNG manages its commercial operation using instruments known as Sale & Purchase Agreements (SPAs) on long term contract basis. This is done through *"existing customers and via Spot Free on Board"* (Facts and Figures on NLNG 2017, p41) in advanced and matured markets using Henry Hub's reference prices.

A key issue here and a good learning for this research is the identification of existing buyer. This tells in clear terms the strategy of the investors and the key factor underlying investment interest – identification of an existing buyer. Another lesson derived here for the model of the sub-Sahara African Natural Gas Market is the absence of market interference in the export segment. Markets were African gas cargoes are destined have been analysed in the quantitative metrics and they are found to be run strictly by market forces that require sophisticated calculable economic techniques to understand and not government orders and sanctions. A third lesson is the instruments used in trade. They are purely commercial contracts entered between the buyer and supplier directly without any government organ or third-party involvement. The sub-Sahara African model therefore will benefit from these lessons.

5.4.3 Analysis of Findings - Tax Questions

Literature proves to us that tax plays important role in investment decision in this industry. This led us to raise the questions on tax that were not clear from literature specific to the sub-Sahara African region. The main point of lesson that comes out of the survey is the potentials and workable possibility of a single tax system. The suggestions from all respondent in unison that this is the missing link in investment destination to the region are instructive enough. Respondents were also ready with a solution which they all agree to be a charter through the African Union. In developing a sub-Sahara Africa market model, this universally accepted suggestion needs to be explored.

5.5 Summary

This chapter turns out to be very instrumental to the project. It underscores the essentials of mixed-methods design for a study of this discipline. The chapter starts with clarifying fundamental questions of qualitative research after the introduction, in which problems of sample and sampling techniques; data collection methods; physiognomics of respondents' basis for semi-structured focus group survey method; and design of survey instruments are, clarified. What follows is the presentation of results which is done in three thematic areas comprising, policy concerns; risk perception and tax matters. These reports emanating from the key institutions of authority in sub-Sahara Africa is like a self-cleansing testimony. The similarity, uniformity, and convergence of thoughts on the issues by the respondents is a happy revelation and good material for the development of a natural gas market for the region. The analysis of findings from these thematic areas present key issues that are germane to modelling of sub-Sahara Africa Natural Gas Market from regulatory approach and these are:

i. The need for governments of the regional states to change focus from foreign exchange pruned behaviours, to domestic optimization of the gas reserves behaviours
ii. The need to revamp and promote new financing policies target at domestic gas investment
iii. Market reforms in the gas industry
iv. Importance of existing domestic market to the investor
v. Free market operation for the investor
vi. Efficacy of the use of purely commercial instruments in trade
vii. Creation of a single regional tax system

CHAPTER SIX: THE PROPOSED MODEL - NATURAL GAS MARKET FOR SUB-SAHARA AFRICA

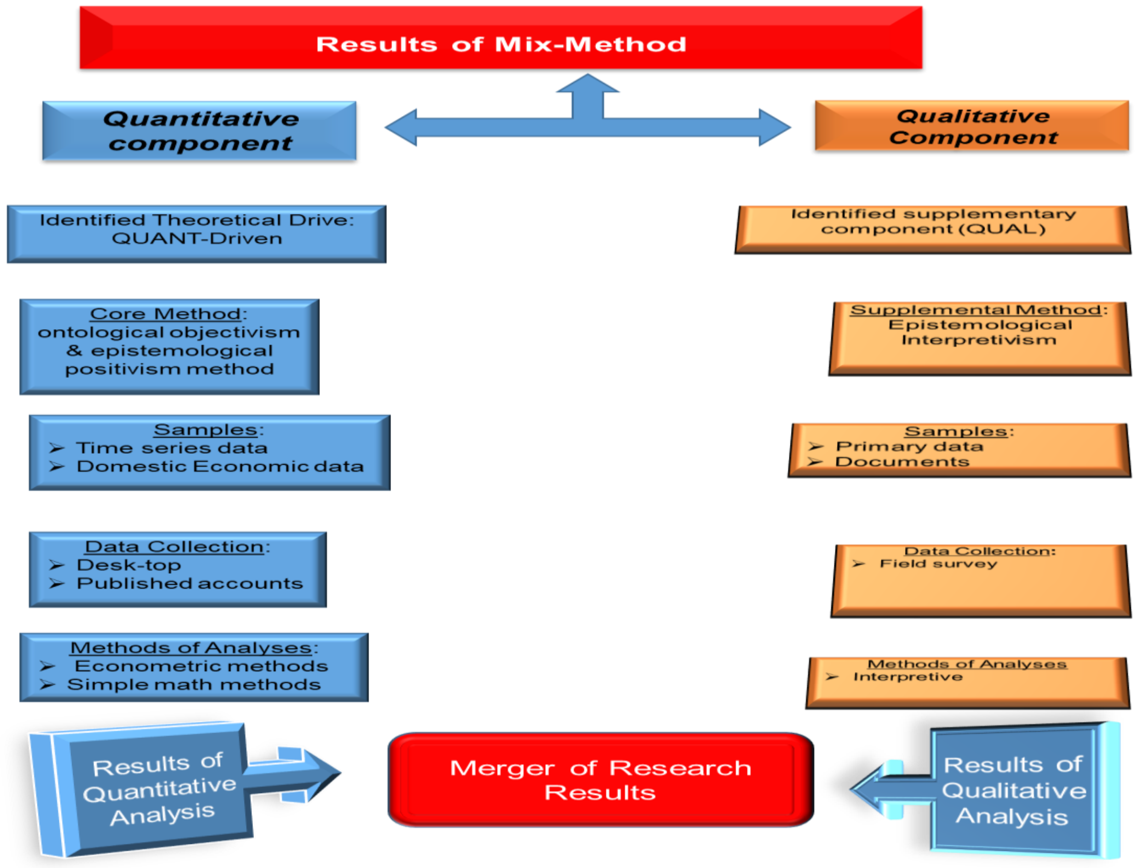
6.1 Introduction

This chapter discusses the proposed model for the sub-Sahara Africa Natural Gas Market. One of the strong motivations for this research is the concern for the poor gas supply in sub-Sahara Africa amidst its abundant natural gas endowment. The model aims to address the issue of a sufficient and sustainable natural gas supply to key economic sectors that are thirsty for the natural gas, such economic sectors like agriculture processes and fertilizer; electric power; house-hold consumption; chemical industries and housing industry which together could trigger an economic reformation in the region. But the question regarding why the situation of this dichotomy of abundant rich natural gas resources amidst insufficient supply to critical economic sectors that need it triggers the search for answers. As it is a case of insufficient supply of a commodity to meet a yawning demand in a particular sub-sectoral area, the study ring-fences the specific market for this specific commodity – natural gas – in a microeconomic sense incorporating three dominant economic actors. As with other markets, the three dominant actors consist of suppliers and consumers in two distinct ways and the third, regulating the activities of the two. In some products, suppliers are known to bear the investment cost. But in this particular market, investment is required from both the suppliers and gas off-takers for infrastructure such pipelines and storage facilities to transport, receive and store the gas commodity from both ends. The high financial requirements and risks as seen in the literature review and sovereign ownership of gas fields and necessity of external interest for capital and technology alter the participation of the regulator, in so much as making the regulator instrumental to the success or failure of the market by the efficacy or otherwise of policy instruments available. Therefore, in modelling the sub-Sahara Africa natural gas market, the research earmarks the investor and government as the primary targets of its investigation. The methods deploy in line with the target actors comprise investment and regulatory approaches. The chapter therefore presents the proposed modelling for of the market on basis of Investment and Regulatory Approaches.

6.2 Contents and procedures for the proposed Modelling of Natural Gas Market for Sub-Sahara Market

The proposed modelling for sub-Sahara Natural Gas Market steps out from the merger of the contents of the two research approaches. Chapter three of this thesis dictates the flow of the study with a final stage mandating the merger of the results of findings of the two approaches. The results are those documented in chapters four and five comprising the quantitative and qualitative segments. The chart below captures these segments from the beginning of each method all through the method processes to the end which culminates into amalgamating the results of the two approaches as in the flow figure below:

Figure 10 - Merger of Results of Mix-Method



Source: Constructed and presented by Author

Figure 10 shows how the research follows the systematic stages of arrangement of the study, using the two approaches concurrently as in Morse and Niehaus (2009) and Terrell (2012), to arrive at the model of the market situation that eventually emanates from the research enquiry. So far in the thesis, all the stages in the construct have been completed with the last stage remaining, which is bringing the deliverables from the two approaches together to form the picture of the research outcome.

First, the philosophical drive of each method was identified, and the necessary data collected using various procedures in line with the nature of the two methods. Derived techniques of analyses were deployed to each method in their uniqueness to obtain results. These results are presented in chapters four and five. According to the grand design methodology, these results are to be merged to form the picture of the research outcome as the final stage of the process which is reflected in the chart above in the centripetal box named the sub-Sahara African Gas Market. Therefore, the highlight of key points from the results that are novel to literature and relevant in the suggestion of a prototype market, desirable for sub-Sahara African Natural Gas Market will be the contents of the centripetal box that translates to chapter six. The highlights are presented beginning with the quantitative method in the following sub-sections.

6.2.1 Highlights of key results from quantitative analysis

The overarching finding captured from the quantitative analysis is the ability of the EGARCH model to capture, analyse and explain the nature of the risk beta that is the main investment decision factor of the investor. From the works of Emhjellen, et al (2011); Ballard, et al (2012); and Osmundsen, et al (2015) examined during the exploration for the theoretical framework of this project in chapter two, it is clarified that the multinational organisations (which are the key industry players) have a unique investment decision model across the globe and it is only adjusted to capture specific country's risk beta. The authors also demonstrate that these multinationals make their investment decisions by applying the traditional Net Present Value (NPV) with an expectation of high Rate of Return (RoR). This RoR we are made to know connotes the commercial profitability expectation of venturing into investing in the industry in any country. The authors also clarify that in practice, these investors use stock values of their corporations listed on the stock exchange to calculate their portfolio systematic commercial risk. The value obtained which is denoted by the beta is used in comparing the viability of specific project intentions to arrive at an objective decision. If the beta of the investment in consideration is higher than the overall beta of the company's global portfolio which indicates a higher risk to the company, then the new investment's RoR must be higher than the RoR of the existing portfolio to qualify for the deployment of fund for the new project. Therefore, the ability to deliver an expected or clear beta direction, is a key deliverable in any investment investigation exercise. In this project as it is in all volatility modelling, the algorithm for detecting behaviour and measure of this beta is the econometric modelling exercise undertaken in chapter four.

A quick note on this beta highlights its key components as below:

i. It is a critical investment decision criterion, in many cases, it is the overarching decision factor.
ii. It is price entrenched. Actualization and guarantee of beta is determined by the future price in the face of market factors and conditions at the time of sales.
iii. It is uncertain. Its future is not known. Only the best articulation of its probabilities can suppress fear of the unknown to attract investment decision.

