UNIVERSITY OF GHANA

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INTRA- AND INTER-GROUP PERFORMANCE OF OIL PRODUCING COUNTRIES: A META- AND GLOBAL FRONTIER ANALYSIS

BY

VICTOR SOSU GAKPEY

(10444001)

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DECLARATION

I do hereby declare that this work is the result of my own research and has not been presented by anyone for any academic award in this or any other university. All references used in the work have been fully acknowledged.

I bear sole responsibility for any shortcomings.

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VICTOR SOSU GAKPEY DATE

(Student)

CERTIFICATION

I hereby certify that this thesis was supervised in accordance with procedures laid down by the University of Ghana.

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DR. KWAKU OHENE-ASARE DATE

(SUPERVISOR)

…………………………………………. …………………………………..

DR. ANTHONY AFFUL-DADZIE DATE

(CO-SUPERVISOR)

DEDICATION

To My Father and Mother

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

Oil and gas is an important factor in the economic growth and development of most economies and an integral part of the global economy. Oil producing countries (OPCs) play a substantial part in the ownership, production and marketing of extracted hydrocarbons. This has made oil and gas production and supply decisions at the country level key to operations managers globally. To enhance their oil and gas management capabilities, some countries in the international oil industry have coalesced into intergovernmental organisations (IGOs) that are aimed at improving their bargaining powers through consensus and cooperation. However, although these IGOs play an important role in the industry, little is known on the production and supply efficiencies of member states. Based on this background, the study provides insights on the dynamics of intra and inter group performance of OPCs in order to inform operations managers in these countries on their performance and benchmarks in the industry. This was done by assessing performance of OPCs in a particular IGO and comparing their performance with other OPCs in other IGOs.

An unbalanced panel of OPCs in four IGOs was used by mainly drawing data from the U.S Energy Information Administration and the World Bank Development Indicators. In all 53 OPCs from the four IGOs in the international oil and gas industry for a 14-year period from 2000 to 2013 were used. Relevant performance measurement techniques in management science and operations management were used. The study identified that the International Energy Agency's (IEA) production frontier outperforms the production frontiers of the other three IGOs in the inter group performance. IEA, on average, were the best performers followed by the Organization of Arab Petroleum Exporting Countries (OAPEC), Organization of the Petroleum Exporting Countries (OPEC) and the Former Soviet Union (FSU) in that order. Finally, IEA and OAPEC production frontiers were seen to be consistently better than both the OPEC and FSU frontiers for all the 14 years of study.

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

Oil and gas play important roles in the economic growth and development of most economies and have become an integral part of global economic life (Barros & Assaf, 2009; Cleveland, Costanza, Hall, & Kaufmann, 1997; Kashani, 2005b; Murphy & Hall, 2011b; Ramachandra, Loerincik, & Shruthi, 2006). Nearly two billion dollars' worth of petroleum are traded globally everyday (Tordo, Tracy, & Arfaa, 2011) and oil is the primary largest commodity of international trade in terms of volume and value traded globally (Desta, 2003; Ismail et al., 2013). The sector supports such industries as energy, transportation, industrialized agriculture, steel and plastic pipe production, health care and chemical industries, which generate income and employment (Francisco, de Almeida, & da Silva, 2012; Ismail et al., 2013). This has made oil and gas production and supply decisions key to most economies globally.

The importance of oil and gas has made oil producing countries (OPCs) play crucial roles in the supply of crude oil (Managi, Opaluch, Jin, & Grigalunas, 2006). OPCs through the production and export of oil and gas, hold substantial amount of the world petroleum reserves, production and marketing (Ike & Lee, 2014). Oil and gas affect relationships of countries and is a factor in determining foreign policy of producer and consumer countries (Hawdon, 2003; Stevens, 2008; Yergin, 2011). Of the 1,148 million barrels of stated oil reserves in the world, 77% are managed by states (Eller, Hartley, & Medlock, 2011). However, efficiency and productivity assessments in the oil and gas industry have ignored the cross-country assessment though OPCs play a critical role in the global oil and gas supply.

Some countries in the international oil sector have coalesced into intergovernmental organisations (IGOs) in order to remain efficient and competitive in oil and gas production and supply. IGOs are international associations established by governments or their representatives that have been sufficiently institutionalized by treaty to require regular meetings, rules governing decision making, a permanent staff and its headquarters (Shanks, Jacobson, & Kaplan, 1996). IGOs' goal is to deliver high quality project outcomes and innovations to operational and economic issues at regional and global levels (Cissokho, Haughton, Makpayo, & Seck, 2013; Dorussen & Ward, 2008; Escobar & Le Chaffotec, 2015; Holland, 1998). In meeting the world's growing economic demands, there have been a number of IGOs with policy direction towards the oil and gas industry. The four IGOs at the forefront of forging global policy in the oil and gas industry are Organization of the Petroleum Exporting Countries (OPEC), Former Soviet Union (FSU) Organization of Arab Petroleum Exporting Countries (OAPEC) and International Energy Agency (IEA). Without IGOs, it may be difficult to monitor performance of oil and gas production and supply over time and set up international regulations and restrictions for countries (Biermann & Bauer, 2004).

Although many oil efficiency studies exist (Al-Obaidan & Scully, 1995; Barros & Antunes, 2014; Barros & Assaf, 2009; Barros & Managi, 2009a; Dike, 2013; Eller et al., 2011; Francisco et al., 2012; Hawdon, 2003; Ike & Lee, 2014; Ismail et al., 2013; Kashani, 2005b; Kim, Lee, Park, & Kim, 1999; Managi et al., 2006; Price & Weyman-Jones, 1996; Ramcharran, 2002; Sueyoshi & Goto, 2012a; Thompson, Dharmapala, Rothenberg, & Thrall, 1994; Wolf, 2009), few have assessed the performance of IGOs (Dike, 2013; Ike & Lee, 2014; Ramcharran, 2002) and they are the only ones who have examined the meta-productive-efficiency, group efficiency, technology gap ratios and frontier differences of IGO members in terms of oil and gas production and supply using the metafrontier analysis

(Battese, Rao, & O'Donnell, 2004; O'Donnell, Rao, & Battese, 2008a) or the global frontier difference (GFD) (Asmild & Tam, 2007). The GFD adequately compares the performance of the best-performing firms between different groups or the differences in the frontiers of different groups of firms. No oil efficiency study has tested the scale elasticity property based on the bootstrap algorithms (Simar & Wilson, 2002). Neither has any study used the Simar-Zelenyuk-adapted-Li test (SZAL) to statistically explore the significant differences in the distribution of meta-efficiency or average frontier differences between different IGOs and oil producing firms within these IGOs (Li, 1996; Simar & Zelenyuk, 2006).

The purpose of this study is thus to contribute to the oil and gas efficiency literature by assessing meta-efficiency, group efficiency, technology gap ratios and frontier differences of oil-producing countries (OPCs) be it inter-IGOs or intra-IGOs using a data envelopment analysis (DEA)-based (Charnes, Cooper, & Rhodes, 1978b) metafrontier analysis (Battese et al., 2004; O'Donnell, Rao, & Battese, 2008b) and the GFD (Asmild & Tam, 2007). 'Intra-IGOs', mean OPCs within one IGO whiles 'inter-IGOs', mean the 4 different groups of IGO in the oil industry. By this, we are able to determine the IGO-group-specific effect on member countries' performance. Next for robustness check, the study tests the differences in the distribution of meta-efficiency levels and frontier estimates between OPEC and OAPEC, OPEC and FSU, OPEC and IEA, OAPEC and FSU, OAPEC and IEA, FSU and IEA using the SZAL (Li, 1996; Simar & Zelenyuk, 2006). Policy prescriptions are provided.

1.1 Statement of Problem

Despite the many oil and gas efficiency related studies (Zhou, Ang, & Poh, 2008), we identify some gaps in the recent literature. First, to the best of our knowledge, no paper has yet assessed the production efficiency or frontier differences between IGOs in the global oil industry. Though, IGOs are explored in environmental policy (Biermann & Bauer, 2004), conflict policy (Dorussen & Ward, 2008), coastal zone management (Hayward & Cutler, 2006) and several other sectors (Cao, 2009; Kalb, 2010). Oil efficiency studies have mainly focussed on policy reforms (Barros & Managi, 2009a; Kashani, 2005b; Price & Weyman-Jones, 1996) and ownership and state involvement (Eller et al., 2011; Stevens, 2008; Sueyoshi & Goto, 2012a).

Second, there are limited oil and gas efficiency and productivity studies that focus on inter-country assessment (international benchmarking) or on oil-producing countries (OPCs). Majority of the studies where mainly on the performance of *oil companies* or the performance of *oil firms in one country* (Hawdon, 2003). For example, whereas Al-Obaidan and Scully (1995), Sueyoshi and Goto (2012a) and Wolf (2009) assessed the performance of oil companies, Barros and Assaf (2009), Barros and Managi (2009a) and Kashani (2005b) focused only on oil firms or blocks or units in a single country. However, OPCs and not oil companies, are usually the owners of natural resources including oil and gas reserves. Besides, it is the performance of OPCs which are more affected by regional or global shocks (Abdalla, 1995; Dike, 2013; Goldthau & Witte, 2011). Yet, only Hawdon (2003) evaluated the efficiency of OPCs although Hawdon (2003) just dwelled on gas distribution.

Third, despite the several efficiency studies in the oil and gas industry (Al-Obaidan & Scully, 1995; Barros & Antunes, 2014; Barros & Assaf, 2009; Barros & Managi, 2009a; Eller et al., 2011; Francisco et al., 2012; Hawdon, 2003; Ike & Lee, 2014; Ismail et al., 2013; Kashani, 2005b; Kim et al., 1999; Managi et al., 2006; Price & Weyman-Jones, 1996; Sueyoshi & Goto, 2012a; Thompson et al., 1994; Wolf, 2009), they all fail to adequately test the scale elasticity property of the industry before estimation. While different models exist to assess efficiency when the industry exhibits constant returns to scale (CRS) or variable returns to scale (VRS), previous studies have arbitrarily selected either or both scale elasticities in assessment. Wrong choice of the scale elasticity property will lead to misleading conclusions (Dyson et al., 2001; Simar & Wilson, 2002, 2011). As yet, only Hawdon (2003) has made some attempts to statistically test the returns to scale property in efficiency assessment in the oil industry. However, Hawdon (2003) relied on the *t*-test and Kolmogorov-Smirnov tests as proposed by Banker (1996) which do not provide consistent results for DEA estimations (Simar & Wilson, 2002).

Finally, there are concerns about the methods used by previous studies to compare performance differences between groups of oil and gas firms. For example, whereas Kashani (2005a, 2005b) and Hawdon (2003) used t-test and Kolmogorov-Smirnov test to compare performance differences of oil and gas fields, Eller et al. (2011), Ike and Lee (2014) and Wolf (2009) relied on dummy variables in regression analysis for such comparison. These parametric and nonparametric statistics as used in previous studies are flawed when used in DEA estimations. First, they are point estimates that rely on the mean or median to the neglect of the entire distribution of scores (Zelenyuk & Zheka, 2006). Second, these tests, especially the parametric ones, require several statistical properties which DEA estimates do not possess (Simar & Wilson, 1998). Finally, they require a careful consideration of whether the groups under consideration are of a dependent sample or independent sample (Epure, Kerstens, & Prior, 2011; Kenjegalieva, Simper, Weyman-Jones, & Zelenyuk, 2009; Simar & Wilson, 2002). No paper in the oil and gas efficiency literature has used the Simar-Zelenyuk-adapted-Li test (SZAL) to statistically explore significant differences in the distribution of efficiency or frontier estimates between different groups in the oil and gas industry (Li, 1996; Simar & Zelenyuk, 2006). This nonparametric test effectively compares the equality of distributions of efficiency estimates using kernel density estimations.

1.2 Contributions of the Study

The purpose of this whole study is to contribute to the oil and gas efficiency literature by assessing meta-efficiency, group efficiency, technology gap ratios and frontier differences of the 65 oil-producing countries (OPCs) belonging to the four IGOs under review using a metafrontier and GFD analysis from the period of 2000 to 2013, to explore the efficiency differences of the IGOs, among member countries, and whether the IGOs have any effect on member countries' performance. This study makes several key contributions to policy, practice and research.

On the basis of policy contributions, member states of the various IGOs in the international oil industry may be adequately informed about their (in) efficiencies in the production and supply of oil relative to other countries. Also the study compares, benchmarks and ranks the performances of the various oil related IGOs which can provide a useful insight into production and supply policy regulation. Since these IGOs will be given an empirically grounded assessment of their performance relative to similar IGOs in the industry, it would provide references for drafting rules governing decision-making on production and supply efficiency based on the outcomes and recommendations. Some useful and insightful managerial contributions are obtainable. It would enhance the decision making of OPCs who do not belong to any IGO to know which IGO to join based on the meta-efficiency levels and frontier difference estimates. OPCs that currently belong to IGOs may also be informed of their performance as compared to other member countries of that particular IGO and provide policy prescriptions and innovation. This, would help them put in measures to improve their performance and become more competitive. From this study, oil production policy makers and governments may be able to quantify the benefits of implementing efficiency measures.

This study also makes five key contributions to research literature. First, it adds to the limited literature on inter-country oil and gas efficiency assessment which has only seen limited attention by Hawdon (2003) in gas distribution. Second, this is a premier oil and gas efficiency and productivity paper to apply the metafrontier and global frontier difference approach both of which cater for group heterogeneities. Estimation of technology gap ratios, group efficiency and meta-efficiency and global frontier difference. This is a novel empirical contribution in the oil and gas efficiency literature. Third, this is among the few studies to test the returns to scale property and the first in the international oil industry using Simar and Wilson (2002). Fourth and finally, this study contributes to the few literature that employ the innovative Simar-Zelenyuk-adapted-Li (1996) test to delve deeper into comparing the frontier differences and the meta-efficiency of IGOs in the international oil and gas industry.

1.3 Research Objectives

The purpose of this study is to contribute to the oil and gas efficiency literature by assessing meta-efficiency, group efficiency, technology gap ratios and frontier differences of oil-producing countries (OPCs) be it inter-IGOs or intra-IGOs over the period, 2000-2013. The specific objectives are:

1. To test the scale elasticity property operating in the international oil industry of OPCs.
2. To assess the intra-IGOs and inter-IGOs group efficiency, meta-efficiency and technology gaps of OPCs.
3. To determine if a statistically significant difference exist in the distribution of the meta-efficiencies group efficiencies and technology indices of the four IGOs in the oil industry respectively.

4. To evaluate the inter-group frontier differences of the four IGOs

1.4 Research Questions

The research seeks to answer the following questions:

1. Does the international oil technology industry of OPCs exhibit constant or variable scale elasticity property?
2. What are the intra-IGOs and inter-IGOs group efficiency, meta-efficiency and technology gap ratios of OPCs?
3. Are there statistically significant differences in the distribution of the meta-efficiencies, group efficiencies and technology indices of the four IGOs in the oil industry respectively?
4. What are the inter-group frontier differences of the four IGOs?

1.5 Limitations of the Study

This study makes several key contributions to policy, practice and research, this notwithstanding there are some few challenges in terms of sample data and scope. Countries used for assessment were drawn from the list of members of the four IGOs under consideration. However, a few were eliminated from the sample because they produce either only oil or only gas. Whiles this is a limitation, majority of members of these IGOs produce both oil and gas. Additionally, in the sample data, a larger sample covering all oil producing countries in the world would have been appropriate but it is difficult to access due to data scarcity. The scope of the research covers the 14-year period from 2000 to 2013 as a result of data unavailability. Even though this period captures several dynamics in the international oil industry beyond this period would have allowed for more insights especially towards the new low price environment the oil industry is currently facing. Finally, there are several other IGOs like European Union (EU), Gulf Cooperation Council (GCC) and Organización Latinoamericana de Energia (OLADE) whose activities may influence the oil supply decisions of member countries. This notwithstanding, most of the members of these other IGOs are also members of the four IGOs that are currently under study.

1.6 Thesis Structure

The thesis is organized into six chapters. Chapter one is the introduction chapter that provides a research background, an overview of the problems being addressed in this thesis, the research contributions, objectives and questions as well as limitations of the study. This is the preliminary chapter that lays the foundations for this thesis. Chapter two is dedicated to review of relevant literature regarding operation of inter-governmental organizations. It begins with a theoretical review where theories that pertain to both inter-group performance and intra-group performance are adequately presented. This is then followed by an empirical review of the contemporary empirical works conducted on IGO-efficiency across various industries as well as the oil and gas industry. Chapter two ends with a conceptual framework that shows the process the research objectives are addressed. Chapter three is the context of the study. It is aimed at providing insights into how the international oil industry operates as well as an overview of the mechanisms for membership and operation of the IGOs under consideration.

The research methodology is presented in chapter four. This chapter provides the research design, the sampling approaches and the mathematical justifications of the models to be used in this study. Research findings based on the objectives of this study are then organized in chapter five. Here, the theoretical and empirical literature reviewed in chapter two are used to support the research findings. Chapter six is the final chapter that provides a summary, conclusion and recommendations for policy, practice and further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The section reviews theories on why membership of IGOs is expected to affect the efficiency of states in international oil industry. This consists of three main parts- a theoretical, an empirical review and a conceptual framework. The first part reviews the theories of intra-group performance that shows how state or firms gain or lose by belonging to a particular group. It also reviews theories on inter-group performance that shows why the performance of separate groups may differ. The second part reviews studies that have been done on efficiency of the oil industry. Finally, a conceptual framework that guides the entire research is presented.

2.1 Theoretical Review

2.1.1 Intra-Group Performance Theories

Theories reviewed under this section provide an understanding of performance gains as a result of membership of a particular group. It will explain how units tend to benefit or lose by belonging to groups. Particularly, Social Network Theory (Mitchell, 1969; Tichy, Tushman, & Fombrun, 1979), Social Facilitation Theory (Triplett, 1898; Zajonc, 1965, 1968) and Institutional Theory (DiMaggio & Powell, 1983; Meyer & Rowan, 1977) will be reviewed.

2.1.1.1 Social Network Theory

The effects of states' membership and formation of IGOs and the importance of such governmental organisations have long been a topic of interest in world politics, economic development and academia. IGOs are formed to link actors (states) in acquiring information about interests and intentions because they create ties between states (Dorussen & Ward, 2008). A Social Network consists of a set of actors (states) and their relations (ties) between the states (Wasserman & Faust, 1994). Social networks are important in sustaining and improving attitudes, behaviours, health and well-being of actors in these social networks (Miles, 2012).

The theory is often credited to earlier works of Barnes (1954), Bott (1957) and Granovetter (1973). Its academic applications span a broad range of disciplines including sociology, operations research, social psychology, political science, mathematics, epidemiology, computer science and economics just to mention a few (Katz, Lazer, Arrow, & Contractor, 2004; Marwell, Oliver, & Prahl, 1988). In operations management for example, complex logistic networks, transportation problems and some facility location decisions are based on social network theoretical considerations (Jackson, 2010), (Lovejoy & Handy, 2011; Lovejoy, Sciara, Salon, Handy, & Mokhtarian, 2013).

The theory explains why individual groups or organization create these ties as an investment in the accumulation of social resources and capital (Katz et al., 2004). The basic idea of the theory is that the behaviour in a set of connection as a whole can be used to explain the behaviour of the actors (state) in the set (Mitchell, 1969; Tichy et al., 1979). States are said to be socially networked when they tend to think and behave similarly because they are connected (Garton, Haythornthwaite, & Wellman, 1997; Miles, 2012). These connections may include; communication ties (who gives information to who); formal ties (who reports to who); affective ties (who trusts who); material ties (who supports who); proximity ties (who is close to who); and cognitive ties (who knows who) (Katz et al., 2004).

Social network theorists believe that the underlying structure of the group determines the type, access and flow of resources to actors in the network (Daly, 2012). Therefore the theory moves away from the adage "It is not what you know, but who you know" to a more accurate adage "Who you know defines what you know" (Cross & Parker, 2004; Daly, 2012; Newman, Barabasi, & Watts, 2006). This theory can be applied to various category of analysis from individuals, organization or nation state that have same attributes for reciprocation (Kadushin, 2004).

There has, however, been concerns on the mode in which the concept such as distance, social structure and cohesion can be applied in real world systems (Embirbayer & Goodwin, 1994). There is also debate over why people join networks. They may form these groups in order to maximize their personal preferences and desires (Katz et al., 2004). However, people may also join networks for more strategic and instrumental reasons (Kilduff & Brass, 2010).

It must be understood that this theory helps explain both the positive and negative consequences of membership of such social networks. These ties or network may provide positive utilization to countries in the oil industry by influencing access to resources, reducing transactional costs and building interest based on coalitions (Lauber, Decker, & Knuth, 2008). It also facilitates the flow of information between actors (Tindall & Wellman, 2001). Countries may stand to benefit from membership of these groups through pooled collaborations in terms of technology and research as well as bargaining on global markets. However, because the ties between states in the group may be weak or strong (Granovetter, 1973; Katz et al., 2004; Miles, 2012), membership of these bodies may not have the same level of success to all actors. Indeed, proponents of the theory believe that even strong membership may constrain an actor in maximizing performance (Daly, 2012; Lucas & Mayne, 2013), especially when the decisions of the group is not leading to improved performance. Eller et al. (2011) and Ike and Lee (2014), for example, have seen that production quotas of OPEC has over the years resulted in lower efficiencies of member states because of their inability to produce at truly efficient production levels. Finally, because individual actors may have overlapping and cross-cutting relationships with a multitude of groups (Katz et al., 2004), inter-group performance may differ

2.1.1.2 Social Facilitation Theory

Individuals respond to a range of incitements in the environment, significant of this is the presence of another actor or audience. This can have a positive or a negative effect on an individual's performance and has been a subject debated for researchers in the field of social science and psychology for centuries (Miles, 2012; Zajonc, 1965).

At the basic level, the social facilitation theory believes that the performance of various actors are not solely dependent on their own performance, but can also be largely influenced by other persons around the individual (Crawford, 1939; Miles, 2012). This theory was first identified by Triplett (1898). The term "social facilitation" was first introduced by the Allport (1920) and defined as an increase or decrease in response to sight and sound of others making the same movement. Crawford (1939) defined it as the measurement of individual activity resulting from the presence of others. According to the theory, social facilitation and interference, the mere presence of others is a source of generic and nondirective arousal that enhances the dominant responses of the performer (Markus, 1978).

Social facilitation deals with the importance of social presence on individual or groups performance. It focuses on the changes in performance that occurs when individuals or groups are evaluated or observed by others (Aiello & Douthitt, 2001). It refers to performance enhancement and improvement effects engendered by the presence of others either as co-actors, more typically as observers or audience (Blascovich, Mendes, Hunter, & Salomon, 1999).

When individuals or group performance or action is the focus of the attention of others, the reactions of the individuals are related to the meaning assigned by the social presence (Uziel, 2007). This is because social presence increases drive and motivate greater effort (Triplett, 1898). The presence of others strengthens the correct responses and has a beneficial effect on performance (Hunt & Hillery, 1973; Martens, 1969; Zajonc & Sales, 1966)

However, Cottrell (1968) on the other hand proposed that the stimulation and drive for individual or group to perform is occasioned by the individual or group concern of others evaluating its performance. The theory is only concerned with a range of performance levels, instead of specific desired outcomes under the effects social presence or the environment (Aiello & Douthitt, 2001; Kelley & Thibaut, 1954).

In the context of this study, it can be thought that other actors in the intergovernmental organization may have effect on the behavior of individual members to improve in their operations for efficiency and gains. In other words, when countries are operating alone, their performance may not be as good as if they are in a group. This is because the mere presence of another person is sufficient to influence an individual's behavior. The power of others to influence an individual behavior is readily apparent in problems of imitation, conformity, competition, helping and aggression (Markus, 1978). Whiles it may be true that the presence of others can improve performance, it is equally likely that performance of individual countries may be constraint by belonging to such groups. This is because group level distractions and negative influences of bad company may hamper the drive of a country towards optimal production levels.

2.1.1.3 Institutional Theory

Organisations in a particular industry tend to act and look same (DiMaggio & Powell, 1983). The concept of the theory is that the organizational structure and process help achieve their own right of effectiveness and efficiency in their desired outcomes through the goals and missions of the institution (Lincoln, 1995)

Institutions have been defined as “regulative, normative, and cognitive structures and activities that provide stability and meaning for social behavior” (Scott, 1995). Institutions therefore exert three types of pressure on organizations; coercive, normative, and mimetic (DiMaggio & Powell, 1983). The theory posits that institutionalized activities occur due to influences on three levels: individual, organizational, and inter-organizational (Oliver, 1997). Whereas managers consciously and unconsciously follow the laid down processes or norms, customs and traditions at the individual organization level (Berger & Luckmann, 1991) shared political, social and cultural belief systems guide the behaviors of a group of organizations (Miles, 2012). At the inter-organizational level, pressure from government, affiliated persons, and society define what is socially acceptable and expected of parties in the institution which drives them to look and act the same (DiMaggio & Powell, 1983).

Most institutional theories see local actors whether individuals, organizations, or national states as being affected by institutions in their environments. Individuals and organizations are affected by societal institutions, and national-states by a world society to effectively operate in a particular manner (Greenwood, Sage, & Sage, 2008). The theories has been applied in the social sciences, and especially in political science (March & Olsen, 1983), economics (Alston, Eggerston, & North, 1996; Khalil, 1995; North, 1990) and in sociology (DiMaggio & Powell, 1983; Scott, 1995; Zucker, 1987).

