PhD Dissertation in Engineering

Competing Factors Influencing Investments in the International Oil and Gas Industry: Empirical Evidence from OPEC Countries

국제 석유 및 가스 산업 투자에 영향을 미치는 경쟁요인
: OPEC국가로부터의 경험적 근거

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Graduate School of Seoul National University

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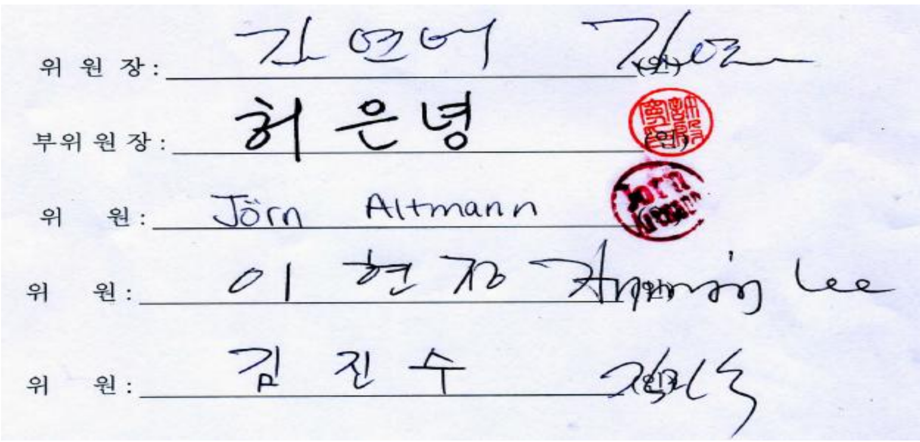

Abstract

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The main objective of this dissertation is to investigate the influence of various competing economic, uncertainty/field performance, technical, and petroleum fiscal policy factors in driving exploration and development investments in the international oil and gas industry. Investment behaviour equations (exploration and upstream for both OPEC and selected non-OPEC countries respectively) were specified and estimated in panel data framework using fixed and random effects models during the period 1980 – 2011. Consequently, Driskoll and Kraay (1998) parametric covariance matrix estimator and Baltagi and Wu (1999) generalized least square estimator were

respectively applied for the most suitable fixed and random effects models to adjust for standard errors in the estimated coefficients. The estimated results of the exploration and upstream investments behaviour models generally show good fitness, robustness, and strong statistical performance with expected signs in most of the tested relationships.

The estimated coefficients of the exploration investment behaviour model convey significant positive influences of oil price, production, reserves replacement, and geological potential as well as significant negative influence of oilfield depletion rate on exploration investment in OPEC countries. This indicates the importance of economic and uncertainty factors on exploration investment behaviour in OPEC. The exploration investment model for non-OPEC shows the significant positive influences of oil price, reserves replacement rate, geological potential, and significant negative influence of cost. This also indicates the significant influences of economic and uncertainty factors on exploration investment behaviour in non-OPEC. In terms of impact, exploration investment show elastic response to increases in oil production and oil price in OPEC and increases in oil price and cost for non-OPEC respectively. This suggests the significant influence of economic factors on exploration investment in both OPEC and non-OPEC countries.

Similarly, the estimated results of the upstream investment behaviour model for OPEC countries show significant positive influences of oil price, production, reserves replacement rate, technological progress, and on the other hand, significant negative influences of oilfield depletion rates and gas rent respectively. This suggests the importance of economic, uncertainty, technical, and petroleum fiscal policy factors (natural fiscal regimes) on upstream investment in OPEC. Conversely, the estimated coefficients of the non-OPEC upstream investment model display significant positive influences of oil prices and technological progress as well as negative significant influences of oil and gas rents respectively. This also indicates the significant influence of economic, technical and petroleum fiscal policy factors in shaping upstream investment behaviour in non-OPEC. In terms of overall impact, upstream investment show significant elastic response to increases in oil price and technological progress in both OPEC and non-OPEC respectively suggesting the importance of economic and technical factors on upstream investment.

The findings of this study suggest that the market development policies of both OPEC and non-OPEC are to favour high oil price increases to offset for rising industry's costs in order to justify economics of oil and gas exploration, development and production ventures, reduce rate of return on investment and increase in cash flow. Furthermore, significance of technological progress on upstream investment indicates the important role of technological advancements for the growth of oil and gas industry. Therefore, both OPEC and non-OPEC countries are to focus on policies to support and encourage

major R&D initiatives in the industry and also provide necessary policy framework for effective development of petroleum industry (sectoral) innovation systems and spur technological development. Production control policies are also desirable to encourage field development and redevelopment investments in both OPEC and non-OPEC, while such policy could retard exploration investment in OPEC countries. Similarly, the results also imply that the depletion strategy of OPEC countries is to favour resource conservation policies to encourage exploration investment while resource conservation policies will slow down investment in field development and redevelopment. In the same context, policies to target increase in reserves replacement ratio are desirable to encourage exploration investment in both OPEC and non-OPEC. Furthermore, it is worth noting that increases in the fiscal regimes has the capacity to decelerate the level of investments in both OPEC and non-OPEC countries. Consequently, succinct and careful sharing of risk and reward mechanisms is desirable when designing fiscal regimes to avoid frequent changes, encourage investments and long term value addition to host both the government and the investors.

Key words: investment behaviour, oil and gas, OPEC, non-OPEC, policy

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Acronyms

ALNAFT	National Agency for Development of Hydrocarbon Resources
ARH	Agency for the Regulation of Hydrocarbon
FE	Fixed effects model
GMM	General Method of Moments
IOCs	International Oil Companies
JV	Joint venture
LFN	Laws of the Federation of Nigeria
MOU	Memorandum of Understanding
NOCs	National Oil Companies
OLS	Ordinary least square
OML	Oil Mining License
OPEC	Organization of Petroleum Exporting Countries
OPEC MCs	OPEC Member Countries
OPL	Oil Prospecting License
PDVSA	Petroleos de Venezuela S.A
PSC	Production Sharing Contract
QP	Qatar Petroleum
RE	Random Effects Model
SC	Service Contract
SR	Sole Risk

Table of Contents

List of Tables

List of Figures

PART I : GENERAL INTRODUCTION

Chapter 1: INTRODUCTION

1.0 Rationale of the Research

Recent studies on global energy demand-supply nexus by intergovernmental energy related agencies[1] have generally pointed to a future of increasing energy demand with oil and gas being the dominant energy source for at least the next four decades. This is primarily due to the perceived population expulsion and accelerated economic growth rates of developing countries. Evidently, timely investments are desirable to ensure adequate oil and gas supplies to meet the unprecedented demand growth, increase energy access and security, and support the changing socio-economic life-style of people. It is interesting to discover an adequate account of investment behaviour in any sector talk less of the oil and gas industry. The recurring global energy crisis and oil market instabilities heighten concerns for incremental productive capacity, 'which is an increasing function of the stock of proved reserves' Cox and Wright (1976). The reserves addition process is a function of exploration and development efforts, which solely depend on investment. Thus, it is

[1] International Energy Agency, Organization of Petroleum Exporting Countries,U.S Energy Information Administration, World Energy Council etc.

pertinent to understand the drivers of investment behaviour to support the diffusion of knowledge that will guide policy makers and corporate strategists in planning timely investment decisions to ensure security of oil and supplies.

Understanding oil and gas investment behaviour is particularly important to consuming nations, considering the adverse effect of supply disruptions on hike in oil prices, which has the capacity to affect other commodity prices. This increases the vulnerability of consuming economies to negative consequences that may harm economic wellbeing and prosperity. Furthermore, considering its complex dynamics, unique characteristics, and interplay of several factors in the upstream oil and gas industry, empirical investigation of the roles of various factors influencing oil and gas investment behaviour will provide basis for reducing the vulnerability of these countries to oil shocks.

From the supply side, oil and gas resources are not evenly distributed across the world despite their strategic importance in fuelling global economy. According to Mark F (2012) and Kevin K.T (2006), more than two-thirds of the world's known proven oil reserves (more than 70% of global proved reserves) are located in OPEC countries which account for about half of daily global oil supplies. As a consequence, the world may progressively look up to these countries, at least for response to call on OPEC, despite the growth in non-OPEC supplies in Russia, Central Asia, US Gulf of Mexico, Gulf of Guinea, Brazil, as well as Alberta. This is more profound considering the low finding, development, and production cost associated with these countries in relation to non-OPEC frontiers on one hand. Consequently, there has been a progressive decline in discovery of giant oilfields and likewise the efficiency of marginal discoveries has significantly weakened globally and daily supplies continue to deplete most of the giant reservoirs (Figure 1.1).

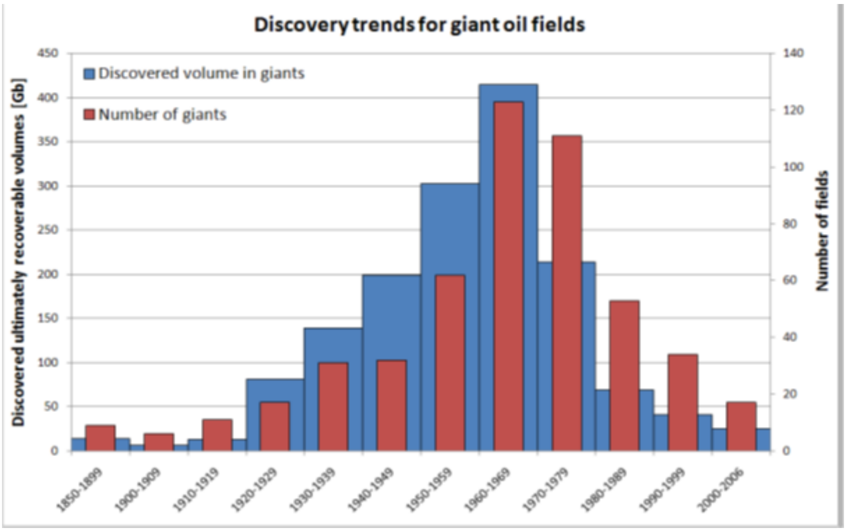

Figure 1.1: World's giant fields discovered and average field sizes
Adapted from Hook (2009)

In addition, gradual depletion of oil reserves, which can have a negative effect on oil supply, can be mitigated through investments in exploration and development to find new reserves and expand supply capacity. Hook (2009) finds the average depletion rates at peak for OPEC and non-OPEC oilfields to be at 6.7 percent and 9.5 percent respectively. Maria Van der Hoeven, Executive Director of IEA buttressed this fact with her statement below:

"Mature oilfield decline rates nearing 7% annually suggesting 47mb/d of new supply will need to be found just to sustain existing supply let alone meet incremental demand growth" Maria van der Hoeven (2011), Executive director, IEA

This translates to huge upstream investments in exploration, development, and production. Capital expenditures of about $4 trillion are required over the period 2001 - 2030 for activities across the upstream, midstream, and downstream value chains of the oil industry to support energy supply and global economic growth expectations (IEA 2003). Oil and gas exploration and development will dominate the capital spending in the sector over the period 2001 – 2030, thus accounting for about 72% of the total spend (Figure 1.2). The basis for this high capital requirement is to replace depleting reserves and increase supply capacity to meet the ever growing demand for oil by new consumers in developing countries. Non-OECD constitutes 47% of global oil consumption which is higher than 25% in 1970; on the other hand, OECD consumption has reduced by 7% (3.6 million barrels per day) since 2005 Mark (2012).

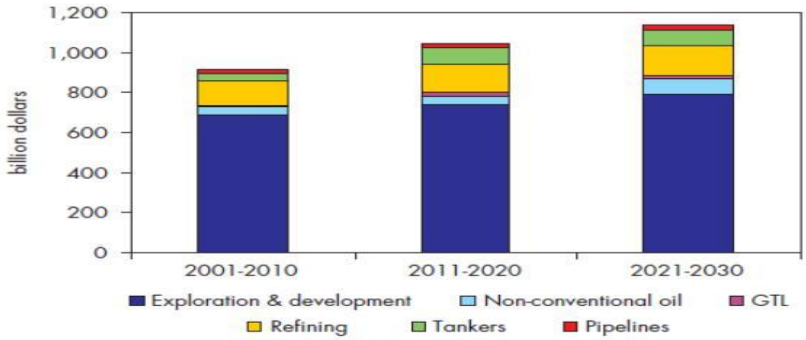

Figure 1.2: World cumulative oil investment
Source: IEA (2003)

Despite these huge capital requirements to fund oil and gas exploration and development, there has been a progressive decline in upstream investment in both OPEC and non-OPEC countries since 2007 (Figure 1.3). The slow recovery of the global economy since the 2008 economic crisis may contribute to the weakening of oil and gas investments. Apparently, the current investment level in oil and gas exploration has not been optimal. Considering figure 1.2, IEA projected that about $700 billion is required between 2000 and 2010 for exploration and development, but the actual investments made was just about $600 billion based on figure 1.2 during the period. This observed shortfall can pose a huge threat to timely future supplies if not adequately addressed, considering the time lag from discovery of oil and/or gas, appraisal of the extent of the reservoir and development of facilities for production. Thus, understanding the factors that significantly influence upstream oil and gas investment behaviour will significantly provide impetus to policymakers and corporate strategists for proper investment planning.

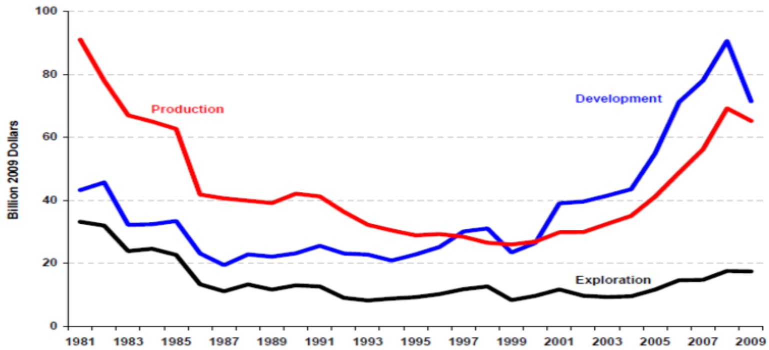

Figure 1.3: Global exploration, development and production investment
Source: U.S. Energy Information Administration, EIA-28

The relationship between energy demand and economic growth is less strong in OECD than developing countries; furthermore, the average share of energy investment per GDP seems inversely proportional to economic affluence Mohn(2008). About 40% of world's oil investments are expected to be accounted for by OECD countries over the next 30 years while non-OECD emerging markets will account for the remaining 60% over the same period due to economic viability and the quest for welfare increment (Figure 1.4). Considering oil investment demand from figure 1.2, about $100 billion is needed annually over the said period to meet economic expectations, reduce energy poverty, and increase access. Exploration and development of fossil fuel is expected to absorb 2/3 of these investments based on IEA estimates.

Most of the investment will be required to maintain production levels at current fields and to find new ones for future supply. The remainder will be required to meet projected demand growth. Investment in un-conventional locations such as Canada and Venezuela will take a significant and growing part of the total investment portfolio IEA (2003). Nevertheless, considering the waning per capita oil revenue of OPEC members, they may be constrained in committing to timely upstream investments required to maintain supply equilibrium to avert lingering higher prices Amirahmadi Hooshang (1996). Hence, foreign capital will be deemed progressively desirable in OPEC countries despite institutional and geopolitical barriers to investment in some of them.

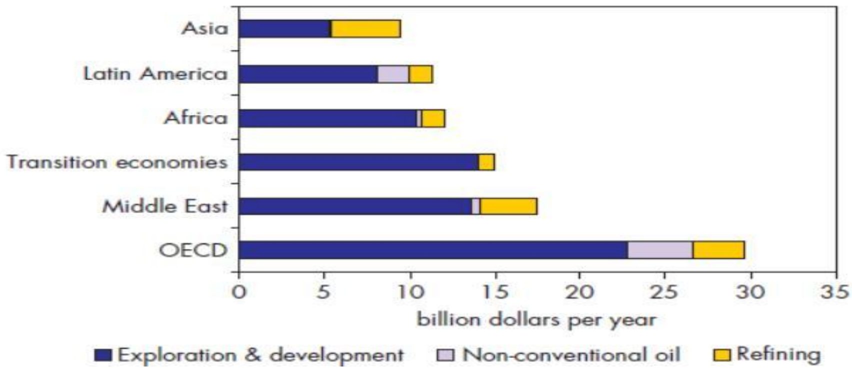

Figure 1.4: Breakdown of oil investment requirement among regions
Source: (IEA, 2003)

As a consequence, it is imperative to investigate drivers of investment behaviour in developing countries where there is paucity of investable funds, institutional or policy barrier, and high competition on foreign capital among destinations with various forms of energy resources. Undoubtedly, this will complement other decision making considerations for the oil and gas industry investors when making timely capital commitments in the sector to avert supply disruption and enhance security of supply on one hand. On the other hand, it will guide informed policy making in the hydrocarbon resource rich developing countries that relies on oil revenue to fund national budgets, economic plans and programmes, as well as cater for their domestic oil supply needs.

Although the investment behaviour in the petroleum industry exhibit similar characteristics with “general corporate investment behavior,” some unique features remain particular to oil and gas exploration, development, and production processes, hence requires industry specific analyses. Exploration activity is composed of huge below-ground geological risks and uncertainties and the issue of reserves development, which faces significant above-ground uncertainties and risks on access to remaining reserves, regulatory challenges, and market conditions, are specific to investments in the hydrocarbon resources development. Other specific characteristics include strong geopolitics and resource nationalism, large indivisible projects, and cyclical investment. Therefore, these distinctive features of the petroleum industry have to be appreciated in terms of investment behaviour as well as the selection and impact of explanatory variables Mohn (2008a). The security of future supply largely depends on the optimal replacement of currently produced volumes through successful discoveries, revision, and extension of previous discoveries. Consequently, empirical analysis may unravel insights on understanding exploration and development processes, which are fundamental for oil supply and provide policy implications influencing exploration investment and provide basis for reversing the currently low global reserves replacement rate.

Furthermore, despite the growing increase in global energy demand, the fast depletion of existing oilfields especially in non-OPEC countries, and the low reserves replacement rates, there has been a progressive decline in exploration and development investment in OPEC countries. Iwayemi and Skriner (1986) opined that the decline in investment in these countries despite having more than half of global proven oil reserves and low supply cost could be due to geopolitics and the global oil market's current state. They further stated that this inefficient allocation due to the concentration of investments in areas with greater reduction of return to oil search effort has the potential to negatively impact global welfare and economic growth. This may lead to global demand and supply imbalance by the turn of the century. Consequently, it is pertinent to empirically examine drivers of investment behaviour in these countries. The results can provide basis for informed policy making and corporate strategy development that can improve exploration and general upstream investment decision.

There is also a growing strand of empirical literature on understanding investment behaviour in the petroleum industry. However, most focus has been on utilizing firm level data of IOCs and NOCs. The available country-level studies are mostly limited to developed countries particularly the U.S, UK, and Norway with few exceptions. But, most of the remaining yet to produce reserves is located in developing countries, particularly the Middle East, Latin America, and Africa, which constitute the greater majority of OPEC membership (Figure 1.5). Thus, it is pertinent to empirically evaluate determinants of oil and gas investments in these countries with most significant potential for expected future supplies. Furthermore, empirical studies on investment behaviour will shed more light on the economics of oil and gas, which has implications for policy makers and strategists in both producing and consuming nations. Such study can provide conclusions that can transform to policies that will improve future oil supply, energy security, and socio- economic wellbeing of nations and people

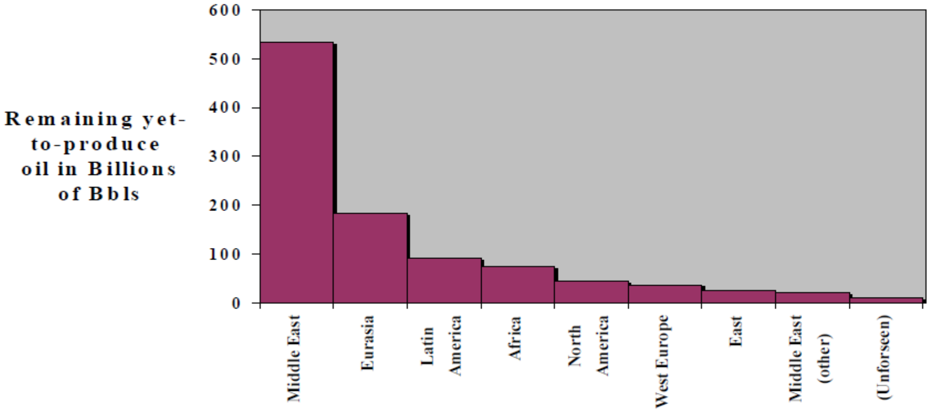

Figure: 1.5: Distribution of remaining yet-to-produce oil reserves in billion barrels by region
Source: Campbell (1997)

From a macroeconomic point of view, oil and gas investments are very important and crucial to the economic growth and development of OPEC members. Income from crude oil sales and resource rents serves as major source of revenue and foreign exchange earnings to each member.

Country	Oil and gas sector's GDP contribution (%)	Oil and gas revenues share in total export earnings (%)
Algeria	35	68
Angola	45	90
Ecuador	20	50
Iran, I.R.	32	74
Iraq	70	95
Kuwait	60	93
Libya	34	95
Nigeria	35	70

Qatar	60	85
Saudi Arabia	50	90
United Arab Emirates	40	
Venezuela	25	95

Table 1.1: Oil and gas sector's contribution to the economy of OPEC members as at 2011

Source: 2012 OPEC statistical bulletin, Revenue Watch International and U.S.EIA

Consequently, public and private oil and gas investments are central to the growth of the industry and economic viability of these countries. Moreover, the oil and gas industry supports the growth of other non-oil sectors in the economy and its non-renewable nature further reinforces its strategic importance to producing countries. This also serves as important motivation for the empirical study on determinants of investment behaviour in the upstream petroleum industry with particular focus on OPEC countries.

1.2 Objectives of the Research

This research seeks to extend the frontier of the literature on investment behaviour in the oil and gas industry through empirical analysis that focuses on OPEC member countries and selected oil and gas endowed jurisdictions across the world. The ultimate goal is to unravel insights that will shed light on factors that greatly influence exploration and development investment behaviour in the oil and gas industry to provide basis for informed policy making and corporate strategic decision making. Most of previous empirical studies recognize various economic, fiscal, and institutional policy factors as the main drivers of investment behavior. As a consequence, focus has been on applying various econometric methods on set of these variables. The importance of these factors is also recognized in this research, but it also considers the influence of specific oilfield's subsurface uncertainty factors which determines the performance of oil and gas assets and ultimately affects investment behavior. Therefore, the following objectives seek to be pursued to achieve the above mentioned goal:

1. Oil price is considered one of the most important factors that influence investment decisions in the upstream oil and gas industry considering its impact on rate of return, project viability, and net present value of return on future investments. Hammad (2011) opined that crude oil price have significant contribution in the planning, evaluation, and implementation of energy investments. Despite recent oil price increases, the level of global exploration activity has been low[2] since 1998 Kvaal et al (2005). However, oil production has been at pace with rising oil demand; but, exploration investment resulting to new discoveries to add to reserves portfolio is declining. Considering the importance of international oil price in defining the cash flow of investors and the need for continual exploration to find

[2] Mohn and Osmunden (2008) also stated that exploration spending has stagnated in the Norwegian continental shelf.

and replace depleting reserves, empirical investigation of the relationship between oil price and exploration investment is particularly important. Consequently, it is considered a paramount objective of this research especially in OPEC countries that have significant potential for future oil supplies and relies heavily on oil revenues for investments and savings.

2. There is observed frequent changes in fiscal regimes and tax policies of most oil producing countries in response to a quest for more revenue generation or motivated by the desire to tap from windfall profits of oil companies. Recently, Nigerian government proposes a Petroleum Industry Bill that among other objectives seeks to increase government take through upward review of oil and gas rents. As a consequence, both indigenous and foreign oil companies operating in Nigeria responded with an outcry and clamor for the reversal or downward review of the proposed increase in royalty and taxes. They further buttressed that rent increase will impede upstream investment influx. On the other hand, the Federal government has maintained that the increase is aimed at increasing government take to levels that will increase the government's revenue while at the same time ensure fair return to investors. The practice of tax and petroleum fiscal changes is prevalent among most oil producing countries especially OPEC members that heavily rely on oil income for revenue generation and

foreign exchange earnings. This increases policy uncertainty and erodes investors' cash flow which can weaken investments in the upstream oil and gas sector. In response to providing substantive evidence on this lingering issue in Nigeria and other OPEC members, empirical investigation of the influence of oil and gas rent on upstream investment behaviour is considered a key objective of this research. This will provide empirical evidence that can support informed policy making in particularly in Nigeria and other OPEC countries in general that share similar economic yearnings and aspirations.

3. Previous researchers have tested the influence of various factors on oil and gas investment. However, the findings have been mixed largely due to varying inherent characteristics among producing nations and differences in applied methodology. This study seeks to further examine the influence of competing economic, uncertainty/oilfield performance, technological and petroleum fiscal policy factors on oil and gas investment in OPEC countries to unravel the most significant drivers. The influence of the same factors will also be investigated on selected non-OPEC countries to effectively infer the dynamics of investment between the two groups. In the same vein, the influence of below-ground uncertainties that relates to geology and the natural fabric of oil and gas bearing formations that determines the behaviour

of oilfields remain largely under investigated. Nevertheless, it is widely acknowledged that these uncertainties define unique peculiarities and inherent characteristics particular to the nature of the oil and gas industry. Thus, one of the objectives of this dissertation is to determine the influence of reserves replacement rate, geological potential, and oil field depletion rates in driving oil exploration and development investment behavior.

4. There is generally few but growing strands of empirical literature on investment behaviour in the oil and gas industry. But, most previous studies focus on applying different estimation techniques on developed countries' data. As a consequence, there is paucity of empirical evidence from developing countries. It is also an objective of this research to bridge this gap by investigating determinants of investment behaviour in OPEC countries. The findings will add to the existing body of knowledge on drivers of oil and gas investments from the developing countries' perspectives. Furthermore, a large number of previous researches utilized time series analysis approach. This research takes advantage of the richness of panel data and recent advances in its econometric estimation and applies panel data estimators that will allow us to control for unobserved specific heterogeneities among our sample countries.

5. Understanding investment behaviour in any industry, market, or sector is generally important owing to the significant role of capital accumulation to economic growth of nations and value addition. In the same vein, the positive role of energy, particularly oil and gas, in driving economic growth has long been established in the literature owing to its importance as critical input in production process and driver of socio-economic wellbeing. More profoundly, oil and gas investment is a major source of foreign exchange earnings and revenue generation to OPEC countries. As a consequence, formulating sound policies that will ensure effective and sustainable growth of their oil and gas sectors is at the core of the respective countries' energy policy and national economic growth policy thrust. Thus, one of the central objectives of this dissertation research is to come up with implications that can guide informed policy making for OPEC and its MCs in particular and also provide additional support for decision making of corporate strategists.

1.3 Structure of the Dissertation

The dissertation is structured in theoretical and empirical analyses sections. The theoretical section comprises of two parts which are made up of five chapters that review various segments of theoretical and analytical insights. The empirical analyses section, on the other hand, comprises of two parts which are also made up of five chapters that describe empirical analysis and conclusion of the study.

<table>
<tr><th>Sections</th><th colspan="2">Theoretical and analytical review</th><th colspan="2">Empirical analysis</th></tr>
<tr><td>Parts</td><td>I</td><td>II</td><td>III</td><td>IV</td></tr>
<tr><td rowspan="4">Chapters</td><td rowspan="4">General Introduction</td><td>Petroleum fiscal policy and Country Analysis</td><td>Analysis of exploration investment behaviour in OPEC countries</td><td rowspan="4">General conclusion and Policy Implications</td></tr>
<tr><td>Understanding OPEC behaviour in the global oil market</td><td>Analysis of upstream investment behaviour in OPEC countries</td></tr>
<tr><td>Literature Review</td><td>Analysis of upstream investment behaviour in non-OPEC countries</td></tr>
<tr><td>Modelling Framework for Oil and Gas Investment Analysis</td><td>Analysis of exploration investment behaviour in non-OPEC countries</td></tr>
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Table 1.2: Outline of dissertation

In parts I and IV, general introduction of the research and conclusion are respectively presented. Parts II and III constitute the main body of the research which describes theoretical insights and empirical analyses respectively. The overall research question that this study seeks to answer is:

what is the influence of various competing factors in driving investment behaviour in the upstream international oil and gas industry with focus on OPEC members and selected non-OPEC members? Four separate essays investigated the tested hypotheses that address the research questions. Specifically, each paper is designed to investigate specific research questions that relate to oil and gas exploration and development investment in the international petroleum industry in order to support the attainment of the objectives of the study. The layout of the dissertation is as described below (schematic in figure 1.5).

PART 1: Introduction

Chapter 1 presents the general introduction of the dissertation. As part of it, I succinctly outlined the rationale behind the research to justify the importance of studying investment behaviour in the international upstream petroleum industry and suitability of the chosen case study. The scope and objectives of the study highlighting coverage period, and the approach of delivering the desired goal were also enumerated. This section also contains the contributions of this research to academia, policy, and corporate strategy cycles. The chapter was concluded with an outline on the structure of the dissertation.

PART 2: Theoretical and analytical review

In chapter 2, review of economic models that describes OPEC behaviour and analytical insights are presented to provide an understanding of the behaviour of OPEC in the world oil market. This encompasses an overview on its evolution, behavior, and role of OPEC in the international oil market; it also covers a review of OPEC investment strategies and impediments to upstream investment in OPEC countries based on economic literature.

Chapter 3 presents petroleum fiscal policy framework governing upstream operations in each OPEC member country and country analyses. This comprises the structure of governance mechanisms in each member country and evolution of upstream investment in response to changing fiscal conditions. Regional comparison is also conducted to unravel the impact of regional effect in influencing petroleum fiscal policy and governance structure's evolutionary process among members' regions, which in turn influence investment behavior.

In chapter 4, review of some theoretical postulations on oil and gas investment behaviour is presented to lay foundation to understand the dynamics of irreversible investments in the upstream petroleum industry and guide variables selection. Similarly, previous empirical literature on determinants of oil and gas exploration and development investment in the upstream oil industry is succinctly outlined.

In chapter 5, the theoretical formulation and assumptions that guided the specification and estimation of the econometric model used for this research within panel data framework to analyze the influence of various economic, policies, technical, and uncertainty/field performance factors on exploration and upstream investment is presented.

PART III: Empirical Analysis

This consists of four separate essays with each being a chapter that examines exploration and upstream investment behaviour in OPEC and non-OPEC countries. Each paper has its own introduction, data analysis, model specification and estimation, analysis of result, and conclusion.

Case study	**Investment models**	
	Exploration	Upstream
OPEC	○	○
Non-OPEC	○	○

Table 1.3: OPEC and non-OPEC oil and gas investment models

In chapter 6, the relationships among exploration investment and selected factors (economic, technical, and uncertainty/oilfield performance) in OPEC countries are examined considering the high propensity of oil reserves in these countries, low cost of exploration, and high geological potential for the discovery of yet to find hydrocarbon and future oil supplies.

Chapter 7 analyzes the influence of selected economic, petroleum fiscal policy, technical, and uncertainty/oilfield field performance factors in driving upstream investment (exploration and development) among OPEC countries.

Chapter 8 tested the influence of same factors on upstream investment in selected non-OPEC countries to confirm the uniformity of effects or otherwise among the two producer groups. Investigating drivers of upstream investment behaviour in non-OPEC countries was considered plausible given the differences in production strategy and policy framework between the two groups, as well as growth in unconventional resources in non-OPEC countries.

Chapter 9 examines the influence of economic, field performance/uncertainty, and geological factors on exploration investment in selected non-OPEC countries.

PART IV: General conclusion

In chapter 10, general conclusion and policy implications based on the foregone analyses are presented. Similarly, considering the special interest of the author on Nigeria, some policy implications are also stated to guide informed policy making in Nigeria. This chapter was wrapped up with an outline on the limitations of this research and recommendations for further studies.

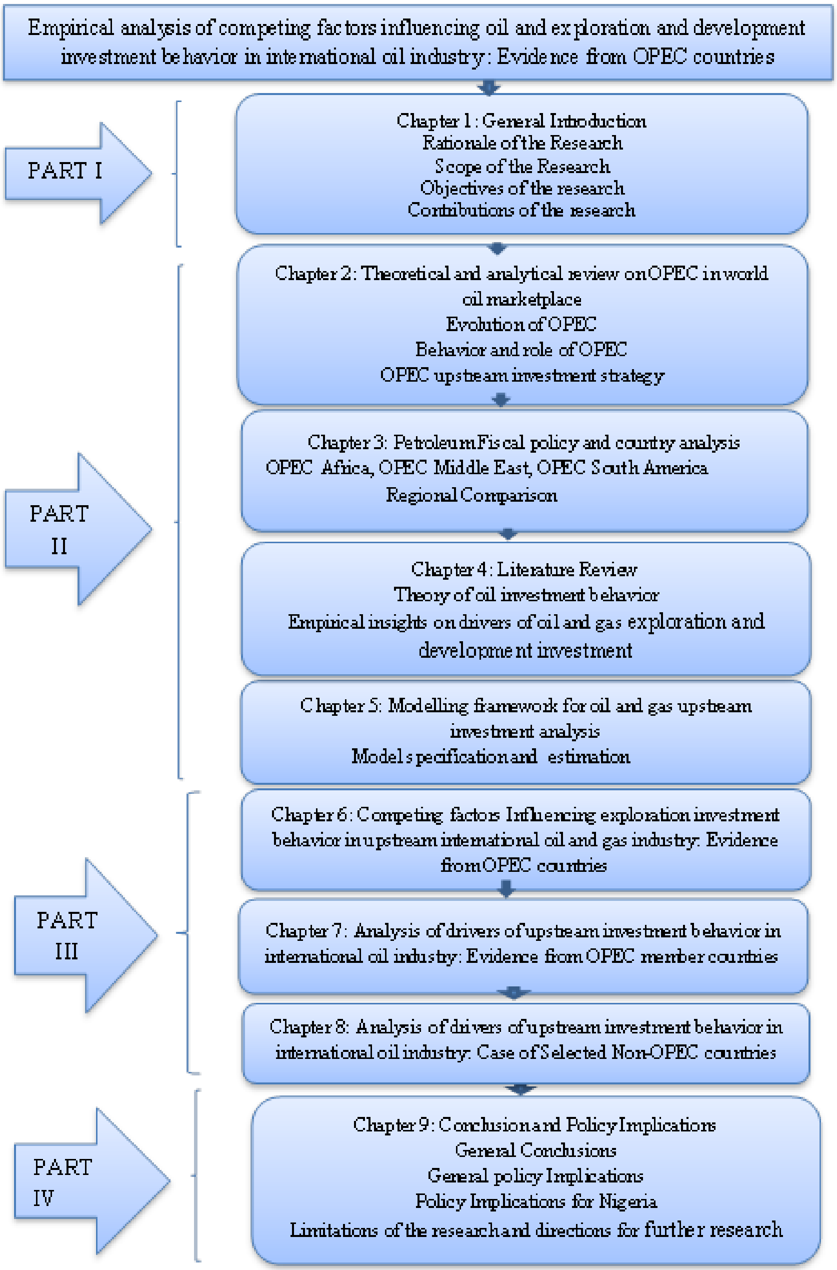

Figure 1.6: Schematic of the dissertation structure

1.4 Contributions of the Research

Since the pioneering work of Hotelling (1931) that foundation on understanding the economics of exhaustible resources, there have been lots of theoretical efforts that explained investment behaviour across sectors of the energy or network industries. Consequently, since the seminal empirical work of Fisher (1964) that modelled oil and gas exploration behaviour in the U.S., there is growth in the strand of empirical literature that provides additional evidence to support some of theoretical postulations or provide new insights on investment behaviour. However, little attention has been paid to developing countries to date, mainly due to challenges with data availability. This study will significantly add to the current body of knowledge on this subject by providing empirical evidence from developing countries.

OPEC countries hold the current global spare capacity, have high potential for future supply capacity, have low supply cost[3], and have a huge demand for investment. But, there is an observed decline in investment level which may have a negative impact on global welfare and economic growth. The findings of this study will add to an understanding of investment dynamics in these countries thereby greatly contributing to existing empirical literature on investment behavior. To the best of my knowledge, it represents the first

[3] Rose (2005) assert that" unit exploration, development, and production costs are much higher in non-OPEC region than in the OPEC region".

attempt of broad empirical investigation of investment behaviour in the upstream oil and gas industry with focus on OPEC countries. The findings of this study will also provide additional implications that will guide and support informed policy making of OPEC on one hand and its respective members on the other for value adding investment decision making.

Oil price is regarded as an influential determinant of oil and gas industry investments in economics and finance literatures. But, it has been difficult to characterize the relationship between oil price and exploration investment in the literature. Most of the previous studies used proxy variables that may not adequately capture exploration spending, thus resulting to misleading results. This study utilized the actual capital and exploration investment of IOCs to investigate this relationship. Hence the results will contribute to the current boundary of knowledge on this topic and provide additional evidence that clarifies the puzzle.

This study also found empirical evidence in the wake of the ongoing policy debate on the negative impact of oil and gas rent increases on upstream investment in Nigeria, and the relationship between oil and gas rent and upstream investment in OPEC jurisdictions. The findings will enormously contribute to informed policy making in Nigeria in particular, and OPEC member countries in general.

There are very few or no previous studies with broad emphasis on both below and above-ground factors. This research contributes in bridging this gap by examining the role of subsurface characteristics of oil fields and geological uncertainty, economic, policy, and technical variables in driving oil and gas investment in the upstream sector. Generally, the findings of this study can also be applied to other petroleum rich jurisdictions that share similar characteristics with OPEC member countries, particularly developing countries and the world over.

The study also examines the influence of same factors on OPEC and non-OPEC countries and the result reveals the varying influences of the factors among these groups. This also provides additional insight that can enrich the literature.

1.5 Scope of the Research

This empirical study of investment behaviour in the upstream petroleum industry seeks to utilize the application of econometric modelling techniques on a long panel of mainly OPEC countries and selected non-OPEC producers with economic, technical, field performance/uncertainty, and petroleum fiscal policy explanatory variables covering the period of 1980 – 2011. The choice of OPEC members is motivated by the fact that there are huge oil and gas reserve bases and significant potential for future supply from these countries.

Furthermore, data availability and scarcity of previous empirical studies focusing on this producer group despite their strategic importance within the global oil and gas supply chain prove strong motivators for the study. Some non-OPEC oil producers were also selected due to growth in unconventional oil and gas resource supplies from these countries. Moreover, understanding the basis of investment behaviour in these countries is essential for OPEC, policy makers, and corporate strategists in their quest for deeper understanding of the dynamics of world oil market and timely supply of oil to fuel the global economy.

The choice of the period (1980-2011) was determined by data availability that covered this time; moreover, a longer period of time is considered necessary to unravel the impact of oil reservoir characteristics that affects oilfield performance (depletion, reserves replacement, and geological potential) and ultimately investment in the oil industry. A minimum of thirty years was assumed to be a representative period for the life of a typical oil field. Thus, thirty-one years was chosen for better performance of the model. Similarly, three decades will accord better opportunities of understanding the influence of variation in economic (oil price, production, and cost) and policy factors (oil and natural gas rents) on investment patterns. During the period 1980-2011, there have been major oil price cycles and structural changes that can affect the rate of return on investments and the revenue stream of producing countries. In the same vein, government fiscal policies are not likely to remain stable for thirty three years. As a consequence, the longer the period of study under consideration, the better the ability to unravel insights on the resulting impact of the changes on investment in the international upstream petroleum sector. Lastly, a long period was chosen to enhance the interactive capacity and general performance of the estimated econometric model, thus taking advantage of the richness of panel data and recent advances that allow incorporation of the heterogeneous nature and individual characteristics of the countries under investigation.

This study leverages on available data and information in public domain accessed through journal publications, text books, reports of intergovernmental energy agencies, international organizations, and websites of petroleum ministries of OPEC countries and their national oil companies respectively.

PART II THEORITICAL REVIEW AND ANALYTICAL INSIGHTS

Chapter 2: UNDERSTANDING OPEC BEHAVIOUR IN THE GLOBAL OIL MARKET: A THEORITICAL AND ANALYTICAL REVIEW

2.0 Introduction

The beginning of this chapter presents an overview of the historical antecedents that were culminated in the formation of OPEC, and the consolidation of its existence highlights the role it has played in the world of oil market over the last 50 years. The strategic importance of energy and disproportionate distribution of oil and gas resources in the world prompted keen interest in understanding the conduct of this producer group. Subsequently, there have been upshots of academic interest in this area. Several economic theories have evolved to add to the understanding of the role and behaviour of OPEC especially in relation to oil price formation. In the same vein, advances in econometric modeling facilitated the response of empirical economists to test some of the theoretical postulations. Thus, some of the foremost scholarly insights are presented to explain the behaviour of OPEC in accordance with economic literature. Furthermore, this chapter qualitatively and descriptively analyzed the investment strategy of OPEC in the wake of changing market fundamentals and recurring instabilities of international oil market. This is pertinent considering the dominance of global proven oil reserves in this producer group, growing domestic budgetary needs of OPEC MCs, growth in oil demand and advances in technological progress. Understanding its approach to investment could guide our quest of unraveling the drivers of investment behaviour in the upstream oil industry which could support mitigating future investment challenges and enhance security of oil supply.

2.1 Evolution of OPEC

The quest for national security and land access to energy supplies on the occasion of war, prompted American President Dwight Eisenhower to institute a law that enforced quotas on Venezuelan and Persian Gulf oil imports in favor of Canadian and Mexican oil in 1960. Subsequently, this action resulted in falling prices of oil in these regions. To ameliorate the situation, Venezuela's President Romulo Betancourt responded with a preemptive strategy of pursuing alliance with oil producing Arab nations to sustain the autonomy and profitability of Venezuela's oil resources Basil

(2011). In response to this call, OPEC was founded in Baghdad in 1960 by five oil-producing developing countries (Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela)[4] . OPEC was formed with two goals:" re-establish a single price structure in the world petroleum markets and to get fair share profits" Rodriguez-Araque (2002)[5].

At that point in time, the international oil industry outside the United States, Canada, USSR, and China was dominated by the large multinational oil companies known as the Seven Sisters - Anglo-Persian Oil company (BP), Gulf oil, Standard oil of California, Texaco (Chevron), Royal Dutch Shell, Standard oil of New Jersey (Esso) and Standard oil of New York

[4] Rodriguez-Araque (2002) further narrated that oil prices were unstable as a result of which in 1930s the US introduced prorationing "the regulation of production by state authorities" like Texas Railroad Commission. At federal level, the Interstate oil and gas Compact Commission was formed to set monthly quotas for principal producing states. The system became internationalized with the informal cooperation of the seven sisters which were controlling production in most oil producing countries. This system stabilizes oil price for about 30 years. However, events took dramatic turn with decline in the US production and prominence as a result of increasing concentration of new discoveries in developing countries and rapid demand growth. Conversely, the seven sisters began to face competition. As a consequence, they began to lost control of production in these countries. It was obvious that the only option was to incorporate the exporting countries into the system of worldwide prorationing. But the international oil companies and the consuming nations refused to take that option. The US opted for import quotas due to strategic significance of its domestic oil. The global oil market was divided into two: the US domestic market retained its usual price scheme in conformity with marginal cost of wells while prices were allowed to "fall in the rest of the world". "Not surprisingly, this was unacceptable to the oil exporting countries and it was at this point that OPEC was founded.''

[5] The objectives of OPEC have since been broadened to achieve the following: (1) Coordinate and unify the petroleum policies of its Member Countries and safe guard their individual and collective interest. (2) Ensure the stabilization of prices in international oil markets to eliminate harmful and unnecessary fluctuations. (3) Provide an efficient, economic and regular supply of petroleum to consumers, a steady income to producers and a fair return on capital for those investing in the petroleum industry (OPEC 2012).

(ExxonMobil). Each of the Seven Sisters was vertically integrated and had significant control of upstream and downstream operations to a lesser extent. As a consequence, the rate of supply of crude oil to international market was controlled by the seven sisters through joint partnership in subsidiaries that operated in various countries across the world. Most of the oil exports from major producing countries were controlled by these multinationals that leveraged on their vertical and horizontal integration to restrict chances of huge oil accumulation with the producing countries thereby reducing the risk of price reduction due to increase of supply to competing independent buyers Fattouh and Mahadeva (2013).

The host governments were not able to participate in the production or pricing of crude oil. They were sellers of concessions that in return, received profits in form of income taxes and royalties Mabro (1984). As part of the concession system, there was the idea of posted price which was the basis upon which the accruable revenue to host governments was being computed. This was not in conformity with market fundamentals of demand and supply. This pricing scheme was meant to lessen the tax payable to host governments by the IOCs which consequently led to a very low and stable official price irrespective of the market situation Fattouh (2007). Evidently, it provided another incentive that led to the formation of OPEC in 1960 in order to thwart reduction in posted price Skeet (1988).

As a result, OPEC served as a trade union for most of the 1960s with the objective of thwarting revenue loss to its members. By the mid-1960s, global oil demand began to rapidly increased at an annual average of more than three million barrels per day and continued till around 1973 (BP 2012). OPEC greatly met this demand surge which led to the increase in its share of global oil production from 44% to 51% in 1965 and 1973 respectively. This renewed market structure greatly enhanced OPEC governments' power in the global oil market relative to the multinational oil companies (basically seven sisters) and produced strong seller's market. This development gave the Libyan government the motivation to reach an agreement with oil companies in September of 1970 for the payment of income taxes at increased posted price and also make backdated payments for the revenue lost since 1965. Subsequently, other oil producing nations insisted that Libya's agreement should be extended to each of them. Conversely, with economic boom of the developed world coupled with the closure of Suez canal, inflation, and increasing fear of reduced supplies, demand for oil sky rocketed with ante dent pressure on supply, oil price rose sharply Edith (1979). Following this development and in response to call by other OPEC members for similar agreement the oil companies had with Libya, Tehran negotiations took place in 1971 and collective decision to increase posted price and tax rates respectively was reached[6] .

[6] In the first decade of OPEC's existence, the international oil companies refused to

Furthermore, OPEC initiated another move to revise the Tehran agreement by calling for increase in posted price in September of 1973. However, the oil companies declined OPEC's request and the negotiation ended. This prompted the six Gulf members of OPEC's decision to increase the posted price of Arabian light crude and announced upward review from \$3.65 to \$5.119 on October 16, 1973 and subsequently, the Organization of Arab Petroleum Exporting Countries without Iraq declared 5% production reduction on October 19, 1973 for September volume and another 5% monthly reduction as a result of the war between Israel and Egypt/Syria in October of 1973.These events were dramatic and culminated in the unprecedented increase in posted price of Arabian light by OPEC to \$11.651 in December of 1973. The year 1973 marked the turning point of power shift in the global oil market towards OPEC. Similarly, the decision of some OPEC governments to discontinue issuing new concessions to multinational oil companies and sought for equity participation in existing acreages, was another revolutionary period in the early 1970s that significantly changed the dynamic and structure of the petroleum industry. In the same vein, a handful of the governments chose full nationalization of petroleum investments at that time. Large oil reserves portfolio was lost by the multinational oil companies

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acknowledge its existence and insisted on dealing with each member country that awarded them concessions individually. The IOCs agreed to enter into collective agreement with OPEC in 1971 with the support of their governments when the world is about to face imminent energy crisis Rodriguez-Araque (2002).

to the governments. This reinforced the power and dominance of OPEC in the global oil market[7].

Furthermore, it was during the 1970s that OPEC MCs assumed control of their petroleum industries and became major stakeholders in the pricing of crude oil in the international markets. Oil prices rose sharply on two occasions in an unstable market mainly caused by Arab oil embargo in 1973 and the eruption of the Iranian revolution in 1979. Similarly, OPEC widens its role with the first Head of States and governments' summit in Algiers in 1975 which deliberated on the predicament of poorer nations and called for new approach to international relations for the sake of global economic development and stability. The outcome was the establishment by the OPEC Fund for International Development in 1976 and ambitious socio-economic growth pursuits by member countries. By 1975, OPEC membership grew to 13 countries (OPEC 2012).

The global economic recession of the mid-1980s which led to the drop in oil demand and rise in non-OPEC oil production due to high oil prices and technological advancements poised serious challenge to the administration of OPEC's pricing system. These factors had combined effects that led to the end of the pricing scheme. The proliferation of new oil discoveries outside OPEC countries implied the growing availability of oil supplies to the international

[7] This section is based on Fattouh and Mahadeva (2013)

market from non-OPEC sources. Impliedly, the increase in new supply sources means growth and diversity of more competitive oil producers, whose price setting follows the market conditions. Oil production from these new sources grew, and there was more supply than quantity demanded by contract buyers. However, these new producers succeeded in selling their production by weakening OPEC prices in the spot market and attracted buyers with competitive prices.

Global oil demands continue to dwindle and OPEC's production fell drastically with ante dent reduction in market share from 51 percent to 28 percent between 1973 and 1985[8] respectively. To check mate the slip in oil price, OPEC introduced quota allocation system in 1982 (still operational), but that did not contain the situation. Oil prices continue to fall and likewise OPEC continue to forfeit its market share. This development was unhealthy for OPEC producers but quite costly for Saudi Arabia such that it decided to quit the managed oil pricing regime in 1985. Furthermore, the situation was not only injurious to OPEC members only. It was realized by both OPEC and some leading non-OPEC producers that collective efforts was required to reestablish confidence to the petroleum industry and bring stability in the oil market with reasonable and generally acceptable oil prices Rodriguez-Araque (2002).Oil prices began to recover in the last part of the decade but to level

[8] Demand for Saudi oil reduced from 10.2 million barrels per day in 1980 to 3.6 million barrels per day in 1985

that was around half of its level in the early part of the decade, OPEC began to regain its share in the newly growing world oil production. The introduction of group production ceiling, reference basket for pricing, and major headway in dialogue and cooperation among OPEC and non-OPEC producers facilitated the attainment of these milestones that brought stability in the world oil market and reasonable prices. Subsequently, environmental issues began to take center stage of global energy agenda (OPEC 2012).

Even though membership of OPEC have progressively increased (currently 12 members), its share of world oil production have relatively remained stable for greater part of 1990s, 2000s, up to 2011 when it reached about 43 percent. But when compared to its reserves portfolio which stood at more than 80 percent of global proven oil reserves as at 2012, this production market share is quite small. However, the dominance of OPEC in international crude oil trade (60% of world's crude oil exports in 2011) and expected growth in exports with oil demand shifting to Asia reinforced its standing in the international oil industry. In the same context, the concentration of spare capacity within OPEC countries notably Saudi Arabia, Kuwait and United Arab Emirates have also strengthen the prominence of this producer group. Saudi Arabia alone holds majority of the global available spare capacity, making it to act as swing producer, increasing supply when there is disruption and modifying output to balance the market and ensure stability Fattouh and Mahadeva (2013).

The 1990s witnessed less dramatic price movements than 1970s and 1980s due to OPEC's timely intervention in the wake of Middle East crisis in 1990-991. However, this period was characterized by general price weakness and excessive volatility. The South-East Asian economic recession and mild Northern hemisphere winter of 1998-1999 pulled the prices back to their 1986 levels. Subsequently, there was vivid recovery of the global oil market in an integrated manner in response to post-Soviet world, greater regionalism, globalization, information, and communications revolution and other high tech developments. Also advances in producer-consumer negotiations corresponded with progressive developments in OPEC-Non-OPEC relationships. According to OPEC (2012), in the beginning of 2000s, new OPEC oil price band instrument facilitated the stabilization and strengthening of crude oil prices. However, combine effect of market forces, speculators and other dynamics pushed prices up in 2004 resulting to increased volatility in a well-supplied international crude oil market. Crude oil prices rose to record levels in mid-2008 before the global financial crisis and economic recession forced it to fall. OPEC became active in supporting the petroleum industry, thus gained prominence in advancing towards addressing the economic turmoil. In the year 2000 and 2007, second and third OPEC summits held in Caracas and Riyadh respectively, recognized stable energy markets, sustainable development, and environmental protection as its guiding principles and to that effect, adopted a comprehensive strategy in 2005.

2.2 Behaviour and role of OPEC in the international oil market

Since the drastic upsurge of oil prices in the 1970s that resulted in painful oil shock and market instabilities during the 1980s and 1990s (Yang, B 2004), there have been an up-shot of attention on understanding the behaviour and role of OPEC in the international oil market. The perception that the OPEC acts as a cartel in the global oil supply arena reinvigorated this interest. The impact of the oil crisis on the global economy strengthened concerns for the security of supply and vulnerability to energy security concerns. In the light of these challenges, understanding the behaviour of major oil suppliers became imperative in designing preventive measures to forestall future incidence of supply disruption and market distortion, or developing mitigation measures to cushion possible effects in the event of future occurrences. Evidently, OPEC, being a strategic player in the global oil production chain, became the focus of policy makers, academicians, and corporate strategists.

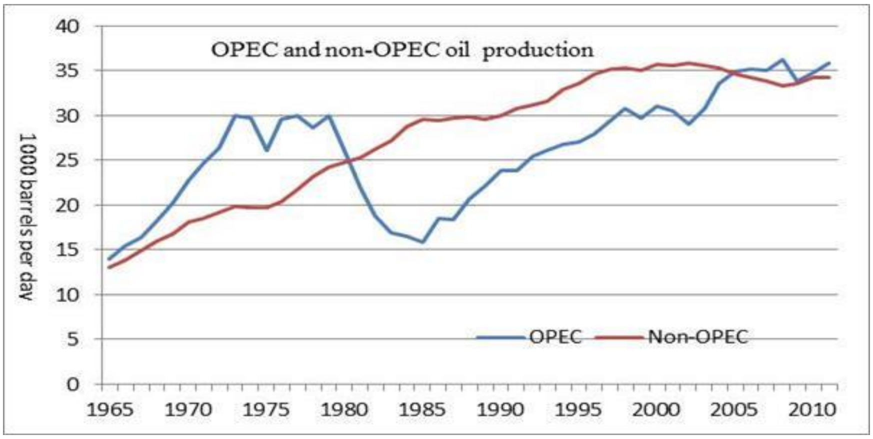

Figure 2.1: OPEC and non-OPEC oil production
Source: Own computation, data from BP (2012)

Conversely, although there have been progressive growth of oil production in OPEC countries at an annual average rate of 2% since 1965, there have also been significant progressive growth in non-OPEC supply since the 1980s at a corresponding annual average of 2.2%, though it starts to decline again in 2005 (Figure 2.1). OPEC's share of global oil supplies stabilizes for the greater part of the 1990s and 2000s until 2011 when it slightly grew to 43%, Fattouh and Mahadeva (2013). Considering the investment-production lag of the oil industry, any negative or positive effect on the productive capacity of OPEC can distort the world oil market, thereby inducing pressure on market equilibrium which may affect crude oil price and negatively impact the world's economy. Hence, understanding the role of OPEC is important to appreciate oil market dynamics, structure, and stability.

Similarly, the comparative advantage of huge reserves' propensity by OPEC was reinforced by the oil industry's unique uncertainties. There are uncertainties and risks associated with politics, geology, regulation, reserves' development, technical, as well as investment-production lag, which are peculiar to the oil industry. In the event of oil supply interruption from any major producer due to these uncertainties or any other unforeseen factor, only OPEC has the sufficient spare capacity to act as swing producer to augment any sudden supply shortage. Although there have been considerable reduction in OPEC spare capacity since early 1990s due to fast demand growth and low growth in non-OPEC supply especially for the period 1990-2004, this basically implies that this deficit in demand has to be met by OPEC Bandyopadhyay (2009). OPEC responds by increasing output, sustaining stability in world oil market, and preventing distortion in market fundamentals and unwanted price increases. This also strengthens the strategic importance of OPEC and the need to understand its behaviour in relation to oil supply to reduce market uncertainties that may affect price discovery processes. Any sudden change in supply may have significant impact on oil price, which in turn can induce multiplier effects on other commodity prices and global economic wellbeing.

There is a huge strand of empirical literature on this subject matter since the seminal work of Griffin (1985)[9,10] similarly, in the theoretical front; there have also been an upsurge of literature on understanding behaviour of exhaustible resource owners since the seminal work of Hotelling (1931) on the economics of exhaustible resources. Initially, the behaviour of OPEC was considered as monopoly or cartel [11] in the economics literature [12]. However, this interpretation has been challenged Griffin (1985)[13] . Therefore, there had been an increase of scholarly articles that hypothesized non-cartel based models to explain OPEC's behaviour, Mead (1979), Johany (1978), McAvoy (1982), and Fattouh and Mahadeva (2013). Fattouh and Mahadeva (2013) asserted that OPEC can constrain output even in competitive behaviour scenario but for non-collusive behaviour reasons [14]. Mead (1979) and Johany (1978) presented a property rights justification, arguing that the handover of

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[9] Some subsequent empirical works are: Dahl and Yucel, (1990), Jones (1990), Dahl and Yucel (1991), Griffin et al, (1994), Al-sultan (1995), Griffin et al, (1997), Alhajji and Huettner (2000), Ramcharran (2001, 2003), Yang (2003) , Yang (2008) and Li (2010).

[10] For comprehensive review of empirical studies on OPEC behavioursee Al-Qahtani etal, (2008), Smith (2005) and Alhajji and Huettner (2000).

[11] "A cartel is defined as a group of firms (or states, in this case) that creates agreements about quantities to produce or prices to charge. A cartel must not only agree on the total level of production but also on the amount produced by each member." Colgan (2013).

[12] Some studies did not ascribe specific model to OPEC behaviour.Examples are: Griffin and Teece (1982), Geroski, Ulph and Ulph (1987), Danielsen and Kim (1988)

[13] Griffin and Teece(1982), Gately (1984) and Li (2010)

[14] For details see Cremer and Salehi-Istifahani (1989)

concession rights from the international oil companies to the exporting countries in the 1970's reduced the effective discount rate resulting to the witnessed price-output behaviour. Similarly, Johany (1980) concurred that the oil price increases of the 1970s due to production cuts were consequences of property rights transfer to the oil exporting governments from the oil companies, while the oil producing governments were disposed to lower discount rates than the international oil companies. On another front, the price increases were credited to supply interruptions caused by political happenings (Mc Avoy, 1982)[15]. Other scholars that favoured target revenue model emphasized that oil production decisions of the 1970s were made based on investment needs and budgetary requirements, which in turn rest on the absorptive capacity of the domestic economies and deficiencies in international market Fattouh and Mahadeva (2013).

Despite these divergent views, attempts have been made to categorize various models proposed in the literature[16]. Yang (2004) grouped OPEC behaviour

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[15] According to Griffin (1985), '' Mac- Avoy (1982) has argued that the long-run trend of oil prices can be adequately explained by a competitive model''.

[16] According to Al-Qahtani, et al, (2008), Griffin and Teece (1982) provided an earlier categorization of OPEC behaviourmodels in the economic literature. They categorized the models into wealth maximizing and non-wealth maximizing models. The wealth maximizing models were further sub-categorized into monopoly model (dominant firm) and competition (property rights). They also sub-categorized the non-wealth maximizing models into target revenue and political models. In the end, they implicitly rejected the property right model due to the existence of economic rent and pricing power.

models into cartel[17] and non-cartel models and further sub-divided the models based on the literature. The cartel based model consists of dominant firm hypothesis like the widely cited work of Professor Adelman, Adelman (1982), Wirl (1991), Gulen (1996), Spilimbergom (2001), and De Santis, (2003) and the cooperative profit maximizer model (Pindyck, 1978). The non-cartel based models can be sub-divided into competitive model (Mac Avoy, 1982), target investment/ revenue models, Cremer and Selehi-Isfahani (1980), (Teece, 1982) and regime switching of property rights models (Johany, 1978, Mead, 1979) Figure 2.2.

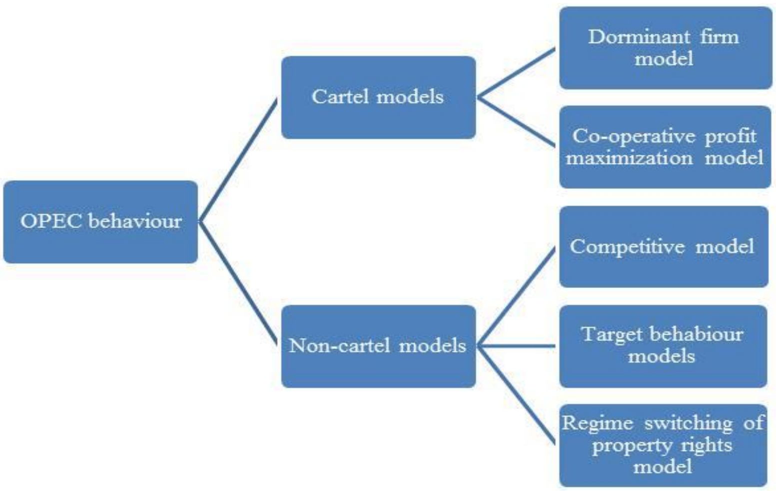

Figure 2.2: OPEC Cartel and non-cartel behaviour models
Modified after Yang (2004)

The Cartel behaviour models appeared to have gained popularity in explaining the rationale behind the unprecedented price surges of the 1970s and

[17] According to Okogu (1991), Johany (1980) "has successfully argued against the classification of OPEC as a cartel".

instabilities of the 1980s and 1990s. Although there are many forms of cartel with varying characteristics, common features of an effective cartel include co-operation and collusion among members to pursue a common course, which in this case is production control and stable price level higher than in competitive scenario Yang (2004).

2.2.1 Cartel models

2.2.1.1. Dominant firm and cooperative profit maximization models

The dominant firm model assumes that OPEC members are pursuing profit maximizing objectives by restricting their production collectively, individually, or through collusion efforts to impact market price Al-Qahtani, et al, (2008). Hence, there exists some power in the oil market as a result of which OPEC itself, OPEC core, [18] or Saudi Arabia alone (as the main producer) can be defined by cartel or dominant firm behaviour[19]. According to Adelman (1982) OPEC cartel is between the cooperative output and dominant firm. In the dominant firm model, the biggest producer (Saudi Arabia) is assumed to act as the residual monopolist firm, while others operate as fringe

[18] Al-Qahtani, et al, (2008) refers to OPEC core as OPEC major producers (Saudi Arabia, Kuwait, Qatar, UAE).

[19] Griffin (1985) asserted that "Theodore Moran (1982), a political scientist, rejects the conventional cartel interpretation in favor of an oil pricing model guided by Saudi Arabia utilizing its market power to maximize its security and influence rather than its wealth".

firms. The dominant producer sets the price, allows other members to produce at will, and then supplies the oil needed to meet the remaining demand. The dominant producer (firm) is therefore, the “swing producer” gripping the market fluctuations (demand and supply variations) to ensure consistent monopoly price. This arrangement may prevent issues of cheating, but there is inherent risk of sufficient new production from the fringe firms to thwart the dominant firm’s strategy.

Obviously, the fringe firms individually maximize profits by gaining from the price set by the dominant firm, and taking into account their individual marginal cost Yang (2004). He further impressed that this model could be easy to manage if OPEC or the top producer has a vast share of the world market. Then, the firmness of the cartel does not rest on the strength and weakness of the cartel unity, but on the interplay between demand and supply resulting in satisfactory demand of the dominant producer’s output at the prevailing price to fulfill its objectives.

There is also another form of cartel; the market sharing cartel, involves collective decision on an individual market share or output level that each member should attain. Consequently, the members may meet regularly to decide on collusive activities that could change market situations and enable the attainment of their objectives. Since each of OPEC members have sovereign control over its output level and no one (except Saudi Arabia) has the capacity to set price favorable to the cartel, members of the cartel considered the market sharing scheme as a platform to realize the cartel goals.

In theory, if the cartel has comparable marginal cost curves, then the ideal market sharing plan could attain the same objectives as the ideal joint profit maximizing cartel model, which have similar results with those of monopolists running many plants Adelman (1982). Hence, the assumption of similar marginal cost may not be out of place considering the fact that the marginal cost of most OPEC members is low (especially Middle Eastern countries) relative to market price. Griffin (1986) stated that the marginal production cost of Middle East OPEC members fall between 15 to 35 cents per barrel while that of non-Middle East countries is between $1 and $2.

However, the enticement for great profits of members that increase market share by double-dealing on production quota can in reality threaten the stability of market sharing cartels. Obviously, some members have strong motivation to digress from the agreement in order to benefit from the cartel price that persisted due to the compliance of production quota by other members. Evidently, market sharing behaviour was demonstrated by the event of March 1982. OPEC established its total production and assigned output quotas to individual countries with Saudi Arabia acting as swing producer to balance OPEC production and demand at targeted market value Yang (2004).

In terms of empirical evidence, Griffin (1985) utilized apply ordinary least square estimation method on the 1971 to 1983 data to test the hypothesis of cartel's market-sharing behaviour. He found evidence that supports the existence of partial market sharing behaviour among OPEC members, whereas non-OPEC countries act by way in Bertrand competitive manner. Subsequently, Yang (2003) extends his model by utilizing data from 1984 to 2000 and estimates simultaneous equation systems model with two stages least square method. His results provide strong evidence that support the fact that OPEC has been operating with market sharing strategy since the early 1980s. The results also confirmed the role of Saudi Arabia as cartel leader and swing producer[20]. Similarly, Kaufman et al (2004 and 2008) modified the Griffin (1985) model and tested the impact of organizational and economic factors on OPEC's production decisions. The results revealed that production quotas significantly determine OPEC production, which is suggestive of OPEC capacity to alter prices, hence exerts market power. Smith (2005) used production-based econometric method and conducted price analysis hat assumed market price is higher than marginal cost is indicative of market power. He also analyzed production decisions in relation to exogenous factors. Conclusively, he found an existence of substantial cooperative determination

[20] Based on his result also only Saudi Arabia's production has negative significance on oil price as well as coefficient of market share, he categorized OPEC members into three groups: 1.Saudi Arabia: cartel leader and swing producer, 2. Iran, Kuwait, Libya, Qatar, U.A.E and Venezuela as market share participants, 3. Nigeria, Algeria and Indonesia as partial market share participants.

among OPEC members to limit output and increase prices; furthermore, he found out that “OPEC is much more than a non-cooperative oligopoly, but less than a frictionless cartel.”

The study of Loderer (1985) conducted for the period of 1974-1983 to test the impact of OPEC on oil price movements within the period find no evidence that support the effect of OPEC decisions on oil price for the period of 1974 to 1980, but there was evidence of collusion for the period 1981 to 1983. He further opined that OPEC was more or less a ‘’trade association’’ during the period 1974 to 1980, as such could not exert any significant influence on oil price. Gulen (1996) used co-integration analysis to test market-sharing cartel behaviour of OPEC members for the period 1965 to 1993, and whether it influences oil price by adjusting output within the period. He did not find OPEC as a cohesive group, but the result showed support for production coordination which suggested that OPEC behaved as a cartel for the period (1982-1993). Alhajji and Huettner (2000) tested the dominant firm hypothesis for OPEC, OPEC core, as well as Saudi Arabia alone as dominant producer, and regarded non-OPEC producers as competitive fringes. Their result showed no support for OPEC or OPEC core to be described as dominant producer, but provided evidence supporting the role of Saudi Arabia as a dominant producer.

On the same note, Spilimbergo (2001) also tested the market-sharing cartel hypothesis for the period 1983 to 1991 and found no evidence to support this behaviour within OPEC countries. Herrera et al (2011) extended the context of Green and Porter (1984) and Porter (1983a) and applied simultaneous switching regression model for the period of 1974 to 2004. The aim was to assess presence of switching behaviour between collusive and non-cooperative conduct. The result showed that there are periods when oil price increases as a result of collusion between OPEC members; however, generally speaking, there was no systematic price increase above cournot competitive levels. As a consequence, they conclude that OPECs behaviour can best be described as a non-cooperative oligopoly with intermittent collusion, which can generally be referred as cournot competition due to competitive fringe competition instituted by non-OPEC producers.

Similarly, Li (2010) applied co-integration tests on recent data (1992 - 2007) to confirm the hypothesis of dominant firm behaviour of OPEC by examining whether OPEC production decides world oil price, and that competitive fringe (non-OPEC countries) produce based on the price. The result revealed that "OPEC production does not granger-cause non-OPEC production or oil price even at 10% significance. However, both non-OPEC production and oil price granger causes OPEC production and that non-OPEC production granger-cause oil price." As a consequence, he concludes that the dominant firm hypothesis do not describe OPEC's behaviour. More recently, Colgan (2013) applied ordinary least square modeling technique on OPEC data covering 1980 – 2010 to test the ascribed cartelization behaviour of OPEC. He finds no evidence in support of OPEC being a cartel and concludes that it has little or no influence on world oil price movements. Other studies simply assumed OPEC to be a cartel Salant (1976), Cremer and Weitzman (1976), Pindyck (1979), Newberry (1981), Morrison (1987), Green (1991), Griffin (1992), Berg et al (1996), Dahl and Celta (2000) and Byzalov (2002)[21] .

Conversely, Al-Qahtani, et al, (2008) further broke down the literature on market power and qualified OPEC behaviour into one-part cartel and two or three parts cartel. The one cartel model lends support to the market sharing and collusive behaviour of OPEC as described previously. The two parts or three part cartel models assumed that OPEC employs two or three parts cartel mechanism to contain production and increase oil price for profit maximization. Earlier enough, Hnyilicza and Pindyck (1976) studied OPEC pricing strategy with the assumption that the cartel is composed of two categories: spenders (countries with high monetary needs) and savers (countries with low monetary needs). They found that the optimal path for each group is dependent on state of production share (fixed or variable). If output is fixed, then monopoly price will be the optimal price, otherwise

[21] Al-Qahtani, et al (2008).

bargaining influence among spenders and savers will determine the optimal price paths[22] . Similarly, Tourk (1977) separated OPEC into countries with large reserves and low population and those with low reserves and high population, and assumed different discount rates for the groups based on their absorptive capacities. "The main objective for each bloc was to maximize net present value of future profits. He concludes that his model seems to explain the ability of OPEC to control supplies." Other scholars described OPEC behaviour by the three part cartel model approach; core members, price maximizers, and quantity maximizers Eckbo (1976), Hosthakker (1979), Darly et al (1982) and Griffin and Steele (1986).