This is why the quantitative approach becomes the main driver of this thesis.

To make investment perception a bit more attractive to multinationals in their investment decisions, this research utilizes Nelson (1991) EGARCH model with adjustment in the distribution term to suit the peculiarities of the sub-Sahara African region. To obtain a convincing beta, the algorithm of the EGARCH volatility model was fastidiousness, meticulousness and exhaustive. The model takes into account, every disturbance term in the equations of the conditional mean, conditional variance and the conditional error distribution uniquely and then combines all the three terms together to arrive at the this particular EGARCH.

Recall in chapter four, the four periodic quadrants in the four-tested global markets. One of such was an economic fundamental of entrance of shale in 2011 that caused the first disruption of Henry Hub in July 2011, a supply effect. In January 2011 Title Transfer had experienced instability based on the displacement of LNG which is a demand fundamental. The volatility in Net Balancing in 2010 is traced to depreciation of Pound Sterling and consistent fall in crude production, while the disturbance that started by the end of 2016 to early 2017 in the same market was underpinned by Bre-Exit trigger, passing through commodity prices, energy prices, declining GDP and sustained for months by falling pound sterling.

On the basis of the identification of these factors, it was clear that there is a need for a choice of a superior econometric model that could generate a sharp focus in identification of these factors or others, for sub-Sahara African Natural Gas Market and the EGARCH.

If it is accepted that these factors, which are: associated behaviour of crude-gas price; economic condition reflected by Gross Domestic Production; exchange rate; interplay between demand and supply political condition should be covered by this model for these markets, then hope that its application to sub-Sahara Africa will generate the same desirable results.

Recall that the EGARCH was also selected on the basis of information criterion where its tests on all the markets outperformed the three other models in information generation.

Earlier, it was explained that information criterion followed a process of selection to identify the unsuitable criterion which is the Akaike Information Criterion and utilized from Akaike (1987) as follows:

AIC = -2(l/T + 2k/T where l is the value of log likelihood k parameters and taking T observation. K is also computed as:

K = T/2(1 + log2ζ) + log(ê'ê/T)) and in T, the smaller the value, the better the fit.

The flexibility introduced in the modification process to fit real markets makes it more suitable for the sub-Sahara African market model. This key attribute is particularly important to the investor for investment decision in the sub-Sahara African market where the risk is higher, partly because of insufficient market information.

The use of all the three-distribution term to select the EGARCH model is therefore the model for the sub-Sahara Africa from the quantitative approach of the research which can be adjusted to capture the region's peculiar domestic market conditions such as relationship of natural gas price with other energy commodities, exchange rate, demand and supply fundamentals and political changes.

6.2.2 Highlights of key results from qualitative analysis

The key highlights from the qualitative approach are narrowed to the specific pillars that are in the findings of the researcher the building blocks of the proposed sub-Sahara Africa natural gas market. These include issues relating to financial structure; market structure, tax system and the single regional gas infrastructural system.

i. Financial Structure

The limitation of the financial system to current gas market operation in sub-Sahara Africa has been discussed in sub-section (ii) of 5.4.1. The capacity of its prime banks also has been analysed in the research analysis of findings in section 5.4 which shows that current financial system cannot aid in anyway, the developments of domestic gas market. However, Cameron and Stanley (2017) provide the experiences of the Canadian and Australian domestic gas markets which benefit from a policy driven pocket of financing - Provincial Stock. This concept could be important in modelling the financing policy of the sub-Sahara African region, not in exact form or attributes but in ways and features peculiar to the economic environment of the region. In 2004, the Nigerian government introduced a Pension Reform Scheme and by 2014 the scheme was amended to include a Contributory Pension Scheme in which contributions are made by employees and their employers in savings to be used at retirement. PWC (2016) reports that in just twelve years, the custodians of the pension contribution are sitting on a vast deposit of over $25 billion from only 8.1% of the Nigerian working population. This indicates a significant and potential source of cheap financing that are appropriate for long term investment like domestic gas opportunities in terms of timing, sustainability, guarantee and liquidity that is currently lacking in the domestic market. It is also interesting to note that various countries in the region like Ghana have replicated the Nigerian's scheme which hosts a substantial amount of funds. Therefore, it takes an amended financial policy as in the Canadian and Australian Provincial Stocks that provide liquidity for their domestic gas enterprises, to avail this saturated investment fund for the purpose of domestic gas market rejuvenation.

ii. Dysfunctional market structure

A market that is owned, operated, controlled and participated by government is not in tune with current energy scenario. This type of structure portrays an image that says that the investors should hand over their invested money into the palms of the government. Result of the focus group discussion with industry practitioners shows an overwhelming discomfort with this market posture from all respondent, interestingly, including the government organs. Many attempts have been made across time and in virtually all the region of Africa as elsewhere, through market reform strategies to privatize domestic energy corporations. This study does not hold competence beyond what has been pointed out in many market-freedom suggestions but will within the scope of the study and fetching from survey evidence point to those areas such as price fixing, domestic obligation and statutory instruments of trade as in the Nigeria's domestic gas obligation that clock the wheels of functional market system to make its conclusion. The prevalence of subsidies as indicated from the survey at the tail end of the gas value chain also affects the market functionality. An example of such is the heavy subsidy mentioned in the survey on the power sector. Recall that subsidy was attributed to the huge debt overhang in the survey returns. A subsidised market with price fixing with industry power held by the government in this kind of industry is unarguably a gridlock. It is therefore not surprising to see investors shying away from such arrangement. Subsidy though is an internal transfer within the economy. An effective fiscal system enthroned in yearly budgetary mechanism of the economy can address this. But for a market to function with price fixing is a hard one. However, the region can draw lessons from the Nigerian Petroleum Product Pricing Regulatory Authority (PPPRA). This organ of government in charge of the domestic market of the Nigerian petroleum products allows the international market demand-supply dynamics to dictate the major components of cost comprising about 90% of the total product cost. This way, prices respond to the dictates of a free market system which allows the market functions well and with no evidence of lack of investment. Nigeria indexes its gas on the Henry-Hub market. Replicating the PPPRA price template in the domestic gas market is the nearest feasible solution to its current market grid-lock.

Two critical factors in the Oil & Gas industry have been established the first being the necessary role of good governance and the second been the differing and unique circumstances the oil and gas industry is subjected to in different countries. Cameron and Stanley (2017, pp. 291) state that "*without good governance many, perhaps most of the benefits of extractive resources development are unlikely to be gained.*" The independent view of this researcher is that, the quality of any good governance in the industry should reflect in its ability to attract investment in order to develop the industry for the benefit of all stake holders. This researcher believes that the model of restricting the role of governance to provision of critical infrastructure supply in addition to the provision of appropriate and adequate content of rules and effective implementation and enforcement of these rules is the immediate feasible way out of the current gas entrapment of the region. As this belief is supported by the overwhelming survey result, the role of governance in the region's gas market should be that which is limited to such provision of critical infrastructural facilities without prejudice to its sovereign oversight on the industry in the general political economy of the continent.

iii. Tax System

The effectiveness of a single tax system also extends to its ability to tackle the tapestry of governance drivers with respect to regional constellation of differing factors from individual states to a unified single market system. The single tax system is the vehicle in which the provision of the right rules, implementation and enforcement of such rules and delivery of critical infrastructural system are made. With the single tax system which translates to a single market operating system, the sub-Sahara Africa Natural Gas Market is on its way to prominence. This assertion finds the support of Cameron and Stanley (2017, p. 292) *These elements are critical if the benefits of private sector investment in the development of publicly owned resources are to be fully realized by all parties involved in the oil, gas and mining development.*

6.2.3 Single regional Infrastructural system

Survey reports show how critical gas infrastructure is to the success of the sub-Sahara Africa natural gas market. Gas infrastructure is the mid-stream sector of the gas value chain. Production centres normally differ from consumption centres and in the case of a region as large as sub-Sahara African, these could be distant apart and very expensive. However, the absence of pipelines cripples off-take consignments thereby cutting off supplies. Receipts of gas supplies and usages have a lime difference. This therefore requires additional facilities in the form of storage terminals. It is because of the high expense of infrastructure that respondents suggested the involvement of governments in a unified single regional model. It is therefore a major pillar in modelling the proposed sub-Sahara Africa natural gas market model.

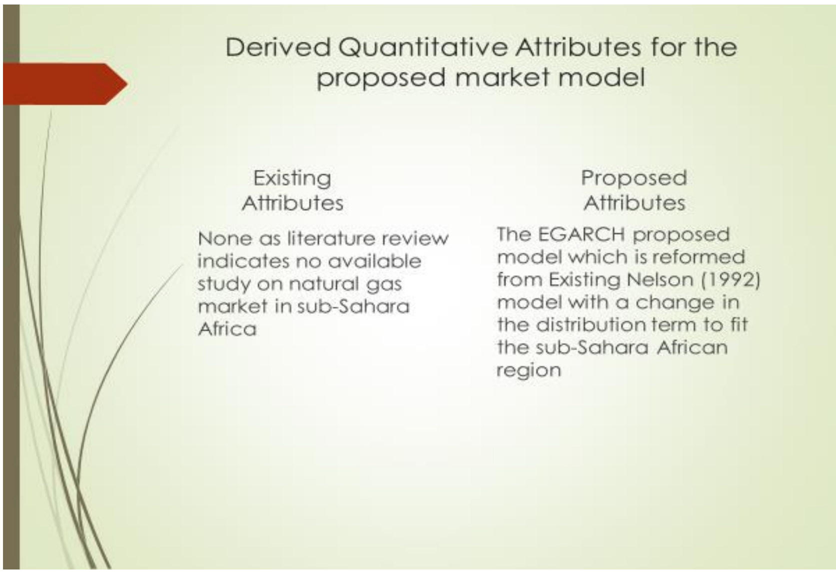
These four issues, derived from qualitative analysis, therefore form part of the suggested market model for the region presented in the sub-section below.

6.3 The Components of Proposed Market Model

The build-up to the establishment of the proposed market model is in two stages. The first stage is the articulation of the attributes that emanate as the ideal fundamental pillars of the market concept as distilled from both quantitative and qualitative methods of the research. These are presented in in figures 16 and 17 below respectively. The next stage is putting these pillars into a hypothetical operational structure to bring out the interlinkages and interdependence of the market mechanism to fit the main market model the research is aimed to offer.