It can therefore be implied that the activities and ways of operation by individual countries in the intergovernmental organization will be very similar to that of other members. This is because countries will be more expected to follow the institutionalized behaviors of the organization. Therefore, if the institutionalized behaviors of a particular IGO is efficiency-improving, it is expected that all members will also enjoy similar levels of efficiency. Conversely, where institutionalized activities do not lead to higher performance, then all members in that particular IGO will suffer. Institutional theory therefore believes that the performance of members in a particular IGO will be very similar.

2.1.2 Inter-Group Performance Theories

The theories on inter-group performance seeks to explain why the performance of different blocs of countries will differ. It is expected that the performance of individual IGOs will differ in the international oil industry. Therefore, two main theoretical views will be used to explain this possibility. These are the game theory (Von Neumann & Morgenstern, 1944) and the resource-based theory (Penrose, 1959).

2.1.2.1 Game Theory

The theory explains decisions individuals or a group of players take in order to win a game when competing with one or more opponents (Von Neumann & Morgenstern, 1944). This theory describes the strategies employed by competitors in their choices of action that enhances their chances of gain or loss by considering the action being taking by their opponents (Miles, 2012). It basically examines the actions players make that decides the outcomes, gains or the optimal decision (Madhani, 2010; Rasmussen, 1989)

The game-theoretical approach studies systems with multiple self-interested parties with the aim of predicting the likely outcomes of the system under rational behavior of the players with mutual and possibly conflicting interests (Trestian, Ormond, & Muntean, 2012; Yin et al., 2012). In other words, game theory studies games, which are mathematical models of relationships and interactions among multiple players, each trying to advance their self-interest by choosing among a set of strategies (Weibull, 1997; Yin et al., 2012). It must be noted that, the theory provides useful mathematical tools necessary to understand the possible strategies that parties may follow when not only competing but also collaborating in games (Trestian et al., 2012; Weibull, 1997). The players seek to maximize their payoffs by choosing among alternative strategies that deploy actions depending on information available at a certain moment. Each player chooses strategies which can maximize their payoff (Trestian et al., 2012).

Although originally adopted in economics, in order to model the competition between companies, it has found wide application in other areas, such as biology, accounting, management, finance, marketing, sociology, politics, international relations, philosophy, computer science, operations research and engineering (Miles, 2012; Trestian et al., 2012; Weibull, 1997). For example, in operations research, Huang (Huang & Li, 2001) applied game theoretical perspective of Stackelberg game to model and solve advertising problems in manufacturer-retailer supply chain problems. Although early understanding of game theory was developed to analyse competitions in which one individual does better at another's expense, zero sum games (von Neumann & Morgenstern, 1947), many equilibrium concepts have been developed and incorporated into the theory to handle situations where both or all parties benefits (Nash, 1996; Weibull, 1997). Among them is the famous Nash equilibrium, in an attempt to capture this idea (Nash, 1996).

The application of game theoretical ideologies in a variety of contexts, including policy-oriented ones, has become an important and expanding research area, particularly where institutions, including government are involved (Eleftheriadou, 2008; Frisvold & Caswell, 2000; O'Toole, 2004; Rigby, Dewick, Courtney, & Gee, 2013). This is probably as a result of the call by O'Toole (2004) for researchers in policy planning and implementation to recognize the importance of interaction between actors for successful policy implementation, and the use of game theory to understand the choices available to such policy actors.

In the application of game theory to such governmental-backed intergovernmental institutions, both inter and intra-group dynamics of collaboration and competition among members can be explained. This has been summarized in Figure 2.1 that show various levels of collaboration among members of a particular IGO and other IGOs. This has been adapted from (Rigby et al., 2013) benchmarking options matrix.

Intra-Group Collaboration	Inter-Group Collaboration: Low	Inter-Group Collaboration: High
Low	Low exchange of information within and between groups results in: 1. Organizational learning not supported 2. Information asymmetries not addressed	Low exchange of information within group renders between group collaboration irrelevant leading to: 1. Organizational learning not supported 2. Information asymmetries not addressed
High	High exchange of information within group but low exchange between group results in: 1. Organizational learning/innovation 2. Information asymmetries not addressed	High exchange of information within and between group results in: 1. Organizational learning/innovation 2. Information asymmetries addressed

Figure 2.1: Outcomes of Inter and Intra Group Collaboration

Source: adapted from (Rigby et al., 2013)

In the bottom left box, where there is a high willingness to collaborate within a particular IGO but low level of cooperation between different IGOs, good intra-group efficiency can result and could benefit individual countries in terms of group learning which meets the objectives of good public policy. However, this will not address possible information asymmetries in policy that may foster achievement of Nash equilibrium or Pareto optimality between different IGOs. On the top left-hand and right-hand boxes, however, low levels of intra-group collaboration mean that, policy aimed enhancing inter-group efficiency will not be met sufficiently (Rigby et al., 2013). This is because, the low level of cooperation between members of a particular IGO will reduce the benefits of even high inter-group collaboration. (Rigby et al., 2013) believe that it is only when there is high intra-group and high inter-group collaboration that a true optimal point can be achieved. This is because, such collaboration will enhance organizational learning and reduce or remove such inter-group information asymmetries.

The theoretical views of game theorists are therefore very important in assessing and understanding the competition and collaboration between various IGOs in the international oil industry. IGOs employ alternative strategies that may be a winning strategy with higher outcome in a particular situation it faces in the competitive environment. Individual member states tend to benefit or suffer in efficiency depending on not only the level of intra-group learning and cooperation, but also inter-group collaboration.

2.1.2.2 Resource-based Theory (RBT)

Groups or organisations want to be seen or identified as unique based on the special competences and resources they possess. In short, the resource-based theory (RBT) studies the differences in outcomes in respect of their resources (Peteraf & Barney, 2003). The theory can be attributable to the early works of Penrose (1959) that theorized about how a firm's resources influence its growth; in particular, where growth is constrained when resources are inadequate (Barney, Wright, & Ketchen Jr, 2001). Theory defines the organization's uniqueness and position in competitive situations in the environment (Hoopes, Madsen, & Walker, 2003). Its emphasis is on differences in efficiency (Peteraf & Barney, 2003). The focus of the theory is how the organization acts against competitors on their strength, competence and resources that shows performance differences in the environment (Barney, 1991; Miles, 2012; Wernerfelt, 1984).

Value, rarity, inimitability, and non-substitutability are among the commonly cited characteristics that provide the core logic linking resources to competitive advantage

(Sirmon, Hitt, Ireland, & Gilbert, 2011). The resource-based theory of strategy (RBT) hinges on the argument that firms with valuable, rare, special and inimitable resources have the potential of achieving superior performance (Amit & Schoemaker, 2012; Barney, 1991; Barney, 1995; Bharadwaj, 2000; Wiklund & Shepherd, 2003). RBT uses the internal characteristics and resources of firms to explain their heterogeneity in strategy and performance (Camisón & Villar-López, 2014). Basically, RBT assumes that there is underlying production heterogeneities or differences across firms (Barney, 1991; Dobbin & Baum, 2000; Peteraf, 1993). Thus production processes and resources are different from firm to firm. Therefore, firms endowed with such superior resources are able to produce more economically and/or better satisfy customer wants (Peteraf, 1993). Heterogeneity in this context also implies that firms of varying capabilities are able to compete in the same marketplace and, at least, breakeven (Dobbin & Baum, 2000; Peteraf, 1993). Accordingly, the main assumption of RBT is that only firms with certain resources and capabilities with special characteristics will gain competitive advantage and, therefore, achieve superior performance (Camisón & Villar-López, 2014).

This is therefore a theory of competitive advantage (Barney, 2001) since the central theme is that privately held knowledge (or resource) is the basic source of advantage in competition (Conner & Prahalad, 1996). A resource-based approach to firm management focuses on costly–to-copy attributes of the firm as sources of economic rent and therefore as the fundamental drivers of performance and competitive advantage (Barney, 1986; Conner & Prahalad, 1996; Rumelt, 1974). In resource-based theory, such resources may be financial, human, intangible, organizational, physical or technological (Dobbin & Baum, 2000). Indeed, (Miller & Shamsie, 1996) broadly separated these resource into knowledge based and those that are property-based resources.

In early conceptions, the RBT emphasized how variation in firms' access to key factor inputs could lead to variation in firm performance (Barney, 1991; Wernerfelt, 1984). However, subsequent extensions include a broader focus including competence-based view (Foss, 1996), commitment (Ghemawat, 1991), dynamic capabilities (Teece & Pisano, 1994; Teece, Pisano, & Shuen, 1997), knowledge-based (Foss, 1996), relation-based (Dyer & Singh, 1998), and attention-based (Ocasio, 1997) approaches. The resource based view generally addresses performance differences between firms using asymmetry in knowledge and in associated competences or capabilities (Amit & Schoemaker, 2012; Conner, 1991; Henderson & Cockburn, 1994; Peteraf, 1993).

This theory is mostly unique to the field of strategic management (Conner & Prahalad, 1996; Peteraf, 1993), although some extensions and applications have been made to related areas like neoclassical microeconomics and evolutionary economics (Barney, 2001). The RBT is undoubtedly consistent with and well rooted squarely in the policy research tradition (Barney, Ketchen, & Wright, 2011; Peteraf, 1993) and hence very important in explaining issues related to inter-organizational performance differences.

This theory of the firm therefore believes that, the way a firm is organized, when combined with firm resources, can better enhance the positive relationship between resources and firm performance (Barney, 1995; Wiklund & Shepherd, 2003). Decades of empirical work have given ample support to the importance of these resource characteristics for firm performance (Crook, Ketchen, Combs, & Todd, 2008; Sirmon et al., 2011) and is widely acknowledged as one of the most prominent and powerful theories for describing, explaining, and predicting organizational relationships (Barney et al., 2011). Therefore, in the context of this study, when an IGO is considered as the unit of analysis, it stands to reason that the unique competencies and resources of members of the particular IGO will give it competitive advantages over other relevant IGOs in the international oil industry. Size of oil and gas reserves, human, technical and technological competencies of member states, political and economic bargaining powers are all relevant tangible and intangible resources that an IGO may use to out-compete others. RBT therefore believes that IGOs with such higher levels of resources will be more efficient.

2.2 Empirical Review

The empirical review presents an overview of peer-reviewed studies on efficiency, performance and productivity of various parties in the oil and gas industry. Extent of knowledge on efficiency of countries, oil firms, drilling blocks as well as intergovernmental organisations have been presented in a manner that will provide adequate understanding of the extent of literature. Review of frontier efficiency papers in the oil industry are based on Appendix B which provides a taxonomy of these papers reviewed. On the other hand, a taxonomy of papers on efficiency of intergovernmental organizations has been presented in Appendix A.

2.2.1 Frontier Efficiency in the Oil Industry

There has been quite a number of efficiency-related research in the oil and gas industry, substantially among the issues are ownership, privatization, environmental efficiency, international comparison, regulation and state intervention. For example, Al-Obaidan and Scully (1995); Ike and Lee (2014); Sueyoshi and Goto (2012a); Wolf (2009) have assessed ownership and efficiency of firms in the industry. The focus of these studies is to understand the differences in the efficiency of state-owned and privately owned oil firms. Closely related to this theme are papers on privatization, government regulation and government intervention (Hawdon, 2003; Kashani, 2005b; Price & Weyman-Jones, 1996). Their focus is to examine the influence of various levels of government involvement in the oil and gas industry and its effects on efficiency of players in the industry. Empirically, the role of government in the industry has been quite adverse, from the negative effects of state ownership (Eller et al., 2011; Ike & Lee, 2014) to the potential for efficiency gains when government influence is removed (Kashani, 2005b; Price & Weyman-Jones, 1996).

Another important theme for assessment is the issue of environmental efficiency. Francisco et al. (2012); Ismail et al. (2013); Sueyoshi and Goto (2012a) have measured efficiency by incorporating harmful by-products of oil and gas exploration, distribution and consumption activities such as CO_2 emissions, and transmission losses. For, Barros and Antunes (2014); Managi et al. (2006) their focus was on technological change, productivity change and comparison of Malmquist and Luenberger indices. Growth Accounting and Productivity Methods have also been investigated by Barros and Managi (2009b) and Thompson et al. (1994). Thompson et al. (1994) explored the integration of DEA and other methods like Assurance Region (AR) and Cone Ratio (CR) in assessing efficiency and performance of international oil companies. Indeed, there have been a number of conceptual papers dedicated to improving the methodology used in such benchmarking (Sueyoshi & Goto, 2012a; Thompson, Dharmapala, Humphrey, Taylor, & Thrall, 1996).

Finally, since this study does international comparison of the oil and gas supply activities of various countries, it is encouraging that some studies have previously attempted such international comparison. Hawdon (2003); Kim et al. (1999) have all attempted such comparison, except that all two studies only focussed on gas distribution to the neglect of crude oil. Similarly, these two papers that have attempted international comparison only focussed on the downstream oil and gas industry. Although the body of literature in the oil and gas industry is substantial, this is rarely done an international benchmarking and in a more aggregated context or mainly geared towards the upstream operations. However very few studies are dedicated to cross country and regional efficiency in the downstream. These includes Hawdon (2003) who analysed the efficiency of 33 countries gas industry, and Kim et al. (1999) who examined 28 natural gas transmission and distribution companies operating in 8 countries.

The various approaches employed in estimating efficiency in the oil and gas industry extends a number of methods including parametric and non–parametric analysis. DEA, a non-parametric technique, and its variations have been largely used in most of the literature for example by Ismail et al. (2013); Sueyoshi and Goto (2012a) who used the method to measure environmental efficiency of 19 and 17 upstream oil firms respectively. Ike and Lee (2014) used the slacks-based measure which is a variant of the DEA non-parametric method. Whiles Barros and Assaf (2009); Hawdon (2003) have applied DEA together with the bootstrapping techniques. Other studies like Al-Obaidan and Scully (1995); Managi et al. (2006) have found support in the use of parametric efficiency techniques like SFA and Aigner and Chu deterministic frontier which require several assumptions which are sometime unrealistic in a real-world contexts (Chase, 2012).

For some, a methodology that combines a number of techniques have been seen to provide a more complementary result. Ike and Lee (2014) combined DEA, Malmquist Productivity Index and Regression to assess 38 upstream oil companies. Eller et al. (2011) estimated efficiency differences of 78 upstream oil firms with DEA and SFA. Similarly, Kim et al. (1999); Lee, Kim, and Park (1996) applied Edgeworth Index and ANOVA, and Multilateral Tornqvist, Managerial Index, System Analysis, and non-parametric efficiency analysis to examine 28 Natural Gas transmission and distribution companies operating in 8 countries. Whereas the diversity of methods used in these assessments are quite appreciable, none of the papers reviewed used methods that adequately cater for group differences (heterogeneities) in estimating the frontier efficiency. Methods like metafrontier analysis, global frontier differences are loudly missing in the literature.

2.2.2 Group Performance and Efficiency

The extant studies regarding group performance and efficiency of IGOs has been heavily skewed towards banking, energy efficiency, and health. For example, whereas Abu-Alkheil, Burghof, and Khan (2012) concentrated on bank efficiency of OAPEC and Gulf Cooperation Countries (GCC), Casu and Girardone (2004, 2006); Casu and Molyneux (2003); Claeys and Vander Vennet (2008); Marius Andrieş and Căpraru (2012), Košak, Zajc, and Zorić (2009); Mamatzakis, Staikouras, and Koutsomanoli-Filippaki (2008) looked at bank efficiency in the European Union (EU). Others worthy of mention are Behname (2012) who examined banking efficiency among OPEC countries and Drakos (2003) who considered same in the FSU and Central and Eastern European (CEE) countries. Just like banking, several studies can be cited for energy efficiency (Adetutu, 2014; Al-Rashed & León, 2015; Filippini & Hunt, 2011; Goldthau & Witte, 2011) and health (Adler-Milstein, Ronchi, Cohen, Winn, & Jha, 2014; Al-Essa, Al-Rubaie, Walker, & Salek, 2015; Oderkirk, Ronchi, & Klazinga, 2013; Retzlaff-Roberts, Chang, & Rubin, 2004).

Other research issues like education (Afonso & St Aubyn, 2005; Afonso & St. Aubyn, 2006; Krishnasamy & Ahmed, 2009) economy (Arestis, Chortareas, & Desli, 2006; Fare, Grosskopf, Norris, & Zhang, 1994; Krishnasamy & Ahmed, 2009), agriculture, (Arnade, 1994; Gorton & Davidova, 2004; Vlontzos, Niavis, & Manos, 2014), insurance (Donni & Fecher, 1997), railways (Oum & Yu, 1994), postal service, environment and policy (Selowsky & Martin, 1997) have also been considered by other studies.

Generally, although these studies see several differences in the level of efficiency of individual members of various IGOs (Oderkirk et al., 2013; Vlontzos et al., 2014) some particular IGOs have been seen to experience modest improvements in efficiency. For example Adetutu (2014) observed that some selected OPEC countries have modest energy efficiency arising from subsidy effect and artificially low energy prices. This notwithstanding, little is known about efficiency of these IGOs with respect to oil and gas production and supply efficiency. Even studies who purposely targeted oil-focussed IGOs like OPEC, OAPEC, FSU and IEA (Adetutu, 2014; Al-Rashed & León, 2015; Behname, 2012; Goldthau & Witte, 2011) rather looked at issues like banking efficiency and energy efficiency which has nothing to do with oil and gas production and supply efficiency. Studies that have come close to examining supply efficiency include Dike (2013) who looked at security in energy exportation of OPEC countries and Ramcharran (2002) who examined efficiency and production responses to price changes in the international oil industry.

When the focus of the review is shifted to which IGOs have attracted substantial research interest, interesting insights are revealed. To aid in this assessment, Figure 2.2 has graphically presented the distribution of research on the various IGOs. This is based on the taxonomy in Appendix A.

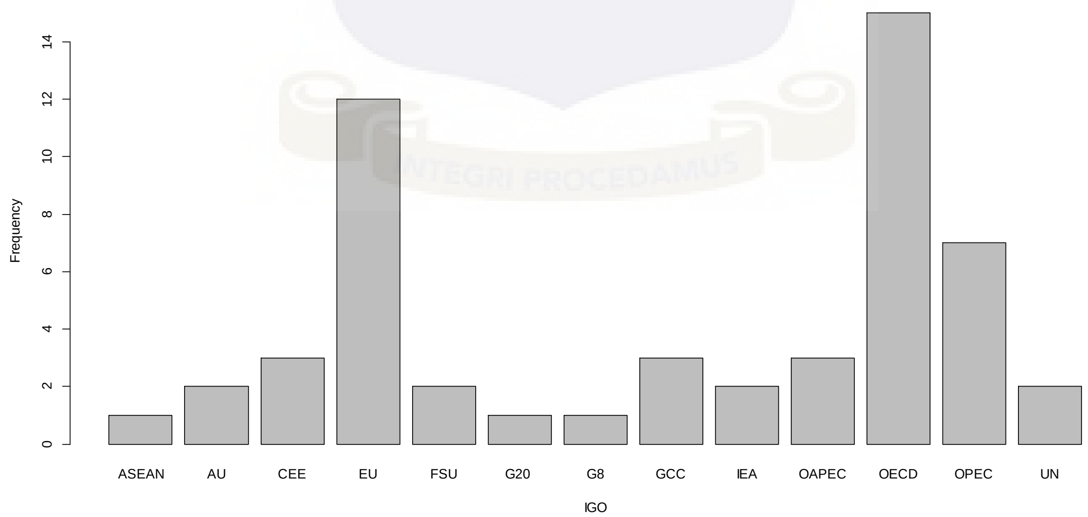

Figure 2.2: Distribution of Efficiency Studies by IGO

Source: Fieldwork (2015)

Quite evident in Figure 2.2 is that for the papers reviewed, OECD has attracted the most research interest with as many as 15 studies purposely studying this IGO individually or together with other IGOs. For example, Afonso and St Aubyn (2005); Çakır, Perçin, Min, and Gunasekaran (2015); Fare et al. (1994); Hori (2012); Krishnasamy and Ahmed (2009); Oderkirk et al. (2013) have all looked at various dimensions of efficiency in OECD countries. EU and OPEC follow with 12 papers and 7 papers respectively. Bosseboeuf, Chateau, and Lapillonne (1997); Casu and Girardone (2004); Casu and Molyneux (2003); Claeys and Vander Vennet (2008); Marius Andrieş and Căpraru (2012) looked at EU whiles Adetutu (2014); Behname (2012); Dike (2013); Goldthau and Witte (2011); Ramcharran (2002); Sari and Soytas (2009) focused their attention on OPEC countries. At the bottom are G20, G8 and ASEAN who recorded only one paper each. It must be clearly noted that FSU, OAPEC and IEA who are among the IGOs to be considered in this study are among those which have seen few research interest from the review. Insights on their efficiency will clearly add to the existing body of knowledge in these IGOs. From the taxonomy in Appendix A, it is also evident that most studies on IGOs concentrate on one particular IGO in their assessment. Gorton and Davidova (2004); Muldoon et al. (2011); Shahabinejad, Mehrjerdi, and Yaghoubi (2013); Taylor, d'Ortigue, Francoeur, and Trudeau (2010) have concentrated on intra-group performance assessment considering efficiency only in that particular IGO of interest. A few studies like Abu-Alkheil et al. (2012); Aristovnik (2012); Drakos (2003); Selowsky and Martin (1997) have based their research arguments on samples comprising two or more IGOs. However, among these studies whose samples cut across various IGOs, there has been little inter-group comparison to identify and rank IGOs with respect to a particular phenomenon understudy. There is therefore room for this study to build literature by not only conducting intra-group assessment, but also an inter-group performance assessment which is lacking in literature.

Finally, the focus is on the methods used in the assessment and whether these methods adequately cater for group heterogeneities. In assessing the performance and efficiency of groups (IGOs), several models relating to the issue of international comparisons and frontier efficiency have been applied. Abu-Alkheil et al. (2012) used DEA to determine banks efficiency in OAPEC and GCC countries between 2005 and 2008. Arestis et al. (2006) applied it to 26 OECD Countries from 1963 to 1992. Afonso and St Aubyn (2005) used both DEA and FDH to estimate the education and health efficiencies of 24 OECD countries. Others like Filippini and Hunt (2011) determined the energy efficiency of 29 OECD countries for 28 years period from1978 to 2006 using SFA. Košak et al. (2009); Mamatzakis et al. (2008) estimated bank efficiency in 5 New EU Member States from 1996 – 2006 and 10 EU countries from 1998–2003 respectively, using the SFA approach. Regression-based estimation approaches like the Translog Cost Function (Adetutu, 2014; Claeys & Vander Vennet, 2008) and Auto Regressive Distributed Lag (ARDL) (Sari & Soytas, 2009) have also seen some considerable use. Whereas all these techniques have their own advantages and disadvantages, it is important that papers that compare various groups use models that can adequately cater for group differences in estimating the efficiency. From the review, only Krishnasamy and Ahmed (2009) used the Metafrontier approach to measure the efficiency and productivity of the economies of twenty six (26) OECD countries from 1980 to 2008. Their paper does not even conduct inter-IGO comparison since the focus was only on OECD. Most of the reviewed literature employed in this study have applied a number of models, some in combination to estimate efficiency of groups or IGOs. But there is rare evidence regarding Global or Meta frontier analysis in the international oil and gas industry. Hence there is enough gap for this paper to situate in efficiency assessment the use of models that adequately cater for such group differences in the estimation of efficiency.

2.3 Conceptual Framework

The process of analysis and assessment of the objectives of this study will follow the Cooper Framework of Emrouznejad and De Witte (2010) which clearly shows the interrelated phases any DEA-based assessment should follow. This is illustrated in Figure 2.3.