2.2.2 Non-cartel models

2.2.2.1 Competitive behaviour Model

MacAvoy (1982) described the oil price variations through demand and supply interactions rather than OPEC's cartel behaviour . He opined that price rose mainly due to supply interruptions. He further clarified that the price increase of 1973 were the results of hypothetical demand increases because of decrease in supply. The increase in prices of 1979 and 1980 was the result of production decline because of Iranian revolution and Iran-Iraq war. He stated that the most of the production cuts enforced by OPEC have not had much

[22] Aperjis (1982) shares the same conclusion.

impact. Mac Avoy found out that the demand and reserve conditions were more significant in inducing oil price rise. He believed that prices unavoidably rose because of paucity of oil reserves and market forces decided the price in the absence of any monopolist influence of OPEC. Considering the fixed physical nature of oil resources combined with increasing depletion puts greater pressure on productive resources. As a result, prices will continue increasing under these conditions.

However, the world oil market is in state of excess most at times in reality. Adelman (1986) argued that marginal cost cannot be resolved with price defined by scarcity of oil, because the marginal cost differs significantly across regions and nations in the world. This is at variance with standard of competitive markets where marginal cost of all market participants supposed to be closer to the market price and also lower cost production should progressively dislodge higher cost production. Adelman further argued that after 1973, areas with high cost like North America, increased their investment and maintained or even increased their production but areas with low cost particularly Persian Gulf depleted little reserves. Since cost takes small fraction of the price, it is rational to increase production considering the vast available global reserves for significant profit maximization. He concluded that Mc Avoy's model failed to predict the fall of oil prices in 1980. This particular model of OPEC behaviour considered that the oil market is main cause of oil price fluctuations. The rise in oil demand and corresponding decline in discoveries during the 1960s, mounted pressure on depletion, increase user costs and resulted in increase in oil price Al-Yousef (1998). Considering the assumption of a competitive market, there would not be any monopoly influence for OPEC and competitive oil producer will set its price close to its marginal cost and user cost. This implies that Saudi Arabia will behave competitively and its price will be determined by market fundamentals. Any change in its production level will not affect price. Under this scenario, Saudi Arabia, and other OPEC members are price takers, assuming that the changes in any member's production will not have any effect on oil price.

Al-Yousef (1998) analyzed this assumptions utilizing data 1974 to 1982; she found out that marginal revenue was higher than marginal cost. The marginal cost of a barrel was less than $1 but oil price never fall below $8 per barrel, indicating that MR>MC. Arguably, one can might attribute this to the nature of oil as exhaustible resources whose marginal cost includes user cost: Marginal cost = Marginal revenue - User Cost; where user cost depends on producer's discount rate. However, given the free for all strategy that swept the oil market in 1986, price could not reach marginal cost. ("For example the lowest price for API 340, was $8/B in August, 1986"). She further narrated that, there was decline in demand for OPEC and Saudi Arabia's oil in 1978 despite increased in global demand. But oil price stabilizes at $12.7 per barrel and demand from OPEC and Saudi Arabia weakened due to greater official prices. In the short run, the competitive model would imply drop in prices as a result of reduced demand for 1979 to 1981. But spot prices moved higher than official prices. However, this spot price performance was due to supply insecurity as a result of political events and the struggle of consumers which offered higher prices.

Subsequently, Saudi Arabia kept spot prices ranging closer to the official by adhering to official prices and reducing its production to preserve for prices from 1982-1985. Had Saudi Arabia not restrict the production control and monitored the spot market, prices may have weakened to considerably lower levels. The event of 1986 affirmed this when Saudi Arabia chose the competitive way; prices fell to less than $10 per barrel after the start of netback pricing and the commencement of market-related prices. When OPEC decided to reduce its production and restore the quota system, prices went back to $17 per barrel. Consequently, oil market was only competitive in 1985/86 when OPEC production was “free for all” and Saudi Arabia was producing close to its full capacity.

2.2.2.2 Target Investment/Revenue Models

Under this model, it is assumed that OPEC MCs have ‘backward bending supply curve,’ implying that the reductions occur when oil prices increase above a definite level where the countries reach certain or fixed target revenue for their internal investment needs. Considering figure 2.3, any increase in price above P2, would result in reduction in production, as the producer needs fixed level of income. Adelman (1982) also asserted that “backward bending supply curve” would describe OPEC behaviour in the short run. Furthermore, other scholars that favours target revenue model emphasized that oil production decisions of the 1970s were made based on investment needs and budgetary requirements, which in turn rest on the absorptive capacity of the domestic economies and deficiencies in international market, Fattouh and Mahadeva (2013). Limitations on absorptive capacity leads to supply curve which is backward twisting Teese (1982) by means of price movement between a high and low price equilibrium dependent upon the point where supply and demand curves transect and with anticipations of long term prices Cremer and Salehi-Istifahani (1989). If price rises are anticipated to be temporary, producers will respond by increasing output to exploit transitory price increase[23].

[23] Output choices were done to meet target investment level. Oil price increase Increase in oil prices will entail low output to meet target, on the contrary, when prices drop producers will raise output in order to meet same level of investment desired Yang (2004).

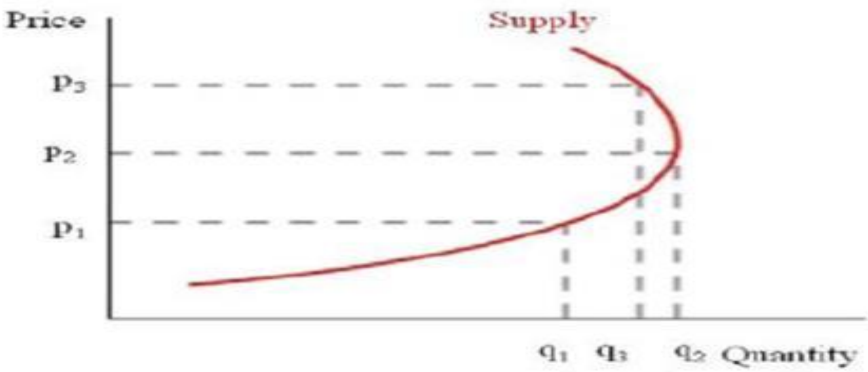

Figure 2.3: Backward bending supply curve for OPEC countries
Adapted from: Al-Qahtani et al (2008)

Teece (1982) defined OPEC conduct as a “target revenue model.” He stressed that it is wrong to classify OPEC as a “wealth maximizing cartel.” He further pointed out that the certain key that OPEC countries fixed their output using definite “budgetary requirements as well as internal and external political constraints.” He recommended that OPEC members reduced their output capability when their export earnings and foreign incomes “meet certain expenditure requirements and increase production if otherwise.” He concluded that this link among price and production remains “best described by a backward bending supply curve.” Salehi-Istifahani (1987) improved Griffin’s (1985) target revenue model by changing “current oil price” in Griffin’s case with “long term price.” He presumed each of the OPEC countries output to be dependent on price and investment requirement and re-predict the model. His findings provide backing for the target revenue model in OPEC countries.

Alhajji and Huttner (2000) estimated three dynamic and one static econometric models that descripted OPEC conduct as target revenue behaviour to investigate target revenue theory for individual OPE countries who did not harmonize output with Saudi Arabia. They assumed that individual output was dependent on oil price and the country's investment requirements in the static model. In the dynamic model, output was assumed to depend on oil price, investment requirement, and "lagged investment needs" in the first model. In the second dynamic model, they assumed that current output depends on "lagged prices, lagged investment needs and lagged production" while the third model presumed that the current output depends on" lagged and lagged investment needs." The findings showed that that production had no effect on budgetary and investment requirements for free market economies but had on "centrally planned, isolated oil dependent economies." But, the results showed Algeria, Nigeria, and Libya to be behaving in conformity with "backward bending supply curve."

Rancharran (2001) also modified Griffins (1985) model and used 1973 to 2000 data to investigate the target revenue theory for OPEC members and determine supply elasticity for OPEC and non-OPEC countries. He found evidence that support "partial target revenue model." In 2002 again, Ramcharran conducted the same study using 1973 to 1997 data and he also find results that was in agreement with that he found in 2001. Thus, he overruled the competitive model for all OPEC countries and acknowledged it for non-OPEC countries. According to Yang (2004), target investment model offer some superficially reasonable clarification to oil price rises of 1973-1974 and 1978-1979, resulting from some stability at high levels. However, the price decrease of $5 in 1983 did not result to output increase, in its place; major OPEC producers reduce output in this period.

2.2.2.3 Target Capacity Model

According to Al-yousef (2008), the target capacity model assumes that OPEC is playing the role of "residual supplier" in the global oil marketplace and its prices are defined by the" gap between its current capacity utilization and some target level of capacity utilization." The model relates the output of OPEC to the degree of capacity utilization, which is measured as the output level divided by the output capacity level. It was concluded that the prices would vividly rise at high capacity-utilization and would also reduce gradually during low degrees of utilization. Impliedly, OPEC agrees on certain capacity utilization and makes efforts to sustain it. Al-Qahtari et al (2008) further explained that when this bound is surpassed, oil price will rise as OPEC shrinks the output to tie with its preset "capacity utilization level." For instance, if capacity utilization is pegged at 80%, it entails that when the degree of OPEC capacity utilization surpasses 80%, greater demand will fuel

OPEC price rises. Demand will then reduce due to higher price and ultimately diminishes OPEC capacity utilization and vice versa.

Powel (1990) used the past performance of the global oil market and calculated the annual percentage change in price and capacity utilization. Moreover, he found the existence of a correlation between the high capacity utilization and price rises, and low capacity utilization and price decline. Bandyopadhyay (2009) asserted that the explanation for this relationship based on the TCU model is that OPEC tried to retain capacity utilization nearby wanted target level. When capacity – utilization surpassed that target level, high demand presents an incentive for OPEC to increase. The increase in prices afterwards lowered the demand and reduced the capacity-utilization to the initial target level. When capacity utilization descent lower than the preferred level, then OPEC tried to decrease prices in order to fuel demand and rise capacity utilization until the preferred level was reached.

2.2.2.4 Target Price Model

Literatures on target price model assumed that OPEC defined a price target and work towards attaining it through oil production variations. Hammoudeh and Medan (1995) combined market anticipations and "inventories shocks" to investigate OPEC pricing mechanism and behaviour to examine oil price dynamics in two models: two sided target zone model and asymmetric tolerance zone model[24.] Their findings showed that OPEC credibility to get involved in the oil market was directly related to oil price sensitivity that caused fluctuations in both production and price anticipations.

In 1997, Hammoudeh examined the price solutions for single and multi-target zone models. He concluded that under normal conditions, market players have anticipations that resulted in price instabilities in expectation of OPEC involvements while under other conditions OPEC moved the target zone when it could not hold the line with previous goals. Subsequently, Tang and Hammoudeh (2002) tried the same model and studied oil price behaviour for 1988 to 1999[25]. They discovered that the OPEC attempted maintaining a weak target zone for the oil price. They concluded that oil price was affected by both OPEC behaviour and the market's anticipation of OPEC behaviour and opined that OPEC became more explicit in implementing a target price zone model.

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[24] OPEC establishes a band for the market price (with an upper and lower limit) around the target price and places a tolerance zone below the target price Bandyopadhyay (2009).

[25] OPEC had a target price of $21 in 1986, Yang (2004).

2.2.2.5. Regime Switching of Property Rights model

As stated earlier in this chapter, the transfer of concessions ownership (property rights) from the International oil companies[26] to host in the first half of 1970s was a historical landmark that changed the structure of the world oil market. Consequent upon this development, Johany (1979) and Mead (1979) came up with the theory of property rights transfer to explain oil price increases of the years 1973-1974. The assumption of the property rights model is that when the ownership is transferred from oil companies to the government of the producing countries, the discount rate plunged due to limited time horizon for the concessionaire in comparison to the host government. Yousef (2008) also elaborated that the high discount rate used by companies, as a result of which they produced excessively was changed to lower rates by the governments[27] due to transfers of ownership rights. Also, the producing governments were inclined to lower their production due to exhaustibility and the fact that they have considerably lower discount rates than the oil companies. The lower the discount rate, the lower the desired production and vice- versa. This implied that the producing governments

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[26] Seven sisters: Anglo-Persian Oil company (BP), Gulf oil, Standard oil of California, Texaco (Chevron), Royal Dutch Shell, Standard oil of New Jersey (Esso) and Standard oil of New York (ExxonMobil).

[27] Mitchell and Stevens (2008) estimate approximate discount rate of 2-3 percent for NOCs and 10 percent for IOCs.

value future production than the international oil companies, hence, they decided not to produce oil reserves but in the future Al-Qahtani et al (2008). Consequently, it would be more appropriate to ascribe the production cuts and oil price increase of 1970s to the transfer of property rights Yang (2004). He further corroborated that it was argued in theory that the companies predicted the imminent loss of the property rights, and therefore produced at high rates to make profit quickly. Conversely, the governments' thoughts were more on the future, hence more likely to reduce output.

Johany (1980) argued that the sudden rise in oil price after the October 1973 Arab Israeli War may not be attributed to increase in the cartel cohesion of OPEC that can reduce production to increase prices. However, it may be attributable to the movement towards direct price setting by the oil producing governments in place of a system of negotiations with oil companies prior to October, 1973. Actually, the role of the oil companies was fundamentally reduced to that of contractors. Furthermore, since OPEC countries enjoys lower discount rate than the companies' effective discount rate, their oil production have been lower than what it could otherwise have been since 1973, considering if the ownership of the crude still rests with the oil companies. Nonetheless, the realism in the oil market is not in conformity with this theory. Going by the theory of exhaustible resources which was the basis of the property rights transfer model, oil price increase should rise slowly in modest way due to steady exhaustion of oil reserves. However, oil prices rose sharply within a short period of time and subsequently, fell drastically. This could have possibly been explained by the application of market influence followed by a distorted collusive scheme Yang (2004).

Conclusively, it is obvious from the OPEC behaviour models available in the economic literature, that there are varied opinions and mixed inferences. It is difficult to pinpoint a particular model that describes OPEC's conduct in absolute terms since the past five decades. Probably, because OPEC seemed not to be acting in a deterministic way, but rather in erratic fashion in response to finding an optimal tradeoff between meeting its members objectives and managing changing market fundamentals to ensure stability in the world oil market. Mohn (2009) also buttressed that the empirical works on OPEC's behaviour in the oil marketplace have largely been futile in establishing strong confirmation of stable cartel behaviour. Similarly, Gately (1984) narrate that "it remains an open question how best to design a model of the behaviour of OPEC." Much later, Bochem (2004) asserted that "There exists neither an accepted theoretical model nor an accepted econometric model of this market" and more recently Smith (2005) expressed that "Contributions remain largely inconclusive regarding the behaviour and impact of OPEC despite the best efforts of those authors." Nevertheless, recent studies recognized that there is some kind of collusion. One thing that is clear is that the production policy of

OPEC members is driven by the dependent on the interactions among global oil demand, physical ceilings due to reservoir characteristics of producing fields / wells that determine its reducibility and lastly production policy ceilings Fesharaki, (1990).He further stated that any of these factors that weighs the most, drives the production decision of OPEC countries. Hence, assuming that OPEC members react only to 'demand, or domestic economic and political pressures in deciding production levels' could be misleading.

Furthermore, there are other emerging factors that seem to influence oil price movements in recent times, it is more significant than the role or behaviour of OPEC notably speculation in futures trading, political unrest in the Arab world etc. According to Beredjick and Walde (1988), the influence of producing countries on setting oil prices has significantly weakened since the advent of spot and future markets for oil irrespective of producers. Despite the great dealings of spot and futures market with 'paper oil', lots of contracts for 'wet oil' are also connected to the spot marketplace [28] . Conversely, technological progress has resulted in the growth of unconventional fossil fuel development notably Canada's oil sand and U.S shale gas. This emerging development will increase inter fuel competition and provide incentive for the substitution among consumers even though prices might be high due to high

[28]"It is estimated that about one third of oil is sold directly on the spot market or at government prices linked to the spot market. Another 50-55% is sold at prices linked to the spot market thought mechanisms such as countertrade, net back pricing, toll processing or spot market formulas. Only 10-15% is currently sold on contract at official prices" Beredjick and Walde (1988).

cost of exploration and development, however, they come with less compensation to the environmental externality. With growth in their supply, demand for OPEC oil may consequently decline in the long term which will further worsen demand uncertainty and slow down upstream investment in capacity expansion among OPEC members. Ultimately, it will also influence the OPEC's future behaviour in the world oil market. For a summary of empirical literature insights on OPEC behaviour models see Table 2.1 below:

Table 2.1: Summary of literature insights on OPEC behaviour.

Author (s)	Behaviour	Models	Conclusion
Pindyck (1978),Griffin (1985), Loderer (1985), Danielsen and Kim (1988), Gullen (1996), Huettner (2000), Spilimbergo (2001), Yang (2003), Kuafman et al (2004) and 2008Alhajji and Smith (2005) and Yousef (2008).	Cartel	Dorminant firm cooperative , profit maximize and Market sharing	OPEC pursue profit maximizing goal by restricting output collectively, individually, collusive action or market sharing (quota allocation) to impact on the price. Saudi Arabia acts as a swing residual monopolist firm while others act as fringe firms. Dominant firm sets the price, acts as swing producer to grip market fluctuations to ensure monopoly price.
Mc Avoy (1982)	Non-cartel	Competitive behaviour	Oil price variations are the result of interaction of demand and supply rather than OPEC cartel behaviour.
Adelman (1982), Teese (1982), Cremer and Salehi-Istifahani (1989), Alhajji and Huttner (2000), Ramcharran		Target investment/ revenue	Oil production decision-making depends on the investment/target budgetary of OPEC MCs. When oil price reach desired

(2001 and 2002) and Al-Qahtani et al (2008).			revenue/investment target levels, oil production is curtailed exhibiting backward bending curve. Increase in oil price leads to low production to meet set target. When the price drops, output is increased to meet desired investment/revenue target.
Hammoudeh and Medan (1995 and 1997), Tang and Hammoudeh (2002) and Bandyopadhyay (2009)		Target price	OPEC defined a price target and adjust its production to attain it
Powel (1990), Al-Qahtani (2008, and Bandyopadhyay (2009).		Target capacity	OPEC prices are defined by the" gap between its current capacity utilization and some target level of capacity utilization". Prices would rise at high capacity-utilization and reduce gradually during low degrees of utilization. Impliedly, OPEC agrees on certain capacity utilization and makes an effort to sustain it.
Johany (1979), Mead (1979), Johany (1980), Yang (2004), Al-Qahtani et al (2008) and Yousef (2008)		Regime switching of property rights	Oil production cuts and price increases of the 1970s were the result of transfer of property rights (concession ownership) from oil companies, which have high discount rate to host governments that have low discount rates.

2.3 OPEC Upstream Investment Strategy

The change in the structure of the international oil and gas industry had significantly influenced investment strategies and patterns of upstream players, particularly since the birth of the oil and gas industry in the U.S. Investments in the upstream oil and gas industry were mostly carried out by international oil companies in the 1970s due to good internal cash flow and robust balance sheets. As a result, they required little effort in raising funds from capital markets to supplement financing exploration, field development, or production related capital projects. When resources rich countries began to exercise sovereign control over their oil resources during the 1980s, the pattern of global investments in oil and gas projects changed with consequential renewal of growing concern about security of supply and price stability among consuming nations. In the case of OPEC, this curiosity received a boost when OPEC members started forming national oil companies (NOCs) as vehicles for their active participation in upstream activities. There was also corresponding response from non-OPEC producers IEA (2003).

Successive oil price rises provide significant income to producing nations and offered limitless credit opportunities to these countries. Consequently, a growing volume of financing for oil projects came from government budgets among OPEC countries. Conversely, for non-OPEC producers, financing was provided through 'government sponsored borrowings from multilateral financial institutions and bilateral donors' IEA (2003). The concern about security of demand heightened because of the financially mutual dependent relationship between the NOCs and host governments. While the NOCs receive funding from government on one hand, the governments also rely on the NOCs for revenue generation and foreign exchange earnings in most producing nations on the other. Thus, this presents a source of differing objectives between the NOCs that pursue profit and social welfare maximization and IOCs that rationally aims to maximize profits only. This is apparent among OPEC countries that have big chunks of the global proven oil reserves, high potential for future supplies, and heavy reliance on oil income to fund national budgets and economic programmes. Consequently, the income of the NOCs may be squeezed to the level of not adequately responding to timely investment needs in exploration, development, and production expansion to meet future oil demand growth and supply requirements. But, higher increases in oil price will translate to substantial cash flow for the producing countries and increase their investment potential. Unfortunately, higher oil price scenarios come with the negative effect of providing incentive for the oil producing governments to increase royalties and other taxes; this is necessary for their quest to tap on windfall profits of oil companies and increase revenue generation to fund national economic programmes[29]. Thus, striking optimal tradeoff between funding national

[29] See Cherif and Hasanov (2012) for study on optimal level of oil investment by large oil

budgets, managing market fundamentals, and investing in upstream oil and gas projects should be the core of OPEC members' investment strategy.

2.3.1 OPEC upstream investment and oil price movements

In the absence of actual oil and gas investment figures among OPEC members, upstream investment is proxy by measure of active rigs operations in a given year among member countries. The choice is consistent with Ringlund eta al (2008) wherein the authors used rig count as proxy for exploration drilling and field development investment. Considering the figure 2.4, historically OPEC MCs rate of investment have been increasing at an annual average of 280 active drilling rigs, which corresponds to an annual average growth rate of 3% for the period of 1982-2011. Generally, OPEC's investment level responded positively to oil price movements during this period.

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exporting nations amidst income volatility.

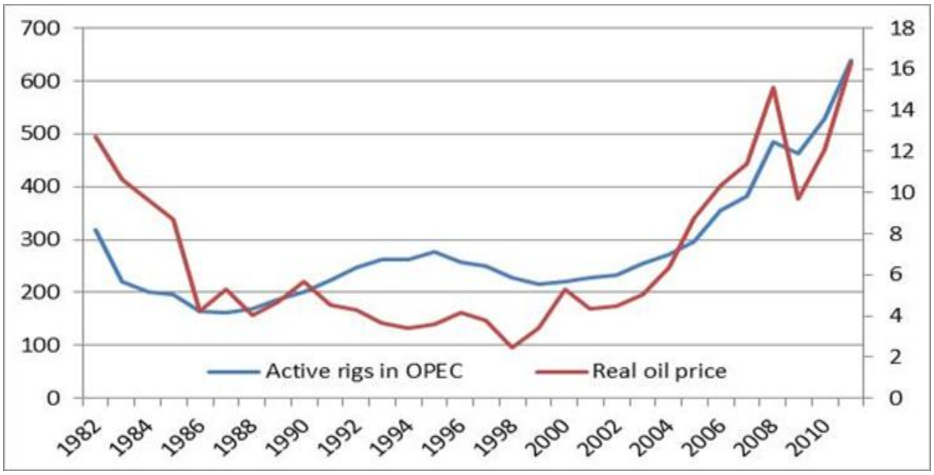

Figure 2.4: Oil price movement and upstream investment in OPEC countries

Source: Own calculation with data from BP (2012)

During the low price regimes of the 1980s there was drastic fall in price by 19.2% from 1982 – 1986 which corresponds to reduction from \$32.97 to \$14.43. OPEC members responded with corresponding decline in rate of investment by 12% thus, reducing the level of drilling activities from 318 wells in 1982 to 165 in 1986. When prices began to recover in 1987, which set the stage for the decoupling of drilling activities with oil price, OPEC responded with an increase in investment level at an average of 7% for the period of 1987 – 1988; this was slightly higher than half of previous increment levels and did not impact investment level despite the price drop in 1988. This corresponds to an increase in number of active drilling rigs from 163 in 1987 to 170 in 1988. Conversely, oil price increased by an average of 1.1% within the period 1987-1988. By 1989 oil price began to rise through

1991 when the level of drilling activities in OPEC countries completely decoupled. There was a steady growth in the rate of investment level at an annual average of 7% from 1990 – 1994 despite the fact that price grew at an average of 18.5% for 1989-1990 only and progressively declines at average rate of 11.9% from 1991 – 1994. These correspond to growth in active drilling rigs from 224 in 1991 to 263 in 1994.

From 1995 - 1996 oil price rose at an average of 11% and began to drastically fall in 1997 through 1998 when the Asian economic crisis set in at an annual average rate of 22%. This resulted in significant price reduction from $19.07 in 1997 to $12.72 in 1998. Conversely, OPEC members did not positively respond to the price increases of 1995 - 1996 with increase in upstream investment level, which could be associated to loss of confidence in the market stability as a result of price reductions of the early 1990s. Furthermore, it may also indicate the option of waiting until price recovers and market stability returns. This investment delay translated to reduction in rate of drilling activities at an annual average rate of 6% from 1995 - 1998. The number of active rigs dropped from 278 to 228 during this period. By 1999, global economy began to recover with consequential increase in oil demand and price increase by 2.4%; it also progressively increased at an annual average rate of 19% from 2000 - 2005 ($28.5 to $54.52), though there was slight price slump in 2001. Within this period, the rate of investment grew at an annual average rate of 8% with corresponding number of active drilling rigs rising from 220 in 2000 to 296 in 2005. It is worth mentioning that the rate of investment decoupled again in 2005.

From 2005 when the rate of investment decoupled, there have been significant steady growths in upstream investment level by OPEC members at an annual average of 18% till 2007, which translates to increase in number of active drilling rigs from 296 to 383. Oil price have also steadily been increasing at an annual average rate of 22% from 2005 – 2007, which corresponds to price increment from $54.52 to $72.39. This significant growth in rate of investment may be attributed to substantial increase in the revenue of OPEC members as a result of high price levels. By the end of 2008, the global economic crisis erupted; oil price began to slide down by 2009, being reduced by 1.6%. The rate of upstream investment dropped by 5% between 2008 and 2009 due to the looming uncertainty on global oil demand that may reduce demand for OPEC's oil. However, the rate of investment picked up in 2010 and progressed through 2011 at average of 18%. The fast economic recovery of emerging economies regenerated demand for oil and price increased at an annual average of 29% from 2010 – 2011, which corresponds to increase in number of active rigs in OPEC countries from 463 in 2010 to 640 in 2011. Apparently, the investment strategy of OPEC has been tailored to respond to progressive increasing rate of investment with significant increases in oil price or stable prices and vice versa.

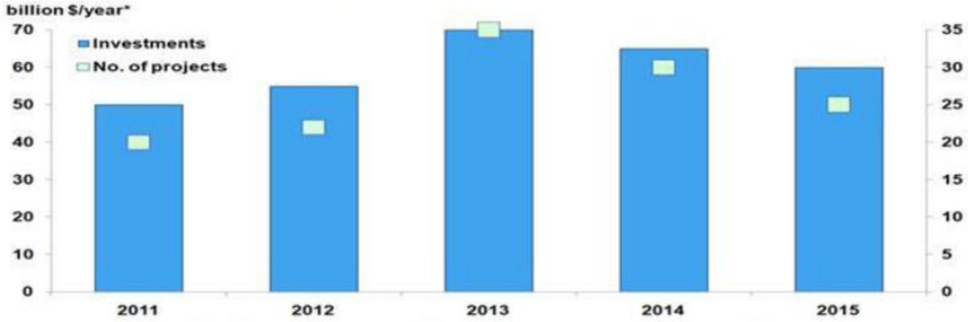

Figure 2.5: OPEC upstream investment plans in the medium term
Source: OPEC 2012 World Oil Outlook

The investment strategy of OPEC in the medium term is hinged on safeguarding the steady supply of oil to fuel global economy through investment in upstream capacity expansion. According to an OPEC long terms strategy report, about 135 projects are expected to come on stream from 2009 to 2015 with an estimated total cost of $300 billion (Figure 2.5) despite the prevailing market fluctuations and growing uncertainties. A total of twenty upstream projects valued at about $40 billion have been planned in 2011. The development of the projects is estimated to heighten through 2012, and peak at a maximum of 35 projects in 2013, gradually declining to 30 in 2014 and 25 in 2015 respectively. It is estimated that the combined impact of these projects on the world oil market when on stream will increase OPEC's net oil production capacity by around 7 million barrels per day to ensure comfortable levels of spare capacity. In general, it is also estimated that cumulative OPEC upstream investment requirement will be between $200 billion and $400 billion through 2030 in the long run (OPEC 2012).

2.3.2 Upstream investment and OPEC Spare capacity

According to U.S. Energy Information Administration (EIA), the world's spare capacity[30] was around 2.4 million barrels per day in the first quarter of 2012, which was lower compared to the space capacity during the same period in 2011 by about 1.3 million barrels per day. The global spare capacity is held by OPEC members to safeguard against sudden supply disruptions in the world oil market. There is virtually little or no spare capacity in non-OPEC producers due to production at maximum capacity. Currently, the oil production spare capacity is about 3% of the world's oil demand which is the lowest since the fourth quarter of 2008. Spare capacity is a vital indicator of the producers' ability to react to potential supply interruptions; thus, low spare capacity is usually connected with high oil prices and volatility. Similarly, rising spare capacity tends to be linked to declining oil prices and decrease in volatility. Nevertheless, spare capacity should also be viewed from the perspective of other factors that can influence oil prices, notably: global

[30] U.S. Energy Information Administration defines spare crude oil production capacity as "potential oil production that could be brought online within 30 days and sustained for at least 90 days, consistent with sound business practices. This does not include oil production increases that could not be sustained without degrading the future production capacity of a field"

demand, supply, and inventory intensities. Historically, global oil demand had progressively outgrown the non-OPEC supply capacity, even with an upsurge in production from Russia that resulted in significant increase of non-OPEC supply capacity in 2000-2002 (figure 2.6). Global oil demand had been growing at an annual average rate of 1.1% from 1980 to 2011, while non-OPEC production has grown at an annual average of 1% within the same period. During the market instabilities of the 1980s, global demand of oil shrank at an average rate of 1% within the period 1980 – 1985. Conversely, non-OPEC producers supplied the market at an annual average growth rate of 3% reducing further demand for OPEC oil. Fortunately, in the mid-1980s Saudi-Arabia negated acting as swing producer and decided to increase its production for expected pursuit of profit maximization Bandyopadhyay (2009), the result was that the market had an excess supply of oil under low demand conditions. In turn, prices progressively reduced at an annual average rate of about 20% from 1981 to 1985 and by 1986, prices had crashed to abysmally low levels, hence, the 1986 world oil glut.

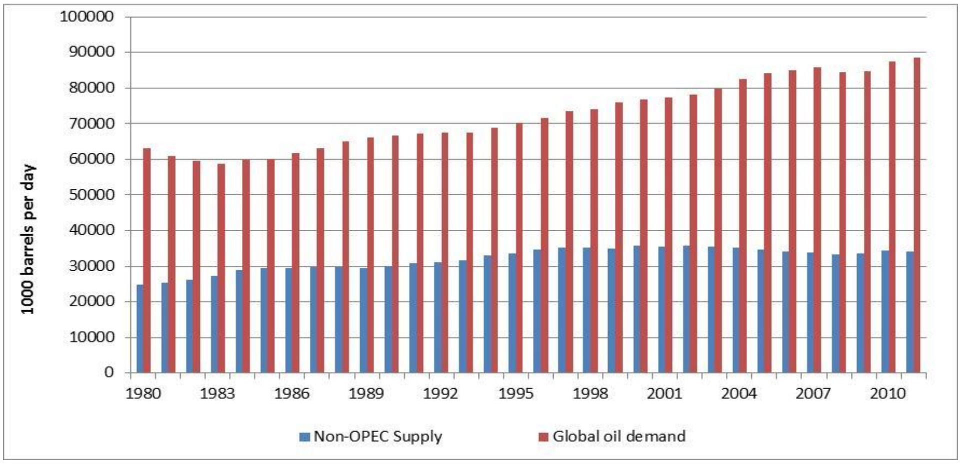

Figure 2.6: Non-OPEC oil supply and global oil demand trends
Source: Own computation, data from BP (2012)

The rapid increase in non-OPEC output and fast reduction in world oil demand in the 1980s reduced demand for OPEC oil far below anticipation on one hand. On the other hand, this development gave rise to the buildup of OPEC's excess production capacity to an average of 17% of global oil demand by 1985.

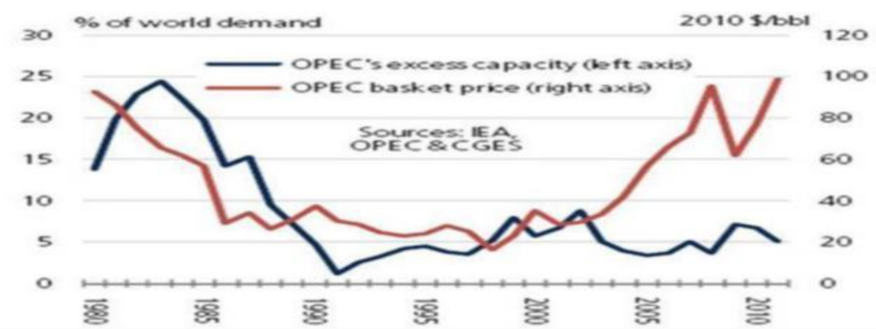

Figure 2.7: Comparison of OPEC spare capacity as percentage change of global oil demand and oil price movement
Source: OPEC & IEA

Obviously, it was the most unprecedented growth in spare capacity in the world oil market (figure 2.7). Generally, the observed decline trend of spare capacity induces a consequential multiplier effect on oil price, thus contributing to its general increasing trend during 1980s to present. (Figure 2.7). From 1986, oil demand began to regain momentum and progressively increased at an annual average rate of 2.3% through 1987-1989. Due to high depletion rates of non-OPEC producers in the early 1980s, there was no room for additional capacity by the late 1980s. Therefore, they could not respond to the rise in oil demand with increase in production for the period of 1987 - 1989 (Figure 2.6). Consequently, there was a call on OPEC to which it responded by increasing production at an annual average growth rate of 9% for the period 1987 - 1989. OPEC's spare capacity reduced about 9% of global demand by 1989 and decoupled at this time. From 1990, demand weakens to an annual average of 1% growth rate through 1995 while OPEC responded with downward revision of production to an annual average of 3% and non-OPEC produced at average growth rate of 2% from 1990 - 1995. Subsequently, this period set the pace for progressive and substantial decline in spare capacity since the early 1990s accompanied by a progressive drop in crude oil prices within the period (1990-1995) (figure 2.7). The situation improves in 1996; demand grew by 2% and progressed at an annual average rate of 1.8% from 1996 to 2000 (figure 2.6); oil price appreciated by 11.2% in

1996 and progressed at an annual average of 13% within the same period. As a result, this development restored some confidence in the market.

From the supply side, non-OPEC producers increased oil production by 3% in 1996 and maintained an annual average growth rate of 1% for the period 1996 - 2000. OPEC member's production rose by 2% in 1996 which is slightly slower than non-OPEC, but progressed at higher rate (average of 3%) during the period 1996 -- 2000. The impact of accelerated oil demand growth coupled by the lack of steady growth in non-OPEC production with consequential rise in OPEC's production capacity is the quick exhaustion of OPEC's spare capacity and depletion of producing fields. As a consequence, there is need for huge upstream investments in exploration to find and replace produced reserves, secondary recovery projects to increase recovery factors, and supply capacity expansion to rebuild spare capacity. However, upstream investment is observed to have decreased by 2% among OPEC members for the period 1996 – 2000.

In 2001, oil demand dipped by 1% and oil price reduced by about 18%. However, demand grew at an annual average of 1.7% within 2000 - 2005 and prices increased at an annual average of 19%. Non-OPEC production increased by 1% in 2001 and stagnated until 2005; OPEC producers increased production by 2% in 2001 and progressively sustained its growth at average rate of 3% from 2001 to 2005. The rate of upstream investment also grew at an annual average of 8%. This translates to an increase in number of active rigs in OPEC members countries from 220 to 296 active rigs. Oil price appreciated by 27.7% in 2006, growth rate dropped to an average of 21.5% during the period 2007 - 2008, and by 2009, oil price reduced by about 1.62%. However, improved global economic recovery reinforced oil demand growth and prices started appreciating at an annual average rate of 29.6% during 2010 - 2011. From the demand side of dynamics, oil demand increased by an average of 1.5% in 2006, dropped by 0.3% during 2007 - 2008, and then revamped progressively at annual average growth rate of 1.6% from 2009 - 2011.

On the supply side, there is an observed decrease in oil output by 2% in 2006, which further continued downward to an average of 1% within the period 2007- 2009. Oil production increased due to growth in demand for non-OPEC during 2010 - 2011 at an annual average of 1%. Conversely, OPEC producers increased output by an average of 2 % in 2006 and adjusted slighted to 1% during 2007 - 2009 to reflect low demand growth. When the market began to stabilize, production increased annual growth rate of 3% during 2010 - 2011 to ensure adequate oil supply in the world oil market. In terms of upstream investment, there was average growth of 18% during the period of 2006 - 2007, which was slashed down to 11% in 2008. Since 2009, an annual average growth of 18% in the rate of upstream investment by OPEC members in response to the growing recovery of global economy is observed, leading to a shortage of demand uncertainty and an increase in cash flow. This translates to growth in drilling rigs engaged in exploration and development activities from 463 in 2009 to 529 in 2010.

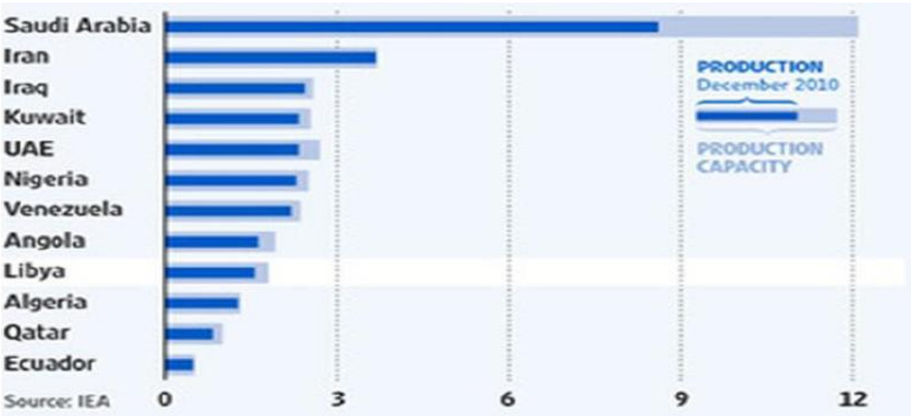

Figure 2.8: Spare capacity of OPEC members as at December, 2010
Source: IEA

However, OPEC spare capacity has been exhausted to very low levels among OPEC members with combined capacity of around 1 million barrels per day, except Saudi Arabia that have excess capacity of about 3.5 million barrels per day as of December 2010. (Figure 2.8). In general, it had progressively dwindled to about 4% of global demand in 2011, in response to sustaining stability in the oil market and security of supplies. OPEC acted as swing producer to augment the shortfall in oil supplies from non-OPEC producers. The fast erosion of the production capacity was the result of rapid progressive demand growth and low growth in non-OPEC oil production especially during

1990 - 2004. Evidently, this creates a reversal of the production-demand situation of the 1980s and reinforces the lingering concern about possible impending shortages, should the world economic condition respond with impressive performance.

Expansion of spare capacity has been low due to the relatively low level of upstream investments among most OPEC members. This could be as a result of frequent price volatilities of the 1980s - 1990s, and growth in domestic budgetary requirement. In addition, Kochhar et al (2005) opined that the consequential decrease in spare capacity has amplified the sensitivity of oil prices to real or probable supply interruptions. Nonetheless, the relatively high oil prices of the 2000s amidst recurrent volatilities have strengthened the investment capacity of OPEC members leading to an increase in upstream investment for capacity expansion (Figure 2.5). Given the time lag between investment and physical availability of capacity, these investment commitments will mature around mid-2000s and may contribute to capacity expansion after maintaining current production levels. Considering the fact that conventional non-OPEC oil output is anticipated to peak around 2010 as a result of fast depletion of current fields plus net declines in proven oil reserves. Lots of the incremental capacity will need to be sourced from OPEC, which currently holds about eighty percent of the world's proven oil reserves Kochhar et al (2005).

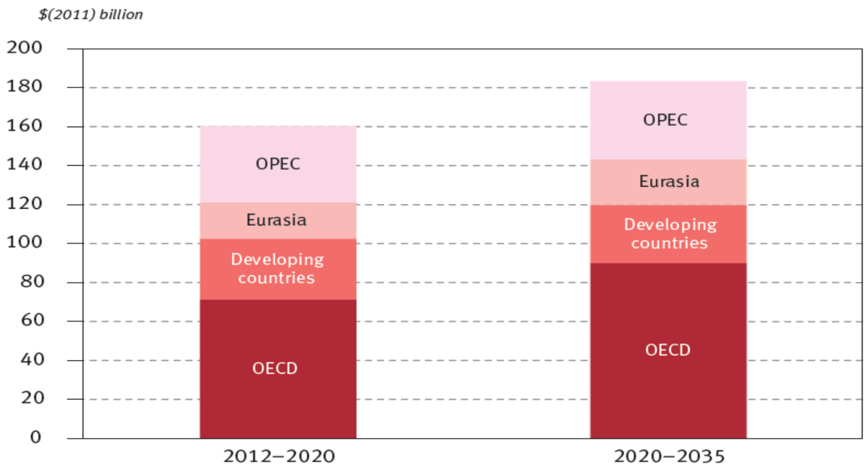

Figure 2.9: Annual upstream investment requirement for capacity additions in the reference case (2012-2035)
Source: OPEC 2012 World Oil Outlook

According to OPEC, looking ahead, upstream investments needed for capacity expansion will amount to about $4.2 trillion in 2011 from 2011 - 2035 (Figure 2.9). The bulk of this investment requirement is in non-OPEC countries in the medium term. An annual average of $95 billion will have to be invested in the medium term and progresses to an annual average of $110 billion in the long term. At the same time, OPEC members have to invest an annual average of $45 billion (Figure 2.9). Most of the investment requirement is to augment the natural declines in existing fields. In addition, the volume of crude oil needed to compensate for loss of capacity is quite large. There will be significant capacity additions, but investment costs per unit of output are expected to fall with the anticipation of additional oil from the Middle East; this is considerably the world's lowest cost region IEA (2003). Accordingly, OPEC spare capacity is estimated to increase further than 5 million barrels per day during 2013 - 2014. The total OPEC persistent capacity was an average of over 34 million barrels per day in 2011, whereas cumulative supply averaged to 29.79 million barrels per day. Given that the anticipation of call on OPEC to approximately remain stable, it is expected that this growing trend will continue in the medium term.

2.3.3 Impediments to Upstream Investments in OPEC Countries

Based on the foregoing analysis and consistency with literature, it is evident that OPEC spare capacity has progressively eroded to an all-time low level in 2010, which was at about 3% of global oil demand and corresponds to about 4.2 million barrels per day. The investment in capacity buildup runs at a slow pace due to a number of uncertainties that are perceived to have heightened difficulties in striking optimal tradeoff between security of demand, supplies, and income of producing nations. Notably among these challenges are demand uncertainty, market instability typified by price volatility, growing financial need of member countries, emerging energy, and environmental policies of major consuming nations as well as regulatory framework and policy developments among OPEC members. This further defines the pace of relationship between OPEC members, NOCs, and partner IOCs. In addition, the presence of huge barriers to entry in some OPEC members limits access to reserves by international oil companies thereby reducing investment influx IEA (2003).

According to Fattouh (2007), IEA and IMF attributed the loss of spare capacity to global under-investment in the oil sector. They argued that there is a need to debottleneck obstacles to investments in order to rebuild spare capacity across the industry’s value chain. They pressed that renewed fears of possible oil shortage have placed upstream investments at the forefront of global policy discussions. This has heightened calls for OPEC and non-OPEC producers as well as international oil companies to raise their output capacities while blaming the present weakening of capacity to stretched period of under-investment Fattouh (2004).

Another issue that can hamper investments among OPEC members is the growing domestic financial burden as a result of population growth and the need for domestic investments in infrastructure and other economic development projects. Because of these, policy makers are faced with the challenge of maintaining optimal balance among these competing needs. Big oil producers (OPEC and non-OPEC) face great revenue volatility and may have substantial savings, but will experience low upstream investments level Cherif and Hasanov (2011). He further stated that oil exporters saved about 30% of their GDP on average when oil prices were high in the 1970s. Alternatively, investment level declined to 20% of GDP in the 2000s when oil price was at a similar level[31]. In the same vein, Kochhar et al (2005) states that the growing financial need of oil exporting countries results to increased revenue demand from NOCs, which consequently erodes their finances and invariably impacts their capacity to make timely upstream investments.

The investment problem is compounded by the inefficient relationship between the government and the national oil companies, and the strenuous relationship between national oil companies and international oil companies. Larger revenues due to higher oil prices can relive the tight capital budget in these few years, but this relief will be only temporary. The fundamental problem lies in the nature of the relationships and the environment it creates, which is not conducive to investment. The nature of these relationships is very slow to change, thus implying long delays in investment. These uncertainties surrounding the world oil market have made the producing nations in particular and oil companies in general to adopt the option to wait and not to invest. This implies that investors can choose to postpone investments until the prevailing uncertainties weakened.

[31] Cherif and Hasanov (2011) studied the problem of optimal allocation among consumption, saving, domestic investment and income volatility for oil exporters using cautionary saving and investment model under ambiguity. They find that the precautionary saving of oil exporters to be about 30% of income and investment level was found to be about 15% of income "given high volatility of permanent shocks to oil revenues and relatively low productivity of the tradable sector."

2.3.3.1 Demand uncertainty

The progressive performance of the world economy after the 2011 economic crisis erupting from the U.S. and Eurozone financial crunch is rekindling optimism on expectations about investments in the upstream activities in the international oil industry. This is fuelled by an increase in global economic growth over the past two years at an annual average rate of 2.5% that has driven rise in oil demand with corresponding price increases at levels that can ensure fair return to investors and does not negatively impact consumers, thus justifying the economics of new upstream projects. However, the certainty about future conditions of the world economy is still unclear. This can heighten fears about security of oil demand, which will invariably reduce investors' incentive to make timely investments in supply capacity expansion for adequate supply in the future.

Furthermore, despite future uncertainties concerning the progress of oil demand and non-OPEC supply, it is generally acknowledged that residual resources will adequately satisfy demand. Although the marginal barrel will progressively come from OPEC, there is ambiguity on the actual quantity that will be required. According to OPEC demand projections, the OPEC oil varies from 31 million barrels per day in 2005, and is reduced to 30 million barrels per day around 2010, and progresses to 34 million barrels per day in

2015; it is estimated to peak to about 38 million barrels per day in 2020. This corresponds to an investment need of $90 billion ($2005) in 2010 rising to $200 billion in 2015 ($2005) until it grows to about $350 billion in 2020 ($2005) (Table 2.1). The lower economic growth case, which is the Prolonged Soft Market, assumes oil demand to vary between 31 million barrels per day in 2005 to about 29 million barrels per day in 2010; it is assumed to grow to 30.5 million barrels per day in 2015 and reach a peak of 32 million barrels per day in 2020. Corresponding investment needs will be at about $60 billion ($2005) in 2010, rising to $140 billion ($2005) in 2015, and reaching a peak of $220 billion ($2005) by 2020 (Table 2.2). In the high economic growth case which is the Protracted Market Tightness scenario, demand for OPEC oil is observed to be around 31 million barrels per day in 2005, yet declines to 30.5 million barrels per day in 2010. It then appreciates to 35 million barrels per day in 2015 in response to an improved economic performance and peaks to around 44 million barrels per day in 2020.

Table 2.2: Oil demand and OPEC upstream investment requirement projections

Source: Own calculation, data from OPEC (2007)

OPEC oil demand projection

Year	Lower growth Case (mb/d)	Reference Case (mb/d)	Higher growth Case (mb/d)
2005	31	31	31
2010	29	30	30.5
2015	30.5	34	35
2020	32	38	42

OPEC Upstream investment projection

Year	Lower growth Case ($ 2005)billion	Reference Case ($ 2005)billion	Higher growth Case ($ 2005)billion
2005	0	0	0
2010	60	90	120
2015	140	200	270
2020	220	350	450

Accordingly, about $120 billion ($2005) was expected to be invested in 2010 which is assumed to rise to $270 billion ($2005) in 2010, and peaks to about $450 billion ($2005) around 2020. This reveals the varying degree of demand for OPEC oil with corresponding investment requirement. Apparently, there is huge ambiguity associated with the required huge financial commitment amidst inconsistent demand growth. This evolving demand confronts the world oil market and is a consequence to the world's economic recovery, response to environmental and tax policies of consuming nations, and growth in non-OPEC supply. It further supports the significance of security of demand to timely investments by producing nations. "For example, lower-than-expected demand in the 1980s led to significant increases in spare capacity amongst OPEC members" Kochhar et al (2005). However, according to OPEC Secretary General, continued dialogue and communication among major consuming and producing nations, as well as close monitoring of world economic developments, will significantly aid in reducing demand uncertainties.

2.3.3.2 Oil price volatility

Oil price remains the most volatile component of investment equation in the oil and gas industry. As seen in foregoing analysis on the relation between upstream investment and oil price movements, OPEC upstream investment has been quite responsive and sensitive to oil price fluctuations. When prices fell in 1985 and 1998, there was an observed subsequent decline in upstream investment among OPEC members. On the contrary, when prices revamped and sustained higher levels in 2001 - 2005, there was also a significant increase in investment spending among OPEC members (Figure 2.4). IEA asserted that international oil and gas investment is expected to plunge considerably with the fall in oil price. Evidently, oil price volatility serves as a major obstacle to timely investments in upstream capacity expansion, by motivating investors to resort to wait and delay capital commitment. This is vital considering the role of oil price level to investment cash flow profile and rate of return determination. According to OPEC, maintaining fair return to investors and ensuring reasonable revenue flows to oil producing nations have been a core strategy behind its commitment to sustain market stability through responding to a call on OPEC and sustainable dialogue with consuming nations. In theory, the investors' willingness to invest in the wake of volatile prices will be low, as the ambiguity associated with upcoming returns is higher. In addition, recent oil price increases have been empirically found to increase capital cost and reduce marginal investments[32] IEA (2003).

2.3.3.3 Regulatory framework and fiscal policy of OPEC members

The developments in fiscal terms are of vital concern in the valuation of the feasibility of an oil exploration and production investments, due to the associated risk of the oil sector and the characteristic uncertainty of the international oil market[33] condition Adenikinju and Oderinde (2009). The regulations governing upstream business environment and applicable fiscal regimes define the cash flow and rate of return structure of upstream investments. The rate of taxes and royalties as shared profits (government take) differs greatly among producing nations in accordance with the maturity level of the industry, investment risks and immediate socio-economic factors Kochhar et al (2005). At the exploration phase, there is a high sunk cost and uncertainty relating to the discovery of oil while at the development phase;

[32]" IEA analysis points to a robust inverse relationship between upstream oil investment and price volatility; an increase in volatility results in a decline in investments, and vice versa. See IEA (2001)".

[33] Mitchel (2009) asserted that for tax rates to be effective in the extractive industry, 'neutral and progressive tax systems' have to be designed to encourage 'corporate innovation and profit-seeking'. Regressive taxes that allocates increasing share of profits to host governments tend to dampen investment.

these uncertainties vanish or are significantly reduced. As a consequence, the fiscal regimes that drive exploration investment may not be suitable for development. Risk sharing and mitigation should be a critical consideration in the design of petroleum fiscal policies. Typically, the Government take is lower in regions with mature oil industries and relatively high extraction costs, such as the North Sea; on the other hand, it is highest in countries with largest production potential and lowest development costs. Furthermore, the growing financial burden of exporting countries compel governments to increases oil and gas rents in a bid to raise revenue flows at the risk of demotivating further investment. Recurrent changes that with hindsight affect the taxation of sunken investments compel investors to increase their impediment rates for future investment decisions to points that are large enough to accommodate the greater perceived risk.

According to the United Nations Conference for Trade and Development World investment Report 2007, Algeria enacted a law mandating a windfall tax on production at prices higher than $30 per barrel of oil in December 2006. The tax rate ranges from 5% to 50% depending on the total production. The new hydrocarbons law of Ecuador in 2006 raised the share of revenue payable to the government from oil and gas activities leading to a series of contract renegotiations and disputes. The Venezuelan government in 2001 enacted a new Hydrocarbons Law, which increased royalty rates and pegged future investments to a maximum of 49% equity ownership in joint projects, and ascribed 51% controlling share for the State-owned oil company, PDVSA. Furthermore, risk service contracts with 17 foreign companies were converted into joint ventures with PDVSA in 2006. Most recently, Nigeria proposed a new sliding scale royalty system in the much debated Petroleum Industry Bill currently under legislative consideration. The new royalty scheme plan for upward review of royalty rate ranging from 5% to 25% depends on the terrain of operation (onshore, shallow offshore or deep water) once oil price exceeds a certain ceiling or the production level of a company reaches a predetermined level reaping from windfall profit of oil companies. Recurrent changes in fiscal policy that with hindsight affect the taxation of sunken investments force investors to raise their hurdle rates for future investment decisions to levels high enough to accommodate the higher perceived risk, Kochhar et al (2005).

IMF (2005) asserted that because of the irreversible nature of upstream investments once committed, the weight of negotiating capacity vividly changes from oil companies to producing governments. This provides incentive governments to offer attractive fiscal regimes before investment is made. However, as the tax base becomes less inelastic, the regime is reset in its own favour and the investors' awareness about this can discourage investment (the hold-up problem), to the detriment of both sides." In addition, progressive revisions of natural resource rents erode investors' cash flow and increase rate of return, hence discouraging adequate future investments in capacity expansion." The stability of fiscal regime is a major issue for upstream investment" IEA (2003).

2.3.3.4 Environmental, energy and tax policies

Environmental concerns progressively impact prospects for upstream investment and impact the cost of new ventures. There is growing concern about high environmental foot print associated with oil and gas drilling activities, which are increasing the risk of, or delaying investments in many countries. Where drilling activity is allowed, environmental regulations may force restraints on operating standards, which invariably increases costs or cause delays. Another issue is the growing opposition and outcry by the public on environmental damages due to the operations of international oil companies, which led to a blockage of IOCs from investing and having legal actions instituted against them by environmental protection and human right advocacy groups. For example, In Nigeria, Shell E&P have been denied access to reserves (estimated to be more than 1 billion barrels of oil) by communities in Ogoni land in Niger delta, on the grounds of gross environmental destruction. Furthermore, they have been sued at domestic and international levels for such negative externality. On another front, energy taxation consuming nations may heighten oil demand uncertainty. Conversely, the domestic subsidy policies of most resource rich countries, particularly OPEC producers, have the capacity to reduce funds available to NOCs for upstream investment and discourage efficient use of energy resources. The removal of subsidies may perhaps result in reducing demand for oil and energy services, but it will not only encourage efficient use of energy but could also build confidence that markets are becoming freer, and more stable; an increase in the availability of funds that can be re-invested in infrastructural development and upstream operation also heighten this confidence.

2.3.3. 5 Barriers to entry and access to reserves

The vast majority of the world's easily producible oil reserves are situated in the Middle East. But, major oil producers like Saudi Arabia and Kuwait are not open to foreign investments and other countries like Iran; these countries use difficult production sharing and buy-back contracts that deter international oil companies' participation [34]. Kochhar et al (2005) argued that the international oil companies have added to this challenge by displaying inadequate appreciation of the nature of the producing countries' reliance on oil and their strategic goals. He further stated that restriction of foreign

[34] Solomon (1989) asserted that cash flow limitations and foreign governments' restrictions have hindered US oil companies' investment abroad most severely in Middle East.

investment influx has also not permitted some host governments to adequately gain from the key technological progresses that had happened in the oil industry over the last two decades.

Apparently, the willingness of countries with huge oil resources to export oriented foreign investments is a significant determinant of the magnitude of upstream investments likely to be made. Hence, the host government's policies on foreign investment, oil field depletion rates, and environmental protection will determine its openness and the availability of prospects for exploration, development, and ultimately upstream investment influx. In the mid-1990s, lots of countries partly attracted foreign investments to the oil industry. However, investments were difficult in Russia, China, and Iran due to regulatory bottlenecks, administrative obstacles, and delays. At present, Kuwait, Mexico, and Saudi Arabia remain largely closed. Although, Kuwait is planning to open access to foreign oil companies and Saudi Arabia has allowed foreign investments in natural gas sector IEA (2003). In addition, the interaction between NOCs and IOCs is an issue facing genuine pressures, which could impact upstream investment and its timing. When IOCs there granted access to participate in the upstream sector, there is likely to be divergent views on essence and extends their participation and the form of investment (capital, technology, or both). This kind of contract suits fiscal regimes to adopt and negotiate processes also compound the difficulty in the relationship, which can result in delay of investments Fattouh (2004). Evidently, the presence of barriers to enter in a number of very high oil reserves bearing OPEC MCs serves as a significant impediment to upstream investments due to increasing domestic financial needs.

2.3.3.6. Geopolitical tension

One of the key barriers to upstream investment among OPEC members could be political instability. It is common knowledge that one of the characteristics of the extractive industries, particularly oil and gas, is severe geopolitical threats due to concentration of hydrocarbon resources in areas prone to instability. This is posing significant threat to investment and world oil supplies. Historically, once there is lingering political tension in any OPEC member country, the world oil market feels the impact with consequential negative effects on investment and oil supply despite, the persistent increase in supply to avert market instability by other OPEC members. Notably, the Iran-Iraq war in 1980, Venezuelan unrest in 1982, Iraq war in 2003, Kuwait invasion in 1991, Arab spring and Libyan crisis in 2011, and recently EU oil embargo on Iran. Clearly, all these events raised doubts about viability of future investments. IEA asserted that with improvement in level of stability in the Middle East, Africa, and transition economies, investment level in these regions could constitute about 47% and 30 % for oil and gas respectively over the next three decades. When there is political tension in these regions, upstream projects may be delayed, suspended, or cancelled since higher risk premium will increase cost of capital. Consequently, under-investment will facilitate increase in oil price which will consequently stimulate investment in higher cost ventures in other oil producing nations or regions of the world

Chapter 3: PETROLEUM FISCAL POLICY AND COUNTRY ANALYSIS

3.0 Introduction

Despite its objective of unifying the petroleum policies of member countries, there are inherent differences in approach to domestic policies. Apparently, OPEC is composed of sovereign nations that have variations in financial needs, natural endowments, population intensities, growth rates, and sociopolitical situations. These provide basis for different policy objectives and goals among member countries, which results to differences in institutional structure and petroleum policy framework. These could determine the phase of upstream investment in each country. It is a known fact that government policies [35] define the industry structure, shaping governance processes and provide strategic direction that influences the behaviour of investors and ultimately the technical performance the industry. Thus, this section provides insights on the ways in which OPEC MC's oil industries are organized and governed in respective regions and descriptively analyzes its impact on the quality of governance consequently affecting investment behaviour. Furthermore, regional belonging could also affect

[35] For analysis on the impact of government policy on petroleum investment, see Cox and Wright (1976)

policy evolutionary process among nations as a result of geographic similarities. Therefore, OPEC members are grouped in terms of regional affiliations for the purpose of this analysis to capture the effect of regional similarities while taking into account individual differences (Table 3.1).

Table 3.1: OPEC members by regional affiliation

OPEC Africa	**OPEC Middle East**	**OPEC South America**
Algeria, Angola, Libya, Nigeria	Iran, Iraq, Kuwait, Qatar, Saudi Arabia, U.A.E	Ecuador, Venezuela

The evolutionary process of fiscal policies governing upstream petroleum operations is presented and analyzed to unravel the impact of changes in fiscal regimes on investment behaviour among OPEC countries[36]. Analysis of similarities and differences in respective fiscal policies in the upstream sector is presented to unravel the presence of any regional trend. Furthermore, this chapter provides analytical insight on the investment response of member countries to varying market conditions. Due to lack of actual investment data, active rig counts[37] is also used as proxy of upstream investment to analyze the

[36] For details on effective tax systems design for extractive industry see Mitchell (2009).

[37] According to Manzano and Guerra (2007), Baker Hughes Inc considered a rig active if it drills for at least 15 days in a month and a rig is considered to be drilling" if it is turning to the right (ie the well is underway but has not reached the target depth)".

investment behaviour of each country in response to fiscal regime changes/increases and oil price fluctuation over the period 1982 - 2011[38]. The countries were categorized in terms of the foregoing heterogeneities and similarities to unravel any regional trend in policy development and investment behaviour. Considering the strategic nature of the oil industry to OPEC economies, it is expected that host governments will strive to provide policies and platforms that will facilitate the growth of the industry, ensure reasonable revenue stream to the governments, environmental sustainability, and fair return to investors. The analysis show investment patterns taking into account the respective countries inherent heterogeneities in domestic policies and investment climates.

3.1 OPEC Africa

3.1.1 Algeria

3.1.1.1 Institutional structure, regulatory and fiscal policy framework

Algeria joined OPEC in 1969 after the discovery of oil in 1948 at Oued Gueterini. Oil production began ten years later and currently is the 3rd largest oil producer in Africa and 9th in the world. The hydrocarbon industry was

[38] The choice of this proxy is consistent with Tourk (1977), Guerra (2007) and Ringlund et al (1984)

previously governed by Law No. 86-14 of 1986, and subsequently Law No.05-07 of 2005 was enacted as a result of industry reform. The key legislation governing the structure and operations of the oil and gas sector is the Hydrocarbon act of 2005 (Law No.05-07 dated 2005/04/28) and its subsequent amendments. The act provides the framework for institutional and regulatory structures, fiscal regimes, licensing, ownership, and general administration across the upstream, midstream, and downstream value chains of the industry[39]. The international oil companies act as contractors and partners to Sonatrach in upstream activities with stipulated maximum equity of 49%. The absolute ownership of hydrocarbon resources is vested in the state. The Ministry of Energy and Mines is responsible for providing general policy direction for optimal development of hydrocarbon resources in the oil and gas sector. The act provides for the establishment of an independent National Agency for the Development of Hydrocarbon Resources known as ALNAFT, saddled with the responsibility of awarding and managing exploration, development, and production contracts on behalf of the government. However, "the State acting through the Council of Ministers has the power to make observations on the terms and conditions of petroleum agreements and operating agreements entered with Sonatrach and its approval is required" Freshfields Bruchhaus Deringer (2013). The agency is also

[39] This section is based on U.S Energy Information Administration country analysis report (2012), Freshfields Bruchhaus Deringer (2013) and Sonatrach's website

responsible for collecting applicable taxes in the industry. There is also an independent regulatory authority (called ARH) in charge of regulating activities in the oil and gas sector and monitors compliance with statutory regulatory provisions governing technical and operational aspects of the sector. Sonatrach, which is the National Oil Company, was established in 1963. It is mandated with the roles of engaging in commercial activities in prospecting, exploring, developing, producing, refining, transporting, and marketing oil and gas. In 1971, the Algerian government nationalized the industry and transferred full ownership of the industry's assets to Sonatrach. As a result, Sonatrach controlled the industry activities across the entire value chains with at about 80% of the total oil production in Algeria. The upstream activities are dominantly carried out by international oil companies in partnership with Sonatrach. The summary of the institutional structure is presented in Figure 3.1

Figure 3.1: Algeria's structure of Institutional Structure in the hydrocarbon industry
Source: Freshfields Bruchhaus Deringer (2013)

In terms of fiscal policy for the hydrocarbon sector, the previously mentioned enactments govern the taxation mechanism applicable to upstream activities depending on when contract agreement is signed. According to Fattouh (2008), the hydrocarbon law enacted in 1986 provided attractive fiscal terms by reducing income tax and royalty rates, which resulted in increase of foreign capital influx. Aissaori (2001) further asserted that exploration investment of about $1.5 billion dollars was attracted during the period 1987 - 2001. As a consequence, more than 30 oil discoveries were made, cumulatively adding about 1 billion barrels of oil. However, due to stiff opposition about the law of 1986 in the parliament, amendment was made and foreign partnership was pegged at 41% and licenses in which discoveries have been made were excluded from foreign partnership, implying that redevelopment of existing fields and enhanced oil recovery projects are not up for investment by foreign companies Fattouh (2008). The international oil companies responded negatively to this development, resulting to a decline in investment influx. This and other reasons necessitated the need for more investor friendly fiscal regimes, hence the reform process that led to the enactment of hydrocarbon law of 2005.

The licensing system is usually through a bidding process that is managed by ALNAFT. Two types of licenses are available: prospecting authorization, which allows investors to prospect for hydrocarbon, but without right for drilling and exploration; and exploitation contract, which is a mining license with rights to explore and drill wells or exploitation contract only. The exploration period is 7 years (3 years initial period and two phases of 2 years period respectively) upon discovery of oil while the exploitation contract is usually 32 years after deducting the exploration period. Following licensing, production sharing agreement [40], risk service contract, or joint venture contracts are signed depending on the location and status of the licensed acreage. The international oil companies act as contractors and enter into operating agreements with Sonatrach, who is the concessionaire legally entitled to 51% minimum stake in all exploration and exploitation licenses. The main difference between Law No.05 – 07 of 2005 and Law No.86-14 of

[40] For details on service, production sharing and joint venture contracts, see Broadman (1985).

1986 is that under Law of 2005, the foreign oil company takes ownership of its equity production at well head, while in Law of 1986 the foreign partner assumes ownership at the port of loading[41]. The basic elements of the Algerian fiscal regime are summarized in Table 3.2.

Table 3.2: Basic elements of Algerian fiscal regimes

Source: Ernest and Young (2012) and Freshfields Bruchhaus Deringer (2013)

Law No.05 – 07 of 2005			**Law No.86-14 of 1986**	
Fiscal parameter	**Rate**	**Remark**	**Rate**	**Remark**
Royalty	5.5% - 20%	Depending on area or zone of operation	Normal rate:20% Zone A & B: 12.5%	Royalty can be reduced to a limit of 10% by the directive of Ministry of Finance
Income Tax	30%	Monthly payment	38%	Applies to profit of foreign partner
Windfall Tax	5% - 50% once arithmetic average oil price exceeds $30 per barrel	Rate depends on contract type	5% - 50% once arithmetic mean of rent price exceeds $30 per barrel	Rate depends on contract type

[41] Freshfields Bruchhaus Deringer (2013)

Gas flaring tax	$100	Per thousand m3 of gas flared exceptionally for limit of 90 days		Not applicable
Capital Allowance	Depreciation rate: 12.5% - 20% Uplift rate: 15 – 20%	Applicable to Research and development expenditure		Not applicable
Water use royalty	$1	Per m^3 of water used. It is payable annually		Not applicable
State Participation	Minimum 51%	Mandatory equity for Sonatrach in all contract types	Minimum 51%	Mandatory equity for Sonatrach in all contract types
Transaction tax	1% of total value of transaction	Transfer of interest to another company		Not applicable
Local content	As specify in contract agreement	Depends on type of contract and zone of operation		Not applicable
Incentives	Exemption from VAT and Customs duties,	Facilities and services directly used for exploration and production of hydrocarbon	Exemption from VAT and Customs duties	Not applicable

3.1.1.2 Impact of fiscal policy changes on upstream investment

There have been progressive decline in the level of upstream investment in Algeria at an annual average rate of 0.6% during the period of 1982 – 2011 corresponding to an annual average of 29 drilling rigs engaged in exploration and development activities (Figure 3.2). Shortly after the world oil glut of 1980, which was generally marked by significant decline in investment as a result of the crash in oil price, the law of 1986 was enacted to reinvigorate investment influx. As a consequence, income tax and royalty rates were reduced. This change in fiscal framework did not yield positive fruits as there was a continued decline of drilling activities at an annual average of rate 0.7 percent from 1986 - 2003 (Figure 3.2). The negative impact of the change profoundly influenced upstream investment considering the fact that oil price rose at an annual average of 6.7 percent between 1986 - 2003, corresponding to an increase from $18.4 ($2011) to $28.8 ($2011). However, investment level grew within the late 1980s by an average of 2.8 percent in 1987 - 1989 with average of 28 active drillings. Unfortunately, the decline progressed at a much higher magnitude in the 1990s, at an annual average rate of 7.9 percent despite corresponding increase in oil price at an annual average rate of 2.1 percent during 1990 - 1999. Drilling activities slid significantly from 35 active rigs in 1990 to 12 drilling rigs in 1999, which was similar to the decline levels of the early 1980s (1982 - 1986). In the early 2000s, upstream investment picked up and grew at an annual average of 15 percent from 2000 – 2003; oil price also rose at a corresponding 15 percent within the period. The number of active rigs rose from 12 in 1999 to 17 in 2000, and 20 by 2003. Subsequently, upstream investment weakened in 2003 - 2004. The negative response of the industry actors prompted another change in fiscal system, and Law No.05 – 07 of 2005 was enacted to revive the investment climate of the industry. Subsequently, the number of drilling rigs increased from 21 in 2005 to 25 in 2006 and the level of investment continued to grow at an annual average rate of 3 percent from 2005 – 2011 with an annual average of 25 active digs in the Algerian upstream hydrocarbon industry. Obviously, soaring oil prices at an annual average of 20 percent during 2005 – 2011 significantly motivated the observed increase in upstream investment. Evidently, the response of industry players to increase in fiscal elements and taxes has been the reduction in the level of upstream investment and vice-versa—all things being equal. Thus, applicable petroleum fiscal policy greatly shapes the behaviour of investors in the Algerian upstream hydrocarbon industry.