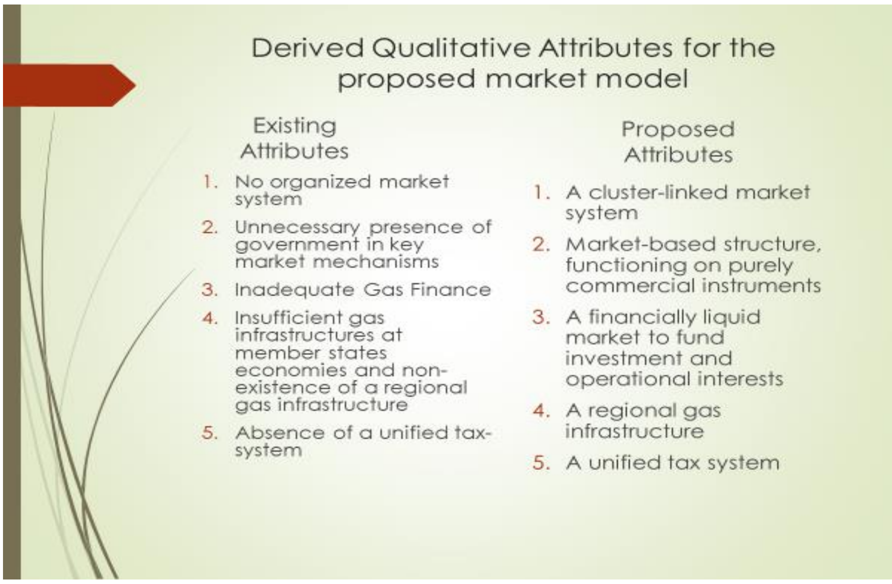
Figures 16 and 17 first try to identify the required pillars to make the model market from what is available in the present actual practice in the market. It then introduces what is derived from results of findings in chapters four and five of this Thesis in terms of components that are ideal for the target model market. The attributes of each component are analysed and reported in section 6.3.1.

Figure 11 - Quantitative Attributes for the proposed Market Model



The report is in two parts, one showing current situation in the existing column and on the other hand, what this research brings into literature.

Figure 12- Qualitative Attributes for the Proposed Market Model



As in 16 above, the same goes for the qualitative attributes in figure 17. The right-hand side panel is the attributes this Thesis introduces to the proposed market model.

All the attributes are further discussed in the following subsections.

6.3.1 The Quantitative Attributes

The search for relevant forecasting tool in any market that portends and contends with volatility is the prima facie requirement for investment decision. This is the bromide of all volatility modelling as shown in all the works of volatility modelling. A substantial part of chapter three and the whole of chapter four discuss the essence, procedures and derivations of the forecasting tools which ended up in the selection of EGARCH based on Akaike Information Criteria.

It is in the same vein and purpose of modelling volatility as the above authors and many that are not quoted that the results of the quantitative part of this project needs to be incorporated in modelling the sub-Sahara African natural gas market. And the fact that market decisions are so dependent on this volatility information makes the quantitative approach the dominant part of the study. Even though there are quite a number of models, most of them relate to the markets of crude oil and financial derivatives. Furthermore, no one model suffices universal application as every market displays differing volatility dynamics. This is the reason why each market has to be modelled specifically to fit its dynamics. The derived EGARCH model for sub-Sahara natural gas market traces its roots to the markets where the region's natural gas commodity is traded. It also allows for flexibilities in its mechanism to be adapted in the circumstance where, the dynamics of African situation differs with the four regions it was fashioned from. Its provision for free choice of the distribution from normal; student and generalized distribution tests is an enhancement of flexibility of application and the oscillation mechanism in the model is in tandem with nature and risk profile of the African region. The parameters of the derived model - conditional mean equation; conditional variance equation and the condition error distribution – are further tested on Henry Hub to prove the efficacy of the model in treating volatility as derived in equations 41, 42 and 43[7].

a. conditional mean equation $Q_t = N_t'\phi + e_t$ which is denoted as (ω)
b. conditional variance equation and $\sigma_t^2 = \zeta + \mu e_{t-1}^2 + \beta\sigma_{t-1}^2$ as (Ψ)
c. conditional error distribution equation $\log(\sigma_t^2) = \alpha + \sum_{j=1}^{q} \varphi j \log(\sigma^2_{t-j}) + \sum_{i=1}^{p} \vartheta i\, |\varepsilon_{t-i}/\sigma^2_{t-j}| + \frac{\varepsilon t-n}{\sigma t-n}$ denoted as (ε)

The tests yield the following results in Table 22.

Table 23- Test Results of Derived Model

	ω	**Ψ**	**ξ**	**λ**
	0.067 (0.029)	0.9701 (0.011)	0.0789	83.584
I/Criterion	**AIC**	**SIC**	**HQC**	
Normal	4.8834	4.9003	4.8896	
Student-t	4.7251	4.7447	4.7323	
GED	4.7765	4.7889	4.7765	

Source: Computed and presented by Author

The main values of interest are the treatment for heteroskedasticity (ω) volatility persistence (Ψ) and asymmetry effect (ε). The conditional mean value of 0.067 indicates the efficiency of the EGARCH in curtailing the effect of volatility for forecasting accuracy. A high value of 0.97 connotes that shocks on the African gas in the Henry Hub market have a near permanent effect. Investors are

[7] These equations have been defined in chapter four.

therefore availed with information regarding any shock occurrence, by the features of the asymmetry effect which in this case shows that negative shocks increase volatility more than positive shocks and take informed decision.

The test of EGARCH on sub-Sahara Gas sales also shows that the Akaike Information Criterion via the student's statics outperforms other information criteria.

6.3.2 Qualitative Attributes

i. Clustered-Market structure

A national or regional gas enterprise can be costly except if is properly scripted on economically viable mode. The best fit of such mode according to report of findings from qualitative analysis documented in chapter five, is to create a clustered-market structure and a clustered-market structure according to same report and the same chapter five, is that market structure which identifies paramount activity centres along the value chain that are economically profitable and link them in a cluster. Economic activities along the value chain of natural gas comprise exploration, production and processing at the upstream; transportation and distribution in the midstream and off-taker and consumption in the retail end. Off-takers have been identified in the research to include: agricultural processing and inputs; chemical industries; electricity; household consumption and construction industry and cement. Equally, the producers are the gas endowed giant Nigeria and the newly found centres like Tanzania and Mozambique. The role of government will now be to create policies that will ensure a market-based driven gas transmission from the producing clusters to the consuming clusters. This will cut out wasteful investments, block leakages and improve profitability which will in turn drive up sustainable investment inflows.

ii. Market-Based Practice

Replacing the counter-productive market instruments like the case we see in the Nigerian domestic gas market with commercially driven instruments checks government undue interferences and improve market efficiency. This way, producers can enter their contractual suppliers with the off-takers directly cutting off government repressive interferences. The practice of price fixing which is a gridlock to the functioning of an effective and matured natural gas market like the four examined is one crucial practice that should be mortified. Market-based practice is what is critically required to mature the market towards the Henry-Hub; Nat Balancing Point; Title Transfer and ZeeBrudge in which current natural gas are traded, thereby creating the right environment for the application of the derived quantitative model.

iii. Financial Liquidity

The need for financial liquidity is not farfetched. Liquidity helps in creating access to capital to actualize viable investment in the entire value chain especially for new entrants and start-ups with good gas business acumen. Liquidity helps in honouring contractual obligations. A liquid market reduces the burden on government to cough up intervention fund in time of crisis as in the Nigeria's case with gas dependent power sector. The role of governments across the region is to domesticate:

a. Its export earnings which are under the management of international institutions;

b. Create access to the vast statutory savings can be opened to gas-targeted businesses;
c. Ensure that financial instruments like functional and easily callable guarantees and counter guarantees by reputable global institutions should feature prominently in the market at the comfort of the producers. This way confidence in the market would be created to drive business flow;
d. Imbibe the concept of resource-for-infrastructure. This suggests that government earnings from the same market which are not part of statutory expectations nor additional tax burden on any economic agent should be re-invested in the infrastructures required in that very industry. An example is mandatory at this point. Nigerian government earns consistently an average of US$873 million yearly from 1999 when it started its NLNG with selected global gas investors to 2016 which accumulates to a whooping sum of US$15.70 billion in dividends alone according to the NLGN Facts and Figures (2017). From the survey focus group discussion, it is understood that the current estimate for the construction of a 36” 450km gas pipeline is US$719 million. Therefore, if Nigeria has applied this principle of resource-for-infrastructure, using 50% of the accumulated dividends of US$15.7 billion, a gas network of 4,913 km would have been added to its current gas pipeline network in that market without recourse to the banking sector and at no cost to the public. A rethink towards the possibility of applying the use of resources-for-infrastructure system going forward is worth including into the sub-Sahara Africa Natural Gas Market model;

e. Consider committing the management of the region's crude oil and gas sales, which are managed by international funds manager like JP Morgan to domestic banks that meet global rating. The policy should entrust (if not all, a strategic portion) of oil & gas sales funds that are under the financial services of these offshore global financial institutions into the management of the systematic important banks in the region that have crossed the global top 500 banks rating. This way, liquidity would have been created in the financial system to strengthen the current financial incapacity of the banking system.