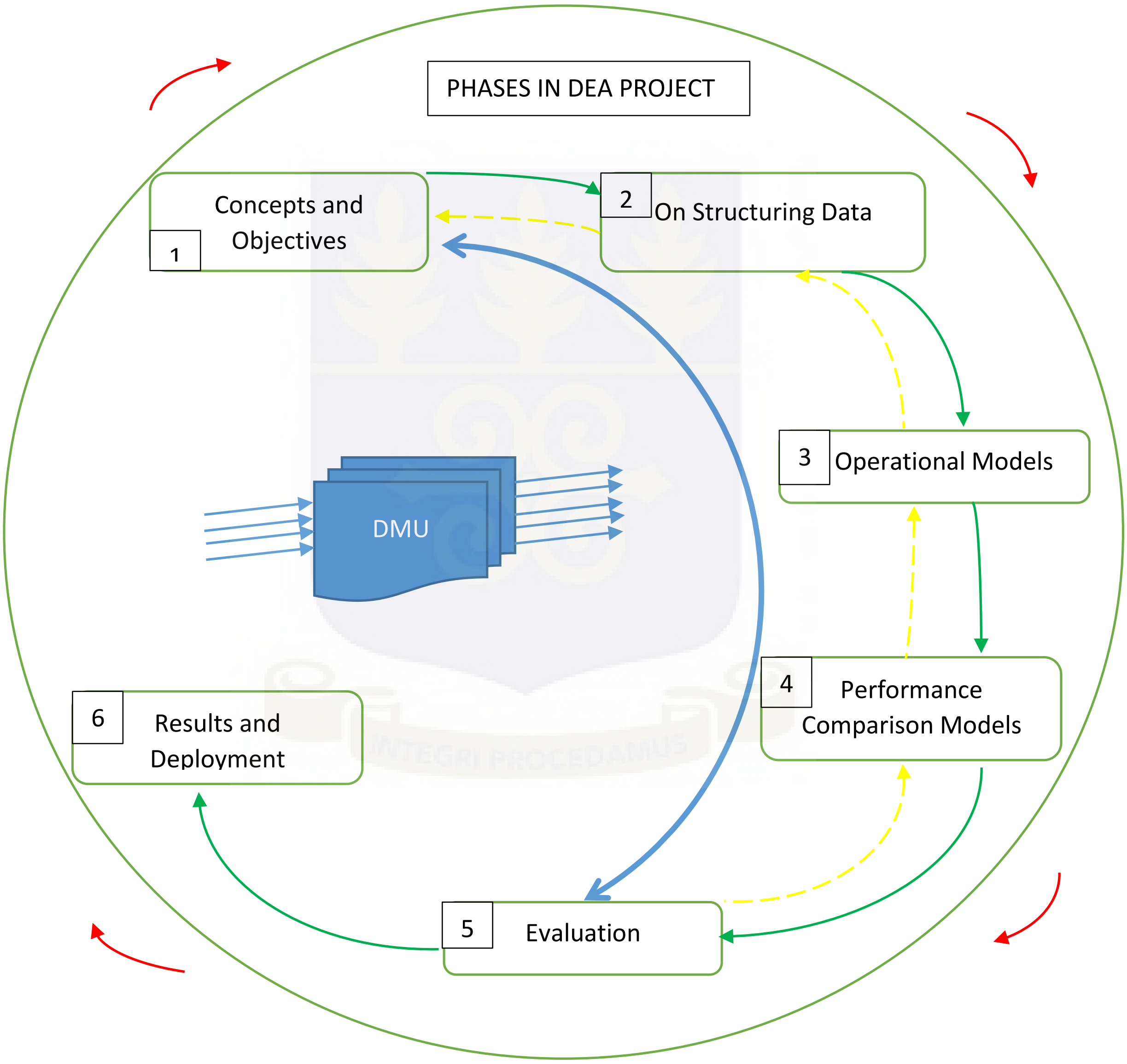

Figure 2.3: The Cooper Conceptual Framework

Source: Emrouznejad and De Witte (2010)

This framework defines the issues and how to understand the processes of decision making units. The first and second phases (the concept and objectives, and the on structuring data) is the problem identification and research objectives captured in the first chapter of this study. The fourth and fifth phases show the outcome and documentation, which is dealt with by the analysis and discussions chapter of this work. Note that there is a link between the evaluation stage and the first phase. The evaluation must be closely linked to the concept and objectives of the study. The middle phases determines the model that is more suitable to best analyse the research issue. The interrelationship of the framework allows for feedback thus connecting phases. Note also that the first letter of each stage make up the acronym "COOPER". On this background the Cooper Framework with respect to the current study are summarised below:

2.4 Conclusion

The chapter provided ample theoretical and empirical grounding for the study. Theoretically, established theories of Social Network Theory, Social Facilitation Theory and Institutional Theory were used to explain intra-group performance while game theory and resource-based theory were used for inter-group performance. Empirical work of frontier efficiency-related studies in the international oil industry as well as a general synopsis of efficiency studies that target IGOs were also presented. Based on these, the Cooper Framework is conceptually presented to aid in this research process.

CHAPTER THREE

CONTEXT OF STUDY

3.0 Introduction

Crude oil is a critical global resource in the economy of nations and an indispensable commodity in socio-economic, political and environmental priorities in the world today (Armaroli & Balzani, 2007; Asif & Muneer, 2007; Holdren, 2006; Igos et al., 2015). States establish agreement between them for socio-economic development but sometimes are unable to resolve the different interest of the individual members which affect them; therefore the formation of supra-national political authorities – IGOs (Bennett & Oliver, 2002; Park, 2015). IGOs are important channels for enhancing socio cultural development, affinities, trust, improved economic development, trade, technology and information among member countries (Ingram, Robinson, & Busch, 2005; Park, 2015). This section will provide an overview of the major IGOs in the international oil industry.

The demand and supply of oil affects the relationship between major oil exporting and importing countries (Yergin, 1991). The supply and sale of oil have created interdependencies in the international oil industry and among nations (Strange, 1989). The study of IGOs have increased over the past centuries due to their importance to global economy and social interaction between states (Barnett & Finnemore, 1999; Cao, 2009; Volgy, Fausett, Grant, & Rodgers, 2008). IGOs may be categorized as political economic IGOs, social/cultural welfare IGOs, environmental IGOs, and governance and defence IGOs (Gomez & Parigi, 2013). The IGOs under study are political economic IGOs. These political economic IGOs address issues affecting trade, economic regulations and commence among member states (Alcacer & Ingram, 2013). These organisations bring together complementary skills and create platforms for innovation and creativity and make full use of the available resources to provide sustainable development for the member nations. This study also presents the relevance of IGOs in the international oil and gas industry.

3.1 International Oil and Gas Supply and Demand

Oil and gas have increased the multifaceted cross boarder relationship of countries in relations to production, consumption, regulatory influences, financial transactions and security of nations (Jones, 1995). Oil, one of the most important among other sources of energy, is critical to countries' economies due to its universal use as fuel to feed manufacturing, industrial production, as well as the transportation sectors (Murphy & Hall, 2011b). Crude oil production and supply also have an impact on the global economy and countries' socio economic development therefore countries are very interested in crude oil reserves. This section reviews the major countries in terms of proven reserves, production and consumption.

3.1.1 Proven Oil and Gas Reserves

Oil and Gas reserves constitute an important dimension that can determine the potential political power of a country in the international oil industry. This is simply the potential capacity of hydrocarbons buried inland that may be extracted in the future. Proven reserves are quantities of petroleum buried underground which by geological analysis and engineering data can be estimated with high confidence to be commercially recoverable from a certain time period, from known reservoirs and under current economic conditions (CIA, 2014). Therefore, the more reserves a country possess, the higher the potential of extracting them and the higher the political power this country has over other importing nations. Table 3.1 presents a summary of the top 11 countries in terms of crude oil proved reserves for 4 different years -2000, 2007, 2013 and 2014. Average values, also reported in the table, are for the entire period from 2000 to 2014. Regional statistics are also presented in the table.

Table 3.1: Crude Oil Proved Reserves (Billion Barrels)

		2000	2007	2013	2014	Average
1	Saudi Arabia	263.50	262.30	267.91	268.35	264.23
2	Canada	4.93	179.21	173.11	173.20	142.48
3	Venezuela	72.60	80.01	297.57	297.74	128.21
4	Iran	89.70	136.27	154.58	157.30	126.09
5	Iraq	112.50	115.00	141.35	140.30	119.65
6	Kuwait	96.50	101.50	104.00	104.00	101.33
7	United Arab Emirates	97.80	97.80	97.80	97.80	97.80
8	Russia	48.57	60.00	80.00	80.00	60.38
9	Libya	29.50	41.46	48.01	48.47	39.53
10	Nigeria	22.50	36.22	37.20	37.14	32.25
11	United States	23.17	22.31	33.40	36.52	25.02
	World	**1018.18**	**1318.00**	**1648.86**	**1655.56**	**1319.55**
	Middle East	675.64	739.20	802.16	803.60	738.34
	North America	56.50	213.87	216.77	219.79	182.53
	Central & South America	89.53	102.80	325.93	328.26	151.43
	Africa	74.89	114.07	127.74	126.73	104.11
	Eurasia	57.00	98.89	118.89	118.89	87.56
	Asia & Oceania	43.99	33.37	45.36	46.01	39.76
	Europe	20.64	15.80	12.02	12.28	15.81

Source: EIA (2015)

All values in Table 3.1 are measured in billions of barrels. Values from 2014 reveal that, out of the over 1.656 trillion barrels of crude oil reserves that have not been extracted in the world, Saudi Arabia possess more than 16% of these reserves making it the highest ranked nation. The country's economy remains heavily dependent on petroleum since petroleum exports accounts for 85% of total export revenues in 2013 (OPEC, 2014). The country holds approximately 268 billion barrels of proved oil reserves. Although Saudi Arabia has about 100 major oil and gas fields, more than half of its oil reserves are contained in eight fields in the northeast portion of the country (EIA, 2014). Looking at the average reserves since 2000, Saudi Arabia (264.23bbls) is followed by Canada (142.48bbls), Venezuela (128.21bbls) and Iran (126.09bbls). Other notable mentions on this list are Libya and

Nigeria, both of which are African countries, who placed 9th and 10th respectively. Finally, the United States has about 25.02 billion barrels of proven crude oil reserves buried especially in the Texas, North Dakota, Gulf of Mexico, Alaska and California (EIA, 2014). Close to half of the countries in this list are Middle Eastern countries – Saudi Arabia, Iran, Iraq, Kuwait and the UAE. It is therefore not surprising that most of the world's proven reserves are found in this region. About 738.34 billion barrels of crude oil, on average, are buried in this location. Given the potential importance of this region, it is not surprising the several political instability in the region since ownership of land is a marker of a strong bargaining power in the world oil and gas supply (EIA, 2014). On the other side of the table is Europe with the smallest crude reserves of about 15.18 billion barrels. This means that Europe is expected to be a major importer of oil products from other regions. Values for natural gas reserves are presented in Table 3.2.

Table 3.2: Proved Reserves of Natural Gas (Trillion Cubic Feet)

		2000	**2007**	**2013**	**2014**	**Average**
1	Russia	1700.00	1680.00	1688.00	1688.00	1683.73
2	Iran	812.30	974.00	1187.00	1193.00	976.90
3	Qatar	300.00	910.50	890.00	885.29	773.97
4	Saudi Arabia	204.50	240.00	287.84	290.81	248.22
5	United States	167.41	211.09	308.04	338.26	236.81
6	United Arab Emirates	212.00	214.40	215.03	215.04	214.50
7	Nigeria	124.00	181.90	182.00	180.74	165.40
8	Venezuela	142.50	152.38	195.10	196.41	164.42
9	Algeria	159.70	161.74	159.05	159.10	159.65
10	Turkmenistan	101.00	100.00	265.00	265.00	147.07
11	Iraq	109.80	112.00	111.52	111.52	111.03
	World	**5149.96**	**6190.88**	**6845.17**	**6972.52**	**6152.82**
	Middle East	1749.24	2566.04	2823.23	2812.83	2443.42
	Eurasia	1977.00	2014.80	2177.80	2177.80	2039.65
	Africa	394.57	485.81	514.81	605.96	475.86
	Asia & Oceania	363.47	419.59	521.46	540.38	449.26
	North America	261.34	283.59	393.43	422.06	315.03
	Central & South America	222.66	240.75	268.92	277.62	256.15
	Europe	181.69	180.30	145.52	135.87	173.46

Source: EIA (2015)

Unlike crude oil, majority of the world's natural gas reserves are held by Russia (1683 cf). This is followed by Iran (976.90 Tcf), Qatar (773.97 Tcf), Saudi Arabia (248.22 Tcf) and United States (236.81 Tcf). Russia's economy is highly dependent on its hydrocarbons, since oil and natural gas revenues account for more than 50% of the federal budget revenues (EIA, 2014). Most of the top crude oil reserve countries are still in the natural gas list, except that Qatar, and Turkmenistan are fresh additions when it comes to natural gas. Middle East continues to dominate natural gas reserves with about 2443.42 Tcf of natural gas which represents about 39.7% of the world's value. Europe is also at the bottom of this list when regional blocks are compared. Figure 3.1 shows the trend of world oil and gas reserves from 1980 to 2014. Note that Natural gas reserves are converted from trillions of cubic feets to billions of barrel equivalent in order to ensure comparison. The graph clearly shows that both resources have seen an upward spiral in volumes over the years. It is possible that the invent of more advanced technologies have increased the probability of discovery. Oil reserves are also seen to mostly out-number equivalent gas reserves globally over this period.

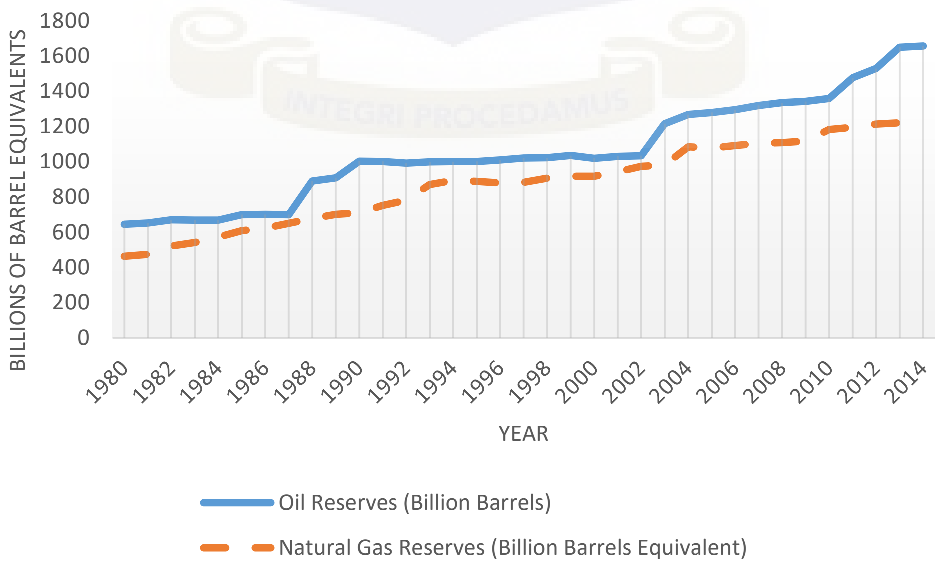

Figure 3.1: Oil and Gas Reserve Trends
Source: EIA (2015)

3.1.2 Oil and Gas Supply

The supply and sale of oil and gas have created interdependencies in the international oil industry and among nations (Strange, 1989). This affects the relationship between major oil exporting and importing countries (Yergin, 1991). The growth of most countries' economies is highly related to the supply of oil (Murphy & Hall, 2011a). Table 3.3 presents a summary of the major oil supplying countries for the years 2000, 2007, 2013 and 2014. Also presented in the table are average values for the entire period from 2000 to 2014. Regional statistics are also reported. It must be noted that total oil supply takes into consideration crude oil, natural gas and other hydrocarbons from oil and gas extraction. The values of all the supplies are in thousands of barrels per day.

Table 3.3: Total Oil Supply (Thousand Barrels Per Day)

		2000	2007	2013	2014	Average
1	Saudi Arabia	9475.75	10748.62	11701.51	11623.70	10729.72
2	United States	9057.78	8469.40	12342.77	14020.82	9640.82
3	Russia	6723.64	9938.18	10757.91	10847.10	9422.16
4	China	3377.53	3953.86	4561.12	4598.05	3984.01
5	Iran	3765.39	4039.03	3194.30	3376.61	3890.54
6	Canada	2753.14	3448.52	4073.07	4383.32	3375.41
7	Mexico	3460.09	3500.29	2915.07	2811.93	3337.80
8	United Arab Emirates	2572.33	2947.50	3443.71	3473.71	2921.25
9	Venezuela	3460.76	2681.99	2684.55	2684.55	2813.37
10	Norway	3354.61	2564.89	1845.05	1904.38	2639.58
11	Kuwait	2200.73	2603.43	2798.64	2767.20	2519.99
	World	**77725.45**	**85130.47**	**91014.47**	**93201.09**	**84960.21**
	Middle East	23484.22	25286.09	27472.12	27836.48	25482.40
	North America	15271.01	15418.22	19330.91	21216.06	16354.03
	Eurasia	8184.70	12687.58	13782.08	13905.19	11909.59
	Africa	7989.70	10485.50	9296.44	8707.23	9447.15
	Asia & Oceania	8316.46	8537.09	9199.47	9257.79	8697.19
	Central & South America	7313.03	7270.57	8120.31	8408.39	7513.66
	Europe	7166.34	5445.43	3813.14	3869.95	5556.19

Source: EIA (2015)

Values of the average oil supply for the period show that of the 84960.21 thousand barrels of oil supplied daily, Saudi Arabia supplies the highest volumes of 10729.72 thousand b/d.

The United States follows in second place with 9640.82 thousand b/d even though the US is a major importer of oil (EIA, 2013). Studying the averages, China who is also another substantial importer of oil comes forth with 3984.01 thousand b/d, after Russia (9422.16 thousand b/d), whiles Iran (3890.54 thousand b/d) and Canada (3375.41 thousand b/d) follow thereafter. When the regional dynamics are carefully examined, it is obvious that the Middle East region as a whole has the highest supply volumes with 25482.40 thousand b/d, followed by North America (16354.03 thousand b/d), Eurasia (11909.59 thousand b/d), Africa (3944.15 thousand b/d) and at the bottom is Europe (5556.19 thousand b/d). Total supply may have substantial portions going to domestic markets, therefore the export volumes of both crude oil and gas productions are examined in Tables 3.4 and 3.5 respectively.

Table 3.4: Exports of Crude Oil (Thousand Barrels Per Day)

		2000	2007	2013	2014	Average
1	Saudi Arabia	6444.00	6968.74	7477.62	7657.93	6888.47
2	Russia	3150.00	5171.58	4892.29	4807.16	4633.31
3	Iran	2309.13	2617.63	2207.42	1401.93	2296.23
4	Norway	3070.00	2012.96	1446.17	1324.11	2251.34
5	Nigeria	2069.18	2120.22	2402.46	2410.57	2162.14
6	United Arab Emirates	1870.00	2289.44	2365.56	2427.59	2113.94
7	Canada	1590.77	1958.06	2338.78	2469.65	1901.58
8	Venezuela	2094.30	2224.72	1253.00	1357.94	1777.36
9	Iraq	2071.66	1617.92	2175.50	2427.72	1740.57
10	Mexico	1763.67	1792.67	1364.73	1280.22	1712.24
11	Kuwait	1316.81	1645.49	1776.96	1824.15	1520.90
	World	**40326.98**	**43699.35**	**43654.98**	**44104.95**	**42519.52**
	Middle East	16242.62	16771.29	18153.22	17806.84	16622.4
	Africa	5941.996	7602.513	7395.989	8142.392	7134.349
	Eurasia	3826.214	6861.941	7204.251	7119.682	6211.378
	Europe	5475.625	3524.847	2513.65	2465.82	3893.751
	North America	3457.058	3879.033	4037.696	4149.29	3767.773
	Central & South America	3105.631	3409.887	2921.627	2997.834	3038.199
	Asia & Oceania	2277.831	1649.84	1428.556	1423.092	1851.666

Source: EIA (2015)

Most oil producing countries depend on the export of the product for the growth of their economy. Table 3.4 presents the total crude oil export of major oil producing countries for 2000, 2007, 2013 and 2014 and statistics from the regional blocks. The values of the average crude oil exported are in thousands of barrels per day. Of the 42519.52 thousand barrels exported throughout the world daily, Saudi Arabia is the highest exporter, distributing about 6888.47 thousand b/d especially to the Asia and Pacific areas (OPEC, 2015). It supplies about 4417 thousand barrels per day to the Asia and Pacific region, 1251 thousand b/d to North America and 952, 273 and 191 thousand barrels daily to the Europe, Middle East and Africa respectively (OPEC, 2015) The remainder goes to several other locations globally. The country's export accounted for 85% of the total earning in 2013 (EIA, 2014). Russia's exports of 4633.31 thousand b/d accounts for about 50% of the country's GDP. Iran comes third with 2296.23 thousand b/d. The world crude oil export is dominated by the Middle East with countries like Saudi Arabia and Iran exporting (9184.78 thousand b/d). They are followed by Africa making up 7134.349 thousand b/d. The Asia and Oceania region is the least exporter of crude oil (1851.666 thousand b/d).

Table 3.5: Exports of Natural Gas (Billion Cubic Feet)

		2000	2007	2013	2014	Average
1	Russia	6590.49	8232.99	7176.01	7801.08	7378.55
2	Canada	3575.50	3843.83	3117.96	2911.72	3530.07
3	Norway	1727.26	3011.66	3878.65	3629.89	2932.40
4	Algeria	2213.54	2061.34	1771.40	1518.55	2009.02
5	Qatar	495.82	1536.20	4400.25	4432.03	1977.09
6	Netherlands	1462.68	1965.92	2133.34	2375.57	1937.41
7	Turkmenistan	1380.82	1744.56	1624.49	2147.15	1486.00
8	Indonesia	1279.11	1295.71	1241.32	1105.36	1289.86
9	Malaysia	780.11	1107.48	1157.27	1250.15	1018.13
10	United States	244.00	822.00	1619.00	1572.00	915.07
11	Australia	362.05	688.36	924.79	1150.00	631.13
	World	**22978.03**	**33262.21**	**37409.38**	**38301.79**	**31107.92**
	Eurasia	8571.66	10927.49	9809.41	11077.96	9724.80
	Europe	4050.77	6232.14	7961.59	7892.69	6182.49
	North America	3827.98	4716.43	4739.82	4484.85	4459.25
	Asia & Oceania	2881.70	3848.66	4233.10	4465.83	3665.44
	Africa	2444.15	3883.52	3561.41	2996.87	3225.82
	Middle East	841.56	2487.51	5619.39	5767.19	2851.40
	Central & South America	360.21	1166.45	1484.64	1616.40	1049.77

Source: EIA (2015)

Table 3.5 shows the major exporters of natural gas. Gas represents a substantial source of energy production in the world. Most countries producing this product export it for improvement of their economies and for social economic development. This table shows the top gas exporting countries in the years 2000, 2007, 20013 and 2014. The values are reported in billions of cubic feet. The average total world export stands at 31107.92 bcf with Russia being the highest exporter (7378.55 bcf) after which Canada (3530.07) Norway (2932.40 bcf) and Algeria (2009.02 bcf) follow by Qatar (1977.09 bcf) from Middle East comes 5th with the United States (915.07 bcf) and Australia (631.13bcf) placing 10th and 11th respectively.

The export of gas by regions is dominated by Eurasia accounting for (31107.92 bcf) followed by Europe (9724.80 bcf) and the North America (4459.25 bcf). Africa, Middle

East, Central and South America represent the least exporting regions with less than 3500 bcf each.

3.1.2 Oil and Gas Consumption

Increase in oil and gas consumption is highly linked with economic growth (Murphy & Hall, 2011b). About half of economic changes in most countries can be explain by oil consumption (Cleveland et al., 1997). Countries with high GDP have been noted to have a high correlation with increases in oil consumption (Murphy & Hall, 2011a). Table 3.6 reveals the pattern of the world's largest consumers of petroleum in 2000, 2007, 2012 and 2013. All values represented here are in thousands of barrels per day.

Table 3.6: Total Petroleum Consumption (Thousand Barrels Per Day)

		2000	2007	2012	2013	Average
1	United States	19701.1	20680.4	18490.2	18961.1	19759
2	China	4795.71	7479.92	10175.1	10480	7139.47
3	Japan	5480.14	5009.22	4697.33	4556.81	5000.42
4	Russia	2578.5	2885.1	3445.1	3493	2891.1
5	India	2147.44	2888.06	3617.85	3660	2791.68
6	Germany	2766.76	2406.69	2389.13	2435.08	2576.51
7	Brazil	2121.28	2296.55	2922.93	3003	2343.19
8	Canada	2007.72	2389.48	2402.8	2374.45	2236.61
9	Korea, South	2135.33	2240.48	2321.62	2328.3	2195.31
10	Saudi Arabia	1537.1	2094.33	2881.65	2961	2111.7
11	Mexico	2095.93	2172.79	2101.38	2090.45	2092.78
	World	**76927.6**	**86788.2**	**90391.8**	**91253.2**	**84523.5**
	Asia & Oceania	20871.9	25474.6	29761.9	30123.7	25082.8
	North America	23812.5	25255.2	23006.5	23438.2	24051.1
	Europe	15924.3	16245.8	14409.8	14233.2	15716.9
	Middle East	4896.88	6523.07	7996.98	8083.49	6463.56
	Central & South America	5191.71	5918.85	6963.32	7085.22	5952.34
	Eurasia	3719.74	4259.88	4644.3	4688.6	4162.05
	Africa	2510.57	3110.9	3608.9	3600.71	3094.73

Two of the largest economies in the world top with United States, the world largest economy, leading with 19759.04 thousand barrels per day, followed China's 7139.47 thousand barrels per day. China's average consumption levels is about 36.13% of that the United States. However, a closer look at the values by year show that China's consumption level is gradually closing up to that of the US. Given the populous nature of these two countries, it is not exactly surprising that they have higher consumption levels. Not also surprising is the fact that Russia and India are all among the top consumers of petroleum due to their land mass and population. The regional representation by oil consumption is largely dominated by Asia and Oceania region accounting for 25082.8 thousand barrels per day. This is followed by North America with 24051.1 thousand barrels per day. Europe consumption of 15716.9 thousands barrels per day is also not surprising given this region's relatively lower possession of oil and gas reserves as seen in earlier sections of this chapter.

In Table 3.7, the major consumers of natural gas around the world are presented. Again the United States is the highest in this regard accounting for 23323.79 bcf out of the world's total average of 108458.90 bcf. Iran accounts for 3985.98 bcf after Russia (14563.48 bcf). United Kingdom, Germany and Italy all Europeans are all among the substantial consumers of gas, albeit in the bottom half with an average of 19168.41 bcf.