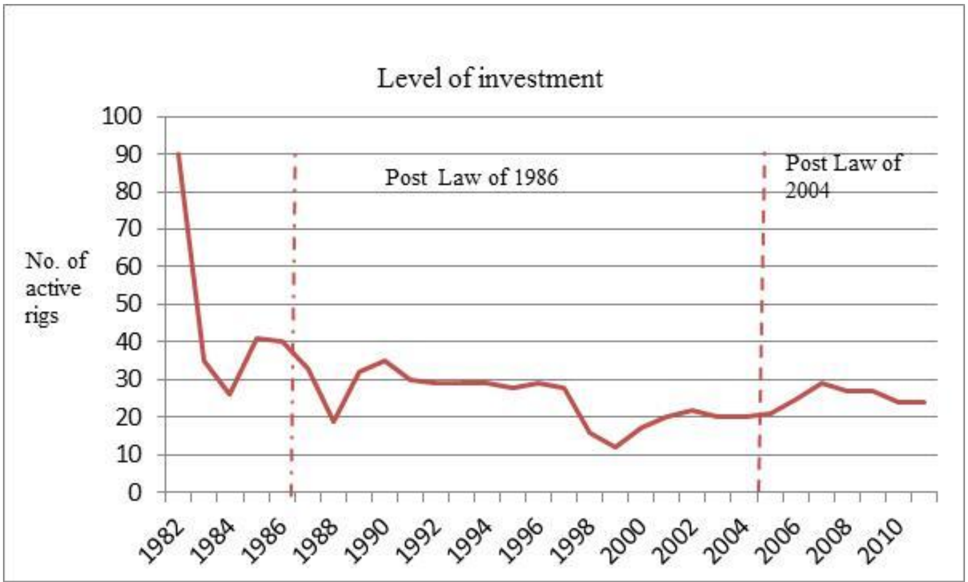

Figure 3.2: upstream investment trends and changing Algerian fiscal conditions

Source: Own computation, data from 2012 OPEC Statistical bulletin

3.1.2 Angola

3.1.2.1 Institutional structure, regulatory and fiscal policy framework

Angola joined OPEC in 2007 and is currently the second largest oil producer in Africa. Oil was discovered at onshore Benfica field in 1955. However, it was the discovery of deep water Girassal field in 1996 that set the stage for the country to be a key player in the global oil and gas industry. The ownership of subsurface natural resources is vested in the State. The key legislation that governs petroleum activities is the Petroleum Activities Law of 2004. The Ministry of Petroleum is in charge of overall coordination, policy development, implementation, and regulation of activities in the oil and gas industry. The government established National Oil Company Sonangol in 1976, and assumed the role of sole concessionaire since the enactment of Law of 2004. Since then, the company holds the majority stake in oil exploration and “took charge of all petroleum industry activities” across the industry value chain. Over the years, Sonangol expanded its upstream operations with increasing participation in international operations. It currently holds interests in Brazil, Cuba, Iraq, Gulf of Mexico, and Venezuela. Although upstream activities are mainly carried out by the IOCs, the government is encouraging indigenous participation through its ambitious local content aspirations. A summary of the basic framework of the Angolan institutional setting is outlined in Figure 3.3.

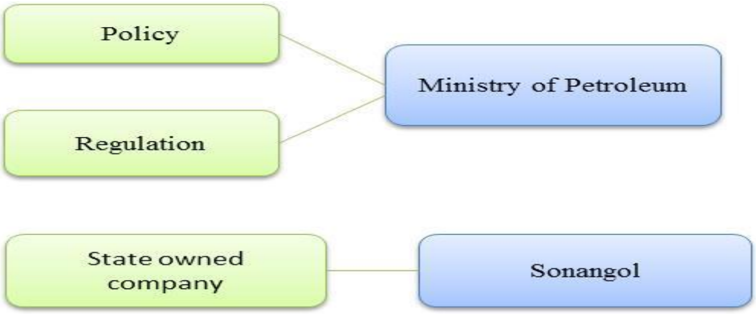

Figure 3.3: Angola’s Institutional structure in the upstream hydrocarbon industry
Source: Ernest and Young (2012) and Freshfields Bruchhaus Deringer (2013)

The Law on Taxation of Petroleum Activities in 2004 provides the fiscal and taxation mechanism that governs oil and gas activities in Angola. Apart from policy and regulatory oversights, The Ministry of Petroleum is also responsible for issuing licenses for exploration, exploitation, and prospecting of oil and gas through bid round or open tendering process. During the licensing process, the expiration period of exploration, Sonangol's share of profit oil in a sliding scale profile and cost recovery rate are all biddable items Fresh fields Bruchhaus Deringer (2013). After the award of license by the Ministry, international and local oil companies enter into production sharing or risk service agreements with Sonangol. There are few joint venture agreements that are operational, but were signed in prior to the enactment of the Law of 2004. The prospecting license valid for a maximum of three years allows an investor (indigenous or foreign) to prospect and explore, but does not offer preferential right to subsequent agreement with Sonangol with respect to exploration and exploitation of hydrocarbon. The basic elements of the Angolan fiscal regime applicable to concessions granted after January 2005 are shown in table 3.3.

Table 3.3: Basic elements of Angolan fiscal regime
Source: Ernest &Young (2013) and Freshfields Bruchhaus Deringer (2013)

Law on Taxation of Petroleum Activities of 2004 and Petroleum Activities Law of 2004		
Parameter	**Rate**	**Remark**

Petroleum production tax	20%	May be reduced to 10%
Petroleum income tax	Production sharing : 50% Other contracts : 65.75%	Angolan indigenous companies : 35%
Petroleum transaction tax	70%	Computed on taxable income
Surface fee	$300 per km^2	Not applicable
Training Tax	Prospecting license: $100,000 annually Exploration stage: $300,000 annually Production stage: $0.15 cents per barrel	Levied on companies engaged in refining and processing of oil and gas
Incentives	Available	Government can grant exemption or modify taxes to be levied by oil and gas companies if justified by prevailing economic conditions
Investment allowance	Available	"Uplift on development expenditure under investment"
Transfer of interest	Sonangol has right of first refusal	Rights can be transferred upon Sonangol consent and approval of Ministry of petroleum

3.1.2.2 Impact of fiscal policy changes on upstream investment

The Angolan upstream sector has enjoyed progressive growth in the level of investment at an annual average rate of 17 percent during the period 1982 – 2011 corresponding to an average of 16 active drillings rigs per annum (Figure 3.4). Nevertheless, there was a progressive decline in the 1980s (1982 - 1989) at annual average of 2.7 percent, which was when the world oil market conditions were quite erratic and hostile marked by very low oil prices. Drilling activity fell to annual average of 7 active rigs in Angola within this period. The investment levels further weakened to an annual average of decline at 34 percent in the early 1990s (1990 - 1992)[42] with an average of 5 active rigs due to a heightened civil war that paralyzed activities in the country. However, general activities began to rebound in 1993 and upstream investment levels picked up and grew at annual average rate of 25 percent from 1993 - 1999, though amidst intermittent periods of war. There was an annual average of 7 drilling rigs in the Angolan upstream sector within the period similar to the drilling activity level of the 1980s. This trend continued through 2000 and 2001, and by 2002 when the war ended, the level of drilling activity had fallen to 2 active rigs. By 2003, there was a renewed confidence

[42] Wikipedia; http://en.wikipedia.org/wiki/Angolan_Civil_War visited on 16/08/2013

about stability in the country and the level of upstream investment grew by 250 percent from its 2002 level, with a corresponding increase in number of active drilling rigs to 7. In addition, the government enacted Law on taxation of petroleum activities in 2004 in order to attract more foreign investments. Evidently, the new fiscal policy made positive impacts; investors responded and investment grew at annual average of 24 percent during the period 2004 – 2011. Needless to say, the combined effect of favorable fiscal regimes and hike in oil prices from $38.3 ($2011) to $111 ($2011) of the mid-2000s stimulated this surge in upstream investment level in Angola.

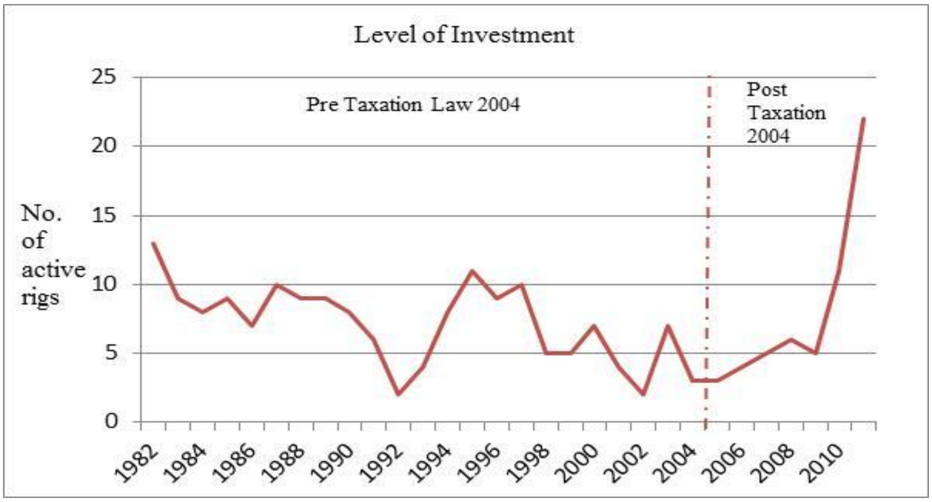

Figure 3.4 upstream investment trends and changing Angolan fiscal conditions

Source: Own computation, data from 2012 OPEC statistical bulletin

3.1.3 Nigeria

3.1.3.1 Institutional structure, regulatory and fiscal policy framework

Nigeria joined OPEC in 1971 and is the largest oil producer in Africa. Oil exploration commenced in 1905, but discovery was made in 1956 at the Oloibiri oil field in Niger delta. Since 1958 when production commenced, there has been progressive growth in production capacity. At the end of 2010, it holds about 37.2 billion barrels of proven oil reserves accounting for 2.68% of the world's oil reserves. The key legislations governing the organization and operation of the upstream sector includes Petroleum Act, 1969 cap P10,LFN 2004, Nigeria National Petroleum Corporation Act Cap N123 LFN 2004, Associated gas Re-injection (Amendment Act) 2004, Petroleum Profit Tax Act Cap P13 LFN 2004, and Nigerian Content Act 2010[43]. In terms of institutional arrangement, The Ministry of Petroleum Resources is responsible for the overall coordination and policy direction of the industry. The Department of Petroleum Resources (DPR), which is an arm of the Ministry of Petroleum Resources, is saddled with the responsibility of technical regulation, monitoring regulatory compliance, issuing licenses and permits, and general supervision of the day to day operations carried out under licenses

[43] Freshfields Bruchhaus Deringer (2013)

and leases across the value chains. The Nigerian National Petroleum Corporation (NNPC) serves as the national oil company and is engaged in commercial activities in exploration, exploitation, refining, processing, distribution, and marketing of oil and gas. The NNPC, through the National Petroleum Management Services (NAPIMS), supervises and manages government investments in the upstream sector. The Nigerian Content Development and Monitoring Board is charged with the responsibility of ensuring compliance with Nigerian content requirements for indigenous participation and value addition to the Nigerian economy through utilization of human and material resources. The Federal Ministry of Environment approves environmental impact assessment reports for oil and gas projects. The basic institutional structure of Nigeria's upstream hydrocarbon industry is outlined in Figure 3.5

Figure 3.5: Nigeria's basic Institutional structure in the upstream hydrocarbon industry
Source: Ernest and Young (2012) and Freshfields Bruchhaus Deringer (2013)

In terms of licensing, oil exploration and exploitation activities are carried out by the grant of oil prospecting (OPL) and mining (OML) licenses. The oil prospecting license allows an investor to explore for hydrocarbon with no right to produce. Upon discovery of commercial hydrocarbon, an application is made for conversion to OML, which grants the right to produce the oil. The OPL is usually granted for a minimum period of 5 years for onshore and territorial waters, and 7 years for continental shelf and exclusive economic zone areas. The DPR manages the licensing award process and upon awarding, the NNPC signs production sharing (PSC), service (SC), and sole risk (SR) contract agreements with the investor. There are indigenous companies that are awarded marginal fields[44] under sole risk agreement with some generous incentives to encourage indigenous participation in upstream activities. The PSC was first signed in 1993 when the government opened the deep water terrain and attracted investment with an attractive offer of zero royalty for water depth greater than 1000m. There exists a joint venture agreement in which the government through NNPC participates with 60% equity stake while the oil company holds 40%. However, the government no longer enters into such agreement for new leases. The fiscal regimes applicable to oil companies are as contained in the PSC, memorandum of understanding, or

[44] Marginal fields are oilfields that produces less than 10,000 barrels per day and lying fallow with multinational oil companies. The Federal government through the Department of Petroleum Resources retrieves them and awards them on competitive bidding to qualified indigenous companies.

other contract agreements signed. In response to the oil glut era of 1986 that resulted in decline in investment, the government provided generous fiscal offers in her bid to increase upstream investment and reserves growth. A memorandum of understanding (MOU) was signed with joint venture partners. It introduced an incentive of $2 per barrel guaranteed notional margin for barrel of reserves added in 1986 (Yinka 2005)[45]. This assured profit margin to operators and safeguarded against likely further crude prices fluctuations. In the same vein, the government reviewed the MOU in 1991 and the notional guaranteed margin was increased to between $2.3 and $2.5 (after tax and royalty) for industry players whose capital investment do not exceed $1.5 per barrel Yinka 2005[46]. As part of the 1991 revised MOU, Reserves Addition Bonus (RAB) was also introduced and any company that increased its reserves more than the production of a given year was entitled to "a bonus by way of an offset against the company's petroleum profit tax" Yinka (2005). This policy, which lasted for five years[47], hedged against risks associated with changes in economic and market conditions of the world oil market and stimulated investment influx, as well as hydrocarbon reserves growth within their implementation period. However, the Federal government have announced its intention to increase royalty rates and introduced other taxation

[45, 39] These are remarkable economic incentive schemes in the history of Nigeria's oil and gas industry fiscal policy development process.

[47] Yinka (2005).

elements in the Petroleum Industry Bill currently under legislative consideration since 2010[48]. The general basic elements of the Nigerian fiscal regime are outline in Table 3.4.

Table 3.4: Basic elements of Nigeria's fiscal regime
Source: Ernest &Young (2012) and Freshfields Bruchhaus Deringer (2013)

Parameter	Rate	Remark
Signature Bonus	Variable depending on terrain and availability of concession	Biddable item above minimum fixed value
Royalty	0 -20%	Depending on location and depth of area of production. Zero royalty applies to water depth >1000m.
Petroleum profit tax	Joint venture: 85% Production sharing: 50% New companies : 65.75%	Not applicable
Resource rent tax	OPL : N200 Non-producing OML: N300 Producing OML: N500	Applicable rates are in Nigerian naira paid annually per km^2

[48] The proposed increase in fiscal regimes has attracted so many outcries from oil companies and thus, has set in major policy uncertainty regarding the investment environment in Nigeria. Evidently, this in addition to other factors may have contributed to recent divestment of onshore and shallow water assets by international oil companies. Shell divested its equity interest in Oil Mining Leases 4, 38 and 41 to Seplat Petroleum, ConocoPhillips Petroleum also sold its interest in Oil Mining Leases 131 60,61,62,63 and Oil prospecting Lease 214 to Oando Plc and Petrobras and Chevron have announced their intentions to divest their equity stakes in some of their assets. In addition, there is observed progressive decline in exploration investment since the pronouncement.

Oil terminal dues	$0.02 per barrel	Payable per barrel of oil loaded on ship
Education tax	2%	
Niger delta Development Commission tax	3%	Niger delta refers Nigeria’s oil producing areas
VAT	5%	Hydrocarbon exports are excluded
Capital allowance	First four years: 20% Fifth year: 19% Balance of 1% to be retained in the books of company	Accelerated depreciation
Investment tax credit	Production sharing contract: 50%	Losses can be carried forward indefinitely

3.1.3.2 Impact of fiscal policy changes on upstream investment

Upstream investments have generally grown at an annual average rate of 6 percent during the period of 1982 - 2011 (Figure 3.6). This corresponds to an average of 14 rigs engaged in exploration and development activities within the period. The industry was marked by low level of upstream activities in the early 1980s with annual decline at an average of 9 percent from 1982 - 1985. The number of active drilling rigs fell to an average of 11 rigs within this period, profoundly in response to falling oil prices. The falling prices of oil during the 1980s prompted the review of the MOU governing the fiscal framework of joint venture contracts. Consequently, the “1986 MOU” which provided some guaranteed profit margin to IOCs, was introduced. The IOCs welcomed this development and responded with an increase in investment level at an annual average of 7 percent from 1986 - 1990 which matched the rise in drilling activity averaging 16 active rigs annually within the period (Figure 3.6). This was despite the observed fall in oil prices at average of 13 percent during the oil glut era of 1986 - 1988. This is suggestive of the willingness of IOCs to make upstream investments even under low oil price regimes given the availability of attractive fiscal offers.

Surprisingly, when the 1986 MOU was further reviewed upwards and the Reserves Addition Bonus (RAB) was alongside introduced in 1991, investment declined at an average of 11 percent annually from 1991 - 1993. This translated to a reduction in the number of active drilling rigs of 16 1990 to 11 in 1993. In 1993, the government extended the industry’s frontier by opening up the deep water to foreign investors with declaration of zero royalty for acreages that are located in areas greater than 1000 metres water depth. This prompted a sudden jump in upstream investment to 14 percent in 1994, and averaging 9 percent within the period 1994 – 1996. Active drilling rigs grew to an annual average of 13 despite an average annual reduction in oil price of 3 percent within the period. Conversely, oil prices revamped from 1996 - 1999 at annual average of 5 percent, but investment progressively weakened by annual average of 11 percent and active drillings fell to average of 10 rigs within this period. With the soaring oil prices of the 2000s, upstream investment grew at an annual average rate of 18 percent corresponding to average of 16 active drilling rigs annually. Although, there is an observed growth in the number of active rigs despite the government's pronouncement of planned increase in fiscal elements, this may not be unconnected with recent increases in oil price that justify the development of discoveries particularly in deep water that were previously delayed (Appendix 1). Conversely, there have been significant decline in exploration investments in the Nigerian upstream sector since the pronouncement Nuhu & Heo (2011). Intuitively, companies are making development and exploration investments that are less risky in response emerging policy uncertainty.

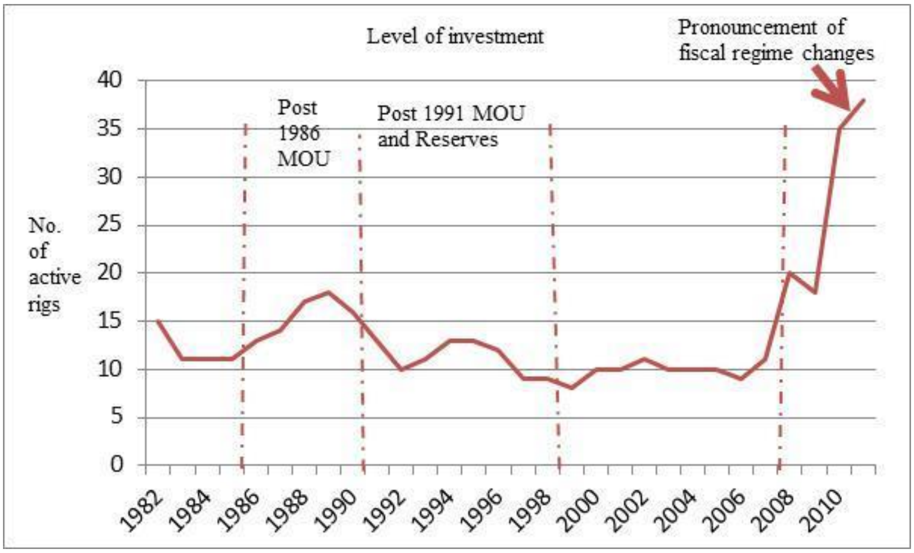

Figure 3.6: upstream investment trends with changing Nigerian fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

3.1.4 Libya

3.1.4.1 Institutional structure, regulatory and fiscal policy framework

Libya joined OPEC in 1962 and is 17th oil producer in the world. As of 2012, Libya holds about 47.1 billion barrels of proven oil reserves which made the country the largest reserves holder in Africa. The key legislation governing activities in the oil and gas industry is the Petroleum Law No.25 of 1955 and its amendments (essentially regulation 9 of 1973), which provided a competitive framework for the development of the oil and gas industry. Since then, there have been various forms of agreements that define the terms of specific contracts. The overall coordination, policy direction and regulation of the oil and gas sector are being undertaken by Ministry of Oil and Gas. The National Oil Corporation serves as the Libyan National Oil Company and is responsible for representing the State in exploration, production, processing, refining, distribution, and marketing of oil and gas, and engaging in its own upstream activities. The NOC through its wholly owned subsidiaries: Arabian Gulf Oil Company, Zueitina Oil Company, Waha Oil Company, and Sirte Oil Company control significant proportion of the oil production in Libya. The basic institutional setting of Libya's hydrocarbon industry is shown in Figure 3.7.

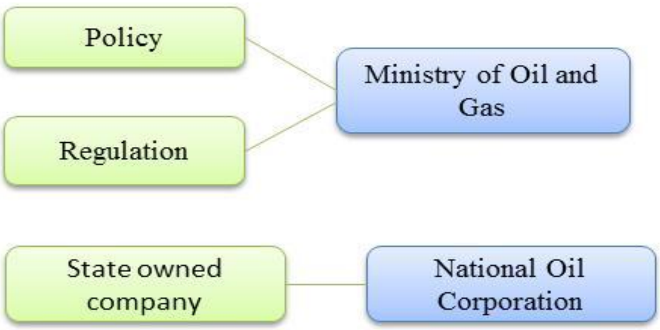

Figure 3.6: Libya's institutional structure in the upstream hydrocarbon industry

In terms of fiscal policy, there had been four generations of exploration and production sharing agreements (EPSA) since the first in 1974. The EPSAs defined fiscal regime parameters that govern the taxation framework applicable to exploration and production operations of an oil company. In

1980, second generation EPSA- II was introduced, but its provisions were considered harsh. As a consequence, third generation EPSA-III[49], which relaxed some of the previous provisions, was introduced in 1988. The Government's quest for increased revenue generation resulted in the introduction of EPSA-IV[50] in 2004. Licenses are awarded through competitive open bid licensing rounds under non-negotiable conditions. Upon success at the end of the bid round, the exploration and production license is awarded for an initial period of 5 years, which is extended to 25 years upon oil discovery. The basic elements of Libya's fiscal regime are shown in Table 3.5.

Table 3.5: Basic elements of Libya's fiscal regime
Source: Ernest &Young (2012)

Parameter	Rate	Remark
Royalty	16.67%	Not applicable
Income tax	20%	Not applicable
Jihad tax	4%	On profit
Signature Bonus	Upon discovery of oil, production of 100 million barrels of oil and milestone production of additional 30 million barrels	It is a biddable item payable at each of the listed milestones
Investment Incentive		Not applicable

49 According to Gurney (1996) the third generation of Exploration and Production Sharing Agreement of 1988 was "more attractive than the previous one".

50 According to Fattouh (2004), the fourth generation of the Exploration and production Sharing Agreement of 2004 was described as the "toughest in the world" with government take of 88%.

Capital allowance	All expenditure is recoverable from cost oil	Through depreciation or amortization

3.1.4.2 Impact of fiscal policy changes on upstream investment

There had been recurrent fiscal policy changes in the Libyan upstream hydrocarbon industry since the introduction of the first Exploration and Production Sharing Agreement in 1974. Upstream investment has generally grown at annual average of 11 percent during 1982 - 2011 (Figure 3.7). The second one (EPSA II) was later introduced in 1980. But, its fiscal terms were considered harsh[51] and consequently there was an increased reduction in investment levels during the implementation period (1980- 1987). Evidently, upstream investment declined at annual average rate of 11 percent within the period corresponding to annual average of 21 active rigs in Libya's upstream sector. The introduction of EPSA III in 1988 worsened the investment climate in Libya, and upstream investments progressively dropped at annual average of 2 percent within the implementation period of the policy (1988 – 2004). Nonetheless, oil price rose at annual average of 7 percent within the period, but the number of active rigs fell to average of 12 active rigs annually. Contrary to what is expected, the soaring oil prices of the early 2000s at

[51] Gurney (1996)

annual average of 19 percent motivated growth in upstream investments at annual average of 11 percent matching the increase in drilling activities with an average of 10 active rigs during 2000 -2004. The quest for an increase in revenue encouraged the introduction of another contract agreement (EPSA IV) in 2004. By 2005, the upstream investment level rose by 108 percent and active rigs grew to 25 in comparison to 9 active rigs in 2004. Investment growth continued at an annual average of 16 percent from 2005 - 2011, and the number of active rigs also grew at annual average of 50 within the same period. The progressive increase in oil price at annual average of 22 percent during that time had a profound effect on influencing the behaviour of investors in the Libyan oil industry despite the increase in fiscal elements. Obviously, the response of the industry in Libya to recurrent changes in fiscal policy has been elastic. When the change brought favourable terms, investment level grew and vice versa.

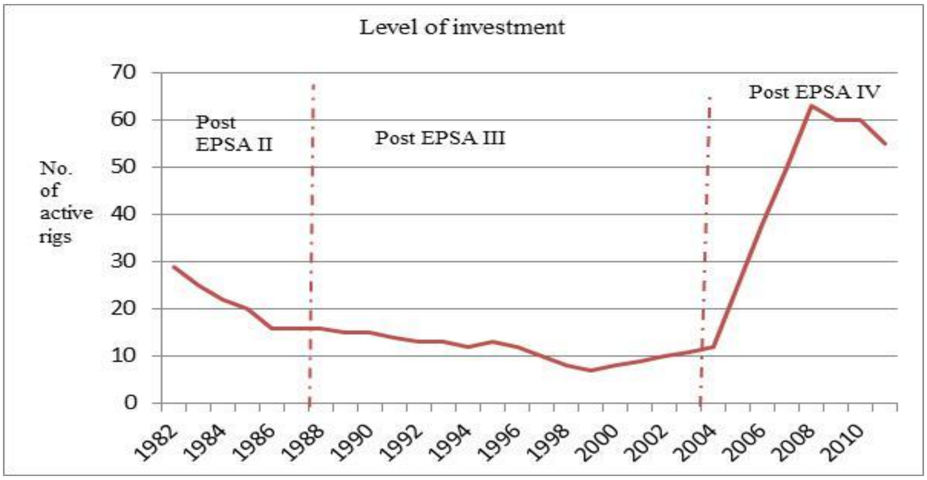

Figure 3.7: Upstream investment trends and changing Libya's fiscal conditions
Source: Author's computation data from 2012 OPEC statistical bulletin

3.2 OPEC Middle East

3.2.1 Iran

3.2.1.1 Institutional structure, regulatory and fiscal policy framework

Iran is a founding member of OPEC in 1960 and holds the 4th largest proven oil reserves in the world estimated to be at 155 billion barrels[52] as of January 2013. It was the first country to start oil exploration in the Persian Gulf in 1901 by D'Arcy Exploration Mohamedi (2013). Oil production began in 1908 from Masjed Soleiman field. Since then, the industry had significantly grown due to favourable geology that resulted in the discovery of giant oil fields, and expansion of productive capacity to the present level as the 4th largest oil producer in the world. In terms of institutional setting, the Supreme Energy Council established in 2001 oversees the activities of the energy sector in Iran. The Ministry of Petroleum Resources is responsible for overall supervision, policy development, and regulation of oil and gas activities in upstream, midstream, and downstream value chains. The National Iranian oil company

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[52] U.S Energy Information Administration: http://www.eia.gov/countries/cab.cfm?fips=IR visited 13/08/2013

is in charge of the day to day running of commercial activities that pertain to exploration, exploitation, distribution, exportation of crude oil and oil products, and transportation of oil[53,54]. The summary of the institutional structure of Iranian upstream hydrocarbon industry is outlined in Figure 3.8[55].

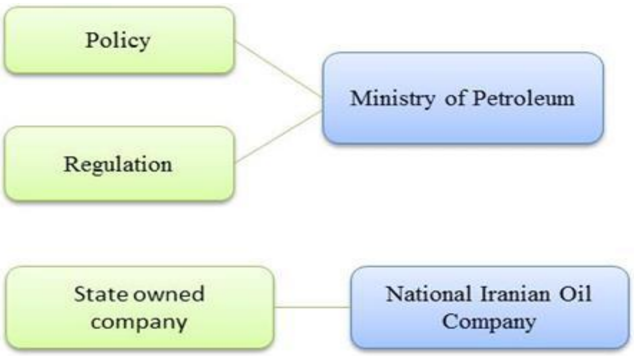

Figure 3.8: Iran's institutional structure in the upstream hydrocarbon industry

Upstream petroleum activities are governed by "the constitution of the Islamic Republic of Iran, Iranian Petroleum Acts, Iranian Budget & Plan Code, forth & fifth five-year Economic, Social & Cultural Development Plan, Foreign

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53 U.S.Energy Information Administration, Iran country analysis report http://www.eia.gov/countries/cab.cfm?fips=IR visited 13/08/2013

54 According to Mohamedi (2013), "The Ministry of Petroleum, which has control over the National Iranian Oil Company, reports to the president with oversight from the parliament. But the dividing line between the ministry and Iran's oil company is often indistinct. The position of NIOC managing director was only established in 2000 as a separate post. But in reality, as a vestige of the past, the two institutions still share personnel and offices".

55 According to Ghorban (2009): "The current structure of the oil and gas industry in Iran is not suited to deal with developments in the world oil and gas sector that have taken place in the past 30 years".

Investment Promotion and Protection Act (hereinafter cited as the FIPPA), and the related executive regulation" Zabbah (2013). The Petroleum Act 1957 forbids foreign ownership of right over petroleum resources, but allows production sharing. Subsequently, the Petroleum Act 1974 was enacted as a result of which production sharing was discontinued, but replaced with service contracts. Petroleum Act 1987 was later enacted after the 1979 revolution and "all kinds of foreign investments in the Petroleum industry were cancelled" except service contracts Zabbah (2013). In 2002, the Foreign Investment Promotion and Protection Act allowed "Buy-Back" or "Build-Operate-Transfer" in the hydrocarbon industry was enacted. Under the buy-back agreement, IOCs sign oil exploration and development contracts with the National Iranian Oil Company (NIOC) or its subsidiaries. When oil production commence after successful field development, the contractor recovers the cost of the project and receives compensation fee. The contractor is entitled to not more than 60% of produced oil until total costs and agreed remuneration are recouped. "The IOC is usually committed to a development period of 2-3 years and a 5-8 years remuneration/operation period"[56] , then the oilfield is handed over to NIOC. Foreign companies are only allowed to participate with not more than 49 percent equity stake in the contracts[57].

[56] Farnejad (2013)

[57] However, there are situations where the Council of Ministers agreed for foreign participation in buy-back contracts with majority equity Zebbah (2013.)

Conoco Phillips signed the first buy-back contract in March, 1995 but it was later transferred to Total in July 1995. New generation buy-back agreements for longer periods (25 years) are now available at an attractive rate of return to foreign investors Investiniran (2013).

3.2.1.2 Impact of fiscal policy changes on upstream investment

Upstream investments in Iran have generally grown at an annual average of 11 percent corresponding to an average of 3 active drilling rigs annually within the period 1982 – 2011 (Figure 3.9). The Iranian upstream sector underwent through several fiscal policy changes as a result of the sociopolitical evolution of the country. The act of 1974 that changed fiscal framework from production sharing to service contract resulted to a positive growth in the level of investments at an annual average of 14.4 percent during 1982 – 1987 despite a progressive decline in oil prices at average of 7.4 percent annually. Expectedly, the cancellation of foreign investments in the sector in 1987 slowed down activity level, but facilitated steady growth. It grew at an annual average of 8 percent with an equivalent average of 26 active drillings engaged in the Iranian upstream industry during the period 1987 - 1994. Nonetheless, oil prices grew at a lower rate of 0.3 percent annually during this period. Apparently, significant investments were made in exploration and capacity expansion by the State owned company (NIOC). By 1995, fiscal policy changes and the buy-back contract were introduced. The industry maintained a similar investment profile with an annual growth rate of 8 percent and average of 26 active drillings during 1995 – 2001. This is despite the boost in oil prices which grew at annual average of 10% during the period. The Iranian government reviewed the buy-back agreement in 2002 in her quest to attract foreign investments. The industry responded positively to the new fiscal provisions, and there was a substantial growth in level of upstream investment at an annual average of 14.5 percent with an annual average of 51 drilling rigs engaged in exploration and development activities during the period 2002 – 2011. The soaring prices of oil at an annual average of 19 percent within this period also reinvigorated the investors' confidence in the world oil market and provided an incentive for increase in capital formation drive. Despite the heightened geopolitical tension of the country during 2010 and 2011, an annual average of 76 percent of drilling activities showed the profound significant growth in investment level. This is suggestive of the importance of attractive fiscal regimes in influencing investment behaviour in the upstream sector despite the existence of high geopolitical uncertainty.

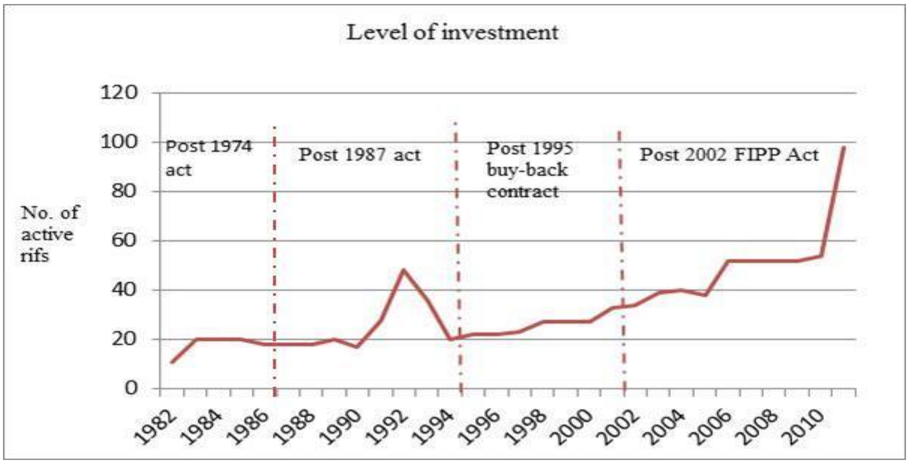

Figure 3.9: Upstream investment trends and changing Iran's fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

3.2.2 Iraq

3.2.2.1 Institutional structure, regulatory and fiscal policy framework

Oil was discovered at Masjid Suleman in 1908. Iraq became a founding member of OPEC in 1960, and by 1964, the Iraq National Oil Company (INOC) was established. Subsequent discoveries of giant fields boosted the country's attention in the international community which now holds the 5th largest oil reserves in the world and is the 2nd largest oil producer as of 2012[58]. The industry expanded rapidly with the dominance of the Iraqi Petroleum Corporation (consortium of foreign oil companies), until 1974 when the

[58] U.S. Energy Information Administration Iraq Country Analysis http://www.eia.gov/countries/country-data.cfm?fips=iz visited on 13/08/2013

government nationalized and transferred all assets to Iraq National Oil Company. Following the re-organization of 1987, INOC was merged with the Ministry of Oil. Since then, the Ministry of Oil is in charge of running the commercial, regulatory, and policy roles of the industry. Under the Ministry, there are four state owned companies in the upstream sector that are "structured around both regional lines and functional duties" Jaffe (2007). The South Oil Company is responsible of managing fields in Zubar, Rumala, Maijoona, and West Luhais while the North Oil Company manages oilfields in the Kirkuk Area. The Iraq Drilling Company operates as a service provider and is saddled with the task of drilling wells, while the Oil Exploration Company is saddled with the task of exploring for hydrocarbon. The State Oil Marketing Company is in charge of selling crude oil outside Iraq and importation of oil products[59]. However, recurrent political instabilities resulted in the existence of quasi-structure for the hydrocarbon industry. This current institutional structure is governed by the provisions of the 2005 Constitution of Iraq. An interim government established the Supreme council for Oil and Gas in 2004 charged with "overseeing medium and long term plans for the industry, major investments, how to source for finances, foreign contracts, crude oil marketing policy, domestic oil pricing, and terms of service for members of the Ministry of oil and the companies under its purview" Jeff

[59] Jeff (2007)

(2007)[60]. The constitution vested the ownership of natural resources in the people of Iraq. Impliedly, this may have provided incentive for the Kurdistan Regional Government (KRG) to independently enter into production sharing agreement or oil exploration and exploitation with IOCs[61]. However, the New Hydrocarbon law proposed in 2007 has had several revisions. In 2011, the parliament drafted proposed law while the executive also drafted a different version mainly to resolve the lingering legal tussle between the Federal government and the RKG. The version of the parliament prescribed more powers to the region. The executive approved their version and sent it to the Parliament for consideration in 2012. But generally, the proposed laws seek to re-establish INOC as state owned oil company that will engage in commercial and operational activities in the industry with "some degree of commercial and administrative autonomy"[62], having the four existing state companies as its affiliates. The draft law also proposed stripping commercial roles from the Ministry and restricting it to regulation and policy making. According to Openoil (2013), all the draft versions proposed the establishment of the Federal Oil and Gas Council that will have representation from all the regions,

[60] At its first meeting in August 2004, the Supreme Oil and Gas Council (SOGC) proposed the establishment of Iraq National Oil Company to be structured as an independent holding company with regional subsidiaries" Jeff (2007).

[61] The first agreement was signed in 1986 with Norwegian energy company (DNO) and many have subsequently been signed with different IOCs but the Federal government considered the action illegal. Openoil (2013).

[62,] Openoil (2013)

governorates, and Federal government. The current institutional structure of Iraq's hydrocarbon industry as depicted in Figure 3.10.

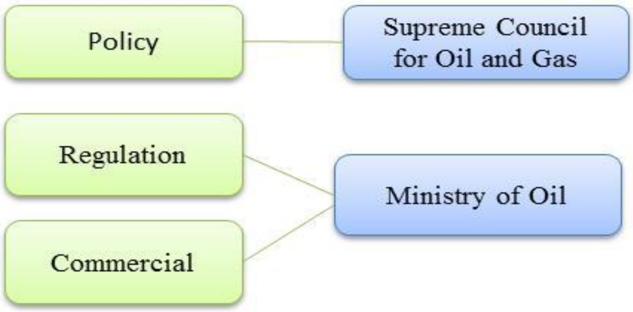

Figure 3.10: Iraq's Institutional structure for upstream hydrocarbon industry

In terms of Iraq's petroleum fiscal policy, upstream activities are currently carried out under the framework laid out by the Iraqi constitution of 2005. Generally, service contract is the form of agreement that is administered in Iraq for IOCs. Following the reorganization of 2007, the first licensing round took place in 2008 and was subsequently held in 2009, 2010, and 2012. Successful bidders signed service contracts with the Ministry of Oil for development of previous discoveries or exploration and exploitation in unexplored areas for a fee which was a biddable item evaluated on a declining rate. The first licensing round provided some attractive fiscal provisions. According to Jiyad (2010), signature bonuses were collected as "interest bearing loans (at LIBOR+1) repayable with interest over five (5) years in quarterly installments commencing two (2) years after the contract's effective date" during the first bid round in 2008[63]. Similarly, changes were made in the 2012 licensing round in which the remuneration fee of companies was reduced. Under the new criteria, investors were not paid for the volume of oil that they subcontracted production of. "The Iraq government subtracts the cost of the subcontract from the total production and pays remuneration for the remaining production" Openoil (2013). Previous bid rounds considered the volume of oil bidders will produce, and service fee as part of the evaluation criteria. Unfortunately, in the 2012 round, the production component was relaxed since most of the blocks on offer were in unexplored areas. The basic elements of the Iraq fiscal regime are summarized in table 3.6.

Table 3.6: Basic elements of Iraq's fiscal regime
Source: Ernest &Young (2012) and Jiyad (2010)

Parameter	Rate	Remark
Company Income tax	35%	Based on 2010 new tax law ratified by parliament. Taxable income of 20% applicable to oil and gas sector
Signature Bonus	Applicable	Variable depending on field
Capital gains tax	35%	Derived from sale of fixed assets
Branch tax rate	35%	Not applicable
Carry back	0	Not applicable
Royalty	15%	Not applicable
Interest	15%	Subject to income tax

[63] According to Jiyad (2010) "Since December 2009 the Iraqi Federal Supreme Court has been considering charges against both the Premier and Minister of Oil submitted by former parliamentarian Mrs. Shetha Musawi challenging the legality of the Rumaila oilfield contract, including the Loan provision of the signature bonus".

Carry forward	5 years	Not applicable
Participation interest	25%	Fixed for State Partner

3.2.2.2 Impact of fiscal policy changes on upstream investment

The fiscal elements of Iraq's upstream hydrocarbon industry have relatively been stable during the period 1982 - 2011 but the country underwent several political crises within the period. Upstream investment generally grew at an average rate of 6 percent annually during 1982 - 2011 (Figure 3.11). This matched annual average growth in number of drilling rigs to 29 during the period. There was a progressive decline in upstream investments in the early - mid 1980s due to the world oil glut lingering with Iran. Investments progressively declined at the rate of 12 annually during 1982 - 1986. By 1987, when the war was nearing an end, the government re-organized the industry and merged the State Oil Company with the Ministry of Oil. The investment climate regained momentum and upstream investments grew by an annual average of 47 percent between 1988 and 1989. This matched growth in drilling activity with an average of 29 drilling rigs engaged in the exploration and development activities during the period. From 1990, when Iraq invaded Kuwait, upstream investments remained stagnant during 1989 at levels with no growth during 1990 – 2007. By 2008, the Asian economic crisis worsened the situation and upstream investment weakened further at an annual average of 13 percent; the number of drilling activity dipped to an average of 26 active rigs annually during this time. The government initiated a new Hydrocarbon law in 2007, but it was marred with plenty of controversy. Consequent upon that, the licensing round was organized in 2008 wherein the fiscal provisions were attractive to investors. The industry responded positively, and by 2009 investment grew at an average of 63 percent between 2010 and 2011. Although the performance has been amidst very high geopolitical and economic uncertainties, the recent fiscal changes suggest the positive response of IOCs to generous fiscal provisions.

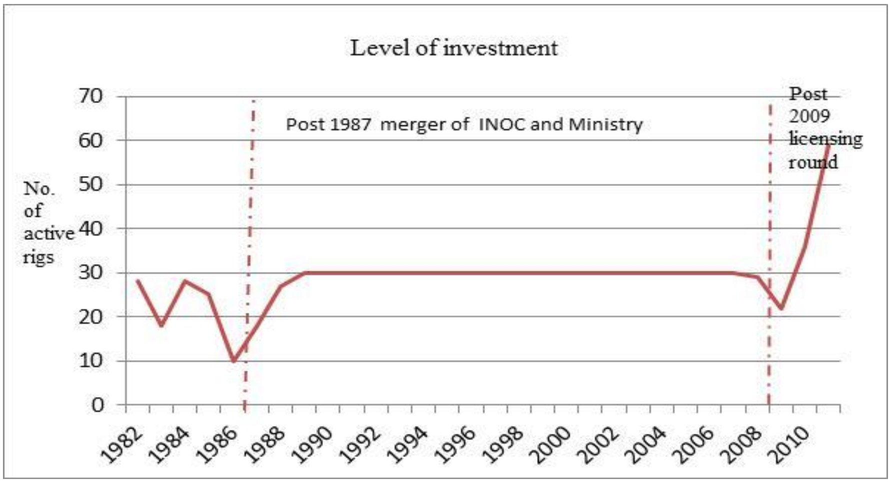

Figure 3.11: Upstream investment trends and changing Iraq's fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

3.2.3 Kuwait

3.2.3.1 Institutional structure, regulatory and fiscal policy framework

Kuwait is a founding member of OPEC in 1960. Oil was discovered in 1933 at Burgan field by Kuwait Oil Limited and the consortium of Protocol British Petroleum (BP) and American Gulf Oil (Chevron) while export commenced in 1946[64]. The Kuwaiti oil industry continued to grow and expand reaching its present level of being the 6th largest oil reserves holder in the world and 10th oil producer in the world[65]. The petroleum policy of Kuwait is anchored to always achieve total ownership of the oil sector. The Oil concession agreement of 1934 was the first agreement that governed activities in the sector under the Ministry of Finance, but was later changed following the growing need of the State to control its hydrocarbon resources. In 1974, the Supreme Petroleum Council was established within the Council of Ministers and was saddled with the general policy formulation for the petroleum sector[66]. Following the nationalization of the industry in 1975, a decree established the

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[64] Kuwait Petroleum Corporation website
http://www.kpc.com.kw/AboutKPC/KuwaitOilHistory/default.aspx

[65] US Energy Information Administration Country Analysis
http://www.eia.gov/countries/country-data.cfm?fips=KUv; visited on 13/08/2013

[66] Ministry of Oil, Kuwait website http://www.moo.gov.kw/About-Us/Ministry-Decrees/Decree-for-Establishing-the-Supreme-Petroleum-Coun.aspx

Ministry of Oil and mandated it with the supervision, regulation, and monitoring of operations in the sector. In 1980, the Kuwait Petroleum Corporation (KPC) was formed via promulgation of decree No.6 of 1980 as the national oil company. It was saddled with undertaking exploration and exploitation of oil. Since then, KPC assumed dominant control of the sector. In 2007, Decree No.78 of 2007, which repealed the previous decree that change Ministry of Oil to Energy in 2003, was promulgated and the Ministry of oil was re-established and assumed the role of policy implementation, supervision, and regulation of the industry. The basic institutional structure governing upstream hydrocarbon sector in Kuwait is outlined in Figure 3.12.

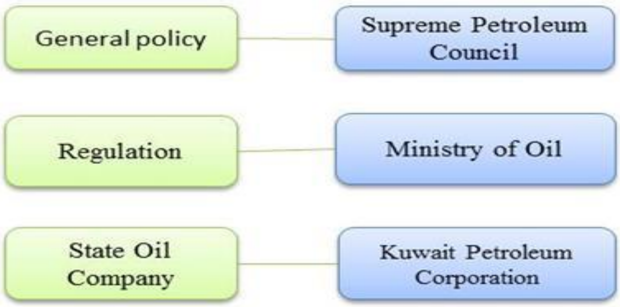


Figure 3.12: Basic institutional structure of Kuwait upstream hydrocarbon sector.

Upstream activities are governed by the constitution of Kuwait, decrees, and their amendments. The operating service agreement is usually the type of contract administered for the purposes of participation of IOCs in the upstream hydrocarbon sector. The Ministry of Oil announces tendering process for interested companies to bid for the development or re-development of a specific number of fields available on offer. Upon evaluation of the bids, successful companies are awarded the fields and the service contract is signed. It is usually for a maximum of 25 years; the contractor bears all the cost of operation with no right over the hydrocarbon. To spread the risk associated with the venture, KPC bears the oil price risk while the IOC bears the technical risks[67]. The contractor is paid an agreed fee for the service after recovering cost, which was a biddable item during the tendering process. In terms of fiscal policy for the upstream sector, there is no separate tax law for oil and gas activities. As a consequence, the provisions of the Corporate income tax law as amended by Law No.2 of 2008 also applies to international non-Gulf cooperation oil companies with a fiscal year of 01/012008. The basic elements of Kuwait's tax/fiscal regime are outlined in Table 3.7

Table 3.7: Basic elements of Kuwait's fiscal regime
Source: Ernest &Young (2012)

Parameter	**Rate**	**Remark**
Royalty	15%	Same as normal business
Income tax	15%	
Resource rent tax	None	Not applicable
Headquarters overhead	Agent: 1.5% Partnership with Kuwaiti Company: 1%	The rates are allowable as expenses
Capital gains	15%	Not applicable
Incentives	Reduced import duty, low interest from local banks	The tax holiday is for non-Kuwaiti shareholder's

[67] Alattar (2010)

	and 10 years tax holiday	profit for approved projects

3.2.3.2 Impact of fiscal policy changes on upstream investment

Kuwait has generally enjoyed upstream investment growth at an annual average of 10 percent during the period 1982 - 2011 under a stable fiscal policy environment (Figure 3.13). However, the industry witnessed a progressive drop in investment levels during the 1980s up to 1990, where the 1980s saw an annual average of 14 percent. Drilling activity remained at an average of 5 drilling rigs during 1982 – 1990. By 1991, investment level rebounds and continued to increase at an annual average of 12 percent between 1991 and 2007. Correspondingly, there was an annual average of 9 drilling rigs engaged in exploration and development activities within the period. The new tax law enacted in 2008 coupled with robust risk sharing provisions of Kuwait's service contract provided an incentive for renewed investments. By 2009, investment rose by 47 percent and grew for the period 2008 – 2011 with corresponding increase in drilling activity to an average of 38 active rigs during the period.

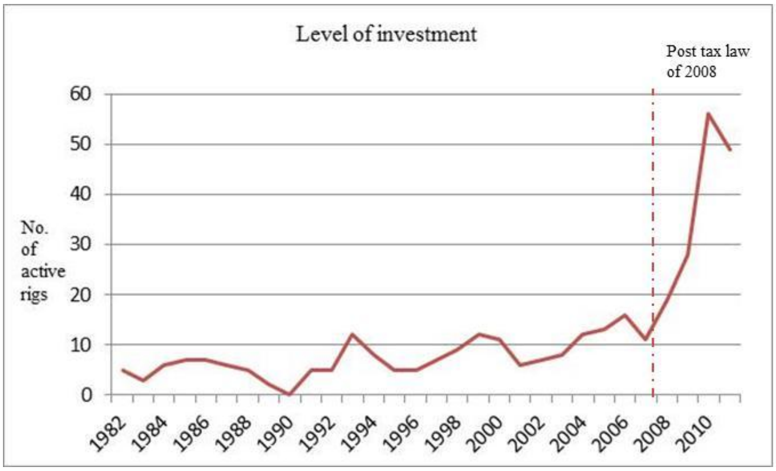


Figure 3.13: Upstream investment trends and changing Kuwait's fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

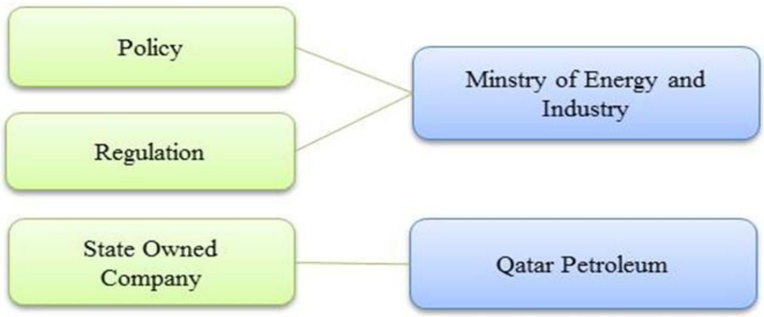
3.2.4 Qatar

3.2.4.1 Institutional structure, regulatory and fiscal policy framework

Qatar joined OPEC in 1967. The first concession for petroleum exploration was awarded in 1935 and the first exploration well—Dhukhan-1, was spudded in 1938. Following commercial oil discovery in the well, oil production commenced in 1940, but World War II delayed exportation until 1949[68]. The first two offshore concessions were granted in the same year consequently leading to the discovery of Idd Al-Shargi and Maydan Mahzam oil fields 1960. By 1970, the largest offshore field Bul Hanine was discovered and came on

[68] Wikipedia http://en.wikipedia.org/wiki/Qatar_Petroleum visited on 14/08/2013

stream in 1972. Since then, the petroleum industry progressively grew and expanded to its present level. Qatar holds 25.4 billion barrels of oil mining and is the 13th largest proven oil reserves holder in the world[69]. It is also the largest exporter of LNG in the world. In terms of institutional structure, Qatar Petroleum (QP) was established in 1974 as a state owned company following the government's nationalization policy of 1973. By 1976, it has taken full control of the onshore and offshore concessions. Qatar Petroleum has since then continued to expand its operations to midstream and downstream of the industry's value chain. Currently, QP is a fully vertically integrated oil company that manages the day to day operations of the industry and partnerships with IOCs. The Ministry of Energy and Industry is responsible for the regulation of the industry as well as policy making. The basic institutional structure of the upstream hydrocarbon industry in Qatar is shown in figure 3.14



[69] http://www.eia.gov/countries/analysisbriefs/Qatar/qatar.pdf visited on 14/3/2013

Figure 3.14: Institutional structure of Qatar's upstream hydrocarbon industry

The petroleum fiscal policy of Qatar for the hydrocarbon industry is anchored on encouraging the participation of IOCs in petroleum exploration and development since the oil glut of the 1980s that dampened activities in the upstream sector of the industry. Consequently, QP initiated massive oil facilities' upgrade and exploration programs in 1991, since then; there have been progressive growth of foreign participation in hydrocarbon exploration and development of hydrocarbon[70]. The type of contracts available for foreign participation in hydrocarbon exploration and development are the Exploration and Production Sharing Agreements (EPSA) and Development and Production Sharing Agreements (DPSA)[71]. Under the PSC regime, QP does not participate in the operations while the development and fiscal is in agreement, but QP participates in the operations with the IOCs. The provisions of the sharing agreement foreign companies sign with Qatar Petroleum and the Tax Law of 2009 governs the fiscal and taxation elements of petroleum operations in Qatar. The basic fiscal elements are shown in Table 3.8

[70] Wikipedia http://en.wikipedia.org/wiki/Qatar_Petroleum visited on 14/08/2013

[71]Qatar Petroleum website; http://www.qp.com.qa/en/Homepage/QPActivities/epsa_dpsa.aspx visited on 2013/08/14

Table 3.8: Basic elements of Qatar's fiscal regime
Source: Ernest &Young (2012)

Parameter	Rate	Remark
Royalty	Variable	Apply to development and fiscal agreement and as specify in the agreement
Bonuses		Apply to PSC only
Income tax rate	35%	Agreements signed prior to enacting the 2009 Law are liable to CIT of 35% - 55%
Investment Incentives	10 years tax holiday Customs duty exemption until start of production No restriction on capital and dividend repatriation	Not applicable
Corporate tax	35%	Agreements signed prior to enacting the 2009 Law are liable to CIT of 35% - 55%
Losses	Can be carried forward for three years	Cannot be carried backward
Ring fencing	Applicable	Both PSC and development agreement
Capital allowances	5% – 33%	Only applicable to development agreement depending on item and on depreciated rate
Petroleum costs	Applicable to only exploration, appraisal development costs	Recoverable as specify in the PSC terms.

3.2.4.2 Impact of fiscal policy changes on upstream investment

The level of upstream investment generally rose at an average of 16.5 percent annually within the period 1982 – 2011 in Qatar's upstream hydrocarbon sector (Figure 3.15). Despite the low oil prices of the 1980s, investment grew at annual average of 25 percent during 1982 – 1989 with a corresponding level of drilling activity to 3 active rigs. In 1990, the government through Qatar Petroleum launched a massive investment campaign; positive effects finally manifested in 1993 when investment grew by 60 percent. Since then, upstream investment had grown at an annual average of 23 percent through the 1990s and the number of active rigs rose to an average of 10 during the period 1993 – 1999. In 2000, the investment level reduced by 25 percent, but later revamped with 11 percent and 30 percent growth in 2001 and 2002 respectively. However, the investment level retracted and there was a progressive substantial decline at an annual average rate of 17 percent with corresponding reduction in average number of active rigs to 7 during the period 2003 - 2008. In 2009, the government enacted a new tax law for the hydrocarbon sector with attractive fiscal terms to facilitate foreign participation in the development of enhanced oil recovery projects to increase the recovery factors of aging fields. The global industry players responded positively to the offer, and upstream investment began to flourish at an annual average of 66.7 percent. Drilling activities also increased significantly to an average of 6 active rigs in Qatar's upstream hydrocarbon industry.

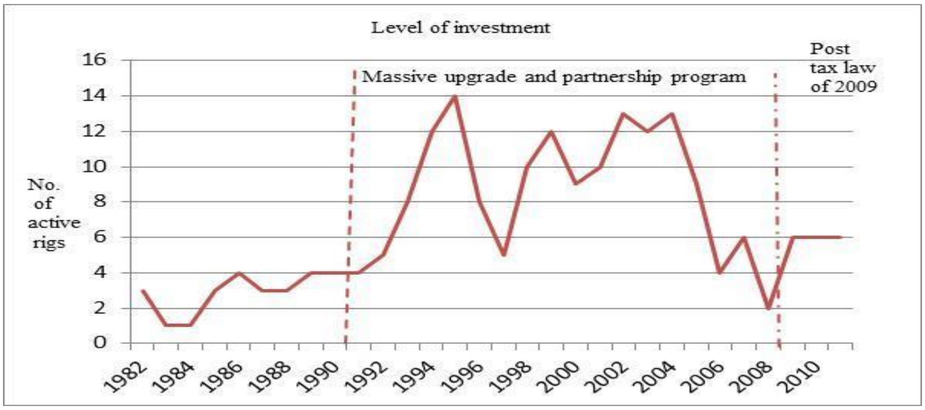


Figure 3.15: Upstream investment trends and changing Qatar's fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

3.2.5 Saudi Arabia

3.2.5.1 Institutional structure, regulatory and fiscal policy framework

Saudi Arabia is a founding member of OPEC in 1960. Saudi Arai Oil exploration commenced in 1933 with the grant of concession to Standard Oil of California. Subsequently, the name of the company was changed to California Arabia Standard Oil and later changed to CALTEX. Commercial quantities of oil were discovered in 1938 by Dammam-7 well in onshore Saudi Arabia and exportation commenced in 1939[72]. In 1943, the name of the company was changed to Arabian American Oil Company (Aramco) and the Saudi government commenced the process of increasing its participation in

[72] Wikipidea: http://en.wikipedia.org/wiki/History_of_the_oil_industry_in_Saudi_Arabia visited on 15/08/2013

the company and control of its resources. The largest offshore oilfield (Safaniya) in the world was consequently discovered in 1951. By 1954, oil production hit 1 million barrels per day. "The government increases its participation interest in Aramco's crude oil concession rights, production, and facilities to 100%, with retroactive financial effect to 1976."[73] In 1988, the government promulgated a royal decree that established state owned oil company and the name was changed to Saudi Aramco. Since then, the company has taken full charge and control of the activities of the hydrocarbon industry in Saudi Arabia. It continued to expand its operations and became a vertically integrated monopoly. The Supreme Council for Petroleum and Minerals is charged with overall policy making inclusive of contracting issues and also Saudi Aramco's strategic planning[74]. The Ministry of Petroleum and Mineral Resources established in 1960 is charged with the responsibility of national planning, monitoring of the activities of Saudi Aramco and its affiliates, and implementing policies ratified by the Supreme Council for the

[73] Saudi Aramco http://www.saudiaramco.com/en/home.html#our company%257C%252Fen%252Fhome%252Four-company%252Four-history.baseajax.html visited on 15/08/2013

[74] U.S Energy Infromation Administration Saudi Arabia country analysis 2012 http://www.eia.gov/countries/analysisbriefs/Saudi_Arabia/saudi_arabia.pdf visited on 15/08/1013

hydrocarbon and mineral sector in Saudi Arabia[75]. The institutional structure of Saudi Arabia's hydrocarbon industry is outlined in Figure 3.16

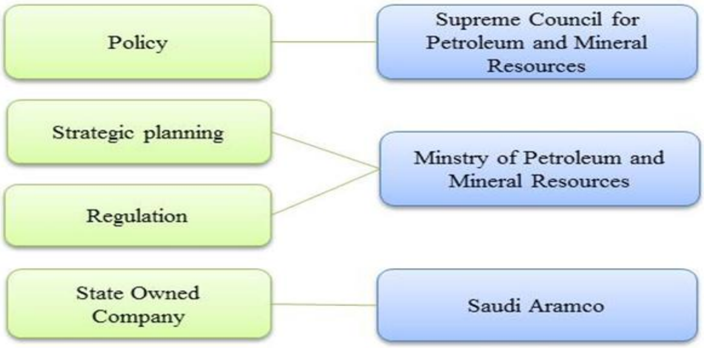


Figure 3.16: Institutional structure of Saudi Arabia's upstream hydrocarbon industry

Saudi Arabia's constitution does not allow foreign ownership in the upstream sector ADFAT (2000). As a consequence, Saudi Aramco retains exclusivity over exploration, development and production of hydrocarbon in Saudi Arabia. According to ADFAT (2000) "Saudi Aramco's exclusive right to explore, drill for and produce gas was lifted in February 1999 and, following a September 1998 request from the Crown Prince, many foreign companies submitted proposals for upstream and downstream gas development investments. Among the most attractive proposals are integrated 'wells to wires' projects which use gas from non-oil bearing fields to produce electricity." As a result four upstream joint ventures were formed for gas exploration and development between Saudi Aramco and Royal Dutch Shell, Lukoil, Sinopec, and Eni/Repsol[76]. The concession agreement is the contract type that IOCs sign with Saudi Aramco[77]. The current Income tax law applicable is the Saudi Arabian income tax law enacted in 2004 The basic elements of the Saudi Arabia's fiscal regimes are outlined in Table 3.9

Table 3.9: Basic elements of Saudi Arabia's fiscal regime
Source: Ernest &Young (2012)

Parameter	Rate	Remark
Royalty	Applicable	As stated in the concession agreement
Income tax rate	Oil production: 85% Natural gas investment fields: 30% General: 20%	Natural gas investment refers to investments in natural gas liquids and condensates
Capital allowance		Not applicable for concession agreement
Ring fencing	Available	Applicable to natural gas investments
Losses	Carry forward allowable indefinitely	25% limit can be offset in a year's profit
Import customs duty	5%	

3.2.5.2 Impact of fiscal policy changes on upstream investment

76 U.S Energy Infromation Administration Saudi Arabia country analysis 2012 http://www.eia.gov/countries/analysisbriefs/Saudi_Arabia/saudi_arabia.pdf visited on 15/08/1013

77 "In oil producing countries or a relevant administrative agency grant the contractors to operate petroleum projects and the right to develop the projects in exchange for a stream of payments or paymentsin-kind" Woosung (2009)

Saudi Arabia's upstream sector has witnessed a positive growth in level of investments at an annual average of 10.5 percent throughout the period 1982 - 2011 (Figure 3.17). Similarly, the fiscal policy and applicable taxation system have been relatively stable during the period. However, the world oil glut of the 1980s dampened upstream activities as a result of falling oil prices at annual average of 5 percent between 1982 and 1989. Upstream investment progressively fell at annual average of 18.4 percent during 1982 – 1989. The 1990s brought some renewed confidence in the world oil market. Upstream investment continuously increased at an annual average of 22 percent despite the growing but slower oil price of 2 percent annually during the period of 1990 – 1999. In the same vein, exploration and drilling activities grew with an average of 20 drilling rigs engage in Saudi Arabia's upstream hydrocarbon sector. It is worth mentioning that throughout this period, there was ban on foreign investments in Saudi Arabia's upstream industry. The aggressive expansion strategy of Saudi Aramco motivated its commitment to investments in exploration and development within the period 1982 – 1999. Conversely, Saudi Aramco's investment strategy changed and there was focus on growing its gas reserves base and capacity expansion. Thus, IOCs were allowed to partner with Saudi Aramco in upstream gas activities from 1999. Upstream investment grew at an annual average of 10.5 percent from 2000 to 2004, but oil prices rose higher at an average of 19 percent annually during the period. Similarly, the number of active rigs increased to an annual average of 31 within the same period. The Saudi Arabian government enacted a new corporate income tax law in 2004, which was favourable to upstream gas investors. Consequently, there was a general positive response from investors. Upstream investment increased sharply at an annual average of 42 percent and active rigs also rose substantially to an annual average of 80 during 2004 – 2008. Evidently, the soaring oil prices levels at an average of 25 percent during that time provided additional incentive that boosted the level of upstream investment. When the global economic crisis broke out in 2008, the investment level in Saudi Arabia began to dip and fell by 19 percent in 2009 and 3 percent in 2010 respectively. The start of global recovery towards the end of 2010 revived confidence on market fundamentals and investment level increased by 23 percent in 2011.

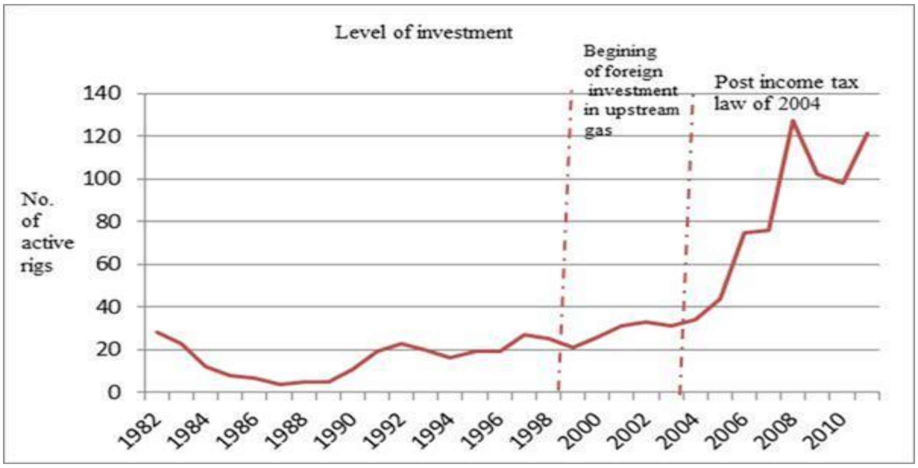


Figure 3.17: Upstream investment trends and changing Saudi Arabia's fiscal conditions
Source: Author's computation data from 2012 OPEC statistical bulletin

3.2.6 United Arab Emirates

3.2.6.1 Institutional structure, regulatory and fiscal policy framework

The United Arab Emirates became OPEC member in 1967. According to U.S Energy Information Administration, it ranks 7th largest proven oil reserves holder in the world estimated to be about 97.8 billion barrels as of 2012 with about 94% of the reserves located in Abu Dhabi with the remaining 6% in the six emirates (Ajman, Al Fujayrah, Dubai, Ras al Khaymah, Sharjah, and Umm al Qaywaynthat) that made up UAE [78]. Dubai holds about 4 billion barrels of proven oil reserve. Each of the emirates, regulate the petroleum activities under its territory. The Supreme Petroleum Council (SPC) is responsible for the overall policy direction of the hydrocarbon sector in Abu Dhabi. As a result of the strategic position of Abu Dhabi in terms of hydrocarbon resources endowment, the SPC is the main policy making body in the country. The Abu Dhabi National Oil Company functions as a state owned company responsible for managing day to day activities of the industry engaging in commercial activities in the upstream sector through partnership

[78] This section is based on US Energy Information Administration UAE country report 2013, http://www.eia.gov/countries/analysisbriefs/UAE/uae.pdf visited on 15/08/2013.

with few big IOCs and implement SPC's policies in the hydrocarbon industry. It operates through six subsidiaries across the upstream, midstream, and downstream value chains. Upstream activities are dominated by ADNOC. Conversely; the Dubai Supreme Council of Energy (DSCE) is saddled with the responsibility of overall policy making for the energy sector in Dubai. In 1963, The Dubai Petroleum Establishment[79] was recognized and charged with the responsibility of exploring, developing, and producing hydrocarbons in Dubai, while the Emirates National Oil Company is responsible for commercial activities in the midstream and downstream segments of the hydrocarbon industry. In Abu Dhabi, petroleum exploration and exploitation activities are carried out under production sharing contract[80] between ADNOC and large multinational oil companies. On the other hand, Dubai and Sharjah carry out activities with IOCs under service contract[81]. The other smaller emirates also use production sharing contracts. In 2008, UAE granted first new concessions to IOCs. In terms of fiscal policy or taxation governing upstream activities, each of the jurisdictions issue tax decrees that applies to all business entities but in reality, the taxation of IOCs is governed by the

[79] Dubai Petroleum Establishment website, http://www.dubaipetroleum.ae/index.php visited on 16/08/2013

[80] Contractor bears all the cost of finding, developing and producing hydrocarbon. Upon discovery, it recover all the cost expended in an agreed manner and the remaining oil is shared with the host country having higher share of the profit oil.

[81] Contractor bears all the cost of upstream activities. Upon successful completion of the project, it pays its cost in cash or in kind and a fee as remuneration.

provisions of the specific concession agreement sign on a company by company basis, which are usually confidential, Ernest & Young (2012)[82]. Since the 2000s, there have been significant decline in discoveries in UAE. As a consequence, the government's upstream policy has focused on intensifying investments in enhanced oil recovery of existing fields to boost recovery and increase reserves growth. The basic institutional setting of the upstream hydrocarbon industries of Abu Dhabi and Dubai are outlined in figure 3.18

Figure 3.18: UAE's main institutional structure for upstream hydrocarbon industry

3.2.6.2 Impact of fiscal policy changes on upstream investment

The level of upstream investments in UAE has progressively weakened at annual average of 1.6 percent throughout 1982 – 2011, although the policy

[82] Ernest &Young global oil and gas tax guide 2012.

environment has remained relatively stable over the period (Figure 3.19). Investment fell at the average of 16.5 percent annually between 1982 and 1988. The level of exploration and development drilling activities was at an annual average of 25 active rigs during the period. This was during the low oil price regimes of the 1980s when the world oil market had an excess supply of oil. In 1988, UAE granted concessions to IOCs and consequently upstream investment rose sharply at the rate of 16 percent annually during the period of 1989 – 1992. However, the level retracted by 5.5 percent in 1993 and progressively declined at an annual average rate of 4.3 percent from 1994 to 2000. Oil price progressively increased at an average of 3.8 percent during the period. But, number of active rigs declined to an average of 15 active rigs during the period. By the 2001, oil price appreciated by 58 percent and prompted substantial increase in upstream investments by 50 percent. Nevertheless, investment continued to weaken at annual average of 3.3 percent from 2002 - 2008. This necessitated another licensing award to IOCs in 2008 in order to foster improvement in upstream investment influx considering the continual decline of reserves without a corresponding replacement rate. The global economic crisis compounded the situation and there was little response from the industry. The rate of investment reduction slightly improved to an annual average of 1 percent between 2009 and 2011. Though there was an observed growth in the level of upstream investment in 2010 by 18 percent and active rigs engaged in the upstream sector also declined to an annual average of 12 active rigs in UAE during the period 2009 – 2011. It is clear that the two licensing awards to foreign firms did not offer attractive fiscal provisions that could justify investment amidst market uncertainties despite the low cost associated with the upstream activities in U.A.E.