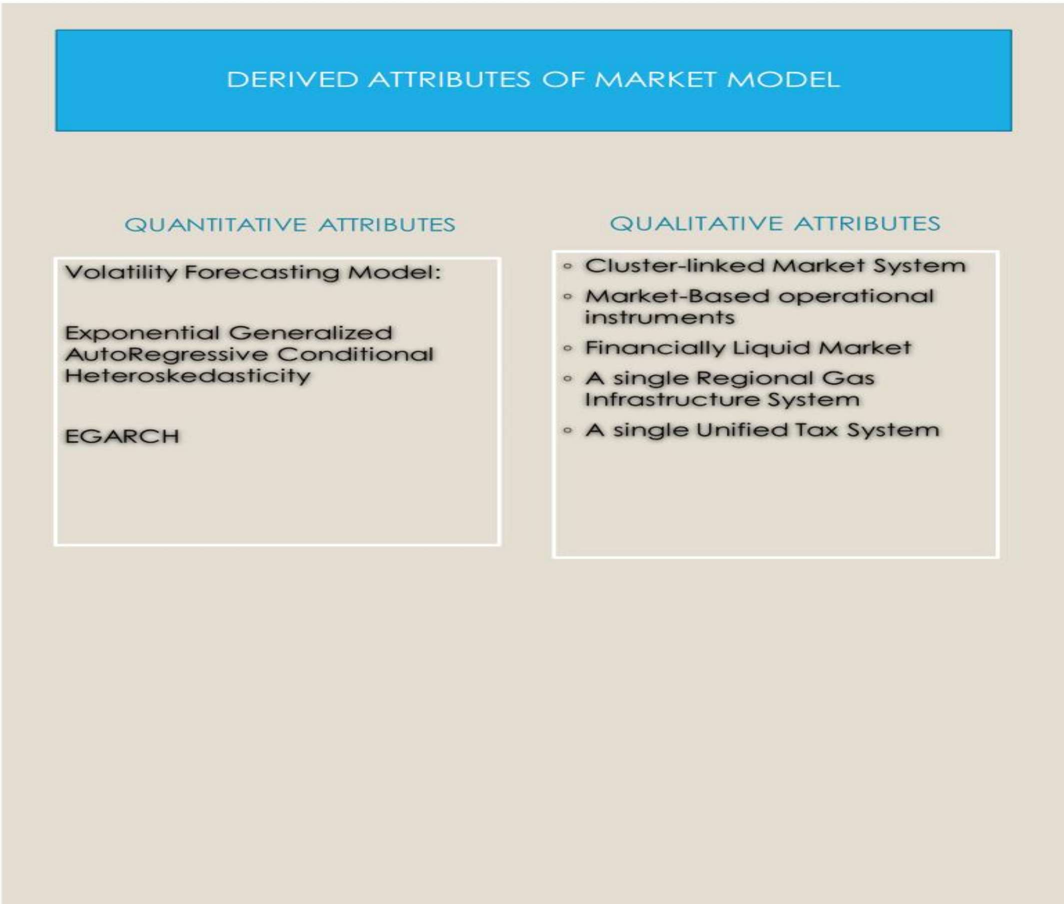
iv. A Regional Infrastructure System

This follows closely with the cluster model suggested. The identified clusters have to be connected. Critical among the facilities required include cross-border pipelines; intermediate transportation and receiving infrastructures; local pipelines and LNG terminals and storage. A regional infrastructure network such as this is neither in the budget of the producer nor that of the off-taker. Rendition from group discussion picks this situation as a vital success factor in bringing gas investment up from current levels. This is because a single regional infrastructure network is easy to manage than individual states' networks. It is also effective as it cuts off border conflicts, and if follows along the concept of activity clustering, it becomes cost-effective and funds invested easily recoverable and in good time. If this is deemed by industry experts in government authority to be key success factor, then it could be useful in the model of natural gas market for sub-Sahara Africa region.

v. A single Tax System

The final pillar of the sub-Sahara Africa natural gas market model is the proposition of a single tax system. Confidence of top managers of the industry in Africa of the potentials and possibilities of this single regional tax system working, inform the decision to include it in the model. These pillars are summarized in figure 18 below.

Figure 13- Combined Attributes for the Proposed Market Model



The combination of these two classes of attributes in this table is used in forming the proposed natural market model in section 6.4 below.

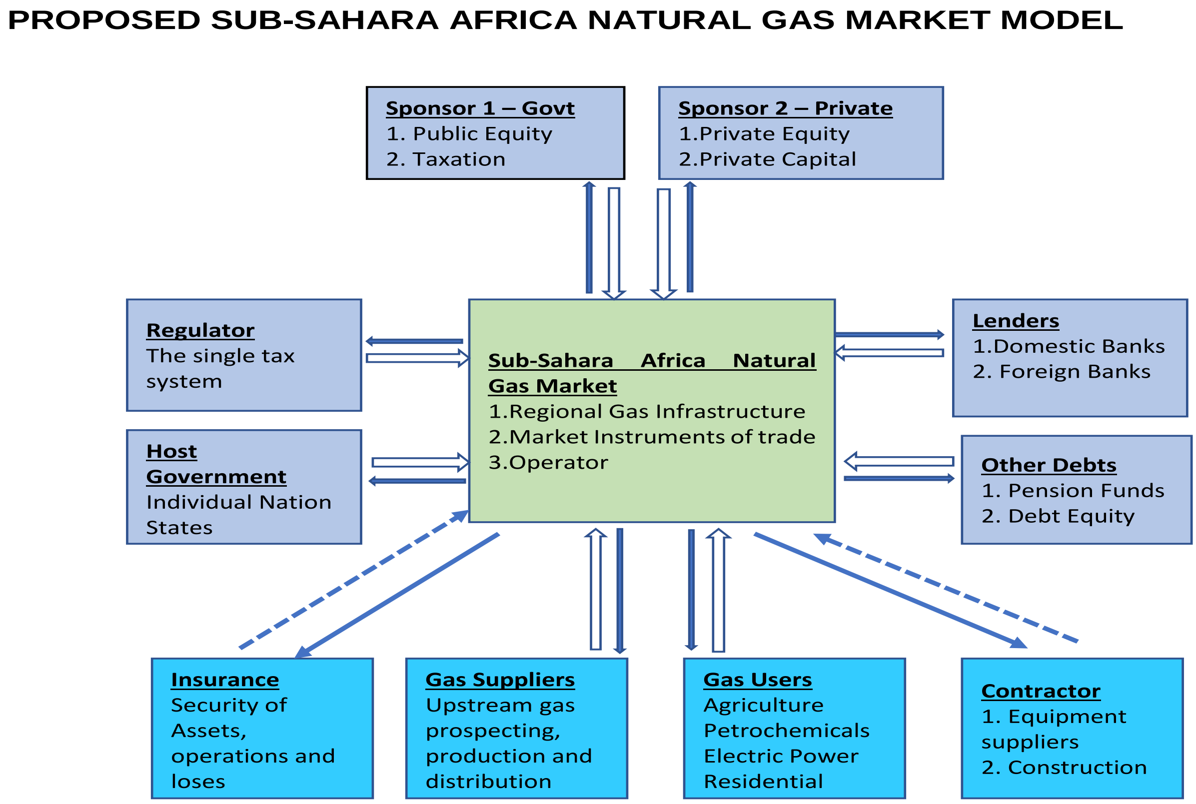
6.4 The Proposed Natural Gas Market Model

By way of summary, what emerged as the proposed natural gas market for sub-Sahara Africa is as in figure 19 below.

The table presents a market integrating economically viable and profitably operating gas businesses in clusters, linked by a single regional gas infrastructural system under a single regional gas tax system and a liquid financially system. Its transactions are consummated through market-based commercial instruments between producers and off-takers, with Exponential Generalized Auto Regressive Heteroscedasticity as derived quantitative tool for investigating volatility parameters. As the entire market operation looks more domestic than the current practice of export, this market model proposed for sub-Sahara Africa is a domestic market. Consequently, research findings suggest that, the market to bring natural gas out of the vast gas endowment in sub-Sahara Africa to feed its viable economic sectors is a domestic market.

The nature and operational dynamics of the market are presented in figure 16 below.

Figure 14 - The Proposed Natural Gas Market



Source: Modelled by Author from research findings

What emerges in figure 19 above as the proposed sub-Sahara Africa Natural Gas Market reflects all the five aspects of market considered in literature review from which questions and hypotheses were raised and the research conducted. In essence, this is the result of the research on sub-Sahara Natural Gas Market from Regulatory and Investment Approaches.

The market assumes a natural setting. As the saying “all roads lead to market” the proposed market in the centre becomes a centripetal force where all market activities are destined. Investment activities, firms’ practices, price behaviour, regulations and Supply-side Economic Solution represented in the boxes have individual and collective interdependence relationship with the centre of activities - the market - in a natural way.

The nucleus of the market contains the critical natural gas infrastructure; trade instruments and an operator. Research result in chapter five indicates that the natural gas infrastructure comprises a regional super gas pipeline network connecting suppliers with users, storage facilities to support the functioning of the network and LNG facilities to serve regions in areas where it is not economical to serve with pipelines. The type of instruments used in the market as mentioned in chapter five in analysis of findings defines character of the market. In this model, commercially traded instruments between all economic agents driven by market dynamics are the proposed instruments. Market operator is the sum up of process owners and drivers in the market such as managers from private and public domains performing a variety of necessary market functions.

The top two boxes are the sponsors of the critical assets but not exclusively as funding and support for the creation of the assets could be drawn from every market participant in any of the boxes. Government sponsorship comes in the form of public equity and taxes while private sponsorship is in form of private equity.

The right-hand boxes provide the liquidity suggested. Opening up the vast pension fund suggested as in the case of Nigeria will release a stream of liquidity into the financial market. Empowering local banks with management of export proceeds from government earnings will generally attract the interest of international banks into the region’s financial market as it engenders attractive investment banking destination.

The left-hand side provides the suggested single regulator who ensures the smooth operation of the market via a single regional tax system. Regional governments in unison provide support in form of right of way and concession. It is here that the instruments of Supply-side Economic Solution will be of use.

The market stands on the four boxes at the bottom. These are the suppliers, off-takers, insurers and contractors. The sum of them comprises the entire value chain of the gas industry.

The suggested model therefore covers the concerns of project top of which are continued government presence in the market, preference for export-led operation, risks, revenue leakages and lack of liquidity.

The model as proposed departs significantly from current operation where there is no structure. Where the entire operation is under government. Where the focus is on export earnings. Revenue leakages are prevalent. Liquidity is provided in this model. Risk covered as in the following figure:

Table 24- Identified Risk and Remedies from Proposed Market Model

Risk	Remedy
Security Risk of assets	✓ Insurance cover for vandalism and operational risks ✓ LNG Operations in volatile areas
Revenue Leakages	✓ Commercial instruments secured by bank arrangements and insurance companies
Sales risk including volume and prices changes	✓ Long Term contracts using commercially driven market instruments ✓ Application of EGARCH in price volatility forecast
Reservoir Risk	✓ Transparent market due to private sector led market operation and commercially driven market instruments to disclose reservoir contents
Political Risks	✓ Insurance cover ✓ Regional harmony through unified regional tax under a regional regulator
Risk of project abandonment	✓ Fixed-price Turnkey arrangement to transfer risk to contractors
Risk of predicted and forecasted cashflows divergent	✓ Deployment of EGARCH models ✓ Owners of assets (like natural gas infrastructure provide professional operations and maintenance managers

Source: Constructed and presented by Author

Part of the market model introduced has provided remedies to the risks identified in literature as shown in this table. However, as the entire systems rests on prediction and forecasts, this is where the quantitative segment becomes the dominant approach of the research investigation. The derived EGARCH is therefore a relevant choice for the oversight of this market in gauging future price volatilities and risk management.

6.5 Conclusion

Engaging all the market aspects such as investment issues, price behaviour, firm theories, regulatory economics and supply-side economics solution in the research – even though it was difficult – this bold approach has paid off by bringing out the attributes that aided in developing the market model. Taking the dualistic approaches was a necessity as one single research approach would have ended in producing only a part of the solution. It is gratifying to see at least a market model that could revolutionize the somewhat dormant natural gas market in sub-Sahara Africa if tested.

CHAPTER SEVEN
SUMAMRY AND CONCLUSION

7.1 Introduction

A worrisome energy situation in sub-Sahara Africa Region motivates the study. The continued and increasing significance of natural gas in the global energy basket serves as a sufficient appeal to attract the interest of energy researchers. This is more so in relation to natural gas prices econometric volatility modelling which has not received adequate attention in response to its growing importance in the energy commodity basket. While sufficient studies have been documented in literature on economic-wide impact of agriculture; chemical industry; electric power supplier and residential consumption of cleaner energy, only few studies (mostly operational research) have been noticed in literature reporting the potentials of natural gas on these dominant economic sectors. On the sub-Sahara Africa region, no comprehensive gas-specific study appears in literature. The totality of these issues attracted this researcher to the study of natural gas economics in sub-Sahara Africa region.