Table 3.7: Dry Natural Gas Consumption (Billion Cubic Feet)

		2000	2007	2013	2014	Average
1	United States	23333.00	23104.00	25538.00	26168.00	23323.79
2	Russia	13058.78	15180.86	15710.94	15598.99	14563.48
3	Iran	2220.96	3992.01	5553.95	5555.58	3985.98
4	Japan	2913.91	3748.09	4471.94	4492.35	3574.33
5	United Kingdom	3373.29	3244.04	2752.06	2734.90	3209.28
6	Canada	2991.36	3050.51	3541.28	3654.78	3176.84
7	Germany	3098.11	3142.61	3001.21	3123.44	3162.80
8	Italy	2498.36	2998.14	2645.62	2474.49	2762.09
9	Saudi Arabia	1759.04	2628.14	3507.84	3532.56	2631.55
10	China	867.05	2489.71	5073.92	5760.12	2615.09
11	Ukraine	2779.29	2906.42	1861.10	1659.81	2505.40
	World	**87236.66**	**105545.38**	**119696.29**	**121357.10**	**108458.90**
	North America	27722.55	28179.40	31500.87	32103.43	29876.56
	Eurasia	19471.53	22543.42	22243.47	21944.56	21334.42
	Europe	17394.37	19873.13	18685.59	18511.95	19168.41
	Asia & Oceania	10484.35	16871.03	22788.93	23626.78	16358.48
	Middle East	6822.15	10674.04	14740.02	15078.16	10733.84
	Central & South America	3303.69	4387.37	5245.73	5518.78	4353.89
	Africa	2038.03	3016.99	4491.68	4573.43	3179.43

Source: EIA (2015)

North America is the highest with respect to regional consumption of 29876.56 bcf of natural gas. Asia and Oceania (16358.48 bcf), Middle East (10733.84 bcf), Central and South America (4353.89 bcf) and Africa (3179.43 bcf) are among the least consumers of natural gas.

3.2 Intergovernmental organizations in the oil industry

Countries in the international oil industry in order for them to stay productive and competitive have coalesced into intergovernmental organisations (IGOs), with a goal of developing fast-based approach in delivering high quality project outcomes, fostering innovations and helping develop solutions for operational and economic issues at regional and global levels (Belyi & Talus, 2015; Cissokho et al., 2013; Dorussen & Ward, 2008; Escobar & Le Chaffotec, 2015; Holland, 1998). These organisations bring together complementary skills and create platforms for innovation, cooperation and creativity, and make full use of the available resources to provide sustainable development for the member nations (Dorussen & Ward, 2008; Holland, 1998). The participation of States in IGOs is to shape their policy in various ways; for example education (Bradley & Ramirez, 1996; Meyer, Ramirez, & Soysal, 1992; Schafer, 1999), environmental protection (Frank, 1997, 1999; Frank, Hironaka, & Schofer, 2000), science (Finnemore, 1993) etc. As the oil and gas industry continues to play a major role in meeting the world's growing economic demands, there have been a number of such IGOs with policy direction towards the oil industry. In the international Oil and Gas industry the four IGOs at the forefront of forging global policy are OPEC, OAPEC, FSU and IEA. Without IGOs, it will be difficult to monitor performance over time, set up international regulations and restrictions for countries as IGOs help to create and bind international administrations (Biermann & Bauer, 2004). This section presents a brief overview of each of these IGOs.

3.2.1 Organization of the Petroleum Exporting Countries (OPEC)

Organization of the Petroleum Exporting Countries (OPEC) established in September 1960, is a permanent intergovernmental organization headquartered in Vienna, Austria, created at the Baghdad Conference (OPEC, 2012). Originally made up of 5 members[1], the five founding members were later joined by nine[2] other members. Currently, OPEC comprises of 12 members, namely Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates (UAE) and Venezuela. The main objective of this IGO is to co-ordinate and unify petroleum policies among member countries in order to secure fair and stable prices for petroleum producers (OPEC, 2012). The organization aims to ensure an efficient, economic and regular supply of petroleum to consuming nations; and a

[1] **OPEC founding members** - (5) Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela.
[2] **OPEC other members** - (9) Qatar, Indonesia, Libya, UAE, Algeria, Nigeria, Ecuador, Angola, Gabon.

fair return on capital to those investing in the industry (OPEC, 2012). Membership is automatic for the five founding members, but opened for any other country with a substantial net export of crude petroleum, which has fundamentally similar interests to those of founding member countries. A new member state is accepted into the organization by a majority of three-fourths of full member countries by the Conference (OPEC, 2012). The Organization functions through three organs: The Conference, Board of Governors; and the Secretariat. The organization is regulated by statute approved in the conference of 1961 which is the highest decision body(Goldthau & Witte, 2011). The membership of OPEC is diversely represented in various characteristics. From the regional stand point they can be grouped into (a) American countries (Ecuador & Venezuela), (b) North Africa (Algeria & Libya), (c) South and West Africa (Angola & Nigeria) and (d) Middle East (Iran, Iraq, Saudi Arabia, Qatar & UAE) (Al-Rashed & León, 2015). OPEC is one of the most important or linchpin in the global oil market accounting for crude oil production of 41 per cent (that is 30.7m b/d) of the world's average production and with proven crude oil reserves as at 2014 at 1,206billion barrels, which is 80.8 per cent of the 1,492.9 billion barrels of the World proven crude oil reserves (BP, 2014; OPEC, 2015; Sari & Soytas, 2009). Additionally, OPEC's export revenue in 2014 was $730 billion (EIA, 2015) With a natural gas proven reserve of 95,129bn standard cubic meters, OPEC represents 47.3 per cent of the world proven gas reserves (OPEC, 2015). The organization phases a challenge of member states not respecting the output policies established (Goldthau & Witte, 2011) OPEC continues to actively engage in international cooperation and dialogue which has become an important industry event an effort in exchanging views and outlooks with other energy stakeholders (OPEC, 2014).

3.2.2 Organization of Arab Petroleum Exporting Countries (OAPEC)

Organization of Arab Petroleum Exporting Countries (OAPEC) is a regional inter-governmental organization concerned with the development of the petroleum industry by fostering cooperation among its members (OAPEC, 2015). OAPEC was establish on 9th January 1968 in Beirut by three[3] Arab states with the headquarters in Kuwait. By 1982 the membership of the Organization had risen to eleven Arab oil exporting countries, namely Saudi Arabia, Kuwait, Libya, United Arab Emirates, Qatar, Bahrain, Algeria, Syrian, Iraq, Egypt, and Tunisia.

OAPEC contributes to the effective use of the resources of member countries through sponsoring joint ventures. The main goals of OAPEC are: member states' cooperation in various forms of the economic activity, development of close links between them, safeguarding the legitimate interests of its members under fair and reasonable terms in the oil industry (OAPEC, 2015). The Organization is guided by the belief of building an integrated petroleum industry as a cornerstone for future economic integration among Arab countries (OAPEC, 2015).

The Organization functions through four organs (OAPEC, 2015): The Council of Ministers, which is the supreme authority responsible for its policies and rules. It appoints the Secretary General and Assistant Secretaries. The next is the Executive Bureau which assists the Ministerial Council in supervising the Organization's affairs and recommendations to the Council on matters related to articles of the Agreement and the execution of the Organization's activities. The Executive Bureau is composed of one representative from each of the member countries. The chairmanship rotates annually in the order followed by the Ministerial Council. OAPEC's oil reserves have been estimated at about 713 billion

[3] **OAPEC founding members** - (3) Saudi Arabia, Kuwait & Libya.

barrels about 55.2% of the proven world's reserves in 2014 (OAPEC, 2015). The production of crude oil, despite OAPEC holding over half of the proven oil reserve, is relatively moderate at 22.9m b/d about 31.2 per cent of the worlds of 73.4m b/d. oil product consumption of OAPEC countries rose from 3.8m 6.8m in 2014. OAPEC now represents an international specialised organisation which supports the cooperation between oil producers and the implementation of common projects connected to the regional integration.

3.2.3 The Former Soviet Union (FSU)

The Post-Soviet States, also collectively known as the Former Soviet Union (FSU) are the 15 independent states[4] that emerged from the Union of Soviet Socialist Republic (USSR) in its dissolution in December 1991 (Minescu, Hagendoorn, & Poppe, 2008). The dissolution of the Soviet Union took place as a result of general economic stagnation, even regression the inter-republic economic connections, leading to even more serious breakdown of the post-Soviet economies (Easterly & Fischer, 1994). Most of the formerly Soviet states began the transition to a market economy in 1990-1991 and made efforts to rebuild and restructure their economic systems, with varying results (Podkorytova & Raskina, 2014). The process triggered a severe transition decline, with Gross Domestic Product (GDP) dropping by more than 40% between 1990 and 1995 (Podkorytova & Raskina, 2014)).This decline in GDP was much more intense than the 27% decline that the United States suffered in the wake of the Great Depression between 1930 and 1934 (Podkorytova & Raskina, 2014). The reconfiguration of public finance in compliance with the principles of market economy resulted in dramatically reduced spending on health, education and other social programs, leading to a sharp increase in poverty. Although the FSU is not a traditional IGO like OPEC

[4] **FSU members** - (15) Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan

and OAPEC, the close historical links, the share of oil and gas reserves and production and collaboration in trade have made their influence critical in such comparison. The FSU holds a sizeable quantity of natural resources in oil and gas that can be economically produced to meet the global demand for energy (Aguilera, 2012). The member states of FSU dependent on this enormous natural resource endowment to build their economy (Aguilera, 2012). The distribution of gas shows that the FSU has the largest natural gas resource by region in the world, holding 3,716 (TCFG) and 30% of stranded gas reserve, followed by the Middle East and USA. The three regions together have about 70% of the global gas reserves(Aguilera, 2012). The FSU is second in oil reserve endowment after the Middle East with 118,886mb (OPEC, 2015). The FSU holds about 16.7 % of regional distribution of conventional oil reserves and with global production of 12,646.7 bd representing 17.2% (OPEC, 2015). Together the FSU region and the Middle East controls about 2/3 of the global conventional oil (Rogner et al., 2012). In view of their importance OPEC and EIA recognize their influence in their annual statistical bulletin.

3.2.4 The International Energy Agency (IEA)

The International Energy Agency (IEA) was establish as an autonomous organization of the OECD after an agreement of the International Energy Program (IEP) in 1974 with membership of sixteen countries and its secretariat in Paris (Colgan, Keohane, & Van de Graaf, 2012). Currently IEA membership stands at 29[5]. They work to ensure reliable, affordable and clean energy for its member countries and most importantly for oil importing countries and beyond. The IEA was founded in response to the 1973-1974 oil crisis, the IEA's initial role was to help countries co-ordinate a collective response to major disruptions

[5] **IEA members** - (29) Australia, Austria, Belgium, Canada, Czech Republic, Denmark, EC, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, Netherlands, NZ, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, UK, US

in oil supply through the release of emergency oil stocks to the markets (IEA, 2014). While this continues to be a key aspect of its work, the IEA has evolved and expanded. It is at the heart of global dialogue on energy, providing authoritative statistics, analysis and recommendations. Today, the IEA's four main areas of focus are: Energy security: Promoting diversity, efficiency and flexibility within all energy sectors; Economic development: Ensuring the stable supply of energy to IEA member countries and promoting free markets to foster economic growth and eliminate energy poverty; Environmental awareness: Enhancing international knowledge of options for tackling climate change; and Engagement worldwide: Working closely with non-member countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns (IEA, 2014). An important part of the Agency's program involves collaboration in the research, development, and demonstration of new energy technologies to reduce excessive reliance on imported oil, increase long-term energy security, and reduce greenhouse gas emissions. The IEA is made up of 29 member countries. Membership is based on four basic criteria. Before becoming a member country of the IEA, a candidate country must demonstrate that it has (a) as a net oil importer, reserves of crude oil and/or product equivalent to 90 days of the prior year's average net oil imports to which the government (even if it does not own those stocks directly) has immediate access should there be activation of the Co-ordinated Emergency Response Measures (CERM) – which provide a rapid and flexible system of response to actual or imminent oil supply disruptions (b) a demand-restraint programme for reducing national oil consumption by up to 10% (c) legislation and organisation necessary to operate, on a national basis, the CERM, and (d) Legislation and measures in place to ensure that all oil companies operating under its jurisdiction report information as is necessary (IEA, 2014).

To fully understand the energy markets, requires bringing on board the concerns, challenges and the solutions being considered by all the important actors in the industry (IEA, 2014). Collaborating with partner countries and others gives a wide array of activities, such as, holding workshop jointly on specific issues such as energy efficiency, policies on emergency response, co-operating on in-depth surveys of specific energy sectors in partner countries.

The IEA also works with other international organisations and forums in the energy field. It engages in an active discussions with producer countries and other IGOs in the oil and gas industry particularly at the International Energy Forum (IEF) (IEA, 2014). In addition, the IEA collaborates with the International Renewable Energy Agency (IRENA) and engages with partner countries and other international agencies to provide all stakeholders including business leaders a true global perspective of the world's energy system.

3.3 Conclusion

This chapter describes the relevance of IGOs and their roles in the international oil and gas industry which informs the global production and supply of the natural resources. The chapter also presents some statistics of major producer and consumer countries globally.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This chapter looks at research design adopted for the study and data and data sources. This is followed by an overview of the methods of assessment of oil and gas producing countries. The aim of the chapter is to provide an overview of the analytical framework and techniques that guide the research.

4.1 Research design

The study is quantitative in nature which provides an objective assessment and testing of theories and the relationship between variables which can be measured through statistical methods (Creswell, 2013). The quantitative approach to research adopted in this study is guided by a positivist philosophical paradigm. This paradigm provides an objective view to data collection and estimation procedure since it detaches itself from research subjects (Creswell, 2013; Wilson, 2010). The study uses a panel data to draw inferences to answer the research questions. By employing panel data to explore efficiency of oil producing countries (OPCs) of the four IGOs in the international oil industry, this study provides findings that are not biased by cross-sectional or firm-specific (time series) restrictions. The study covers the period from 2000 to 2013. The study relies on a secondary data sourced from the US Energy Information Administration (EIA) database on OPCs and World Bank's World development indicators which is assessed using various Data Envelopment Analysis (DEA) techniques. The adopted research design is experimental in nature. This enables comparison of groups with high standard of internal validity as this study seeks to examine the efficiency and the frontier differences within and between the various groups of OPCs (Bhattacherjee, 2012; Creswell, 2013).

4.2 Data for modelling

The study is based on population of all OPCs under the period of review from 2000 to 2013. Although 2014 data is available, there are several missing values for some variables and is therefore not included. Although various countries may specialise in either oil resources or natural gas exploration and extraction, to provide a holistic assessment, the study is interested in countries who hold both oil and gas resources. The governments of most of the OPCs own oil blocks and are involved in either of the two segments, that is, the upstream or downstream segments of the oil and gas industry. The upstream is for the exploration and production of oil and gas from the reserves whilst the downstream deals more with processing, bulk storage, distribution, and marketing. This study is interested in only the upstream segment.

Whiles all oil and gas producing countries are eligible for selection, based on the research objectives, the population of the study comprises the 65 oil and gas producing countries of the four IGOs - OPEC (12 countries), IEA (28 countries), FSU (15 countries) and OAPEC (10 countries). Of these 65 members of the four IGOs understudy, 62 countries produce oil and 54 countries extract gas. Only 53 members are producers of both oil and gas. This is clearly presented in Table 4.1. Therefore, the study is based on the 53 OPCs who produce both oil and gas. It is important to note that some OPCs belong to two IGOs, but when the duplicate OPCs, especially in OPEC and OAPEC are excluded from the sample, the effective number of IGOs become 46 unique countries.

Table 4.1 : Membership distribution of IGOs

IGO	Membership	Oil Producing	Gas Processing	Oil & Gas
OPEC	12	12	12	12
IEA	28	27	22	21
FSU	15	13	10	10
OAPEC	10	10	10	10
Total	**65**	**62**	**54**	**53**

The primary data source for this study is the US Energy Information Administration (EIA). This institution gathers data on the oil and gas activities of all countries globally. Information on Production, Reserves and Consumption of Petroleum, Natural Gas, Electricity and other renewables collated from the period from 1980 to 2014 are available in this database. Additionally, the World Development Indicators database of World Bank is used to gather mostly labour statistics.

4.3 Efficiency modelling and other considerations

In recent years, considerable methods have been used to examine and compare frontier efficiency performance of different countries and groups. The two widely used methods to estimate frontier efficiency of decision making units (DMUs) are the nonparametric constant return to scale (CRS) Data Envelopment Analysis (DEA) (Charnes, Cooper, & Rhodes, 1978a), which was later extended by (Banker, 1984), and the parametric Stochastic Frontier Analysis (Aigner, Lovell, & Schmidt, 1977) which was later extended to variable return to scale (VRS). This study relies on the DEA approach because unlike the SFA, it does not require several impractical model specifications on the production frontier as seen in the SFA approach (Jacobs, 2001). DEA is a nonparametric mathematical programming method based on a linear programming model used to estimate and compare the efficiency of organisations or DMUs given their available resources (inputs) to create a set of outcomes (outputs) relative to other units (Ramanathan, 2007). DEA is a technique which depends on input-output data to construct a production frontier which is used as the benchmark to evaluate other units in the sample.

DEA was introduced by Charnes et al. (1978a) to compare efficiencies of organisations. Their approach was based on a constant return to scale (CRS) production frontier which holds the assumption of full proportionality of inputs and output relationship. Banker, Charnes, and Cooper (1984) extended this methodology using the variable returns to scale (VRS) frontier, which holds that the proportionality assumption is not always upheld. In the model, the DMUs with the best efficiency in converting inputs into output are identified as the best and the other DMUs are ranked relative to the most efficient DMUs. Arguably, one key benefit of this approach for relative assessment of DMUs is because it can estimate efficiencies even when a particular DMU has multiple inputs and outputs.

Often the interest in evaluating the efficiency and performance of DMUs is constrained by substantial differences in geographical boundaries or group dynamics of the DMUs under consideration. The metafrontier and global frontier approaches allow for better handling of these group specific heterogeneities in the efficiency assessment. This study relies on these two frontier frameworks to measure and compare the efficiency of countries in different IGOs in the oil and gas industry. The next section presents an overview of these frontier approaches.

4.3.1 Metafrontier analysis

Metafrontier in DEA has been attributed to the works of Battese et al. (2004); Battese and Rao (2002b); O'Donnell et al. (2008b). It was later extended by De Witte and Marques (2009). However the idea is based on the concept of meta-production function by Hayami and Ruttan (1971) (Battese et al., 2004; O'Donnell et al., 2008b). The meta-production function has some advantages but the lack of comparable data and the presence of inherent differences across groups was the major limitation of this approach (Battese et al., 2004). Therefore, the metafrontier approach fills in these disadvantages by allowing comparison across heterogeneous groups (Battese & Rao, 2002a; O'Donnell et al., 2008b). Oil producing countries are in different groups and regions and are faced with different production capabilities such as the quality of physical and human capital, economic infrastructure and resource endowment. Metafrontier, most importantly, envelops all group frontiers. In other words, this frontier combines all firms irrespective of which group they belong to. It then measures efficiencies relative to the metafrontier and the group frontier and can be decomposed into two components: A component that measures the distance from an input – output point to the group frontier, and another component that measures the differences between the group frontier and the metafrontier. Therefore, given y and x nonnegative real output and input vectors, the meta-technology set is defined as:

$$T = \{(x, y) : x \geq 0; y \geq 0; x \text{ can be used to produce } y\} \qquad (1)$$

The output-oriented technical efficiency (Meta efficiency) of a DMU relative to the metafrontier $(TE_0^M(x, y))$ based on a CRS assumption, can be defined as:

$$\begin{aligned} TE_0^M(x, y) &= Max\,\theta \\ s.t.: & \\ \sum_{j=1}^{n} y_{rj}\lambda_j &\geq \theta y_{ro} \qquad \forall r = 1, \ldots, p \\ \sum_{j=1}^{n} x_{ij}\lambda_j &\leq x_{io} \qquad \forall i = 1, \ldots, m \\ \lambda_j &\geq 0 \qquad j = 1, \ldots, n \end{aligned} \qquad (2)$$

Where TE_0^M represent the technical efficiency with respect to metafrontier of a DMU. A firm is said to be technically efficient if TE_0^M = 1. In the model in Eqn. (2), x_{ij} denotes the amount of the i^{th} input used by the j^{th} DMU. y_{rj} is the amount of the r^{th} output produced by the j^{th} DMU. Note that, in the sample, we have *m* number of inputs and *p* number of outputs for a set of *n* number of DMUs. Also λ_j is the intensity weight defining the convex combination of the best practice units that are compared with the j^{th} unit. θ is equivalent to TE_0^M which measures the maximum percentage of expansion of the output of a particular DMU necessary to make that DMU efficient.

The existence of sub-groups in the meta-technology can be defined and assessed. Here, we now assume that the set of DMUs can be divided into *K* groups (where *K* > 1). The production technology defined in Eqn. (1) can be redefined for the k^{th} group as:

$$T^k = \{(x, y) : x \geq 0; y \geq 0; \; x \text{ can be used by DMUs in group } k \text{ to produce } y \; \} \tag{3}$$

In a similar way, a group-specific technical efficiency, $TE_0^k(x, y)$, can be formulated for a DMU this time relative to its group frontier. This is defined in Eqn. (4) as:

$$\begin{aligned} & TE_0^k(x, y) = Max\,\theta \\ & s.t: \\ & \sum_{j=1}^{n} y^k{}_{rj} . \lambda^k{}_j \geq \theta y_{ro} \qquad \forall r = 1, \ldots, p \\ & \sum_{j=1}^{n} x^k{}_{ij} . \lambda^k{}_j \leq . x_{io} \qquad \forall i = 1, \ldots, m \\ & \lambda^k{}_j \geq 0 \qquad j = 1, \ldots, n \end{aligned} \tag{4}$$

Based on these two efficiency scores- meta efficiency and the group efficiency, a technology gap ratio can be computed. According to Battese et al. (2004) the output oriented technology gap ratio of a group k , $\text{TGR}_0^k(x, y)$, can be defined as the ratio of the Meta technical efficiency to the group technical efficiency.

$$\text{TGR}_0^k(x, y) = \frac{TE_0^M(x, y)}{TE_0^k(x, y)} \quad (5)$$

The ratio takes value between zero and one and measures the diversion from the metafrontier (available technology irrespective of group) due to membership of a particular group *k*. In other words, how far back, or close, is a particular firm due to membership of a particular group *k*. This shows that the meta technical efficiency can be decomposed as follows:

$$TE_0^M(x, y) = \text{TGR}_0^k(x, y) \times TE_0^k(x, y) \quad (6)$$

The meta-efficiency estimated relative to the meta frontier which represents the existing state of knowledge irrespective of group can therefore be decomposed into the product of a group-specific technical which represents the existing state of knowledge and the physical, social and economic environment that characterizes that particular group *k* and the technological gap ratio (meta-technology ratio) for group-*k* which provides a measure of how close the group-*k* frontier is to the metafrontier (O'Donnell et al., 2008a).

To illustrate the Metafrontier approach, a hypothetical data of 9 DMUs who belong to three IGOs (OPEC, IEA and FSU) have been presented in Table 4.2. Each firm uses 1 input (reserves) to produce 2 outputs (Oil and Gas).

Table 4.2: Data of Hypothetical OPCs and IGOs

DMUs	IGO	OIL PRODUCED	GAS PRODUCED	RESERVES
O1	OPEC	9	3	1
O2	OPEC	6.5	4	1
O3	OPEC	6	2	1
I1	IEA	7.5	3.5	1
I2	IEA	5	4	1
I3	IEA	5.5	5.5	1
F1	FSU	4	5	1
F2	FSU	7	3	1
F3	FSU	2	3	1

To graphically illustrate this dataset, the outputs have been normalised by the inputs. This can be depicted in Figure 4.1.