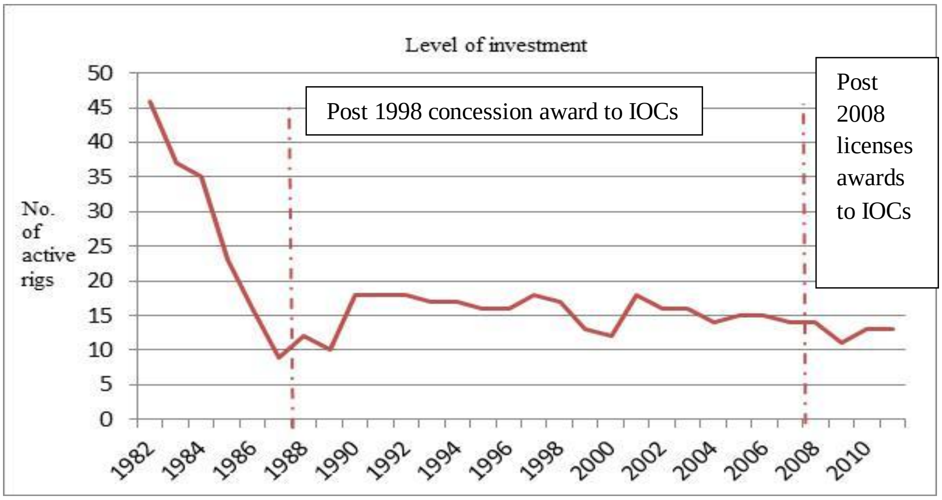


Figure 3.19: Upstream investment trends and changing U.A.E's fiscal conditions
Source: Author's computation data from 2012 OPEC statistical bulletin

3.3 OPEC South America

3.3.1 Ecuador

3.3.1.1 Institutional structure, regulatory and fiscal policy framework

Ecuador suspended its membership from OPEC in 1992 and joined again in 2007. According to U.S. Energy Information Administration, it is the smallest OPEC producer with about 500,000 barrels per day, but remains as the 5th largest in South America. It is estimated to hold about 7.2 billion barrels of proven oil reserves as of 2011. In terms of institutional structure, the Ministry of Non-renewable Resources is responsible for policy issues and supervisory oversight of the activities in the hydrocarbon industry. The National Agency for Control and Regulation of Hydrocarbon is saddled with regulatory functions for the industry[83]. Petro Ecuador is the State national oil company and controls most of the activities in the upstream sector. It was founded in 1989 after it succeeded Corporación Estatal Petrolera Ecuatoria (CEPE) founded in 1972[84]. It performs a commercial role and manages partnership with IOCs. Hydrocarbon resources are exclusively own by the state. The basic institutional setting is outlined in Figure 3.20

[83] Enerst & Young (2013)

[84] Wikipedia: http://en.wikipedia.org/wiki/Petroecuador

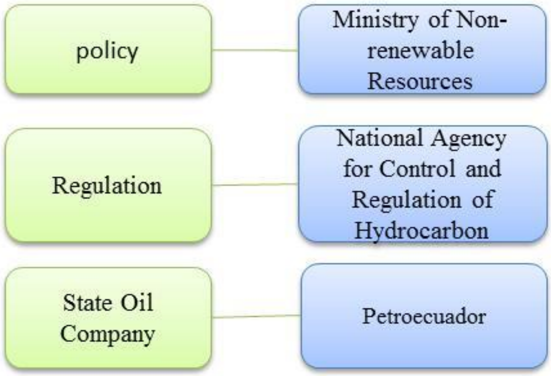


Figure 3.20: Ecuador's institutional structure for upstream hydrocarbon industry

In terms of fiscal policy for upstream activities, it allows foreign participation in the upstream sector in partnership with Petro Ecuador. According to U.S. Energy Administration Ecuador country analysis report (2012), "the nature of its contractual terms and legal uncertainties has deterred private investment." Previously, joint venture and production sharing contract are administered for upstream activities. For low quality heavy crude, marginal field contract also existed.[85]The government introduced a new hydrocarbon law in 2010 which geared towards increasing government take. The new legal framework replaced the previous production sharing contract it signed with IOCs with a

[85] They represent less than 1% of national production. Under this contract all production belong to the state with exploration costs being capitalized annually. The tax basis for these costs (adjusted for amortization) is considered an asset of the contractor .For the development of the contract, the contractor receives reimbursement of operational costs of the base curve of production in dollars and participation in the volume of the crude resulting from the increase over the base production.The base curve is estimated on future production from developed proven reserves using mathematical simulation and studies of the wells;it is specifically detailed in the contract (Enerst & Young (2013).

service contract where a fixed amount is paid per barrel for hydrocarbon exploration and production. This consequently led to the exit of Noble Energy and Petrobras from upstream business in Ecuador. In the same vein, Petro Ecuador confiscated the assets of Occidental Petroleum when its contract expired in 2006. Similarly, the government took over two blocks assigned to Perenco in 2009 as a result of tax disagreement[86]. Exploration period is allowed for four years and can be extended for an additional two years. The basic elements of Ecuador's fiscal regime are outline in Table 3.10

Table 3.10: Basic elements of Ecuador's fiscal regime
Source: Ernest &Young (2012)

Parameter	**Rate**	**Remark**
Corporate income tax	23%	Not applicable
Royalty	12.5% - 18.5%	Depends on production level
Exploration and production fee	1%	After computing profit sharing and income tax
Sovereign margin	25%	25% of gross income of field production
Excess sale on price (windfall)	70%	Paid to government. Difference between selling price of crude and base

[86] This section is based on U.S. Energy Administration Ecuador country analysis report (2012); http://www.eia.gov/countries/analysisbriefs/Ecuador/Ecuador.pdf visited on 15/08/2013

		price agreed in the contract
Production sharing	81.5% – 87.5%	Contractor share applicable to PSC once production commences.
Investment incentives	10% reduction in CIT	Reinvestment of profit
Profit Losses	Carry forward	Against profits for next five years if not more than 25% of year's profit

3.3.1.2 Impact of fiscal policy changes on upstream investment

Ecuador enjoyed continued increase in upstream investments at the rate of 26 percent annually during the period of 1982 – 2011 (Figure 3.21). During this time, averages of 8 active rigs were annually engaged in hydrocarbon exploration and development activities. The fiscal policy framework governing activities in the upstream industry was generally stable through 1980s and 1990s, but investment behaviour was fairly erratic. However, upstream activities of this period had a negative impact on the environment and consequently resulted in the current environmental agitations against hydrocarbon exploration and exploitation activities in Ecuador. The early 1980s was characterized by significant progressive decline in investment at annual average of 48 percent during 1982 – 1984. However, by 1985, the rate of investment peaked up and there was unprecedented growth by 200 percent. Upstream investment continued rising at average rate of 39 percent annually from 1986 to 1988 despite the world oil glut that crippled oil prices within this period. The situation changed by 1989 and investment weakened by 57 percent and 33 percent between 1989 and 1990 respectively. Activities revamped in 1991 and the rate of upstream investment appreciated by 100 percent and grew progressively at an average of 38 percent annually during 1991 - 1994. This corresponds to an average of 5 active rigs operational in the Ecuadorian upstream hydrocarbon sector during this period. The level of investment deteriorated by 33 percent in 1995 and continued to weaken annually at the rate of 1 percent from 1995 - 1999. In the year 2000, the level of investment rose sharply by 125 percent and progressed at slower pace of 15 percent annual growth within the period 2001- 2005, though there were dips in 2002 and 2003 respectively despite growth in oil price at average of 8.7 percent with these years. The seizure of Occidental Energy's assets in 2006 brought about major policy uncertainty in Ecuador. This reduced the level of upstream investment in 2006 and 2007 by 14 percent and 25 percent respectively. Investment climate improved in 2008 with 100 percent growth rate. Nonetheless, another asset seizure took place in 2009 due to tax related conflict between the Government and Perenco. Subsequently, the industry reacted negatively to this development and investments declined at average rate of 21 percent between 2009 and 2010 respectively. In 2010, the government took major policy shift and changed the fiscal conditions governing upstream activities in Ecuador. Some fiscal elements were increased and the contracting regime was changed in order to increase the government's revenue stream. The soaring oil prices of 2011 justified the economics of upstream projects despite the rise in fiscal provisions and there was a tremendous growth in the level of investment by 254 percent in that year. Drilling activities were at all-time high with 39 active rigs operational in Ecuador in 2011 against a mere11 in 2010. The industry responded unfavorably to investments when policy change was perceived to be detrimental to investors. However, the tax increases of 2011 and consequential dramatic rise in upstream investment suggests the influence of oil price on driving investment behaviour in upstream hydrocarbon sector despite existence of unattractive fiscal policy.

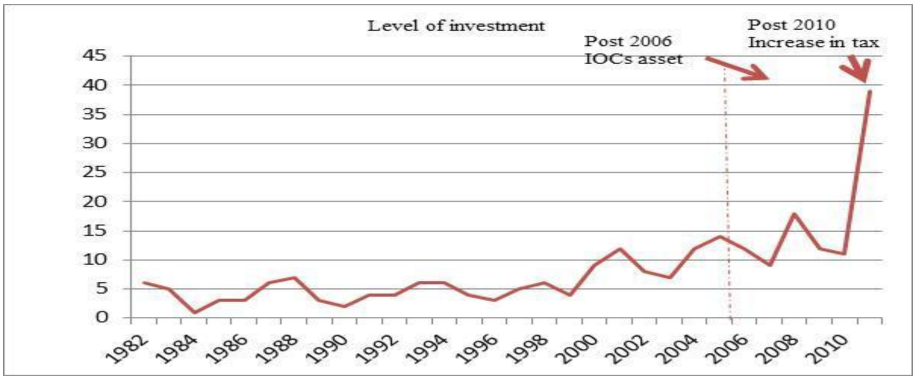


Figure 3.21: Upstream investment trends and changing Ecuador's fiscal conditions

Source: Author's computation data from 2012 OPEC statistical bulletin

3.3.2 Venezuela

3.3.2.1 Institutional structure, regulatory and fiscal policy framework

Venezuela is a founding member of OPEC in 1960. It holds the 4^{th} largest oil exporting country and holds second largest reserves of heavy oil after Canada. Oil exploration dated back to 1880 when the first company Compania Nacional Petrolia del Tachira started drilling wells. In 1908 when General Juan Vicente Gomez took over power, he opened the Venezuela's oil industry to foreign participation and Venezuelan Oilfield Exploration Company was granted the right to explore in twelve of the twenty Venezuelan states. In 1911, the concessions were revoked due to inadequate revenue and royalty. The concessions were subsequently transferred to Royal Dutch Shell Oil Company in 1913. By 1922, Venezuela became a key oil producer in the world. Subsequently, the government commenced the nationalization process in 1970s and by 1976, it enacted a law that restricted oil exploration and exploitation to the government and "Petroleos de Venezuela S.A. (PDVSA)" was established in that same year, saddling the responsibility of "planning, coordinating, and supervising the oil industry" Alvarez and Fiorito (2005). A year later, PDVSA reached 2.3 million barrels production per day and investments had grown significantly. By the 1980s, the company had gained significant prominence in the global oil industry. PDVSA launched operation agreements that again provided an opportunity for the participation of foreign companies in the upstream sector in the 1990s. The company attracted substantial foreign partnerships with investment influx of more than $2 billion between 1993 and 1996. When Hugo Chavez took over in 1999, he started reform process. In 2001, a new hydrocarbon law was enacted that domesticated oil exploration and production activities back to Venezuela's domain excluding joint ventures for extra heavy oil and capped foreign ownership to maximum of 49% stake in capital stock of upstream joint ventures in addition to 100% ownership already existing for gas production ventures [87]. Royalty was increased but income tax was reduced from 67.6% to 50% for upstream actors in 2001. The government re-echoed another nationalization policy for the upstream sector in 2006 and mandated 60% share to PDVSA in projects. As a result of their refusal to comply, Total and Eni assets were confiscated since PDVSA have had turbulent periods with increasing government control and demand for social services to the society, thus, eroding its investment capacity. The Ministry of Energy and Petroleum is responsible for general policy direction of the upstream industry. The basic institutional setting is as summarized in figure 3.22

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[87] Wikipedia;
http://en.wikipedia.org/wiki/History_of_the_Venezuelan_oil_industry#2001_Hydrocarbons_la
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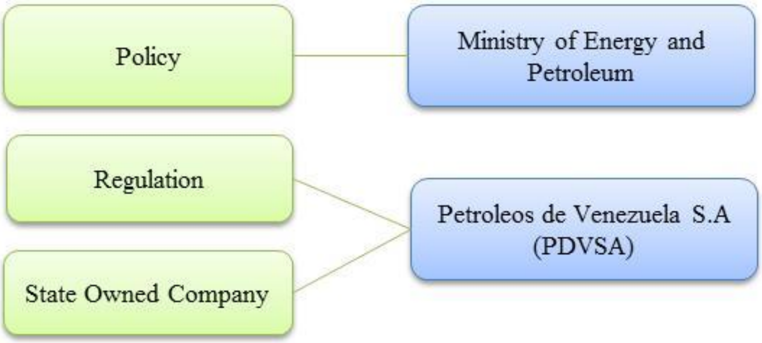

Figure 3.22: Institutional setting of Venezuela's upstream hydrocarbon sector

The fiscal policy governing petroleum exploration and production activities in Venezuela rests the sole right of upstream activities in the State which can be either directly or through partnership with PDVSA. Joint venture agreement is the prevailing contract for IOCs participation with the State having minimum of 50% stake, thus qualifying them as State owned enterprises Ernest & Young (2013). The basic elements of the fiscal regime governing upstream activities are outlined in Table 3.11

Table 3.11: Basic elements of Venezuelan fiscal regimes
Source: Ernest & Young (2012)

Parameter	Rate	Remark
Corporate income tax	50%	On net profit
Royalty	Up to 33.3%	Depending on production level
Capital gains tax	50%	Not applicable
Alternative minimum tax	50%	On gross profit

Owned consumption tax	10%	Per m^3 of products derived from produced hydrocarbon and used for operations
Tax on dividends	50%	Dividend declared that exceed previously taxed net income
Relief on Losses	Can be carried forward for 3 years	Carry back is not allowed
State participation	50%	Minimum level

3.3.2.2 Impact of fiscal policy changes on upstream investment

There was a general growth in upstream investments in Venezuela at an annual average of 4.5 percent throughout the period 1982 – 2011 (Figure 3.22). This occurred despite the numerous changes in fiscal policy that characterized the upstream sector within the period. The early to mid-1980s was marked by a progressive decline in the level of investment at an annual average of 13.4 percent from 1982 0 1986 which could be a consequence of falling oil prices at an annual average of 16 percent annually during the period. Correspondingly, an average of 32 rigs was engaged in exploration and development activities during the period. The level of upstream investment appreciated at an annual average growth rate of 16 percent from 1987 - 1992 in response to the increase in oil prices. The number of active drilling rigs increased to an average of 42 during this period. By 1993, the government opened up to foreign participation in upstream activities. Upstream investment rate reached a peak of 24 percent in that year and continued to grow at an average rate of 16 percent during 1994 -1995, while active drilling rigs rose to an annual average of 90 in the Venezuelan upstream sector during 1993 - 1995. The fiscal provisions of the production sharing agreement were attractive and stimulated substantial investment influx despite falling oil prices at an average of 9.4 percent during the 1993 – 1994 periods. The progressive decline in oil prices at an annual average of 7 percent perhaps continued to negatively influence upstream investment resulting to a continued reduce of annual average rate to 14 percent from 1996 – 1998. Exploration and development drilling activities weakened to annual average of 79 active drillings within the period. In 1999, Hugo Chavez took over the government and increased fiscal provisions governing upstream activities in the country in order to increase government take. The change in policy further dampened the rate of investment at a progressive rate of 11 percent from 1999 to 2001 notwithstanding the rise in oil prices at an annual average of 29 percent during the period (Figure 3.22). Similarly, active drilling rigs fell further to an annual average of 54 rigs in the Venezuelan upstream industry. The investment climate revamped with sustained rise in oil prices at 22.4

percent and exploration and development activities rose at an average of 11 percent annually during 2002 - 2006. In 2006, the government also increased the state participation equity, but the stable increase in oil prices of the late 2000s at an annual average of percent during 2007 – 2011 served as an incentive for investments despite increase in state equity. Upstream investment grew progressively at an annual average of 10 percent during the period. However, there is an observed decline in rate of upstream investment in 2011 by 7.2 percent. Evidently, the foregone analysis is indicative of the interwoven influence of oil prices and fiscal policy on investment behaviour in Venezuela. While there was negative response to investment consequential to increase in taxes and fiscal elements, there were also instances of positive response despite the increases which is indicative of the dominating influence of oil price on driving investment behaviour.

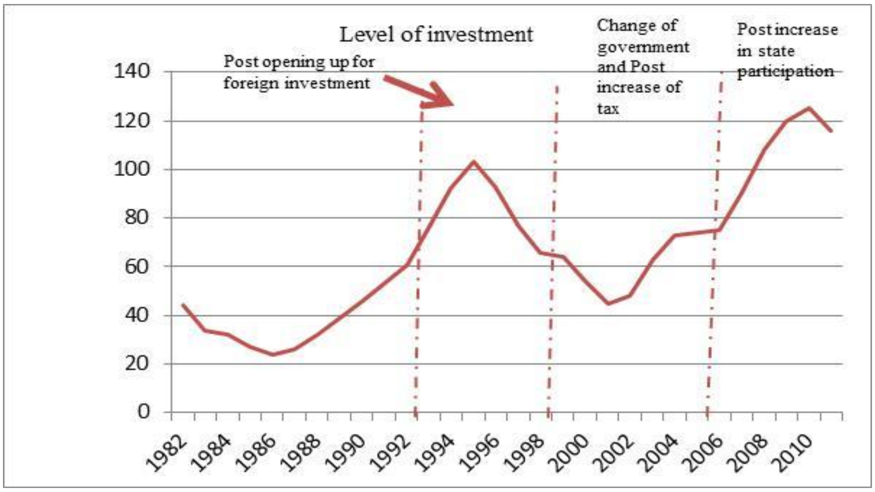

Figure 3.23: Upstream investment trends and changing Venezuela's fiscal conditions
Source: Author's computation data from 2012 OPEC statistical bulletin

3.4 Regional Comparison

Regional factors may shape policy development process and investment behaviour in the oil industry, considering the uneven distribution of hydrocarbon resources in the world and their geologic concentration in some regions. This section seeks to detect the influence of regional characteristics in influencing investment behaviour and evolution of institutional structure as well as petroleum fiscal policy framework, which determines the quality of governance mechanisms in oil producing countries and in turn, influence investment decisions. In view of this, the impact of stability of policies and quality of governance systems on oil and gas investment will also be assessed. According to United Nations Conference on Trade and Development World Investment Report 2007, the ability of natural resource rich countries to cope with economic, environmental, socio-political challenges, and attract investments depends greatly on its governance system. Thus, the quality of institutions before the discovery of oil and the ability of producing country to regulate, supervise, and implement activities in the industry are essential. For the purpose of this analysis, OPEC MCs are categorized as shown in table 3.12.

Table 3.12: Regional categorization of OPEC members based on inherent characteristics
Source: Author's categorization

Region	Characteristics
OPEC Africa	Medium upstream cost, medium to high oil reserves, high population, medium to high oil production capacity
OPEC Middle Eat	Low upstream cost, high oil reserves, low population, high oil production capacity,
OPEC South America	Medium to high upstream cost, medium to high oil reserves, low population, low to high oil production capacity

Although the Middle East constitute the highest membership of OPEC, the presence of favourable characteristics (Table 3.12) peculiar to the countries from the region seems to significantly motivate the evolution of fiscal policies and investment conduct in the upstream oil sector. Initially, concession agreements that were signed ascribed greater portion of the countries to few companies but, with growth in reserves, production capacity and income, the need for absolute ownership and control was reinforced. This reason may have reinforced the dominant adoption of service contract[88] and joint venture

[88] IOCs are engaged as contractors to find, develop and produce oil for an agreed remuneration fee after recovering cost of investment.

agreements[89] for foreign participation in upstream activities in addition to general policy of not allowing foreign ownership of oil resources (Table 3.13).

Despite the highest frequency of changes in fiscal elements governing upstream activities, the region recorded the highest level of upstream investments (Figure 3.23). This is consistent with high positive correlation coefficient 0.75 between aggregate investment level and the frequency of policy changes[90] (Figure 3.24). However, this may be attributed to the investment effect of Saudi Arabia[91] which has been quite huge due to significant capacity expansion of Saudi Arabia, which has been the largest oil producer in the world over the past 4 decades. Over the period 1982-2011, total of 4000 rigs were actively engaged in exploration and development drilling activities in the region (Figure 3.24). But, 1238 drilling rigs were active in Saudi Arabia alone within the period. Similarly, the effect of frequent policy changes associated with the region is less effective in dampening performance of upstream investment since most of the investments are carried out by the NOCs.

[89] For details on service contract and joint ventures, see Broadman (1985).

[90] Cox and Wright (1976) find positive impact of fiscal taxes on investment in the US during production prorationing period.

[91] Saudi Arabia began allowing foreign investments in 1999 but only for upstream gas development.

	freqpo~g	invest~l
freqpolchng	1.0000	
investlevel	0.7542	1.0000

Figure 3.25: Correlation matrix of aggregate investment and policy changes

However, Fee (1988) asserted that stable and friendly policy framework is required to achieve an optimal trade-off between conflicting objectives of IOCs and oil producing countries NOCs and facilitate upstream investments. Furthermore, strict regulation of active foreign participation in the Middle East producing nations resulted to assignment of absolute control of upstream activities to respective NOCs. The characteristic high oil production and low population result in high income which enabled the NOCs to independently fund upstream projects[92] or have easy access to private capital in form of loans[93]. Apparently, the present structure of the global oil industry, which provides the existence of separate upstream technology vendors that are

[92] According to Hvozdyk and Marcer-Balckman (2010) "NOCs in a number of major oil producers – particularly where financial constraints are less binding or it is easy to attract private capital – ratcheted up plans for investment since 2005. Large companies – saudi Arabia's Aramco, UAE's ADNOC, and Kuwait's KPC, which can self-finance projects and were able to maintain their human and productive capital base during the lean years of the 1990s – have developed ambitious capacity expansion plans at all levels of the production chain. Saudi Aramco is investing more than $50 billion between 2007 and 2012 to expand production by almost 20 percent and refining by 50 percent; Abu Dhabi National Oil Company (ADNOC) is increasing production capacity by 30 percent and Kuwait Petroleum Company (KPC) by 60 percent by 2020".

[93] Cherif and Hasanov (2012) in their analysis on optimal investment level by oil exporters in the face of high income volatility find that 'precautionary saving' of oil exporters is substantial (30 percent of revenue), whereas investment is fairly low (15 percent of income) given high perpetual shocks to oil proceeds and rather 'low productivity of the tradable sector'.

competing for markets, also strengthen the stand alone approach of Middle East NOCs, coupled with accumulated knowledge and tacit experience in upstream operations as a consequence of long period of involvement in oil exploration and production.

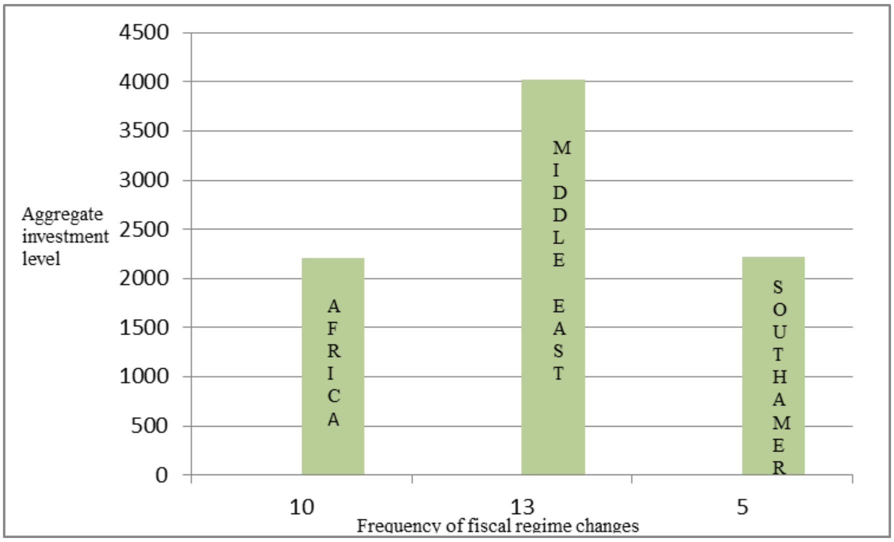

Figure 3.24: Frequency of fiscal policy changes and upstream investment trend

Source: Author's computation data from 2012 OPEC statistical bulletin

Conversely, in OPEC Africa, the petroleum fiscal policy governing upstream activities evolved in response to the growing interface between the characteristics defined in Table 3.12. Initially the host governments were involved in joint financing of upstream operations, but with growth in population, production sharing contract agreement dominated the contract sign with IOCs (Table 3.13). This is in response to the growing domestic budgetary needs and quest for increase in revenue generation capacity resulted in transfer of risk to investors. The host governments' policies are tailored towards attracting foreign investments since there is a paucity of investable funds and the NOCs lack adequate technical competence to single handedly undertake upstream ventures. In addition, the prevalence of foregone characteristics has reinforced structuring of policies in this direction (Table 3.12). During the period under consideration, about 2200 active rigs were engaged in exploration and development drilling, which was about half of the aggregate investment level of Middle East (Figure 3.23). Most of the investment growth was due to Angola that has progressively attracted the highest upstream investment level in the region since 2004 when the country stabilizes from civil unrest. This is suggestive of the positive response of IOCs to producing areas with attractive fiscal elements. Apparently, the frequent changes in fiscal policies have had less negative impact on aggregate investment level in the region. This is also consistent with the finding of high correlation between investment and policy changes (Figure 3.24). This suggests the willingness of oil and gas companies to invest even when there is high uncertainty associated with frequent policy changes.

Table 3.13: Summary of applicable contract agreements in OPEC members/regions

Region	Country	Type of upstream fiscal contract		
		Production Sharing	**Service Contract**	**Joint Venture**

		Contract		
Africa	Algeria	•	•	
	Angola	•	•	
	Nigeria	•	•	•
	Libya	•		
Middle East	Iran		•	
	Iraq		•	
	Kuwait		•	
	Qatar	•		
	Saudi Arabia			•
	U.A.E	•		
South America	Ecuador		•	
	Venezuela			•

*Saudi Arabia only upstream gas development are allowed for foreigners

On the other hand, in OPEC South America, the difference in natural endowments seems to have influenced the evolution and adoption of different fiscal policies. While Ecuador signed service contracts with IOCs, Venezuela signed joint venture contracts (Table 3.13). The lowest frequency of fiscal regimes changes/increases prevalent in this region may explain high level of upstream investments slightly higher than the level in African region and half that in Middle East, despite its lowest membership in OPEC. Apparently, Venezuela which is a major oil producer is responsible for upshot in investment[94] level but since the late 2000s, Ecuador has attracted the highest investment level among OPEC members in percentage terms. Despite its disputes with some IOCs which slightly dampened the investment its favourable fiscal offers made it into an investment haven for IOCs. In the case of Venezuela which has been less inclined to foreign investments due to huge oil reserves with capable and financially sound NOC[95], its vast heavy oil reserves necessitated the opening up for foreign investments due associated high cost and difficulty in development and production.

Evidently, the above analysis has reasonably showcased the influence of regional specific characteristics in shaping policy development process as evidenced by the adoption of similar policy objectives among OPEC members of the same region. Moreover, the result indicates the risk of the adverse nature of some oil and gas companies as evidence by high investment levels despite high frequency in fiscal policy changes. However, this does not preclude the importance of stability in fiscal policy environment. A lot of risk adverse investors will shun away or contemplate investments where policy uncertainty is high. Government influence reserve addition and production in the oil industry through tax systems and various forms of government take

[94] According to Stojanovski (2008) "Venezuelan PDVSA in the 1990s was considered among the highest performing NOCs in the world"

[95] The financial situation of PDVSA has deteriorated significantly since 2001 when the government began to burden the company with increase in welfare programs and socio economic development needs.

which impact on the profit of profit-maximizing companies. Modifications in tax and regulatory systems, increases the uncertainty of returns on new investment. Consequently, incentives may be influenced by the regulatory framework at the industry level Mohn (2009). Padilla (1992) further buttressed that the impact of institutional factors (taxation, contractual terms and political risks) changed the operator's expectations. Consequently, these considerations by oil companies' alter their behaviour so differently from what it would have been without exposure to these "non-market" forces. More recently, Cate and, Mulder (2007) and Nakhle (2007) find increases in fiscal regimes (taxes) negatively impact on exploration and development investment in the Dutch and UK continental shelves respectively.

In terms of the effect of regional similarities on the evolution of institutional structure, the monarchial and kingdom system of government prevalent in Middle East, coupled with characteristics outlined in Table 3.12 may have influence the assignment of policy making role to the Supreme Council rather than government ministry in most OPEC Middle East nations (Table 3.14). The ministry is saddled with regulatory oversight, or in some instances, separate entity is assigned the role or the NOC combined dual role of commercial and regulatory functions. Conversely, in OPEC Africa, democratization, high population, and other characteristics listed may have contributed in separation of policy, regulation and commercial oversights among different government entities or distinct policy arm and combination of dual role of regulation and commercial activities to NOC (Table 3.14). In OPEC, South America has also begun democratization and foregone peculiarities that may have influence the adoption of the African model among the two members that are prevalent.

Table: 3.14: Summary of institutional structure among OPEC members/regions

Region	Country	**Institutional structure**				
		Separate Policy arm (Ministry)	Separate Regulator	Separate State Oil Company	Policy and Regulator	National Oil company as regulator
OPEC Africa	Algeria	•	•	•		
	Angola			•	•	
	Nigeria	•	•	•		
	Libya			•	•	
OPEC Middle East	Iran			•	•	
	*Iraq	•				•
	*Kuwait	•	•	•		
	*Saudi Arabia	•	•	•		
	Qatar			•	•	
	*UAE	•				•
OPEC	Ecuador	•	•	•		

South America	Venezuela	•				•

* The role of policy making in carried out by Supreme councils in these countries rather than Ministries

Some of the recent studies that explored the merits and demerits of the separation of functions in oil sectors with varying inferences include Al-kasim (2006a), Lahn et al (2007), and Boscheck (2007). Thurber at al (2011) noted that the separation of policy, regulation and commercial activities, among three separate entities, have proved to be effective in the driving the exploration and production performance of Norway to excellence. The intuition behind the separation of roles is that the NOC can concentrate on its commercial activities, optimize its operational, investment conduct, and enhance profitability to the state. Autonomous policy and regulatory entities can improve the monitoring and benchmarking capabilities of the government on the activities of both the NOC and other upstream actors, thereby improving overall performance of the industry Thurber and Istad, (2010). Similarly, it will avert conflict of interest and unfair usage of regulatory powers, to the benefit of the NOC or becoming a “distorting and destabilizing state within a state” through intense lobbying of other state institutions Noreng (1980). However, another strand of scholars has concurred that the governance policies that work well in nations with mature institutions may not be suitable to states deficient in certain ‘institutional endowments.’

Most of the development economics literatures on institutional quality and governance mechanisms have utilized general governance assessment indicators developed by international organizations and non-governmental organizations to evaluate the performance of governments or sectors of economies. In the most recent work of Thurber et al (2011) that evaluated the effect of administrative design on oil sector performance, they used World Bank's government effectiveness index as proxy for assessing the relationship between the institutional quality and performance of oil producing nations. In this research, the most recent (2012) resource governance index, developed by Revenue Watch International, to measure the quality of governance in extractive industries of natural resources endowed nations. In particular, the assessment seeks to establish the effectiveness of host governments in managing the income of exhaustible resources for sustainable economic growth, regulatory framework, and policies that will facilitate investment influx. This is employed to assess the quality of institutional structure, and enabling environment of OPEC members/regions, which in turn, determine the quality of hydrocarbon industry governance which influence the conduct of upstream investment.

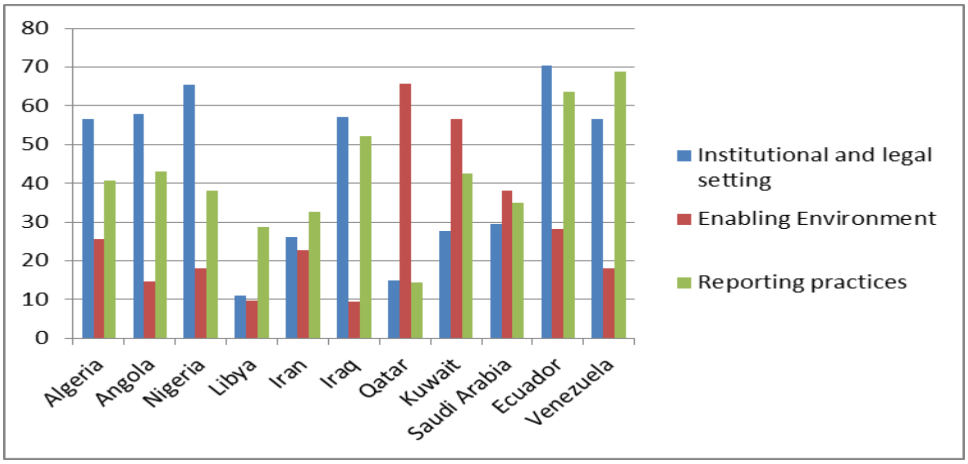

Figure 3.25: Resource governance index for OPEC countries/regions
Source: Author's computation data from Revenue watch international (2013)

The score rating defined 0-40 points as fail, 41-50 as weak, 51-70 as partial, and 71-100 as satisfactory performances respectively for each of the indicators. The indicators relevant to this study were chosen, and equal weighting was assigned to them. Generally the performance varied significantly across regions. OPEC South America has relatively highest governance performance in comparison to other regions, despite low rating in enabling environment as evidenced by satisfactory score of Ecuador in institutional setting and partial conduct in reporting practices. Venezuela, on its part, performed relatively satisfactorily in reporting practices (transparency initiatives) and had partial performance in institutional setting. In terms the impact of governance on level of upstream investment, it can be deduced that the high quality of governance in OPEC South America may have had positive influence on upstream investment behaviour as seen in figure 3.23. Conversely, there is an observed weak performance across OPEC Africa in terms of institutional setting with exception of Nigeria that performed partially. Similarly, the rating on transparency drive and provision of enabling environment has been generally been weak to failure signifying low performance in governance. The low level of upstream investments in the region may be aligned to low quality of hydrocarbon sector governance. Apart from Qatar and Kuwait, that have partial scores in the provision of enabling environment, and Iraq that also scored partially in institutional setting and reporting practices, the general performance of OPEC Middle East in governance have been the lowest among the regions. This is not surprising considering the tight regulation of foreign investment prevalent in the countries. It has also provided additional support to the fact that the observed increase in the level of upstream investment is mainly due endogenous factors and the effect of Saudi Arabia and Kuwait which are high producers and heavy investors in capacity expansion. Conclusively, it can be argued that good hydrocarbon sector governance facilitate investment influx in upstream activities and low quality of governance retard investments. This supports our expectation that sound governance mechanisms, defined by the efficacy of institutional and legal setting as well as favourable policies, play a crucial role in influencing upstream investment behaviour. ODI (1997) asserted that the dearth of transparency in the approval processes of investment and broad bureaucratic structure deters foreign investment in some countries. Although it is difficult to characterize the relationship between the quality of governance and the investment in oil and gas industry, it is plausible to ascribed positive relationship based on the foregone descriptive examination.

CHAPTER 4: LITERATURE REVIEW

4.0 Introduction

This section describes some of the foremost scholarly contributions in the economics literature on the theory of oil investment behaviour and empirical studies conducted to shed light on the determinants of oil and gas investment behaviour. The review is limited to economic theories that are gaining popularity in empirical studies on oil investment behaviour due to the huge strand of theoretical literature on general investment behaviour and the need to capture the inherent characteristics of the petroleum industry. For recent comprehensive surveys of theoretical models on investment behaviour see Euklund (2013). Consequently, some theoretical postulations that guided our assumptions and variable selection for the empirical specification of models used for this study are also presented. On the empirical front, there are few pragmatic studies on investment behaviour in the oil industry with the exclusion of studies by major international organizations Hvozdyk and Mercer-Blackman (2010). But, there is a growing interest in this subject. The growing strand of scholarly interest in understanding oil investment behaviour is reflective of its importance as exhaustible energy resources with restrictive geographical spread, high geological uncertainty associated with its replenishment, and the unstable nature of the world oil market. The empirical literatures on oil investment behaviour generally apply various econometric methods to investigate determinants of oil investment using above ground (mainly economic, institutional and policy) variables or below ground factors. It is worth noting that there is paucity of studies with broad emphasis on below[96] ground uncertainties that influence upstream investment. One of the frequently captured below ground variable in the empirical literature is depletion effect[97], which is widely proxied by cumulative drilling efforts. However, the depletion variable was constructed for this research in line with the standard definition of the term in the oil and gas industry. This will be more representative and will capture the depleting effects more accurately. Most of empirical literature that investigated investment behaviour in the upstream oil industry focused on OECD countries particularly the US ,UK, and Norway due to data availability. Generally, there is a scarcity of studies that focus on developing countries. To the best of our knowledge, there is very little but growing empirical studies on unraveling oil and gas investment drivers in developing countries. Similarly, there are very few studies that investigate oil and gas investment behaviour across the upstream value chain in an integrated manner. Another strand of empirical literature focuses on

[96] Hvozdyk and Mercer-Blackman (2010) stated that "below ground risks are statistically very important in deterring real investment" in the upstream oil sector. Below ground risks imply geology and technology challenges while above ground risks relates to market access for IOCs, changes in regulatory, taxation and general policy framework.

[97] Iledare and Pulsipher 1999; Managi et al. 2005; Mohn (2007) and Kemp and Kasim 2006) used cumulative drilling effort as proxy for resource depletion.

finding the causality between oil price and exploration or upstream investment [98]. Other group of researchers focused on investigating oil investment behaviour at the company level, mainly national oil companies[99] and international oil companies. The general conclusions within the existing literature have been varied possibly due to a variation in the domestic structure of the oil and gas industry resulting in varying market conditions in across countries and application of different methodologies. Apparently, there is a growing need for empirical investigation of upstream behaviour in developing countries considering the huge propensity of proven oil and gas reserves in both OPEC and non-OPEC developing nations. This research will greatly extend the boundary of the current literature by unraveling empirical evidence from developing countries' perspectives on competing factors that influence upstream investment in OPEC countries. Similarly, the influence of the explanatory variables on the selected non-OPEC countries will provide additional insights on the upstream investment behaviour of non-OPEC developing countries. This is due to the fact that most of the selected countries fall in this category with the exception of Canada, Mexico, UK, and Norway. The findings will provide policy implications that can guide informed policy

[98] Hammad (2011) asserted that crude oil price have significant contribution in the planning, implementation and evaluation of energy investments.

[99] See Marcel (2006), Eller et al (2007), Mitchell and Stevens (2008), Hartley and Medlock (2008) and Victor (2008).

and decision making in governmental and corporate cycles. Consequently, some theoretical postulations relevant to the study and summary of recent empirical insights with focus on exploration and development investment behaviour are presented.

4.1 Overview of Oil and Gas Investment Theory

Considering the non-deterministic nature of OPEC behaviour as seen in sub-chapter 2.1 which resulted in mixed findings, it is plausible to assume a non-competitive conduct[100]. The assumptions of static Hotelling (1931) model presented in Guerra (2007) and its extension by Cremer y Salehi-Istfahani (1991) provide the theoretical framework that lay the foundation for understanding oil investment behaviour and guide our econometric specification. A producer with amount (R) of an exhaustible natural resource faces the decision for producing a quantity (q) for a fixed market price (p) at a cost (c). Similarly, the investment choice involves cost i(d) for new reserves development (d). The quantity of reserves progresses with new discoveries and diminishes with the quantity produced. The mathematical representation is as follows:

The producer faces the following maximization problem

[100] Also according to Mohn (2009)"the competitive model fails in providing a trustworthy description of OPEC supply. The failure of competitive models in explaining OPEC supply behaviour is simply a reflection of the imperfect competition in the global oil market. He further concluded that empirical studies of OPEC's role in the oil market have generally failed to establish firm evidence of stable cartel behavior".

$$\max_{q,d} \int_0^T [p * q - c(q) - i(d)]\, e^{-rt}$$

Subject to R = d – q, D = d

The second derivative satisfies the first order conditions, thus

$$(p - c_q)e^{-rt} = \lambda \qquad (1)$$

$$\lambda = 0 \qquad (2)$$

$$i_d e^{-rt} = \lambda + \varphi \qquad (3)$$

$$\varphi = 0 \qquad (4)$$

The set of equations above defined the Hotelling basic static model and states as follows: Equation (1) means that oil price will raise at a positive real rate “r”, called the scarcity rent; equation (2) implies that oil reserves do not devalues; equation (3) positions that investment worth will equal the shadow value of actual and new reserves; equation (4) explains that new reserves also do not devalues; and equation (5) levies that if all the oil is extracted or when reserves remains, its shadow value will be equal to zero.

He assumed r to be the real risk – free interest for the investment with no extraction cost and market price per unit of resource (Fattouh, and Mahadeva, 2013). For a perfectly competitive market structure, Hotelling found that the expected unit price will be the driver of the resources' owner's behaviour in response to output. If the expected price is higher when production rate is slower compared to prices during rapid production, the exhaustion period will be prolonged. The optimal extraction track of exhaustible resource will be such that its price will increase over time at the interest rate r. In the case of a monopolist, Hotelling found that the extraction track to be different from the competitive market setting. Marginal revenue increases at the interest rate rather than the price. The price trajectory of rational monopolist is expected to be higher, since the monopolist will initially leverage on lower price elasticities to control output and set higher prices (Fattouh and Mahadeva 2013). However, in the future, the monopoly prices will plunge below the competitive prices. According to Pindyck (1978a), this permits OPEC to have substantial gains to equalize the costs of cartelization. He further extends Hotelling's model allowing the resource owner to select the rate of production and the level of investment that will get reserves to production level. Under this scenario, he found prices to move slower than what Hotelling found since the resource exploration work is dependent on the level of reserves available. Furthermore, there was a longer investment delay in monopoly than competitive market setting, provided that the reserves' level is still much.

Under the aforementioned postulations, the assumption of constant price implies that investment will not respond to sudden transitory oil price changes.

Consequently, oil production will rise to the point where the first order condition is satisfied. Nevertheless, assuming the non-changeable fixed price, the shadow value of an oil barrel; reserve would not change and as a consequence, investment level will not adjust. Therefore, for investment to change in response to price changes there has to be a permanent increase or sudden temporal rise that will stimulate investment prior to the upsurges. The extension of the Hotelling's model to non-competitive framework permits incorporation of some essential implications that will pave way for investment to change with changing oil price.

(a) The form of mining of the exhaustible resource will be inclined towards "Conservationism" (Q non-competitive < Q competitive up to a certain point in which the arrangement will reverse).

(b) Once the number of partakers grew to infinite, the condition evolves to the competitive case. This extension is important because the geographic spread of oil reserves is not homogenous, notwithstanding the different perspectives about any particular market situation. OPEC members hold about 78 percent of proven global oil reserves and majority of it is the Middle East.

Considering the high uncertainty level and high fixed and variable costs nature associated with investment in the upstream oil industry, a strand of theoretical literature also explore the irreversibility of oil investment under uncertainty[101]. The idea of irreversible investment is applicable to oil and gas exploration Mohn and Osmundsen (2008). Once investment is made and oil wells are producing, the investment cannot be reversed even when stricter conditions are later imposed by the host country[102]. According to Favera et al (1994), oil investment process comprises three distinct, but closely related actions: exploration, development, and extraction. The exploration activity can be regarded as availing the option to invest, while the development as signifying the irreversible aspect of the investment. Enormous capital commitments, long investment intervals, and field-specific series of investment choices encompass sequences of waiting options Mohn and Osmundsen (2008).

When an investment decision is pricy to reverse and the payouts are ambiguous, the decision comprises matching the value of investing now with the present value of spending at all possible future dates. The investment spending includes the cost of adopting the option to invest in the future and a project is accepted only when the estimated remuneration is higher than the cost by an amount equal to the 'value of the option'. Option pricing techniques have been used to examine the determinants of irreversible

[101] The issue of irreversible investment behaviour under uncertainty has lately received a great deal of interest in the theoretical literature (see, for example, McDonald and Siegel, 1986; Pindyck, 1988; Dixit, 1992; Ingersoll and Ross, 1990; Bertola, 1990).

[102] UNCTD World Investment Report 2007.

investment under uncertainty, and it is shown that even risk-neutral firms may be reluctant to invest when the future is uncertain. For theoretical applications of the theory of irreversible investment under uncertainty to oil investment, see Ekern (1988), Paddock et al (1988), Miller and Zhang (1992), and Favera et al (1994). Dixit and Picdyck (1994) considered the high sunk cost nature of upstream oil sector, irreversibility of capital stock, and inconsistency of output price and modelled investment under uncertainty. The real options' approach to investment asserts a negative correlation among investment and uncertainty Dixit and Pindyck (1994). Mohn (2008) asserted that increased uncertainty positively influence the option value of waiting to invest under the theory of irreversible investment. He further stated that investment not only suggests the cost of a waiting option, but also a "potential reward from the acquisition of future development and growth options." The value of both waiting and "growth options" will rise with increase in uncertainty. Fattouh (2004) concluded that the option to wait and not invest becomes very valuable due to the uncertainties surrounding the oil market. Impliedly, oil producing nations and IOCs could choose to delay their investments. If demand growth progresses as predicted by observers nowadays, it will create 'the worst possible scenario for both oil producers (especially OPEC) and consumers.'

According to Hvozdyk and Mercer-Blackman (2010), characterizing the correlation amongst investment, prices, and costs have proved challenging and there is no definite consensus in the literature. Dixit and Pindyck (1994) and Abel and Everly (2004) postulated that investment tend to decline under the assumptions of uncertainty and sunk cost when there is higher price volatility. Conversely, Casassus et al (2005) consider investment in oil field to be "infrequent and lumpy" due to static adjustment cost. In their work, oil price was modelled as a "regime switching process" revealing many of the significant characteristics of oil prices (like backwardation). They found strong support for the existence of static investment costs and variable investment-price regimes (two regimes) to be unconditionally "continuous component in the no-investment region and singular component at the investment boundary." Their findings support the idea of "lumpiness and non-linearity" in oil investment[103].

On another front, the Keynes and Flexible accelerator theories of investment are gaining application within the economics and finance literature on investment analysis of the extractive industry[104]. Similarly, the neoclassical theory and Tobin's Q theoretical frameworks are foremost applicable theories in some empirical studies on investment behaviour. According to Mlambo (2010), the main postulates of the Keynes theory as identified by Pentecost

[103] Based on Hvozdyk and Mercer-Blackman (2010)

[104] Mlambo (2010) estimated determinants of mining investment in Zimbabwe based on Keynes and flexible accelerator models.

(2000) are the role of expectations and supply price of capital goods[105]. The theory stresses that investment is consequential to firms “balancing the expected return on new capital with the cost of capital, which depends primarily on the real interest rate” Parker (2010). Keynes expected a drop in the return on investment (and so a drop in the demand price) as investment spending increases, since the weakening in the scarcity of capital decreases the “quasi-rent earned by capital” Falls and Natke (2007)[106]. They further assert that other scholars associated the drop in the demand price when investment rises to views of limited output marketplaces by firms. Pentecost (2000) summarized the Keynesian investment function as shown below:

$$I = \beta_0 - \beta_1 i$$

Where I = net investment, i = market interest rate

β_0 captures the exogenous shifts in business expectations, which affect the firm’s rate of return. Consequently, the rate of return and the rate of interest could be determinants of oil investment.

[105] For details see Keynes (1936).

[106] See also Davidson (1972). Also according to the Keynes’s theory, “the investment-demand curve is volatile because it depends on firms’ expectations of the profitability of investment” Parker (2010).

The flexible accelerator theory[107] assumes the presence of a balance, optimum, preferred, or long-run stock of capital necessary to yield a specified output for certain technology, rate of interest, and so forth Gujurati (1988). Mlambo (2010) summarized the assumptions of the theory as follows:

$$K_t^* = \beta_1 Q_t \qquad (1)$$

$$K_t - K_{t-1} = \delta\left(K_t^* - K_{t-1}\right) \qquad (2)$$

$$I_t^g = K_t - K_{t-1} + \alpha K_{t-1} \qquad (3)$$

where t indicates period t, K*t is desired oil capital stock, Qt is current oil output, K_t is current capital stock, K_{t-1} is previous capital stock, $I^g t$ is gross investment, α is the depreciation rate, and δ is the coefficient of partial adjustment. Jorgensen (1971) and Bischioff (1971) find "output to be one of the main determinants of investment. Other theories of investment are the Tobin Q and neoclassical theories. Tobin's Q theory assumes that the ratio of the market value of the existing capital stock to its replacement cost (the Q ratio) is the main force driving investment Ajide and Lawanson (2012). Tobin (1969) argues that firms will have the desire to invest when rise in the market value of an additional unit is higher than the replacement cost[108]. He further

[107] According to Michaelides et al (2005), the theory stem from Chenery (1952) and Koyck (1954) that assumed the proportionality of level of desired capital to output.

[108] According to Michaelides et al (2005)," empirical evidences have led to poor performance of the q-models".

argues that "delivery lags and increasing marginal cost of investment are the reasons why Q would differ from unity." Conversely, the neoclassical theory of investment[109] assumes that the preferred level of 'capital services' depends on the function of 'relative prices' Michaelides (2005). This implies that the cost of capital includes the interest rate[110].Obviously, the determinants of investment behaviour in the oil industry can be deduced based on different theories briefly outlined above: Hotelling's theory, irreversible investment under uncertainty, Keynes, and flexible accelerator theories. Consequently, review of empirical insights on drivers of exploration and upstream investment is presented.

4.2 Empirical insights on drivers of oil and gas exploration and development investment in international oil industry

The initial empirical literature on oil exploration investment emanates from the US[111] since the pioneering work of Fisher (1964) in which he estimated

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[109] The works of Ross and Von Sjeliski (1948) and Ross (1958) originated the neoclassical theory of investment.

[110] Pentecost (2000) also asserts that the theory assumes relevance of real rate of interest in the computation of user cost.

[111] According to Mohn (2008), theory-based econometric study on the oil and gas industry requires that the data to be used spawned from an industrial setting essentially led by

equations for the drilling rate, success rate, and the discovery rate to unravel the influence of oil prices, seismic crews, and drilling cost on oil exploration for different petroleum provinces covering the period 1946 – 1955. Since then, empirical literature on exploration behaviour grew astronomically in the US[112]. Dahl and Duggan (1998) provides a survey of the empirical exploration behaviour models for the US. Subsequently, empirical analysis of exploration investment behaviour in the UK continental shelf sprang up in the 1990s with the work of Pesaran (1990)[113] and continued to grow with focus on OECD oil producing nations. However, recent improvement in data availability and quality motivates empirical studies of exploration behaviour in developing countries, but with still great inadequacy. Iledare (1995) estimated a natural gas exploration drilling behaviour model for West Virginia for pooled cross sectional data of 18,000 wells drilled spanning 1977 – 1987. He estimated a non-linear disaggregate two equation model and tested the hypothesis of natural gas reserves additions to be a function of "resource availability, economic incentives and policy incentives, depletion, geological knowledge, and engineering capability." He found positive significant influence of net

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commercial ethics. Additionally, longer history of the actual activity increases the quality of the data. This explicates the reason behind using U.S data on most of the research that applied economic theory to understand exploration behavior.

[112] See Khazzoom (1971), MacAvoy and Pindyck (1973), Uhler (1976), Pindyck (1978), Kim and Thompson (1978), and Eckbo et al. (1978), Uhler (1979), Griffin and Moroney (1985), Rose et al. (1986), Deacon et al. (1990),Iledare (1995) and Iledare and pulsipher (2001).

[113] For extension of this work, see Favero (1992) and Favero and Pesaran (1994). Favero et al. (1994).

economic value of new reserves and technological progress on drilling activity and negative significant relationship among reserves market conditions (proxy by reserves life index) and drilling levels. The results also show negative effects of resource depletion as cumulative drilling increases. Expectedly, drilling efforts change through geologic formations with changes in geologic conditions in West Virginia. Well head price increases were found to have a positive relationship with drilling and new reserves additions. Increase in tax rates also exerts negative influence on both the level of drilling activity and reserves additions.

Similarly, Iledare and Pulsipher (1999) estimated a seemingly unrelated regression model for region-specific exploration behaviour using panel data of north and south Louisiana for the period 1977 – 1994. They found that the net economic value of new reserves generated from previous exploration effort positively leads to an increase in drilling activity in both north and south Louisiana. Furthermore, cumulative drilling (learning effect) exerts greater influence on the number of wells drilled in both provinces. The higher the quality of geological knowledge gained, the more drilling decisions are made; depletion also exerts positive influence on drilling. Similarly, the negative significant coefficient of technical progress implies higher drilling choices with reduction in dry holes due to better seismic identification of drilling targets in both provinces. In the same vein, Yarzin (2001) specified an econometric model for proven reserves additions in the US for the period 1950 – 1995. He tested the effect of technological progress, expected resource price, and cumulative reserves development on reserve additions while departing from Hotelling's assumption of fixed and known reserves. He found strong statistical evidence supporting the significant effect of the explanatory variables on additions to US proven reserves and estimated price elasticity reveal small effect of the order of 1.5 -4.5 percent.

Furthermore, Iledare et al (1999) specified oil drilling equation and applied ordinary least square model for the time series data of US Gulf of Mexico Outer Continental Shelf region for the period 1970 - 1993. They investigated the effect of net operating profit, success rate, technical progress proxy by cumulative reserves discovered, as well as changing oil market condition and institutional changes on the finding rate of oil. They found a statistically significant positive effect of net unit operating profit and success rate on finding rate. Their result show negative effect of resource depletion, institutional changes, and market conditions on oil finding rate. But, technological progress exerts a positive effect on finding rate.

Furthermore, Managi et al (2005) estimated an oil exploration-discovery behaviour model for the Gulf of Mexico. They applied seemingly unrelated regression approach on data range of 1947 - 1998 to investigate the impact of technological change and drilling cost on oil exploration and yield per effort at regional and field levels. They developed a noble weighting index for technological change taking into account the significance and impact of various technological innovations on offshore oil and gas exploration rather than using a time trend proxy. Despite having their studies on exploration efficiency, the initial part of their findings explain drivers of exploration investment behaviour. Water depth positively influences exploration behaviour at 5 percent significance level. They also found technological progress to have a statistically positive significant influence on yield per effort at 1 percent levels, while depletion exerts negative influence of same magnitude. Furthermore, oil and gas reserve levels were found to have a positive significant relationship with exploration drilling at 1 percent level.

On the same note, Osmundsen et al (2010) estimated an ordinary least square log-log model for Norwegian data spanning 1966 – 2008 to examine drivers of exploration investment behaviour from the drilling efficiency point of view. Their model tested the influence of water depth, metres, temperature, total number of exploration wells drilled, technological change, lagged oil price and several dummies type of rig, status of well (plug & abandoned), type of oil company, location of well (Barents sea, North sea, Norwegian sea), and type of well (wildcat or appraisal) on exploration drilling efficiency (proxy by metres drilled per day). The estimated coefficients reveal that appraisal wells are less productive than wildcat wells. In terms of location effect, wells in the

Norwegian Sea are more productive; from there, productivity level declines in North Sea and worsens in Barents Sea. Dry wells are more productive than discovery wells. Increase in depth of drilling exerts a statistically negative insignificant influence on exploration productivity and also oil price increases influences drilling productivity negatively. The result also shows that drilling efficiency is less when many wells are drilled in general due to high activity level induced by high oil price levels. Finally, technological changes influence drilling efficiency positively in the Norwegian sector. For other studies that investigated exploration investment in terms of drilling efficiency see Iledare and Pulsipher (1999) Corts (2000), Iledare and Pulsipher (2001), Kasim and Kemp (2006), and Kellog (2007).

Kasim and Kemp (2006) develop a regional exploration behaviour model for the UK continental shelf. They applied a 3-stage least square systems method on annual data covering 1975 – 2002 to examine the effect of economic, technology, depletion, tax, expected reserves (yet to be discovered) on exploration efficiency, and finding cost across five petroleum producing regions in the UK. Maturity level of petroleum province (depletion) exerts a negative dominant statistically significant influence in all regions except in the Central and Northern North Sea region where it has insignificant influence. Similarly, technological progress has a significant effect in driving exploration efficiency in all regions except Southern North Sea. Conversely, the effect of current real oil prices on exploration drilling is only statistically significant in Southern North Sea, but the moving averages of oil prices exert similar significant influence in Southern North Sea, Central North Sea, and Irish Sea. This shows evidence that other factors have stronger effects in driving exploration drilling in other regions than oil price or economic effect. The level of yet to find reserves (expected) has a statistically significant effect on exploration and appraisal drilling only in West of the Scotland region. The influence of tax relief on costs and taxes on production income were negative and statistically significant in Southern North Sea, but both variables have strong positive statistical significance in Central North Sea. On the other hand, full cycle costs has dominant positive influence in Northern North Sea and significant in West of Scotland region but was not significant determinant in Southern and Central North Sea.

On another front, Mohn (2007) applied vector equilibrium correction modeling on Norwegian Continental Shelf time series data that spans 1969 - 2004 to investigate oil exploration behaviour. He found the effects of oil price changes, licensing policies, previous exploration success, and depletion proxy by accumulated drilling efforts, and intensity of information gathering process proxy by seismic survey activities, and technological progress on exploration drilling in Norway. Previous exploration success and licensing policies exerts short term positive influence on exploration drilling with somewhat higher impacts in the short than long term. Depletion had negative effect on average field size with no effect on exploration drilling. His result also indicates that increase in oil price positively affects exploration behaviour in the long run. Furthermore, Mohn and Osmundsen (2008) estimated an oil exploration and appraisal model for the Norwegian continental shelf for the period 1965 – 2004 using structural modeling approach to capture long terms effects and error correction modeling technique for short term dynamics. They regressed changes in drilling activity as a function of oil price changes, lagged discoveries, and lagged changes in available exploration acreages. They found modest oil price elastic effect of 0.2 and 0.4 which is indicative of low responsiveness of exploration activity to oil price changes in a highly regulated environment. The result show also modest short run effect of exploration acreages to exploration drilling. The responsiveness of exploration drilling to exploration success was immediate with elasticity of 4, which declines progressively leaving a long run effect of 0.5 percent. Consequently, the coefficients of cumulative discoveries suggest that exploration drilling is inhibited once the oil and gas province ages.

More recently, Mohn (2009) applied the simultaneous equation modeling approach to Norwegian continental shelf data that spans 1972 – 2004 to estimate the effect of depletion (proxy by cumulative drilling), technology (proxy by seismic activity), government regulation (proxy by availability of acreages), and oil price on exploration behaviour. Reserves addition is considered to consist of exploration effort, average discovery rate and size. The responsiveness of size of discovery to depletion is negatively elastic with -1.29 percent responses. But, drilling success and efforts show positive inelastic response to changes in depletion. Conversely, the responsiveness of exploration effort and success was negatively inelastic in the order of 0.05 percent. Oil price exerts a positive significant influence on exploration drilling, discovery rate and size. The responsiveness of exploration to oil price is about 9 percent, implying the willingness of companies to undertake risky exploration increases when oil prices increases. Awarding of new acreages also enhance reserves additions due to its positive influence on exploration drilling and discovery size. Technology plays a significant but inelastic influence on reserves addition, but it offsets the negative effect of depletion.

Other strands of literature explore the relation between oil price and exploration investment.[114] But, the role of oil price in driving investment in oil industry is complex. Profit expectations relate to future prices but investors' cash flow is impacted by current and past prices Padilla (1992). Meanwhile, exploration investment which is riskier and capital intensive is mostly self-financed. Thus, characterizing the effect of oil price changes on exploration

[114] "Oil prices have been one of the fulcrum of exploration industry's decision making" Michot (2000).

investment has yielded mixed findings within the literature[115] with differences among countries and regions. Enebeli et al (2012) applied vector autoregressive modeling on Nigeria's average annual daily crude oil production as proxy for exploration activity and Brent crude spot prices to explore the relationship between oil price and exploration activity in Nigeria for the period 1976 - 2010. They found that increase in oil price does not granger cause exploration activity but granger cause oil production[116]. Conversely, Guerra (2007) specified vector autoregressive model and estimated the causality and responsiveness of oil investment to oil price changes in OPEC and non-OPEC countries. He used aggregate number of oil rigs as proxy for oil investment and tested the effect of oil production of OPEC and non-OPEC producers, Brent oil price in real terms on oil investment and OECD activity index as proxy for world oil demand. He found aggregate oil investment responded greatly to oil price changes and barely significant response of oil price shocks to oil investment, but exhibit transitory behaviour. His findings are consistent with Hotelling's model by the responsiveness of oil investment to long term oil price changes. The

[115] Fee (1988) asserted that increase in oil prices generates higher profit for the industry which results to expansion of activity levels. Similarly, Arora (2013) asserted that higher prices fuel drilling decisions since the financial return structure appear more encouraging. Conversely, Broadman (1985) argues that oil price increase can lead to decline in consumption which induces less incentive on the industry to increase exploration effort in the near term.

[116] Siddaya (1980) find oil price not to have statistically significant influence on exploration drilling in Southeast Asian countries.

responsiveness of OPEC and Non-OPEC investment levels to permanent oil price changes are at highest level of 2.5 and 4.9 percent respectively.

Riglund et al (2008) analyzed the estimated dynamic relationship between rig activity and oil price to determine the responsiveness of rig activity as proxy for exploration activity to changes in oil price in non-OPEC countries. They applied the equilibrium correction mechanism model with stochastic trend on time series data covering 1995 – 2002 for Europe, non-OPEC Middle East, and Latin America, non-OPEC Africa and Asia Pacific, and 1987 – 2002 for the US. Similarly, they used separate crude oil reference markers for each region in real prices; "US WTI for the US and Latin America, Brent Blend for Europe, Dubai for the Middle East and Asia Pacific, and Nigeria for Africa." They found significant short run price elasticity of about 0.15 and long run price elastic effect of 1.7 for the US. The high responsiveness in the US is suggestive of the high activity level, ease of hiring a rig for drilling operations, and the competitive nature of the oil market in the US. Conversely, their result show insignificant short run elasticity and long run elastic effect in Europe lower than in the US by 60 percent, which is indicative of lower speed of adjustment. In the case of the responsiveness of investment to oil price changes, they found immediate but insignificant price elasticity effect to be higher once Venezuela is omitted in the model. Nonetheless, the findings show that Latin American countries, excluding Venezuela, appear to respond more greatly to price changes. It is also supportive of the non-competitive behaviour of Venezuela in the oil market. The Asia Pacific model reveals long run elasticity closer to 1 in the 36 months smoothed price model and less than 0.2 in the 12 months scenario. There is also insignificant immediate price elastic effect which is even lower than in non-OPEC Latin America, and likewise the long run price effect and speed of adjustment is smaller than most other regions. The immediate responsiveness of Non-OPEC Middle East is significant and comparable to the US, but in the long run, the price elasticity of the region is observable. The response of exploration activities in Africa excluding OPEC members to oil price changes show insignificant elastic response similar to Non-OPEC Latin America in the short run. The long run elastic response was lower, but higher than Asia Pacific and Non-OPEC Middle East. However, it was attributed to estimation errors.

From the developing countries' perspectives, Broadman (1985) specified time series regression modeling on non-OPEC oil producing and non-oil producing developing countries' data covering 1970 – 1982. He regressed level of exploration activity as a function of geologic promise (proxy by success ratio), extent of infrastructural development, type of contractual arrangement offered, nature of taxation, and degree of political risk of each country. Generally, the model showed satisfactory performance for the producers' panel and very low performance in non-producers. He found a significant positive influence of success ratio on oil producer's panel and income tax rates for both panels on the level of exploration activity. The level of infrastructural development in oil producing countries exert strong positive effect in driving the level of exploration, and likewise contractual arrangement (service and joint venture contracts), but with less magnitude for production sharing contracts. The coefficient of political stability shows a statistically insignificant effect on oil exploration in both panels. The influence of oil prices reveal strong positive significance for oil producers and negative insignificant effect on non-producers' panel. The presence of national oil companies and areal size also show positive statistical significant influences on exploration activity in Non-OPEC, oil-producing developing countries. A summary of the empirical literature is presented in Table 4.1

Table 4.1: Summary of empirical literatures on exploration investment

Author	**Variables**	**Data and model**	**Main findings**
Broadman (1985)	Dependent: exploration activity Independents; geologic promise, infrastructural development, type of contract, degree of political risk, NOC	Non-OPEC oil producing and non-oil producing developing countries (1970 – 2002) using time series regression	Positive effect of geological promise, infrastructure, service and joint venture contracts, oil price and NOC in oil producing nations. Insignificant effect of

	and oil price		political risk in both panels.
Iwayemi and Skriner (1986)	Dependent: Exploration investment Independents: oil price, demand, companies profitability, past investment, technological progress, and reserves replacement	Oil companies (1980 – 1996) using least square regression	Weak influence of oil price and demand. Positive significant effect of company's profitability, past investment, and technical progress and negative effect of reserves replacement
Iledare (1995)	Dependent: drilling level Independents: tax rate, resource depletion, technical progress, discoveries, market conditions	West Virginia data (1977 – 1987) using econometric modelling	Strong positive influence of new reserves economic value and technical progress. Positive effect of oil price increases and negative effect of depletion, tax increase and market conditions.
Iledare and Pulsipher (1999)	Dependent: exploration effort	North and South Louisiana	Positive influence of learning effect,

	Independents: depletion, learning effect, geological knowledge, technical progress. economic value of previous reserves	(1977 – 1994) using seemingly unrelated regression	geological knowledge, depletion and net economic value of previous reserves. Negative effect of technical progress on exploration.
Iledare et al (1999)	Dependent: drilling rate Independents: technical progress, success rate, unit operating profit, depletion, market conditions and institutional changes	US Gulf of Mexico (1970 – 1993) Ordinary least square	Positive influence of unit profit and success rate. Negative effect of depletion, institutional changes and market conditions on exploration drilling rate
Farzin (2001)	Dependent: additions to reserves Independents: technical progress, expected oil price and cumulative reserves	US (1950 -1995) using Econometric modelling	Positive statistical significance of the regressors on oil reserves addition

Riglund et al (2008)	Dependent: exploration activity Independent: oil price	Non-OPEC Africa, Asia Pacific Europe Non-OPEC Latin America and Non-OPEC Middle East countries (1995 - 2002) using Equilibrium correction model	High elasticity in Europe but lower than US. Insignificant elasticity in Africa and Latin America but higher than Asia Pacific. Significant elasticity in Middle East
Managi et al (2005)	Dependents; oil exploration and yield per effort Independents: technical progress, water depth, depletion, reserves level	Gulf of Mexico (1947 – 1998) using seemingly unrelated regression	Positive impact of water depth, technological progress and oil and gas reserves. Negative impact of depletion
Kasim and Kemp (2006)	Dependent: exploration efficiency and cost Independents: oil price, technology, depletion, tax, expected reserves	5 oil producing regions in UK (1975 – 2002) 3 stage least square	Mixed effect of economic, technology, policy and reserves across the regions

Guerra (2007)	Dependent: aggregate oil investment Independent: oil price and production	OPEC and Non-OPEC countries data Using vector auto regressive model	Oil price granger cause oil investment but oil investment weakly granger cause oil price shocks
Mohn (2007)	Dependent: oil exploration Independents: oil price, licensing policy, previous exploration success, depletion and technical progress	Norwegian continental shelf (1969 – 2004) using vector equilibrium correction model	Positive long run effect of oil price and positive short term influence of licensing policy and previous exploration success. Depletion was insignificant
Mohn (2009)	Dependent: exploration Independents: depletion, government regulation (award of acreage), oil price and technical progress	Norwegian continental shelf (1972 – 2004) using simultaneous equation model	Positive effect of government regulation, oil price and technical progress. Negative effect of depletion
Mohn and Osmundsen (2008)	Dependent: drilling activity Independents: lagged	Norwegian continental shelf (1965 – 2004) using	Modest elasticity of oil price and exploration acreage.

	and cumulative discoveries, oil price, exploration acreage,	structural model and error correction modelling	Significant elastic response to success ratio and negative response to cumulative discoveries
Osmundsen et al (2010)	Dependent: exploration and its efficiency Independents: water depth, number of wells, technical progress, type of well, location, lagged oil price	Norway (1966 – 2008) Ordinary least square	Positive influence of technical progress and negative effect of number of wells and water depth
Enebeli et al (2012)	Dependent exploration activity Independent: Oil price and production	Nigeria (1976-2010) Using vector autoregressive model	Oil price does not granger cause exploration drilling but granger cause oil production

From the perspectives of investigating drivers of general upstream investment, it appears there is far less attention within the empirical literature than expected, more so on developing countries. Apparently, there is a growing need for empirical investigation of upstream behaviour in developing countries considering the huge propensity of proven oil and gas reserves in both OPEC and non-OPEC, developing nations. The findings of empirical economists vary. Drollas (1986) estimated an exploration and production drilling behaviour non-linear econometric model on U.S data covering 1938 – 1982. He investigated exploration and production drilling as a function of real oil price, discoveries, real cost of drilling, level of produced refined products, shut-in wells, and oil reserves. All the variables turn out to be statistically significant except real cost of drilling. But, the results find real oil prices to have a strong positive influence on exploration and production drilling levels. In terms of speed of adjustment, he found adjustment to desired levels for exploratory drilling, production drilling, and production to be 10, 1.6, and 1.3 years respectively.

From a broader point of view, Barry (1989) applied ordinary least square modeling approach on US data spanning 1977- 1986 to unravel determinants of US companies' domestics and foreign investments in search for oil. He tested determinants of exploration and development spending in the country. He examined the effects of real oil price, US demand for petroleum products, oil and gas reserves' level of firms, income tax rate, lifting costs (production taxes and royalty), and dummy for the effect merger of three major oil. He found negative significance of income tax rate on exploration and development expenditure in OECD Europe, Canada, Africa, Middle East, and

Western hemisphere, but a stronger influence in Africa and Middle East at 1 percent level. However, the firm's oil and gas reserves exert a positive significant influence on investments in these regions at 1 percent level. Cash flow of firms exhibit positive significant relationship across all regions except the Middle East and Eastern hemisphere, where its magnitude was less at 5 percent level. Total lifting cost had positive significant influence in OECD Europe and Canada at 5 percent level, but exerts a stronger impact on exploration and development spending in Western hemisphere at 1 percent level. Conversely, it has a negative insignificant influence in Africa, Middle East, and Western hemisphere. The merger effect has a negative insignificant relationship with upstream investment in all regions except Africa where it's positively related to upstream spending. Oil price has positive insignificant influence on exploration and development spending in all the regions.