The study however for the reason of scope departs from a general-economic-wide study. A general-economic-wide research would have required aggregation of all economic variables, systems, institutional frames and demography. It therefore focuses on this specific natural gas market in a microeconomic model, taking all the market pillars to suggest a market model that could bring more gas out of the vast natural gas endowment in the region.

This introduction is followed by summary of the thesis in section 7.2. Sections 7.3 and 7.4 contain highlights of areas the thesis has made contribution to literature and areas of the project’s limitation respectively. Section 7.5 suggests possible areas for further research while 7.6 by way of conclusion presents some recommendations.

7.2 Summary of the thesis

Chapter two reports a comprehensive literature review on each of these fundamental market pillars comprising: investment; firm theories; natural gas price fundamentals; economics of regulation and Supply-side Economic Solution. The necessity of including Supply-side Economic Solution is dictated by the fact that the problem is that of supply rather than demand. In each of the five market components, gaps are identified leading to research questions. The questions raised fall into two parts with each set requiring a different research technique. In the context of these differing technique requirements, a search for the appropriate methodology and relevant tools to find answers to the questions raised is documented in chapter three.

It turns out in chapter three that the research is best conducted on a quantitative-lead mix-method supported by a qualitative supplement. Chapter three also suggests use of ontological objectivism to answer, “what is there to be studied” questions and epistemological positivism to organize the “how” to conduct the research on sub-Saharan Africa natural gas market with strands of interpretivism to support and or clarify quantitative findings. This is how the study acquires the pluralistic dualism comprising ontological objectivism and epistemological positivism augmented by normative interpretive epistemology. For research axiology and rhetoric, this study adopts value-free and unbiased axiology and formal use of accepted quantitative words as its rhetoric. Chapters four and five are reports of finding from the two sets of research approaches.

Chapter four reports the quantitative part while chapter five documents the supplementary results. After a series of tests results, the adjusted EGARCH proves to serve the sub-Sahara Africa Natural Gas market better than other models. This EGARCH is modelled in such a way as to give flexibility in the distribution term to reflect changes in economic situations that are likely to defer from the markets the model is dug out from. Full attention is given to the derivation of the EGARCH as volatility modelling is the key task of the project. It is therefore modelled in a way that reflects the five fundamental components of market as market volatility is the eventual product of the dynamics of investment decision, firms' behaviour, price behaviour, regulations in terms of policies and supply fundamentals. The quantitative aspect rightly deserves the attention of the research as all the key stake-holders depend on forecast values and trends of market parameters to make informed decision. It is the overarching decision factor for potential investors and policy formulation for the managers of the natural gas endowment. The qualitative result in chapter five brought out germane issues for market modelling. These comprise the need for liquidity for the market; a unified tax system; free market operation and a single regional infrastructural network. Lack of liquidity is identified as a major setback to the development of a sustainable regional gas market in sub-Sahara Africa. Evidences provided include inability of the market to fund large tickets businesses, resulting to defaulting contractual agreements which piles up huge debt and has become a formidable gridlock to the progress of the market evolution. The qualitative results state that there are however potentials to unleash adequate liquidity into the regional gas market through various avenues such as domestic utilization of pension funds, constitutional provisions and localising management of export earnings by domestic banking institutions. The unified tax system in the report of findings in chapter five is to engender a smooth and effective tax system across the region to cut out restrictions emanating from customs and immigration diversities which are reported to limit the functioning of effective regional market. Differing laws, customs and restrictions on movements of human and material capital might not guarantee an effective regional market especial with presence of weak and ineffective institution permeating the region. The market scenario in Nigeria which is a reference country in the qualitative analysis is all government infested. Prices are fixed according to information from focus group interview denying the functioning of natural market. Government owns almost eighty per cent of the industry according to findings. If there is dispute that this kind of scenario cannot help in creating an efficient market and growing it to a matured setting such as the four regional markets the region's current natural gas trades in currently, that dispute will be a minority.

Chapter five also demonstrates a need for a single regional infrastructural system. This is coming from respondents' rendition as to the expensive nature of critical infrastructure such as pipelines and the explanation that investors along the entire value chain may not want to take the burden of providing this kind of infrastructure.

Chapter six is the amalgamation of the quantitative and qualitative results on the basis of research methodology described in chapter three. This amalgamation translates to the forming of market model that is suggested for the sub-Sahara African region. In chapter three, it is required that following the Morse and Niehaus (2009) Route “B”, the quantitative findings be integrated with that of qualitative result during the discussion of research findings in chapter six. What emerges is the proposed Natural Gas Market for sub-Sahara Africa Region.

7.3 Contribution of the Research to Literature, Policy and Practice

Being a nascent research as in Edmondson and Mcmanus (2007) the research has made contributions to the relevant literature, policy and practice in the area of energy economics in general and gas industry in sub-Sahara Africa specifically. These are briefly highlighted in the sub-topics of this section as follows:

7.3.1 Contribution to Literature

From the research questions all through the illustrative methods for data collection to contribution, as in Edmondson and Mcmanua (2007), a study can be classified as nascent. This study like in nascent studies employs open-ended inquiries, conducted focus group discussions in its part of data generating process for the qualitative part, uses thematic content analysis in interpretive way and develops a new market model suggestion. It is in this way that it compares with other nascent studies like: Gersick (19988); Barker (1993) and

Maznevski and Chudoba (2000). By the virtue of its nature as nascent, it has opened an interesting area of study.

Specifically, the study’s contributions to literature include:

i. Allowing for flexibility in the distribution term of the Exponential Generalized Autoregressive Heteroskedasticity model. From the point of view of volatility modellers this deliverable is valuable in the explaining behaviour of natural gas market volatility to both investors and policy makers. The flexibility introduced will also allow adaptation of the model in the sub-Sahara Africa region.

ii. In terms of shock persistence, demonstrating that shock persistence can be shown in number of days is additional contribution.

iii. The establishment and introduction of a single regional tax system is a very important contribution to literature. So also, is the identification of potential efficacy of a single regional infrastructural system.

iv. The emergence of clustering system in the market model in chapter six is entirely new. This is also considered as an important contribution.

v. Unbundling the findings and suggestions of liquidity, aspects such as the banking reforms are novel. No finding in literature has suggested deploying the management of external earnings to local banks to create liquidity.

vi. Another contribution of this research is addition of one more voice to the voices of researchers in literature that use mixed methods. A dominant group of economic researchers are bent on the exclusive application of quantitative methods seeing little or no benefits of qualitative approaches. In all of the literature examined in this study, few use a combination of methods as in this research. Starr (2014) however documents a rising profile of qualitative support groups of economic researchers but examination of their methods indicates that they were on either side of the divide and not on mixed methods. Sometimes in-between the late eighties, up to 2011, literature documents a number of qualitative economic researches including the works of Schwartz (1987), Bewley 1995), Van Staveren (1997) and Valente (2011). However, studies on energy, especially crude oil markets concentrate mainly on quantitative methods. This study has therefore brought out the usefulness in mixed methods as each of the methods contributes essentially to the forming of the model market suggested for sub-Sahara Natural Gas Market.

vii. Finally, the study has developed and introduced a new market model to literature. What emerges from the research on sub-Sahara Natural Gas Market from Investment and Regulatory Approaches is the market model in chapter six. The proposed market portrays the features of a natural market setting, where all market components considered in the research, work inter-relatedly in a mechanism without undue interference. These components we recall from literature include: Investment activities, firms' practices, price behaviour, regulations and Supply-side Economic Solution. In this way, what emerged departs significantly with current practice in the region where the entire market operation is government-led with focus on export earnings. With this market model, income leakages, security matters, business risks that are the major findings of this research identified to impede investment flows are to an appreciable degree, addressed.

7.3.2 Contribution to Policy

Key areas of policy issues relate mainly to liquidity, security of assets and their operations, the call for change of government focus regarding foreign exchange expectations from the gas business and other governance issues. The problem of liquidity is demonstrated in the analysis of findings in chapter five which calls for far-reaching financial policies including expansion of banking business to include management of earned foreign income now residing with offshore banks. The vast deposit of pension funds is another area requiring policy shift just as the creation of the concept of municipal special funding for the gas sector as in the examples of Canada and other countries reported in the qualitative report of findings. To secure assets and operations of gas business in the face of current security challenges is another area requiring policy deployment. It is highlighted in the qualitative report of findings that security of lives and property is becoming a real threat in the region. Security of financial assets such as leakages in revenue requires policy withdrawals, such as winding down the dominant role of government in the market. In terms of foreign exchange, a major government re-orientation is required. Report of qualitative findings raises this as the bane of weaknesses underlying poor policy formulation and weak implementation of domestically viable policies in the region. The above key findings of this research are useful contributions and policy trust for the region in its efforts to change the current narrative of its natural gas market.

7.3.3 Contribution to practice

The proposed model as sculpted in chapter 6 and presented in figure 19 is purely a practical essence. For instance, the withdrawal of government participation alone entrenches private practice that the research outcome identifies as a critical success factor in the operation of the proposed model. Other features of the model such as the proposed business clustering seem to possess far reaching constructive and useful appeals to potential investors in practice. This is because they seem to comprise some feasible means that might help reduce wasteful asset creation and counter-productive activities.

7.4 Significance of the study

Gleaning from the aforementioned contributions of the study portrays this research as a significant study of natural gas business in sub-Sahara Africa first, to the government of the region on one hand and then potential investors on the other hand. The proposed model market thus semantically captures and dictates the practical ways in which both parties should participate synergistically to achieve their mutual objectives without hurting the growth of the industry in any ways. The study being a nascent study creates various ways of academic engagement as captured in section 7.6 below.

7.5 Limitations of the study

With all the efforts put, care and attention given, the study still contends with some short comings from both quantitative and qualitative approaches.

From the quantitative side, it is a matter of scope. In the model selection exercise that leads to the choice of EGARCH for market volatility prediction, in-sample, sub-sample and out of sample forecast should have been made. However, the scope was limited to incorporate forecast results of the three segments on four markets, which would have resulted to generating over thirty-six sets of reports – one set comprising twelve reports in in-sample, a second and third set with similar numbers for sub-samples and out of sample tests. However, the robustness of the three information criteria and their suitability to the competing models and tractability in application generated the desired result. Model selection based on information criteria in most research works is considered as a superior algorithm in volatility forecasting modelling. In addition to this, the fact that EGARCH outperforms all other competing models in several tests leaves little doubt of its superiority in modelling volatility prediction in markets where sub-Sahara Natural Gas trades, compares to other competing models. Therefore, the omission of further tests as these three tests forecast is in no way detrimental to the study.