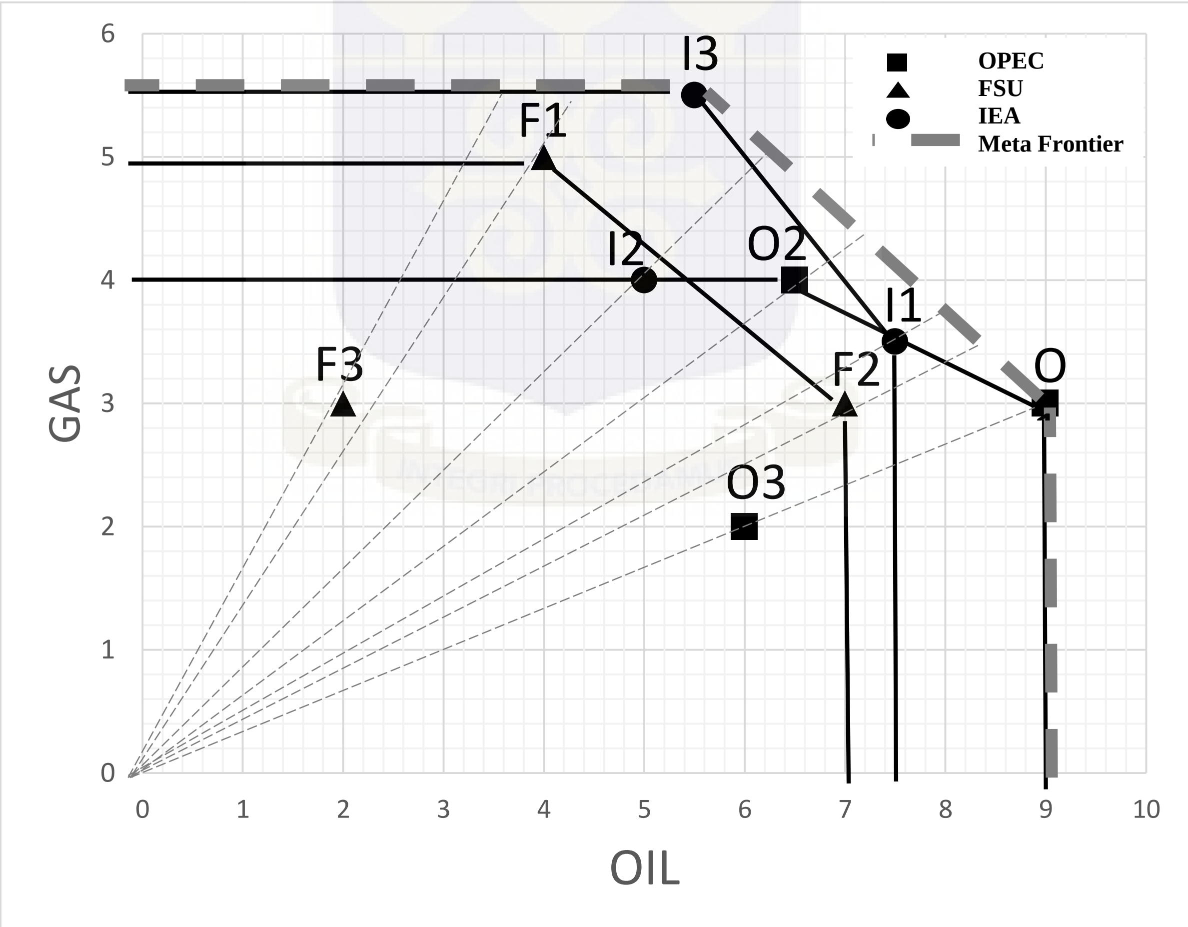

Figure 4.1: Graphical Illustration of Hypothetical Data

Here, while round bullets represents the IEA group, the group specific frontiers of OPEC and FSU are square and triangular bullets respectively. Finally, all DMUs can be enveloped into a meta frontier represented by the black dashed line. The output oriented group efficiency of a DMU can be estimated as a radial projection of the DMUs on the frontier and the current location of the DMU. For example, the group-specific efficiency of DMU O3 can be estimated as 9/6 = 1.5. Where 9 is the projected location and 6 is the current location. Although these values are picked on the X-axis, values on the Y-axis can also be used. The efficiency score of the same DMU using the Y-axis can be estimated as 3/2 = 1.5. This holds because of the proportionality condition. Note also that, for DMU O3, its meta efficiency score will also be 1.5 since at the target point, the group frontier is the same as the meta frontier. The technology gap ratio (TGR) of DMU O3 can therefore be estimated based on notations in Equation (5) as: 1.5/1.5 =1. Which means that O3 experiences no difference in production capabilities by belonging to the OPEC group. It therefore makes 100% use of all technological spillovers. The VRS linear programming model for DMU O3 for its group specific frontier and metafrontier are presented below:

Output-oriented VRS model for DMU O3 relative to OPEC frontier

$$
\begin{aligned}
& TE_{O3}^{OPEC}(x,y) = Max\,\theta \\
& \quad \text{s.t} \\
& 9\lambda_{o1} + 6.5\lambda_{o2} + 6\lambda_{o3} \geq 6\theta \\
& 3\lambda_{o1} + 4\lambda_{o2} + 2\lambda_{o3} \geq 2\theta \\
& \lambda_{o1} + \lambda_{o2} + \lambda_{o3} \leq 1 \\
& \lambda_{o1} + \lambda_{o2} + \lambda_{o3} = 1 \\
& \lambda_j \geq 0
\end{aligned}
$$

$$\Rightarrow TE_{O3}^{OPEC}(x,y) = 1.5$$

Output-oriented VRS model for DMU O3 relative to Meta frontier

$$TE_{O3}^{META}(x,y) = Max\,\theta$$

s.t

$$9\lambda_{o1} + 6.5\lambda_{o2} + 6\lambda_{o3} + 7.5\lambda_{I1} + 5\lambda_{I2} + 5.5\lambda_{I3} + 4\lambda_{F1} + 7\lambda_{F2} + 2\lambda_{F3} \geq 6\theta$$

$$3\lambda_{o1} + 4\lambda_{o2} + 2\lambda_{o3} + 3.5\lambda_{I1} + 4\lambda_{I2} + 5.5\lambda_{I3} + 5\lambda_{F1} + 3\lambda_{F2} + 3\lambda_{F3} \geq 2\theta$$

$$\lambda_{o1} + \lambda_{o2} + \lambda_{o3} + \lambda_{I1} + \lambda_{I2} + \lambda_{I3} + \lambda_{F1} + \lambda_{F2} + \lambda_{F3} \leq 1$$

$$\lambda_{o1} + \lambda_{o2} + \lambda_{o3} + \lambda_{I1} + \lambda_{I2} + \lambda_{I3} + \lambda_{F1} + \lambda_{F2} + \lambda_{F3} = 1$$

$$\lambda_j \geq 0$$

$$\Rightarrow TE_{O3}^{META}(x,y) = 1.5$$

The group-specific efficiencies as well as the meta efficiencies and TGR for all DMUs are presented in Table 4.3. For output orientation as in this case, the inverse of the TGR is used in order to ensure that the values are bounded by 0 and 1.

Table 4.3 : Group and Meta Efficiencies

DMUs	IGO	Meta Efficiencies ($TE^{M}(x,y)$)	OPEC Frontier ($TE^{OPEC}(x,y)$)	IEA Frontier ($TE^{IEA}(x,y)$)	FSU Frontier ($TE^{FSU}(x,y)$)	TGR
O1	OPEC	1	1	-	-	1
O2	OPEC	1.091	1	-	-	0.92
O3	OPEC	1.5	1.5	-	-	1
I1	IEA	1.065	-	1	-	0.94
I2	IEA	1.245	-	1.2222	-	0.98
I3	IEA	1	-	1	-	1
F1	FSU	1.1	-	-	1	0.91
F2	FSU	1.179	-	-	1	0.85
F3	FSU	1.833	-	-	1.6667	0.91

Based on the values in Table 4.3, DMU O2 for example is producing at 91% of its potential due to membership of the OPEC frontier.

4.3.2 Global-frontier differences

Whereas the metafrontier approach is able to provide a group specific efficiency assessment based on the group frontier as well as the metafrontier, it is sometimes necessary that best performing in two different groups are compared to see which group outperforms the other.

Whereas the metafrontier approach is an intra-group performance indicator, the global frontier shift differences measure is an inter-group performance indicator that compares groups of DMUs. The global frontier shift index is a component of the global Malmquist productivity index and is the primary model used in comparing the frontier differences between various groups (Asmild & Tam, 2007). This examines the overall rather than the individual changes in the frontier of various groups (Asmild, Hollingsworth, & Birch, 2013). This means that this model can draw conclusions about performance differences for the entire sample. It is better since aggregating other performance indices can be problematic using other methods in sparsely populated data set and unbalanced panel (Otsuki, 2013). The global frontier shift index therefore performs better than traditional frontier shift indices. It can also cater for overlapping frontiers.

In estimating the global frontier differences, it is important to define a technology index for each group k (TI^k), which is a geometric mean of the efficiency scores of all firms belonging to a particular group *k*. This is defined as:

$$\mathrm{TI}^k(x_j, y_j) = \left(\prod_{\substack{j=1,\dots n \\ K=1,\dots,k}} TE^k(x_j^K, y_j^K) \right)^{1/j} \qquad (7)$$

The global frontier shift index or global technical change or the global frontier difference between different groups k_1 and k_2 is defined as:

$$\mathrm{GFD}^{k_1,k_2} = \frac{\mathrm{TI}^{k_2}(x_j, y_j)}{\mathrm{TI}^{k_1}(x_j, y_j)} = \frac{\left(\prod_{\substack{j=1,\ldots n \\ K=1,\ldots,k}} TE^{k_2}(x_j^K, y_j^K)\right)^{1/j}}{\left(\prod_{\substack{j=1,\ldots n \\ K=1,\ldots,k}} TE^{k_1}(x_j^K, y_j^K)\right)^{1/j}} \quad (8)$$

This is the ratio of the geometric mean of the efficiencies of all firms relative to k_2 frontier to the geometric mean of the efficiencies of all firms relative to k_1 frontier. The efficiency scores are computed using similar model formulation to that already presented in equation (4). The GFD >1 indicate that group 1 is, on average better that group 2 frontier**.** When GFS = 1 then the indication is that group 1 frontier is not better than group 2 frontier. Finally, if GFS < 1, then group 1 frontier is worse than group 2. Frontier shift is used where changes in time are being assessed. However, where the frontiers are of different groups, then the term global frontier differences is preferred.

To illustrate the Global Frontier Differences approach, we use the same dataset and graph shown in Table 4.2 and Figure 4.1 respectively. Now efficiencies scores of all the 9 DMUs will estimated using each of the group frontiers. For example, the efficiency of DMU O3 relative to the IEA frontier will be 7.5/6 = 1.25. O3's efficiency relative to FSU's frontier will be 7/6 = 1.167. This process is done for all DMUs. The mathematical programming models for the efficiency of DMU O3 relative to the IEA and FSU frontiers are presented below:

Output-oriented VRS model for DMU O3 relative to IEA frontier

$$TE_{O3}^{IEA}(x,y) = Max\,\theta$$

s.t

$$\begin{aligned}
7.5\lambda_{I1} + 5\lambda_{I2} + 5.5\lambda_{I3} &\geq 6\theta \\
3.5\lambda_{I1} + 4\lambda_{I2} + 5.5\lambda_{I3} &\geq 2\theta \\
\lambda_{I1} + \lambda_{I2} + \lambda_{I3} &\leq 1 \\
\lambda_{I1} + \lambda_{I2} + \lambda_{I3} &= 1 \\
\lambda_j &\geq 0
\end{aligned}$$

$$\Rightarrow TE_{O3}^{IEA}(x,y) = 1.25$$

Output-oriented VRS model for DMU O3 relative to FSU frontier

$$TE_{O3}^{FSU}(x,y) = Max\,\theta$$

s.t

$$\begin{aligned}
4\lambda_{F1} + 7\lambda_{F2} + 2\lambda_{F3} &\geq 6\theta \\
5\lambda_{F1} + 3\lambda_{F2} + 3\lambda_{F3} &\geq 2\theta \\
\lambda_{F1} + \lambda_{F2} + \lambda_{F3} &\leq 1 \\
\lambda_{F1} + \lambda_{F2} + \lambda_{F3} &= 1 \\
\lambda_j &\geq 0
\end{aligned}$$

$$\Rightarrow TE_{O3}^{FSU}(x,y) = 1.16667$$

The efficiencies for all the firms are therefore presented in Table 4.4

Table 4.4: Efficiencies for Global Frontier Difference Analysis

DMUs	IGO	OPEC Frontier ($TE^{OPEC}(x,y)$)	IEA Frontier ($TE^{IEA}(x,y)$)	FSU Frontier ($TE^{FSU}(x,y)$)
O1	OPEC	1	0.8333	0.7778
O2	OPEC	1	1.0476	0.92
O3	OPEC	1.5	1.25	1.1667
I1	IEA	1.0154	1	0.902
I2	IEA	1	1.2222	1.0455
I3	IEA	0.7273	1	0.8364
F1	FSU	0.8	1.1	1
F2	FSU	1.1379	1.0714	1
F3	FSU	1.3333	1.8333	1.6667
Geometric Mean		**1.0334**	**1.1248**	**1.0104**

Therefore, based on the geometric means in Table 4.4, and the notations in Equation (8), the GFD between IEA and OPEC can be estimated as 1.1248/1.0334 = 1.09. This shows that the IEA frontier is about 9% better on the average than the OPEC frontier. A matrix of the GFD between the three groups is presented in Table 4.5.

Table 4.5: Global Frontier Differences

	OPEC	IEA	FSU
OPEC	1		
IEA	1.09	1	
FSU	0.98	0.90	1

Therefore, for the hypothetical data, whereas IEA frontier is 9% better than OPEC, FSU frontier is 2% worse than the OPEC frontier. Indeed, the FSU frontier is 10% worse than the IEA frontier.

4.3.3 Bootstrapping

DEA nonparametric efficiency scores have an inherent bias since efficiency scores can be affected by changes in the data and presence of the outliers and do possess the necessary statistical properties for making inferences (Gitto & Mancuso, 2012; Simar & Wilson, 2000; Simar & Wilson, 2015). Although parametric efficiency estimators like stochastic frontier analysis (SFA) permits statistical inference (Atkinson & Cornwell, 1994), when the sample observations are few these parametric statistics may not be applicable (Lothgren & Tambour, 1999). To correct the deficiencies of bootstrapping, Simar and Wilson (1998); (2000) proposed a bootstrap method which allows for statistical inferences on distance function estimates (efficiency scores) estimated using the DEA approach along the lines of the bootstrap approach which was introduced by Efron (1979). Bootstrap procedures offer realistic assessment for improving the bias of the efficiency estimates and for building confidence intervals for the efficiency scores (Simar & Wilson, 2015). The idea of bootstrapping introduced by (Efron, 1979) is to use empirical distribution of resampling data to generate a new dataset to estimate and reproduce repeated efficiency score from the observed data. This is the process of regenerating the original data repeatedly and each time estimating the efficiency scores. The re-generation of the data is perform by resampling with replacement of the original data (Hoff, 2006). It is a computer intensive approach (Simar & Wilson, 1999).

The aim of the bootstrap algorithm is to mimic the distribution of DEA scores $\widehat{TE}^{j}(x,y)$, in order to approximate the true unknown efficiency score $TE^{j}(x,y)$. However, since the true score is unknown, the difference between the true score and the estimated score $\left\{TE^{j}(x,y)-\widehat{TE}^{j}(x,y)\right\}$ is also unknown. However, appropriate bootstrap approximation provides the opportunity to proxy $\left\{TE^{j}(x,y)-\widehat{TE}^{j}(x,y)\right\}$ to the bootstrap counterpart, $\left\{TE^{j*}(x,y)-\widehat{TE}^{j}(x,y)\right\}$, where; $TE^{j*}(x,y)$ is the bootstrap estimate which is completely known after the resampling procedure. The approximation between the two distributions is appropriate when the homogenous bootstrap is used (Kneip, Simar, & Wilson, 2008). Once the distributions are mimicked, statistical properties like the bias, bias-corrected score and confidence intervals for each DMU are easily derived.

It is given by the following bootstrapped counterpart, the bias for a DMU is the difference between the average of the bootstrap samples for the DMU and the original estimated efficiency score, such that:

$$\begin{aligned}\widehat{\text{BIAS}}\,(\widehat{TE}^{j}) &= \text{E}(\widehat{TE}^{j*})-\widehat{TE}^{j} \\ &= B^{-1}\sum_{b=1}^{B}\widehat{TE}_{b}{}^{j*}-\widehat{TE}^{j} \qquad \forall j=1,\ \dots\ ,n\end{aligned} \tag{9}$$

Where $\widehat{TE}_b^{\,j*}$ is the bootstrapped efficiency and B is the number of bootstrap samples. After estimating the bias, the bias-corrected DEA efficiency scores can be estimated as:

$$\begin{aligned} \widehat{TE}^{\,j**} &= \widehat{TE}^{\,j} - \widehat{\text{BIAS}}\,(\widehat{TE}^{\,j}) \\ &= 2\widehat{TE}^{\,j} - B^{-1}\sum_{b=1}^{B}\widehat{TE}_b^{\,j*} \qquad \forall j = 1, \ldots, n \end{aligned} \tag{10}$$

It must be recognized that DEA efficiencies are corrected unless the ratio between absolute value of bias and standard deviation is greater than 0.25:

$$\tau = \frac{\left|\widehat{\text{BIAS}}\,(\widehat{TE}^{\,j})\right|}{\widehat{std}\,(\widehat{TE}^{\,j})} > 0.25 \qquad \forall j = 1, \ldots, n \tag{11}$$

where,

$$\widehat{std}\,(\widehat{TE}^{\,j}) = \left[\frac{1}{B-1}\sum_{b=1}^{B}(\widehat{TE}_b^{\,j*} - \overline{TE}_b^{\,j*})^2\right]^{1/2}, \qquad \forall b = 1, \ldots, B \tag{12}$$

and $\overline{TE}_b^{\,j*}$ is the mean of the bootstrapped efficiency scores. As the bootstrap distribution $\left\{TE^{\,j*}(x,y) - \widehat{TE}^{\,j}(x,y)\right\}$ is completely known, the relative α_α^* and β_α^* quartiles, for a given level of probability could be easily found. These are good proxies for the quartiles of the unknown distribution $\left\{TE^{\,j}(x,y) - \widehat{TE}^{\,j}(x,y)\right\}$ and can be used in the bootstrap approximation as $\Pr\left(-b_\alpha^* \le TE^{\,j}(x,y) - \widehat{TE}^{\,j}(x,y) \le -a_\alpha^*\right) \approx 1-\alpha$. Hence, the $1-\alpha$ percent confidence interval is given by the lower bound at the level $\widehat{TE}^{k} + \alpha_\alpha^{\ *}$ and the upper at the level $\widehat{TE}^{k} + \beta_\alpha^{\ *}$.

4.3.4 Testing returns to scale

Without statistical testing, it is uncertain whether the production technology set that operates in an industry exhibits a constant or variable return to scale (CRS) or a variable one (VRS) in the measurement of efficiency in a nonparametric DEA model (Camanho & Dyson, 2005). It is therefore imperative to investigate the returns to scale characteristics of the international oil industry in order to use the appropriate models relating to the appropriate underlying technology. There have been few studies on statistical testing of returns to scale estimators in DEA especially in the oil and gas industry. Testing of the returns to scale hypothesis in DEA-models was earlier discussed in the works of Banker (1993, 1996). However, the semiparametric nature of this returns to scale approach by Banker (1993) has been seen by Simar and Wilson (2002) to be problematic. Therefore, the bootstrap method proposed by Simar and Wilson (2002) is used to test the scale elasticity of the oil and gas industry. Simar and Wilson (2002) introduce the DEA bootstrap method for testing the returns to scale in order to know whether the technology shows constant return to scale everywhere on the frontier or otherwise.

The basic idea of the test of returns to scale is along the lines of Färe and Grosskopf (1985) by computing ratios of the CRS technical efficiency score to the VRS technical efficiency score $(TE_j^{crs}(x,y) / TE_j^{vrs}(x,y) \leq 1)$ for each observation $j = 1,\ldots,n$ in the technology set T. With this idea, if the ratio is equal to 1 (i.e. $TE_j^{crs}(x,y) / TE_j^{vrs}(x,y) = 1$), then the estimated technology is assumed to exhibit CRS at the benchmark point of that particular DMU; otherwise, the estimated technology is assumed to exhibit a variable returns to scale at this point. This means that, if for any particular observation $TE_j^{crs}(x,y) / TE_j^{vrs}(x,y) < 1$, then CRS may not hold for this observation. However, without a formal statistical testing procedure, it is quite difficult to determine whether this is due to non-constant returns to scale or merely due to sampling variation (Simar & Wilson, 2002). Therefore, the null (H_o) and alternative (H_1) hypotheses for the Simar and Wilson (2002) test of returns to scale are stated as follows:

H_0: T is globally CRS (i.e. the technology set exhibits CRS for all observations)

H_1: T is VRS (i.e. the technology set does not exhibit CRS for all observations)

To develop the test statistic to be used in testing the hypotheses above, consider first an estimator of scale efficiency $s(x,y)$ of a particular DMU, defined as $\hat{s} = \widehat{TE}_j^{crs}(x,y) / \widehat{TE}_j^{vrs}(x,y)$ the mean of ratios of all observations can be used as the test statistic for this test. This is defined as:

$$\hat{S}_1^{crs} = n^{-1} \sum_{j=1}^{n} \left(\frac{\widehat{TE}_j^{crs}(x,y)}{\widehat{TE}_j^{vrs}(x,y)} \right) \tag{13}$$

which is an estimator of the mean scale efficiencies for all observations. If the null hypothesis (H_0) is true, then the CRS technical efficiencies for all observations is expected to be the same as the VRS scores, and $\hat{S}_1^{crs} = 1$. Otherwise $\hat{S}_1^{crs} < 1$ which signifies that the mean of ratios is significantly less than unity. Other test statistics can be used but the mean of ratios is employed just like Tortosa-Ausina, Grifell-Tatjé, Armero, and Conesa (2008) because the mean of ratios has an intuitive geometric interpretation (Simar & Wilson, 2002). Finally, in order to statistically test the hypotheses, there is the need for an appropriate critical value or p-value. However, since the statistical distribution of the scale test is unknown, the bootstrap methodology developed in Simar and Wilson (1998) can be extended in order to generate an empirical distribution of the scale test from which critical values, confidence intervals and p-values can be estimated.

4.3.5 Testing of differences in the distribution of efficiency scores

Testing of differences in efficiency among various groups is an important area of concern for empirical studies (Simar & Zelenyuk, 2006). One of the issues of concern is that DEA estimated efficiency scores are restrictive efficiency scores distributed across population of given set of DMUSs and do not provide good basis for statistical tests (Simar & Zelenyuk, 2006; Trinh & Zelenyuk, 2015). Therefore, traditional tests of differences like t-test, anova, Mann Whitney test and Wilcoxon's tests, will not provide the appropriate statistical power. In examining whether the differences in the efficiencies scores of the IGOs in the international oil and gas industry are statistically significant, or whether due to only estimation variations, a test of difference in the distribution of the efficiency scores is important. The study employs the Simar-Zelenyuk-adapted-Li test (SZAL) to statistically explore significant differences in the distribution of efficiency or frontier estimates between different IGOs in the oil and gas industry (Li, 1996; Simar & Zelenyuk, 2006). This nonparametric test effectively compares the equality of distributions of efficiency estimates using kernel density estimations. The non-parametric kernel density estimator, is largely gaining more significance in research (Banker, Cooper, Seiford, Thrall, & Zhu, 2004; Simar & Zelenyuk, 2006) and is very useful since there is no distributional assumptions imposed on the efficiency scores across the groups.

In comparing the density of distribution of efficiency scores between two random groups for which the random samples $\{TE^{A,j} : j = 1,\ldots,n\}$ and $\{TE^{B,j} : j = 1,\ldots,n\}$, representing the efficiencies of the two subgroups A and B in a population. Now, given that f_l denotes the density of the distribution of the efficiency $TE^{l}(l = A, B)$ our null and alternative hypotheses would be

$$H_0 : f_A(TE^A) = f_B(TE^B),$$
$$H_a : f_A(TE^A) \neq f_B(TE^B) \tag{14}$$

The true technical efficiency scores in each subgroup, $\{TE^{A,j} : j = 1,\ldots,n\}$ and $\{TE^{B,j} : j = 1,\ldots,n\}$, are independently and identically distributed (i.i.d.) within each subgroup with densities $f_A(.)$ and $f_B(.)$, respectively. The bootstrap algorithm for the Simar and Zelenyuk adapted Li-test in comparing the distributions of efficiency scores can be summarized as follows:

1. For each DMU estimate the $TE(x, y)$ using the DEA approach, therefore obtaining a sequence of estimated efficiency scores for all DMUs $\{ TE^j \mid j = 1,\ldots,n \}$.

2. Smooth the original estimates of the efficiency scores using the smoothing rule:

$$TE^*(x^j, y^j) = \begin{cases} TE(x^j, y^j) + \varepsilon^j, & \text{if } TE(x^j, y^j) = 1 \\ TE(x^j, y^j), & \text{otherwise} \end{cases}$$

   Based on this, split the sample estimates into two sample estimates into two subsamples of DEA estimates, *A* and *B* thus obtaining:

$$\{ TE_b^{*A,j} \mid j = 1,\ldots,n_A \} \tag{A1}$$

$$\{ TE_b^{*B,j} \mid j = 1,\ldots,n_B \} \tag{A2}$$

3. Next, estimate the Li (1996) test statistic using the subsamples in (A1) and (A2) and bandwidth $h^* = \min\{ h_A^*, h_B^* \}$, where h_A^* and h_B^* are obtained using same optimal rule applied to (A1) and (A2) respectively.

4. Resample from the largest subsample out of (A1) or (A2) in order to obtain the bootstrap analogues of (A1) and (A2) and call them:

$$\{ TE_b^{**A,j} \mid j = 1,\ldots,n_A \} \tag{A3}$$

$$\{ TE_b^{**B,j} \mid j = 1,\ldots,n_B \} \tag{A4}$$

5. Estimate the bootstrapped Li test statistic using (A3) and (A4) and $h_b^{**} = \min\{ h_{b,A}^{**}, h_{b,B}^{**} \}$, where $h_{b,A}^{**}$ and $h_{b,B}^{**}$ are obtained using the same optimal rule applied to (A1) and (A2) in step 3 to (A3) and (A4) respectively.
6. Repeat steps 4 and 5 $B|b = 1, \ldots, B$ times to obtain B bootstrap estimates of the Li statistic that will mimic the distribution of the original estimate of the Li statistic under the null hypothesis.

4.4 Modelling inputs and outputs

Three inputs and two outputs are selected for the efficiency estimation process. Oil reserves, gas reserves and total labour force employed were chosen as inputs to generate natural resources of oil and gas. The two outputs, oil and gas quantities are physically generated from the oil and gas reserves using human resources. These variables are selected because the issue under consideration is how oil producing countries are converting their resource inputs into maximum outputs obtainable. Table 4.6 presents a summary of the selected variables to be used in the analysis. Selection is mainly guided by literature.