Furthermore, Reiss (1989) used 44 independent oil and gas companies' data that spans 1978 to 1986 and investigated the influence of economic and financial factors on firm's exploration and development investment behaviour. He estimated ordinary least square and instrument variable models to unravel the interaction among oil and gas prices, exploration and development wells drilled, net revenue of firms, dry wells, exploration and development costs, debt payment/liquidity, effect of firms production level, and exploration and development drilling proxy by equivalent oil discoveries. He found general decreasing return to scale in OLS and increasing return to exploration wells in IV. He found that decrease in previous cash flow by 1 dollar will decrease investment spending by 21 cents while other variables remain constant. The previous year's cash flow has significant impact on firm's net revenue in exploration well, but less in development wells. Similarly, smaller firms sustained considerably less average net revenue interest in drilled wells. Exploration well and development wells have significant influence on reserves additions and investment spending. On the average, 1 percent increase in exploration wells results to reserves increase by 0.12 percent, but development wells induce reserves increases by about 4 times higher value than that amount. Lagged current debt maturities have negative significant effect on exploration and development spending in the following year. Oil and gas prices have positive significant influence on exploration and development investment.

Kaufmann and Cleveland (2001) applied error correction model on the time series data of US lower 48 states covering 1938 - 1991 to investigate determinants of production behaviour among producers in the various states. They found statistically significant and positive long run relationship between oil price increases and oil production, but there is a negative relation between average cost and production prorationing decisions of Texas Rail Road Commission (TRC) on oil production. However, their results indicate that a rise in the operator's allowable productive capacity affects oil production positively. Furthermore, Iledare and Pulsipher (2001) examined the determinants of exploration and development behaviour in the US Gulf of Mexico Outer continental shelf using the data range 1977 – 1998. They estimated and applied a seemingly unrelated regression model and unraveled the effect of technical change (time trend), economic (expected oil and gas prices), resource depletion (cumulative drilling), drilling cost, market condition (reserve production ratio), and economic incentives (royalty relief act) on drilling rate, success rate and yield per effort. The equations of drilling and yield per effort rates result to satisfactory statistical performances. Their result shows the negative statistical significance of resource depletion on reserves additions through exploration and development drilling. The coefficients show the positive influence of oil and gas prices and technical progress on exploration and development drilling. Economic incentives exert a positive, statistically significant influence on exploration and development drilling, and success rates respectively while market condition has a statistically significant negative influence on exploration and development drilling and success rates respectively. Although the effect of depletion was significant, the response of reserves addition to it was inelastic. The proxy variable for market conditions was negatively elastic.

To further unravel determinants of reserves additions in US Gulf of Mexico, Iledare (2009) estimated a hybrid log linear model and unraveled the responsiveness of exploration and development drilling rate to technological progress, economic, and depletion factors. Specifically, he specified the discovery rate, drilling rate, and discovery size equations for slope, deep, and ultra-deep water terrains in the Gulf of Mexico, and examined the effect of real oil and gas prices, water depth, technology and depletion (proxy by cumulative wells drilled) on exploration and development behaviour over the period of 1983 – 2005. The estimated results revealed the positive inelastic response of drilling rate to changes in real gas prices, but there is no statistical significant influence of changes in real oil price on drilling rate. The rate of discovery is shown to exhibit negative inelastic response to gas price changes and responds positively in an elastic manner to changes in oil price. Similarly, discovery rate responds in less negative elastic manner to oil and gas prices, but show positive elastic response to changes in oil price as water depth increases in the Gulf of Mexico. The effect of technological progress is significantly positive and progresses with increase in water depth[117]. His results also indicate that the effect of depletion on oil exploration and discovery has is offset by technological improvements.

[117] On the other hand, Snead (2005) find exponential increase in average well cost per feet with increase in water depth in Oklahoma.

Peseran (1990) developed the oil exploration and extraction supply and investment behaviour model for producers in the UK continental shelf. He estimated and applied non-linear generalized instrumental variables estimator (non-linear two stage least square) for the supply and exploration models respectively using data of 1978 – 1986. He tested the effect of oil price, production, expected price of oil, unit exploration cost, and cumulative efforts proxy by number of exploration wells drilled on exploration and production levels. He found oil price to have a significant positive effect on oil exploration with price elastic response of 0.45 and 0.67 in the short and long runs respectively. Oil production influences oil price positively with an elastic response of 0.31 and 1.07 in shut and long runs respectively. The effect of oil price changes on oil output is smaller and builds up slowly. Keeping oil reserves constant, the mean lag between output changes after oil price movements is about 6 years. Oil price also offers a linkage amongst exploration and the production decisions. A prompt increase in production by rising extraction costs reduces the price of oil in the ground and, for at a certain level of expected costs, oil price anticipations reduces the anticipated return to exploration, and therefore the degree of exploratory effort.

To test the dynamics of oil's irreversible investment under uncertainty, Hurn and Wright (1994) estimated and applied a proportional hazard regression model in discrete time to investigate drivers of oilfield appraisal and production investment behaviour between discovery and field development using the UK continental shelf oil fields' data covering 1969 – 1991. They tested the influence of economic factors (expected oil price and variance of oil price), geological features (level of oil and gas reserves, geological age of field, location, water depth, and number of appraisal wells drilled), and political factors (number of licenses associated with developing a field and a dummy variable to signify whether oil block extends to neighboring areas). They found expected oil price and oil and gas reserves levels to have significant influence on appraisal duration, but there is no significant effect of variability of oil price on appraisal decision. Oil price exerts positive effect on hazard rate, while the effect of its variance is negative. Political factors also exert significant influence on oil field's appraisal investment behaviour. The result also show that once government approval is granted, economic variables are not influential in driving the startup of production, but rather geology drives production startup. Geology and political factors determines the lag length among decision to invest and commencement of production.

Other strands of literature analyzed investment behaviour at company level. More recently, Hvozdyk and Mercer-Blackman (2010) investigated investment behaviour among IOCs and NOCs. They applied Arellano-Bond general methods of modeling on the data of 73I IOCs and 29 NOCs spanning 1993 – 2007 to unravel which among the below ground and above ground risk factors exert most influence on determining investment in the upstream oil sector. Their results signify below ground risks as the most significant determinants of oil investment. They found statistically robust results with investment being significantly influenced by past investment levels, finding and development costs, as well as expected price. Similarly, the profit of an oil company exhibits positive and significant relationship with investment, but at less magnitude than expected output price. Their results also found the level of company's reserves and assets to have insignificant effect in driving investment behaviour. Similarly, the control variables of cost of capital, merger, and OPEC dummies were also not significant in explaining oil investment. Surprisingly, political stability and fiscal policy of host country were also not significant determinants of oil investment. Although technical risk was also not significant for their entire sample, it has a significant negative impact on the investment of companies operating in more difficult terrains (deep water, oil sands, etc). They also investigated the time lag in response of investment to oil price signal (spare capacity as proxy for price signal). Their results showed that the investment response of major IOCs was generally slower, but have increased to 2-3 years higher than its levels prior to 1993.

Similarly, they applied fixed effect regression and analyzed the effect of oil production on investment. Their results show statistically significant positive relationship between oil production and investment. In the same vein, Dada (2005) investigates the determinants of investment behaviour of NOCs and IOCs. He found two exciting results suggesting that OPEC spare capacity acts as a significant deterrent to investment by IOCs because it serves as paramount indicator of oil market glut, and NOCs investment is significantly driven by subsequent year's budgetary allocations. Hartley and Medlock (2008) analyzed the production behaviour and investment of NOCs and found that NOCs' investments are less efficient, mainly due to its dual role of oil production and serving as platform for redistributing wealth or employment to the populace. Furthermore, Iwayemi and Skriner (1986) applied least square regression model to firm level data of oil companies for the period of 1980 - 1996. They found a weak correlation between oil price, demand, and exploration efforts. This may be due to collinearity problem associated with their data. However, their result confirmed a high positive statistical significance of oil companies' profitability, past investment, and technological progress to oil investment decision. Reserves replacement rate negatively affect exploration investment. For recent comprehensive study on NOCs see Victor, (2008).

Cox and Wright (1976) departed from the most widely investigated determinants of upstream investment and investigate the impact of US government policies (federal corporate income tax for petroleum, import quota, production, and price control) on investments in petroleum reserves during the production prorationing period. They estimated and applied the least square model on data covering 1959 – 1971. They regressed proven oil reserves, market demand factor (set by Texas Railroad Commission), depletion rate, production and severance tax, royalty share, relative oil price, cost of production, and output. They found that various policies had significant direct and indirect impact on upstream investment in the prorationing sector. Restriction on quantity of petroleum import indirectly impacted upstream investment by limiting supply. Market demand, oil prices, and production output were controlled by state and federal governments at the time. The positive effects of oil price and production variables suggest that import quota restriction policy increased investments in the upstream sector and also special corporate income tax provisions has significant positive effect on investment. The significant positive influence of market-demand factor at lower levels increased investment in exploration and development to increase reserves. In terms of the implication of their results, limiting oil imports in relation to domestic oil production at a fixed rate resulted to an increase in domestic oil production thus resulting in faster depletion of domestic oil reserves and reducing self-sufficiency. In the same vein, special corporate income tax imposed that time has "made the present pursuit of independence more costly."

Moreover, Cate and Mulder (2007) examined the impact of oil price and fiscal policies on exploration and development investment in the Dutch continental shelf. They estimated and applied the ordinary least square modeling on data covering 1981 – 2003 to determine the effect of past and expected profit (proxy by oil price) and fiscal factors (depreciation at will (DAW) and 40 percent government participation interest dummies) on exploration and development drilling of gas. Their results show the exploration and development drilling appear to respond relatively fast to oil price variation. Development drilling responds significantly to unit profit (oil price); 1 percent increase in unit profit results to 0.8 percent increase in development drilling. Fiscal policy variable (DAW) exerts influence at its own level on development drilling with resultant increase by about 40–80% in development wells. Conversely, the DAW has a positive effect on exploration drilling in its form of change in the exploration equation, but the effect vanished swiftly subsequently. “The size of this change effect is considerable, with a small standard error.” The summary of the empirical literature on oil and gas exploration and development investment is shown in Table 4.2.

Table 4.2 : Summary of empirical literatures on upstream investment

Author	**Variables**	**Data and Model**	**Main findings**
Cox and Wright (1976)	Dependent: upstream investment Independents: proven	US (1959 – 1971) using ordinary least square	Income tax rate, market demand factor, relative oil

	reserves, market demand factor, depletion, income tax rate, and production	model	price, depletion, and production had positive influence on oil investment during prorationing period.
Drollas (1986)	Dependent: exploration and production drilling Independents: real oil price, discoveries, real cost of drilling, level of refined products, shut-in wells, and oil reserves	US (1938 – 1982) using Non-linear model	All variables are significant except cost of drilling. Oil price have strong positive influence and other variables exert positive influence.
Solomon (1989)	Dependent: exploration and development drilling Independents: real oil price, US demand for oil products, oil and gas reserves level, income tax rate, lifting cost, cash flow, and major oil companies merger dummy	US companies in OECD Europe, Canada, Middle East, Africa, West and East hemisphere (1977 – 1986) using ordinary least square	Oil and gas reserves have positive influence in all regions. Lifting cost is positive except Africa and Middle East. Cash flow of oil companies is also positive in most regions. Oil price is positively insignificant in all

			regions
Reiss (1989)	Dependent: exploration and development drilling Independents: oil price, exploration and development cost, net revenue, exploration and development wells drilled, debt/liquidity, and oil discoveries	44 independent oil and gas companies (1978 – 1986) using ordinary least square and instrument variable estimator	Oil price and cash flow exert positive effect. Debt level has negative influence. Exploration and development wells drilled exert significant positive impact.
Peseran (1990)	Dependent: exploration and production level Independents: oil price, expected oil price, production, exploration cost, and cumulative drilling effort.	UK continental shelf (1978 – 1986) using non-linear 2 stage least square	Positive effect of oil price and oil production. Negative effect of expected price and cost.
Hurn and Wright (1994)	Dependent: appraisal and production investment Independents: expected oil price,	UK Continental shelf (1969 – 1991) using proportional hazard regression model	Expected oil price has significant effect but its variance exerts insignificant effect. The number of

	variance of oil price, level of reserves, location of wells, geological age of field, water depth, number of appraisal wells drilled, and number of approvals for field development		licenses associated with field development exerts positive significant effect. Geological and political factors drive the lag length between decision to invest and production startup rather than economic factors.
Iledare and Pulsipher (2001)	Dependent: oil and gas reserves addition Independents: oil and gas prices, technical change, economic incentive, drilling cost, market condition, and depletion	US Gulf of Mexico (1977 – 1998) using seemingly unrelated regression	Positive effects of oil and gas prices and economic incentives. Negative effects of depletion and market conditions
Kaufmann and Cleveland (2001)	Dependent: oil production Independents: oil price, cost, and operator's production allocation	US lower 48 states (1938 – 1991) using error correction model	Significant positive long run effect of oil price on production. Positive effect of operator's allowable production and

			negative effect of cost on oil production
Cate and Mulder (2007)	Dependent: exploration and development investment Independents: expected profit (oil price), and fiscal policy factors (depreciation at will and government participation interest)	Dutch Continental shelf (1981- 2003) using ordinary least square	Positive significant influence of expected profit and fiscal policy factors.
Iledare (2009)	Dependent: exploration and development drilling Independents: oil and gas prices, technical progress, resource depletion, and water depth	US Gulf of Mexico (1983 – 2005) using hybrid log linear model	Positive inelastic response to gas price changes and statistically insignificant influence of oil price changes. Positive effect of depletion, technology and water depth.
Hvozdyk and Mercer-Blackman (2010)	Dependent: upstream investment Independents: past	73 IOCs and 29 NOCs (1993 – 2007)	Positive significant effect of profit, past investment,

	investment, oil and gas reserves, profit, expected oil price, development cost, fiscal regime, and political risk.	Using Arenallo-Bond general moment of methods	development cost and expected oil price. Insignificant influence of oil and gas reserves level, political risk and fiscal regime.

CHAPTER 5: MODELLING FRAMEWORK FOR OIL AND GAS UPSTREAM INVESTMENT ANALYSIS

5.0 Introduction

Selecting the appropriate model for estimating drivers of investment in the upstream oil and gas industry has not been easy taking into account the incorporation of observed and unobserved effects in the multi-country analysis of investment behaviour. This chapter describes the detailed specification of the theoretical model and the assumptions that guided its specification. It further narrates estimation technique and procedure within the panel data framework and succinctly presents description of the data used for the research and testable hypotheses.

5.1 Method

This research seeks to examine drivers of investment in oil and gas exploration and development in an international context with particular focus on OPEC MC and selected non-OPEC countries. Several researchers specify dynamic investment models using first order differences and lagged variables laying emphasis on the dependence of oil investment to past and future events. In this research, the author departs from this notion and specifies investment function in static framework due to the following considerations. (1) It is assumed that upstream investments in the oil and gas industry respond typically to current market indicators as pointers of future economic conditions particularly oil price. This assumption is closely related to Solomon (1989), but he further emphasized on the role of internal cash flow of firms as critical determinant of firms investment decision. Solomon (1989) pointed that the characteristic volatility of oil markets makes forecasting enormously risky, thus reaffirming the suitability of this assumption. (2) Including lagged dependent variables in the right hand side of the equation will introduce endogeneity problem in the model due to potential simultaneity effect among dependent variables and lagged dependent variables. (3) There is an issue of biasness in dynamic panel models with fixed effect (Nickell, 1981), which can be overcome by applying Arellano-Blundell-Bond GMM estimator or estimate the first differenced equation, which could exclude country specific effects and ensure that variables are stationary. Lestage et al (2013) asserted that such an estimate could still be biased since first differencing introduces correlation between the lagged dependent variable and the new error term. The GMM estimators of Arenallo and Bond (1991) and Blundell and Bond (1998) are considered a solution to this issue. However, there is a growing argument on the suitability of GMM for panels with large time dimension Lestage et al (2013). Owen and Judson (2009) suggest the use of “restricted GMM” for panels with up to 20 years’ time dimension. Since our panel is T=31, the use of restricted GMM is inappropriate.

Consequently, static investment function was specified to investigate the drivers of investment in the international upstream oil and gas industry. Since the data is composed of a combination of cross-section (countries) and time-series (observed over 31 years), the option of specifying panel data models (otherwise referred to as unobserved effects models[118]) is apparent following the result of Breusch-Pagan lagrange multiplier test for random effect for both OPEC and non-OPEC data sets. The statistics of the tests suggest that there are significant differences across the countries as evidenced by prob > $\chi 2$ higher than 0.05 (1.00) in both cases (figure 5.1). This indicates the inappropriateness of applying ordinary least squares for this research. Thus, confirming the suitability of panel models for this experiment.

OPEC data

	Var	sd = sqrt(Var)
invest	4.76e+08	21817.06
e	3.88e+07	6227.069
u	0	0

Var(u) = 0
chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Non-OPEC data

	Var	sd = sqrt(Var)
explora~n	4508984	2123.437
e	2347437	1532.135
u	0	0

Var(u) = 0
chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Figure 5.1: Breusch-Pagan L.M. test for random effect

Otherwise, the entire data can be pooled and treated as a large cross sectional sample and estimate one model for all observations using ordinary least squares Andersson (2007).

118 Andersson (2007).

Furthermore, the choice of panel data modeling approach is due to several advantages it offers over pooling or time series data frameworks. Since it relates to individuals, firms, countries etc., it is inherent that over time there can be heterogeneity among these entities.The essential benefit of using the panel format is that it offers the ability to model individual differences between OPEC countries under the assumption that such heterogeneities exist (Greene, 2003). Baltagi (1998) also asserted that such heterogeneities can be considered by panel data estimators, which take into account subject specific variables. He also asserts that panel data is more informative and accurate since it combines time series of cross sectional observations. It also gives more variability, degree of freedom, and less collinearity among variables, which enhances the efficiency of the estimation.

In the same vein, Hsiao (1986) and Baltagi (2001) further asserted that panel data allows the specification of more complex behavioural hypotheses, including effects which would not otherwise be captured by using pure cross-sectional or time-series data. For the attainment of our goal, three separate models were specified for the empirical analysis to unravel the determinants of exploration and development investment among OPEC MCs and selected non-OPEC members (see Table 5.1). An equation to test the impact of explanatory variables on exploration investment in OPEC MCs was specified. The factors were broadened and their influence was tested on exploration and upstream (exploration and development) investments among OPEC MCs; and lastly, similar model utilizing same variables was specified for selected non-OPEC countries.

Table 5.1: panels grouping of oil and gas investment models

OPEC		**Non-OPEC**	
Estimation of drivers of exploration investment. Model#1	Estimation of drivers of upstream investment Model#2	Estimation of drivers of upstream investment Model#3	Estimation of drivers of exploration investment Model#4
Algeria, Angola, Ecuador, Nigeria, Libya, Iran, Iraq, Qatar, Kuwait Saudi Arabia, U.A.E, Venezuela.	Algeria, Angola, Ecuador, Nigeria, Libya, Iran, Iraq, Qatar, Kuwait Saudi Arabia, U.A.E, Venezuela	Brazil, Canada, Gabon, Mexico, UK, Norway, Malaysia, Indonesia.	Brazil, Canada, Mexico, UK, Norway, Malaysia, Indonesia

In addition to the assumption in section 4.1 the following assumptions are also made during the models specification:

1. OPEC MCs are not price takers and non-OPEC countries are price takers. In the same vein, non-OPEC countries follow an exploration and development track that maximizes the expected net present value of returns from all future petroleum investments. This is suggestive of the fact that once output price changes, a competitive producer will change its investment level to fulfill an optimal condition, which

states that the “value of an additional unit of reserves added to proven reserves as a result of exploration and development drilling must be equal to the unit cost of drilling that additional exploration and development well” Iledare (2000).

2. Larger oil reservoirs are discovered first and remaining reserves declines as cumulative drilling increases making the chances of subsequent discovery to contracts as the petroleum basin matures. This is consistent with Pindyck (1978) and Iledare (2009).
3. OPEC and non-OPEC producers use same type of technology, but produce heterogeneous products (oil and gas). This assumption closely follows that of Reiss (1989), but differs in that he assumed producers produce homogenous products, but in reality it is known that the type and quality of oil produced in Saudi Arabia differs from that produced in Nigeria, Norway etc. due to differences in chemical composition.

Previous researchers have investigated the influence of global oil demand, unit exploration and development cost, and income tax rate as proxies for oil demand, cost structures, and petroleum fiscal regimes. They hypothesized a positive relationship between oil demand and a negative relationship among cost and taxation regime on upstream investment. We tested these variables but found them to be highly correlated with dependent variables.

Consequently, the variables were dropped from the model. Hence, economic, technical, and country specific factors (petroleum fiscal policy and uncertainty/oilfield performance variables) are considered in the general specification of the models against two dependent variables; (1) exploration investment and (2) upstream investment are required for the analysis of level of exploration and development investment.

Exploration investment = f (economic factors, country specific factors) and

Upstream investment = f (economic factors, technical factors, and country specific factors)

Considering the cross country nature of the study, the general form of the panel data models takes the functional forms as shown:

$$Exploinvest_{it} = \alpha + \beta_1 E_{it} + \beta_2 FP_{it} + \varepsilon_{it} \qquad \text{(i)}$$

$$Invest_{it} = \alpha + \beta_1 E_{it} + \beta_2 FP_{it} + \beta_3 T_{it} + \beta_4 PFP_{it} + \varepsilon_{it} \qquad \text{(ii)}$$

$Exploinvest_{it}$ is the exploration investment in each country in year t, $Invest_{it}$ is the upstream investments in each country in year t, E_{it} is the vector of economic factors of ith country in year t, FP represents the vector of field performance/uncertainty factors of ith country in year t, Tit is the vector of technical factor in ith country in year t, PFPit represent petroleum fiscal policy factors in ith country in year t, and εit is the error term.

Subsequently, sub-functional forms are specific for each sub-study and presented as part of the study under empirical analysis section.

5.1.1. Factors Influencing Oil and Gas Investment

5.1.1.1 Variables Description and Hypotheses

The ultimate goal of this research is to determine the factors that influence oil exploration and development investment behaviour in the international upstream oil and gas industry and provide some policy implications that will guide informed policy making. To achieve this goal, this dissertation mainly examines the following research questions: What is the influence of economic, technical, and country specific factors on exploration and upstream investments respectively? Which among the factors exert significant influence on exploration and upstream investments respectively? What is the relationship between real oil price and exploration investment? What is the influence of oil and gas rent increases on upstream investment? In order to achieve the research objective, attention was paid to examining the behaviour of OPEC producers and selected non-OPEC producers to test the uniformity or otherwise of factors that drives exploration and development spending. Moreover, it is important for OPEC and other market players to understand the drivers of upstream investment in non-OPEC jurisdictions. Hence, data description, construction of independent variables, and development of testable hypotheses will be discussed in this section.

We utilized a long panel data that spans 1980 – 2011 for 12 OPEC and 8 selected non-OPEC countries respectively to investigate the research questions stated above. The unique peculiarities and characteristics of the oil and gas industry, the numerous challenges facing the world oil market, and the cross country nature of this research presents unique challenges for variables selection and sourcing data. Consequently, extensive review of previous empirical literature on determinants of oil and gas investment behaviour informed the decision of suitable variables to be selected for this study. Similarly, insights for economic theories of investment behaviour also reinforced the variables selection decision. As a consequence, explanatory variables were selected based on literature review in section 4.1 and 4.2 respectively. Generally speaking, the data were sourced from several secondary sources. See Table 5.2 and Appendix 5.1 for list of various sources and descriptive trend of the variables among OPEC MCs and Non-OPEC countries.

5.1.1.1 Dependent variables

According to Gugler et al (2003), the usual representation of investment opportunities in the literature is the Tobin's q or some deviation from it.

Eklund (2013) assert that there are measurement errors associated with Tobin's average q[119] and Carruth et al (2008) find q to have weak explanatory power on both "within sample and out-of-sample." Moreover, it is a general measure of all types of investment Mahlich (2006). On the contrary, the choice of suitable proxy for investment in the upstream oil and gas industry has been challenging within the literature especially on country-level studies due to lack of data. Most commonly used proxies for oil and gas exploration and development investment are active rig counts in a country or number of exploration and/or development wells drilled. While this can serve our purposes, there is an apparent deficiency in capturing actual level of spending or magnitude of expenditure level by these proxies since drilling rigs and daily rates varies with geology and terrain. In this research, expenditure variables that suggest more representative measure of investment in the upstream oil and gas industry are used. Upstream exploration and capital expenditure of six multinational oil companies (ExxonMobil, ChevronTexaco, Shell, BP, and Total's) in million dollars was used as proxy for exploration in OPEC countries as well as upstream investments in OPEC and non-OPEC countries respectively. The lack of investment data of OPEC and non-OPEC NOCs also motivated the selection of this proxy variable. Similarly, the preponderance of these major companies in the global upstream business,

[119] Tobin's average $Q = M_t/K_t$ where M_t is the total market value, K_t is the replacement cost of capital at time t .Both numerator and denominator may have measurement errors.

coupled with the fact that most of the upstream investment in OPEC and non-OPEC members is undertaken by these companies in partnership with the host NOCs or on standalone basis, also informed the choice of the proxy. This data was sourced from the 2012 OPEC statistical bulletin, which was gathered based on the respective oil companies' annual reports. Furthermore, the choice is consistent with Hvozdyk and Mercer-Blackman (2010). Similarly, the exploration expenditure of 33 US based oil and gas producing companies outside the US in 2009 reached millions of dollars as proxy for exploration investment in the selected non-OPEC countries. The data was compiled by the US Energy Information Administration based on the financial reporting system requirement.

5.1.1.2 Independent variables

The independent variables are selected following extensive review of empirical and theoretical literatures on oil and gas investment behaviour. The variables are grouped into economic, field performance, fiscal policy, and technical variables to examine their relationship with the dependent variables. The economic factors consist of oil price, production, and cost. Field performance variables, which also represent uncertainty factors, comprise of reserves replacement rate, oilfield depletion rate, and geological potential. These variables are constructed in line with the literature and standard oil and gas industry definitions. Oil and natural gas rents as percentage of GDP were used as proxy for petroleum fiscal policy variables. Even though it captures income, which is economic in definition, its quantum value depends on the increase or decrease of oil and gas rents payable by industry players. Thus, it is considered plausible to represent fiscal policy using these variables. Technical variable is represented by technological progress which is a time trend variable. The detail description of each explanatory variable is as outlined below:

Economic factors:

International oil price: The OPEC Reference basket price[120] expressed in dollar real terms (Base year: 1973 = 100$/b), which is the average of OPEC member countries crude streams, was used as proxy for crude oil rise considering the fact that it is more representative of OPEC crude streams than West Texas Intermediate or Brent. However, it is comparable to Brent crude oil in terms of quality. The influence of oil price on exploration and development investment is particularly important, considering its role in defining cash flow profiles and rate of return on investment as well as revenue stream. Mohn (2007) asserted that oil price is the fulcrum of exploration

[120] Is the weighted average price of OPEC MC various crudes introduced on 16 June 2005 which is currently made up of the following: Saharan Blend (Algeria), Girassol (Angola), Oriente (Ecuador), 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). http://www.opec.org/opec_web

investment decisions. According to Hammad (2011), crude oil price has significant contribution in the planning, implementation, and evaluation of energy investment. Producers' expectation of lower future price would provide an incentive to change from riskier exploration drilling to less riskier development drilling, besides reducing the total number of wells likely to be drilled Farzin (2001). Fee (1988) assert that increase in oil prices generates higher profit for the industry resulting to expansion of activity levels with corresponding increase in cost of manpower and equipment by the services industry. Furthermore, it also results to the likely increase of taxes by host governments through imposition of windfall profit taxes on operators. Conversely, when oil prices decrease, industry profits also decrease inducing a decline in activity levels with ante rent reduction in cost of services. This decrease in rent-taking leads to improved margins that induce a renewed raise in activity level. While the effect of changes oil price affect the activity level of the exploration industry immediately, the interaction of industry forces seems to move action backwards and towards the initial stage. Although price increases can, in the short run, improve field level economics, additional rent-taking by host governments and service vendors considerably decreases the net effect. Michot (2000) pointed that oil price is the "fulcrums of exploration industry's decision." Arora (2013) further opined that higher prices spark drilling decisions since the financial return structure appears more encouraging. When prices decline, companies are prone to reduce their exploration levels, and if low prices are sustained for a long time, operators may close high-cost wells, holdup development activities, and delay high risk ventures. Moreover, Cisse (2007) concludes that hikes in crude oil prices influence investment decisions and stimulate the rig industry. Evidently, oil price is considered one of, if not the most important factor that influence investment decisions in the upstream oil and gas industry considering its impact on rate of return, project viability, and net present value of return on future investments. The choice of this variable is in line with Hotelling (1931) and empirical literature (See Riglund et al (2004), Iledare (1995), Iledare and Pulshiper (1999), Fee (1988), and Enebeli et al (2012) Hammad (2011), Farzin (2001). Michot (2000), Cisse (2007), Riglund et al (2004), Drollas (1986), Solomon(1989) and Reiss (1989). Consequently, a positive relationship between oil price and exploration and development investment is expected.

Hypothesis 1: Oil price exerts positive influence on exploration and development investment in the upstream oil and gas industry.

Oil production: The flexible accelerator theory stresses the importance of output in driving desired capital accumulation. Oil production data in million barrels per day was sourced from the 2012 BP Statistical Review. OPEC MC Output level has been the subject of academic investigation and serves as an intense puzzle due to its consequential influence on oil prices, stability of world oil market, and global economy. Furthermore, it is considered a key driver of investment decision largely because of its role in defining the cash flow profile of producers and investors. This implies that increase in production upsurges the cash flow of producers and investors, and enhances the ability to invest in risky exploration ventures, which are mostly carried out through self-funding. The economic theory suggests that the attainment of equilibrium position between market fundamentals is key to optimal market stability and social welfare maximization. But, the exhaustible nature of oil resources and its associated uneven distribution poses a progressive threat to the attainment of this goal. While global oil demand is expected to grow progressively, at least in the near and mid-terms, the uncertain nature of this demand poses great pressure on investment in capacity expansion from the supply side. On the other hand, inadequate investment in production capacity expansion will increase the exposure of world oil markets to price volatility and increase energy insecurity. In the long run, it may negatively impact the producers' cash flow and income levels, thus ultimately affecting exploration and development spending. Impliedly, this suggests the importance of oil production in driving investment. Several authors characterized this relationship and found positive influence of production on upstream investment. In addition to theoretical justification on the importance of output, the choice is also consistent with Keynes theory and empirical literature (See Cox and Wright (1976), Pesaran (1990), Hvozdyk and Mercer-Blackman

(2010), Kaufmann and Cleveland (2001) and Guerra (2007). Consequently, oil production is expected to have positive relationship with oil and gas investments.

Hypothesis 2: Oil production exerts positive influence on oil exploration and development investment in the upstream oil and gas industry.

Cost: Cost is a critical determinant of competitiveness of any venture because of its role in defining profitability of investments. This is especially true in the oil and gas industry that is characterized by huge capital outlay and long investment periods. Geological uncertainty and risks inherent with exploration and development investment reinforces the importance of cost as a critical factor that shape investment behaviour. According to Inkpen and Moffet (2011), cost in the upstream oil and gas industry can be classified into pre-production and production costs. Pre-production costs comprise of finding and development costs incurred prior to production of commercially recoverable oil and gas. Production costs (otherwise called lifting costs) are costs incurred during the commercial production of oil and gas that relates to operation, maintenance of facilities. For the purposes of this research, only finding cost component of pre-production costs is considered due to its relevance to exploration investment. These include cost of exploration and appraisal campaigns as well as cost of acquiring or purchasing reserves through mergers and acquisitions, farm-ins etc. The U.S Energy Information Administration

(EIA) defines finding cost as the average costs of adding proved reserves of oil and natural gas via exploration and development activities, and the purchase of properties that might contain reserves. Consequently, the finding costs of 33 U.S. based oil and gas companies outside United States is used as proxy for cost in this study. These costs measure oil and gas on a combined basis in dollars per barrel of oil equivalent and sourced from Energy Information Administration. EIA measured the finding costs as the ratio of exploration and development expenditures (including expenditures on unproved acreage, but excluding expenditures on proved acreage) to proven reserve additions (excluding net purchases of proven reserves) over a specified period of time. In this case, finding costs were computed as a weighted average over a period of 3 years. It is worth mentioning that the main driving force behind level of finding cost is the location and geological nature of the petroleum bearing basin. As a consequence, the shallower the oil and gas reservoir and simpler its geological characteristics, the lower the cost of finding and developing a barrel all things being equal and vice versa. Furthermore, with global depletion of peat of producing oilfields averaging 7.5 % and 11.5% for OPEC and non-OPEC respectively as well as decrease in size of marginal discoveries as seen in figure 1.1, it is plausible to deduce the progressive shift of the industry to deeper and more geologically complex terrains for search of exploration prospects and leads. This could translates to increase in exploration cost *ceterus peribus*. Thus, positive relationship between finding cost and exploration investment is ascribed. The choice if this variable is consistent with Iledare and Pulsipher (2001), Mohn (2009), Fattouh (2010).

Hypothesis 3: Finding cost positively influences exploration investment.

Field Performance /uncertainty factors:

Reserves Replacement Rate: The theory of irreversible investment under uncertainty theory postulates the negative relationship of uncertainty and investment level. The findings of several empirical economists have confirmed the validity of this assertion in the oil industry. Reserves replacement is a key growing fundamental uncertainty confronting policy makers and corporate strategists in the global oil and gas industry. This is due to progressive exhaustion of easy to find and cheap oil resources, reduction in average field of discoveries, and change in the structure of globally proven reserves ownership. OPEC NOCs dominantly controlled more than 70 percent of proven reserves due to increased resource nationalism, thus resulting in increased barriers to access reserves for IOCs. The international oil industry has entered a period where progressive maintenance of oil production levels involves profound risk taking, rising costs, and tighter margins[121]'. Majority of the oil that is easily available to IOCs is technically difficult and expensive to

[121] http://priceofoil.org/content/uploads/2010/12/RRR_final_A3spreads.pdf

produce such as the Canadian tar sands, deep water and ultra-deep water resources in Gulf of Mexico, Brazil, West and East Africa etc. Although technological progress has facilitated oil exploration, development and production from these technically challenging terrains remain as burden. Moreover, the efficiency of discoveries in terms of yield per effort still remains an issue. This may have informed the recurrent mergers and acquisitions prevalent in the international oil industry as a strategy to boost reserves replacement rate to reduce uncertainties associated with physical replacement efforts.

According to Investopedia (2013), investors and analysts use reserves replacement rate as one of measures of assessing the performance of oil companies. Reserves replacement rate (RRR) is a "measure of the amount of proved reserves added to a firm or country's reserve base during the year relative to the amount of oil and gas produced."[122] Indeed, the ultimate state is when RRR is steadily over 100 percent, as it indicates replacing more oil and gas than there is to produce. Persistence of RRR below 100 percent is indicative that the entity concern is running out of oil and gas reserves stock. We used annual proven oil reserves data in billion barrels from the US Energy Information Administration to construct this variable in line with the aforementioned definition. Despite the frequent discourse about dwindling

[122] http://www.investopedia.com/terms/r/reserve-replacement-ratio.asp

reserves replacement rate within the literature, very few empirical studies tested its influence on exploration and development investment. Consequently, the variable was selected in line with the theory of irreversible investment under uncertainty and us consistent with Iwayemi and Skriner (1986). Thus, a negative relationship between RRR and oil and gas investment is expected.

Hypothesis 4: The rate of oil reserves replacement positively influence exploration and development investment

Oilfield depletion rate: The progressive depletion of the world's giant oil fields at rates far higher than replacement levels, have been a topical source of concern for policy makers and investors in the global oil industry due to its impact on future oil supplies. Reliable forecast of future production requires careful understanding of depletion rates of oil reservoirs[123]. From investment perspectives, oil upstream investment strategy and planning relies heavily on sound understanding of depletion behaviour of oil reservoirs to understand expected future oil production and capacity expansion requirements Hook (2009). This is owing to the critical role of depletion strategy in defining future production behaviour of oil reservoirs. According to IEA about two-thirds of additional gross capacity required in the short term is to replace

[123] Hook (2009) assert that "depletion is a key factor for fluid flows within the reservoir and its connection to flow fundamentals makes it an important parameter for understanding oil production."

production declines from existing fields. It is worth noting that investment requirements are more sensitive to decline rates that rate of oil demand growth IEA (2003)[124]. It is worth mentioning that the decline rates differ widely among regions and over time depending on geology, production technology, age of field, and production policies. Usually, larger oilfields have lower decline rates due to low initial production rates relative to reserves base and pressure decline is also slower. Several scholars have examined the relationship between investment level and oilfield depletion rates, but widely used accumulated drilling activity, as proxy for resource depletion. Examples include: Ringlund et al (1984), Iledare (1995), Farzin (2001), Iledare and Pulsipher (1999), Managi et al. (2005); Kemp and Kasim (2006), Mohn (2007). But, accumulated drilling does not adequately capture the effect since some wells drilled could be dry. On the other hand, it can better serve as learning or contribute to accumulated knowledge effect. In this research, the variable was chosen in line with theoretical postulation and consistent with aforementioned empirical literatures. However, we constructed the variable based on standard definition of depletion rate in the oil and gas industry to capture the actual effect of resource depletion. Depletion rate refers to the ratio of annual production to oil reserves Sorrell et al (2009). It is simply the percentage of the remaining proved reserves that is produced each year. The

[124] For example, considering a given cost of field development, average decline rate of 10% per annum would imply that more than twice as much investment would be required in comparison to decline rate of 5% IEA (2003.

use annualized proved oil reserves data from the US Energy Information Administration and oil production data from the 2012 BP Statistical Review. Since it depicts the annual rate at which the remaining recoverable reserves of a field or region are being produced, we expect a positive relationship between exploration and development investment and oilfield depletion rate.

Hypothesis 5: Oil field depletion rate exerts positive influence on exploration and development investment

Geological potential: Geology is widely considered as a fundamental below ground uncertainty confronting the oil industry operators and host governments. Investments are made without absolute assurance of the likelihood of success in oil find. When investment results to discovery of oil or gas, the estimated volume of oil or gas in place remain a key concern due to the uncertainty associated with the extent and thickness of the hydrocarbon bearing reservoir. The success of upstream investment relies greatly on the applicable geology of the petroleum bearing basin. Once the geological potential of an area is ascertained to be robust, significant risks and uncertainties are mitigated. Consequently, it is a critical driver of upstream investment. Despite its importance, few researchers investigated the influence of geological potential on oil and gas investments. The variable was chosen in conformity with Broadman (1985), Hurn and Wright (1994) . The number of completed wells in OPEC countries was chosen as proxy for geological success, considering the fact that only successful wells are completed and the success of a well defines the promising nature of the geology of the area under consideration. The data was sourced from OPEC's 2012 Statistical bulletin and denoted in numbers.

Hypothesis 6: Geological potential of petroleum basin exerts positive influence on exploration investment.

Petroleum fiscal policy factors:

Oil and gas rents as percentage of GDP: The fiscal and taxation policy of oil producing countries greatly influences the behaviour of investors. An oil and gas rent refers to the totality of taxes and royalties, an investor pays the host government due to oil and gas exploration, development, and production. The rate of taxes an investor pays the host government influences the cash flow profile and rate of return of investments. The relationship between fiscal regime (taxes) and upstream investment have been widely analyzed in the literature. Recently, Cate and, Mulder (2007) and Nakhle (2007) found increases in fiscal regimes (taxes) negatively impacting exploration and development investment in the Dutch and UK continental shelves respectively. Padilla (1992) further reinforced that the impact of institutional factors (taxation, contractual terms, and political risks) change operator's expectations. Consequently, a negative relationship is expected between oil rent and upstream investment. Most of previous researchers use income tax rate as proxy for fiscal regime, but we find income tax rate to have positive correlation with our dependent variable. Hence, it was dropped due to high likelihood of endogeneity, which negatively impacts the validity of our result. Even though oil and gas rents as percentage of GDP are income indicators, it adequately captures the total taxes payable to government by oil companies. Thus, we can consider it plausible to adopt it as proxy for petroleum fiscal policy. The choice was in line with Cox and Wright (1976), Solomon (1989), Iledare (1995), Kasim and Kemp (2006), Nakhle (2007), Padilla (1992), Cox and Wright (1976), Solomon (1989), Iledare (1995), Cate and Mulder (2007) and Hvozdyk and Mercer-Blackman (2010). The data in percentage was sourced from World Bank's world data bank.

Hypothesis 7: Oil and gas rents exert negative influence on exploration and development investments in the upstream oil and gas industry.

Technical factor:

Technological progress: Technological advancement has been a key driver of upstream investment in the oil and gas industry. The industry has historically relied on technological progress to advance the frontier of oil and gas exploration, development, and production. Since the dawn of the 20th century, the importance of technological innovation has gained a renewed importance due to fast exhaustion of easy to find oil and limited access to reserves for IOCs. This provides incentive for research and development on exploration, development, and production of hydrocarbon resources from difficult and technically challenging terrains. The advent of 3D seismic technology has prompted deep water exploration which has been a major source of incremental oil discoveries in West Africa, Brazil, Gulf of Mexico, and North Sea. It has also reduced failure in exploration (dry holes), increased accumulation of geological knowledge (learning effect), and increase efficiency of marginal discoveries. Managi et al (2005) pointed that the industry heavily depends on technological improvements to progressively maintain output and reduce costs. In the same vein, horizontal drilling, deep-water platforms, and seismic technologies have resulted in the addition of economic reserves and the decrease in cost of discovery (Bohi, 1997). The advent of 4D seismic technology revolutionized the industry’s ability to monitor the behaviour of oil reservoirs and fluid movements, thus enhancing well placement and recoverability of oil. Mohn (2009) further asserts that advances in exploration and development technologies have improved the gathering and interpretation of geological data, efficiency of well placement and drilling, as well as real-time monitoring and measurement of the down hole reservoir conditions. Consequently, positive influence of technological progress on oil investment is expected. The effect of technological progress has been widely examined in the empirical literature and time trend variable has been mainly used as proxy. Due to lack of data on actual patents registered, we also use time trend variable as proxy for technical progress under the assumption that technology improves with time. It is defined such that first year equals 1, second year equals 2, up to 31. The choice was in line with Iwayemi and Skriner (1986), Iledare (1995), Iledare (1999), Iledare and Pulsipher (1999), Iledare (2001), Farzin (2001), Managi et al (2005), Mohn (2007), Mohn (2009), and Osmundsen et al (2010), (Bohi, 1997), Iledare and Pulsipher (2001).

Hypothesis 8: Technical progress exerts positive significant influence on exploration and development investments in the upstream oil industry.

To test the hypothesized relationships to examine the research questions and attained the objectives of this research, the coefficients of the explanatory variables were estimated using fixed and random effects models respectively.

Table 5.2: Summary of variables description and sources used for the research

Acronym	Variable name	Description	Source
Exploinvest	OPEC exploration investment	Capital and exploration expenditure of Shell, Chevrontexaco, Exxonmobil, Total, Conocophillips and BP in $million	OPEC 2012 Statistical Bulletin
explo	Non-OPEC exploration investment	Exploration expenditure of 33 US based oil and gas	US Energy Information Administration

		companies outside US in $million (2009 $ constant)	
invest	Upstream investment	Capital and exploration expenditure of Shell, Chevrontexaco, Exxonmobil, Total, Conocophillips and BP in $million	OPEC 2012 Statistical Bulletin
oilprice	International oil price	OPEC reference basket price expressed in real terms (base:1973 = 100$/b)	OPEC 2012 Statistical Bulletin
oilprod	Oil production	Annualized oil production in million barrels	US Energy Information Administration
cost	Cost	Average finding and development cost of a barrel oil equivalent in $million	US Energy Information Administration
oil reserves	Oil reserves	Annualized proven oil reserves in billion barrels at end of 2011	BP 2012 Statistical review
deprate	Oilfield depletion rate	Ration of annual production to reserves in a given year expressed in percentage	Author's construction
resrep	Reserves replacement rate	Ratio of net additions to reserves and annual production in agiven year expressed in percentage	Author's construction

geolpoten	OPEC geological potential	Number of completed exploration and development wells in OPEC countries	OPEC 2012 Statistical Bulletin
geolpoten	Non-OPEC geological potential	Number of completed exploration and development wells of 33 US based oil and gas companies outside US	US Energy Information Administration
oilrent	Oil rent	Oil rent as percentage of GDP expressed in percent	World bank data base
gasrent	Natural gas rent	Natural gas rent as percentage of GDP expressed in percent	World bank data base
techprog	Technological progress	Time trend with first year in the data series = 1, second year = 2 up to 31	Author's construction in line with literature

5.2 Theoretical Model

Fixed and random effects models are estimated for this research to examine the factors that influence exploration and upstream investment (exploration and development) mainly in OPEC MCs and selected non-OPEC producers[125]. However, it is acknowledged that there are varied and diverse forms of panel

[125] According to Andersson (2007), the most basic forms of panel data models can be grouped into fixed effects (FE) and random effects (RE).

data econometric models[126] than the basic models (fixed and random effects), but the desire of incorporating the effects of unmeasured or unobserved factors on upstream investment and eliminate biasness due to omitted variables reinforce this choice. Wooldridge (2002) stressed the advantage of 'eliminating omitted variable biasness' as an argument for unobserved effects models. If the unmeasured effects are constant over time (time-invariant), a 'fixed or random effects model would account for this feature and allow us to estimate models based on a sample of OPEC and non-OPEC countries. The group specific effects can either be modelled as countries constants or countries specific random elements' Andersson (2007). Thus, the procedure applied using fixed and random effect models to attain the objective of investigating the effects of various explanatory variables in influencing upstream investment in OPEC and non-OPEC countries within the period 1980 – 2011, is as outlined below (figure 5.2):

1. Correlation matrix of the variables was firstly examined to check for possible correlation among variables that can introduce biasness in our estimated result.
2. Descriptive statistics was computed to understand the basic statistical characteristics of the data in terms of mean, standard deviation, number of observations, minimum values, and maximum values.

[126] For details on panel data models see Wooldridge (2002) and Baltagi (2005)

3. Fixed effect and random effect models were estimated to get the coefficients of our explanatory variables and determine the fitness of the regressors/models.
4. The Hausman test was conducted to guide the choice of most consistent model between the two models given our data structure for better results.
5. The Breusch-Pagan test was carried out to check for cross sectional dependence among the residuals.
6. The Woodridge test of serial correlation was conducted to check for autocorrelation within the data.
7. Test for group wise heteroskedastcity was conducted to detect presence of heteroskedasticity among the variables.
8. The Driscoll and Kraay covariance matrix estimator was applied to adjust the standard errors of the coefficient estimates for serial correlation and cross sectional dependence.
9. The Hadri test for unit roots was carried out to check for stationary or non-stationary nature of the variables.

It is worth noting that the cross country analysis conducted utilizes panel data approach and used the fixed effect model with Driscoll and Kraay standard errors and random effect models. These models were estimated and applied for exploration investment equation of OPEC MCs, upstream investment behaviour equations of OPEC MCs and selected non-OPEC countries as shown in Table 5.1 to determine separate coefficients of the regressors in order to discern their effects on the dependent variables.

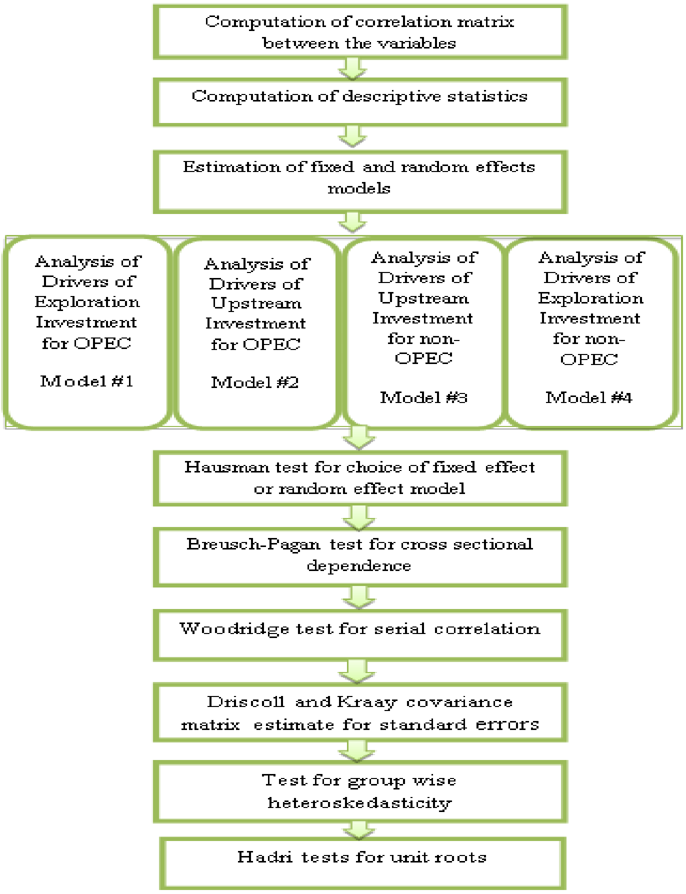

Figure 5.2: Models estimation procedures

Fixed effects and Random effects models

The basic assumption of the fixed effect model is that the explanatory variables are correlated with the country's time-invariant, unobserved heterogeneities. Random effects model assume no correlation between country's specific time–invariant, unobserved characteristics and the explanatory variables Woodridge (2009) & Baltagi and Chang (1994). Kohler and Kreuter (2009) stated that the advantage of RE is that time-invariant variables can be included in the model while in FE; these variables are absorbed by the intercept. They further asserted that the time-invariant characteristics in FE are unique to each country and should not be correlated with other country's characteristics. Each country is different, therefore one's error term and constant (which captures country's characteristics) should not be correlated with the others. Thus, the estimated coefficients of the FE model will not be biased because of omitted time-invariant characteristics. If the error terms are correlated, then FE is not appropriate since inferences may not be correct and RE model may be suitable in this case. The mathematical formulation of the two models flows as outlined below.

Consider the following linear unobserved effects formulation

$$y_{it} = \alpha + \beta X_{it} + \mu_i + \varepsilon_{it} \qquad (1)$$

$i = 1 \ldots \ldots \ldots 12 \; and \; t = 1 \ldots \ldots \ldots .31$ And

$$i = 1 \ldots\ldots\ldots 8 \; and \; t = 1 \ldots\ldots\ldots 31$$

Where y_{it} is the dependent variable, X_{it} is the independent variable, μ_i is the unobserved country specific time invariant effect, and ε_{it} is the error term.

As mentioned earlier, the fixed effect model allows correlation of unobserved constant effects μ_i with regressor matrix X_{it} unlike random effects model that do not permit such interaction.

The above stated FE assumption implies strict exogeneity of the X_i conditional to μ_i (unobserved time invariant characteristics Woodridge (2002), mathematically denoted as:

$$E/(\varepsilon_{it}/X_{it}, \mu_i) = 0, \text{ t} = 1, 2\ldots\ldots\ldots31 \qquad \text{(a)}$$

For β to be estimated under above assumption (a) of FE, equation (1) have to be transformed to eliminate the unobserved effects μ_i. Thus, the transformation is obtained by averaging equation (1) over t =1………..31 to derive the cross equation.

$$\overline{\overline{yi}} = \alpha + \beta\overline{X}_i + \mu_i + \overline{\overline{\varepsilon}}_i \qquad (2)$$

Where $:\overline{y}_i = \frac{1}{T}\sum_{t=1}^{T} yit, \overline{X}_i = \frac{1}{T}\sum_{t=1}^{T} Xit, \overline{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon it$

Taking the difference between equations (2) and (1) for each t yields FE transformed equation

$$y_{it} - \overline{y}_i = \beta(X_{it} - \overline{X_i}) + (\varepsilon_{it} - \overline{\varepsilon}_i) \quad (3)$$

The set of equations (1) – (3), forms the mathematical basis for estimating fixed effects model. In the software Stata, it is estimated using the command xtreg devar varlist, fe

As previously mentioned, in the case of random effects model, the assumption of no correlation between μ_i and X_i holds which is a strict exogeneity assumption in terms of zero correlation implying that:

$$\text{Cov}\,(X_{it}, \mu_{it}) = 0,\ t=1, 2\ldots\ldots\ldots\ldots31. \quad \text{(b)}$$

For justification of statistical inference and efficiency, there is a need for stronger RE assumptions in terms of conditional expectations Woodridge (2002).

$$\text{E}\,(\varepsilon_{it} / X_i, \mu_i) = 0,\ t=1, 2\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..31 \text{ (exogeneity condition)} \quad \text{(c)}$$

$$\text{E}\,(\mu_i / X_i) = \text{E}\,(\varepsilon_i) = 0 \qquad \text{(orthogonality condition)} \quad \text{(d)}$$

Now consider the following formulation

$$y_{it} = \alpha + \beta_1 X_{it} + \mu_i + \varepsilon_i \quad (4)$$

Considering assumption (c) in the random effect framework, the error term is composite in nature having two components, thus;

$$\vartheta_i = \mu_i + \varepsilon_{it} \qquad \text{(e)}$$

Therefore, Cov $(X_{it}, \vartheta_i) \neq 0$ (f)

Consequently, there is likelihood of serial correlation in the composite error (d). Therefore, strict assumption of exogeneity between the composite error term and explanatory variables is required. Hence, equation (5) can be written as:

$$y_{it} = \alpha + \beta_1 X_{it} + \vartheta_i \qquad (5)$$

And assumption (d) can also be written as:

$$\text{E}\ (\vartheta_{it}/X_i) = 0, \ \ t=1,\ 2\ldots.31 \qquad \text{(g)}$$

To eliminate the serial correlation problem, equation (5) was transformed to

$$\tilde{y}_i = \alpha + \beta_1 \tilde{X}_{it} + \tilde{\vartheta}_i \qquad (6)$$

Introducing γ in equation (6) and taking the difference between equations (5) and (6), the random-effects estimator became equivalent to estimation of:

$$y_{it} - \gamma \tilde{y}_i = (1-\gamma)\alpha + (X_i - \gamma \tilde{X}_i)\beta_1 + [(1-\gamma)\vartheta_i + (\vartheta_{it} - \gamma \tilde{\vartheta}_i)] \qquad (7)$$

Where γ is a function of $\theta_\mu^2 + \theta_\varepsilon^2$. Since both within and between information are used by the random effects estimator, let's consider a variation in equation (1)

$$y_{it} = \alpha + \beta_1 X_i + (X_{it} - X_i)\beta_2 + \mu_i + \varepsilon_{it} \quad (8)$$

And variation in equations (2) and (3)

$$y_i = \alpha + \beta X_i + \mu_i + \varepsilon_i \quad (9)$$

$$y_{it} - y_i = (X_{it} - X_i)\beta_2 + (\varepsilon_{it} - \varepsilon_i) \quad (10)$$

Thus, β_1 is estimated by the within estimator and β_2 is estimated by the between estimator.

Furthermore, the quality of fitness with respect to equations (1), (2), and (3) can be measured:

Given $\widehat{\alpha}$ and $\widehat{\beta}$ estimates of β

$$\hat{y}_{it} = \hat{\alpha} + X_{it}\hat{\beta} \quad (11)$$

$$\hat{\bar{y}}_i = \widehat{\alpha} + \bar{X}_i\widehat{\beta} \quad (12)$$

$$\hat{\hat{y}}_{it} = (\hat{y}_{it} - \hat{\bar{y}}_i) = (X_{it} - \bar{X}_i)\widehat{\beta} \quad (13)$$

The set of equations (4) – (10), forms the mathematical basis for estimating random effects model. In the software Stata, it is estimated using the command *xtreg devar varlist*, *re*

PART III: EMPIRICAL ANALYSIS

Chapter 6: COMPETING FACTORS INFLUENCING EXPLORATION INVESTMENT BEHAVIOUR IN UPSTREAM OIL AND GAS INDUSTRY: EVIDENCE FROM OPEC COUNTRIES[127]

6.0 introduction

Oil and gas can be considered as the cornerstone of the modern society because of its role in providing affordable energy to energize production processes, fuel global economy, provide income for producers, and support everyday life. However, the uneven distribution of oil resources, fast exhaustion and depletion of existing oilfields, and the progressive reduction in size of discoveries threaten the global oil supply balance and energy security. It is more profound that demand for oil is rising and exploration investment is declining. It is therefore pertinent to investigate the drivers of exploration investment. Investment in exploration is indeed required to add to reserves and replace the depleting recoverable volumes to ensure adequate future

[127] This is a revised update of the paper presented during the 36th International Association of Energy Economist International Conference at Daegu, South Korea, June, 2013.

supplies. Thus, exploration is the traditional way of adding to reserves stocks, but the extension or revision of existing oilfields also lead to reserves addition. However, the exploration process is confronted with numerous uncertainties and risks such that even with technological improvement, it remains to be a big gamble due to the lack of certainty on commercial availability of oil in a given petroleum basin prior to oil discovery. Exploration plays [128] are identified based on geological and geophysical analysis, as well as expert knowledge. Exploration wells are drilled into several layers under the ground that are presumed to hold oil and/or gas resources Mohn (2009). Exploration drilling may take place in unexplored areas where discovery has not been made. It may also occur in underexplored areas where not many discoveries have been made. The same is applicable to areas where fields have been developed and chances of success are higher; from there, wells are developed for oil processing and transportation infrastructure. Irrespective of the nature of the exploration terrain, the investment decision and exploration strategy involves dynamic interaction and tradeoff among competing factors. Even when the geological potential is promising, economic, technological, and policy considerations have to be prioritized and managed among contending

[128] A petroleum play is a geographically bounded area where a combination of geological factors suggests that producible petroleum can be discovered. The four most important factors are: 1) a reservoir rock where petroleum is contained 2) a tight geological structure (a trap) that covers the reservoir rock to prevent oil from migration 3) a mature source rock containing organic material that can be converted into petroleum 4) top seal that prevent lateral migration of oil and/or gas .Modified from Norwegian Petroleum Directorate, 2007

exploration opportunities. Furthermore, most, if not all the risky investments involve partnership and collaboration with producing countries NOCs which do not only pursue profit maximizing objectives. This difference in objectives between NOCs and IOCs also present an additional investment challenge. Maximizing social benefits derived from the exploitation of petroleum resources is the primary concern of host governments Tord (2010). Consequently, the fiscal terms and sharing mechanisms at the exploration phase, compounds the uncertain nature of investment decision Bhattacharya (2010). Several researchers have analyzed the influence of various factors (economics, policy, technology, and geology) in driving exploration investment decision in various petroleum rich jurisdictions. Less attention has been on examining investment behaviour in developing countries. Similarly, there is lack of empirical studies on drivers of exploration investment with broad emphasis on below ground uncertainties. At the exploration phase, below ground factors play critical roles in making investment decisions, considering the fact that the success of the venture depends largely on below ground unknowns. Even when oil price is high, non-promising geological conditions may inform delay, suspension, or complete change of investment plans. This study seeks to broadly investigate the influence of below ground factors (reserves replacement, oilfield depletion rates, and geological potential), economic (oil price and production) on exploration investment in OPEC countries which have high potential for marginal oil discoveries. In another front, Michot (2000) stressed that oil price is one of the "fulcrums of exploration industry's decision making." Considering the strategic importance of oil price in investment decision due to its influence in defining cash flow and rate of return on investment, this study also seeks to investigate the relationship between oil price and exploration investment.

6.1 Empirical Analysis

6.1.1 Data

Economic and uncertainty/field performance variables are used for this experiment to investigate the influence of various competing factors on exploration investment. The critical roles of these variables that guided their selection for this experiment, are consistent with theoretical and empirical insights as outlined in section 5.1.1.1. and described in section 5.1.1. As a first step in the empirical analysis, the descriptive statistics of the variables are computed to understand the basic statistical structure and properties of the data as presented in Table 6.1 and details in Appendix 6.1. Evidently, there is a significant variation among the variables as indicated by standard deviation, which is suggestive of within subject variability.

Table 6.1: Descriptive statistics of variables used for exploration investment analysis

sum exploinvest oilprice oilprod deprate resrep geolpoten

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**

exploinvest	384	41232.47	29532.23	16307	135370
oilprice	384	7.374344	4.011016	2.44	16.331
oilprod	384	8.24e+08	8.06e+08	4.70e+07	4.10e+09
deprate	384	.0265313	.0229991	.001	.15
resrep	384	3.413021	16.92952	-76	227
geolpoten	384	163.1589	243.7338	0	1560

Consequently, the correlation matrix of the variables was computed to check the adequacy and validity of the variables for this experiment against possible multicollinearity due to feedback between dependent variable and independent variables, or among the independent variables. The result was found to be within acceptable ranges with no significant correlation between any pair wise, which is suggestive of lack of simultaneity effect among the variables (Table 6.2 and details in Appendix 6.2). Similarly, the result also gives an idea of the association among the variables.

Table 6.2: Correlation matrix of variables used for exploration investment analysis

pwcorr exploinvest oilprice oilprod deprate resrep geolpoten

	exploinvet	Oilprice	oilprod	deprate	resrep	geolpoten
exploinvest	1.0000					
oilprice	0.6255	1.0000				
oilprod	0.1708	0.0395	1.0000			
deprate	-0.0899	-0.0028	0.3373	1.0000		

resrep	0.1306	0.0810	0.0315	0.1546	1.0000	
geolpoten	0.2051	0.1448	0.2795	0.1400	0.0696	1.0000

6.1. 2 Model estimation

To achieve the objectives of this research and test the hypotheses that flow of exploration investment is positively influenced by oil production, reserves replacement rate and geological success, oilfield depletion rate and determined relationship between oil price and exploration investment, oil exploration is assumed to be a function of these variables. Additionally, the assumptions outlined in section 5.1 also hold. Consequently, the exploration investment equation is as follows:

Exploinvest = *f* (oil price, oil production, reserves replacement, oilfield depletion, geological potential)

The cross country panel data approach was used to investigate the drivers control for and/or account for country specific heterogeneities. Hence, fixed effects and random effects models were specified and estimated based on the aforementioned assumptions in section 5.1 as follows:

$$EI_{it} = \alpha_i + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 geolpoten_{it} + \varepsilon_{it}$$

(Fixed effect model) (1)

$$EI_{it} = \alpha + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 geolpoten_{it} + \mu_{it} + \varepsilon_{it}$$

(Random effect model) (2)

Where i = 1……12 , t = 1………..32

EI_{it} is the exploration investment in each country in year t, $oilprice_{it}$ is the oil price in ith country and year t, $Prod_{it}$ is the oil production of ith country in year t, $resrep_{it}$ is the reserves replacement rate of ith country in year t, $deprate_{it}$ is the oilfield depletion rate of ith country in year t, $geolpoten_{it}$ is the geological potential of ith country in year t, αi is each country's unknown intercept which captures each country's unobserved time-invariant specific heterogeneity in the fixed effect model , ε_{it} is the error term in the fixed effect model. While in the random effect specification, ε_{it} and u_{it} are within and between countries error terms respectively.

6.1.3 Empirical Results

The estimated results of the two equations that tested hypothesized relationships and constitute exploration investment models for OPEC countries are reported in Table 6.3 and details are in Appendix 6.3a & b. The models generally show expected signs and confirm the validity of hypotheses 1, 2, 4, 5 and 6. In hypothesis 5, positive influence of depletion rate is anticipated but the results revealed negative relationship with exploration investment. The models also show satisfactory performance as evidenced by F-test which revealed a Prob > F less than 0.005 (0.000) in all cases confirming that the coefficients are different from zero. However, the fixed effects model shows more robust statistical performance and relationships among our dependent variable, and the explanatory variables with an R^2 of 0.5922. This indicates that a significant portion (59.2%) of the observed variation in exploration investment within OPEC members from 1980 – 2011 is explained by the independent variables. Conversely, the random effect model shows an R^2 of 0.4258 implying that about 43% of the variation of exploration investment within and between the countries during this period is explained by the regressors. Furthermore, the fixed effects model revealed statistically significant influence of the oil price, production, oilfield depletion rate, and geological potential on exploration expenditure at 0.001 and 0.005 levels respectively. On the other hand, the random effects model show a significant effect of only oil price and production on exploration investment at 0.001 and 0.1 levels respectively. As expected, 76 percent of the variance is due to differences across panels in the fixed effects model as evidenced by rho = .76738187 while none in the random effects model (rho = 0).

Table 6.3: Results of fixed and random effect models regression for exploration investment

Variable	Exploration investment in OPEC Countries	
Exploration	Fixed effect model	Random effect model

investment		
Oil price	4077.001 *** (0.000)	4444.485*** (0.000)
Oil prod	.000038 *** (0.000)	4.39e-06 ** (0.005)
Depletion	-356324 *** (0.000)	-32728.26 (0.545)
Reserves replacement	114.6463 (0.059)	133.064 (0.056)
geological potential	20.70088 * (0.014	9.13078 (0.067)
cons	-14476.83 *** (0.000)	3765.267 (0.245)
rho	.76738187	0
R^2	0.5922	0.4258
F-test	F(5,367) = 106.59, prob > F = 0.0000	Wald chi2(5) = 280.28 Prob > chi2 = 0.0000
Sigma_ u	34991.64	0
Sigma_e	19265.52	19265.52
N	12	12
No. of obs	384	384

Legend: * P < .05, ** P < .01, *** P <. 001 p-value in parentheses

6.1.3.1 Panel Tests

A series of statistical tests performed confirmed the validity of the estimated results. The Hausman test carried out inferred fixed effect model as the most suitable over random effects model given our data structure. Since our data is a macro panel with long dimension (T=31); the Breuch-Pagan LM test carried out to check for cross-sectional dependence in fixed effects framework, while the Wooldridge test for serial correlation indicates that the residuals are correlated across entities and the errors are also serially correlated. The Driscoll and Kraay covariance matrix estimator was subsequently applied to adjust the standard errors of the coefficient estimates for dependency in the residuals. The Woodridge test for the presence of group wise hetersokedasticity among the variables was also performed. Hadri LM test for stationarity was also implemented to check for the presence of unit roots among the variables. The detail result of the tests is presented as follows:

6.1.3.1.1 Hausman Test

Hausman (1978) designed a test for orthogonality between the regressor and the random effect to guide selection between the FE and RE specifications Greene (2003). The test statistics calculated for time varying regressors determining whether there is significant difference between fixed and random effects models. Under the null hypothesis, the difference between the estimates of the two models should not differ systematically. The result of the test is presented in Table 6.4 with details presented in Appendix 6.4

Table 6.4: Result of Hausman test for exploration investment analysis

Variable	Fixed effect coefficients (b)	Random effect coefficients (B)	b-B
Oil price	4077.001	4444.485	-367
Oil production	0.000038	4.39e-06	0.00000336
Depletion rate	-356324	-323595.7	-323595.7

Reserves replacement	114.6463	-18.41771	-18.41771
Geological potential	20.70088	9.13078	11.5701
Hausman's test statistics χ^2 (4) = 37.39		Prob > $\chi 2$ = 0.0000	

The value of the test statistic 37.39 exceeds the critical value 1.96 and prob. value is 0.0000 which is less than 0.005. This implies the rejection of the null hypothesis and acceptance of the alternative. Therefore, the decision criteria confirms the suitability of fixed effect model over random effect model. FE estimator is consistent under both the null and alternative hypothesis given the data structure, while the RE estimator is efficient under the null, but inconsistent under the alternative. The test was conducted using Stata software through the command *hausman fe re*

6.1.3.1.2 Breusch-pagan test (1980) for cross sectional dependence

According to Baltagi (2001), cross sectional dependence can be a problem in macro panels with long time series (over 20-30 years). However, it is not much of a problem in micro panels (few years and large numbers of cases). Breusch-Pagan (1980) developed a Lagrange multiplier test to check whether residuals are correlated across entities. Torres-Reyna (2013) pointed that Cross-sectional dependence can result to bias in tests results. Several scholars apply Breusch-Pagan LM test for cross-sectional correlation in a fixed effects model and panel data models. The test assumes independence of errors. Drukken (2003) pointed that this test has good size and power properties in a reasonably sized sample. The null hypothesis of the tests assumes that residuals across entities are not correlated. Deviation from independence of errors in panel data is the likelihood of contemporaneous correlation across entities. The LM test statistics show evidence of dependency as evidenced by Pr < 0.05, thus rejecting the null hypothesis becomes apparent. The result is presented in Table 6.5 and details are in Appendix 6.5. The test was conducted on Stata software using the command *xttest2*.

Table 6.5: Result of Breusch-Pagan LM test of cross sectional dependence in exploration investment models

Breusch-Pagan LM test of independence
χ^2 (66) = 1312.112 , Pr = 0.0000
based on 32 complete observations over panel units

6.1.3.1.3 Woodridge (2002) test for Serial Correlation

Serial correlation is also a potential problem associated with macro panels with long time series (over 20-30 years). Serial correlation causes the standard errors of the coefficients to be biased leading to less efficient results (smaller than actual and higher R-squared). Thus, there is the need to check for serial correlation in the idiosyncratic error term in panel data linear models. Woodridge (2002) developed a robust and simple test for serial correlation, which utilizes the residuals from the regression in first differences. It is worth noting that first differencing data removes the individual-level effect based on time-invariant covariates and the constant. The test is reported to possess good statistical power properties in reasonably sized data samples (Drukker, 2003). The null hypothesis of the test assumes no first order serial correlation. The result of the test indicates that the errors are serially correlated as evidenced by Pr < 0.005 (0.0000) (Table 6.6 and Appendix 6.6). Hence, the null hypothesis is rejected. The test is performed using *xtserial dependent variable independent variables* on Stata.