On the qualitative method, two challenges worthy of note manifested during the survey. One was managing the flow of discussion. Because it is mainly discussion, sometimes a member of a focus group strays from the point. However, because the setting was formal, with one focus group discussant (the most senior) assuming the role of a leader, derailing from discussions were brought into track. The work of Donley (2012) plays out in some of these incidences of derailing. The second was recording. Oil & Gas business is shrouded in secrecy. No voice recording was allowed. It was therefore challenging to record every word from each participant. However, because talking point were sent to each institution before the meeting and each organisation was taking notes as well as generating minutes of the meeting, responses to themes of discussion were adequately captured. The research also uses documents, statutes and policies made available covering the themes of discussion during the focus group discussions. Information generated in the conduct of the survey was successful and satisfactory.

A third and final of what might be considered as a short coming was in the choice of route “B” in interfacing research results from the two approaches. Being a quantitative-led approach, it might appear that route “A” of Morse and Niehaus (2009) should have been chosen, rather than route “B”. This is because route “A” calls for transforming the textual data into numeric – being supplementary - and integrating it to the quantitative result to give one single analysis. In this way, there would have been no need for chapter five. But in the opinion of this researcher, Morse and Niehaus (2009) route “A” does not apply in this particular instant. This is supported by the fact that route “A” as conceived by the authors is not for universal application in all qualitative research. Its use in this case depends on the area of research, method of survey instrument administered and the level and nature of the supplementary role of the qualitative data. In other studies, not related to natural gas market, and using other qualitative methods such as structure questionnaires, this would have been necessary. It is the opinion of this researcher that high quality and relevant information was derived using the semi-structured focus group discussions and the most effective method of analysis employed. The results of the study are attestation to the suitability of the chosen route.

7.6 Possible Areas for Further Research

Being the first of its kind, the study opens a host of possible areas for further investigations. In the quantitative aspect, volatility modellers may want to model volatility of natural gas market in sub-Sahara Africa differently. There is scope for other researchers to investigate relationships of natural gas prices with other energy prices in sub-Sahara Africa and also to investigate the drivers of natural gas prices in the region. Along the line, some researchers may want to test the efficiency of the proposed sub-Sahara Africa natural gas market model at any stage.

Volatility modellers within the GARCH-models with further interest in the sub-Sahara Africa natural gas market might model volatility on pure non-parametric models or combine the parametric errors approach as in this research with non-parametric errors approaches or go for a partial parametric error modelling. Some may want to use multivariate approaches. Studies such as Narayan and Narayan (2007), Beckers, Herwartz and Seidel (2017), Nelson (1991), Wang and Wu (2012) and a host of others that were applied to crude markets may be attracted to the proposed natural gas market model with a prospect of repeating their works this time around, on sub-Sahara Natural Gas Market. The work of Engle and Victor (1993) can be used to measure and test the impact of news on the volatility of the proposed model. It also likely that authors like Arouri et at (2012), Salisu Fasanya (2013), Ewing and Malik (2017) that were equally crude oil market specific studies incorporating structural breaks may see reasons in applying the same models on sub-Sahara Africa Natural Gas Market. Others may want to try Inclan and Tiao (1994) Bai and Perron (2003), Andrews (1993) on the proposed model to account for regime shifts.

In the area of investigating relationship of natural gas and other related volatility markets like petroleum products, crude oil, electricity, foreign exchange and inflation, the works of Hartley, Medlock and Rosthal (2008), Hassan (2013) Salisu and Mobolaji (2013) which are crude oil market specific studies come handy. Others may want to use the Johansen methodology as in Hjalmarsson and Osterholm (2010) to test the proposed model. Investigating relationship is an important area of study especial for sub-Sahara African economy in the case of volatility of natural gas prices and foreign exchange nexus. Essential policy instrument in terms of choice between domesticating natural gas market and continued export of the commodity is one of such cases. This type of investigation is also useful in the area of policy choices regarding energy supply in the region. Focus has been disproportionately given to electric power supply to household consumption with little effort on gas supply to this economic sector. It could be argued that this is because of insufficient research to show the competitiveness or otherwise of gas to household consumption as an example.

Nick and Theons (2014) is one of the few studies in testing drivers of natural gas price volatility. Even though their focus is on Germany, such studies could be extended to test this model. Researchers may want to use the work of Hwang and Huang on US crude oil market to analyse factors that could explain volatility in the proposed market model. One specific market factor affecting natural gas volatility in matured markets which is not applicable to sub-Sahara Africa is weather (in terms of temperature). Cultural issues like believe in most parts of

Africa that modern cooking appliances do not generate good aroma of some traditional foods might also be a factor that is not common in matured climes. These criss-crossing and differing factors could lead researchers to apply their investigating tools to the proposed market model in effort to shade more light on factors of potential market changes. Others like Charles and Darne (2009) may want to test the efficiency of the proposed market using variance ratio tests or any econometric model.

Therefore, it can be summed-up that the proposed sub-Sahara Africa natural gas model is a forerunner of several likely areas of further studies at least, in this quantitative examination.

The qualitative pillars that make up the proposed market model in chapter six also exhibit areas of research interest. One of such areas is the impact of import substitution from the proposed market domestication. Domestic gas supply could impact directly in displacing imports of related commodities like petroleum products that are close substitutes. It is also likely to cut down the volume of imports of petrochemicals, fertilizer and cement imports. This scenario brings up a trade-off between export earnings and import expense in an inverse relationship. Economists might be interested to know which direction best suits domestic economic fortune for policy prescription. In such a case, researchers will be attracted to further study the proposed market model. Governments of the region that are endowed with gas do export a larger part of it and use the proceeds to import refined petroleum liquids, processed gas products and agricultural inputs. Mathews (2014) attempts a similar study but limited his study on infrastructural and logistic comparison. The actual trade-off between import and export in economic terms are not clearly brought out in Mathews' (2014) attempt. This leaves a huge gap for further exploration. Although there are pockets of sponsored studies documented like All Africa (2008, 2009a), but these are specific, dedicated researches to serve the exigencies of the periods they were conceived. There is therefore a high probability that further studies on this aspect are likely to attract research interests.

The proposed regional single tax system by indication is a new and untested recommendation. Its high score lies in the fragile and weak multifaceted hydrocarbon laws that are a gridlock to the development the gas market in the region. Nonetheless, because of multiple governance differences in the continent, further studies might be required, at least on a kind of "what is in it for me" question. Researchers could design projects to answer such questions as they are likely to come up.

A single infrastructural network system may look simple, but there may be implicit complications unknown. Even though it could score high in terms of winnings from economy of scale if compares with disaggregated network systems, its operational efficiency will attract studies digging into it. There is also the issue of determining its economic opportunity cost at the point of implementation. Although one of the suggestions made in this research was the use of resource-for-infrastructure. However, the magnitude of the infrastructural system required is far beyond the capacity of this source of capital. That means financing of this huge infrastructure most come from other public sponsored sources. This is where the research on the opportunity cost will emerge.

A final area to look at is wealth distribution from the proposed market across the region. If clustering becomes successful, and income generation feasible, the next rational economic interest turns to equitable wealth distribution first, among national states and then among its class of people. Nations cut out of the cluster of main economic activities are apparently at disadvantage compares with the main activities that are centres for receiving cash flows and other financial benefits. Welfare economists with interest in the proposed market model are likely to take such studies.

The study from the foregoing may attract several research interests.

7.7 Recommendation

The ramification and implication of the study requires the attention of the target focus domain. Natural gas is needed in the sub-Sahara African region. The research identifies such areas of economic potentials that require gas. Pillars have been raised to form the components of a market model. The model is proposed for test in the sub-Sahara Africa region.

It is therefore recommended that the market model be presented to the relevant institutions in the region to explore the possibilities of implementation. Chiefly among these institutions are:

The African Union which is the umbrella under which the region's economic policy prescription and implementation are pursued. African Union participated effectively in the survey. The body has a dedicated energy desk with oversight function on African Energy Commission. It is the opinion of this researcher that this organization can use its vintage position to drive the proposed model to logical implementation if it finds it useful.

Nigeria's Ministry of Petroleum and Nigerian National Petroleum Corporation in Nigeria currently lead in the region's natural gas market and is a reference point to new entrants of the African nation states in both the supply and consumption of natural gas. Such fundamental pillars as the clustering and single regional task proposals can be driven effectively by these Nigerian institutions mentioned as well. Contribution to domestic finance also rests on the shoulders of Nigeria which has substantial fortunes off-shore that if brought to the domestic management by the region's top banks could increase liquidity. Nigeria also has a substantial amount of unused savings in the form of pension funds.

Therefore, it is recommended that the attention of these institutions be drawn to the suggested model taking into account their active participation in the survey.

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Appendix

Appendix I: Survey Data Collection Material

Group 1 Gas Aggregation Company

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

FOCUS GROUP DISCUSSION - OF INDUSTRY EXPERTS

Introduction

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

Kindly note that:

1. *Your organization's participation in this discussion is absolutely voluntary and participation can be withdrawn at any time without giving explanation.*
2. *The anonymity of the organization's representatives will strictly be guided and maintained.*
3. *The information your organization provides will not be used for any purpose other than the conduct of the specified research.*
4. *All documents received from your organization in this survey would be treated as confidential and in strict adherence to the specific use of the project.*

Objective of the survey

The objective of the survey is to get all the information itemized below which are critical to the success of the study. Where there are documents in respect of the discussion, the researcher would be grateful to have such documents. The discussion will cover the understated sections and numbered discussion points.

Kindly therefore assist this project, by providing critical information required as follows:

Section One

Cultivating and sustaining interest in natural gas investment in sub-Sahara Africa

There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its potential market opportunities. This is why this research work wants to know the fundamental socio-pollical and economic factors that can entice and keep investment flows into the region.

Kindly therefore assist this research work by discussing the following points in this regard:

1. Your opinion on the current investment status in the vast natural gas reserves in sub-Sahara African Region is important to this project. Can we discuss it please?

2. Can we also discuss the fundamental investment factors like government policies on gas investment, the region's economic condition, community and environmental factors as they might appeal to investors in natural gas business?

3. What in your opinion and experience keeps investors away from investing in the sub-Saharan African natural gas market?

4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?

5. Could you share with us the basis of your answer above?

6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

Section-Two
Risk Perception

One of the peculiarities of the oil & gas industry, which differentiates it with other industries is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

Kindly therefore assist this research work by discussing the following points:

7. Kindly discuss the perception of gas business risk in sub-Sahara Africa by prospective investors.

8. From the risks discussed above, do they have specific features rather than normal business risks found in literature and in some practices?

9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

Section – Three
Tax System

It is commonly accepted that the success of a country's or region's oil & gas market is driven by its tax system. Kindly therefore help this research work by discussing the following points of interest:

11. From your experience with sub-Sahara African Region, is there any country that has a tax system appealing to investors?

12. Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?

13. Could you also share with the researcher those elements that are bad?

14. What do you think should be done to improve the defects stated?

15. How sTable are petroleum tax regimes in the key participating countries of the region?

16. What in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?

17. Could you also kindly explain your suggestion of point 16?

End of Discussion.

Group 2 West African Gas Pipeline Authority

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

SURVEY BY INTERVIEW OF WAPCo.

Introduction

Introduction

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

Kindly note that:

1. *Your organization's participation in this discussion is absolutely voluntary and participation can be withdrawn at any time without giving explanation.*
2. *The anonymity of the organization's representatives will strictly be guided and maintained.*
3. *The information your organization provides will not be used for any purpose other than the conduct of the specified research.*
4. *All documents received from your organization in this survey would be treated as confidential and in strict adherence to the specific use of the project.*

Objective of the survey

The objective of the survey is to get all the information itemized below which are critical to the success of the study. Where there are documents in respect of the discussion, the researcher would be grateful to have such documents. The discussion will cover the understated sections and numbered discussion points. Kindly therefore assist this project, by providing critical information required as follows:

Section One

Cultivating and sustaining interest in natural gas investment in sub-Sahara Africa

There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its potential market opportunities. This is why this research work wants to know the fundamental socio-pollical and economic factors that can entice and keep investment flows into the region.

Kindly therefore assist this research work by discussing the following points in this regard:

1. Your opinion on the current investment status in the vast natural gas reserves in sub-Sahara African Region is important to this project. Can we discuss it please?

2. Can we also discuss the fundamental investment factors like government policies on gas investment, the region's economic condition, community and environmental factors as they might appeal to investors in natural gas business?

3. What in your opinion and experience keeps investors away from investing in the sub-Saharan African natural gas market?

4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?

5. Could you share with us the basis of your answer above?

6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

Section-Two
Risk Perception

One of the peculiarities of the oil & gas industry, which differentiates it with other industries is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

Kindly therefore assist this research work by discussing the following points:

7. Kindly discuss the perception of gas business risk in sub-Sahara Africa by prospective investors.

8. From the risks discussed above, do they have specific features rather than normal business risks found in literature and in some practices?

9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

Section – Three
Tax System

It is commonly accepted that the success of a country's or region's oil & gas market is driven by its tax system. Kindly therefore help this research work by discussing the following points of interest:

11. Taking dominant countries in terms of contribution to the regional gas business, is there any country that has a tax system appealing to investors?

12. Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?

13. Could you also share with the researcher those elements that are bad?

14. What do you think should be done to improve the defects stated?

15. How sTable are petroleum tax regimes in the key participating countries of the region?

16. From your experience with West Africa Gas Pipeline, what in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?

17. Could you also kindly explain your suggestion of point 16?

End of Discussions.

Group 3 African Union

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

FOCUS GROUP DISCUSSIONS - AFRICA UNION REPRESENTATIVES

Introduction

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

Kindly note that:

1. *Your organization's participation in this discussion is absolutely voluntary and participation can be withdrawn at any time without giving explanation.*
2. *The anonymity of the organization's representatives will strictly be guided and maintained.*
3. *The information your organization provides will not be used for any purpose other than the conduct of the specified research.*
4. *All documents received from your organization in this survey would be treated as confidential and in strict adherence to the specific use of the project.*

Objective of the survey

The objective of the survey is to get all the information itemized below which are critical to the success of the study. Where there are documents in respect of the discussion, the researcher would be grateful to have such documents. The discussion will cover the understated sections and numbered discussion points. Kindly therefore assist this project, by providing critical information required as follows:

Section One

Cultivating and sustaining interest in natural gas investment in sub-Sahara Africa

There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its potential market opportunities. This is why this research work wants to know the fundamental socio-pollical and economic factors that can entice and keep investment flows into the region.

Kindly therefore assist this research work by discussing the following points in this regard:

1. Your opinion on the current investment status in the vast natural gas

reserves in sub-Sahara African Region is important to this project. Can we discuss it please?

2. Can we also discuss the fundamental investment factors like government policies on gas investment, the region's economic condition, community and environmental factors as they might appeal to investors in natural gas business?

3. What in your opinion and experience keeps investors away from investing in the sub-Saharan African natural gas market?

4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?

5. Could you share with us the basis of your answer above?

6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

Section-Two
Risk Perception

One of the peculiarities of the oil & gas industry, which differentiates it with other industries is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

Kindly therefore assist this research work by discussing the following points:

7. Kindly discuss the perception of gas business risk in sub-Sahara Africa by prospective investors.

8. From the risks discussed above, do they have specific features rather than normal business risks found in literature and in some practices?

9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

Section – Three
Tax System

It is commonly accepted that the success of a country's or region's oil & gas market is driven by its tax system. Kindly therefore help this research work by discussing the following points of interest:

11. Taking dominant countries in terms of contribution to the regional gas business, is there any country that has a tax system appealing to investors?
12. Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?
13. Could you also share with the researcher those elements that are bad?
14. What do you think should be done to improve the defects stated?
15. How sTable are petroleum tax regimes in the key participating countries of the region?
16. What in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?
17. Could you also kindly explain your suggestion of point 16?

End of Discussion.

Group 4 Economic Commission for Africa

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

<u>FOCUS GROUP DISCUSSIONS – ECONOMIC COMMISSION FOR AFRICA</u>

<u>Introduction</u>

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

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The objective of the survey is to get all the information itemized below which are critical to the success of the study. Where there are documents in respect of the discussion, the researcher would be grateful to have such documents. The discussion will cover the understated sections and numbered discussion points. Kindly therefore assist this project, by providing critical information required as follows:

Section One

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There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its potential market opportunities. This is why this research work wants to know the fundamental socio-pollical and economic factors that can entice and keep investment flows into the region.

Kindly therefore assist this research work by discussing the following points in this regard:

1. Your opinion on the current investment status in the vast natural gas reserves in sub-Sahara African Region is important to this project. Can we discuss it please?
2. Can we also discuss the fundamental investment factors like government policies on gas investment, the region's economic condition, community and environmental factors as they might appeal to investors in natural gas business?
3. What in your opinion and experience keeps investors away from

investing in the sub-Saharan African natural gas market?

4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?

5. Could you share with us the basis of your answer above?

6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

Section-Two
Risk Perception

One of the peculiarities of the oil & gas industry, which differentiates it with other industries is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

Kindly therefore assist this research work by discussing the following points:

7. Kindly discuss the perception of gas business risk in sub-Sahara Africa by prospective investors.

8. From the risks discussed above, do they have specific features rather than normal business risks found in literature and in some practices?

9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

Section – Three
Tax System

It is commonly accepted that the success of a country's or region's oil & gas market is driven by its tax system. Kindly therefore help this research work by discussing the following points of interest:

11. Taking dominant countries in terms of contribution to the regional gas business, is there any country that has a tax system appealing to investors?

12. Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?

13. Could you also share with the researcher those elements that are bad?

14. What do you think should be done to improve the defects stated?

15. How sTable are petroleum tax regimes in the key participating countries of the region?

16. What in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?

17. Could you also kindly explain your suggestion of point 16?

End of Discussion.

Group 5 GasInvest Limited

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

<u>FOCUS GROUP DISCUSSION - OF INDUSTRY EXPERTS</u>

<u>Introduction</u>

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

Kindly note that:

1. *Your organization's participation in this discussion is absolutely voluntary and participation can be withdrawn at any time without giving explanation.*
2. *The anonymity of the organization's representatives will strictly be guided and maintained.*
3. *The information your organization provides will not be used for any purpose other than the conduct of the specified research.*

4. *All documents received from your organization in this survey would be treated as confidential and in strict adherence to the specific use of the project.*

Objective of the survey

The objective of the survey is to get all the information itemized below which are critical to the success of the study. Where there are documents in respect of the discussion, the researcher would be grateful to have such documents. The discussion will cover the understated sections and numbered discussion points. Kindly therefore assist this project, by providing critical information required as follows:

Section One

Cultivating and sustaining interest in natural gas investment in sub-Sahara Africa

There seems to be lack of investment interest in the natural gas market in sub-Sahara Africa Region, despite its potential market opportunities. This is why this research work wants to know the fundamental socio-pollical and economic factors that can entice and keep investment flows into the region.

Kindly therefore assist this research work by discussing the following points in this regard:

1. Your opinion on the current investment status in the vast natural gas reserves in sub-Sahara African Region is important to this project. Can we discuss it please?

2. Can we also discuss the fundamental investment factors like government policies on gas investment, the region's economic condition, community and environmental factors as they might appeal to investors in natural gas business?

3. What in your opinion and experience keeps investors away from investing in the sub-Saharan African natural gas market?

4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?

5. Could you share with us the basis of your answer above?

6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

Section-Two
Risk Perception

One of the peculiarities of the oil & gas industry, which differentiates it with other industries is the dominant participation of foreign actors. Therefore, risk perceptions differ from one party to the other. It is important for this research to know the risk perception of the investor.

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8. From the risks discussed above, do they have specific features rather than normal business risks found in literature and in some practices?

9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

Section – Three
Tax System

It is commonly accepted that the success of a country's or region's oil & gas market is driven by its tax system. Kindly therefore help this research work by discussing the following points of interest:

11. From your experience with sub-Sahara African Region, is there any country that has a tax system appealing to investors?

12. Could you share with this researcher, the fundamental elements/instruments of the tax system that make this system attractive?

13. Could you also share with the researcher those elements that are bad?

14. What do you think should be done to improve the defects stated?

15. How sTable are petroleum tax regimes in the key participating countries of the region?

16. What in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?

17. Could you also kindly explain your suggestion of point 16?

End of Discussion.

Group 6 Nigerian National Petroleum Corporation

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

FOCUS GROUP DISCUSSION - NIGERIAN NATIONAL OIL COMPANY

Introduction

A doctoral research on "Modelling Natural Gas Market for sub-Sahara Africa through investment and regulatory approaches" for a PhD is being taken at Dundee Business School, Abertay University. The purpose of the study is to answer various questions bordering on the dichotomy of sub-Sahara Africa energy landscape which is assessed to be endowed with large gas reserves but has poor patronage from entrepreneurs. Your organization has been identified as a key industry player in the global natural gas market. Therefore, contribution from this organization is vital to the success of this research.

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Objective of the survey

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Section One

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3. What in your opinion and experience keeps investors away from investing in the sub-Saharan African natural gas market?
4. Could you discuss the current sub-Sahara Africa gas investment policies in terms of adequacy and sufficiency to attract an unwilling investor?
5. Could you share with us the basis of your answer above?
6. Besides policies, are there other critical success factors that may entice an investor into - not so attractive - government policies?

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Risk Perception

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9. How could they be addressed to attract investment?

10. Is your organization familiar with how investors adjust their Rate of Return in new investment to capture perceived or estimated risk?