Table 4.6: Model Variable Selection

Purpose	Variable	Unit		
Inputs	Crude Oil Proved Reserves	Billions of barrels	**Reason**	Very important asset and is regarded as accurately reported (Eller et al., 2011)
			Used by:	(Eller et al., 2011; Ike & Lee, 2014; Kashani, 2005b; Sueyoshi & Goto, 2012a; Thompson et al., 1996; Wolf, 2009)
	Proved Reserves of Natural Gas	Trillion of Cubic Feet	**Reason**	Very important asset and is regarded as accurately reported (Eller et al., 2011)
			Used by:	(Eller et al., 2011; Ike & Lee, 2014; Kashani, 2005b; Sueyoshi & Goto, 2012a, 2012b; Thompson et al., 1996; Wolf, 2009)
	Employees	Millions	**Reason**	This is a proxy for labour as a factor of production
			Used by:	(Eller et al., 2011; Ike & Lee, 2014; Kashani, 2005b; Sueyoshi & Goto, 2012a, 2012b, 2014; Thompson et al., 1996; Wolf, 2009)
Outputs	Total Oil Supply	Thousand Barrels Per Day	**Reason**	The input resources must be accounted for and the maximum obtainable output from oil reserves using best practice is oil production (Ike & Lee, 2014)
			Used by:	(Barros & Assaf, 2009; Barros & Managi, 2009a; Eller et al., 2011; Ike & Lee, 2014; Kashani, 2005b; Sueyoshi & Goto, 2012a, 2012b; Thompson et al., 1996; Wolf, 2009)
	Gross Natural Gas Production	Billion Cubic Feet	**Reason**	The input resources must be accounted for and the maximum obtainable output from gas reserves using best practice is gas production (Ike & Lee, 2014)
			Used by:	(Barros & Assaf, 2009; Barros & Managi, 2009a; Eller et al., 2011; Ike & Lee, 2014; Kashani, 2005b; Sueyoshi & Goto, 2012a, 2012b; Thompson et al., 1996; Wolf, 2009)

4.4.1 Inputs

The three inputs used for generating oil and gas outputs for all the oil producing countries are oil and gas reserves estimated differently and the labour force employed.

4.4.1.1 Oil and Gas reserves

Oil and gas reserves are commercially identified volumes of oil and gas that can be recovered in the future. Oil reserves are volumes of an estimated quantity of crude oil identified in a specific area through geographic analysis and data from demonstrated engineering surveys (EIA, 2013). The resource are converted into outputs that generates significant revenue (Wolf, 2009). It is the most important asset and is regarded as more accurately reported by all countries than other inputs (Eller et al., 2011). These two reserves are measured separately. Whereas oil reserves are measured in billions of barrels (bbls), natural gas reserves are measured in trillions of cubic feet (tcf).

4.4.1.2 Labour force

Labour is a critical resource in the production process. It is therefore a key resource in all production efficiency estimation models, including DEA. The oil industry is both labour and capital intensive process. Although labour can be measured in numbers, wages and salaries as well as labour hours, there is no comprehensive database or source for this variable. However, time series datasets of the total labour force for all countries are available in the World-Bank's World Development Indicator database. This labour force statistic will not be an appropriate proxy as labour for the oil industry of these countries since it includes persons operating in all other industries of the country. Therefore, labour force of these countries are estimated in relation to the industry's contribution to the total GDP of the country at a particular time. Therefore, oil and gas labour force for a country *j* at time *t* is estimated as a function of the total labour force of that country at time *t* given an average of the oil rents and the natural gas rents. Note that the oil and gas rents are estimated as a percentage of the GDP and can be seen as a proxy of the contribution of the oil and gas industry towards the GDP of the country. This is can be expressed as:

$$OLF_{jt} = \left(LF_{jt} \times \left(\frac{GR_{jt} + OR_{jt}}{2} \right) \right) \quad (15)$$

OLF_{jt} = Oil and Gas Labour force for country *j* at time *t*.

LF_{jt} = Labour force for country *j* at time *t*.

GR_{jt} = Natural Gas Rents for country *j* at time *t* as a percentage of GDP.

OR_{jt} = Oil Rents for country *j* at time *t* as a percentage of GDP.

Whereas natural gas rents are the difference between the value of natural gas production at world prices and total costs of production, oil rents are the difference between the value of crude production at world prices and total costs of production (World Bank, 2011).

4.4.2 Outputs

The two outputs are the oil and gas quantities physically generated from the critical inputs of oil producing countries. Oil and gas production is the quantity of oil and gas that have been recovered in a given time period. This is primarily output from operations of drilling from the oil and gas reserves as an end product of the upstream industry activities (Wolf, 2009). By this, increasing the production output is an essential pointer for improved economic performance of oil producing countries (OPCs). Oil and gas producing countries are looking forward to meeting the growing demands on improving the socioeconomic activities of their countries essentially from oil and gas production generated revenue. Hence production in thousands of barrels per day and billion cubic feet for oil and gas respectively are good estimates for measuring performance of not just output generated revenue, but also for benchmarking and appropriate technology use.

4.5 Other DEA consideration

Two DEA models input and output orientations are used in the efficiency assessment. The adapted model for this study is the output-orientation DEA model for the four IGOs, and sample of 65 oil producing countries belonging to them. In the output orientation, the proportional output expansion level is observed to provide the best practice technology being applied whilst the input is held constant. Technically efficient oil producing countries will be required to increase their output for a given set inputs. More specifically the output-oriented technical efficiency measure is appropriate in respect of a group(s). This has been applied to most oil and gas related efficiency studies (Barros & Assaf, 2009; Eller et al., 2011; Ike & Lee, 2014; Ismail et al., 2013). This is because oil producing countries are more concerned with the maximum production output for supply to the various areas (oil consuming countries) since pricing decisions are left with market conditions. Apart from that, output-orientated measure is more inclined to industries with critical demand schedules (Zhou et al., 2008). For all estimations, R software version 3.1.1 used with the rDEA, Benchmarking and Nonparaeff packages. MaxDEA and EMS were also used for confirmatory purposes.

4.6 Conclusions

The discussion of this chapter emphasized and provided a clear and precise description on the methodology and the adopted assumptions in the assessment of this study. It also showed the data source as well as the quantitative, experimental and positivist research approaches employed in the data collection and analysis process.

CHAPTER FIVE

ANALYSIS AND DISCUSSIONS

5.0 Introduction

This section provides empirical results aimed at answering the research questions and achieving the objectives of the study. The chapter is divided into five sections. Whereas the first presents a description of the data used, the final section presents a summary of the chapter. The remaining three sections provides empirical results that directly answer the research questions. Whereas section two presents answers to research question 1, section three presents answers to research questions 2 and 3. Finally, section four provides answers to questions 4 and 5. For each of these research questions addressed, discussions are made with respect to literature and practice.

5.1 Data Description

The data for the analysis was primarily sourced from the US Energy Information Administration's (EIA) database of oil and gas statistics of oil producing countries (OPCs) in the international oil industry. Whereas data for several countries are available, data for the 52 OPCs under consideration were gathered from the period 2000 to 2013. Annual oil reserves, annual gas reserves, daily oil production and gas production levels were gathered from this source. The data needed for the estimation of labour force of these OPCs was from the World Banks's World Development Indicators database. Generally, three inputs and two outputs are used for the efficiency estimation. Whereas the oil reserves, gas reserves and labour force are the inputs, production levels of oil and gas are the two outputs. Descriptive statistics of the variables for the pooled dataset covering the 14-year period from 2000 to 2013 is presented in Table 5.1. The number of observations (N), mean, standard deviations, minimum and maximum values for each variable and for each IGO are presented. Also included in the table are the results of a test of differences using one-way ANOVA to test differences in the variables between the four IGOs understudy.

Table 5.1: Descriptive Statistics of Pooled Data from 2000 to 2013

		N	Mean	Std. Dev.	Minimum	Maximum	ANOVA	
							F	Sig.
Oil Reserves	FSU	140	8.53	18.30	0.01	80.00	71.32	.000
	IEA	280	9.09	34.50	0.01	180.02		
	OAPEC	138	56.18	81.33	0.12	267.91		
	OPEC	165	78.76	75.83	2.12	297.57		
	Overall	**723**	**33.87**	**63.28**	**0.01**	**297.57**		
Gas Reserves	FSU	140	202.98	497.81	0.10	1700.00	25.07	.000
	IEA	280	25.88	54.29	0.02	334.07		
	OAPEC	138	147.93	232.06	2.30	910.52		
	OPEC	165	245.66	301.78	0.25	1187.00		
	Overall	**723**	**133.63**	**296.81**	**0.02**	**1700.00**		
Labour Force	FSU	140	13621277	21562330	1734672	77074406	19.91	.000
	IEA	280	23798984	33942132	1931619	159144632		
	OAPEC	138	6427296	6786129	303604	27742106		
	OPEC	165	10870575	12351137	332190	54196350		
	Overall	**723**	**15561972**	**25022196**	**303604**	**159144632**		
Oil Production	FSU	140	1174.84	2785.94	0.21	10757.91	25.12	.000
	IEA	280	856.94	2157.16	3.19	12342.77		
	OAPEC	138	2163.83	3010.28	47.40	11840.68		
	OPEC	165	2875.40	2556.94	392.72	11840.68		
	Overall	**723**	**1628.59**	**2679.15**	**0.21**	**12342.77**		
Gas Production	FSU	140	2870.49	6462.89	0.00	24317.91	1.46	.223
	IEA	280	2338.43	5694.76	0.18	30005.00		
	OAPEC	138	1680.55	2006.22	68.51	7104.88		
	OPEC	165	2308.40	2188.92	38.85	8169.49		
	Overall	**723**	**2309.03**	**4749.99**	**0.00**	**30005.00**		

Overall, the dataset is made up of 723 observations over the 14-year period for the 52 OPCs who belong to the four IGOs in the international oil industry. In Table 5.1, the range between the minimum and maximum values for all variables are high showing the possibility of differences in the sizes of the oil and gas industries of the countries understudy. This view is supported by the size of the deviations from the sample means. For example, the mean of the oil production output of 1628.59 thousands of barrels of crude per day has an even larger standard deviation of 2679.15.

Shifting attention towards the individual IGOs, for oil reserves, OPEC holds the highest oil reserves (*M*=78.76, *SD*=75.83). OAPEC follows in second place (*M*=56.18, *SD*= 81.33), followed by IEA (*M*= 9.09, *SD*= 34.5) and FSU (*M*= 8.53, *SD*= 18.30). There is evidence of significant differences in the oil reserves capacities of the various IGOs (*F*=71.32, *p*<0.001). The reserve endowment ranking seem to change a little when gas reserves are considered. Although, OPEC member states possess the largest amounts of gas reserves (*M*=245.66, *SD*= 301.78), they are closely followed by FSU member states (*M*= 202.98, *SD*= 497.81) who were seen to possess the least oil reserves. In third place for gas reserves is OAPEC (*M*= 147.93, *SD*= 232.06). Finally, IEA members hold the least gas reserves on average (*M*= 25.88, *SD*= 54.29). Similarly, significant differences were identified in the average gas levels of member states (*F*=25.07, *p*<0.001).

For the levels of labour force employed, IEA has the highest number of workers (*M*=23798984, *SD*=33942132), FSU comes second (*M*=13621277, *SD*=21562330) and then OPEC (*M*=10870575, *SD*=12351137). The F-statistic of 19.91 with p-value less than 0.1% also indicates significant differences among the labour force of the IGOs. Although it is possible that higher resource endowment can lead to higher production levels and hence higher efficiencies compared to less endowed IGOs, it is equally possible that higher resource endowment can lead to lower efficiencies if the production capabilities of these countries are not streamlined adequately to ensure higher production levels.

The oil production outputs in thousands of barrel per day of the four IGOs are also significantly different (*F*=25.12, *p*<0.001). OPEC member states produce the highest levels of oil outputs (*M*=2875.40, *SD*=2556.94). This is encouraging since they also are the highest endowed IGO in terms of oil reserves. OAPEC is the second largest producer of oil outputs (*M*=2163.83, *SD*=3010.28) followed by FSU. IEA has the lowest oil production levels (*M*=856.94, *SD*=2157.16). It is also clear that with gas production levels, FSU leads the pack (M=2870.49, SD=6462.89). FSU, however, is closely followed by the remaining IGOs. Indeed, there are no statistically significant differences in the average gas production levels of the various IGOs (F=1.46, p=0.223).

Summary of the annual statistics of the data have been attached in Appendix C. A test of differences for each variable over time is also included in Appendix C. The One way Anova test of differences for each variable are not statistically significant, giving an indication of little variation in the industry over time, and providing justification for using a pooled frontier for efficiency estimation.

The final stage in the data description process in DEA estimation is the isotonicity test. The isotonicity property of DEA requires a positive correlation between all inputs and outputs (Cooper, Seiford, & Zhu, 2011; Thanassoulis, 2001). This means that, its expected consumption of more inputs will lead to higher outputs. The inputs and outputs correlation test in a nonparametric frontier analysis is necessary for robust analysis. The correlations between the inputs and outputs are presented in Table 5.2.

Table 5.2: Correlations between Inputs and Outputs

	Oil Production	Gas Production	Oil Reserves	Gas Reserves	Labour Force
Oil Production	1				
Gas Production	.673**	1			
Oil Reserves	.749**	.157**	1		
Gas Reserves	.526**	.618**	.261**	1	
Labour Force	.435**	.764**	-.032	.280**	1

*** p < 0.01*

From Table 5.2, all inputs from the table are positively and significantly associated with both outputs. For example, whereas the correlation between oil production and oil reserves is 0.749, the correlation between gas production and labour force is 0.764. All correlations are significant at the 1% level therefore the isotonciity characteristic of DEA which requires that an output should not decrease with an input increase (Dyson et al., 2001; Honma & Hu, 2008; Wanke, Barros, & Faria, 2015) is not violated. The intuition for the positive associations is that employing more inputs is expected to lead to higher production levels. It is not surprising that there is a stronger correlation between oil production and oil reserves as compared to the correlation between oil production and gas reserves. This is because oil production emanates from oil reserves. Same remark is evident for gas production as well. Finally, there are relatively weaker correlations among the inputs. Even the correlation between the oil reserves and labour force is not statistically significant (r = -0.032, $p > 0.05$). The weak or no correlations among the inputs is also an encouraging sign in DEA estimations since it provides evidence of the discriminatory power of the inputs used (Dyson et al., 2001). This means that the inputs actually measure different dimensions in the production process.

5.2 Scale Elasticity in the International Oil Industry

The first objective is to test the scale elasticity properties of the industry. The assumption on returns to scale of the underlying technology is one of the important a priori assumptions necessary to employ DEA (Badunenko, 2008). While the production frontier can exhibit either constant return to scale or variable return to scale, previous researchers have failed to statistically test it. The consequence is that research finding from previous study may be biased since the appropriate production technology may not have been assumed. Here, Simar and Wilson's (2002) bootstrap-based scale elasticity test is used. The elasticity property of the frontier is first tested on annual bases, thereby assuming heterogeneity in the production technology over time (Canhoto & Dermine, 2003). Subsequently the data for the entire period is pooled and tested to see the scale elasticity based on the assumption of technological homogeneity (Canhoto & Dermine, 2003). This procedure is adopted by

Gómez-Calvet, Conesa, Gómez-Calvet, and Tortosa-Ausina (2014). In here, the mean of ratio is used following Tortosa-Ausina et al. (2008). The intuition behind this test is that as long as the difference between the CRS and VRS efficiency score is small we will not have the statistical confidence to reject the null hypothesis of CRS (Mahlberg & Url, 2010). Therefore, if the p-value for the test statistic is greater than the significance level we will fail to reject the null hypothesis of CRS, otherwise we will reject the null hypothesis in favour of a VRS frontier. Result of this test are presented in Table 5.3. The unbiased test statistic is from bootstrap DEA estimates based on 2000 replications.

Table 5.3: Scale Elasticity Tests (Simar & Wilson, 2002) using the Mean of Ratios

Year	S test	p-value	Decision
2000	0.8307	0.22	CRS
2001	0.8351	0.27	CRS
2002	0.8362	0.29	CRS
2003	0.8671	0.42	CRS
2004	0.8585	0.25	CRS
2005	0.8535	0.28	CRS
2006	0.8529	0.19	CRS
2007	0.8134	0.19	CRS
2008	0.7966	0.24	CRS
2009	0.7995	0.29	CRS
2010	0.8309	0.22	CRS
2011	0.8371	0.29	CRS
2012	0.8337	0.33	CRS
2013	0.8251	0.25	CRS
Overall/Pooled	**0.8070**	**0.051**	**CRS**

From Table 5.3 the result of the test values for each year from 2000 to 2013 as well as the p-values provides a statistical indication that size does not matter in the international oil industry of OPCs. This is because the p-values of each of the 14 years is greater than the 5 percent significance level. By implication, we fail to reject the null hypotheses and conclude that the production frontier exhibits constant scale elasticities for each year. Additionally, test results based on the pooled frontier also provide same conclusions since the p-value of 0.051 is larger than the 0.05 significance level.

This provides both statistical and empirical justification to adopt CRS in all DEA efficiency estimations in this work. This means that OPCs are of similar production capacities irrespective of the size of the country's oil and gas resource endowment. Even the pooled data for the period also indicate same. The justification for the finding is probably because of the capital intensive nature of oil and gas exploration and production activities. Indeed, Szilas (1985) underscores that investment in the oil and gas industry, no matter the level of involvement, requires heavy monetary and logistical commitments. This means that, previous study by Hawdon (2003) on inter-country efficiency in the gas industry is questionable since he failed to adequately test for the returns to scale property. The reliance of Hawdon (2003) on t-test and Kolmogorov-Smirnov test for the returns to scale resulted in mixed findings. This current work therefore provides basis for the adoption of CRS by subsequent papers that aim to assess efficiency of OPCs.

5.3 Meta and Group Analysis of Inter- and Intra-IGO Performance

This section provides results and details of meta and group frontier analysis as well as technological gap ratio estimated using the metafrontier approach of DEA. The metafrontier analysis provides a meaningful model for the comparison of efficiencies among and between groups of countries (Barnes & Revoredo-Giha, 2011). These results aid in achieving the second and third objectives of this study. Whereas objective two is aimed at assessing the intra and inter group performance of countries in each IGO, objective three aims to provide empirical comparison of the performance of various IGOs using the Simar Zenlenyuk adapted Li Test (SZAL). Whereas the intra group assessment looks at the performance of countries in a particular IGO, inter group assessment compares the performance of different blocks of IGOs.

The metafrontier approach provides a curve enveloping all the group frontiers constructed for assessing DEA scores for each group and presents an empirical application using cross-country data (O'Donnell et al., 2008b). Metafrontier analysis ensures that heterogeneous countries or groups can be examined based on their distance from an identical and common frontier (Assaf, Barros, & Josiassen, 2010). Therefore, the metafrontier approach fills in these disadvantages by allowing comparison across heterogeneous groups (Battese & Rao, 2002a; O'Donnell et al., 2008a). The metafrontier provides benchmarking for all sample in the data set separately from the frontier in which they are members (Kounetas, Mourtos, & Tsekouras, 2009). The frontier analysis can be used by decision makers to pinpoint non performing units among the whole in other to orientate policy prescriptions for them. The section is divided into 2 parts. The first part considers only intra-group performance evaluation. The second part then considers similarities and differences in the performance of different IGOs (inter-group performance) in the international oil industry.

Intra-Group Performance Evaluation

Tables 5.4, 5.5, 5.6, and 5.7 presents results of metafrontier analysis for FSU, IEA, OAPEC and OPEC respectively. For each table, bootstrapped meta-efficiency scores, bootstrapped group efficiency scores and bootstrapped technological gap ratios (TGR) are reported. The meta-efficiency scores measure efficiency relative to the metafrontier which represents the existing state of knowledge in the industry irrespective of the particular group a country belongs. This is decomposed into the groups-specific efficiency and the TGR. Whereas the group efficiency scores represent the existing state of knowledge, the physical, social and economic environment that characterizes a particular group, the TGR provides a measure of how close the group frontier is to the metafrontier (O'Donnell et al., 2008a). In other words, the group efficiencies allow for an investigation of the relationship between different groups-specific technologies and is used to explain the differences in the production opportunities attributed to the resource endowments of a particular group. The value of the TGR explains the technological progress or regress between the group and the industry as a whole (Battese & Rao, 2002a). Therefore, a score closer to 1 signifies lower discrepancy between the group-specific frontier and the meta frontier (Ahmed & Krishnasamy, 2013). The TGRs of countries in each IGO have therefore been ranked in order of importance.

Table 5.4: Intra-Group Analysis of FSU Member States

Country	IGO	Meta Efficiencies	Group Efficiencies	TGR	Rank
Azerbaijan	FSU	3.2583	1.4763	0.4531	4
Belarus	FSU	2.0023	1.1233	0.5610	2
Georgia	FSU	24.7591	7.2097	0.2912	9
Kazakhstan	FSU	4.3545	1.3011	0.2988	8
Kyrgyzstan	FSU	24.6788	8.7513	0.3546	6
Russia	FSU	2.8920	1.3199	0.4564	3
Tajikistan	FSU	68.0373	9.6844	0.1423	10
Turkmenistan	FSU	1.3249	1.2247	0.9244	1
Ukraine	FSU	4.9945	1.6374	0.3278	7
Uzbekistan	FSU	2.7007	1.1421	0.4229	5
Geomean		**6.0057**	**2.2911**	**0.3815**	
ANOVA	**F**	**62.548**	**70.715**	**99.771**	
	Sig.	.000	.000	.000	
Kruskal Wallis	χ^2	**125.773**	**116.754**	**120.802**	
	Sig.	.000	.000	.000	

The intra group analysis of the 10 member states of the FSU listed in Table 5.4 shows their meta-efficiency, group efficiency, TGR and the ranking of the TGR based on a dataset from 2000 to 2013. Starting with the group efficiencies, it can be observed that no country has efficiency score exactly equal to 1. This is as a result of the bootstrap based bias correction of efficiency scores and is consistent with Hawdon's (2003) assertion that in real market systems probability of a unit being exactly 100 percent efficient is zero. This notwithstanding, best performing countries in this IGO include Belarus (1.1233), Uzbekistan (1.1421), and Turkmenistan (1.2247). However, most other countries in the FUS have high inefficiency levels. For example Georgia, Kyrgyzstan and Tajikistan all have group efficiency score greater than 1. Even worse is when the meta-efficiency scores are considered. Except Turkmenistan, all other members of this FSU have meta-efficiency scores greater than 2.00.

The disparities between the meta-efficiencies and group efficiencies give an indication that countries in this IGO are not producing using the best state of knowledge in the industry. Even the TGRs for all members except Turkmenistan (0.9244) and Belarus (0.5610) are below 50 percent. The average TGRs of all countries in the IGO is about 0.3815 signifying that on average countries in FSU produced using only 38.15 percent of the existing state of knowledge in the industry. Ranking of TGRs show that Turkmenistan, Belarus, Russia, and Azerbaijan are among the best countries in the FSU to capitalize on the existing global technological spill overs whilst Tajikistan, Georgia, Kazakhstan and Ukraine are trailing. Also reported in the table are result of Anova and Kruskal Wallis test of differences. Based on the results there are significant differences in the performance of individual countries in this IGO for all three indicators. This shows that not all countries are equally good or poor in this industry. Summary of the Tukey HSD pairwise comparison test as reported in Appendix D, for example shows that whereas Turkmenistan has the significantly highest TGR, the TGRs of Azerbaijan and Belarus are not statistically significantly different.

Turkmenistan’s higher TGR of 0.9244 is far above that of the other countries in this FSU. The closest country is Belarus with TGR of 0.5610. Turkmenistan’s higher TGR may be a payoff from their government’s continual policy of modernizing and expanding infrastructure in the oil and gas industry by increasing investment to develop its resources and the implementation of market reforms to facilitate intensive production and supply of more gas (EIA, 2013). Belarus is the next best performing country in the FSU. The Belarusian government after the collapse of the Soviet Union took control of the country’s development and ensured high level of government's involvement in the oil sector (Ghedrovici & Ostapenko, 2013). The huge state support for the sector possibly has accounted for their level performance. The strong industry that was maintained after the union collapse could also be a factor to their TGR of 0.5610. Another reason is their close links with the developed EU market that has advanced the level of orientation and the quality of market reforms (Gaytaranov, 2013; Ghedrovici & Ostapenko, 2013). The country's performance is also due to their high level of human capital (Podkorytova & Raskina, 2014). Russia has the third largest TGR in the IGO. Russia's performance can be associated with the policy of allowing the participation of private and foreign investors to manage and extract large oil and gas prospects (EIA, 2013). The investment include allowing international oil companies like Lukoil, Surgutneftegas, Novatek and Tatneft to invest and participate in the industry with tax incentives. Also, the use of advance technology and improved recovery techniques has accelerated oil production output from existing oil deposits and contributed to their supply improvement (EIA, 2013). This notwithstanding, Russia needs more efforts in the industry in order to move their TGR above the 0.50 mark.

The low performance of most countries in the FSU may be attributable to their historical developments. Members of this IGO are states that were formed after the collapse of the Soviet Union (Minescu et al., 2008; Podkorytova & Raskina, 2014). The collapse generated diverse legal interpretation regarding boundary issues (EIA, 2013). The new independent states started the development of the large deposits of untapped oil and gas resource endowment with diverse and sometimes adversarial approaches individually (EIA, 2013). Therefore, the initial rivalries among states and the individual approach towards oil and gas development may have contributed to the poor performances of states. This view can also be seen based on the ideas of the theory of social networks which explains the importance of good ties among states as investment in the accumulation and management of social resources and capital (Katz et al., 2004). In other words, if states have strong ties they are bound to help themselves improve their social capital. However, when states have adversarial ties, as is seen in the FSU, the consequence may be detrimental to the wellbeing of these states. In addition when countries are operating alone, their performance may not be as good as if they were in a group as indicated in the theory of social facilitation (Markus, 1978) because the external presence is not sufficient to influence their behaviors. Further to this, because these countries are not well institutionalised or do not follow any institutionalized behaviors as “regulative, normative, and cognitive structures and activities that provide stability and meaning for social behavior” (Scott, 1995) their performance are affected negatively base on institutional theory views. Their low performance may in part also be attributable to the fact that most FSU countries lack innovative technology, the infrastructure and investment to support the oil and gas sectors (EIA, 2014).