Table 6.6: Result of Woodridge test for serial correlation for exploration investment model

FE Model	H0: no first order serial correlation F (1,11) = 2148.253 Prob >F = 0.0000

6.1.3.1.4 Test for group wise heteroskedasticity

The Heteroskedasticity problem arises when the variance of the unobserved error depends on the explanatory variable. As a consequence, the estimated model will not be able to get unbiased estimators of the ceteris paribus effects of the explanatory variable on the dependent variable Woodridge (2006). The most likely deviation from homoscedastic errors in the context of panel data is error variances specific to the cross-sectional units. Group wise heteroskedasticity arise when error process is homoskedastic within cross sectional units, but its variance differs across units. Green (2000) developed Modified Wald test to check group wise heteriskedasticity in panel models. Stata command *xttest3* computes a modified Wald statistic for group wise heteroskedasticity in the residuals of a fixed-effect regression model in line Green (2000). The null hypothesis of the test assumes homoscedastic error process within cross sectional units implying that $\sigma_i^2 = \sigma^2$ for $i = 1 \ldots\ldots\ldots 12$.. According to Baum (2001), the modified Wald statistic calculated is feasible once the assumption of normality is disrupted at least in asymptotic terms. He further asserted that the power of the test is very low in the context of fixed effects with Large N, small T panels. This reaffirms the suitability of the test in this case given our sample structure Large T and small N. The resulting test statistic presented in Table 6.7 and Appendix 6.7 is distributed Chi-squared under the null hypothesis of homoscedasticity. The result confirms the consistency of the null hypothesis in our model as evidenced by (P>0.05) which suggest no evidence of group wise heteroskedasticity. The null hypothesis is therefore accepted.

Table 6.7: Results of modified Wald test for group wise heteroskedasticity in fixed effect model

FE model	H0: sigma (i)^ 2 = sigma ^ 2 for all i Chi2 (12) = 12.64 Prob > chi2 = 0.3960

6.1.3.1.5 Driscoll and Kraay (1998) test for robust standard errors

The Driscoll and Kraay (1998) test was applied to estimated coefficients of the fixed effects models to correct for the presence serial and auto correlation in the estimated models. The presence of serial and auto correlation in estimated panel models causes the biasness of standard errors. Antoine et al (2010) pointed that ignoring correlation of regression disturbances over time in the estimated panel data models can result in biasness of statistical inference. Most recent studies that use panel data models use robust standard error estimators which entail the application of covariance matrix estimators to adjust the standard errors of the estimated coefficients for possible dependence in the residuals. Antione et al (2010) pointed that standard error estimates of commonly applied covariance matrix estimation techniques are biased due to the inadequacy in accounting for auto correlation. Driscoll and Kraay (1998) modified the standard nonparametric covariance estimator in such a way that it is robust to general forms of cross-sectional and temporal dependence relying on large T- asymptotics Hoechle (2007). He applies the Newey-West type adjustment to the sequence of cross sectional averages of the moment conditions Hoechle (2007). Changing the standard error estimates in this form ensures that the covariance matrix estimator is consistent, independently of the cross-sectional dimension N. The test assumes that the error structure is heteroskedastic or (homoscedastic as in this case), auto correlated up to some lag, and possibly correlated between the panels. Since it is known that investment shock in one year could continue into several years, the assumption of 3 years lag made in this regards. This is consistent with Hvozdyk and Mercer-Blackman (2010) who found 2-3 years lag between price signal and investment of major IOCs. The results of the test confirmed the correction of the error structure in the fixed effect model. Stat command *xtscc dependent variable, independent variables, fe* is used to perform the test. The result is presented in the section for analysis of FE result.

6.1.3.1.6 Hadri (2000) test for unit roots

The unit root test for stationarity of variables has widely been applied in time series analyses, but recently, there is growing interest in its application in panel data models. Hadri (2000) developed Lagrange Multiplier (LM) procedures to test the null hypothesis that all the individual series in the panel are stationary (either around a mean or around a trend) against the alternative hypothesis that at least one series contain unit root exist. The assumption of normal distribution of error terms also hold and implemented for panel models with fixed effects, individual deterministic trends, and heterogeneous errors across cross-sections. It is suitable for panels with Large T and moderate N like in this case (T=32, N=12) and requires data to be strongly balanced like in this case. The test is correct asymptotically as T tends to infinity followed by

N tending to infinity. The LM tests are based on the simple average of the individual univariate stationarity test, which after a suitable standardization follows a standard normal distribution. The results of the test is consistent with the null hypothesis as evidenced by the test statistics and p-value <0.005 (Table 6.8). Hence accepting the null hypothesis and concluding stationarity of all the series. The Stata command for this test is *xtunitroot hadri variable*. For details of the test results see Appendix 6.8.

Table 6.8: Results of Hadri (2000) test for unit roots in exploration investment model

H0: All panels are stationary Ha: Some panels contain unit roots Time trend: Not included Heteroskedasticity: Not robust	Number of panels: 12 Number of periods: 31 Asymptotics: T,N -> Infinity sequentially	
Variables	Statistics	P-Value
Exploration investment	43.9336	0.0000 (Null accepted)
Oil price	12.0797	0.0000 (Null accepted)
Oil production	40.7501	0.0000 (Null accepted)
Reserves replacement	2.77742	0.0000 (Null accepted)
Oilfield depletion	20.7630	0.0000 (Null accepted)
Geological potential	24.8141	0.0000 (Null accepted)

6.1.4 Justification for the choice of fixed effects model

The fixed effect model implies within-effect, while the random effects model constitutes both within and between effects. The estimated coefficients of the fixed effect models could be considered as average within-country effects of independent variables on the dependent variable implying the degree of change of dependent variable when an independent variable increases by one unit. Conversely, the coefficients of the random effects model can be interpreted as the average effect of the independent variables over the dependent variable when the independent variables change across time and between countries by one unit. The decision criteria of selection between the two models entail tradeoff between bias and variance. According to Clark and Linze (2012), fixed effects model produce unbiased estimates of β depending on sample to sample variability. On the other hand, random effects model will, in most cases, introduce bias in estimates of β due to partial pooling of information across entities. However, it can significantly constrain the variance of the estimates making them closer to the true value on the average. Since the coefficients of β in the fixed effects model are averaged within effects of x on y, it may produce estimates that are highly sample dependent – that is, overly sensitive to the random error in the data set in the case of few observations per unit or that x does not vary much within each unit, relative to the amount of variation in y (Clark and Linze, 2010). They further pointed that in that case, estimates of the within-unit effects of x on y can differ greatly from the true effect. Additionally, when there is relatively small number of units, it becomes progressively possible for the within-unit effects to differ from the true effects in the same direction. Then, the estimates of β produced by the fixed effects model can be quite different from the true β also under this condition. Nevertheless, none of this assertions applies to this study given the structure of the data used (No. of observations = 384, No. of units = 12 and rho =76 percent). This implies that the estimates of β in the fixed effect models are representation of its true estimates. Similarly, the quality of inferences about β under either model can be objectively compared based upon the size and characteristics of the researcher's dataset. Lee and Yu (2012) found that the within estimate is asymptotically as efficient as the random effects estimate when T is large. As shown earlier, the results of Hausman test confirms the violation of its assumption and thus rejection of the null hypothesis in favour of fixed effect model. Consequently, the results of the fixed effects models will generally be analyzed and discussed in the subsequent sections due to aforementioned reasons and the following additional insights:

1. There is high likelihood of endogeneity effect due to omitted variables in random effects model, and also simultaneity effect due to potential feedback among the variables or within the regressors. Wooldridge (2002) stressed that the advantage of excluding omitted variable bias is a valid argument for using fixed effects model over random effects model.

2. Woodridge (2002) further asserted that the fixed effect analysis is more robust than random effect analysis with the relaxation of the

orthogonality assumption; partial effects in the presence of time-invariant omitted variables that can arbitrarily relate to the observed X_{it} are consistently estimated.

3. The fixed effect model show a much bigger estimated standard deviation of residuals within the group u_i (sigma_u) which is 34991.674 in relation to the standard deviation of residuals of overall error term ε_{it} (sigma_e) which is 19265.52 in both fixed and random effects models. This suggests that the country specific component of the error is much more important than the idiosyncratic error. This also lay credence to the suitability of fixed effect model over random effect model given the characteristics of the data and is consistent with Antoine et al (2010).

4. Since the objective of this research is measuring the effect of the explanatory variables on exploration investment among OPEC MCs while controlling the individual effect rather than the effect of the explanatory variables on differences in exploration investment between OPEC MCs, it is plausible to use estimated coefficients of fixed effect model. This is consistent with Snijders (2005).

6.1.5 Analysis of Result

The results of panel tests conducted to ascertain the validity and adequacy of estimated results in explaining the effects of the independent variables on exploration investment suggest the presence of auto and serial correlations. Consequently, the non-parametric covariance matrix estimator suggested by Driskoll and Krayy (1998) was applied to correct standard errors in the estimated coefficients of the preferred model (fixed effect). The findings of the corrected fixed effect model presented in Table 6.9 are analyzed and discussed as follows. (See Appendix 6.9 for the details of the results).

Table 6.9: Estimated results of fixed effects model with Driskoll and Kraay standard error

Variable	
Exploration investment	Fixed effect model
Oil price	4077.001 (0.026)*
Oil production	.000038 (0.0000)***
Depletion	-356324 (0.011)*
Reserves replacement	114.6463 (0.042)*
Geological potential	20.70088 (0.016)*
Cons	-14476.83 (0.221)
R^2	0.5922
F-test	F (5,31) = 6.66, Prob > F = 0.0000
N	12
No. of observations	384
Number of lags	3

Legend: * p < 0.05, ** p <.01, *** p < .001 P-values in parentheses

The estimated result of the standard errors corrected fixed effects model generally show expected signs and confirm the validity of hypotheses 1, 2, 4,5 and 6. In hypothesis 5, positive influence of depletion rate is anticipated, but the results revealed negative relationship with exploration investment. The models also show satisfactory performance as evidenced by F-test which revealed a Prob > F less than 0.005 (0.000). This suggests that the coefficients are different from zero. The result also shows robust statistical performance in determining the effect of the explanatory variables on the dependent variable with an R^2 of 0.5922. This indicates that a significant portion (59.2%) of the observed variation in exploration investment within OPEC members from 1980 – 2011 is explained by the independent variables. Overall, the model shows significant effects of the regressors in driving exploration investment behaviour.

Oil production exerts a statistically significant positive influence on exploration investment at 0.01 levels. Similarly, oil price, reserves replacement rate, and geological success exhibit statistically significant positive relationships with the exploration investment at 0.05 levels respectively. Oilfield depletion is statistically significant at 0.05 level, but with negative influence on exploration investment. To further determine the impact and responsiveness of exploration investment to changes in the regressors, average elasticities of the covariates at their means was computed[129]. Stata software enables this computation after the estimation of the fixed effect model with Driskoll and Skaay standard errors using the

[129] According to Iledare and Pulsipher (2001), elasticity is the percent change in a dependent variable as a result of one percent change in an independent variable.

command *margins, eyex(independent variables) atmeans*. The decomposed average elasticities are as shown in Figure 6.1 with details presented in Appendix 7.0.

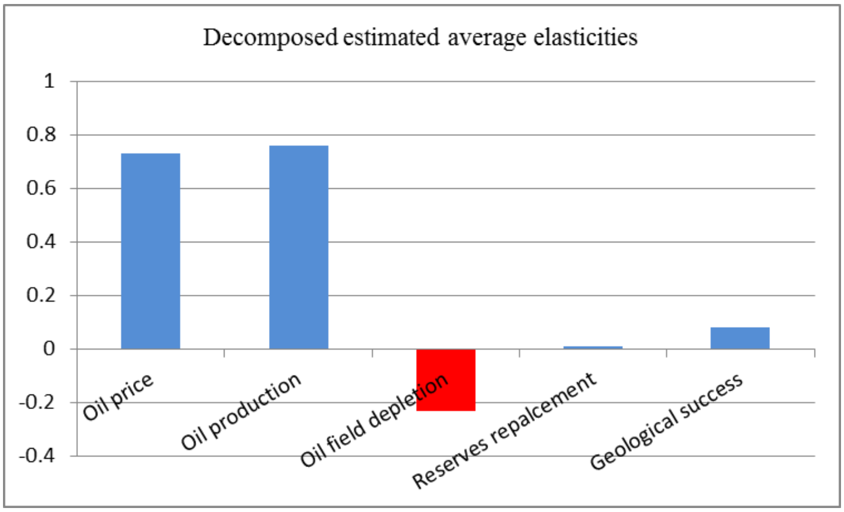

Figure 6.1: Estimated average elasticities of exploration investment to changes in regressors

Overall, the results show the significant impact of oil price and production on exploration investment behaviour. The responsiveness of exploration investment to oil production and price is quite elastic. On the average, 1 percent increase in the level of oil production keeping other factors constant is expected to result to 0.76 percent change in exploration expenditure. Similarly, a one percent increase in oil price could result in 0.73 percent corresponding increase in exploration spending on the average, holding other factors constant. Evidently, the responsiveness of exploration investment to oil price movement is also significantly elastic. Intuitively, any increase in output and oil price induce corresponding dual effects of reducing the investors' rate of return, increase cash flow, and consequently, provide incentive for investment in finding new reserves. Additionally, the combined positive effects of oil price and production increases on exploration spending suggest the reliance of operators on internally generated funds to invest in risky exploration drilling. This is intuitive given the fact that most exploration drilling is funded through internal funds rather that capital market, investment banks, or venture capital financing due to high risks associated with the venture.

Surprisingly, the responsiveness of exploration investment to the level of oilfield depletion is significantly inelastic. On the average, a 1 percent increase in depletion rate is expected to decrease in exploration investment by 0.23 percent, which implies diminishing return as exploration increases. The estimated negative impact of oilfield depletion on exploration investment suggests that less prospects and leads are likely to be available for exploration. Where drillable prospects and leads are available, the average field size and discovery rate progressively diminishes due to maturity of the OPEC MCs' petroleum basins. Increase in oilfield depletion rate enhances setting stage for the attainment of oilfield decline, and since there is less probability of success, investors will be reluctant to invest in risky exploration drilling to replace depleting volumes. This is plausible in the case of OPEC MCs, since most of the producing fields (like Ghawwar, the largest oilfield in the world located in

Saudi Arabia) have been producing for a very long time. Increase in cumulative drilling efforts results to the maturing of petroleum basins. Although exploration investment is significantly inelastic to geological success and reserves replacement, its responsiveness to geological success is higher. A 1 percent increase in geological potential could, on the average, result to 0.08 percent increase in exploration spending. This is also intuitive, the higher the success recorded after drilling the first exploration well, the higher the incentive to drill subsequent exploration/appraisal wells. The inelastic response of exploration spending to increase in reserves replacement rate could be due to the fact that the efficiency of marginal discoveries shrink in matured petroleum basins as drilling progresses, because the big oil reservoirs are most likely to be discovered first. Increasing the recovery factors of existing fields through enhancement of oil recovery schemes or mergers and acquisitions can serve as better and easier means of replacing reserves and are ultimately positive additions to reserves than riskier exploration. As a consequence, it is sensible for risk adverse operators to distribute and hedge reserves replacement risks by investing more in enhancement efforts and tertiary oil recovery schemes and less in exploration.

6.2 Conclusion

Static investment equations were specified and estimated using fixed and random effects models to investigate the role of competing factors in influencing oil and gas exploration investment within OPEC countries. The fixed effects model turn out to be the most suitable model based on the result of Hausman's test and other considerations in line with the literature. But, statistical tests suggest the presence of auto and serial correlation among the residuals of the model can be biased against the estimated coefficients. Driskoll and Kraay's parametric covariance matrix estimates for standard errors were applied to adjust for standard errors on the fixed effect. The estimated result of the corrected exploration behaviour model used to test our hypotheses showed good fitness, robust, and strong statistical performance with expected signs in four out of the five tested hypotheses. The model provides useful information to assess using basic economic concept of elasticity, the competing factors influencing exploration investment decisions.

Overall, the estimated result show that economic and uncertainty factors significantly influence exploration investment in OPEC countries. However, in terms of impact, the results reveal the sensitive effects of oil price and production on exploration investment as evidenced by its elastic response. 1 percent increase in oil price and production respectively on the average could result to 0.73 and 0.76 percent increases in exploration spending respectively. Furthermore, reserves replacement rate and geological potential exhibit significant positive influences on exploration investment, but its response to these factors is inelastic. Conversely, negative inelastic response of exploration spending to increase depletion levels show that producers favour investing in development and enhancing recovery efforts in OPEC countries to increase output capacity due to the matured nature of the petroleum basins rather than exploration. The result is also consistent with theoretical postulations and previous empirical findings within the literature. The findings lay support to the postulations of theories of irreversible investments uncertainty, Hotelling's and Keynes flexible accelerator theory. Similarly, the result is consistent with Broadman (1985), Iledare and Pulsipher (1999), Yarzin (2001), Kasim and Kemp (2006), Mohn and Osmundsen (2008), Guerra (2007), Ringlund et al (2008), and Mohn (2009) and Nuhu and Heo (2013a):

Chapter 7: ANALYSIS OF DRIVERS OF UPSTREAM INVESTMENT BEHAVIOUR IN THE INTERNATIONAL OIL AND GAS INDUSTRY: EVIDENCE FROM OPEC MEMBER COUNTRIES[130]

7.0 Introduction

It is usually interesting to find a satisfactory explanation for investment behaviour in any industry or market talk less of the oil and gas industry because of the significant role of capital accumulation to the economic growth of nations and value addition to society. The positive role of energy particularly oil as critical input in production processes, fuelling the modern economy, and driving economic growth has long been established in the literature. More profoundly, oil is a major source of foreign exchange earnings and revenue generation to OPEC MCs in particular and other petroleum producers. In the same context, agriculture and food production are heavily dependent on oil for fuel and fertilizers Connor (2009). However, the exhaustible nature of oil and gas resources, reserves development, high sunk

[130] This is a revised update of the paper presented during the 22nd World Energy Congress at Daegu, South Korea, October, 2013.

cost, below and above ground uncertainties, long investment cycles as well as uneven geographical spread strengthened the critical importance of understanding drivers of investment behaviour in oil and gas exploration and development. According to S.C. Bhattacharyya (2010), there is a considerable uncertainty facing the investment decision across the upstream oil industry value chain. At the oil exploration phase, the presence of the resource is not known during the investment decision-making. Fiscal terms and risk sharing mechanisms also compounded the uncertain nature of this decision. He further stated that when investment decision subsequently results to discovery of oil, amidst these uncertainties, the development stage presents its peculiar significant investment challenges relating to the size of the discovery or in-place reserves, availability of infrastructure or facilities development, future market prospects and those related to regulatory and business environment. Beside these, a major concern of the global supply industry is the depletion of known reserves, difficulties associated with replacing depleting volumes and find new reserves to sustain its operation. When reserves replacement becomes increasingly challenging, oil companies try to sustain the rate of return by reducing exploration efforts to only highly ranked prospects and leads, or replace declining reserves through merger and acquisition of other companies Enebeli et al (2012). This was a norm widely practiced in the global oil and gas industry in the last two decades[131].

[131] Weston et al (1999) asserted that oil price volatility and increase in other risks in the oil

As regards the argument of future oil supplies, several authors declared that the world is not running out of oil. But IEA, through its chief Energy Economists Dr Fatih Birol, asserted that the world [132]is running out of oil faster than previously anticipated Connor (2009)[133]. The result of IEA's first detailed assessment of more than 800 oil fields in the world which covers three quarters of global reserves, show that the majority of the biggest oilfields have already peaked and decline rate of oil production is running at nearly twice the rate calculated before. This corresponds to the decline in oil production in existing oilfields at 6.7 per cent yearly compared to the 3.7 per cent decline calculated in 2007 based on IEA estimates. IEA findings are in agreement with that of Hook (2009), following his seminal work on global oil field depletion analysis (Table 7.1). Evidently, high depletion and high decline rates of non-OPEC oilfields in comparison to OPEC oilfields suggest short life span of non-OPEC fields and faster drop of production from non-OPEC fields, most especially offshore fields. Conversely, the lower the decline and

industry have triggered Mergers, acquisitions and restructuring.

[132] For details see Connor (2009).

[133] According to Bently (2002), global conventional oil supply is currently at political risk because the sum of conventional oil production from other producers except the five main Middle-East suppliers, is approaching the maximum set by physical resource limits. Should Middle-East producers decide to markedly decrease oil supplies, the deficit would not be substituted by conventional oil from other sources. Despite little spare capacity in the Middle East countries, there will be progressive call on them for marginal supplies as oil production declines somewhere else. Although there are vast quantities of non-conventional oil resources, and various oil substitutes, but the speed of the decline in conventional oil production makes it apparent that these non-conventional resources may not be available fast enough to entirely compensate. The result will be a sustained global oil shortage.

depletion rates of OPEC MCs suggest that the oilfields in OPEC MCs depart from the plateau phase at a lower percentage of ultimate recoverable reserves[134] as produced volumes Hook (2009). A longer decline phase will have less annual decrease instead of a prolonged plateau has generally been favourable production strategy of OPEC MCs in comparison to non-OPEC oilfields. Evidently, OPEC oilfields have much softer decline rates than those in non-OPEC in both land and offshore. This implies that the future oil supplies from non-OPEC offshore fields, which present the most significant potential for yet to find resources[135], reserves development, and capacity expansion is under threat.

Table 7.1: OPEC and Non-OPEC oilfields decline and depletion rates Source: Hook (2009)

Terrain	OPEC		Non-OPEC	
	Decline rate (%)	Depletion at peak (%)	Decline rate (%)	Depletion at peak (%)
Land	3.8	5.9	5.7	7.5
Offshore	7.7	7.5	10	11.5
Average	5.75	6.7	7.85	9.5

[134] According to Society of Petroleum Engineers," ultimate recoverable reserves refers to the quantities of oil and gas which are estimated on a given date, to be potentially recoverable from an accumulation, plus those quantities already produced there from". Hook (2009) simply defines it as the "upper limit for cumulative production".

[135] According to Society of Petroleum Engineers, this refers to quantity of petroleum estimated, on a given date, to be contained in accumulations yet to be discovered.

In terms of upstream investment requirement, IEA Energy Investment outlook 2003 outlined that about \$3 trillion is needed for investments in upstream oil industry from 2001 to 2030, at an annual average of \$103 billion, which is likely to progressively rise as demand increases. The annual capital expenditure will increase from \$92 billion, in the current decade, to \$114 billion in the last decade of the projected period due to capacity exhaustion and demand increases. Exploration and development will take the highest proportion of the oil-sector spending with over 70% of the total investment requirement outlay over the period of 2001-2030. Majority of this investment will be required to sustain production levels at current fields, arresting natural decline from producing wells and find new ones that will come on stream in the future to meet anticipated demand growth. However, in addition to the previously narrated challenges, confronting the global oil supply industry, Dr. Fatih has also echoed that “there is a problem of chronic under-investment by oil-producing countries, a feature that is set to result in an oil crunch.” Iwayemi and Skriner (1986) further opined that the decline in oil investment in OPEC countries despite having more than half of global proven reserves and low supply cost have been influenced by the geopolitics of oil and state of the oil market. They argued that this inefficient resource allocation, due to concentration of investments in areas with greater reduction of return to oil search effort, have the capacity to impact negatively on global welfare and economic growth which can lead to global demand/supply imbalance by the turn of the century. In terms of the impact of the investment on the global economy, the estimated investment will give rise to increase in global oil supply from 77 million barrels per day in 2002 to 120 million barrels per day in 2030 IEA (2003). Consequently, understanding the drivers of investment behaviour in OPEC MCs that possess most significant potential for yet to find resources with low cost of finding and developing marginal barrel is strategically important and timely for global social welfare improvement, economic prosperity and energy security. Thus, the central objective of this study is to examine the drivers of upstream investment in OPEC MCs. The findings of this study will immensely contribute to the literature on economics of oil and gas by providing empirical support on investment behaviour from developing countries' perspectives.

7.1 Empirical Analysis

7.1.1 Data

Economic, technical, uncertainty/field performance, and petroleum fiscal policy variables are used to examine the effect of various competing factors on upstream investment in OPEC MCs. The critical roles of these variables that guided their selection for this experiment are consistent with theoretical and empirical insights as outlined in section 5.1.1.1. As a first step for the empirical analysis, descriptive statistics of the variables is computed to understand the basic statistical structure and properties of the data as presented in Table 7.2 with details in Appendix 7.1 Evidently, there is a significant variation among the variables as indicated by the standard deviation, which is suggestive of within subject variability.

Table 7.2: Descriptive statistics of variables used for OPEC upstream investment analysis

sum invest oilprice oilprod deprate resrep techprog oilrent gasrent

Variable	Obs	Mean	Std. Dev.	Min	Max
invest	384	41232.47	29532.23	16307	135370
oilprice	384	7.374344	4.011016	2.44	16.331
oilprod	384	8.24e+08	8.06e+08	4.70e+07	4.10e+09
deprate	384	.0265313	.0229991	.001	.15
resrep	384	3.413021	16.92952	-76	227
techprog	384	16.5	9.245138	1	32
oilrent	384	30.63986	23.89096	0	209.4809
gasrent	384	3.282925	4.306507	0	26.23817

Subsequently, correlation matrix of the variables was calculated to check the adequacy of the variables for this experiment against possible feedback between the dependent variable and the independent variables or among the independent variables. The result was found to be within acceptable ranges, with no significant correlation between any pair wise, which is suggestive of lack of simultaneity effect among the variables that can introduce endogeneity problem in the estimated result (Table 7.3) with details in Appendix 7.2. Also, the result also gives an idea of the association among the variables.

Table 7.3: Correlation matrix of variables used for OPEC upstream investment analysis

pwcorr invest oilprice resrep deprate oilrent gasrent techprog oilprod

	invest	oilprice	resrep	deprate	oilrent	gasrent	techprog	oilprod
invest	1.0000							
oilprice	0.6255	1.0000						
resrep	0.1306	0.0810	1.0000					
deprate	-0.0899	-0.0028	-0.1546	1.0000				
oilrent	0.1558	0.1193	-0.0620	-0.0109	1.0000			
gasrentog	0.2068	0.0531	0.0451	0.0659	-0.0599	1.0000		
techprog	0.7880	0.0962	0.0562	-0.1250	0.1982	0.3147	1.0000	
oilprod	0.1708	0.00395	-0.0315	-0.3373	0.1600	0.0029	0.2185	1.0000

7.1. 2 Model Estimation

To attain the objectives of this research and test the hypotheses that upstream investment is positively influenced by oil price, production, oilfield depletion rate, reserves replacement rate, technological progress as well as negatively influenced by oil and gas rents respectively, upstream investment exploration is assumed to be a function of these variables. In addition, the assumptions highlighted in section 5.1 also hold. Consequently, the upstream investment equation follows:

Invest = *f* (oil price, production, reserves replacement rate, oilfield depletion rate, oil rent, gas rent, technical progress)

Cross country panel data approach was used to investigate the drivers control for and/or account for country specific heterogeneities. Hence, fixed effects and random effects models were specify and estimated as follows:

$$I_{it} = \alpha_i + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 oilrent_{it} + \beta_6 gasrent_{it} + techprog_{it} + \varepsilon_{it}$$

(Fixed effects model) (1)

$$I_{it} = \alpha + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 oilrent_{it} + \beta_6 gasrent_{it} + techprog_{it} + \mu_{it} + \varepsilon_{it}$$

(Random effects model) (2)

Where i = 1……12 , t = 1………..32

I_{it} is the upstream investment in each country in year t, $oilprice_{it}$ is the oil price in ith country and year t, $Prod_{it}$ is the oil production of ith country in year t, $resrep_{it}$ is the reserves replacement rate of ith country in year t, $deprate_{it}$ is the oilfield depletion rate of ith country in year t, $techprog_{it}$ is the technological progress of ith country in year t, oil $rent_{it}$ is the totality of royalty and taxes as percentage of GDP paid due to oil exploration, development and production in ith country in year t, gas $rent_{it}$ is totality of royalty and taxes paid due to gas exploration, development and production in ith country in year t, αi is each country's unknown intercept which captures each country's unobserved time-invariant specific heterogeneity in the fixed effect model , ε_{it} is the error term in the fixed effect model. While in the random effect specification, ε_{it} and u_{it} are within and between countries error terms respectively.

7.1.3 Empirical Results

The estimated results of the two equations that tested the hypothesized relationships and the constituted upstream investment models for OPEC MC are reported in Table 7.4 and the details are in Appendix 7.3. The models generally show expected signs and confirm the validity of hypotheses 1,4,5,7 and 8. In hypothesis 2, positive influence of oil production is expected, but the results revealed its negative relationship with upstream investment. The models also showed satisfactory performance as evidenced by the F-test which revealed a Prob > F less than 0.005 (0.000) in all cases confirming that the coefficients are different from zero. However, the fixed effects model showed more robust statistical performance and relationships between the dependent variable and the explanatory variables with an R^2 of 0.9414. This suggests that the significant portion (94%) of the observed variation in upstream investment within OPEC members from 1980–2011 is explained by the independent variables. Conversely, the random effects model shows an R^2 of 0.9354 implying that about 93% of the variation of upstream investment within and between the countries during this period is explained by the regressors. Furthermore, the FE model reveal the statistical significant influence of all the regressors, but the RE model showed significant influence of most with the exception of oil production and oilfield depletion level. As expected, 30 percent of the variance is due to differences across panels in the fixed effects model as evidenced by rho = .30648138 while none in the random effects model (rho = 0).

Table 7.4: Results of fixed and random effect models regression for OPEC upstream investment

Variable	Upstream investment in OPEC MC	
Upstream investment	Fixed effect model	Random effect model
Oil price	4152.325** (0.000)	4119.76*** (0.000)
Oil prod	-3.97e-06* (0.016)	-4.81e-08 (0.927)
Depletion	63681.32* (0.034)	23506.84 (0.199)
Reserves replacement	69.01171** (0.003)	76.83352** (0.001)
Technological progress	2634.85*** (0.000)	2458.871*** (0.000)

Oil rent	-84.65613*** (0.000)	-79.91612*** (0.000)
Gas rent	-1087.92*** (0.000)	-495.0438*** (0.000)
cons	-25351.01*** (0.000)	-26491.87*** (0.000)
rho	.30648138	0
R^2	0.9414	0.9354
F-test	F(7,365) = 838.40, prob > F = 0.0000	Wald chi2(7) = 5447.56 Prob > chi2 = 0.0000
Sigma_ u	4866.2283	0
Sigma_e	7320.1419	7320.1419
N	12	12
No. of obs	384	384

Legend: * P < .05, ** P < .01, *** P <. 001 p-value in parentheses

7.1.3.1 Panel Tests

Several of the panel data statistical tests conducted showed the validity of the estimated results. Hausman test was carried out to infer most suitable among fixed and random effects models given the data structure. Since the data is a macro panel with long dimension (T=32), Breuch-pagan LM test carried out to check for cross sectional dependence in fixed effects framework on the other hand, and Wooldridge test for serial correlation indicates that the residuals are correlated across entities and the errors are also serially correlated. Driscoll and Kraay covariance matrix estimator was subsequently applied to adjust the standard errors of the estimated coefficients for dependency in the residuals in line with the literature. Woodridge test for the presence of group wise hetersokedasticity among the variables was also implemented. Hadri LM test for stationarity was also conducted to check for the stationarity of the variables. The detail result of the tests is presented as follows:

7.2.1.1 Hausman Test

Hausman (1978) designed a test for orthogonality between the regressor and the random effect to guide the selection between the FE and RE specifications Greene (2003). The test statistics calculated for time varying regressors test, whether there is significant difference between fixed and random effects models. The null hypothesis states that the difference between the estimates of the two models should not differ systematically. The result of the test is presented in Table 7.5and details in Appendix 7.4

Table 7.5 : Result of Hausman test for OPEC upstream investment analysis

Variable	Fixed effect coefficients (b)	Random effect coefficients (B)	b-B
oil price	4152.325	4119.76	
oil production	-3.97e-06	-4.81e-08	1.55e-06
Depletion rate	63381.32	23506.84	23705.75
Reserves replacement	69.01171	76.83352	
Technological progress	2634.85	2458.871	33.68573

Oil rent	-84.65613	-79.91612	9.424299
Gas rent	-1087.92	-492.0438	119.9184
Hausman's test statistics χ^2 (4) = 41.44		Prob > $\chi2$ = 0.0000	

The value of the test statistic 41.44 exceeds the critical value 1.96 and the prob. value is 0.0000 which is less than 0.005, implies the rejection of the null hypothesis and acceptance of the alternative. Thus, the decision criteria confirm the suitability of fixed effect model over random effect model. FE estimator is consistent under both the null and alternative hypothesis given the data structure, while the RE estimator is efficient under the null, but inconsistent under the alternative. In addition to the result of the hausman test, the reasons outlined in section 6.1.4 further justify the adoption of fixed effects model as the preferred option. The test was conducted using Stata software through the command *hausman fe re*

7.2.1.2 Lagrange multiplier test for cross sectional dependence

According to Baltagi (2001), cross sectional dependence can be a problem in macro panels with long time series (over 20-30 years). However, it is not much of a problem in micro panels (few years and large numbers of cases). Breusch-Pagan (1980) developed a Lagrange multiplier test to check for whether residuals are correlated across entities. Torres-Reyna (2013) pointed that Cross-sectional dependence can result to bias in estimated results. Several scholars apply Breusch-pagan LM test for cross-sectional correlation in a fixed effects model and panel data models. The test assumes independence of errors. Drukken (2003) pointed that this test has good size and power properties in reasonably sized sample. The null hypothesis of the tests assumes that the residuals across entities are not correlated. Deviation from independence of errors in panel data is the likelihood of contemporaneous correlation across entities. The presence of significant residual correlation, as indicated by the large value obtained for the statistic χ^2 (66) =1433, contradicts the model which predicts that the residuals of oil investment function should be uncorrelated across entities. The LM test statistics show evidence of dependency as evidenced by Pr < 0.05, thus rejecting the null hypothesis becomes evident. The result is presented in Table 7.6 and details in Appendix7.5. The test was conducted on Stata software using the command *xttest2*.

Table 7.6: Result of Breusch-Pagan LM test of cross sectional dependence for OPEC upstream investment analysis

Breusch-Pagan LM test of independence
χ^2 (66) = 1433.703 , Pr = 0.0000
based on 32 complete observations over panel units

7.2.1.3 Test for Serial Correlation

Serial correlation is also a potential problem associated with macro panels with long time series (over 20-30 years). Serial correlation causes the standard errors of the coefficients to be biased leading to less efficient results (smaller than actual and higher R-squared). Thus, there is the need to check for serial correlation in the idiosyncratic error term in panel data linear models. Woodridge (2002) developed a robust and simple test for serial correlation which utilizes the residuals from the regression in first differences. First differencing of the data removes individual-level effect based on time-invariant covariates and the constant. The test is reported to possess good statistical power properties in reasonably sized data samples (Drukker, 2003). The presence of significant residual serial correlation, as indicated by Prob >F = 0.000 less than 0.05 contradicts the model which predicts that the disturbances of oil investment function should be serially uncorrelated (Table 7.7 and Appendix 7.7). The null hypothesis is therefore rejected. The test is performed using *xtserial dependent variable independent variables* on Stata.

Table 7.7: Result of Woodridge test for serial correlation for OPEC upstream investment model

FE Model	H0: no first order serial correlation F (1,11) = 202.752 Prob >F = 0.0000

7.2.1.4 Test for group wise heteroskedasticity

Heteroskedasticity problem arises when the variance of the unobserved error depends on the explanatory variable. As a consequence, the estimated model will not be able to get unbiased estimators of the ceteris paribus effects of the explanatory variable on the dependent variable Woodridge (2006). The most likely deviation from homoscedastic errors in the context of panel data is the error variances specific to the cross-sectional units. Group wise heteroskedasticity arise when error process is homoskedastic within cross sectional units, but its variance differs across units. Green (2000) developed Modified Wald test to check group wise heteroskedasticity in panel models. Stata command *xttest3* computes a modified Wald statistic for groupwise heteroskedasticity in the residuals of a fixed-effect regression model in line Green (2000). The null hypothesis of the test assumes homoscedastic error process within cross sectional units which imply that $\sigma_i^2 = \sigma^2$ for i = 1………12. Baum (2001) asserted that the power of the test is very low in the context of fixed effects with Large N, small T panels. This reaffirms the suitability of the test in this case given our sample structure Large T and small N. The estimated test statistic presented in Table 7.8 and Appendix 7.7 is distributed Chi-squared, under the null hypothesis of homoscedasticity. The result confirmed the consistency of the null hypothesis in our model as evidenced by Prob> $\chi2$= 0.352 which is greater than 0.05.Hence, indicates no evidence of groupwise heteroskedasticity. The null hypothesis is therefore, accepted.

Table 7.8: Results of modified Wald test for groupwise heteroskedasticity in fixed effect model of OPEC upstream investment analysis

FE model	H0: sigma (i)^ 2 = sigma ^ 2 for all i Chi2 (12) = 13.33 Prob > chi2 = 0.3529

7.2.1.5. Driscoll and Kraay (1998) test for robust standard errors

Driscoll and Kraay test was applied to estimated coefficients of the fixed effects models to correct the presence serial and auto correlation in the estimated models. The presence of serial and auto correlation in estimated panel models causes the biasness of standard errors. Antoine et al (2010) pointed that ignoring the correlation of regression disturbances over time in the estimated panel data models can result into biasness of the statistical inference. Most recent studies that used panel data models used robust standard error estimators which entailed the application of covariance matrix estimators to adjust the standard errors of the estimated coefficients for possible dependence in the residuals. Antione et al (2010) pointed that the standard error estimate of the commonly applied covariance matrix estimation techniques are biased due to inadequacy in accounting for auto correlation.

Driscoll and Kraay (1998) modified the standard nonparametric covariance estimator in such a way that it is robust to general forms of cross-sectional and temporal dependence relying on large T- asymptotics Hoechle (2007). He applies the Newey-West type adjustment to the sequence of cross sectional averages of the moment conditions Hoechle (2007). Changing the standard error estimates in this form ensures that the covariance matrix estimator is consistent, independently of the cross-sectional dimension N. The test assumes that the error structure is heteroskedastic or (homoskedastic as in this case), auto correlated up to some lag and possibly correlated between the panels. Three years lag was assumed for running the test, considering the fact that investment shock in one year could continue into several years. This is consistent with Hvozdyk and Mercer-Blackman (2010), who found a 2-3 years lag between price signal and investment of major IOCs. The results of the test confirmed the correction of the error structure in the fixed effect model. Stat command *xtscc dependent variable, independent variables, fe* is used to perform the test. The result is presented in the section for analysis of FE result.

7.2.1.6 Hadri (2000) test for unit roots

Unit root test for stationarity of variables have widely been applied in time series analysis. However, recently, there is a growing interest in its application in panel data models. Hadri (2000) developed Lagrange Multiplier (LM) procedures to test the null hypothesis that all the individual series in the panel are stationary (either around a mean or around a trend) against the alternative hypothesis that at least one series contain unit root exist. The assumption of normal distribution of error terms also holds and implemented for panel models with fixed effects, individual deterministic trends, and heterogeneous errors across cross-sections. It is suitable for panels with Large T and moderate N like in this case (T=31, N=12) and requires that the data to be strongly balanced like in this case. The test is correct asymptotically as T tends to be infinity followed by N tending to infinity. The LM tests are based on the simple average of the individual univariate stationarity test, which after a suitable standardization, follows a standard normal distribution. The results of the test are consistent with the null hypothesis as evidenced the test statistics and p-value <0.005 (Table 6.6). Hence, the null hypothesis is accepted confirming the stationarity of all the series. The Stata command for this test is *xtunitroot hadri variable*. For details of the test results see Appendix 7.8.

Table 7.9: Results of Hadri (2000) test for unit roots for OPEC upstream investment analysis

H0: All panels are stationary Ha: Some panels contain unit roots Time trend: Not included	Number of panels: 12 Number of periods: 31 Asymptotics: T,N -> Infinity sequentially

Heteroskedasticity: Not robust		
Variables	Statistics	P-Value
Upstream investment	43.9336	0.0000 (Null accepted)
Oil price	12.0797	0.0000 (Null accepted)
Oil production	40.7501	0.0000 (Null accepted)
Reserves replacement	2.77742	0.0000 (Null accepted)
Depletion	20.7630	0.0000 (Null accepted)
Technical progress	68.2349	0.0000 (Null accepted)
Oil rent	24.4479	0.0000 (Null accepted)
Gas rent	41.5477	0.0000 (Null accepted)

7.1.4 Analysis of Result

The reasons enumerated in section 6.1.4, which informed the choice of fixed effect, also apply in this case. The results of panel tests conducted to ascertain the validity and adequacy of estimated results in explaining the effects of the independent variables on upstream investment indicate the presence of auto and serial correlations. Consequently, the non-parametric covariance matrix estimator suggested by Driskoll and Krayy (1998) was applied to correct standard errors in the estimated coefficients of the preferred model (fixed effect). The findings of the corrected fixed effect model presented in Table 7.10 are analyzed and discussed as follows. (See Appendix 7.9 for the details of the results).

Table 7.10: Estimated results of fixed effects model with Driskoll and Kraay standard error

Variable OPEC upstream investment	Fixed effect model
Oil price	4155.325 (0.000) ***
Oil production	-3.97e-06 (0.001) ***
Depletion	63681.32 (0.031) *
Reserves replacement	69.01171 (0.002) **
Technological progress	2634.85 (0.000) ***
Oil rent	-84.65613 (0.050)
Gas rent	-1087.92 (0.002) ***
Cons	-25351 (0.000)
R^2	0.9414
F-test	F (7,31) = 144.47, Prob > F = 0.0000
N	12
No. of observations	384
Number of lags	3

Legend: * p < 0.05 , ** p <.01 , *** p < .001 P-values in parentheses

The estimated result of the standard errors corrected fixed effects model generally show expected signs and confirm the validity of hypotheses 1, 4, 5, 6, 7and 8. In hypothesis 2, positive influence of oil production is expected, but the results revealed a negative relationship with upstream investment. The models also show satisfactory performance as evidenced by F-test, which revealed a Prob > F less than 0.005 (0.000) suggesting that the coefficients are different from zero. The result also shows robust statistical performance in determining the effect of the explanatory variables on the dependent variable with an R^2 of 0.9414. This suggests that a significant portion (94.1%) of the observed variation in upstream investment within OPEC members from 1980 – 2011 is explained by the independent variables. Overall, the model shows significant effects of the regressors in driving upstream investment behaviour. Oil price and technological progress exerts statistically significant positive influence on upstream investment at 0.001 levels respectively. Similarly, the result show significant negative influence of oil production rate at 0.001 level. While the influences of reserves replacement and gas rent appear significant at 0.01 levels respectively, the latter exerts negative effect and the former positive effect. Oilfield depletion is statistically significant at 0.05 level but surprisingly, oil rent appears exerts negative insignificant influence on upstream investment. To determine the responsiveness of upstream investment to changes in the regressors, average elasticities of the covariates at their means was computed. Stata software enables this computation after the estimation of the fixed effect model with Driskoll and Skaay standard errors using the command *margins, eyex(independent variables) atmeans*. The decomposed average elasticities are as shown in Figure 7.1 with details in Appendix 7.10

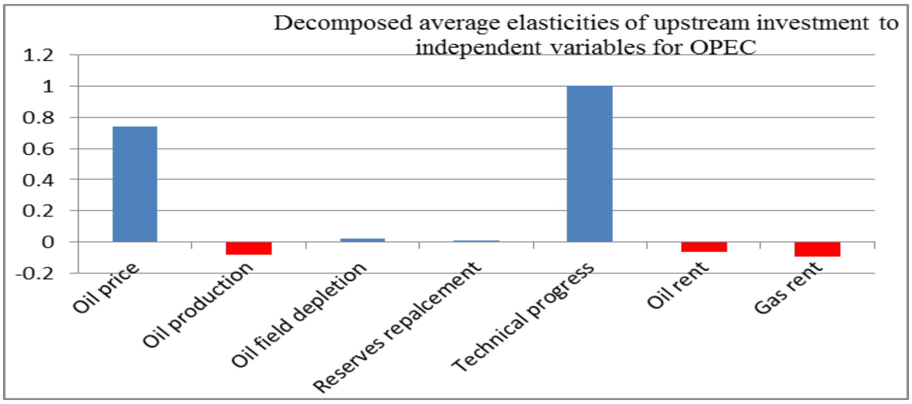

Figure 7.1: Estimated average elasticities of upstream investment to changes in regressors

Overall, the results show significant elastic response of upstream investment to changes in technological progress. On the average, 1 percent increase in technological progress is expected to induce corresponding 1 percent increase in upstream investment keeping other factors constant. The sensitivity of upstream investment to technological improvements owes credence to the fact that the oil and gas industry relies heavily on technology to mitigate most of the ever increasing uncertainties and challenges confronting the industry and extending frontiers. It is worth noting that technological advancement not only optimized the ways in which oil and gas resources are found, developed, and produced but also enables cost efficiency, and faster and safe operations in the upstream activities especially now that the industry is shifting focus to more technically challenging and capital intensive deep water and ultra-deep water terrains. Advances in 3D seismic, 4D seismic, and drilling technologies significantly enhance success rates in exploration and recovery rates from producing reservoirs. At the field development phase, breakthroughs in subsea infrastructure development, multiphase metering, floating production supply, and offloading vessels just to mention a few, have enabled an increase in oil supplies from remote and harsh environments.

Similarly, the responsiveness of upstream investment to oil price movement is quite elastic. On the average, 1 percent increase in international price of oil keeping other factors constant is expected to result to 0.74 percent increase in upstream spending. Intuitively, any increase in oil price induce corresponding trio effects of reducing investor's rate of return, increase cash flow, and justifying the economic viability of previous discoveries and development plans that were previously uneconomic. Consequently, it provides incentive for investment in exploration and development spending. However, Hannesson (1998) hinted that the initial response of the industry to hike in oil price may not be increase in exploration effort, but fast tracking the re-appraisal, development, and production of earlier discoveries that were previously considered uneconomic. Additionally, in mature areas where the industry has discovered most of the big and attractive finds, higher oil price is required to justify the economics of exploration, development, and redevelopment given the rising cost of enhanced oil recovery projects and exploiting deep water and heavy oil resources. Surprisingly, the responsiveness of upstream investment to the level of oilfield depletion is significantly inelastic. On the average, 1 percent increase in depletion rate is expected to increase upstream investment by 0.04 percent. This is plausible considering the low depletion rate of OPEC countries (average of 6.7 %), current low level of spare capacity, and recently observed increase in OPEC production due to shortfall from non-OPEC producers or argument supply disruption from any OPEC member. Investments are made in exploration and development to replace depleting reserves and boost spare capacity. The estimated positive impact of oilfield depletion on upstream investment in OPEC countries implies that operators will increase investment in enhanced oil recovery techniques and field re-development since less prospects and leads are likely to be available for exploration except in frontier petroleum basin areas that are underexplored. Farzin (2001) lay support on this and argues that the higher the risk adverse nature of producers, the higher their preference for development drilling than exploration and vice versa all things, being equal.

Upstream investment show significant, but inelastic response to increases in oil production. On the average 1 percent increase in oil production is expected to reduce upstream spending by 0.08 percent keeping other factors constant. This is intuitive considering the huge impact of increases of OPEC production on global oil supplies and stabilizing or destabilizing the world oil market. Since non-OPEC countries produce competitively to maximum capacity, any increase in oil supplies from OPEC that is not in response to market fundamentals could result to excess supply in the global market, which may impact negatively on oil price movement and market stability. This can induce a multiplier effect of reducing cash flow profiles, increase rate of return on investments, and consequently disincentivize further investment on one hand. On the other hand, operators could be reluctant to invest in the period of oil supply increases to gain as much windfall profit as they could, especially considering the low marginal cost of OPEC members. It also provides an incentive for capital re-allocation to other competing ventures with less risk and higher or similar rate of return. Evidently, the observed significant increase in OPEC's oil production (mainly Saudi Arabia) in the mid-1980s, which resulted in the global oil glut that crashed oil prices and dampened upstream investment, provide support to negative relationship between oil production increases and upstream investment.

Similarly, oil and natural gas rent appear to have a negative statistical relationship with upstream investment. However, natural gas rent exerts significant statistical influence at 0.01 level and higher inelastic response in comparison to oil rent but oil rent appears insignificant surprisingly. A 1 percent increase in natural gas rent is expected to reduce upstream investment by 0.09 percent on the average, holding other factors constant. On the other hand, 1 percent increase in oil rent is expected to reduce on the average about 0.06 percent level of upstream spending. The significant influence of gas rent increases and higher responsiveness of upstream investment to its increases imply the fact that investors are more sensitive to increases in natural gas rent than in oil. Given the fact that oil has been the main source of energy supplies that fuel global economy, significant proportion of the proven reserves have been produced and depleted. Furthermore, growing resource nationalism in petroleum resources rich nations place oil at the centre of global energy geopolitics, resulting in restricted access to IOCs in some OPEC MCs where there is huge potential for oil future oil supplies. Therefore, although increases in oil rent retard investments, it can be inferred that the responsiveness of investors to its increases is lower than gas rent increases due to barriers to access to reserves. Conversely, investors respond more to increases in gas rent due to the huge availability and access to gas resources outside OPEC countries, thus serving as competing investment destinations on one hand, and complex nature of gas development and long term nature of its marketability on the other hand. Any increases in gas rent significantly induce negative effects on rate of return on upstream gas investment and reduce cash flow since the natural gas is normally sold under long term gas sales agreements. This makes price of gas less volatile than oil prices despite gas price indexation with oil prices.

7.2 Conclusion

Static investment equation was specified and estimated using fixed and random effects models to analyze the role of competing factors in driving upstream investment within OPEC countries. The result of statistical tests confirm the suitability of the fixed effects model given our data structure over the random effect model. However, the presence of auto and serial correlation among the residuals of the model, which can be biased against the estimated coefficients, was indicated. Subsequently, Driskoll and Kraay (1998) parametric covariance matrix estimate was applied to adjust for standard errors on the preferred estimated fixed effect model to adjust for standard errors. The estimated result of the corrected upstream behaviour model used to test our hypotheses show robust and strong statistical performance with expected signs in five out of the six tested hypotheses.

Overall, the model show robust statistical performance and provides useful information to assess using the basic economic concept of elasticity, the influence of competing factors in driving upstream investment decisions. The estimated result shows significant influences of technological progress, oil price, gas rent, and oil production on upstream investment spending and its high sensitivity to increases in technological progress and oil price as evidenced by its elastic response. 1 percent increase in technological progress and oil price respectively on the average is expected to induce increase in upstream investment by 1 and 0.74 percent respectively keeping other factors constant. Furthermore, natural gas rent and reserves replacement exerts significant influence on upstream investment at 0.01 levels respectively. While the former influences investment negatively, the latter positively influences upstream expenditure; it's response to these factors is inelastic. Similarly, oil field depletion rate shows a statistically significant positive influence on upstream investment at 0.001 level, but an insignificant elastic response of upstream spending to increases in depletion rate. The findings of the study conforms to previous empirical findings within the literature and lay support to Hotelling's and Keynes flexible accelerator theories on the importance of oil price and output respectively. The result is also consistent with Cox and Wright (1976), Drollas (1986), Barry (1989), Reiss (1989), Pesaran (1990), Iledare and Pulsiper (2001), and Iledare (2009) and Nuhu and Heo (2013b).

Chapter 8 ANALYSIS OF DRIVERS OF UPSTREAM INVESTMENT BEHAVIOUR IN THE INTERNATIONAL OIL AND GAS INDUSTRY: CASE OF SELECTED NON-OPEC MEMBER COUNTRIES

8.0 Introduction

The global energy industry is confronted with numerous challenges despite the projected growth in global oil demand due to the impressive economic performance of developing nations. But, the instability associated with the world oil market heightened fears of the negative impact on the global economy as a result of supply likely disruptions. However, the exhaustible nature of oil and gas resources as below and above ground uncertainties confronts reserves development, high sunk cost, long investment cycles, and uneven geographical distribution echoed the strategic importance of timely oil and gas exploration and development investments dynamics. Bently (2002) asserted that global conventional oil supply is currently at political risk because the sum of conventional oil production is approaching the maximum set by physical resource limits from other producers except in the Middle East. Although there are vast quantities of non-conventional oil resources, and various oil substitutes, the speed of the decline in conventional oil production, decrease in size of marginal discoveries (figure 1.1), and difficulty in replacing the depleting volumes, makes it apparent that non-conventional resources may not be available fast enough to entirely compensate what's lost. Furthermore, high depletion and decline rates of non-OPEC oilfield suggest short life span and earlier fall of production due to quick pressure drop in oil reservoirs from non-OPEC oilfields most especially in the offshore area[136] Hook et al (2009). According to Maria Van der Hoeven, the Executive Director of IEA, the annual decline rate of matured oil fields nears 7 percent, suggesting the need for about 47 million barrels per day of new supplies maintain existing supply levels, let alone meet incremental demand growth. The existence of barriers to foreign investment and access to oil reserves in most of the Middle East oil rich nations heightened fears of energy insecurity and necessitated the need for supply diversification to enhance energy security and increase availability. Advances in technology have enabled the industry to extend its frontier to technically challenging and capital-intensive, unconventional terrains for easier access to oil and gas resources and security of supplies. This resulted in significant discoveries in in non-OPEC regions, most notably in the US Gulf of Mexico, deep waters of Brazil, East Africa, Australia, oil sands of Canada, and the US shale gas. As a consequence, there

[136] Hook (2009) stated that non-OPEC oil fields averagely have 7.85 and 9.5 percent decline and depletion at peak rates respectively.

has been a growth in oil supplies from the non-OPEC producers. Although, OPEC producers enjoy low finding and development cost, the quest for energy security justify the economics of investments in non-OPEC countries. According to IEA (2003), offshore field developments will constitute about one - third of the estimated rise in production until 2030, and they will consume a substantial portion of investment requirements due to high cost of development. Apparently, the investment requirement in non-OPEC countries will be higher due to the propensity of deep-water resources in these countries. In terms of impact of the investment on the global economy, the estimated investment will give rise to an increase in global oil supply from 77 million barrels per day in 2002 to 120 million barrels per day in 2030.

On another note, Broadman (1984) argued that high geological success rate of a particular geological province is not sufficient, but is a necessary condition for exploration and development investment. He further pointed that the nature of general infrastructural development to support upstream operations of the area, friendliness of fiscal regime, stability of policy environment, and extent of political risk of a country are the main driving factors for investment in upstream activity in a particular area. Evidently, since some OECD petroleum resources rich nations are part of the non-OPEC producers, the likelihood of attracting upstream investments is higher in those countries than OPEC producers. Similarly, the quest for oil reserves' growth and income by the developing non-OPEC oil and gas producers may motivate less stringent barriers to entry in these countries than their OPEC counterparts. Thus, it is imperative to investigate drivers of upstream investment in non-OPEC countries. Moreover, it is essential for OPEC and other market players to understand the drivers of upstream investment in non-OPEC countries for strategic planning purposes. In this study, eight countries (four OECD and four non-OECD) were selected based on oil and gas reserves base, potential for future supplies, and geographical spread to pursue the objective of empirically investigating determinants of oil and gas exploration and development investment in these countries.

8.1 Empirical Analysis

8.1.1 Data

Economic, technical, field performance/uncertainty, and petroleum fiscal (policy factors) used for OPEC countries in section 7.11 also apply to examine the influences of various competing factors on upstream investment in non-OPEC countries. The critical roles of these variables that guided their selection for this experiment is consistent with theoretical and empirical insights as outlined in section 5.1.1.1. As a first step for the empirical analysis, descriptive statistics of the variables is computed to understand the basic statistical structure and properties of the data as presented in Table 8.1 with details in Appendix 8.1. Evidently, there is significant variation among the variables as indicated by standard deviation which is suggestive of within subject variability.

Table 8.1: Descriptive statistics of variables used for this analysis for OPEC exploration analysis

sum invest oilprice oilprod deprate resrep techprog oilrent gasrent

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
invest	256	412e+10	2.96e+10	163e+10	1.35e+11
oilprice	256	7.374344	4.013637	2.444	16.331
oilprod	256	6.02e+08	3.91e+08	5.59e+07	1.40e+09
deprate	256	.0743318	.0516226	.0052358	.2263948
resrep	256	.6052576	14.31285	-134.9182	135.0572
techprog	256	16.5	9.245138	1	32
oilrent	256	12.71313	14.84544	.3388161	54.1128
gasrent	256	1.611736	1.755016	.0303287	9.911007

Subsequently, the correlation matrix of the variables was computed to check the adequacy of the variables for this experiment against possible feedback between dependent variable and independent variables, or among the independent variables. The result was found to be within acceptable ranges with no significant correlation between any pair wise, which is suggestive of lack of simultaneity effect among the variables that can introduce endogeneity problem in the estimated result (Table 8.2) with details in Appendix 8.2. Moreover, the result also gives an idea of the association among the variables.

Table 8.2: Correlation matrix of variables used for the study

pwcorr invest oilprice resrep deprate oilrent gasrent techprog oilprod

	invest	oilprice	oilprod	resrep	deprate	techprog	oilrent	gasrent
invest	1.0000							
oilprice	0.6255	1.0000						
oilprod	0.0935	-01043	1.0000					
resrep	-0.0805	-0.0773	-0.0763	1.0000				
deprate	0.0220	-0.0919	0.0743	0.0207	1.0000			
techprog	0.7880	0.0962	0.2260	-0.0365	0.1076	1.0000		
oilrent	0.0251	0.1173	-0.0544	-0.0538	-0.1540	-0.0200	1.0000	
gasrent	0.2181	0.1631	0.0831	-0.0133	-0.0559	0.2676	-0.0832	1.0000

8.1. 2 Model estimation

To attain the objectives of this research and test the hypotheses that upstream investment is positively influenced by oil price, production, oilfield depletion rate, reserves replacement rate, technological progress, and oil and gas rents respectively, upstream investment is assumed to be a function of these variables. In addition, the assumptions stated in section 5.1 also apply. Consequently, the upstream investment equation follows:

Invest = *f* (oil price, production, reserves replacement, oilfield depletion, technical progress, oil rent, gas rent)

The cross country panel data approach was used to investigate the drivers of investment and control /or account for country specific heterogeneities. Hence, fixed effects and random effects models were specified and estimated as follows:

$$I_{it} = \alpha_i + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 oilrent_{it} + \beta_6 gasrent_{it} + techprog_{it} + \varepsilon_{it}$$

(Fixed effect model) (1)

$$I_{it} = \alpha + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 oilrent_{it} + \beta_6 gasrent_{it} + techprog_{it} + \mu_{it} + \varepsilon_{it}$$

(Random effects model) (2)

Where i = 1……8 , t = 1………..29

I_{it} is the upstream investment in each country in year t, $oilprice_{it}$ is the oil price in ith country and year t, $Prod_{it}$ is the oil production of ith country in year t, $resrep_{it}$ is the reserves replacement rate of ith country in year t, $deprate_{it}$ is the oilfield depletion rate of ith country in year t, $techprog_{it}$ is the technological progress of ith country in year t, oil $rent_{it}$ is the totality of royalty and taxes as percentage of GDP paid due to oil exploration, development, and production in ith country in year t, gas $rent_{it}$ is totality of royalty and taxes paid due to gas exploration, development and production in ith country in year t, αi is each country's unknown intercept which captures each country's unobserved time-invariant specific heterogeneity in the fixed effect model , ε_{it} is the error terms in the fixed effect model. While in the random effect specification, ε_{it} and u_{it} are within and between countries error terms respectively.

8.2 Empirical Results

The estimated results of the two equations that tested hypothesized relationships and constitute upstream investment models for selected non-OPEC countries are reported in Table 8.3 and details in Appendix 8.3. The models generally show expected signs and confirm the validity of hypotheses 1 and 7. In hypotheses 2, 4, and 5 positive influence of oil production, reserves replacement, and oilfield depletion rate are expected, but the results reveal negative relationships with upstream investment in non-OPEC producers. The models also show satisfactory performance as evidenced by F-test which revealed a Prob > F less than 0.005 (0.000) in all cases confirming that the coefficients are different from zero. However, the fixed effects model shows more robust statistical performance and relationships between the dependent variable and the explanatory variables with an R^2 of 0.9455. This suggests that significant portion (about 95%) of the observed variation in upstream investment within the selected non-OPEC countries from 1980 – 2011 is explained by the independent variables. Conversely, the random effect model shows an R^2 of 0.9328 implying that 93% of the variation of upstream investment within and between the countries during this period is explained by the regressors. Although the two models show negative insignificant effects of oil production, depletion, and reserves replacement rates on upstream investment, the FE model shows the statistical significant influence of oil price, technological progress, oil and rents at 0.001 levels respectively. Conversely, the RE model shows the statistical significant influences of oil price and natural gas rent at 0.001 levels respectively, while oil rent appears significant at 0.05 level. As expected, 60 percent of the variance is due to differences across panels in the fixed effects model as evidenced by rho = .60126407, while none in the random effects model (rho = 0). Furthermore, the reasons stated in section 6.1.4 also informed the choice of fixed effect model.

Table 8.3: Results of fixed and random effect models regression

Variable	Upstream investment in selected non-OPEC countries	
Upstream investment	Fixed effect model	Random effect model
Oil price	4.45e+09 *** (0.000)	4.17e+09*** (0.000)
Oil production	-3.152386 (0.292)	-1.066091 (0.411)

Reserves replacement	-3.18e+07 (0.315)	-2.67e+07 (0.436)
Oil field depletion	-5.08e+09 (0.774)	-9.38e+09 (0.332)
Technological progress	2.49e+09 *** (0.000)	2.42e+09*** (0.000)
Oil rent	-5.63e+08 *** (0.000)	-7.32e+07 * (0.029)
Gas rent	-2.83e+09 *** (0.000)	-1.35e+09*** (0.000)
cons	-1.86e+10*** (0.000)	-2.50e+10 *** (0.000)
rho	.60126407	0
R^2	0.9455	0.9328
F-test	F(7,241) = 597.09, prob > F = 0.0000	Wald chi2(7) = 3442.65 Prob > chi2 = 0.0000
Sigma_ u	8.716e+09	0
Sigma_e	7.098e+09	7.09e+09
N	8	8
No. of obs	256	256

Legend: * P < .05, ** P < .01, *** P < . 001 p-value in parentheses

8.1.3.1 Panel Tests

Most of panel data statistical tests conducted show the validity of the estimated results. The Hausman test was carried out to infer most suitable among fixed and random effects models given our data structure. Since our data is a macro panel with long dimension (T=32), the Breuch-Pagan's LM test carried out to check for cross sectional dependence in fixed effects framework and the Wooldridge test for serial correlation indicates that the residuals are correlated across entities and the errors are also serially correlated. Consequently, Driscoll and Kraay covariance matrix estimator was applied to adjust the standard errors of the estimated coefficients for dependency in the residuals in line with the literature. The Woodridge test for the presence of group wise hetersokedasticity among the variables was also implemented. The Hadri LM test for unit root was also conducted to check for the stationarity of the variables. The detail result of the tests is presented as follows:

8.1.3.1.1 Hausman Test

Hausman (1978) designed a test for orthogonality between the regressor and the random effect to guide selection between the FE and RE specifications Greene (2003). The test statistics calculated for time varying regressors test whether there is significant difference between fixed and random effects models. The null hypothesis states that difference between the estimates of the two models should not differ systematically. The result of the test is presented in Table 8.4and details in Appendix 8.4

Table 8.4 : Result of Hausman test

Variable	Fixed effect coefficients (b)	Random effect coefficients (B)	b-B
oil price	4.45e+09	4.17e+09	2.86e+08
oil production	-3.152386	-2.086296	-2.086296

Reserves replacement	-3.18e+07	-2.67e+07	-5086635
Oilfield depletion	-5.08e+09	-9.38e+09	4.30e+09
Technological progress	2.49e+09	22.42e+09	6.45e+07
Oil rent	-5.63e+08	-7.32e+07	-4.90e+08
Gas rent	--2.83e+09	-1.48e+09	-1.48e+-9
Hausman's test statistics χ^2 (6) = 72.14		Prob > $\chi2$ = 0.0000	

The value of the test statistic 72.14 exceeds the critical value 1.96 and the prob. value is 0.0000 (less than 0.005) suggest the rejection of the null hypothesis and acceptance of the alternative. Thus, the decision criteria confirms the suitability of the fixed effect model over random effect model. FE estimator is consistent under both the null and alternative hypothesis given the data structure, while the RE estimator is efficient under the null, but inconsistent under the alternative. The test was conducted using Stata software through the command *hausman fe re*

8.1.3.1.2 Lagrange multiplier test for cross sectional dependence

According to Baltagi (2001), cross sectional dependence can be a problem in macro panels with long time series (over 20-30 years). However, it is not much of a problem in micro panels (few years and large numbers of cases). Breusch-Pagan (1980) developed a lagrange multiplier test to check for whether residuals are correlated across entities. Torres-Reyna (2013) pointed that cross-sectional dependence can result to bias in estimated results. Several scholars apply Breusch-Pagan LM test for cross-sectional correlation in a fixed effects model and panel data models. The test assumes independence of errors. Drukken (2003) pointed that this test has good size and power properties in reasonably sized sample. The null hypothesis of the tests assumes that residuals across entities are not correlated. Deviation from independence of errors in panel data is the likelihood of contemporaneous correlation across entities. The LM test statistics show evidence of dependency as evidenced by Pr = 0.000, which is less than 0.05, thus rejecting the null hypothesis becomes apparent. The result is present in Table 8.5 and details in Appendix 8.5. The test was conducted on Stata software using the command *xttest2*.

Table 8.5: Result of Breusch-Pagan LM test of cross sectional dependence

Breusch-Pagan LM test of independence
χ^2 (28) = 562.739 , Pr = 0.0000
based on 32 complete observations over panel units

8.1.3.1.3 Test for Serial Correlation

Serial correlation is also a potential problem associated with macro panels with long time series (over 20-30 years). Serial correlation causes the standard errors of the coefficients to be biased leading to less efficient results. Thus, there is the need to check for serial correlation in the idiosyncratic error term in panel data linear models. Woodridge (2002) developed a robust and simple test for serial correlation which utilizes the residuals from the regression in first differences. It is worth noting that first differencing of the data removes individual-level effect based on time-invariant covariates and the constant. The tests are reported to possess good statistical power properties in reasonably sized data samples (Drukker, 2003). The null hypothesis of the test assumes no first order serial correlation. The result of the test indicates that the errors are serially correlated as evidenced by Pr = 0.000, which is less than 0.05 (Table 8.6 and Appendix 8.6). Hence, the null hypothesis is rejected. The test is performed using *xtserial dependent variable independent variables* on Stata.

Table 8.6: Result of Woodridge test for serial correlation

FE Model	H0: no first order serial correlation F (1,7) = 216.904 Prob >F = 0.0000

8.1.3.1.4 Test for group wise heteroskedasticity

Heteroskedasticity problem arises when the variance of the unobserved error depends on the explanatory variable. As a consequence, the estimated model will not be able to get unbiased estimators of the ceteris paribus effects of the explanatory variable on the dependent variable Woodridge (2006). The most likely deviation from homoscedastic errors in the context of panel data is error variances specific to the cross-sectional units. Group wise heteroskedasticity arise when error process is homoskedastic within cross sectional units, but its variance differs across units. Green (2000) developed the Modified Wald test to check group wise heteriskedasticity in panel models. Stata command *xttest3* computes a modified Wald statistic for group wise heteroskedasticity in the residuals of a fixed-effect regression model in line Green (2000). The null hypothesis of the test assumes homoscedastic error process within cross sectional units which implies that $\sigma_i^2 = \sigma^2$ for $i = 1 \ldots\ldots\ldots 12$. According to Baum (2001), the modified Wald statistic calculated is feasible once the assumption of normality is disrupted at least in asymptotic terms. He further asserted that the power of the test is very low in the context of fixed effects with Large N, small T panels. This reaffirms the suitability of the test in this case given our sample structure Large T and small N. The estimated test statistic presented in Table 8.7 and Appendix 8.7 is distributed Chi-squared under the null hypothesis of homoscedasticity. The result confirms the consistency of the null hypothesis in our model as evidenced by Prob> $\chi 2$= 0.5075 which is greater than 0.05. Hence, suggesting no evidence of group wise heteroskedasticity. The null hypothesis is therefore accepted.

Table 8.7: Results of modified Wald test for groupwise heteroskedasticity in fixed effect model

FE model	H0: sigma (i)^ 2 = sigma ^ 2 for all i Chi2 (8) = 7.27 Prob > chi2 = 0.5076

8.1.3.1.5 Driscoll and Kraay test (1998) for robust standard errors

The Driscoll and Kraay test was applied to estimated coefficients of the fixed effects models to correct for the presence serial and auto correlation in the estimated models. The presence of serial and auto correlation in estimated panel models causes the biasness of standard errors. Antoine et al (2010) pointed that ignoring correlation of regression disturbances over time in the estimated panel data models can result in biasness of statistical inference. Most recent studies that use panel data models use robust standard error estimators which entail the application of covariance matrix estimators to adjust the standard errors of the estimated coefficients for possible dependence in the residuals. Antione et al (2010) pointed that standard error estimate of commonly applied covariance matrix estimation techniques are biased due to inadequacy in accounting for auto correlation. Driscoll and Kraay (1998) modified the standard nonparametric covariance estimator in such a way that it is robust to general forms of cross-sectional and temporal dependence relying on large T- asymptotics Hoechle (2007). He applies the

Newey-West type adjustment to the sequence of cross sectional averages of the moment conditions Hoechle (2007). Changing the standard error estimates in this form ensures that the covariance matrix estimator is consistent, and independently of the cross-sectional dimension N. The test assumes that the error structure is heteroskedastic or (homoscedastic as in this case), and auto correlated up to some lag and possibly correlated between the panels. Three years lag was assumed for running the test considering the fact that investment shock in one year could continue into several years. This is consistent with Hvozdyk and Mercer-Blackman (2010) who finds 2-3 years lag between price signal and investment of major IOCs. The results of the test confirmed the correction of the error structure in the fixed effect model. Stat command *xtscc dependent variable, independent variables, fe* is used to perform the test. The result is presented in the section for analysis of FE result.