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15. How sTable are petroleum tax regimes in the key participating countries of the region?

16. What in your opinion and experience could be a successful Tax system that can improve current natural gas market in the region?

17. Could you also kindly explain your suggestion of point 16?

End of Discussion.

Group 7 Nigeria Gas Company Limited

MODELLING NATURAL GAS MARKET FOR SUB-SAHARA AFRICA: INVESTMENT AND REGULATORY APPROACHES

FOCUS GROUP DISCUSSION - OF INDUSTRY EXPERTS

Introduction

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End of Discussion.

Appendix II: Results of Econometric Models

Group Series Statistics
Date: 09/16/17
Time: 00:24
Sample: 1/01/2010 8/31/2017

	HHUB	NBP	TTF	ZEE
Mean	3.450220	49.87856	20.61015	49.70773
Median	3.469500	50.80000	21.23000	50.05000
Maximum	6.149000	75.97000	29.35000	73.25000
Minimum	1.639000	26.42000	10.70000	26.00000
Std. Dev.	0.840161	12.05668	4.664060	11.98420
Skewness	0.157349	-0.045186	-0.294285	-0.112026
Kurtosis	2.491714	1.885937	2.002560	1.872989
Jarque-Bera	29.66340	103.6922	111.3281	109.5893
Probability	0.000000	0.000000	0.000000	0.000000
Sum	6872.838	99358.09	41055.41	99017.80
Sum Sq. Dev.	1405.387	289418.6	43311.13	285949.7
Observations	1992	1992	1992	1992

Group Return Statistics
Date: 09/16/17
Time: 00:29
Sample: 1/01/2010 8/31/2017

	HHUBR	NBPR	TTFR	ZEER
Mean	-0.001646	-0.014765	-0.011492	-0.015324
Median	0.058055	0.054555	0.073638	0.000000
Maximum	11.93123	16.86227	10.24150	35.85679
Minimum	-69.31472	-18.23216	-14.90356	-33.47926
Std. Dev.	3.091617	2.332662	1.868715	2.328902
Skewness	-5.859164	-0.781489	-0.764788	-0.164510
Kurtosis	129.8733	13.40752	9.789408	55.74463
Jarque-Bera	1346759.	9188.412	4018.142	230798.7
Probability	0.000000	0.000000	0.000000	0.000000
Sum	-3.276789	-29.39772	-22.88067	-30.50935
Sum Sq. Dev.	19020.61	10828.21	6949.272	10793.34
Observations	1991	1991	1991	1991

Henry Hub ARCH (p, q) Test

Dependent Variable: HHUBR
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 10/02/18 Time: 22:40
Sample (adjusted): 1/05/2010 8/21/2017
Included observations: 1990 after adjustments
Convergence achieved after 31 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.005815	0.054701	0.106310	0.9153
HHUBR(-1)	0.066349	0.029214	2.271145	0.0231
		Variance Equation		
C	0.672480	0.156513	4.296645	0.0000
RESID(-1)^2	0.265945	0.019211	13.84314	0.0000
GARCH(-1)	0.716166	0.030533	23.45585	0.0000
R-squared	-0.009045	Mean dependent var		5.13E-05
Adjusted R-squared	-0.009553	S.D. dependent var		3.091466
S.E. of regression	3.106198	Akaike info criterion		4.890598
Sum squared resid	19181.15	Schwarz criterion		4.904658
Log likelihood	-4861.145	Hannan-Quinn criter.		4.895762
Durbin-Watson stat	1.936264			

Net Balancing Point ARCH(p, q) Test

Dependent Variable: NBPR
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 10/02/18 Time: 22:45
Sample (adjusted): 1/05/2010 8/21/2017
Included observations: 1990 after adjustments
Convergence achieved after 31 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.001229	0.038998	-0.031508	0.9749
NBPR(-1)	-0.050973	0.024901	-2.046975	0.0407
		Variance Equation		
C	0.060195	0.007534	7.989580	0.0000
RESID(-1)^2	0.080511	0.006353	12.67379	0.0000
GARCH(-1)	0.919360	0.005361	171.4763	0.0000
R-squared	0.003185	Mean dependent var		-0.015216
Adjusted R-squared	0.002683	S.D. dependent var		2.333162
S.E. of regression	2.330030	Akaike info criterion		4.334521
Sum squared resid	10792.93	Schwarz criterion		4.348581
Log likelihood	-4307.849	Hannan-Quinn criter.		4.339685
Durbin-Watson stat	2.012261			

Title Transfer ARCH(p, q) Test

Dependent Variable: TTFR
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 10/02/18 Time: 22:48
Sample (adjusted): 1/05/2010 8/21/2017
Included observations: 1990 after adjustments
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.016812	0.026658	-0.630642	0.5283
TTFR(-1)	-0.036207	0.025242	-1.434410	0.1515
		Variance Equation		
C	0.107251	0.014305	7.497587	0.0000
RESID(-1)^2	0.203033	0.013105	15.49319	0.0000
GARCH(-1)	0.797810	0.011672	68.35006	0.0000

R-squared	-0.002862	Mean dependent var	-0.011956
Adjusted R-squared	-0.003366	S.D. dependent var	1.869070
S.E. of regression	1.872214	Akaike info criterion	3.841308
Sum squared resid	6968.306	Schwarz criterion	3.855368
Log likelihood	-3817.101	Hannan-Quinn criter.	3.846471
Durbin-Watson stat	1.880996		

ZeeBrudge ARCH(p, q) Test

Dependent Variable: ZEER
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 10/02/18 Time: 22:51
Sample (adjusted): 1/05/2010 8/21/2017
Included observations: 1990 after adjustments
Convergence achieved after 34 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.001786	0.034068	-0.052413	0.9582
ZEER(-1)	-0.045593	0.021583	-2.112468	0.0346
		Variance Equation		
C	0.007301	0.001958	3.727718	0.0002
RESID(-1)^2	0.052949	0.003286	16.11348	0.0000
GARCH(-1)	0.953522	0.002234	426.8210	0.0000

R-squared	0.008210	Mean dependent var	-0.015769
Adjusted R-squared	0.007711	S.D. dependent var	2.329403
S.E. of regression	2.320404	Akaike info criterion	4.184340
Sum squared resid	10703.94	Schwarz criterion	4.198400
Log likelihood	-4158.418	Hannan-Quinn criter.	4.189504
Durbin-Watson stat	2.135620		

Henry Hub Correlogram of Squared Residuals

Date: 10/01/18 Time: 00:27
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.466	-0.466	432.39	0.000
		2	0.062	-0.198	440.06	0.000
		3	-0.029	-0.115	441.74	0.000
		4	0.003	-0.069	441.76	0.000
		5	-0.003	-0.042	441.77	0.000
		6	-0.013	-0.044	442.12	0.000
		7	0.026	-0.002	443.45	0.000
		8	-0.004	0.009	443.49	0.000
		9	-0.004	0.003	443.52	0.000
		10	-0.018	-0.024	444.16	0.000

Net Balancing Point Correlogram of Squared Residuals

Date: 10/01/18 Time: 00:36
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.511	-0.511	521.06	0.000
		2	0.002	-0.352	521.06	0.000
		3	0.007	-0.266	521.16	0.000
		4	0.016	-0.189	521.67	0.000
		5	0.002	-0.132	521.67	0.000
		6	-0.047	-0.171	526.04	0.000
		7	0.026	-0.160	527.43	0.000
		8	0.009	-0.136	527.57	0.000
		9	-0.009	-0.132	527.75	0.000
		10	0.020	-0.090	528.53	0.000

Title Transfer Correlogram of Squared Residuals

Date: 10/01/18 Time: 00:39
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.484	-0.484	466.43	0.000
		2	-0.021	-0.333	467.29	0.000
		3	0.017	-0.230	467.90	0.000
		4	-0.012	-0.188	468.19	0.000
		5	0.024	-0.118	469.38	0.000
		6	-0.086	-0.211	484.17	0.000
		7	0.091	-0.119	500.69	0.000
		8	-0.032	-0.115	502.73	0.000
		9	0.004	-0.096	502.76	0.000
		10	-0.007	-0.101	502.87	0.000

ZeeBrudge Correlogram of Squared Residuals

Date: 10/01/18 Time: 00:41
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.541	-0.541	582.66	0.000
		2	0.027	-0.375	584.14	0.000
		3	0.044	-0.227	588.06	0.000
		4	-0.053	-0.214	593.58	0.000
		5	0.018	-0.187	594.26	0.000
		6	0.011	-0.147	594.52	0.000
		7	-0.026	-0.157	595.90	0.000
		8	0.021	-0.137	596.82	0.000
		9	0.006	-0.104	596.89	0.000
		10	-0.003	-0.076	596.92	0.000

Henry Hub EGARCH Correlogram of Squared Residuals

Date: 10/02/18 Time: 23:33
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.004	-0.004	0.0389	0.844
		2	0.009	0.009	0.2039	0.903
		3	-0.002	-0.002	0.2091	0.976
		4	-0.007	-0.007	0.3164	0.989
		5	0.009	0.009	0.4750	0.993
		6	-0.004	-0.004	0.5038	0.998
		7	-0.002	-0.002	0.5100	0.999
		8	-0.000	-0.000	0.5100	1.000
		9	-0.003	-0.003	0.5254	1.000
		10	-0.002	-0.002	0.5347	1.000

*Probabilities may not be valid for this equation specification.

Net Balancing Point EGARCH Correlogram of Squared Residuals

Date: 10/02/18 Time: 23:39
Sample: 1/01/2010 8/31/2017
Included observations: 1990

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.022	0.022	0.9734	0.324
		2	-0.001	-0.002	0.9761	0.614
		3	-0.017	-0.017	1.5326	0.675
		4	-0.009	-0.009	1.7077	0.789
		5	0.015	0.015	2.1459	0.829
		6	-0.002	-0.003	2.1517	0.905
		7	-0.009	-0.009	2.3164	0.940
		8	-0.014	-0.013	2.7150	0.951
		9	-0.024	-0.023	3.8915	0.918
		10	0.001	0.002	3.8957	0.952

*Probabilities may not be valid for this equation specification.

ZeeBrudge EGARCH Correlogram of Squared Residuals

Date: 10/02/18 Time: 23:47
Sample: 1/01/2010 8/31/2017
Included observations: 1990
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.013	-0.013	0.3341	0.563
		2	-0.057	-0.057	6.7508	0.034
		3	0.001	-0.001	6.7522	0.080
		4	-0.019	-0.022	7.4720	0.113
		5	-0.042	-0.042	10.944	0.052
		6	-0.030	-0.034	12.731	0.048
		7	0.017	0.012	13.330	0.064
		8	0.014	0.011	13.749	0.089
		9	0.016	0.016	14.251	0.114
		10	-0.003	-0.004	14.271	0.161

*Probabilities may not be valid for this equation specification.