Table 5.5: Intra-Group Analysis of IEA Member States

Country	IGO	Meta Efficiencies	Group Efficiencies	TGR	Rank
Australia	IEA	2.5025	2.3667	0.9457	4
Austria	IEA	2.3571	2.2408	0.9506	3
Canada	IEA	1.4636	1.1617	0.7938	16
Czech Republic	IEA	2.0217	1.9230	0.9512	2
Denmark	IEA	1.3178	1.1886	0.9020	11
France	IEA	1.2901	1.1651	0.9031	10
Germany	IEA	2.9925	2.3907	0.7989	15
Greece	IEA	1.8586	1.7283	0.9299	5
Hungary	IEA	1.8614	1.7059	0.9165	8
Italy	IEA	3.0119	2.7236	0.9043	9
Japan	IEA	1.3818	1.2702	0.9192	7
Netherlands	IEA	1.3123	1.1573	0.8819	13
Norway	IEA	1.2524	1.1629	0.9285	6
NZ	IEA	1.7235	1.2943	0.7510	18
Poland	IEA	3.9728	3.5796	0.9010	12
Slovakia	IEA	2.2430	2.1672	0.9662	1
Spain	IEA	2.4080	1.3765	0.5716	20
Turkey	IEA	2.5924	1.5230	0.5875	19
UK	IEA	1.4797	1.1413	0.7713	17
US	IEA	1.4600	1.2827	0.8786	14
Geomean		**1.9140**	**1.6255**	**0.8493**	
ANOVA	**F**	**30.269**	**34.467**	**46.729**	
	Sig.	.000	.000	.000	
Kruskal Wallis	χ^2	**98.333**	**98.453**	**60.007**	
	Sig.	.000	.000	.000	

The intra group analysis of the 20 member states of the IEA listed in Table 5.5 shows their meta-efficiency, group efficiency, TGR and the ranking of the TGR based on a dataset from 2000 to 2013. Starting with the group efficiencies, it can be observed that the efficiency score of all the countries in the IEA are quite close to 1 and are mostly similar to each other. Similarly, no country has a score of exactly 1 as result of the bootstrap based bias correction of efficiency scores. However, best performing countries in this IGO include UK (1.1413), Netherlands (1.1573), Canada, Norway and France having score slightly above (1.16). This notwithstanding, some countries in this IGO seem to have efficiency scores that are quite different from the rest. These countries are Poland (3.5796), Italy (2.7236), Germany

(2.3907), Australia (2.3667) and Austria (2.2408). In addition, the meta-efficiency scores of all the countries do not seem far apart from their group efficiency scores. This gives an indication that countries in this IGO may be producing using the best state of knowledge in the industry. Even the technology gap ratio for all members except Spain (0.5716), Turkey (0.5875) and New Zealand (0.575) are above 0.77. The average technology gap ratio of all countries in the IGO is about 0.8493 signifying that, on average countries in IEA produced using about 84.93 percent of the existing state of knowledge in the industry. Ranking of TGRs show that Slovakia, Czech Republic, Austria, and Australia are the best producers in the IGO whilst New Zealand, Turkey and Spain are trailing. Also reported in the table are result of Anova and Kruskal Wallis test of differences. Based on the results there are significant differences in the performance of individual countries in this IGO for all three indicators. This shows that all the countries are not performing at the same level of efficiency in this industry. Summary of the Tukey HSD pairwise comparison test as reported in Appendix D, for example shows that all the countries have significantly higher TGRs than Spain and Turkey.

For this IGO, all members have relatively high TGRs. Even Spain which places 20th in the rankings has a TGR which is greater than 0.5. The performance of the countries in this IGO is instructive. Because most of the states are very close to the frontier after the bootstrap estimates. This possibly may be as a result of the strong ties that exist between the countries and the fact that the IGO membership are mostly drawn from the industrial regions of Western Europe and North America (Colgan, Keohane, & Van de Graaf, 2011). The IEA is part of a much stronger OECD with a framework of achieving high sustainable economic growth for it member countries in the process of economic development (Bamberger, Scott, Agency, & Development, 2004). As stated in the aim of IEA, the organization promotes rational policy through co-operative relations with industry and other international organizations (Bamberger et al., 2004). Social network theory suggests that the structure of a group determines the access and flow of resources in the network (Daly, 2012). The IEA's clear concern for compliance monitoring, execution and evaluation of efficiency policies in line with the continuous transfer of policy to member countries also might have contributed to the performance observed (Jollands et al., 2010). It can therefore be implied that the activities and ways of operation by individual countries in the IEA will be very similar to that of other members and is consistent with the theory that organizational structure and process helps achieve effectiveness and efficiency in their desired outcomes as predicted by institutional theory. Therefore, it is expected that all members will also have close to similar levels of efficiency. The IEA policy for the development and technology transfer remains a key factor for the cooperation among member states (Colgan et al., 2011). This notwithstanding, as Taylor et al. (2010) posits, the relatively lower performance of countries like Spain (0.5716) and Turkey (0.5875) scores may be attributable to the differences in production infrastructure across countries.

Table 5.6: Intra-Group Analysis of OAPEC Member States

Country	**IGO**	**Meta Efficiencies**	**Group Efficiencies**	**TGR**	**Rank**
Algeria	OAPEC	2.4920	1.1606	0.4657	9
Bahrain	OAPEC	1.3046	1.1399	0.8738	3
Egypt	OAPEC	3.5822	1.8823	0.5255	8
Iraq	OAPEC	4.2290	2.4220	0.5727	5
Kuwait	OAPEC	1.1972	1.1299	0.9438	1
Libya	OAPEC	2.4402	1.2840	0.5262	7
Qatar	OAPEC	1.2729	1.1669	0.9167	2
Saudi Arabia	OAPEC	1.4135	1.0949	0.7746	4
Syria	OAPEC	2.5099	1.4184	0.5651	6
Tunisia	OAPEC	2.6699	1.2394	0.4642	10
Geomean		**2.1083**	**1.3469**	**0.6389**	
ANOVA	**F**	**14.469**	**10.065**	**421.286**	
	Sig.	.000	.000	.000	
Kruskal Wallis	χ^2	**117.784**	**67.857**	**125.137**	
	Sig.	.000	.000	.000	

Next IGO under consideration is the OAPEC whose membership comprises only Arab oil and gas producing countries. Results of the intra group analysis of the 10 member states of OAPEC shown in Table 5.6 are based on a dataset from 2000 to 2013. For their group efficiencies, it can be observed that the efficiency scores of most of the countries in the group are moderately high and not very far from the absolute efficiency score of 1. Judging by means of the group efficiency scores, best performing countries include Saudi Arabia (1.0949), Kuwait (1.1299), Bahrain (1.1399), Algeria (1.1606) and Qatar (1.1669). This notwithstanding three countries in this IGO seem to have efficiency scores that are quite high. These countries are Iraq (2.4220), Egypt (1.8823) and Syria (1.4184). In addition, the meta-efficiency scores are quite high and quite away from the absolute efficiency score of 1. There are quite small differences between the meta-efficiencies and group efficiencies giving an indication that countries in this IGO may be producing, to a large extent, close to the best state of knowledge in the industry. Even the technology gap ratio for all members except Tunisia (0.4642) and Algeria (0.4657) are above 0.525. The average technology gap ratio of all countries in the IGO is about 0.6389 signifying that on average countries in OAPEC produced using 63.89 percent of the existing state of knowledge in the industry. Ranking of TGRs, together with the TukeyHSD results in Appendix D, show that Kuwait and Qatar are the best performing countries in the IGO followed by Bahrain, and then Saudi Arabia. Tunisia and Algeria are trailing. Anova and Kruskal Wallis test of differences show some significant differences in the performances of individual countries in this IGO for all three indicators.

The results show the performance of members to be moderate to high for almost all the member countries. OAPEC is made up of Arab countries having a distinct characteristic of being close in same location in the Middle East (Colgan et al., 2011). The objective of organization to support member countries in the effective use of their resources by sponsoring joint venture is very informative. This may have been a contributory factor to the performance of its member countries. Which is evident in the TGRs in Table 5.6. Although some member states have quite high TGRs, a few other states have lower than 0.5 TGRs, this shows some level of dispersion in the performance of member states. This can be viewed through the lenses of the institutional theory. It is possible that the regulative, normative, and cognitive structures and activities that are required to provide stability for behavior of member states (Scott, 1995) may not be widely followed by all states. This is because the theory posits that, if members strictly followed the organizational structures and ideologies, we expect members to look and act the same (DiMaggio & Powell, 1983). This is especially true because some members of the OAPEC group, such as Iraq, Libya, Saudi Arabia, Kuwait, Algeria, and Qatar, are also members of other similar IGOs like OPEC. This means that there can be the possibility of conflicts in institutional guidelines of the various IGOs, hence states may not follow the laid down policies in the group. This may be the reason for the differences in performances of states in this IGO.

Table 5.7: Intra-Group Analysis of OPEC Member States

Country	IGO	Meta Efficiencies	Group Efficiencies	TGR	Rank
Algeria	OPEC	2.4920	1.0820	0.4342	10
Angola	OPEC	1.5269	1.1925	0.7810	4
Ecuador	OPEC	1.4769	1.1941	0.8085	3
Iran	OPEC	8.3536	2.5220	0.3019	12
Iraq	OPEC	4.2290	2.6755	0.6326	6
Kuwait	OPEC	1.1972	1.1282	0.9424	1
Libya	OPEC	2.4402	1.2646	0.5182	9
Nigeria	OPEC	5.5772	3.2812	0.5883	7
Qatar	OPEC	1.2729	1.1826	0.9290	2
Saudi Arabia	OPEC	1.4135	1.0934	0.7735	5
UAE	OPEC	2.1083	1.1957	0.5671	8
Venezuela	OPEC	5.4166	2.0236	0.3736	11
Geomean		**2.5228**	**1.5201**	**0.6026**	
ANOVA	**F**	**118.877**	**77.475**	**218.370**	
	Sig.	.000	.000	.000	
Kruskal Wallis	χ^2	**1473694**	**118.339**	**153.835**	
	Sig.	.000	.000	.000	

The final IGO under consideration is OPEC which has membership comprising oil and gas producing countries from the Middle East, Africa and South America. This is one of the foremost and most influential IGOs in the international oil industry (Ike & Lee, 2014) therefore their performance dynamics are very important. Results from the analysis of the 12 member countries are detailed in Table 5.7. For their group efficiencies, it can be observed that the efficiency scores of most of the countries in the group are slightly high although not very far from the absolute efficiency score of 1. In this group, Algeria (1.0820), Saudi Arabia (1.0934), and Kuwait (1.1282) are among the best performers in terms of group efficiency. Other countries like Qatar, United Arab Emirates, Ecuador, and Angola have scores ranging from 1.1826 to 1.1957. For other countries like Venezuela (2.0236), Iran (2.5220), Iraq (2.6755), and Nigeria (3.2812), their group efficiency scores are very high showing high levels of inefficiency by these countries within the IGO. Meta-efficiency scores of OPEC countries seem also high. However, there are some countries with similar group efficiency scores and meta-efficiencies. Kuwait for example has a group efficiency score of 1.1282 whiles its meta- efficiency score is 1.1972. These two scores are not far apart signifying that for some countries in the IGO, they are producing using similar states of knowledge as available in the industry. For some other members of this IGO, however, their meta-efficiency scores are far apart from their group efficiencies. Algeria, for example which had the best group efficiency score of 1.0820 has a meta-efficiency score of 2.4920. Meaning that it does not adequately use the best available state of knowledge in its production efforts. A better sense of the disparities between the group efficiencies and the meta-efficiencies can be gained by reference to the technology gap ratios. For all member states, except Venezuela (0.3736), Iran (0.3019) and Algeria (0.4342), TGRs are above 0.50. The average technology gap ratio of all countries in the IGO is about 0.6026 signifying that on average countries in OPEC produced using about 60.26 percent of the existing state of knowledge in the industry. Ranking of TGRs show that Kuwait, Qatar, Ecuador, Angola and Saudi Arabia are the best producers in the IGO whilst Libya, Algeria, Venezuela and Iran are trailing. Anova and Kruskal Wallis tests of differences also reveal significant differences in the scores of these countries.

OPEC member countries, unlike OAPEC, are a diverse set with many shared characteristics (Al-Rashed & León, 2015). These countries are at different stages of social and economic development with different economic structures (Al-Rashed & León, 2015). This may be the reason for the large variations in the TGR estimates of member countries as shown in Table 5.7. Countries like Kuwait, Qatar and Ecuador have scores above 0.8, whiles Angola, Saudi Arabia and Iraq have scores above 0.6. Iran, Algeria and Venezuela have TGRs below 0.5. As an institution, it is expected that the member countries follow similar processes as laid down rules by OPEC. This is expected to result in similar performance levels as the proponents of the institutional theory postulate (Lincoln, 1995). Differences in the performance is an indication that the members do not well follow the institutional policies and frameworks available. This may be the reason for the large differences in their TGR scores. For OPEC, evidence abound in literature to show that some members have exhibited loose adherence to announced production cutbacks (OPEC, 2002).

From the regional point of view, OPEC countries can be categorised as belonging to one of four geographical regions: sub-Saharan African countries (Angola and Nigeria), North African countries (Algeria and Libya), Middle East countries (Iran, Iraq, Kuwait, Saudi Arabia, Qatar and UAE) and South American countries (Ecuador and Venezuela). This diversity in membership may also be the reason for the differences in TGRs since as the proponents of Social Network Theory argue, when members do not share similar social bonds performance may be different (Barnes, 1954; Bott, 1957; Granovetter, 1973). The main purpose of OPEC is to protect the collective interests of individual member states and to ensure balance in their international oil market transactions (Desta, 2003). But there seems to be a lack of co-ordination on broader policy issues impacting on the common interests of members (Arena, 2008). This has resulted in most countries hardly adhering to the organization's policy leading to them adopting their own development in dealing with multilateral transaction (Desta, 2003). Hence the large variation their performance and efficiency score. This is true of the social network theory which argues that there are both positive and negative consequences of membership in social network. The theory explains that states are said to be socially networked when they tend to think and behave similarly because they are connected. However, because the ties between states in the group may be weak members may not have the same level of success. Again issues of internal collective action challenges and the rise of new producers can explain the differences in their performance (Goldthau & Witte, 2011). The practice of supply restrictions of production output may be the reason for low performance of some of its members (Desta, 2003; Ike & Lee, 2014) like Venezuela and Angola.

Inter-Group Performance Evaluation

This part analysis the inter-group performances of the IGOs in this study. Tables 5.8 summarizes the results of metafrontier analysis with respect to the four IGOs under study. The average meta-efficiencies, group efficiencies and technology gap ratios of each IGO is first presented in Table 5.8. Values in this table are then presented graphically in Figure 5.1 for better conceptualization of deductions. IGOs are also ranked based on their TGRs to identify the best performing ones in order of importance.

Table 5.8: Inter-IGO Metafrontier Results

IGO	Meta Efficiencies	Group Efficiencies	TGR	Rank
FSU	6.0057	2.2911	0.3815	4
IEA	1.9140	1.6255	0.8493	1
OAPEC	2.1083	1.3469	0.6389	2
OPEC	2.5228	1.5201	0.6026	3

Results of the inter-group performance comparison of the four IGOs under consideration as detailed in Table 5.8 are based on the dataset from the period 2000 to 2013. The group efficiency scores of member states of each of these IGOs as computed are quite high. Since the group efficiencies are computed relative to different production frontiers, it is not appropriate to compare the group's specific efficiency scores of these different groups (Canhoto & Dermine, 2003; Dietsch & Lozano-Vivas, 2000). It can however be noted that, whereas OAPEC member states are producing at about 74% (1/1.3469 = 0.74) of their potential capacity, FSU states are only producing at 44% (1/2.2911 = 0.44) of their potential production capacity. IEA and OPEC states are producing at 62% and 66% of their potential production capacities respectively. The meta-efficiency scores, can however, be compared since they are all based on the same pooled frontier. Meta-efficiencies are quite high indicating more inefficiencies since most scores are away from the efficiency score of 1. The IEA (1.9140) is the only IGO with a meta-efficiency score that is quite similar to their group efficiency score. The differences between the meta-efficiencies and group efficiencies of OAPEC and OPEC are fairly high but not too far away from each other. Again, scores for FSU seem to show quite high differences between the two efficiency scores. This is an indication that, as compared to other IGOs, IEA member states are producing using the best state of knowledge in the industry since their TGR at 0.8493. OAPEC and OPEC are producing, to some extent, close to the best state of knowledge in the industry with TGRs slightly above 0.60. FSU could only manage 0.3815 of the state of knowledge available in the international oil industry. Also, the TGRs of all IGOs except FSU (0.3815) are above 0.6026. This means that given the inputs IEA is producing at 84.93% close to the available state of production technology in the international oil industry. OAPEC and OPEC are producing at 63.89% and 60.26% respectively.

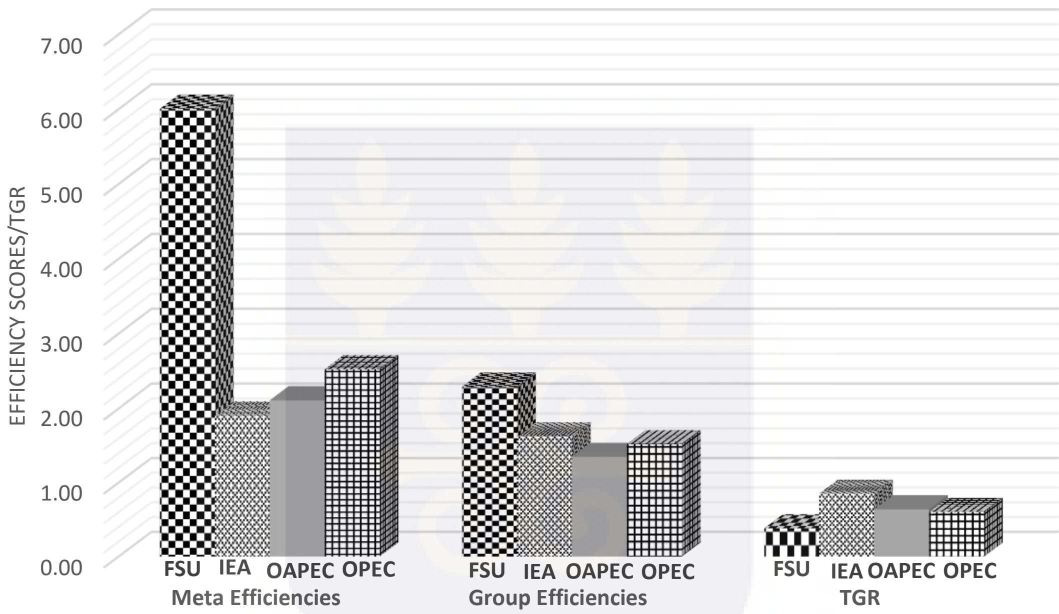

Figure 5.1: Distribution of Metafrontier Scores of the IGOs

Figure 5.1 presents a graphical depiction of the distribution of the metafrontier scores of the IGOs being considered. The graphical view allows for easy understanding of how different scores of specific IGOs are from other ones. The Figure shows the meta-efficiencies, group efficiencies as well as the technological gap ratio of these IGOs. From Figure 5.1, it is clearly seen that the meta-efficiency score, on average, of FSU is higher than all other IGOs, signifying higher levels of inefficiencies by member state relative to the best possible technology in the industry as compare with member states of other IGOs. IEA has the closest meta-efficiencies, on average, to the efficiency score of 1. When each IGO's meta-efficiencies are compared with the group efficiency scores, it is clear that unlike other IGOs, the meta and group efficiencies of IEA states are quite similar. Disparity between the meta-efficiency and group efficiency scores of FSU is much more pronounced. The result is that FSU has the lowest TGR. IEA, however, has clearly, the highest technology gap ratio, followed closely by OAPEC and OPEC. What is not obvious in these inter-group comparison is whether differences in the meta-efficiencies and TGRs of these IGOs are statistically significant. This is the basis for the pairwise comparisons presented in Table 5.9.

To achieve the third objective of this study, a pairwise comparison of the scores of these IGOs are presented based on a dataset from 2000 to 2013. The performance of the four IGOs are first compared using traditional point estimate comparison statistical techniques. Independent t-test and Mann Whitney U tests are used to conduct pairwise comparison of the means and ranks of the various IGOs. Whiles these tests are well known, it only compares point estimates and neglect the distribution of the entire dataset (Li, 1996; Simar & Zelenyuk, 2006). To cater for this weakness, the SZAL test, which uses kernel density estimators to compare the distribution of the scores are used here. Notice that in Table 5.9, test statistics are presented together with p-values in parenthesis. Notice also that group efficiencies are not compared in this table since the group efficiency scores of the various IGOs are based on separate production frontiers.

Table 5.9: Pairwise Comparisons of Inter-IGO Performance

		T-test	Mann Whitney	SZAL
FSU - IEA	Meta Eff.	6.288 (0.000)***	7462 (0.000)***	27.75 (0.000)***
	TGR	-21.997 (0.000)***	3080 (0.000)***	67.38 (0.000)***
FSU - OAPEC	Meta Eff.	6.114 (0.000)***	4390 (0.000)***	16.77 (0.000)***
	TGR	-9.854 (0.000)***	3129 (0.000)***	33.28 (0.000)***
FSU – OPEC	Meta Eff.	5.706 (0.000)***	6865 (0.000)***	17.45 (0.000)***
	TGR	-8.602 (0.000)***	5326 (0.000)***	19.14 (0.000)***
IEA – OAPEC	Meta Eff.	-2.464 (0.015)*	18015 (0.261)	4.199 (0.000)***
	TGR	11.055 (0.000)***	7804 (0.000)***	30.78 (0.000)***
IEA – OPEC	Meta Eff.	-6.021 (0.000)***	18624 (0.001)**	2.992 (0.001)**
	TGR	12.365 (0.000)***	8887 (0.000)***	35.77 (0.000)***
OAPEC - OPEC	Meta Eff.	-3.654 (0.000)***	9746.5 (0.031)*	2.88 (0.002)**
	TGR	1.219 (0.224)	10399 (0.194)	14.80 (0.000)***

****p <0.001. **p<0.01. *p<0.05*
values in parenthesis ( ) are the p-values

First pairwise comparison in between the scores of FSU and IEA. This is a comparison of the two extremes, since previous results from Table 5.8 and Figure 5.1 revealed that FSU has the highest meta-inefficiency scores of 6.0057 and lowest TGR of 0.3815 whiles IEA had the best meta-efficiency score and TGR of 1.9140 and 0.8493 respectively. Statistical comparisons for all three estimators reveal significant differences in the meta-efficiencies and TGRs of FSU and IEA at the 0.1% significance level. IEA member states significantly outperform their FSU counterparts on both meta-efficiency and TGR. FSU states are next compared with OAPEC member states. Conclusions on both the meta-efficiencies and the TGR are similar to that revealed when FSU and IEA were compared. OAPEC states, on average, outperform FSU states on both indicators and on all three estimators of difference. OPEC member states also significantly outperform FSU states on both meta-efficiency and TGR. Results from the metafrontier analyses therefore reveal that FSU is the least performing IGO in the international oil industry.

Next, results for IEA are compared with that of OAPEC. From Figure 5.1, IEA is seen to have lower meta-inefficiencies but higher TGR on average. The question is however, whether these differences are statistically significant. Starting with the meta-efficiency scores, mixed results are observed between the results of the parametric t-test and its nonparametric counterpart- Mann Whitney test. Whereas results from the t-test reveal that IEA states have significantly lower average meta-inefficiencies than OAPEC states (t = -2.464, $p < 0.05$), Mann Whitney shows no statistically significant differences in the ranks on these two IGOs (U = 18015, p = 0.261). It is amidst these disparities in conclusions that the utility of the SZAL test is seen. SZAL results show statistically significant differences in the distribution of meta-efficiency scores of IEA and OAPEC states (l = 4.199, p< 0.001). Results of the SZAL test is more reliable since it compares all members of one group against all members in the other. It is also based on nonparametric techniques which are important because of the nonparametric nature of DEA estimation technique. For the TGR, all three estimation techniques observe significant differences in the TGRs of IEA and OAPEC states. IEA states therefore significantly outperform OAPEC counterparts. This can be graphically observed with reference to Figure 5.2 which shows the kernel density distribution of the TGRs of the four IGOs. From Figure 5.2 shows it is clear that whereas the distribution of scores for IEA seem to gain more density towards the score of 1.0, that of OAPEC seem to peak between 0.4 and 0.6.

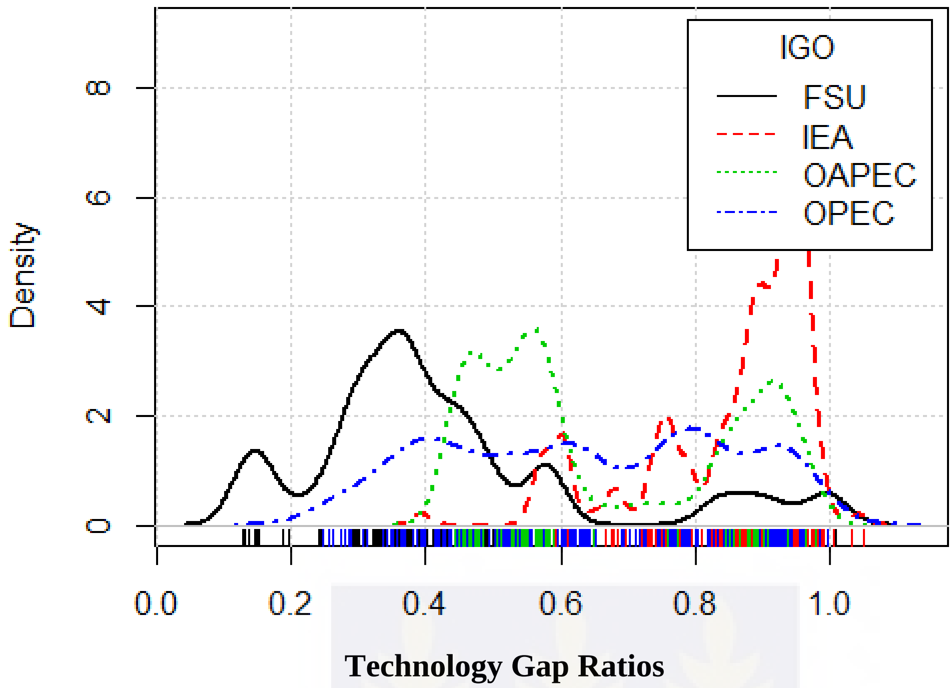

Figure 5.2: Distribution of Technological Gap Ratios

IEA states are then statistically compared with OPEC states. Results are quite straightforward. There are statistically significant differences in the means, ranks and distributions of these two IGOs for both the meta-efficiency scores and TGRs. IEA has significantly lower meta-inefficiencies than OPEC and higher TGRs than OPEC on average. IEA states therefore significantly outperform OPEC states on both meta-efficiency scores and TGRs.