8.1.3.1.6 Hadri (2000) test for unit roots

Unit root test for stationarity of variables have widely been applied in time series analysis, but recently there is a growing interest in its application in panel data models. Hadri (2000) developed Lagrange Multiplier (LM) procedures to test the null hypothesis that all the individual series in the panel are stationary (either around a mean or around a trend) against the alternative hypothesis that at least one series contain unit root exist. The assumption of normal distribution of error terms also holds and implements for panel models with fixed effects, individual deterministic trends, and heterogeneous errors across cross-sections. It is suitable for panels with Large T and moderate N like in this case (T=31, N=8) and requires that the data to be strongly balanced like in this case. The test is correct asymptotically as T tends to infinity followed by N tending to infinity. The LM tests are based on the simple average of the individual univariate stationarity test, which after a suitable standardization follows a standard normal distribution. The results of the test is consistent with the null hypothesis as evidenced the test statistics and p-value <0.005 (Table 8.8). Hence accepting the null hypothesis and conclude stationarity of all the series. The Stata command for this test is *xtunitroot hadri variable*. For details of the test results see Appendix 8.8.

Table 8.8: Results of Hadri (2000) test for unit roots

<table>
<tr><td>H0: All panels are stationary
Ha: Some panels contain unit roots

Time trend: Not included
Heteroskedasticity: Not robust</td><td colspan="2">Number of panels: 8

Number of periods: 31

Asymptotics: T,N -> Infinity sequentially</td></tr>
<tr><td>Variables</td><td>Statistics</td><td>P-Value</td></tr>
<tr><td>Upstream investment</td><td>35.8716</td><td>0.0000 (Null accepted)</td></tr>
<tr><td>Oil price</td><td>9.8630</td><td>0.0000 (Null accepted)</td></tr>
<tr><td>Oil production</td><td>40.1399</td><td>0.0000 (Null accepted)</td></tr>
</table>

Reserves replacement	1.1247	0.0000 (Null accepted)
Oilfield depletion	35.30006	0.0000 (Null accepted)
Technical progress	55.7135	0.0000 (Null accepted)
Oil rent	13.9720	0.0000 (Null accepted)
Gas rent	22.6231	0.0000 (Null accepted)

8.1.4 Analysis of Result

In addition to the results of the Hausman test conducted, the reasons stated in section 6.1.4 further informed the choice of fixed effects model as preferred option. The results of panel tests conducted to ascertain the validity and adequacy of estimated results in explaining the effects of the independent variables on upstream investment suggest the presence of auto and serial correlations. Consequently, the non-parametric covariance matrix estimator suggested by Driskoll and Kraay (1998) was applied to correct for standard errors in the estimated coefficients of the preferred model (FE). The findings of the corrected fixed effect model presented in Table 8.9 are analyzed and discussed as follows. See Appendix 8.9 for the details of the results.

Table 8.9: Estimated results of fixed effects model with Driskoll and Kraay standard error

Variable Upstream investment	Fixed effect model
Oil price	4.45e+09 (0.000) ***
Oil production	-3.152386 (0.055)
Reserves replacement	-3.18e+07 (0.379)
Oilfield depletion	-5.08e+09 (0.559)

Technological progress	2.49e+09 (0.000) ***
Oil rent	-5.63e+08 (0.000) ***
Gas rent	-2.83e+09 (0.000) ***
cons	-1.864+e10 (0.000) ***
R^2	0.955
F-test	F (7,31) = 76.06, Prob > F = 0.0000
N	8
No. of observations	256
Number of lags	3

Legend: * p < 0.05, ** p <.01, *** p < .001 P-values in parentheses

The estimated result of the standard errors corrected fixed effects model show expected signs in four out of the seven variables tested, and confirm the validity of hypotheses 1 and 6. In hypotheses 2, 3, and 4, positive influence of oilfield depletion, reserves replacement, and oil production are anticipated but the results revealed negative relationship with upstream investment. The model also show satisfactory performance as evidenced by F-test which revealed a Prob > F less than 0.005 (0.000) suggesting that the coefficients are different from zero. The result also shows robust statistical performance in determining the effect of the explanatory variables on the dependent variable with an R^2 of 0.9455. This indicates that significant a portion (about 95%) of the observed variation in exploration investment within the selected non-OPEC producers from 1980 – 2011 is explained by the independent variables. Overall, the model shows significant effects of oil price, technological progress, as well as oil and gas rents in driving upstream investment behaviour. The result also shows the insignificant influence of oilfield depletion, reserves replacement, and oil production on upstream investment in non-OPEC countries. Oil price and technical progress exert statistically significant positive influence on upstream investment behaviour at 0.001 levels respectively. Conversely, oil and gas rents apply statistically significant negative influence on upstream investment at 0.001 levels respectively.

Average elasticities of the covariates at their means were estimated to further unravel the sensitivity of upstream investment to changes in the independent variables. Stata software enables this computation after the estimation of the fixed effect model with Driskoll and Kraay standard errors using the command *margins, eyex(independent variables) atmeans*. The decomposed average elasticities are as shown in Figure 8.1 with details in Appendix 8.10

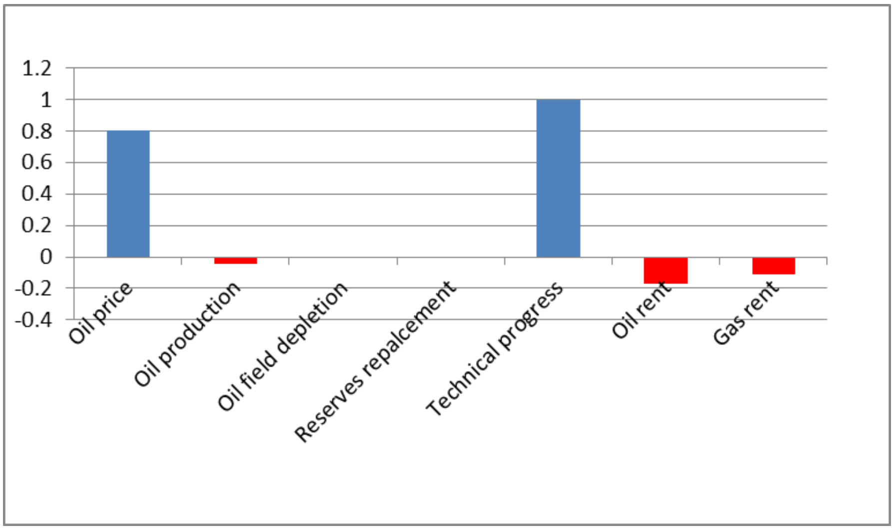

Figure 8.1: Decomposed estimated average elasticities of upstream investment to changes in the regressors in non-OPEC countries

Overall, the responsiveness of upstream investment to technological improvement is significantly elastic. On the average, 1 percent increase in oil technological progress on the average could result to corresponding 1 percent increase in upstream expenditure keeping other factors constant. Given the concentration of unconventional resources that are technically more challenging and costly to find and extract in non-OPEC countries, it is plausible to find high elastic response of upstream investment in these countries to changes in technological progress. The success in exploring, developing, and producing these resources depends solely on improvements in technology. Advances in technology provide the platform for unlocking huge hydrocarbon resources in deep waters of US Gulf of Mexico, Brazil, East and West Africa, Central Asia, and\ Australia. Beyond the deep water, oil and gas resources in ultra-deep water and geologically challenging deeper plays (example Brazils pre-salt and arctic) are being explored and produced mostly in non-OPEC countries, courtesy for technological progress.

The responsiveness of upstream investment to increases in oil prices appears also elastic. On the average, 1 percent increase in oil price is expected to result in 0.8 percent increase in upstream investment in non-OPEC countries. Consequently, higher oil prices are required to justify the economics of the exploring and exploiting the unconventional resources in non-OPEC countries giving the rising cost and couple with fact that investment level respond to changing market fundamentals.

Furthermore, the estimated result shows insignificant negative elastic response of upstream investment to changes in oil and gas rents respectively. On the average, 1 percent increase in oil rent is expected to reduce upstream investment spending by 0.17 percent, while 1 percent increase in gas rent keeping other factors constant could reduce upstream investment by 0.11 percent. Evidently, the sensitivity of upstream investment to increases in petroleum fiscal regimes is higher for oil than gas in non-OPEC countries. This is intuitive given the preponderance of natural gas resources in non-OPEC countries, any increases in oil rent will provide incentive for investors to shift focus on gas investments. Additionally, considering the low propensity of proven oil reserves in these countries, high depletion rates, and the fact that success and size of marginal discoveries decline as a petroleum basin matures with cumulative drilling, increases in oil rent will disincentivizes oil investments since chances of success is low and costlier to find or develop oil resources.

Conversely, the results show significant inelastic negative response of upstream investment to increase in oilfield depletion, production, and reserves replacement rate. One the average, one percent increase in oilfield depletion rate is expected to reduce upstream investment by 0.09 percent. The estimated negative impact of oilfield depletion on upstream investment may be attributed to the fact that less prospects and leads are likely to be available for exploration. The assumption is that since non-OPEC producers produce at maximum capacity (competitively), making oilfields have higher depletion rates. From there, the chances of discovery and size of the discovery, if encountered, weakens with cumulative drilling. Any increase in depletion will enhance fast exhaustion of reserves, further reduce reservoir pressure, and enhance ultimate attainment of field decline level. Thus, retarding investments in finding and replacing reserves since investors are confronted with high risk of less probability of success.

Similarly, 1 percent increase in oil production could result to 0.05 percent decrease in upstream investment holding other factors constant. The intuition is that since non-OPEC producers produce competitively in response to oil price movement, any increase in oil production that is non-due to changing market fundamentals, could result to instability in the world oil market, impacting negatively on investors’ cash flow profile. In the same vein, 1 percent increase in reserves replacement rate is expected to reduce upstream investment by 0.0005 percent. However, the negative effect of oilfield depletion and reserves replacement is offset by a significant positive influence of technological progress on upstream investment. Improvements in technology has the capacity to increase geological success rates in exploration and secondary/tertiary recovery techniques to increase recovery factors thereby aiding reserves replacement drive.

8.2 Conclusion

Static investment equations were specified and estimated using fixed and random effects models to investigate the role of competing economic, technical, uncertainty/field performance, and petroleum fiscal policy factors in driving upstream investment within selected non-OPEC countries. The results of panel tests and insights from the literature confirm the suitability of fixed effect model given our data structure. However, the presence of auto and serial correlation among the residuals of the model which can bias the estimated coefficients was also detected. Consequently, Driskoll and Kraay (1998) parametric covariance matrix estimator was applied to adjust for standard errors on the preferred estimated fixed effects model. The estimated result of the corrected upstream behaviour model show good fitness, robust, and strong statistical performance with expected signs in most of the tested relationships. Overall, the model provides useful information to assess using basic economic concept of elasticity, the competing factors influencing upstream investment decisions. The estimated result shows the significant influences of technological progress and oil price on upstream investment as evidenced by its significant elastic responses (1 and 0.8 percent respectively).

This indicates the importance of economic and technological factors in shaping upstream investment behaviour also in non-OPEC countries. Given the propensity of unconventional oil and gas resources in non-OPEC countries, successful exploration, development, and production of these resources depends solely on technological improvement. Furthermore, oil and natural gas rents show strong negative statistical influences on upstream investment, but insignificant elastic response of upstream investment to changes in oil and gas rents respectively. This also suggests the significance of petroleum fiscal policy factors in influencing upstream investment behaviour within non-OPEC. The sensitivity of upstream investment to increases in petroleum fiscal regimes is higher for oil than gas in non-OPEC countries. Given the difficulty and high cost associated with oil exploitation, any increases in oil rent can provide incentive for investors to shift investments to competing gas resources that are less risky, more accessible and environmentally friendly.

The estimated result also show insignificant negative influences of oilfield depletion, reserves replacement and oil production on upstream investment in non-OPEC countries. Similarly, the responsiveness of upstream investment to changes in these factors is significantly inelastic. The findings of this study are consistent with previous results in empirical literature (Iwayeni and Skriner (1986), Iledare (1995), Iledare et al (1999), Iledare and Pulsipher (1999), Mohn (2007), Hvozdyk and Mercer-Blackman (2010), Nuhu, H. and

Heo, E (2013b) and support the postulations of theories of irreversible investments under uncertainty and Hotelling's on the role of oil price in driving oil investment.

Chapter 9: COMPETING FACTORS INFLUENCING EXPLORATION INVESTMENT BEHAVIOUR IN UPSTREAM OIL AND GAS INDUSTRY: CASE OF SELECTED NON-OPEC COUNTRIES

9.0 introduction

Global access to oil and gas reserves for international oil companies in OPEC countries have continuously weakened as a result of significant barriers to entry in most OPEC countries. This is due to growing resource nationalism. As a consequence, there has been growing interests among IOCs in accessing both conventional and unconventional exploration opportunities in most non-OPEC countries where there are less barriers to entry. Furthermore, the competitive conduct of non-OPEC producers as opposed to their OPEC counterparts, strengthen the oil and gas sector's competitiveness and enhance the industry's development in most non-OPEC countries, thereby presenting investment opportunities for international oil companies. Non-OPEC countries currently supply about 57 percent of the global daily oil supplies with progressive anticipated growth. Apparently, timely investment in oil and gas exploration and development is critical to the availability of future supplies needed to prevent supply disruption, meet future demand growth, and ensure global energy security. Moreover, there is low propensity of geopolitical challenges in most non-OPEC nations. However, oil and gas reserves development in most of these countries is facing geological and higher technical cost challenges. This is mainly due to the relatively low geological potential of unconventional reservoirs in petroleum basins in comparison to OPEC countries. But, technological advancements are optimizing these challenges and enhancing discoveries in deep water and other unconventional plays. This culminated in the spate of world class oil and gas discoveries in deep waters of US Gulf of Mexico, Gulf of Guinea, and oil sands of Alberta, and most recently Brazil's pre-salt plays, deep water East and West Africa. In terms of investment requirement, International Energy Agency projected about $3 trillion will be required for investments in upstream oil and gas industry with about 70 percent going into exploration and development. But, significant proportion of the capital outlays will be in non-OPEC countries as a result of rising cost of exploration and development. Still, technology is playing a key role in ensuring cost efficiency in this regards. Thus, it is imperative to empirically examine the factors that influence investment behaviour in these countries to provide basis for effective investment planning and policy formulation. Consequently, the central objective of this study is to investigate the influence of various competing economic and uncertainty factors on exploration investment in

Canada, UK, Norway, Malaysia, Brazil, Indonesia, and Mexico using data covering 1980 – 2009.

9.1 Empirical Analysis

9.1.1 Data

Economic and uncertainty/field performance variables are used for this experiment to investigate the influence of various competing factors on exploration investment in selected Non-OPEC countries. The critical roles of these variables that guided their selection for this experiment are consistent with theoretical and empirical insights as outlined in section 5.1.1.1. As a first step in the empirical analysis, the descriptive statistics of the variables is computed to understand the basic statistical structure and properties of the data as presented in Table 9.1 and details featured in Appendix 9.1. Evidently, there is significant variation among the variables as indicated by standard deviation, which is suggestive of within subject variability.

Table 9.1: Descriptive statistics of variables used for exploration investment analysis

sum exploration oilprice oilprod deprate resrep geolpoten cost

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
exploration	210	8026	2123.437	5155	11792
oilprice	210	6.917633	3.680705	2.44	15.094
oilprod	210	6.73e+08	3.64e+08	6.90e+07	1.40e+09

deprate	210	.0736205	.0527581	.005236	.226395
resrep	210	.8391705	9.583891	-21	135
geolpoten	210	2811.88	1618.603	1095.6	6092.4
cost	210	12438.37	3590.85	9151	23522

Consequently, correlation matrix of the variables was computed to check the adequacy and validity of the variables for this experiment against possible multicollinearity due to feedback between dependent variable and independent variables or among the independent variables. The result was found to be within acceptable ranges with no significant correlation between any pair wise, suggestive of the lack of simultaneity effect among the variables (Table 9.2 and details in Appendix 9.2). Similarly, the result also gives an idea of the association among the variables.

Table 9.2: Correlation matrix of variables used for exploration investment analysis

pwcorr exploration oilprice oilprod deprate resrep geolpoten cost

	exploratn	oilprice	oilprod	deprate	resrep	geolpoten	cost
exploration	1.0000						
oilprice	0.6530	1.0000					
oilprod	-0.0555	-0.1453	1.0000				
deprate	-0.0686	-0.1250	0.1235	1.0000			
resrep	0.0453	-0.0587	-0.0147	-0.0553	1.0000		

geolpoten	0.3098	0.2286	0.1941	0.2290	-0.0097	1.0000	
cost	0.2047	0.4226	0.1241	0.1179	-0.0459	0.5249	1.0000

9.1. 2 Model estimation

To achieve the objectives of this research and test the hypotheses that flow of exploration investment is positively influenced oil price, oil production, reserves replacement rate, geological potential, and oilfield depletion rate and is negatively influenced by finding cost, exploration investment is assumed to be a function of these variables. Additionally, the assumptions outlined in section 5.1 also apply. Consequently, the exploration investment equation is as follows:

Exploinvest = *f* (oil price, oil production, reserves replacement, oilfield depletion, geological potential, finding cost)

Cross country panel data approach was used to investigate the relationships and control for and/or account for country specific heterogeneities. Hence, fixed effects and random effects models were specify and estimated based on the aforementioned assumptions in section 5.1 as follows:

$$EI_{it} = \alpha_i + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 resrep_{it} + \beta_4 deprate_{it} + \beta_5 geolpoten_{it} + \beta_6 cost_{it} + \varepsilon_{it}$$

(Fixed effect model) (1)

$$EI_{it} = \alpha + \beta_1 oilprice_{it} + \beta_2 prod_{it} + \beta_3 \quad resrep_{it} + \beta_4 deprate_{it} + \beta_5$$

$$geolpoten_{it} + \beta_6 cost_{it} + \mu_{it} + \varepsilon_{it} \quad \text{(Random effect model)} \qquad (2)$$

Where i = 1……7 , t = 1………..29

EI_{it} is the exploration investment in each country in year t, $oilprice_{it}$ is the oil price in ith country and year t, $Prod_{it}$ is the oil production of ith country in year t, $resrep_{it}$ is the reserves replacement rate of ith country in year t, $deprate_{it}$ is the oilfield depletion rate of ith country in year t, $geolpoten_{it}$ is the geological potential of ith country in year t, $cost_{it}$ is the cost of finding and developing a barrel of oil equivalent in ith country in year t, αi is each country's unknown intercept which captures each country's unobserved time-invariant specific heterogeneity in the fixed effect model , ε_{it} is the error terms in the fixed effect model. While in the random effect specification, ε_{it} and u_{it} are within and between countries error terms respectively.

9.1.3 Empirical Results

The estimated results of the two equations tested hypothesized relationships and constitute exploration investment models for Non-OPEC countries are reported in Table 9.3 with the details featured in Appendix 9.3a & b. The models generally show expected signs and confirm the validity of hypotheses (1,2,4,5 and 6). In hypothesis 3, positive relationship is anticipated between finding cost and exploration investment but the results show negative relationship. The models also show good suitability as evidenced by F-test, which revealed a Prob > F less than 0.05 (0.000) in all cases confirming that the coefficients are different from zero. However, random effects model show better statistical performance as evidenced by R^2 of 0.4920 indicating that about 50% of the observed variation in exploration investment within the selected non-OPEC countries from 1980 – 2009 is explained by the independent variables, while the fixed effect model show an R^2 of 0.4878 indicating about 49% of the observed variation due to the explanatory variables. Moreover, only about 12 percent of the variance is due to differences across panels in the fixed effects model as evidenced by rho = .0120069 while none in the random effects model (rho = 0) which supportive of the suitability of random effect model for this experiment. However, both models reveal the positive statistically significant influences of oil price and geological potential on exploration investment at 0.001 levels and negative statistical significant influence of finding cost at 0.001 level. The estimated coefficients of the two models show statistical insignificant influence of oil production, reserves replacement, and oilfield depletion rates on exploration investment in the selected non-OPEC countries.

Table 9.3: Results of fixed and random effect models regression for exploration investment

Variable	Exploration investment in OPEC MC	
Exploration investment	Fixed effect model	Random effect model
Oil price	410.1825 *** (0.000)	399.8569***(0.000)
Oil prod	5.05e-07 (0.444)	1.19e-07 (0.698)
Depletion	976.319 (0.849)	606.7911 (0.771)
Reserves replacement	20.82315 (0.071)	20.40874 (0.067)
geological potential	.3322291 *** (0.000)	.34913744*** (0.000)
Finding cost	-.1361024*** (0.001)	-.1302839*** (0.001)
cons	5518.411 *** (0.000)	3765.267 (0.245)
rho	.0120069	0
R^2	0.4934	0.4920
F-test	F(6,197) = 31.98 prob > F = 0.0000	Wald chi2(6) = 196.57 Prob > chi2 = 0.0000
Sigma_ u	171.61151	0
Sigma_e	1556.7106	1556.7106
N	7	7
No. of obs	210	210

Legend: * P < .05, ** P < .01, *** P <. 001 p-value in parentheses

9.1.3.1 Panel Tests

Series of statistical tests performed confirmed the validity of the estimated results. Hausman test revealed the suitability of random effects model over foxed effect given the structure of the data. Since our data is a macro panel with long dimension (T=29), Pesaran's test carried out to check for cross sectional dependence and Wooldridge test for serial correlation indicates that the residuals are correlated across entities and the errors are also serially correlated. Consequently, Driscoll and Kraay (1998) covariance matrix estimator was subsequently applied to adjust the standard errors of the coefficient estimates for dependency in the residuals. Woodridge test for the presence of group wise hetersokedasticity among the variables was also performed. Hadri (2000) LM test for stationarity was also implemented to check for presence of unit roots among the variables. The detail result of the tests is presented as follows:

9.1.3.1.1 Hausman Test

Hausman (1978) designed a test for orthogonality between the regressor and the random effect to guide selection between the FE and RE specifications Greene (2003). The test statistics calculated for time varying regressors test whether there is significant difference between fixed and random effects models. Under the null hypothesis, the difference between the estimates of the two models should not differ systematically. The result of the test is presented in Table 9.4 and details in Appendix 6.4

Table 9.4: Result of Hausman test for exploration investment analysis

Variable	Fixed effect coefficients (b)	Random effect coefficients (B)	b-B

Oil price	410.1825	399.8569	10.32557
Oil production	5.05e-07	1.19e-07	3.87e-07
Depletion rate	976.319	606.7911	369.5279
Reserves replacement	20.82315	20.40874	.414419
Geological potential	.3322291	.3491374	-.0058186
Finding cost	-1361024	-.1302839	-.0169083
Hausman's test statistics χ^2 (3) = 0.46		Prob > χ2 = 0.9281	

The value of the test statistic 0.46 is less than the critical value 1.96 and prob. value is 0.9281 which is higher than 0.005 imply the acceptance of the null hypothesis and rejection of the alternative. Thus, the decision criteria confirm the suitability of random effect model over fixed effect model. RE estimator is consistent under the null given the data structure, while the FE estimator is efficient under the alternative but inconsistent under the null. The test was conducted using Stata software through the command *hausman fe re*

9.1.3.1.2 Pesaran CD test for cross sectional dependence

According to Baltagi (2001), cross sectional dependence can be a problem in macro panels with long time series (over 20-30 years). However, it is not much of a problem in micro panels (few years and large numbers of cases). Pesaran (2004) developed simple test procedure for where residuals are correlated across entities. It is based on a simple average of all pair-wise correlation coefficients of the Ordinary Least Squares (OLS) residuals from the individual regressions in the panel Peseran (2004). It is also based on the assumption that the underlying error processes are symmetrically distributed. Its asymptotic distribution under the null hypotheses is proven and shown to be strong to single or multiple breaks in the slope coefficients and/or error variances provided the unconditional means of variables in the panel remain constant over time. The test statistics show evidence of dependency as evidenced by Pr < 0.05, thus rejecting the null hypothesis that errors are not correlated becomes apparent. The result is present in Table 6.5 and details in Appendix 9.5. The test was conducted on Stata software using the command *xtcsd, pesaran abs*

Table 9.5: Result of Pesaran CD tests for cross sectional dependence in non-OPEC exploration investment models

Pesaran's test of cross sectional independence = 24.685,Pr = 0.0000
Average absolute value of the off-diagonal elements = 0.983

9.1.3.1.3 Woodridge (2002) test for Serial Correlation

Serial correlation is also a potential problem associated with macro panels with long time series (over 20-30 years). Serial correlation causes the standard errors of the coefficients to be biased leading to less efficient results (smaller than actual and higher R-squared). Thus, there is the need to check for serial correlation in the idiosyncratic error term in panel data linear models. Woodridge (2002) developed a robust and simple test for serial correlation which utilizes the residuals from the regression in first differences. It is worth noting that first differencing of the data removes individual-level effect based on time-invariant covariates and the constant. The test is reported to possess good statistical properties in reasonably sized data samples (Drukker, 2003). The null hypothesis of the test assumes no first order serial correlation. The result of the test indicates that the errors are serially correlated as evidenced by Pr < 0.005 (0.0000) (Table 6.6 and Appendix 6.6).Hence, the null hypothesis is rejected. The test is performed using *xtserial dependent variable independent variables* on Stata.

Table 9.6: Result of Woodridge test for serial correlation for exploration investment model

FE Model	H0: no first order serial correlation F (1,6) = 1038.921 Prob >F = 0.0000

9.1.3.1.4 Test for group wise heteroskedasticity

Heteroskedasticity problem arises when the variance of the unobserved error depends on the explanatory variable. As a consequence, the estimated model will not be able to get unbiased estimators of the ceteris paribus effects of the explanatory variable on the dependent variable Woodridge (2006). The most likely deviation from homoscedastic errors in the context of panel data is error variances specific to the cross-sectional units. Group wise heteroskedasticity arise when error process is homoskedastic within cross sectional units, but its variance differs across units. Green (2000) developed Modified Wald test to check groupwise heteriskedasticity in panel models. Stata command *xttest3* computes a modified Wald statistic for groupwise heteroskedasticity in the residuals of a fixed-effect regression model in line Green (2000). The null hypothesis of the test assumes homoscedastic error process within cross sectional units which imply that $\sigma_i^2 = \sigma^2$ for $i = 1.........12$. According to Baum (2001), the modified Wald statistic calculated is feasible once the assumption of normality is disrupted at least in asymptotic terms. He further asserted that the power of the test is very low in the context of fixed effects with Large N, small T panels. This reaffirms the suitability of the test in this case given our sample structure Large T and small N. The resulting test statistic presented in Table 9.7 and Appendix 9.7 is distributed Chi-squared under the null hypothesis of homoscedasticity. The result confirm the consistency of the null hypothesis in our model as evidenced by ($P>0.05$) which suggest no evidence of groupwise heteroskedasticity. The null hypothesis is therefore accepted.

Table 9.7: Results of modified Wald test for groupwise heteroskedasticity in fixed effect model

FE model	H0: sigma (i)^ 2 = sigma ^ 2 for all i Chi2 (7) = 0.23 Prob > chi2 = 1.0000

9.1.3.1.5 Baltagi and Wu (1999) generalized least square estimator for random effects model

The presence of serial and auto correlation in estimated panel models causes the biasness of standard errors. Antoine et al (2010) pointed that ignoring correlation of regression disturbances over time in the estimated panel data models can result in biasness of statistical inference. Baltagi and Wu (1999) provided a feasible generalized least squares procedure as a weighted least squares approach that can be applied to correct for auto and serial correlation in random effects model. This technique is simple to compute and offers natural estimates of the serial correlation and variance components parameters. It transmutes serially correlated error-component disturbances into spherical disturbances by removing the AR (1) component. AR (1) obtains estimates of a regression equation whose errors are serially correlated. These estimates are efficient when the disturbances in the equation follow an autoregressive process of order one. The regression equation of the estimates which are corrected for first order serial correlation is obtained through AR (1) command *xtregar a*s generalized least square estimator for random effect model. The result of the corrected RE model is presented and discussed in the section for analysis of result.

9.1.3.1.6 Hadri (2000) test for unit roots

The Unit root test for stationarity of variables have widely been applied in time series analyses, but recent growing interest in its application in panel data models are more prominent. Hadri (2000) developed Lagrange Multiplier (LM) procedures to test the null hypothesis that all the individual series in the panel are stationary (either around a mean or around a trend) against the alternative hypothesis that at least one series contain unit root exist. The assumption of normal distribution of error terms also holds and implements for panel models with fixed effects, individual deterministic trends, and heterogeneous errors across cross-sections. It is suitable for panels with Large T and moderate N like in this case (T=31, N=7) and requires that the data is strongly balanced like in this case. The test is correct asymptotically as T tends to infinity followed by N tending to infinity. The LM tests are based on the simple average of the individual univariate stationarity test, which after a suitable standardization follows a standard normal distribution. The results of the test is consistent with the null hypothesis as evidenced the test statistics and p-value <0.005 (Table 9.8). Hence accepting the null hypothesis and conclude stationarity of all the series. The Stata command for this test is *xtunitroot hadri variable*. For details of the test results see Appendix 9.8.

Table 9.8: Results of Hadri (2000) test for unit roots in exploration investment model

H0: All panels are stationary Ha: Some panels contain unit roots Time trend: Not included Heteroskedasticity: Not robust	Number of panels: 7 Number of periods: 30 Asymptotics: T,N -> Infinity sequentially	
Variables	Statistics	P-value
Exploration investment	2.8564	0.0021 (Null accepted)
Oil price	8.2707	0.0000 (Null accepted)
Oil production	37.4250	0.0000 (Null accepted)
Reserves replacement	-1.0995	0.8642(Null rejected)
Oilfield depletion	30.6165	0.0000 (Null accepted)
Geological potential	27.0262	0.0000 (Null accepted)
Finding cost	25.6221	0.0000 (Null accepted)

9.1.4 Analysis of Result

The results of panel tests conducted to ascertain the adequacy of estimated results in explaining the influences of the independent variables on exploration investment suggest the presence of auto and serial correlations. Consequently, Baltagi and Wu's (1999) generalized least square estimator was applied to the preferred random effects model to correct the serially correlated component errors. The findings of the corrected random effect model presented in Table 9.9 are analyzed and discussed as follows: (See Appendix 9.9 for the details of the results).

Table 9.9: Estimated results of random effects model with Baltagi and Wu generalized least square estimator

Variable	
Exploration investment	Corrected Random effect model
Oil price	380.4401*** (0.000)
Oil production	-1.75e-08 (0.968)
Depletion	-46.05441 (0.987)
Reserves replacement	20.21602* (0.042)
Geological potential	.3508896*** (0.001)
Finding cost	-.0883513 (0.052)
Cons	5540.377 (0.221)
R^2	0.4878
F-test	Wald chi2 (7) = 119.09
	Prob > chi2 = 0.0000
N	7
Rho_ar	.34668238
Number of lags	3

Legend: * p < 0.05, ** p <.01, *** p < .001 P-values in parentheses

The estimated result of the auto and serial correlation corrected random effects model generally show expected signs and confirm the validity of hypotheses 1, 3, 5, 6, and 7. Positive influences of oil production and oil field depletion on exploration investment are expected in hypotheses 2 and 4, but the results show negative relationships with exploration investment. The model also show good suitability and satisfactory performance as evidenced by F-test which revealed Prob > chi^2 less than 0.005 (0.000) suggesting that that the coefficients are different from zero. The estimated result also shows encouraging statistical performance in determining the effect of the explanatory variables on the dependent variable with an R^2 of 0.4878. This indicates that about 49 percent of the observed variation in exploration investment within and between non- OPEC members from 1980 – 2009 is explained by the independent variables. Overall, the model show significant effects of oil price, reserves replacement and geological potential in driving exploration investment behaviour. This indicates the significant role of economic and uncertainty factors in shaping exploration investment behaviour in non-OPEC countries.

International oil price and geological potential of petroleum bearing basin exerts a statistically significant positive influence on exploration investment at 0.001 levels respectively. Similarly, reserves replacement rate has a statistically significant positive influence on exploration investment at 0.05 levels. This is intuitive considering the competitive behaviour of non-OPEC producers, any increase in oil price will increase income levels thereby enhancing internal cash flow and availability of funds to invest in risky exploration. Despite increase in the maturity of the basins with increases in drilling and consequential decline in size of discoveries, when the geological potential of the basin or unexplored part of it enhances, it encourages investments in reserves replacement efforts to find additional reserves. This entails investments in exploration prospects and leads. However, oil production, oilfield depletion, and finding costs exert negative insignificant influence on exploration spending in the selected non-OPEC countries. Apparently, any increase in non-OPEC production that is not due to demand growth may distort market fundamentals, which may have negative consequences on oil prices and income levels. To further determine the impact and responsiveness of exploration investment to changes in the regressors, average elasticities of the covariates was computed[137]. The Stata software enables the computation after the estimation of the corrected random effect model with Baltagi and Wu's (1991) generalized least square estimator using the command *xtregar dep var independent variables, re* . The decomposed average elasticities are as shown in Figure 9.1 with details in Appendix 7.0. Overall, the responsiveness of exploration investment to changes in oil price and geological potential appear elastic.

[137] According to Iledare and Pulsipher (2001), elasticity is the percent change in a dependent variable as a result of one percent change in an independent variable.

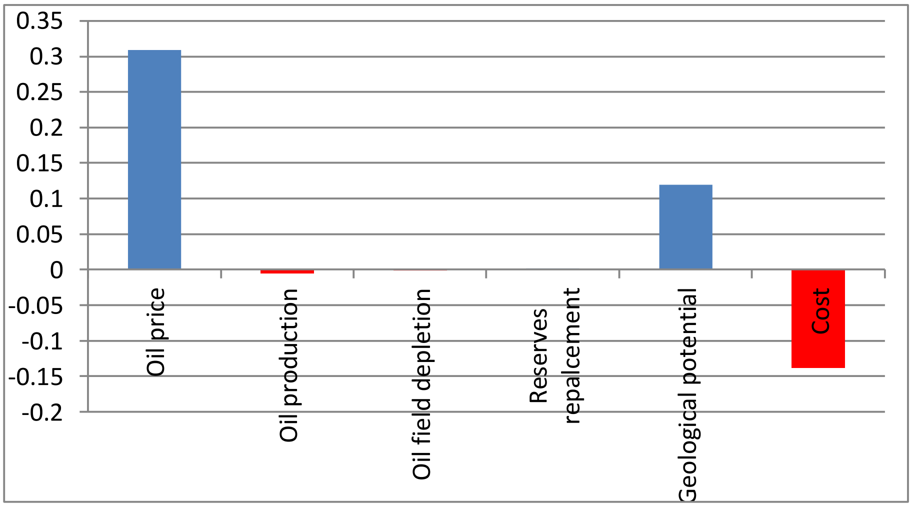

Figure 9.1: Estimated decomposed average elasticities of exploration investment to changes in regressors in non-OPEC

On the average, 1 percent increase in international oil price keeping other factors constant is expected to result to 0.34 percent increase in exploration expenditure. Although geological potential exerts higher influence on exploration investment behaviour, investment appears to be slightly more responsive to changes finding cost. A 1 percent increase in geological potential could lead to 0.12 percent increase in exploration expenditure on the average keeping other factors constant, while 1 percent increase in cost of finding and developing a barrel is on the average is expected to reduce exploration investment by 0.14 percent keeping other factors constant. Conversely, the elastic responsiveness of exploration investment to changes in reserves replacement, oilfield depletion, and oil production appear insignificant. On the average, 1 percent increase in reserves replacement rate is expected to increase exploration spending by 0.002 percent keeping other factors constant. Similarly, 1 percent increase in oilfield depletion rate could decrease investment by 0.0004 percent on the average. In the same vein, 1 percent increase in oil production is expected to reduce exploration investment by 0.0052 percent holding other factors constant.

9.2 Conclusion

Static investment equation was specified and estimated using fixed and random effects models to investigate the role of competing factors in influencing exploration investment in selected non-OPEC countries. Random effects model turned out to be the preferred model based on the result of the Hausman test. But, statistical tests suggest the presence of auto and serial correlation among the residuals of the model can bias the estimated coefficients. The Baltagi and Wu (1999) generalized least square estimator was applied to the random effect model to correct correlation in errors. The estimated result of the corrected exploration behaviour model used to test our hypotheses show good fitness and robust statistical performance with expected signs in most of the tested hypotheses. Overall, the estimated results show the significant positive influences of oil price, geological potential and reserves replacement on exploration investment signifying the importance of economic and uncertainty factors. In terms of impact, exploration investment appears to dominantly respond to changes in oil price, geological potential, and cost. These findings lay support to the postulations of Hotelling's and the theory of irreversible investment uncertainty. Similarly, the result is consistent with Broadman (1985), Iledare and Pulsipher (2001), Drollas 91986), Reiss (1989), Pesaran (1990), Iledare (1995), Iledare (1999), and Kaufmann and Cleveland (2001).

PART IV: GENERAL CONCLUSION

CHAPTER 10: GENERAL CONCLUSION AND POLICY IMPLICATIONS

10.0 General conclusion

The main objective of this dissertation is to investigate the influence of competing economic, uncertainty/field performance, technical, and petroleum fiscal policy factors in driving exploration and development investment behaviour of international oil and gas industry. To achieve this objective, upstream investment in the oil and gas industry is assumed to typically respond to current market indicators as pointers of future economic conditions, particularly oil price[138]. Consequently, investment equations (exploration and upstream investments in OPEC and selected non-OPEC countries) were specified and estimated in panel data framework using fixed and random effects models for the period 1980 – 2011. The models tested the hypotheses used to find explanation for the research questions under investigation. Statistical tests conducted to ascertain the adequacy of the estimated result for this experiment suggest the presence of auto and serial correlation among the residuals of all the models, which can bias the estimated coefficients. The test

[138] This is consistent with Solomon (1989).He further pointed that the characteristic volatility of oil markets makes forecasting enormously risky.

results also suggest the suitability of fixed effect models as most suitable models that explain the effect of the explanatory variables in influencing OPEC exploration, OPEC upstream, and non-OPEC upstream oil and investment behaviour models. Consequently, Driskoll and Kraay (1998) parametric covariance matrix estimator was applied to adjust for standard errors in the most suitable estimated coefficients of two fixed effects models for OPEC and one for non-OPEC countries. In the case of non-OPEC exploration behaviour model, random effects model, appear most suitable and Baltagi and Wu's (1999) generalized least square estimator was applied to correct for correlation in the error structure. Generally, the estimated results of the exploration and upstream investment behaviour models for both OPEC and non-OPEC countries show good fitness, robustness, and strong statistical performance with expected signs in most of the tested relationships thus attaining the objectives of the study.

The estimated coefficients of the OPEC exploration investment model show significant positive influence of oil production (at 0.001 level of statistical significance), oil price, reserves replacement, and geological potential (at 0.05 levels respectively) ; and negative influence of resource depletion (0.05 level) on exploration investment. This indicates that both economic and uncertainty factors are important drivers of exploration investment behaviour in OPEC countries. However, the impact of oil price and production appear quite significant as evidenced by the elastic response of exploration investment to changes in oil production and price. On the average, 1 percent increase in oil production could result to 0.76 percent increases in exploration investment within OPEC keeping other factors constant. Similarly, 1 percent increase in oil price is expected to result to 0.73 percent increase. This indicates the sensitivity of exploration investment in OPEC countries to changes in economic factors (oil price and production).

Conversely, the exploration investment behaviour model for non-OPEC show significant positive influences of oil price (at 0.001 levels of significance), geological potential, and reserves replacement (0.05 levels respectively) on exploration investment and insignificant positive influences of oil production, resource depletion, and negative influence of finding cost. This also indicates the effectiveness of economic (oil price) and uncertainty factors (geology and reserves replacement) in influencing exploration behaviour in non-OPEC countries. In terms of impact, exploration investment show elastic response to changes in oil price, geological potential, and cost. On the average, 1 percent increase in oil price is expected to increase exploration expenditure by 0.34 percent keeping other factors constant. Similarly, 1 percent increase in geological potential and cost could, on the average, increase exploration investment by 0.12 percent while cost may reduce exploration investment by 0.14 percent respectively.

In the case of OPEC upstream investment model, the estimated results show significant influences of economic, uncertainty, technical, and petroleum fiscal policy factors on upstream investment. In terms of impact, the result shows significant elastic response of upstream investment to changes in technological improvement and oil price movement suggesting higher influences of economic and technological factors in shaping upstream investment behaviour in OPEC countries. A 1 percent increase in technological progress on the average is expected to induce corresponding 1 percent increase in upstream investment; and 1 percent increase in oil price could result to 0.75 percent increase in upstream spending within OPEC countries keeping other factors constant. Similarly, oil production and natural gas rent exerts significant negative influence while resource depletion and reserves replacement also exerts positive significant influence upstream investment. This also show the important role uncertainty and petroleum fiscal policy factors play in shaping upstream investment decisions. Nevertheless, the responsiveness of upstream investment to changes in oil production, oil rent, natural gas rent, oilfield depletion, and reserves replacement appears inelastic.

Similarly, the estimated results of the Driskoll and Kraay (1998) standard error adjusted upstream investment model for non-OPEC countries also reveal statistically significant and elastic response of upstream investment to changes in oil price and technological progress respectively. 1 percent increase in technological progress on the average could induce corresponding increase of about 1 percent in upstream spending holding other factors constant. This indicates the dominating effect of economic and technological factors in influencing upstream investment also in non-OPEC. It is worth noting that the success of oil and gas exploration and development in non-OPEC countries that have preponderance of unconventional resources depends heavily on technological developments. Similarly, 1 percent increase in oil price is expected to result to about 0.8 percent increase in upstream investment within the selected non-OPEC countries. The higher elastic response of upstream investment in non-OPEC countries to oil price movement suggests and supports the fact that non-OPEC producers behave in a more competitive manner than OPEC producers. Similarly, oil and natural gas rents appear to have statistical significant influence on upstream investment in non-OPEC countries at 0.001 levels respectively indicating the effectiveness of both natural gas and oil fiscal regimes in influencing upstream investment in non-OPEC in comparison to OPEC where only natural gas fiscal regime appears to have significant influence on upstream investment. However, oil production and uncertainty/performance variables (reserves replacement and depletion rates) show insignificant negative influence on upstream investment in non-OPEC countries. This suggests the significance of above ground factors in driving exploration and developing investment over below ground factors in non-OPEC. Considering the low proven oil reserves' propensity in these regions and relatively low geological potential of petroleum basins in comparison to OPEC MCs, investors are aware of the existence of these uncertainties. As a consequence, the huge positive impact of technology offset for these uncertainties, and investors rely on economic and petroleum fiscal policy factors to enhance and justify exploration and development investment decisions.

Conclusively, the oil and gas investment behaviour models show the significance of economic, technical factors and petroleum fiscal policy factors at varying levels in shaping investment behaviour in the international upstream petroleum industry in general. While economic, uncertainty and technical factors appear to greatly influence investment in OPEC countries, only economic, technical and fiscal policy factors strongly influence investment behaviour in non-OPEC countries. Below ground factors influence exploration and development spending in non-OPEC countries in an insignificant manner. The empirical results also provide support for the negative influence of frequent increases in petroleum fiscal regimes on upstream investment, which descriptive and qualitative analyses in chapter 2 suggest. The exploration and upstream investment behaviour models in the case studies provide useful information to assess, using basic economic concept of elasticity, the influence of competing factors influencing oil investment decisions in OPEC and non-OPEC countries. The findings of this research are consistent with theoretical postulates on investment behaviour in the oil industry and consistent with the result of previous empirical researches.

10.1 General Policy Implications

In general, the estimated results show the significant influence of economic, technical, uncertainty, and petroleum fiscal policy factors in driving exploration and upstream investment in OPEC countries. Conversely, economic, technical, and petroleum fiscal policy factors show significant influence on oil and gas exploration and development investment in non-OPEC countries. The significant influence of oil price suggests its important role on investment decisions in the oil and gas industry. Consequently, the market development policies of OPEC and non-OPEC countries are to favour high oil prices to increase cash flow of operators, reduce rate of return, and provide incentive for capital intensive exploration, development, and redevelopment oil and gas ventures. While examining the long run effect of high oil prices on oil and gas investments is beyond the scope of this research, it is safe to assert that sustained higher oil prices may not be in the best of interest of producers and consumers given the possibility of negative effect on the economy of consumers and enhancing interfuel substitution for producers. As a consequence, avoiding market distortion and enhancing the interplay of market fundamentals can be an effective strategy that can ensure high oil prices that can ensure fair return of investment to producers with less or no harm on the economy of consumers.

The positive influence of increase in oil production on exploration investment in OPEC countries imply that production control policies could retard risky exploration investment by squeezing operators' cash flow. The significant positive influences of oil price and production on exploration investment in OPEC countries suggests the reliance of operators on internally generated funds to finance risky exploration ventures. Considering the positive impact of oil prices and rising cost of finding additional barrels, especially in deep water area and deeper horizons, increase in oil production will increase cash flow and additional windfall earnings of operators' thus providing incentive for investment in risky exploration drilling ventures. Evidently, the combined positive effects of oil price and oil production suggest the reliance of exploration drilling on higher cash flow and additional revenue through windfall profits to encourage investment in risky oil and gas exploration. This is intuitive given the fact that most exploration investment is financed with internally generated funds. Consequently, reserves growth policies of OPEC should de-emphasize production control to encourage exploration spending in underexplored areas like deep-water terrain.

Conversely, the negative influence of oil production on upstream investment in both OPEC and non-OPEC countries suggest the effectiveness of production control policies in encouraging upstream investment mainly in oil and gas field development and redevelopment. This is plausible given the maturity of most OPEC and non-OPEC petroleum basins and low depletion level, operators are encouraged to invest in enhanced recovery and pressure support projects to arrest pressure decline and delay the period of reserves exhaustion. Similarly, operators will invest in enhanced oil recovery projects to increase recovery factors and adds to reserves due to diminishing return to size of discoveries. Therefore, OPEC and non-OPEC reserves growth policies are to focus on production control policies to encourage investments in field redevelopment, redevelopment, as well as secondary and tertiary oil recovery projects in matured or well explored petroleum basins. Increase in oil supply can motivate operators to focus on profit savings for higher shareholder returns in the short term rather than capital formation.

The significant influence of technological progress on upstream investment in both OPEC and non-OPEC countries also indicates that redevelopment of aging producing oil fields to enhance recovery factors, deep water, and heavy oil resource exploration and development rely greatly on advances in exploration and exploitation technologies. As a consequence, policies to encourage adopting cutting edge exploration and exploitation technologies as well technological innovation are highly desirable. OPEC and non-OPEC countries should actively engage, collaborate, and/or support industry wide

R&D projects that have the potential to develop cutting edge E&P technologies that will optimize exploration, development, or enhance oil recovery support. In the same context, OPEC countries in particular and non-OPEC producing nations alike should provide necessary policy framework for the effective development of petroleum industry innovation systems in their respective countries to grow innovative domestic capabilities.

The estimated results show the negative relationship between in oil and gas rents and upstream investments. This suggests that fiscal regime increases can retard oil and gas exploration and development in both OPEC and non-OPEC countries. This is intuitive given the role of taxes and royalties in defining investors rate of return and cash flow profile, any increase in fiscal elements will squeeze investor’s revenue and disincentivize investments in oil and gas exploration and development. The sensitivity of upstream investment to changes in gas rent in OPEC in comparison to oil rent suggest the ability of investors to withdraw/delay, cancel, or redirect gas investments due to the increase in gas fiscal regimes since its readily more accessible. Conversely, the negative influence of oil rent on upstream investment in OPEC suggest that investors will reduce less upstream investment due to increase in oil taxes and royalties given the preponderance of oil reserves in OPEC countries and its limited global spread and accessibility. Consequently, investment and economic development policies of OPEC and non-OPEC countries should de-emphasize on frequent fiscal regime increases. Moreover, care should be taken when designing fiscal regimes and upstream contracts for effective risk and reward sharing mechanisms to avoid frequent increases.

The negative influence of oilfield depletion on exploration investment for OPEC countries implies that fast depletion strategy will retard exploration investment given the maturity of the oilfields. It is obvious that an increase in depletion will fast track reserves exhaustion. Since the chances of discovery diminish as the petroleum basin matures, operators will be demotivated to invest in risky exploration drilling. Moreover, the depletion strategy of OPEC countries is supposed to favour resource conservation to encourage exploration investment. Conversely, the positive influence of oilfield depletion on upstream investment in OPEC countries suggest that resource conservation policies will retard investment in field development, secondary and pressure support schemes. It is also obvious that the higher the depletion rate, the faster the reservoir pressure drops and the more operators invest in pressure maintenance and support projects. Similarly, since there is a less likelihood of discovery, increase in depletion will motivate investments in secondary and tertiary recovery schemes as a viable means of additions to reserves. Consequently, OPEC depletion policies is supposed to favour fast exhaustion of producing wells to encourage investment in field development, redevelopment, and pressure support and enhance oil recovery projects.

Similarly, the positive effect of reserves replacement rate on exploration suggests that policies should target increase in reserves replacement rate as desirable. Intuitively, the higher the reserve replacement level, the higher investments in finding more reserves particularly in under explored areas of petroleum basins in OPEC countries. To support reserves replacement efforts, economic incentives could be administered to encourage operators to embark on risky exploration ventures especially in periods of low oil prices and rising exploration cost. In the same vein, the positive effect of geological potential on exploration investment in OPEC and non-OPEC countries suggest that strategies to increase partnership with speculative survey companies and effective data management are desirable to increase the geological viability of petroleum basins especially the frontier and underexplored areas through the deployment of state of art seismic technologies are desirable. This is to acquire high quality and resolution data that will make new geological knowledge available and increase exploration success by reducing exploration risk and enhancing the value of the petroleum basins.

10.2 Policy Implications for Nigeria

One of the objectives of this research is to empirically find clarification for the ongoing debate between the Federal Government of Nigeria and IOCs regarding the potentially negative effect of the proposed increase in oil and gas fiscal regimes in the Petroleum Industry Bill (PIB) currently under legislative consideration. The findings of this research show that increases in oil and gas rents will retard investment in oil and gas exploration and development. More importantly, increases in natural gas fiscal regime could significantly reduce upstream investments as per estimated coefficient (-25351) and P-value (0.000). The intuition is that, there is wider spread and easy accessibility of natural gas reserves over oil reserves across the world which imply more competing destinations for gas investments. Thus, providing incentive for investors to respond negatively to increases in gas fiscal regimes. Similarly, Nuhu and Heo (2013) also find the negative influence of oil and gas rent increases on exploration drilling and oil and gas reserves growth in Nigeria at 0.05 levels respectively. Consequently, Government policies are to de-emphasize on increases in fiscal regimes to facilitate oil and gas upstream investments that can induce multiplier effect on the economy and significant value addition in the long terms. Considering the current abysmal level of gas flaring—14.6 billion cubic metres as at 2011[139] and the Federal Government policy of monetizing both the flare and unflared volumes of gas to enhance domestic gas utilization and increase export capacity, decoupling gas fiscal regimes from oil with associated increases in taxes and royalties will de-incentivize investments in deliberate gas

[139] World bank global gas flare reduction: A public-private partnership via http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/EXTGGFR/0,,contentMDK:22137498~menuPK:3077311~pagePK:64168445~piPK:64168309~theSitePK:578069,00.html on 18/12/2014

exploration, development, and utilization thus reducing investment influx and affecting the actualization of national gas development policy objectives. It is worth noting that capital accumulation could bring spillover effects on the economy making deferment of oil and gas rent increases more beneficial in terms of overall impact and value addition to the economy. Interestingly, the recent spate of divestments by IOCs and subsequent buy-over by indigenous operators is manifestation of the positive spillover effect of foreign investments in terms of developing the technical and managerial skills of Nigerians following their employment with IOCs due to previous investments made by IOCs.

The findings of this study revealed the significant influence of technological progress on exploration and development investment in the oil and gas industry at 0.001 levels. Similarly, the responsiveness of upstream investment to changes in technological progress is significantly elastic. On the average, 1 percent increase in technological improvement is expected to induce a corresponding 1 percent increase in upstream investment keeping other factors constant. This suggests the importance of technological improvements in facilitating oil and gas investments. Impliedly, government is supposed to provide necessary policy framework for the effective development of petroleum industry innovation system to facilitate R&D activities geared towards enhancing creative imitation of exploration and exploitation technologies by indigenous players and subsequently upgrade the area of marginal field development, geological, and geophysical studies, as well as facilities engineering to increase investments and value addition to the economy, which is at the core of attaining the objectives of Nigerian content policy. As a first step to achieving this target, policy initiatives are supposed to target facilitating effective linkages and R&D cooperation between academia and industry. Furthermore, considering the maturity of onshore Niger Delta petroleum basin, deliberate policies to support adoption and deployment of cutting edge exploration and development technologies to enhance investments in secondary and tertiary recovery techniques to increase recovery factors of aging and producing fields as well as deep play exploration are particularly desirable. Similarly, the positive influence of technological improvement and geological potential on exploration and development investment lays support to the importance of deploying state of art seismic technologies in the acquisition of high quality seismic data, which will make more geological knowledge available and enhance the value of petroleum basins. Given the desire of the Federal Government to attract investments to inland basins and ultra-deep water, policies and strategies to enhance partnership with speculative survey vendors are highly desirable. Similarly, strengthening data storage and management capabilities will greatly enhance availability of quality data that could enhance geological understanding and spur investments.

The estimated results also suggest that production control policies will retard risky exploration investments in the under explored deep water considering the reliance of exploration to internally generated funds due to high risk. Increase in production will increase cash flow and motivate risky exploration ventures. Conversely, in matured onshore Niger Delta, basin production control policies can encourage investments in field redevelopment as wells secondary and tertiary oil recovery projects. The assumption is that since the onshore Niger Delta is matured, oilfields have relatively low depletion levels, which will encourage operators to invest in pressure support projects to arrest pressure decline, delay the period of ultimate reserves exhaustion, and extend the cash flow profile of the field. Similarly, operators will invest in enhanced oil recovery projects to increase recovery factors and add to reserves due to diminishing return to size of discoveries,

The negative influence of depletion on exploration investment provides support for resource conservation policies in shallow offshore and deep water terrains where there is higher probability of exploration success. Evidently, increase in depletion will fast track attainment of field decline level and reserves exhaustion. Since the chance of discovery diminishes as the petroleum drilling increases, operators will be demotivated to invest in risky exploration drilling. Therefore, depletion strategy is favour resource conservation to encourage exploration drilling. Conversely, positive influence of oilfield depletion on upstream investment suggests that resource conservation policies will retard investment in field development, secondary and pressure support schemes. It is also obvious that the higher the depletion rate drives, the faster the drop is in reservoir pressure which serves as incentive for operators to invest in pressure maintenance and support projects to defer decline and ultimate exhaustion. Similarly, since there is less likelihood of discovery, increase in depletion will motivate investments in secondary and tertiary recovery schemes as a viable means of additions to reserves. Consequently, onshore depletion policies should favour fast exhaustion of producing wells to encourage investment in oilfield development, redevelopment, and pressure support and enhance oil recovery projects.

10.3 Limitations of the Research

It is inherent that any research endeavor will be limited in some ways. Naturally, incorporating more variables could increase the explanatory power of the model and provide more insights. The lack of actual investment data of OPEC NOCs inhibits examining investment behaviour across the entire value chain. Similarly, the lack of data limits the extension of the study period to longer periods of time (say 1960s-1970s) to capture in more details the influence of the explanatory variables on the oil investment behaviour. Extension of the study period to 1960s or 1970s will provide more insight on the dynamics of oil and gas exploration and development behaviour among OPEC countries. In the same vein, conducting the research on period by period comparison, for example examining investment behaviour patterns among OPEC and non-OPEC during low oil price or high price periods, may provide additional insights. Furthermore, considering the current energy era, there can be many perspectives to understanding drivers of energy investments particularly from the point of view of consumers, like renewable energy or other sources of energy. But, to attain the objectives of the study, focus was made on the oil and gas industry.

10.4 Recommendations for future research

The role of capital formation in driving economic growth has long been established in the literature. But, the findings in the literature have been varied and diverse among nations. Most petroleum resources endowed nations rely heavily on oil and gas revenues to for income, savings, and re-investments in oil and gas activities. But, whether oil and gas investments lead to economic growth in these countries remains unknown. It would be interesting to investigate this relationship in both OPEC and non-OPEC countries considered in this study to find the direction of causality among the variables. Considering the variation in geological potential among the petroleum basins of OPEC countries and differences in the maturity level of the basins, it would be interesting to investigate the exploration efficiency within OPEC countries to determine the role of country specific time variant and invariant heterogeneities. Similarly, empirical investigation of determinants of investment with focus on variability of fiscal system (production sharing contract, joint venture and service contract) among OPEC and non-OPEC and as well as petroleum subsidies will provide additional insights on the influence of policy factors on oil and gas exploration and development investment. It would also be interesting to conduct this experiment in a dynamic framework in order to ascertain the timing and speed of adjustment of the regressors, considering the characteristic time lag between exploration, development and first oil by modelling investment behaviour within ten-year time periods to reduce endogeneity problems in dynamic models associated with long time period (T.> 15). Similarly, examining the relationship between oil and gas investment and other renewable or energy sources will provide insights on investment dynamics and inter-relationship among various energy sources.

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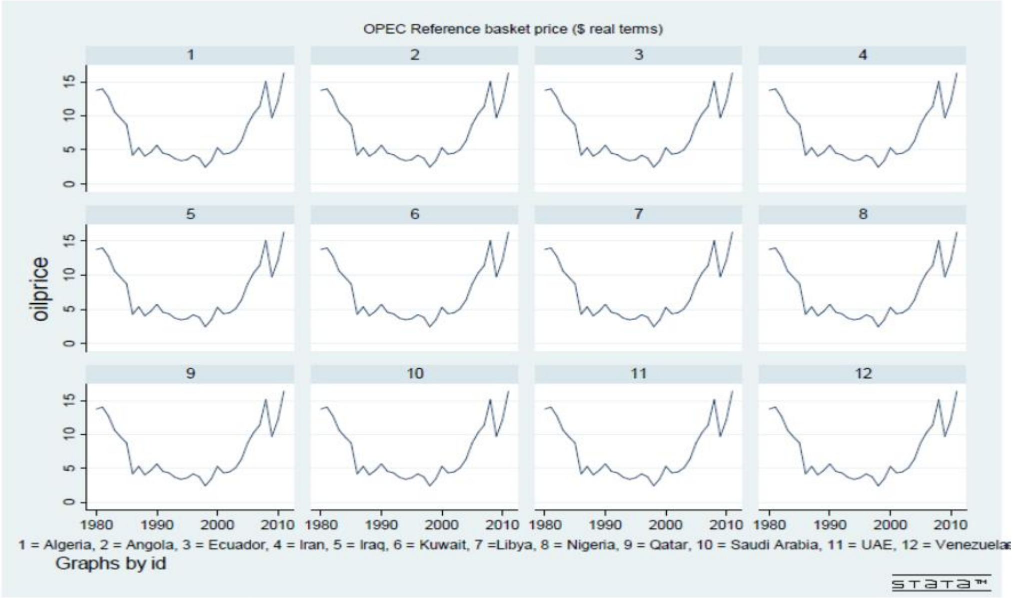
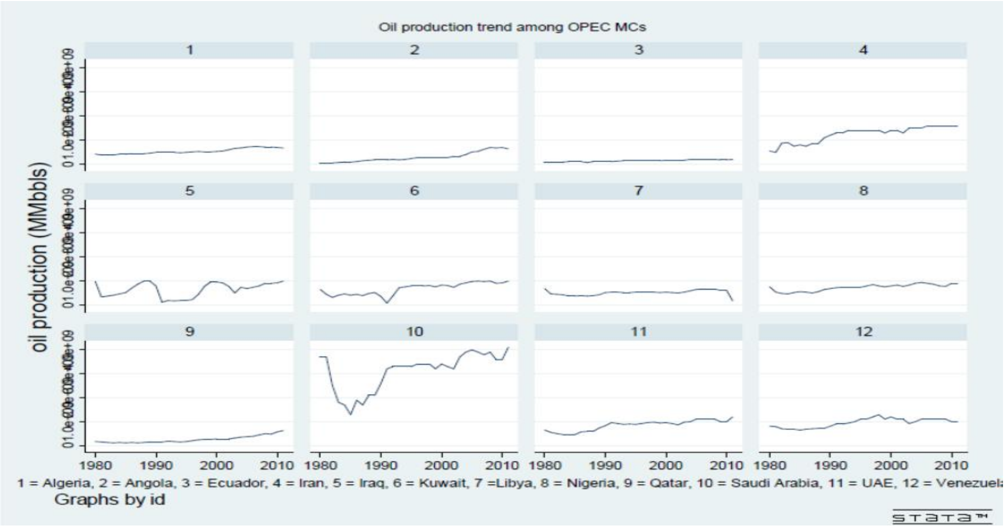
Appendices

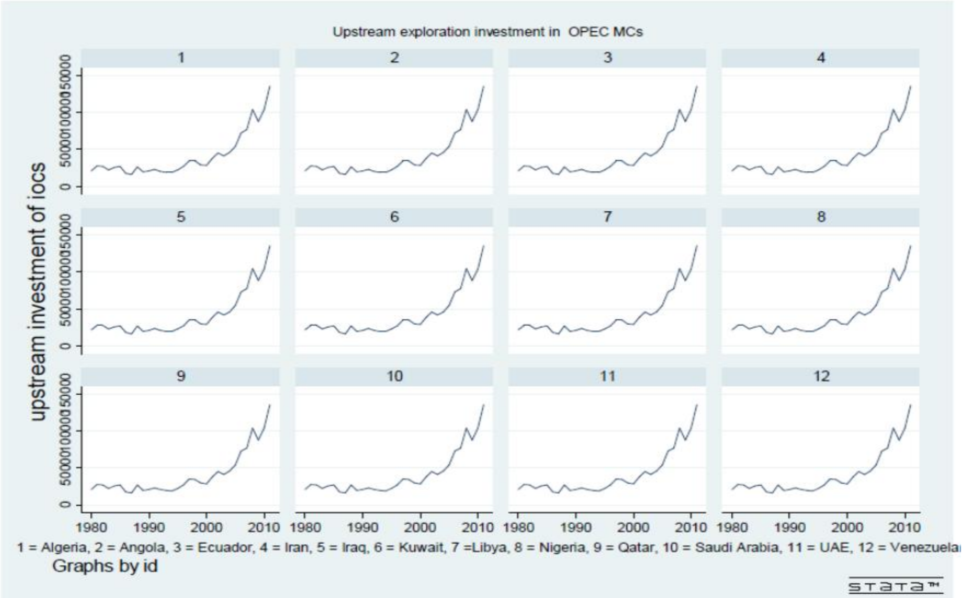
5.1a: OPEC Oil price



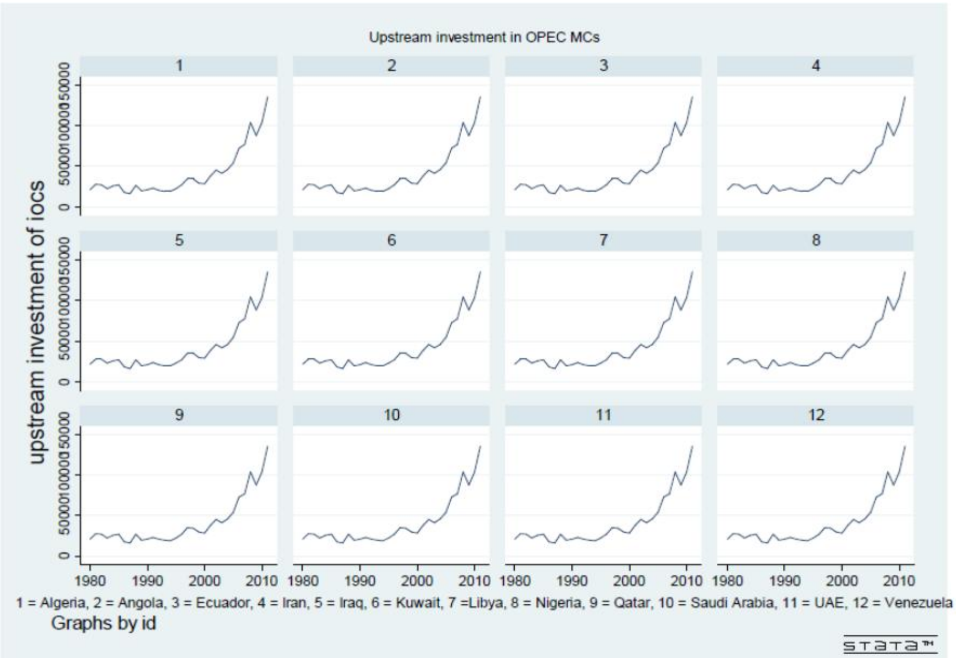
5.1b: OPEC Oil production



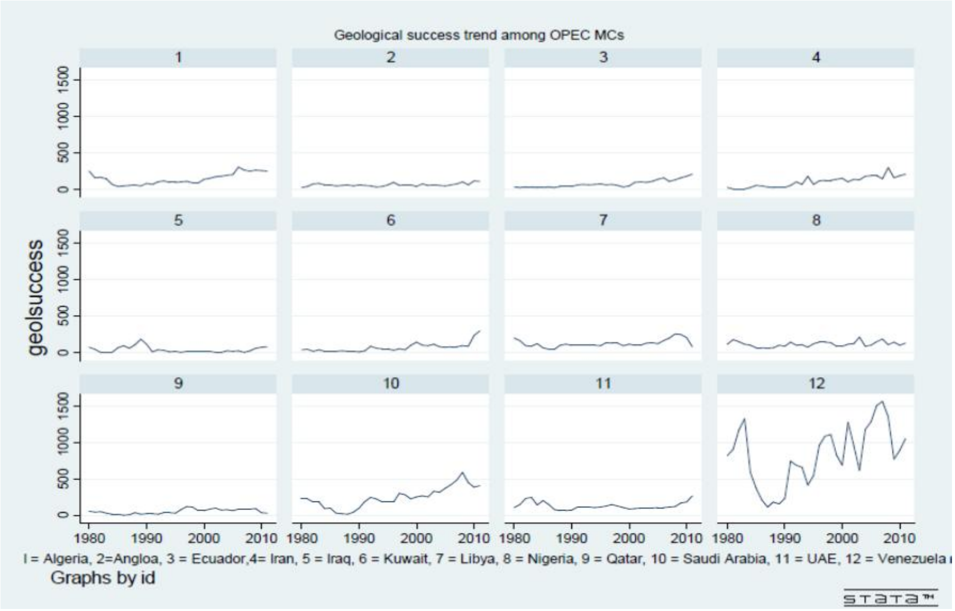
5.1c: OPEC Exploration investment



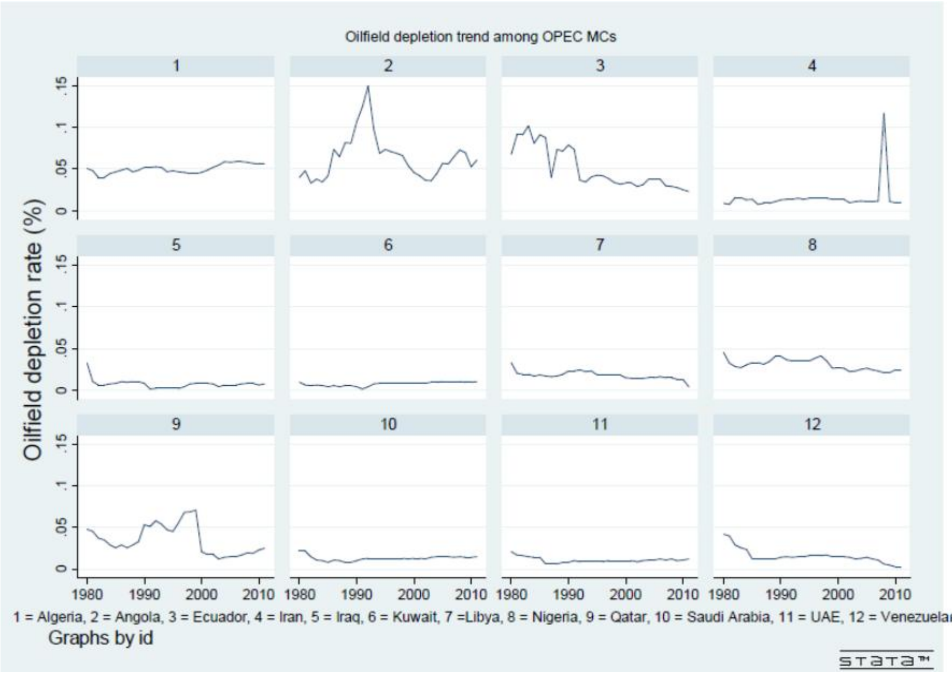
5.1d: OPEC Upstream investment



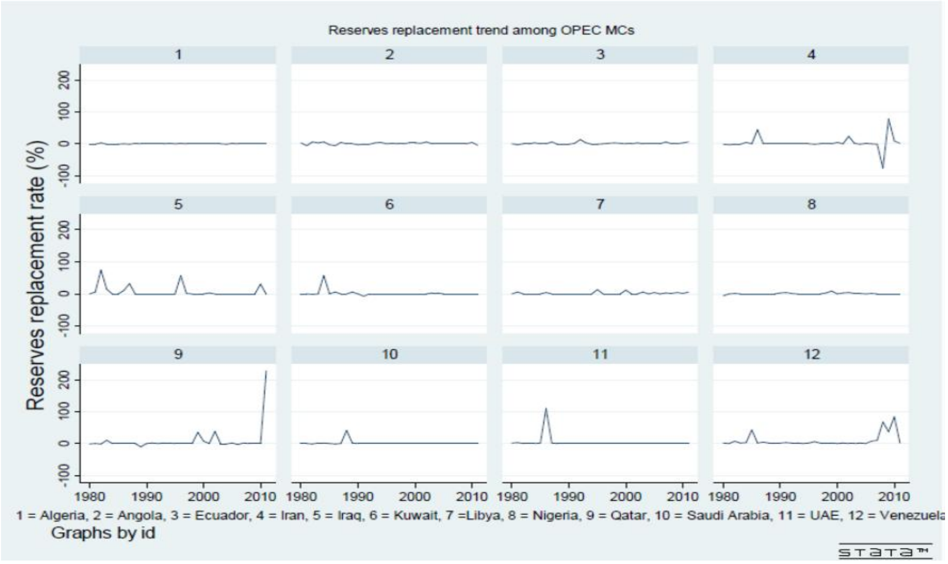
5.1e: OPEC Geological success



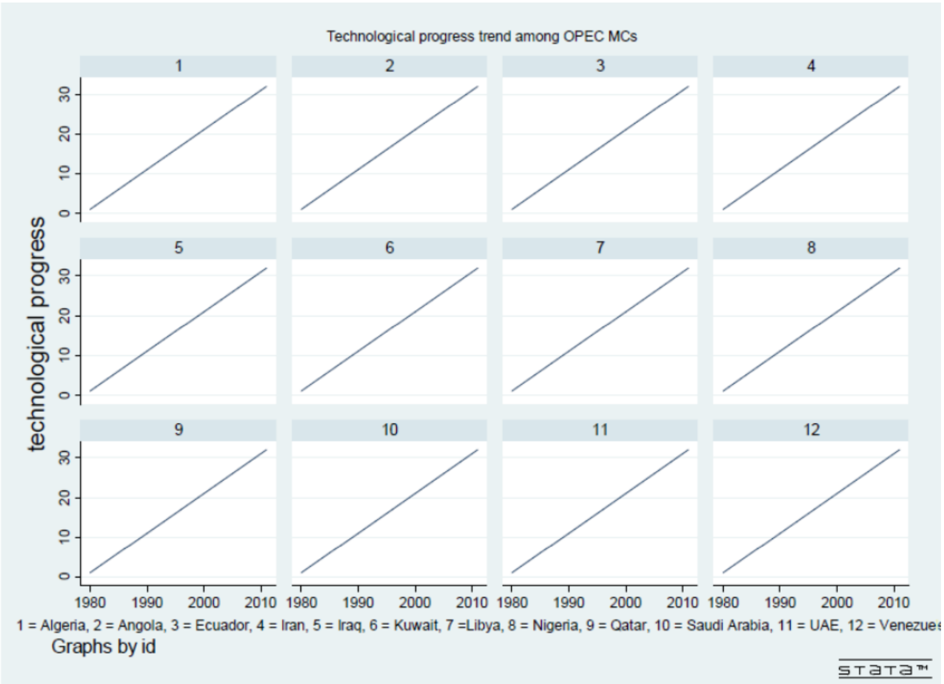
5.1f: OPEC Oilfield depletion rate



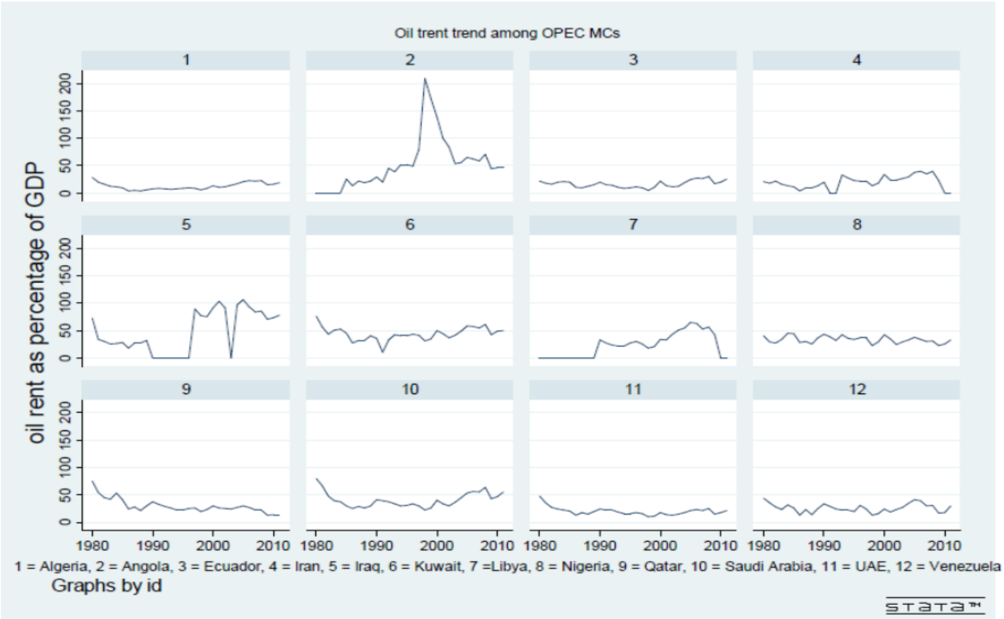
5.1g:OPEC Reserves replacement rate



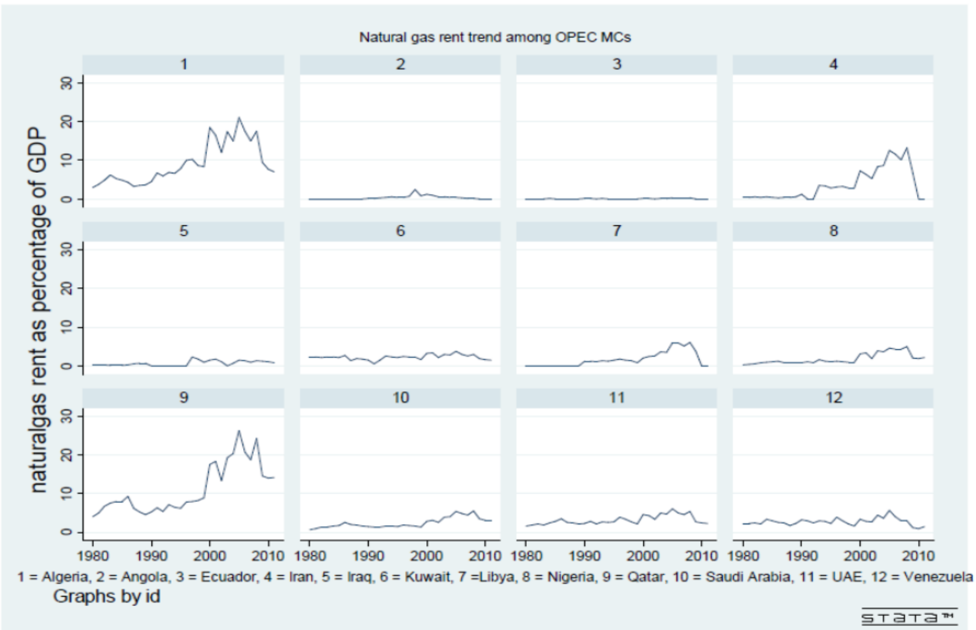
5.1h: OPEC Technological progress



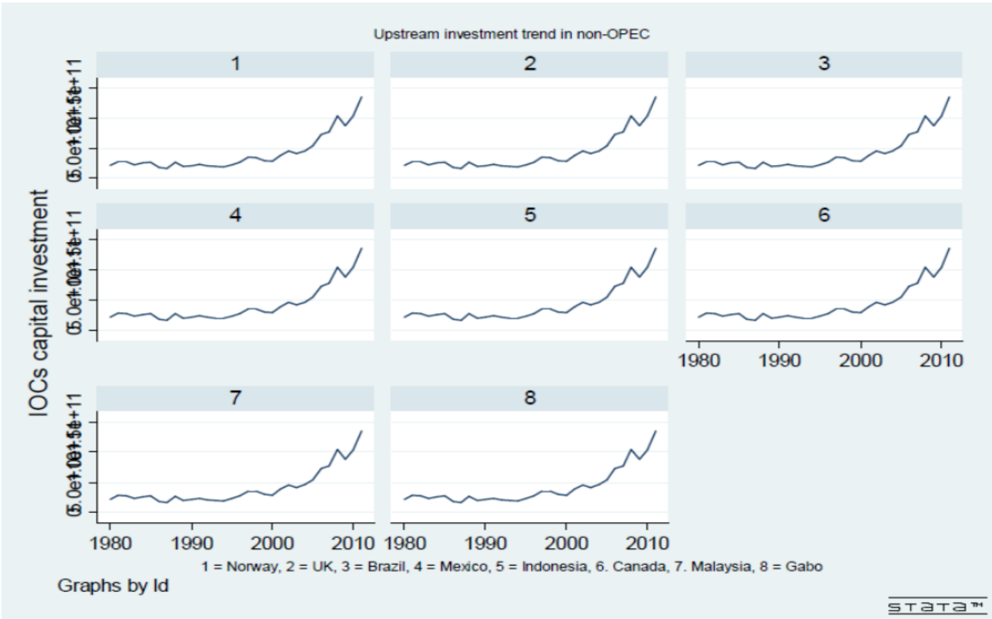
5.1i: OPEC oil rent



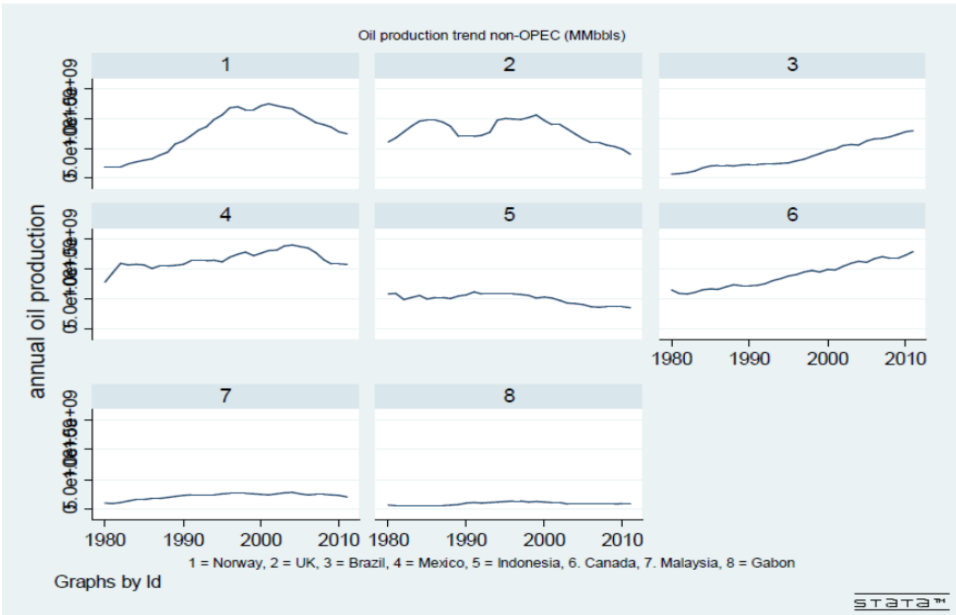
5.1j: OPEC gas rent



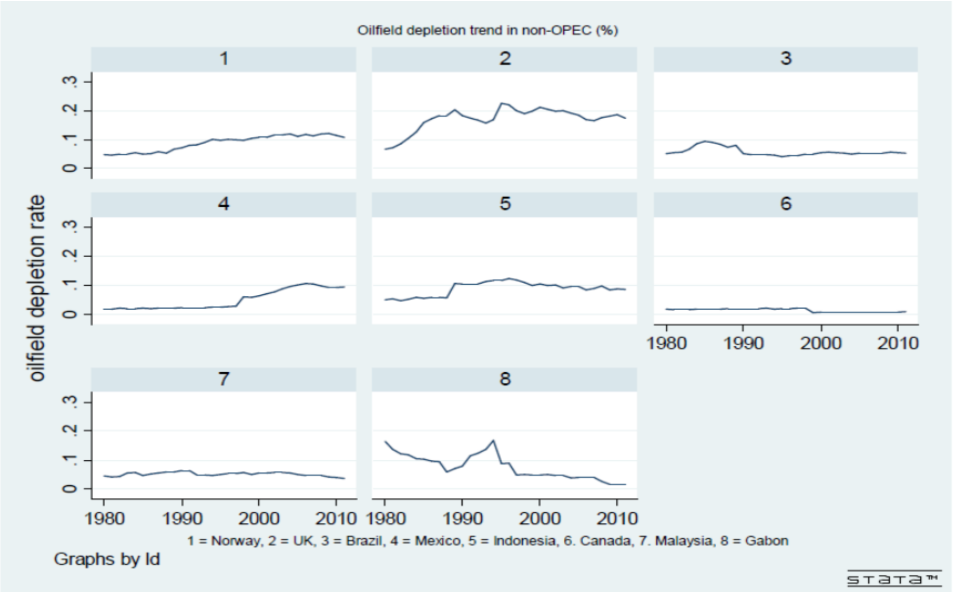
5.1k: Non-OPEC upstream investment



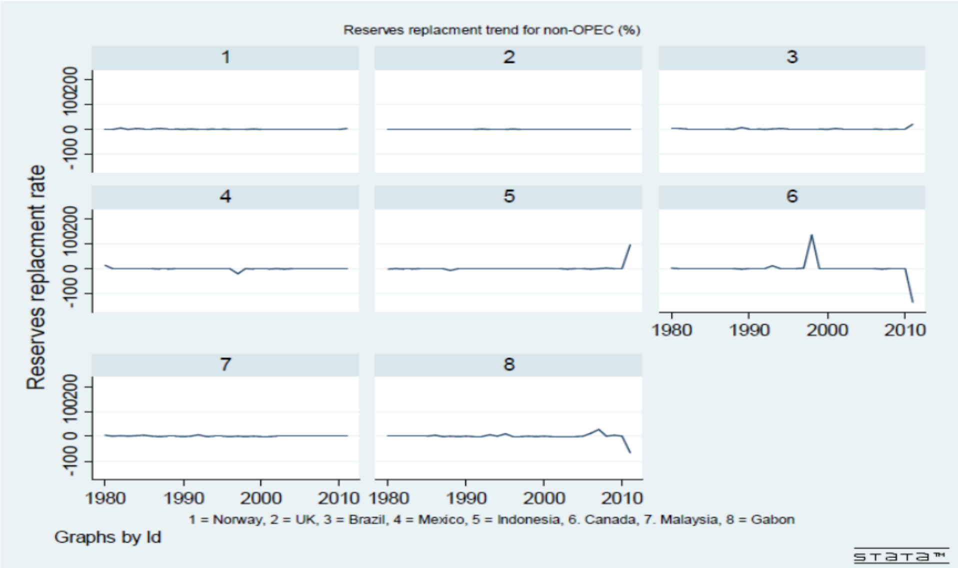
5.1l: Non-OPEC oil production



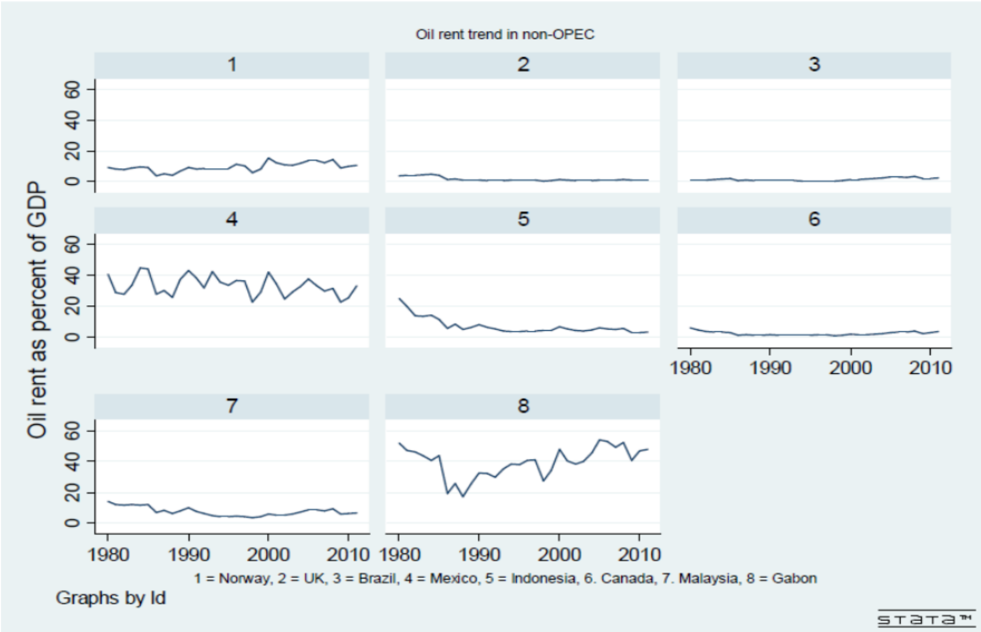
5.1m: Non-OPEC oilfield depletion



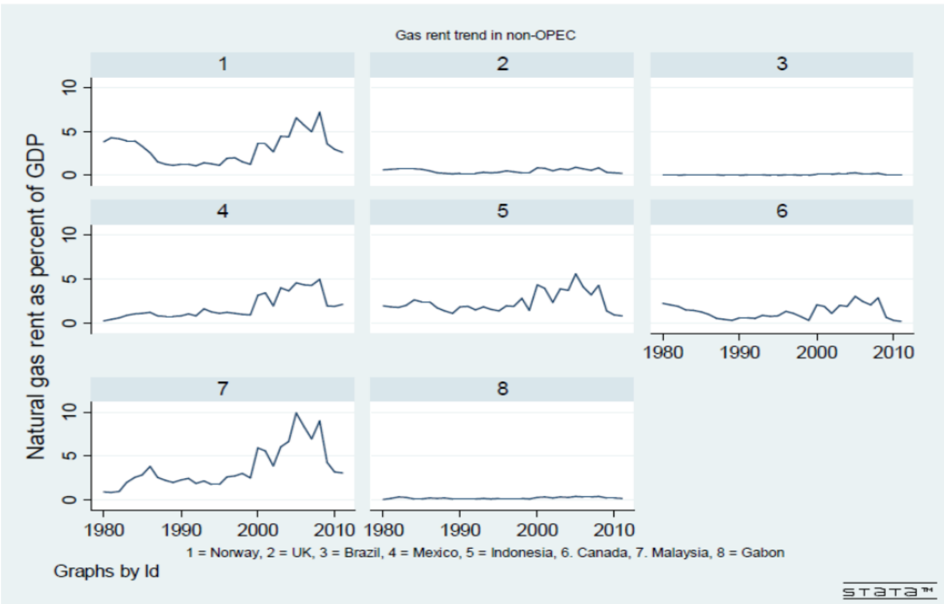
5.1n: Non-OPEC reserves replacement rate



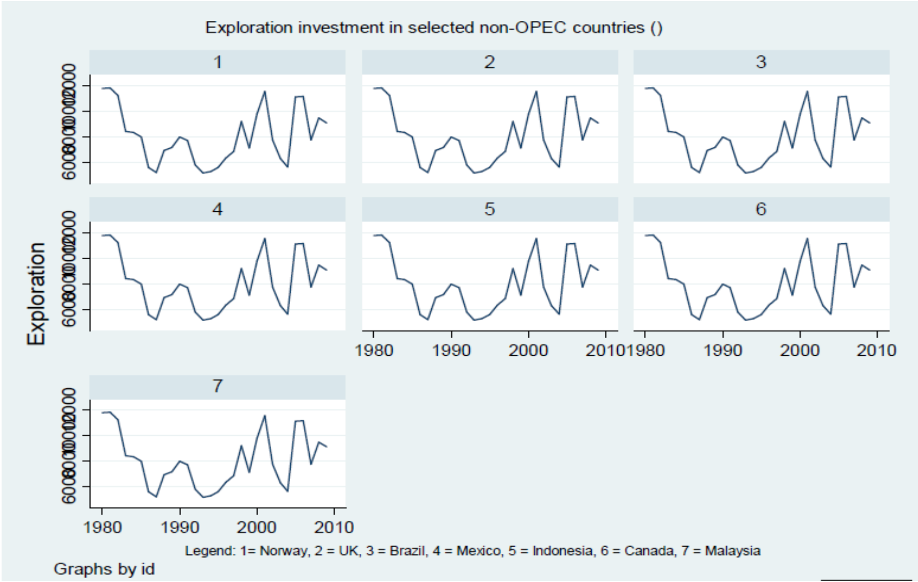
5.1o: Non-OPEC oil rent



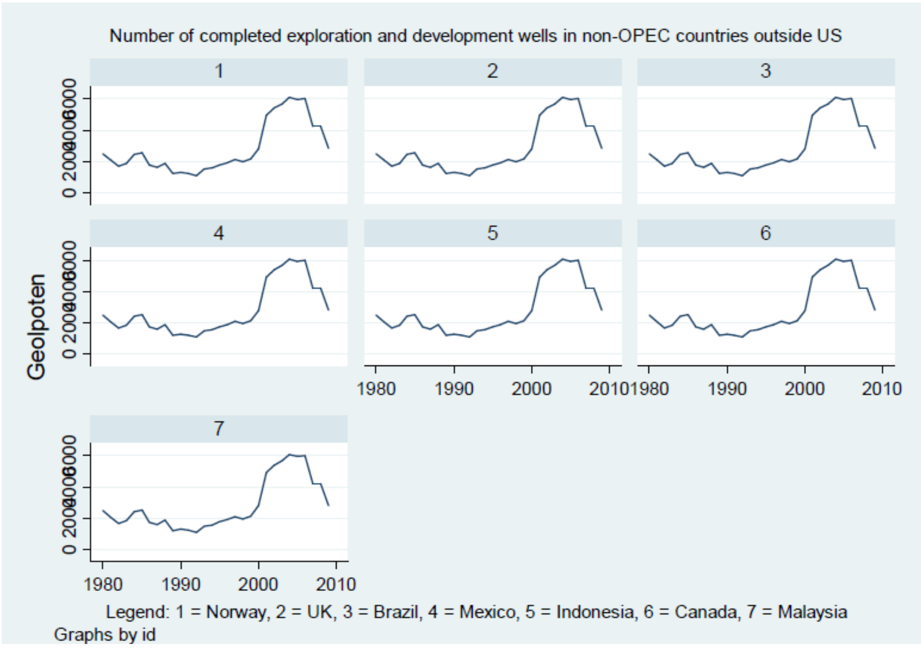
5.1p: Non-OPEC gas rent



Non –OPEC Exploration Investment



Non-OPEC Cost



Non-OPEC geological potential

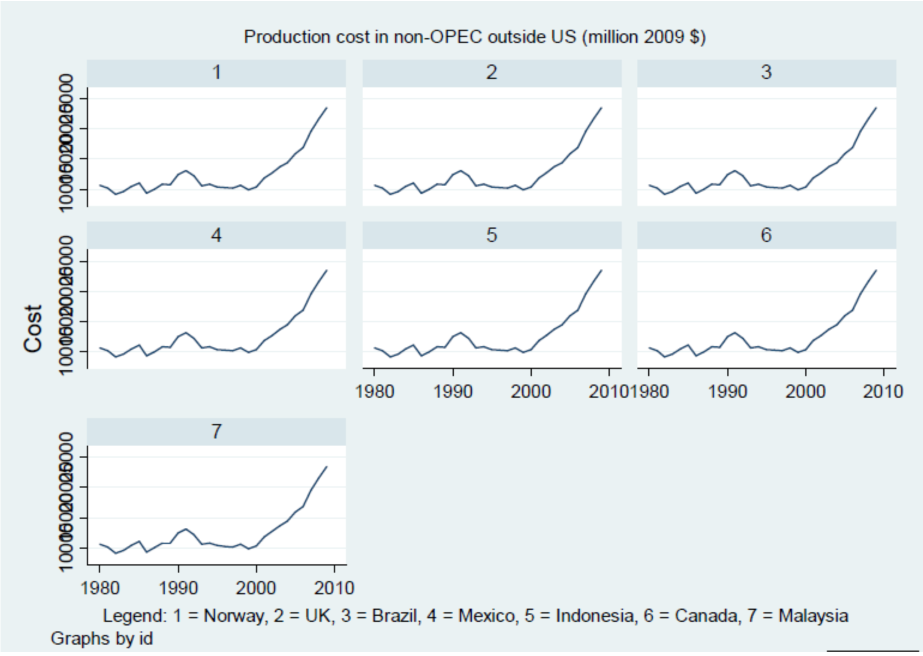


Table 6.1: Descriptive statistics of variables used for OPEC exploration investment analysis

```
. sum exploinvest oilprice oilprod deprate resrep geolsuccess
```

Variable	Obs	Mean	Std. Dev.	Min	Max
exploinvest	384	41232.47	29532.23	16307	135370
oilprice	384	7.374344	4.011016	2.444	16.331
oilprod	384	8.24e+08	8.06e+08	4.70e+07	4.10e+09
deprate	384	.0265313	.0229991	.001	.15
resrep	384	3.413021	16.92952	-76	227
geolsuccess	384	163.1589	243.7338	0	1560

6.2: Summary Statistics of variables used for OPEC exploration investment analysis

```
pwcorr exploinvest oilprice oilprod deprate resrep geolsuccess
```

	exploi~t	oilprice	oilprod	deprate	resrep	geolsu~s
exploinvest	1.0000					
oilprice	0.6255	1.0000				
oilprod	0.1708	0.0395	1.0000			
deprate	-0.0899	-0.0028	-0.3373	1.0000		
resrep	0.1306	0.0810	-0.0315	-0.1546	1.0000	
geolsuccess	0.2051	0.1448	0.2795	-0.1400	0.0696	1.0000

6.3a: Result of Fixed effects model for OPEC exploration investment analysis

```
. xtreg exploinvest oilprice oilprod deprate resrep geolsuccess,fe

Fixed-effects (within) regression               Number of obs      =       384
Group variable: id                              Number of groups   =        12

R-sq:  within  = 0.5922                         Obs per group: min =        32
       between =      .                                        avg =      32.0
       overall = 0.1863                                        max =        32

                                                F(5,367)           =    106.59
corr(u_i, Xb)  = -0.8279                        Prob > F           =    0.0000

------------------------------------------------------------------------------
 exploinvest |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    oilprice |   4077.001   255.7006    15.94   0.000     3574.179    4579.824
     oilprod |    .000038   3.60e-06    10.55   0.000     .0000309    .0000451
     deprate |    -356324   75181.17    -4.74   0.000    -504163.9     -208484
      resrep |   114.6463   60.47712     1.90   0.059    -4.278916    233.5714
 geolsuccess |   20.70088   8.359079     2.48   0.014     4.263183    37.13859
       _cons |  -14476.83   3808.443    -3.80   0.000    -21965.94    -6987.72
-------------+----------------------------------------------------------------
     sigma_u |  34991.674
     sigma_e |   19265.52
         rho |  .76738187   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(11, 367) =    13.62             Prob > F = 0.0000
```

6.3b: Results of random effects model for OPEC exploration investment analysis

```
. xtreg exploinvest oilprice oilprod deprate resrep geolsuccess,re

Random-effects GLS regression                   Number of obs      =       384
Group variable: id                              Number of groups   =        12

R-sq:  within  = 0.0000                         Obs per group: min =        32
       between = 0.0000                                        avg =      32.0
       overall = 0.4258                                        max =        32

                                                Wald chi2(5)       =    280.28
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
 exploinvest |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    oilprice |   4444.485   290.9246    15.28   0.000     3874.284    5014.687
     oilprod |   4.39e-06   1.58e-06     2.79   0.005     1.30e-06    7.48e-06
     deprate |  -32728.26   54065.04    -0.61   0.545    -138693.8    73237.28
      resrep |    133.064   69.48951     1.91   0.056    -3.132965    269.2609
 geolsuccess |    9.13078   4.983819     1.83   0.067    -.6373259    18.89889
       _cons |   3765.267   3241.995     1.16   0.245    -2588.928    10119.46
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   19265.52
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

6.4: Results of Hausman test for fixed and random effects models of exploration investment

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
oilprice	4077.001	4444.485	-367.484	.
oilprod	.000038	4.39e-06	.0000336	3.24e-06
deprate	-356324	-32728.26	-323595.7	52241.55
resrep	114.6463	133.064	-18.41771	.
geolsuccess	20.70088	9.13078	11.5701	6.710868

```
                 b = consistent under Ho and Ha; obtained from xtreg
  B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =       37.39
            Prob>chi2 =      0.0000
            (V_b-V_B is not positive definite)
```

6.4: Result of Breusch-Pagan (1980) test for cross sectional dependence

```
. xttest2

Correlation matrix of residuals:
```

	__e1	__e2	__e3	__e4	__e5	__e6	__e7	__e8	__e9	__e10
e1	1.0000									
e2	0.8851	1.0000								
e3	0.9325	0.7953	1.0000							
e4	0.7876	0.6215	0.8202	1.0000						
__e5	0.8877	0.8342	0.7916	0.6078	1.0000					
e6	0.9547	0.9126	0.9411	0.7613	0.8420	1.0000				
e7	0.9906	0.8634	0.9405	0.7865	0.8683	0.9500	1.0000			
e8	0.9892	0.8690	0.9540	0.8239	0.8508	0.9579	0.9862	1.0000		
__e9	0.8883	0.9018	0.7783	0.6142	0.8464	0.8639	0.8440	0.8699	1.0000	
e10	0.2765	0.2473	0.4092	0.3087	0.0467	0.3649	0.3224	0.3680	0.2172	1.0000
e11	0.9619	0.7658	0.9344	0.8262	0.8173	0.9150	0.9620	0.9697	0.8017	0.3395
__e12	0.8246	0.7791	0.8188	0.6666	0.6245	0.8281	0.8453	0.8508	0.6595	0.5358

	__e11	__e12
e11	1.0000	
__e12	0.8021	1.0000

```
Breusch-Pagan LM test of independence: chi2(66) =   1312.112, Pr = 0.0000
Based on 32 complete observations over panel units
```

6.5: Result of Woodridge (2002) test for serial correlation

```
. xtserial exploinvest oilprice oilprod deprate resrep geolsuccess

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      11) =   2148.253
           Prob > F =      0.0000
```

6.6: Result of modified Wald test for group wise heteroskedasticity

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (12)  =       12.64
Prob>chi2 =      0.3960
```

6.7: Results of Hadri (2000) tests for unit roots

```
. xtunitroot hadri exploinvest

Hadri LM test for exploinvest
------------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:             Not included         Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:            (not used)
------------------------------------------------------------------------------
                        Statistic      p-value
------------------------------------------------------------------------------
 z                       43.9336        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilprice

Hadri LM test for oilprice
------------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:             Not included         Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:            (not used)
------------------------------------------------------------------------------
                        Statistic      p-value
------------------------------------------------------------------------------
 z                       12.0797        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot hadri oilprod

Hadri LM test for oilprod
------------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:             Not included         Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:            (not used)
------------------------------------------------------------------------------
                        Statistic      p-value
------------------------------------------------------------------------------
 z                       40.7501        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri resrep

Hadri LM test for resrep
------------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:             Not included         Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:            (not used)
------------------------------------------------------------------------------
                        Statistic      p-value
------------------------------------------------------------------------------
 z                        2.7742        0.0028
------------------------------------------------------------------------------
```

```
. xtunitroot hadri deprate

Hadri LM test for deprate
--------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:           Not included           Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                     20.7630        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot hadri geolsuccess

Hadri LM test for geolsuccess
--------------------------------
Ho: All panels are stationary                Number of panels  =     12
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:           Not included           Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                     24.8141        0.0000
------------------------------------------------------------------------------
```

6.8: Results of fixed effects model with Driskoll and Kraay standard errors

```
. xtscc exploinvest oilprice oilprod deprate resrep geolsuccess,fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       384
Method: Fixed-effects regression                 Number of groups  =        12
Group variable (i): id                           F(  5,     31)    =      6.66
maximum lag: 3                                   Prob > F          =    0.0003
                                                 within R-squared  =    0.5922
```

exploinvest	Coef.	Drisc/Kraay Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	4077.001	1747.93	2.33	0.026	512.0748	7641.928
oilprod	.000038	9.66e-06	3.94	0.000	.0000183	.0000577
deprate	-356324	132429.4	-2.69	0.011	-626415.5	-86232.47
resrep	114.6463	54.03411	2.12	0.042	4.442956	224.8496
geolsuccess	20.70088	8.102182	2.55	0.016	4.176374	37.22539
_cons	-14476.83	11591.13	-1.25	0.221	-38117.09	9163.439

6.9: Estimated average elasticities of exploration investment to changes in regressors

```
. margins, eyex( oilprice oilprod deprate resrep geolsuccess) atmeans
Warning: cannot perform check for estimable functions.

Conditional marginal effects                    Number of obs    =        384
Model VCE     : Drisc/Kraay

Expression    : Fitted values, predict()
ey/ex w.r.t. : oilprice oilprod deprate resrep geolsuccess
at            : oilprice         =    7.374344 (mean)
                oilprod          =    8.24e+08 (mean)
                deprate          =    .0265313 (mean)
                resrep           =    3.413021 (mean)
                geolsuccess      =    163.1589 (mean)
```

	ey/ex	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	.7291705	.2335926	3.12	0.002	.2713375	1.187004
oilprod	.7598207	.1961783	3.87	0.000	.3753183	1.144323
deprate	-.2292807	.0930113	-2.47	0.014	-.4115796	-.0469819
resrep	.0094899	.0050134	1.89	0.058	-.0003361	.019316
geolsuccess	.0819152	.0375555	2.18	0.029	.0083078	.1555226

7.2: Descriptive statistics of variables used for OPEC upstream investment analysis

```
sum invest oilprice resrep deprate oilincome naturalgasincome techprog oil
```

Variable	Obs	Mean	Std. Dev.	Min	Max
invest	384	41232.47	29532.23	16307	135370
oilprice	384	7.374344	4.011016	2.444	16.331
resrep	384	3.413021	16.92952	-76	227
deprate	384	.0265313	.0229991	.001	.15
oilincome	384	30.63986	23.89096	0	209.4809
aturalgas~e	384	3.282925	4.306507	0	26.23817
techprog	384	16.5	9.245138	1	32
oilprod	384	8.24e+08	8.06e+08	4.70e+07	4.10e+09

7.3: Summary Statistics of variables used for exploration upstream analysis in OPEC MCs

. pwcorr invest oilprice resrep deprate oilincome naturalgasincome techprog oilprod

	invest	oilprice	resrep	deprate	oilinc~e	natura~e	techprog
invest	1.0000						
oilprice	0.6255	1.0000					
resrep	0.1306	0.0810	1.0000				
deprate	-0.0899	-0.0028	-0.1546	1.0000			
oilincome	0.1558	0.1193	-0.0620	-0.0109	1.0000		
naturalgas~e	0.2068	0.0531	0.0451	0.0659	-0.0599	1.0000	
techprog	0.7880	0.0962	0.0562	-0.1250	0.1982	0.3147	1.0000
oilprod	0.1708	0.0395	-0.0315	-0.3373	0.1600	0.0029	0.2185

	oilprod
oilprod	1.0000

7.4a: Result of Fixed effects model for upstream investment analysis in OPEC MCs

. xtreg invest oilprice oilprod deprate resrep techprog oilrent gasrent, fe

Fixed-effects (within) regression   Number of obs = 384
Group variable: id   Number of groups = 12

R-sq: within = 0.9414   Obs per group: min = 32
between = .   avg = 32.0
overall = 0.9171   max = 32

F(7,365) = 838.40
corr(u_i, Xb) = -0.1607   Prob > F = 0.0000

invest	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	4152.325	94.9539	43.73	0.000	3965.6	4339.051
oilprod	-3.97e-06	1.64e-06	-2.43	0.016	-7.19e-06	-7.56e-07
deprate	63681.32	29948.59	2.13	0.034	4787.881	122574.8
resrep	69.01171	23.0877	2.99	0.003	23.6101	114.4133
techprog	2634.85	57.47755	45.84	0.000	2521.822	2747.879
oilrent	-84.65613	19.39276	-4.37	0.000	-122.7917	-46.52057
gasrent	-1087.92	153.7807	-7.07	0.000	-1390.327	-785.5121
_cons	-25351.01	1480.843	-17.12	0.000	-28263.06	-22438.95
sigma_u	4866.2283					
sigma_e	7320.1419					
rho	.30648138	(fraction of variance due to u_i)				

F test that all u_i=0:   F(11, 365) = 274.67   Prob > F = 0.0000

7.4b: Results of random effects model for upstream investment analysis in OPEC MCs

```
6 . xtreg invest oilprice oilprod deprate resrep techprog oilrent gasrent,re

  Random-effects GLS regression                   Number of obs      =       384
  Group variable: id                              Number of groups   =        12

  R-sq:  within  = 0.0000                         Obs per group: min =        32
         between = 0.0000                                        avg =      32.0
         overall = 0.9354                                        max =        32

                                                  Wald chi2(7)       =   5447.56
  corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

  ------------------------------------------------------------------------------
        invest |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
  -------------+----------------------------------------------------------------
      oilprice |    4119.76   97.89205    42.08   0.000     3927.895    4311.625
       oilprod |  -4.81e-08   5.27e-07    -0.09   0.927    -1.08e-06    9.84e-07
       deprate |   23506.84   18301.78     1.28   0.199    -12363.99    59377.68
        resrep |   76.83352    23.4134     3.28   0.001     30.94409    122.7229
      techprog |   2458.871   46.57189    52.80   0.000     2367.592     2550.15
       oilrent |  -79.91612    16.9488    -4.72   0.000    -113.1352   -46.69709
       gasrent |  -495.0438   96.27086    -5.14   0.000    -683.7312   -306.3564
         _cons |  -26491.87   1261.736   -21.00   0.000    -28964.82   -24018.91
  -------------+----------------------------------------------------------------
       sigma_u |          0
       sigma_e |  7320.1419
           rho |          0   (fraction of variance due to u_i)
  ------------------------------------------------------------------------------
```

7.5:Results of Hausman test for fixed and random effects models of exploration investment

```
. hausman fe re

Note: the rank of the differenced variance matrix (6) does not equal the number of
        coefficients being tested (7); be sure this is what you expect, or there may be
        problems computing the test.  Examine the output of your estimators for anything
        unexpected and possibly consider scaling your variables so that the coefficients are
        on a similar scale.

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
    oilprice |    4152.325      4119.76        32.56491               .
     oilprod |   -3.97e-06    -4.81e-08       -3.92e-06        1.55e-06
     deprate |    63681.32     23506.84        40174.48        23705.75
      resrep |    69.01171     76.83352       -7.821812               .
    techprog |     2634.85     2458.871        175.9794        33.68573
     oilrent |   -84.65613    -79.91612       -4.740009        9.424299
     gasrent |    -1087.92    -495.0438       -592.8758        119.9184
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       41.44
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

7.6: Result of Breusch-Pagan (1980) test for cross sectional dependence

```
. xttest2

Correlation matrix of residuals:
```

	e1	__e2	__e3	__e4	__e5	__e6	__e7	__e8	__e9	__e10
e1	1.0000									
__e2	0.7831	1.0000								
e3	0.7813	0.8530	1.0000							
e4	0.9144	0.7350	0.7898	1.0000						
e5	0.8212	0.8803	0.8796	0.7763	1.0000					
e6	0.7594	0.8341	0.9783	0.7704	0.8755	1.0000				
__e7	0.8727	0.7817	0.9220	0.9135	0.8397	0.8892	1.0000			
e8	0.8186	0.8239	0.9885	0.8163	0.8771	0.9750	0.9334	1.0000		
e9	0.8104	0.4655	0.5358	0.7290	0.6365	0.5415	0.6907	0.6115	1.0000	
e10	0.8016	0.7427	0.9005	0.7985	0.8302	0.8872	0.8826	0.8938	0.5795	1.0000
__e11	0.7828	0.8187	0.9850	0.8068	0.8569	0.9614	0.9260	0.9803	0.5287	0.8925
__e12	0.7181	0.7903	0.9518	0.7377	0.8034	0.9355	0.8854	0.9536	0.4310	0.8165

	e11	__e12
e11	1.0000	
__e12	0.9547	1.0000

```
Breusch-Pagan LM test of independence: chi2(66) =  1433.703, Pr = 0.0000
Based on 32 complete observations over panel units
```

7.7: Result of Woodridge(2002) test for serial correlation

```
. xtserial invest oilprice oilprod deprate resrep techprog oilrent gasrent

 Wooldridge test for autocorrelation in panel data
 H0: no first-order autocorrelation
     F(  1,      11) =    202.752
            Prob > F =      0.0000
```

7.8: Result of test for heteroskedasticity

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (12)   =       13.22
Prob>chi2 =       0.3529
```

7.9: Result of Hadri tests for unit roots

```
. xtunitroot hadri invest

Hadri LM test for invest
------------------------------------------------------------------------------
Ho: All panels are stationary              Number of panels  =     12
Ha: Some panels contain unit roots         Number of periods =     32

Time trend:          Not included          Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                              sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     43.9336        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilprice

Hadri LM test for oilprice
------------------------------------------------------------------------------
Ho: All panels are stationary              Number of panels  =     12
Ha: Some panels contain unit roots         Number of periods =     32

Time trend:          Not included          Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                              sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     12.0797        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilprod

Hadri LM test for oilprod
------------------------------------------------------------------------------
Ho: All panels are stationary              Number of panels  =     12
Ha: Some panels contain unit roots         Number of periods =     32

Time trend:          Not included          Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                              sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     40.7501        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri deprate

Hadri LM test for deprate
------------------------------------------------------------------------------
Ho: All panels are stationary              Number of panels  =     12
Ha: Some panels contain unit roots         Number of periods =     32

Time trend:          Not included          Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                              sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     20.7630        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot hadri resrep

Hadri LM test for resrep
--------------------------------------
Ho: All panels are stationary                  Number of panels  =     12
Ha: Some panels contain unit roots             Number of periods =     32

Time trend:          Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     2.7742        0.0028
------------------------------------------------------------------------------

. xtunitroot hadri techprog

Hadri LM test for techprog
--------------------------------------
Ho: All panels are stationary                  Number of panels  =     12
Ha: Some panels contain unit roots             Number of periods =     32

Time trend:          Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                    68.2349        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilrent

Hadri LM test for oilrent
--------------------------------------
Ho: All panels are stationary                  Number of panels  =     12
Ha: Some panels contain unit roots             Number of periods =     32

Time trend:          Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                    24.4479        0.0000
------------------------------------------------------------------------------


. xtunitroot hadri gasrent

Hadri LM test for gasrent
--------------------------------------
Ho: All panels are stationary                  Number of panels  =     12
Ha: Some panels contain unit roots             Number of periods =     32

Time trend:          Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                    41.5477        0.0000
------------------------------------------------------------------------------
```

7.10: Result of Driskoll and Kraay test for standard errors in fixed effect model

```
. xtscc invest oilprice oilprod deprate resrep techprog oilrent gasrent, fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       384
Method: Fixed-effects regression                 Number of groups  =        12
Group variable (i): id                           F(  7,       31)  =    144.47
maximum lag: 3                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.9414
```

invest	Coef.	Drisc/Kraay Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	4152.325	435.9548	9.52	0.000	3263.19	5041.461
oilprod	-3.97e-06	1.07e-06	-3.70	0.001	-6.16e-06	-1.78e-06
deprate	63681.32	28199.25	2.26	0.031	6168.574	121194.1
resrep	69.01171	20.10356	3.43	0.002	28.01022	110.0132
techprog	2634.85	228.9176	11.51	0.000	2167.97	3101.731
oilrent	-84.65613	41.52958	-2.04	0.050	-169.3563	.0440064
gasrent	-1087.92	315.6783	-3.45	0.002	-1731.75	-444.0895
_cons	-25351.01	4964.192	-5.11	0.000	-35475.54	-15226.47

7.11: Estimated Average elasticities of the covariates at their means

```
. margins, eyex( oilprice oilprod deprate resrep techprog oilrent gasrent) atmeans
Warning: cannot perform check for estimable functions.

Conditional marginal effects                     Number of obs    =        384
Model VCE    : Drisc/Kraay

Expression   : Fitted values, predict()
ey/ex w.r.t. : oilprice oilprod deprate resrep techprog oilrent gasrent
at           : oilprice        =    7.374344 (mean)
               oilprod         =    8.24e+08 (mean)
               deprate         =    .0265313 (mean)
               resrep          =    3.413021 (mean)
               techprog        =        16.5 (mean)
               oilrent         =    30.63986 (mean)
               gasrent         =    3.282925 (mean)
```

	ey/ex	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	.7426421	.076642	9.69	0.000	.5924265	.8928578
oilprod	-.0793533	.0227164	-3.49	0.000	-.1238766	-.0348301
deprate	.0409765	.0186742	2.19	0.028	.0043757	.0775772
resrep	.0057125	.0017439	3.28	0.001	.0022945	.0091305
techprog	1.054398	.0951444	11.08	0.000	.8679187	1.240878

—more—

8.1: Results of descriptive statistics of the variables for non-OPEC upstream investment model

```
. sum invest oilprice oilprod deprate resrep techprog oilrent gasrent
```

Variable	Obs	Mean	Std. Dev.	Min	Max
invest	256	4.12e+10	2.96e+10	1.63e+10	1.35e+11
oilprice	256	7.374344	4.013637	2.444	16.331
oilprod	256	6.02e+08	3.91e+08	5.59e+07	1.40e+09
deprate	256	.0743318	.0516226	.0052358	.2263948
resrep	256	.6052576	14.31285	-134.9182	135.0572
techprog	256	16.5	9.251179	1	32
oilrent	256	12.71313	14.84544	.3388161	54.1128
gasrent	256	1.611736	1.755016	.0303287	9.911007

8.2: Results of the correlation matrix of the variables for non-OPEC upstream investment model

```
. pwcorr invest oilprice oilprod deprate resrep techprog oilrent gasrent
```

	invest	oilprice	oilprod	deprate	resrep	techprog	oilrent
invest	1.0000						
oilprice	0.6255	1.0000					
oilprod	0.0935	-0.1043	1.0000				
deprate	0.0220	-0.0919	0.0743	1.0000			
resrep	-0.0805	-0.0773	-0.0763	0.0207	1.0000		
techprog	0.7880	0.0962	0.2260	0.1076	-0.0365	1.0000	
oilrent	0.0251	0.1173	-0.0544	-0.1540	-0.0538	-0.0200	1.0000
gasrent	0.2181	0.1631	0.0831	-0.0559	-0.0133	0.2676	-0.0832

	gasrent
gasrent	1.0000

8.3: Estimated results of the fixed effects model for non-OPEC countries

```
. xtreg invest oilprice oilprod deprate resrep techprog oilrent gasrent, fe

Fixed-effects (within) regression               Number of obs      =       256
Group variable: id                              Number of groups   =         8

R-sq:  within  = 0.9455                         Obs per group: min =        32
       between =      .                                        avg =      32.0
       overall = 0.8748                                        max =        32

                                                F(7,241)           =    597.09
corr(u_i, Xb)  = -0.2734                        Prob > F           =    0.0000

------------------------------------------------------------------------------
      invest |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    oilprice |   4.45e+09   1.33e+08    33.60   0.000     4.19e+09    4.71e+09
     oilprod |  -3.152386    2.98609    -1.06   0.292    -9.034555    2.729782
     deprate |  -5.08e+09   1.77e+10    -0.29   0.774    -4.00e+10    2.98e+10
      resrep |  -3.18e+07   3.16e+07    -1.01   0.315    -9.39e+07    3.04e+07
    techprog |   2.49e+09   6.08e+07    40.94   0.000     2.37e+09    2.61e+09
     oilrent |  -5.63e+08   1.09e+08    -5.15   0.000    -7.79e+08   -3.48e+08
     gasrent |  -2.83e+09   4.03e+08    -7.02   0.000    -3.62e+09   -2.04e+09
       _cons |  -1.86e+10   2.32e+09    -8.03   0.000    -2.32e+10   -1.41e+10
-------------+----------------------------------------------------------------
     sigma_u |  8.716e+09
     sigma_e |  7.098e+09
         rho |  .60126407   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(7, 241) =   323.23              Prob > F = 0.0000
```

8.4: Estimated results of the random effects model for non-OPEC countries

```
. xtreg invest oilprice oilprod deprate resrep techprog oilrent gasrent, re

Random-effects GLS regression                   Number of obs      =       256
Group variable: id                              Number of groups   =         8

R-sq:  within  = 0.0000                         Obs per group: min =        32
       between = 0.0000                                        avg =      32.0
       overall = 0.9328                                        max =        32

                                                Wald chi2(7)       =   3442.65
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      invest |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    oilprice |   4.17e+09   1.26e+08    33.11   0.000     3.92e+09    4.41e+09
     oilprod |  -1.066091   1.296316    -0.82   0.411    -3.606824    1.474642
     deprate |  -9.38e+09   9.67e+09    -0.97   0.332    -2.83e+10    9.58e+09
      resrep |  -2.67e+07   3.43e+07    -0.78   0.436    -9.38e+07    4.05e+07
    techprog |   2.42e+09   5.65e+07    42.92   0.000     2.31e+09    2.53e+09
     oilrent |  -7.32e+07   3.36e+07    -2.18   0.029    -1.39e+08    -7327913
     gasrent |  -1.35e+09   2.94e+08    -4.60   0.000    -1.93e+09   -7.75e+08
       _cons |  -2.50e+10   1.69e+09   -14.84   0.000    -2.83e+10   -2.17e+10
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  7.098e+09
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

8.5: Results of the hausman test for fixed and random effects models

```
. hausman fe re

Note: the rank of the differenced variance matrix (6) does not equal the number of
        coefficients being tested (7); be sure this is what you expect, or there may be
        problems computing the test.  Examine the output of your estimators for anything
        unexpected and possibly consider scaling your variables so that the coefficients are
        on a similar scale.
```

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
oilprice	4.45e+09	4.17e+09	2.86e+08	4.16e+07
oilprod	-3.152386	-1.066091	-2.086296	2.690037
deprate	-5.08e+09	-9.38e+09	4.30e+09	1.48e+10
resrep	-3.18e+07	-2.67e+07	-5086635	.
techprog	2.49e+09	2.42e+09	6.45e+07	2.25e+07
oilrent	-5.63e+08	-7.32e+07	-4.90e+08	1.04e+08
gasrent	-2.83e+09	-1.35e+09	-1.48e+09	2.76e+08

```
                     b = consistent under Ho and Ha; obtained from xtreg
      B = inconsistent under Ha, efficient under Ho; obtained from xtreg

   Test:  Ho:  difference in coefficients not systematic

               chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                       =       72.14
             Prob>chi2 =      0.0000
             (V_b-V_B is not positive definite)
```

8.6: Results of Breusch-pagan test for auto correlation

```
. xttest2

Correlation matrix of residuals:

          __e1     __e2     __e3     __e4     __e5     __e6     __e7     __e8
__e1    1.0000
__e2    0.6752   1.0000
__e3    0.7638   0.9704   1.0000
__e4    0.7688   0.7563   0.8088   1.0000
__e5    0.6994   0.9092   0.8637   0.7364   1.0000
__e6    0.8009   0.9523   0.9534   0.7617   0.9265   1.0000
__e7    0.9085   0.6196   0.7240   0.8073   0.6644   0.7437   1.0000
__e8    0.8304   0.7540   0.7979   0.6884   0.7168   0.8019   0.6185   1.0000

Breusch-Pagan LM test of independence: chi2(28) =   562.739, Pr = 0.0000
Based on 32 complete observations over panel units
```

8.6: Results of test for serial correlation

```
:3 . xtserial invest oilprice oilprod deprate resrep techprog oilrent gasrent

 Wooldridge test for autocorrelation in panel data
 H0: no first-order autocorrelation
     F(  1,       7) =    216.904
            Prob > F =      0.0000
```

8.7: Result of hadri tests for unitroots

```
. xtunitroot hadri invest

Hadri LM test for invest
-----------------------------------
Ho: All panels are stationary                 Number of panels  =      8
Ha: Some panels contain unit roots            Number of periods =     32

Time trend:          Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                    35.8716        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilprice

Hadri LM test for oilprice
-----------------------------------
Ho: All panels are stationary                 Number of panels  =      8
Ha: Some panels contain unit roots            Number of periods =     32

Time trend:          Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     9.8630        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilprod

Hadri LM test for oilprod
-----------------------------------
Ho: All panels are stationary                 Number of panels  =      8
Ha: Some panels contain unit roots            Number of periods =     32

Time trend:          Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                    40.1399        0.0000
------------------------------------------------------------------------------


Time trend:          Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity:  Not robust                                sequentially
LR variance:         (not used)
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 z                     1.1247        0.1303
------------------------------------------------------------------------------
```

```
. xtunitroot hadri resrep

Hadri LM test for resrep
---------------------------------------------
Ho: All panels are stationary                Number of panels  =      8
Ha: Some panels contain unit roots           Number of periods =     32


. xtunitroot hadri deprate

Hadri LM test for deprate
---------------------------------------------
Ho: All panels are stationary                Number of panels  =      8
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:         Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic       p-value
------------------------------------------------------------------------------
 z                   35.3006         0.0000
------------------------------------------------------------------------------

. xtunitroot hadri techprog

Hadri LM test for techprog
---------------------------------------------
Ho: All panels are stationary                Number of panels  =      8
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:         Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic       p-value
------------------------------------------------------------------------------
 z                   55.7135         0.0000
------------------------------------------------------------------------------

. xtunitroot hadri oilrent

Hadri LM test for oilrent
---------------------------------------------
Ho: All panels are stationary                Number of panels  =      8
Ha: Some panels contain unit roots           Number of periods =     32

Time trend:         Not included             Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic       p-value
------------------------------------------------------------------------------
 z                   13.9720         0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot hadri gasrent

Hadri LM test for gasrent
------------------------------------------------------------
Ho: All panels are stationary            Number of panels  =     8
Ha: Some panels contain unit roots       Number of periods =    32

Time trend:         Not included         Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                               sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 z                   22.6231        0.0000
------------------------------------------------------------------------------
```

8.8: Estimated result of Driskoll and Kraay test for standard error in the fixed effect model

```
. xtscc invest oilprice oilprod deprate resrep techprog oilrent gasrent, fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       256
Method: Fixed-effects regression                 Number of groups  =         8
Group variable (i): id                           F(  7,      31)   =     76.06
maximum lag: 3                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.9455
```

invest	Coef.	Drisc/Kraay Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	4.45e+09	4.81e+08	9.27	0.000	3.47e+09	5.43e+09
oilprod	-3.152386	1.579436	-2.00	0.055	-6.373667	.068895
deprate	-5.08e+09	8.60e+09	-0.59	0.559	-2.26e+10	1.25e+10
resrep	-3.18e+07	3.56e+07	-0.89	0.379	-1.04e+08	4.09e+07
techprog	2.49e+09	2.09e+08	11.93	0.000	2.06e+09	2.91e+09
oilrent	-5.63e+08	1.27e+08	-4.44	0.000	-8.22e+08	-3.05e+08
gasrent	-2.83e+09	8.42e+08	-3.36	0.002	-4.55e+09	-1.11e+09
_cons	-1.86e+10	5.10e+09	-3.66	0.001	-2.90e+10	-8.24e+09

8.9: Estimated average elasticities of the covariates at their means

```
. margins, eyex( oilprice oilprod deprate resrep techprog oilrent gasrent) atmeans
Warning: cannot perform check for estimable functions.

Conditional marginal effects                    Number of obs   =        256
Model VCE    : Drisc/Kraay

Expression   : Fitted values, predict()
ey/ex w.r.t. : oilprice oilprod deprate resrep techprog oilrent gasrent
at           : oilprice        =    7.374344 (mean)
               oilprod         =    6.02e+08 (mean)
               deprate         =    .0743318 (mean)
               resrep          =    .6052576 (mean)
               techprog        =        16.5 (mean)
               oilrent         =    12.71313 (mean)
               gasrent         =    1.611736 (mean)
```

	ey/ex	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	.7965039	.0843718	9.44	0.000	.6311381	.9618697
oilprod	-.0460134	.0225574	-2.04	0.041	-.0902251	-.0018018
deprate	-.0091624	.0153047	-0.60	0.549	-.039159	.0208343
resrep	-.0004663	.0005174	-0.90	0.368	-.0014804	.0005479
techprog	.9956921	.0914852	10.88	0.000	.8163844	1.175
oilrent	-.1737322	.0389691	-4.46	0.000	-.2501103	-.0973541
gasrent	-.1106547	.0324269	-3.41	0.001	-.1742103	-.0470992

9.1 Results of descriptive statistics for non-OPEC exploration investment model

exploration	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	410.1825	37.81527	10.85	0.000	335.6078	484.7572
oilprod	5.05e-07	6.59e-07	0.77	0.444	-7.93e-07	1.80e-06
resrep	20.82315	11.46529	1.82	0.071	-1.787295	43.43361
deprate	976.319	5120.381	0.19	0.849	-9121.477	11074.12
cost	-.1361024	.0398694	-3.41	0.001	-.214728	-.0574768
geolpoten	.3322291	.0833719	3.98	0.000	.1678132	.496645
_cons	5518.411	583.0872	9.46	0.000	4368.517	6668.305
sigma_u	171.61151					
sigma_e	1556.7106					
rho	.0120069	(fraction of variance due to u_i)				

F test that all u_i=0:   F(6, 197) =   0.09   Prob > F = 0.9969

9.2: Correlation matrix of variables used for non-OPEC exploration investment analysis

```
. pwcorr exploration oilprice oilprod resrep deprate cost geolpoten
```

	explor~n	oilprice	oilprod	resrep	deprate	cost	geolpo~n
exploration	1.0000						
oilprice	0.6530	1.0000					
oilprod	-0.0555	-0.1453	1.0000				
resrep	0.0453	-0.0587	-0.0147	1.0000			
deprate	-0.0686	-0.1250	0.1235	-0.0831	1.0000		
cost	0.2047	0.4116	0.1241	-0.0459	0.1179	1.0000	
geolpoten	0.3098	0.2286	0.1941	-0.0553	0.1281	0.5249	1.0000

9.3a: Result of Fixed effects model for non-OPEC exploration investment analysis

```
. xtreg exploration oilprice oilprod resrep deprate cost geolpoten,fe

Fixed-effects (within) regression               Number of obs      =       210
Group variable: id                              Number of groups   =         7

R-sq:  within  = 0.4934                         Obs per group: min =        30
       between =      .                                        avg =      30.0
       overall = 0.4878                                        max =        30

                                                F(6,197)           =     31.98
corr(u_i, Xb)  = -0.1062                        Prob > F           =    0.0000
```

exploration	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
oilprice	410.1825	37.81527	10.85	0.000	335.6078	484.7572
oilprod	5.05e-07	6.59e-07	0.77	0.444	-7.93e-07	1.80e-06
resrep	20.82315	11.46529	1.82	0.071	-1.787295	43.43361
deprate	976.319	5120.381	0.19	0.849	-9121.477	11074.12
cost	-.1361024	.0398694	-3.41	0.001	-.214728	-.0574768
geolpoten	.3322291	.0833719	3.98	0.000	.1678132	.496645
_cons	5518.411	583.0872	9.46	0.000	4368.517	6668.305
sigma_u	171.61151					
sigma_e	1556.7106					
rho	.0120069	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(6, 197) =      0.09              Prob > F = 0.9969
```

9.3b: Results of random effects model for non-OPEC exploration investment analysis

```
. xtreg exploration oilprice oilprod resrep deprate cost geolpoten,re

Random-effects GLS regression                   Number of obs      =       210
Group variable: id                              Number of groups   =         7

R-sq:  within  = 0.0000                         Obs per group: min =        30
       between = 0.0000                                        avg =      30.0
       overall = 0.4920                                        max =        30

                                                Wald chi2(6)       =    196.57
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

exploration	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	399.8569	33.06178	12.09	0.000	335.057	464.6568
oilprod	1.19e-07	3.05e-07	0.39	0.698	-4.80e-07	7.17e-07
resrep	20.40874	11.15514	1.83	0.067	-1.454935	42.27241
deprate	606.7911	2084.372	0.29	0.771	-3478.504	4692.086
cost	-.1302839	.0376065	-3.46	0.001	-.2039912	-.0565765
geolpoten	.3491374	.0783582	4.46	0.000	.1955583	.5027166
_cons	5757.906	438.608	13.13	0.000	4898.25	6617.562
sigma_u	0					
sigma_e	1556.7106					
rho	0	(fraction of variance due to u_i)				

9.4: Results of Hausman test for fixed and random effects models of non-OPEC exploration investment

	Coefficients (b) fe	Coefficients (B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
oilprice	410.1825	399.8569	10.32557	18.3552
oilprod	5.05e-07	1.19e-07	3.87e-07	5.84e-07
resrep	20.82315	20.40874	.414419	2.648709
deprate	976.319	606.7911	369.5279	4676.932
cost	-.1361024	-.1302839	-.0058186	.0132409
geolpoten	.3322291	.3491374	-.0169083	.0284757

```
                      b = consistent under Ho and Ha; obtained from xtreg

      B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =        0.46
            Prob>chi2 =      0.9281
```

9.4: Result of Pesaran CD test for cross sectional dependence

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =    24.685, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.983
```

9.5: Result of Woodridge (2002) test for serial correlation

```
. xtserial exploration oilprice oilprod resrep deprate cost geolpoten

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,       6) =   1038.921
           Prob > F =      0.0000
```

9.6: Result of modified Wald test for group wise heteroskedasticity

```
7 . xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (7)  =        0.23
Prob>chi2 =      1.0000
```

9.7: Results of Hadri (2000) tests for unit roots

```
. xtunitroot hadri exploration

Hadri LM test for exploration
------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:           Not included            Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                 sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                      2.8564        0.0021
------------------------------------------------------------------------------

. xtunitroot hadri oilprod

Hadri LM test for oilprod
------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:           Not included            Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                 sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                     37.4250        0.0000
------------------------------------------------------------------------------

. xtunitroot hadri resrep

Hadri LM test for resrep
------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:           Not included            Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                 sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                     -1.0995        0.8642
------------------------------------------------------------------------------

. xtunitroot hadri deprate

Hadri LM test for deprate
------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:           Not included            Asymptotics: T, N -> Infinity
Heteroskedasticity:   Not robust                                 sequentially
LR variance:          (not used)
------------------------------------------------------------------------------
                      Statistic      p-value
------------------------------------------------------------------------------
 z                     30.6165        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot hadri cost

Hadri LM test for cost
------------------------------------------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:         Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                 sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 z                   25.6221       0.0000
------------------------------------------------------------------------------

. xtunitroot hadri geolpoten

Hadri LM test for geolpoten
------------------------------------------------------------------------------
Ho: All panels are stationary                 Number of panels  =      7
Ha: Some panels contain unit roots            Number of periods =     30

Time trend:         Not included              Asymptotics: T, N -> Infinity
Heteroskedasticity: Not robust                                 sequentially
LR variance:        (not used)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 z                   27.0262       0.0000
------------------------------------------------------------------------------
```

9.8: Results of random effects model with Baltagi and Wu GLS estimator

```
. xtregar exploration oilprice oilprod resrep deprate geolpoten cost, re

RE GLS regression with AR(1) disturbances      Number of obs      =       210
Group variable: id                             Number of groups   =         7

R-sq:  within  = 0.4882                        Obs per group: min =        30
       between =      .                                       avg =      30.0
       overall = 0.4878                                       max =        30

                                               Wald chi2(7)       =    119.09
corr(u_i, Xb)      = 0 (assumed)               Prob > chi2        =    0.0000
```

exploration	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	380.4401	41.73058	9.12	0.000	298.6497	462.2305
oilprod	-1.75e-08	4.31e-07	-0.04	0.968	-8.62e-07	8.27e-07
resrep	20.21602	9.956051	2.03	0.042	.7025204	39.72952
deprate	-46.05441	2933.321	-0.02	0.987	-5795.258	5703.149
geolpoten	.3508896	.1012733	3.46	0.001	.1523976	.5493817
cost	-.0883513	.0454769	-1.94	0.052	-.1774844	.0007819
_cons	5540.377	591.0014	9.37	0.000	4382.036	6698.718
rho_ar	.34668238	(estimated autocorrelation coefficient)				
sigma_u	0					
sigma_e	1452.9467					
rho_fov	0	(fraction of variance due to u_i)				
theta	0					

.

9.9: Estimated average elasticities of exploration investment to changes in regressors

```
. margins, eyex( oilprice oilprod resrep deprate geolpoten cost)

Average marginal effects                          Number of obs   =        210

Expression   : Linear prediction, predict()
ey/ex w.r.t. : oilprice oilprod resrep deprate geolpoten cost
```

	ey/ex	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
oilprice	.3090052	.0338173	9.14	0.000	.2427245	.3752859
oilprod	-.0015217	.0374333	-0.04	0.968	-.0748897	.0718462
resrep	.0018633	.0006843	2.72	0.006	.0005221	.0032045
deprate	-.0004394	.0279916	-0.02	0.987	-.0553018	.0544231
geolpoten	.119718	.033813	3.54	0.000	.0534457	.1859903
cost	-.138055	.0715279	-1.93	0.054	-.2782472	.0021372

요약

국제 석유 및 가스 산업 투자에 영향을 미치는 경쟁요인

: OPEC국가로부터의 경험적 근거

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이 논문은 국제 석유 및 가스산업의 탐사 및 개발 투자에 있어 경제성, 불확실성, 기술, 석유회계정책 등의 다양한 경쟁요인이 미치는 영향을 연구하는 것을 목표로 한다. 투자행동방정식(OPEC 및 일부 비OPEC 회원국 각각의 탐사 및 상류사업 관련)은 1980년에서 2011년 사이의 기간 동안 고정 및 임의 요인 모델을 사용하는 panel data framework에서 상술 및 예측하고 있다. 따라서, Driskoll and Kraay(1998)의 parametric covariance matrix estimator(모수적 공분산행렬 추정량)와 Baltagi and Wu(1999)의 generalized least square estimator가 추정공동요인(estimated coefficients)의 표준오차를 조정하는데 각각 적용되어 최적의 고정 및 임의 요인 모델을 산출하였다. 탐사 및 상류사업 투자행동 모델의 추정 결과는 일반적으로 양호한 타당성, 역동성을 보이며 대부분의 테스트에서 예측했던 지표와 함께 강한 통계적 성능을 보인다.

탐사투자행동모델의 추정공동요인은 유가, 생산량, 대체매장량, 지질학적 가능성이 중대한 긍정적 영향을 미치는 한편, OPEC 국가의 탐사사업 투자에 대한 생산량감소율이 부정적 영향을 미친다. 이는 경제적 요

인 및 불확실성 요인이 OPEC국가의 탐사투자행동에 지대한 영향을 미친다는 것을 보여준다. 비OPEC회원국을 위한 탐사투자모델은 유가, 매장량대체율 및 지질학적 가능성이 매우 긍정적인 영향을 미치고, 비용이 매우 부정적인 영향을 미친다는 것을 보여준다. 이 또한 경제적 요인 및 불확실성 요인이 비OPEC국가의 탐사투자행동에도 지대한 영향을 미친다는 것을 보여준다. 영향력과 관련하여 OPEC국가에서 탐사투자는 원유생산량과 유가 상승에 매우 유연한 반응을 보이며 비OPEC국가에서 탐사투자는 유가 및 비용 상승에 매우 유연한 반응을 보인다. 이는 경제적 요인들이 OPEC 및 비OPEC국가 모두에서 탐사사업 투자에 지대한 영향을 미친다는 것을 보여준다.

마찬가지로 OPEC국가의 상류사업 투자행동모델의 추정결과도 유가, 생산, 매장량대체율, 기술적 진보가 매우 긍정적인 영향을 미치는 것으로 나타나며, 유전생산량감소율 및 가스가격이 각각 부정적 영향을 미치는 것으로 나타난다. 이는 OPEC국가의 상류사업 투자에서 경제성, 불확실성, 기술, 석유회계정책(일반적 회계제도) 요인들의 중요성을 보여준다. 반대로 비OPEC국가의 상류사업 투자모델의 추정공동요인은 유가와 기술적 진보에 매우 긍정적인 영향을 받는 것으로 나타나며, 원유 및 가스 가격에 부정적인 영향을 받는 것으로 나타난다. 이 또한 비OPEC국가의 상류사업 투자행동 형성에 경제성, 기술, 석유회계정책 요인들이 지대한 영향을 미치는 것을 보여준다. 전체적인 영향력의 측면에서 보면 OPEC 및 비OPEC국가 모두 상류사업 투자는 유가변동과 기술적 진보에 유연한 반응을 보임으로서 경제적, 기술적 요인들이 상류사업 비용투자에 지배적인 영향을 나타낸다고 할 수 있다.

본 연구를 통해 OPEC국가 및 비OPEC국가의 시장개발정책들은 높은 유가상승을 촉진함으로서 관련산업의 비용상승 상쇄, 석유 및 가스의 탐사, 개발, 생산사업의 경제성 보장, 투자이익률 축소, 현금흐름 증가

를 꾀하고 있음을 알 수 있다. 기술적 진보의 지대한 영향은 관련 산업 성장을 위한 기술성장 역할의 중요성을 보여준다. 이에 따라 OPEC 및 비OPEC국가 모두 관련 산업의 주요 R&D 사업을 지원하고 장려하는 정책들에 중점을 두고 있으며 석유산업(분야별) 혁신시스템의 효과적인 개발을 위해 필요한 정책적인 틀을 제공하고 기술개발에 박차를 가하고 있다. 생산관리 정책들은 OPEC국가 및 비OPEC국가 모두에서 유전개발 및 투자에 대한 재개발 장려를 위해 바람직한 정책이지만, 이러한 정책들이 OPEC 국가에서는 탐사사업 투자를 방해할 수도 있다. 마찬가지로 본 연구는 OPEC국가들의 생산감소전략은 탐사사업에 대한 투자를 장려하기 위한 자원보존정책을 추진하는 방향으로 가고 있음을 보여준다. 하지만 자원보존정책은 유전개발 및 재개발에 대한 투자를 방해할 수도 있다. 같은 맥락으로 OPEC국가 및 비OPEC국가 모두에서 매장량대체율 증가를 목표로 하는 정책들은 탐사사업 투자를 장려하는 것이 바람직하다. 게다가 회계제도의 증가는 OPEC국가 및 비OPEC국가 모두에서 투자를 방해하는 요인이 될 수 있다는 점은 주목할 만 하다. 따라서 빈번한 변경을 피하고, 투자를 장려하고, 정부와 투자자의 장기적 가치창출을 위해서는 회계제도 수립 시 간결하고 주의 깊은 리스크 분배와 보상체계를 확립하는 것이 중요하다.

키워드: 상류사업투자(upstream investment), 석유 및 가스(oil and gas), OPEC, 비OPEC(non-OPEC), 정책(policy)

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