From deductions made, it is clear that FSU is the worst performing IGO based on the metafrontier analyses, whiles IEA is the best IGO. What is not clear is whether any differences exist between the performances of OAPEC and OPEC. Both IGOs were seen in Table 5.8 to have meta-efficiencies slightly below 2.60 and TGRs slightly above 0.6. Although OAPEC has larger TGR of 0.6389 compared to OPEC's of 0.6026 and smaller meta-efficiency of 2.1083 compared with OPEC's of 2.5228, there question remains whether there are statistically significant differences. Just like previous comparisons, scores of OAPEC and OPEC are statistically compared on all three estimators of differences. For the meta-efficiency scores, all three statistical approaches revealed significant differences between the scores of OAPEC and OPEC. OAPEC therefore has lower meta-inefficiencies compared with OPEC states on average. The result is not that straightforward when the TGRs are compared. For both point estimators, no statistically significant differences were observed between the scores of these two IGOs. There are no statistically significant differences in the means (t = 1.219, p = 0.224) and ranks (U = 10399, p = 0.194) of TGRs of OAPEC and OPEC member states. This notwithstanding, there is a statistically significant difference between the distribution of OAPEC and OPEC states (l = 14.80, $p <$ 0.001). This can be inferred from Figure 5.2 where it is seen that whereas OAPEC gathers greater mass between 0.4 and 0.6 as well as between 0.8 and 1.0, OPEC states seem to be distributed relatively evenly across a wider range of scores. There are even quite a number of OPEC states with scores lower than the 0.4 mark whiles only few OAPEC members fall in this sector. OAPEC states therefore seem to outperform OPEC states in this regard. Statistical tests therefore reveal that IEA is the best performing IGO followed by OAPEC. OAPEC is closely followed by OPEC states. FSU is, however, in a distant fourth place on the ranking.

The inadequate level of cooperation among governments of FSU countries probably underscores the reasons for its inefficiencies. There is no agreement coupled with differences in political and economic interest in the development of the oil resource in their respective countries (Aguilera, 2012). These essential ties, cooperation or networks as expounded by social network theory provides positive utility to countries in the oil industry, by influencing access to resources, reducing transactional costs and building interest based on coalitions (Lauber et al., 2008). However, absence of higher levels of such cooperation may be detrimental to the group interest since differences in the individual goals may not engender group performance. Another issue that probably impacts on the higher inefficiency of members in this IGO is the concentration on internal use of the oil and gas produced by the FSU countries (EIA, 2013). Excessive government subsidies on the oil and gas supplied for domestic market can be a disincentive to higher production levels since economic benefits from higher production levels may not be realised by the producing organisations. Additionally, it is possible that because most oil produced in this region is heavy (EIA, 2013; Goldemberg, 2000), it is a contributory factor to their inefficiencies. Heavy oil requires enhanced oil recovery techniques. This stands to reason that since higher production technology is required for exploring heavy oil, as social network theory explains, countries stand to benefit from collaborations in terms of technology and research as well as reducing the transactional cost. Therefore the poor performance can be associated to lack of collaboration in technology and research in the industry (Goldemberg, 2000).

The progress of IEA member countries may be explained by the distinct policy of collaboration by the IGO with groups across the international oil and gas industry (Bamberger et al., 2004). The performance of the group members can be attributed to the framework that allows for consultation with oil companies by member countries, to establish permanent basis for consulting in an appropriate manner for the request for information from individual oil companies on all important aspect of the oil industry. The agency allows participating countries to endure to promote cooperate relations with oil producing countries and consuming country. This probably has created ample opportunities for promoting dialogue and solution for members' unique challenges. For OAPEC, the organization's assistance in facilitating access to a more scientific and new technological developments in the industry could also account for their performances (OAPEC, 2015). OAPEC maintains its international collaboration with similar organizations by organizing and participation in expert scientific seminars particularly those concerned with regional and international energy affairs (OAPEC, 2015) to improve on the group's performance which is consistent with social facilitation theory. OPEC states are not far behind OAPEC on average. Their results are much more mixed in nature since whereas some OPEC states are performing quite well, other OPEC states seem to suffer because of the membership of this IGO. It is quite difficult to believe that OPEC states do not follow organizational guidelines and there is absence of policies by the IGO that governs the oil and gas exploration and production activities of member states like the FSU. Indeed, the several production quotas that critically affect the world oil prices is ample evidence of standardised organisational policies. Policies that consider global supply and associated prices have always been critical targets for OPEC members (Wolf, 2009). It stands to reason that, although there exist such policies for OPEC, and member states follow them, although sometimes loosely, these policies may not be ones that adequately benefit member states. Ike and Lee (2014) for example observe that production quotas of OPEC significantly affect the performance of OPEC states. Similarly, Desta (2003) believes that the practice of supply restrictions of production output may be the reason for low performance of some of its members.

5.4 Global Frontier Differences Analysis of Inter-IGO Performance

Section 5.4 provides empirical reasons to help achieve objectives four and five of this study. Whiles objective four evaluates the inter-group frontier differences of the four IGOs, objective five determines whether there are statistically significant differences in the distribution of the technological indices (TI) between the various IGOs in the international oil industry. First, technology indices are estimated for all the IGOs. This is then followed by the frontier differences with respect to each individual IGO. Finally, results for the statistical comparison of the TIs for the various IGOs are presented.

The technological index, as expressed in equation (7) of the forth chapter of this work, measures the geometric mean of the efficiencies of all the observations relative to the frontier of the particular group under consideration (Asmild & Tam, 2007). In an output orientation, where inefficient DMUs have scores greater than 1, and superefficient DMUs have scores less than 1, when the TI of a particular group's frontier is greater than one, it means that, on average that frontier is better than most of the observations. However, if the TI is less than 1, it means that the frontier is worse than most observations since on average DMUs are superefficient (score < 1 in output oriented model). In short, higher TIs signify better frontier on average. The average TI for each IGO is presented in Table 5.10 for each year from 2000 to 2013. The average for the pooled dataset is also included.

Table 5.10: Technology Indices for the IGOs

	Tech Indices (OPEC)	Tech Indices (IEA)	Tech Indices (FSU)	Tech Indices (OAPEC)
2000	0.75527	1.96932	0.62074	1.02384
2001	0.74587	2.00257	0.62470	0.99897
2002	0.75488	2.03378	0.63499	0.97886
2003	0.84372	2.05208	0.65695	1.00207
2004	0.78535	1.97307	0.61539	0.95344
2005	0.76513	1.91421	0.60085	0.91389
2006	0.76211	1.93629	0.60752	0.90892
2007	0.76679	2.15787	0.64191	0.97376
2008	0.74015	2.17450	0.64533	0.97248
2009	0.77802	2.12043	0.64587	0.95175
2010	0.76870	2.10701	0.65830	0.95040
2011	0.82907	2.24633	0.72576	1.04132
2012	0.80028	2.14188	0.70450	0.98054
2013	0.84220	2.24973	0.72976	1.03601
Pooled	**0.78055**	**2.07384**	**0.64950**	**0.97680**

It is obvious from Table 5.10 that, for each year, IEA has had the highest TI. The TI for IEA has consistently been greater than 1, signifying that most observations (especially from the other IGOs) have been inefficient relative to the IEA frontier. Although the score fluctuates above 2.00 mark, it declined below 2.00 in 2004, 2005, 2006. It however regained momentum in 2007, and has maintained TI scores above 2.10 mark since then. However, even in the periods that IEA's indices were lower 2.00 mark, its TI was still better than all the other IGOs. IEA's worse TI of 1.9142 is even higher than OAPEC's best of 1.04132. OAPEC seems to have technological indices fluctuating around 1.00. It has in effect had periods where its frontier is better than most observations, on average and periods where its frontier has not been that good on average. Whiles the TI of OPEC ranges from 0.7459 to 0.8438, the TIs of FSU have had the lowest levels of the technological indices having achieved their highest index of 0.7298 in 2013. FSU's largest TI is even lower than the lowest of OPEC's TIs. For the pooled dataset, on average, whereas IEA has the highest average of 2.07384 and OAPEC has a score of 0.97689, OPEC and FSU have scores of 0.78055 and 0.64950 respectively. These scores have been graphically presented in Figure 5.3.

From Figure 5.3, it is obvious how far apart IEA's scores are from the other IGOs. IEA technological indices appear to fluctuate, however on the whole it seems to be on an upward spiral. The scores for the FSU, OPEC and OAPEC seem quite close. They seem to be fluctuating around the same scores but there is no real progress in the indices over the period. Another observation is that, at no point do two curves intersect. Performance of these IGO's seem to have remained stable over the years.

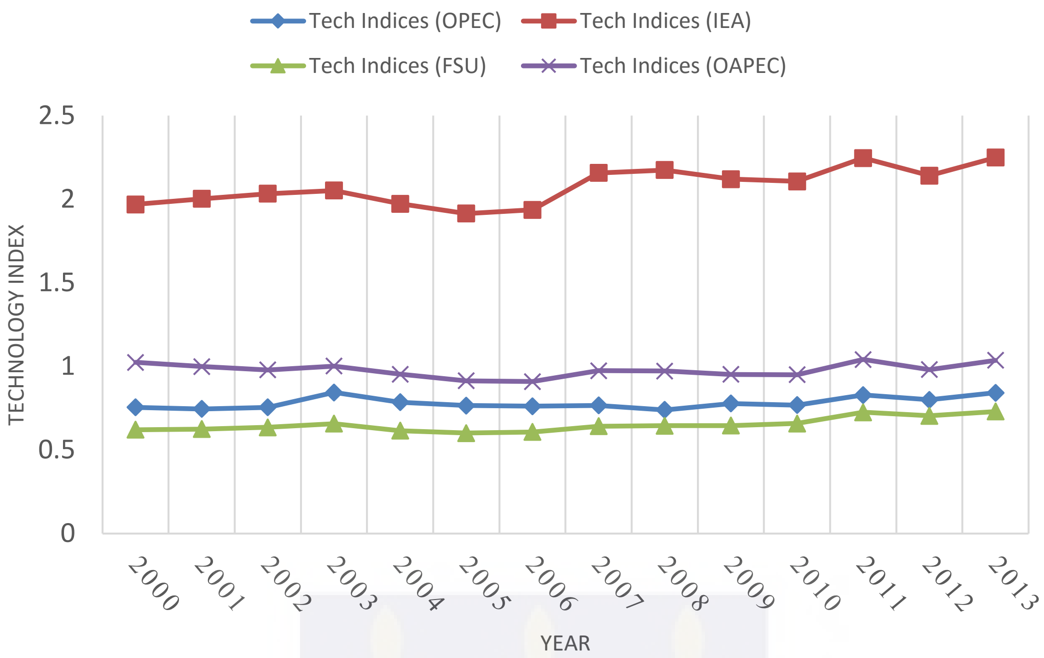

Figure 5.3: Distribution of Technological Indices

Whereas the TI will give an indication of how good the frontier is, it provides no real indication of how well a particular group's frontier is as compared to that of another specific group. This is where the global frontier differences (GFD) approach of Asmild and Tam (2007) gains utility. The TI are used in the estimation of the global frontier differences between the different groups. Results of the global frontier difference are presented subsequently. GFD measures and provides the overall conclusions about whether one group is superior to the other (Asmild & Tam, 2007). This approach provides an overall estimation of the differences between two frontiers or more importantly between groups. The frontier can differentiate between the efficiencies of two frontiers or two groups without considering shift overtime. The GFD tells by how much a particular IGO is far away from or close to another IGO. Mathematical notations of the index are presented in equation (8) of the fourth chapter of this work. Results are presented in Tables 5.11, 5.12, 5.13 and 5.14**.**

Table 5.11: Global Frontier Differences against OPEC Frontier

YEAR	OPEC	IEA	FSU	OAPEC
2000	1.0000	2.6075	0.8219	1.3556
2001	1.0000	2.6849	0.8375	1.3393
2002	1.0000	2.6942	0.8412	1.2967
2003	1.0000	2.4322	0.7786	1.1877
2004	1.0000	2.5123	0.7836	1.2140
2005	1.0000	2.5018	0.7853	1.1944
2006	1.0000	2.5407	0.7972	1.1926
2007	1.0000	2.8142	0.8371	1.2699
2008	1.0000	2.9379	0.8719	1.3139
2009	1.0000	2.7254	0.8301	1.2233
2010	1.0000	2.7410	0.8564	1.2364
2011	1.0000	2.7095	0.8754	1.2560
2012	1.0000	2.6764	0.8803	1.2252
2013	1.0000	2.6713	0.8665	1.2301
Pooled	**1.0000**	**2.5145**	**0.8010**	**1.2582**

Table 5.11 presents GFDs between OPEC and all other IGOs. In other words, it presents how the other IGOs view the OPEC frontier over the period. First using the pooled results, on average, IEA and OAPEC are 151.45% $([2.5145-1]\times100)$ and 25.82% $([1.2582-1]\times100)$ better than OPEC frontier, whereas FSU on average is 20% $([1-0.80]\times100)$ worse than OPEC. These overall dynamics are observed across all periods under review. IEA and OAPEC have consistently been better than OPEC from the results, whiles FSU always underperform the OPEC frontier.

Observing results from Table 5.12 which assesses how the other IGOs view the IEA frontier, it is readily seen from the GFDs that the IEA frontier is far better than that of all other IGOs under study. This is because, for the entire study period, all three other IGOs reported GFDs lower than 1 relative to the IEA frontier. Overall, FSU recorded the worse overall performance with respect to the IEA frontier. FSU frontier was, on average, 68.68% $([1-0.3132]\times100)$ worse than IEA's frontier. This was closely followed by OPEC which had a GFD of 0.3763 signifying that OPEC frontier was on average 62.37%

$([1-0.3763]\times 100)$ worse than IEA's frontier. The closest group to the state of technology employed by IEA was OAPEC, which had a frontier 52.91% worse than IEA's.

Table 5.12: Global Frontier Differences against IEA Frontier

YEAR	OPEC	IEA	FSU	OAPEC
2000	0.3835	1.0000	0.3152	0.5199
2001	0.3725	1.0000	0.3119	0.4988
2002	0.3712	1.0000	0.3122	0.4813
2003	0.4112	1.0000	0.3201	0.4883
2004	0.3980	1.0000	0.3119	0.4832
2005	0.3997	1.0000	0.3139	0.4774
2006	0.3936	1.0000	0.3138	0.4694
2007	0.3553	1.0000	0.2975	0.4513
2008	0.3404	1.0000	0.2968	0.4472
2009	0.3669	1.0000	0.3046	0.4488
2010	0.3648	1.0000	0.3124	0.4511
2011	0.3691	1.0000	0.3231	0.4636
2012	0.3736	1.0000	0.3289	0.4578
2013	0.3744	1.0000	0.3244	0.4605
Pooled	**0.3763**	**1.0000**	**0.3132**	**0.4709**

Table 5.13: Global Frontier Differences against FSU Frontier

YEAR	OPEC	IEA	FSU	OAPEC
2000	1.2167	3.1725	1.0000	1.6494
2001	1.1940	3.2057	1.0000	1.5991
2002	1.1888	3.2029	1.0000	1.5415
2003	1.2843	3.1237	1.0000	1.5253
2004	1.2762	3.2062	1.0000	1.5493
2005	1.2734	3.1858	1.0000	1.5210
2006	1.2545	3.1872	1.0000	1.4961
2007	1.1945	3.3617	1.0000	1.5170
2008	1.1469	3.3696	1.0000	1.5069
2009	1.2046	3.2831	1.0000	1.4736
2010	1.1677	3.2007	1.0000	1.4437
2011	1.1423	3.0951	1.0000	1.4348
2012	1.1360	3.0403	1.0000	1.3918
2013	1.1541	3.0828	1.0000	1.4197
Pooled	**1.2014**	**3.1928**	**1.0000**	**1.5035**

Results from Table 5.13 show the GFDs relative to the FSU frontier. It shows how the other IGOs view the FSU frontier. From the results, it is evident that FSU frontier is the worse frontier among the groups under study. All other IGOs scored values greater than 1. IEA reported the strongest performance with an overall average of 3.1928, whereas OAPEC had an overall GFD of 1.5035. For OPEC, its score of 1.2014 on average means that OPEC's frontier is about 20.14% better than FSU's frontier. The final of the global frontier difference comparisons is relative to the OAPEC frontier. These scores are reported in Table 5.14. OAPEC's frontier shows some interesting results. Whereas on average, OAPEC's frontier seems better than the OPEC (0.7991) and FSU (0.6651) frontiers, it is not better than that of IEA (2.1236).

Table 5.14: Global Frontier Differences against OAPEC Frontier

YEAR	OPEC	IEA	FSU	OAPEC
2000	0.7377	1.9235	0.6063	1.0000
2001	0.7466	2.0046	0.6253	1.0000
2002	0.7712	2.0777	0.6487	1.0000
2003	0.8420	2.0478	0.6556	1.0000
2004	0.8237	2.0694	0.6454	1.0000
2005	0.8372	2.0946	0.6575	1.0000
2006	0.8385	2.1303	0.6684	1.0000
2007	0.7875	2.2160	0.6592	1.0000
2008	0.7611	2.2360	0.6636	1.0000
2009	0.8175	2.2279	0.6786	1.0000
2010	0.8088	2.2170	0.6927	1.0000
2011	0.7962	2.1572	0.6970	1.0000
2012	0.8162	2.1844	0.7185	1.0000
2013	0.8129	2.1715	0.7044	1.0000
Pooled	**0.7991**	**2.1236**	**0.6651**	**1.0000**

From all the GFDs reported in the four preceding tables, IEA's frontier has consistently been better than that of all other IGOs. IEA's frontier on average is 2.5145 times better than OPEC's frontier, 3.1928 times better than FSU frontier and 2.1236 times better than OAPEC's frontier. This seems to give credence to earlier observation that IEA is the best performing IGO in terms of oil and gas production efficiency in the international oil industry. Best performing countries in IEA are much better than even the best performing countries in all other IGOs under study. OAPEC seems to be the next best IGO based on the GFDs. Its frontier, although 62.37% $([1-0.3763]\times 100)$ worse than IEA's frontier, is 25.82% $([1.2582-1]\times 100)$ better than OPEC frontier and 50.35% $([1.5035-1]\times 100)$ better than FSU frontier. OPEC then follows in terms of rankings. Its frontier is seen to be better than that of FSU whiles trailing those of IEA and OAPEC. Finally, the frontier of FSU states is seen to be the worse relative to all other IGOs in the international oil industry.

The final part of this section is aimed at achieving the fifth and final objective of this study. This is to examine whether a statistically significant difference exist in the technology indices of the various IGOs. Whereas the global frontier differences will inform on the difference between specific frontiers, it does not inform on whether the differences between two frontiers are statistically significant. Therefore, three tests of differences are used in this part. In achieving objective five of this study, a pairwise comparison of the scores of these IGOs are presented based on a dataset from 2000 to 2013. Independent t-test and Mann Whitney U tests are used to measure the pairwise comparison of the means and ranks of the various IGOs. Additionally, the SZAL test which uses kernel density estimators to compare the distribution of the scores are used here. Test statistics are for each statistical technique are presented together with the p-values for each pairwise comparison.

Table 5.15: Pairwise Comparisons of Technology Indices

	t-test	Mann Whitney	SZAL
FSU - IEA	-45.262 (0.000)***	105 (0.000)***	6.11 (0.000)***
FSU - OAPEC	-21.034 (0.000)***	105 (0.000)***	7.72 (0.000)***
FSU – OPEC	-9.019 (0.000)***	105 (0.000)***	7.58 (0.000)***
IEA – OAPEC	34.985 (0.000)***	105 (0.000)***	7.10 (0.000)***
IEA – OPEC	41.924 (0.000)***	105 (0.000)***	6.10 (0.000)***
OAPEC - OPEC	13.755 (0.000)***	105 (0.000)***	7.75 (0.000)***

****p <0.001. **p<0.01. *p<0.05*
values in parenthesis ( ) are the p-values

Pairwise comparison begin with the scores of FSU and IEA. Based on results in Table 5.10, IEA was seen to have the greatest TI than all other IGOs. Statistically, IEA's higher TIs are also statistically significant based on all three statistical techniques. IEA also has significantly larger TIs than OAPEC and OPEC as all of these comparisons are statistically significant, IEA is therefore the best IGO in this industry. OAPEC is also seen to have significantly larger TIs than OPEC and FSU whiles it has a statistically significantly lower TI than IEA. OAPEC is therefore the second best IGO in this industry. This is then followed by OPEC which has statistically larger TIs than FSU but statistically lower than OAPEC and IEA. Finally, just as previously observed, FSU is seen to statistically underperform all other IGOs in industry since their TIs are seen to be significantly lower than all three other IGOs.

The technological index comparison shows the magnitude of differences in the frontier in relations to the four IGOs being evaluated. IEA is seen to have higher technological indices and higher production frontier relative to the three other IGOs. The difference may be due to fact that the IEA is made up of more industrialized western countries with much higher resource in terms of human capital, technology, infrastructure and capital for investment, political and economic stability, bargaining power and collaborations with many more intergovernmental organizations (Bamberger et al., 2004; Colgan et al., 2011; Duffield, 2012; Jollands et al., 2010). This is theoretically supported by the resource base theory (RBT), which believes that the way an organization is organized combined with it resources, can better enhance the positive relationship between resources and the performance of the organization. This is justified by the empirical works which give credence to the importance of these resource characteristics for firm performance (Crook et al., 2008; Sirmon et al., 2011). This means that the IEA is able to put their resources to a better use for high performance. With respect to game theory the IEA strategy of maintaining minimum oil and gas stocks in the face of production cuts and price hikes (Bamberger et al., 2004) as well as the strong inter and intra group collaboration is consistent with the theory. When there is high inter and intra group collaborations it results in high exchange of information within and between groups. It then leads to organizational learning, innovation and information asymmetries are addressed (Rigby et al., 2013).

OAPEC's frontier showed a better score as compared with OPEC and FSU. This is an all Arab organization and perhaps this is the reason for their good performance. The group is seen to share similar cultural and political values due to them being closely linked with each other and in the same geographical location. This is buttressed by social network theory which posits that, states are said to be socially networked when they tend to think and behave similarly because they are connected (Garton et al., 1997; Miles, 2012). OAPEC sponsored ventures also help them to keep pace with developments and succeeds in enhancing their performance in the industry (OAPEC, 2010). This is true as predicted by game theory that stronger and more strategic the group collaboration within and with other groups, the higher the levels of learning and innovation and this leads to improved performance. OAPEC's oil reserves have been estimated at about 713 billion barrels about 43% of the proven world's reserves in 2014 (OAPEC, 2015). The large oil and gas resource endowment may be another factor influencing their level of performance as predicted by the RBT. The theory indicates that, there is a link between organization resources and performance. The more resource endowed an organization is, the better its performance. Overall, during the entire period of the study, OAPEC countries displayed almost similar scores indicating that the level of influence by member countries are relatively the same. This is justified by the theory of social facilitation which postulates that members of an organization are expected to exhibit similar levels of performance (Crawford, 1939; Miles, 2012).

OPEC's frontier follows OAPEC as the next best production frontier with scores better than the FSU. The composition of the members cuts across countries from Africa, South America and Asia. OPEC's coordination between major producers and consumers and their participation in international energy forums show the extent of engagement within the group and among other groups in the international oil and gas industry (Goldthau & Witte, 2011). It stand to reason that their better performance as compared with FSU may be a result of this collaborations, solidarity and other factor favouring the group in the coalition among member countries (Mikdashi, 1974). This is supported by game theory (Von Neumann & Morgenstern, 1944), which explains that, where there is a strategic collaboration within a particular group and among other groups there is a group learning and innovation that is possible to enhance the group's performance. Since the FSU frontier is significantly below the production frontiers of the other IGOs, the suggestion is that there is inadequate levels of coordination and collaboration among member countries and other groups. It will therefore be critical for them to come together and form a stronger IGO to create stronger and more sustainable ties among them. As suggested by social network theory. The establish ties will help improve their performance. There is probably information asymmetry among member states since the levels of cooperation among FSU states is not adequate. Hence, their coming together will to some extent help improve their efficiencies significantly and contribute to individual country's stronger development and growth.

5.5 Conclusions

In this chapter, results of the metafrontier and global frontier difference analysis were presented. This was earlier preceded by an examination of the returns to scale properties of the international oil and gas industry. Discussions based on theory, empirical literature and practice are provided to answer the research questions of the study. The analysis compared the production and supply efficiencies of the 53 countries in the four IGOs for the period.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This is the final chapter of this study. It first summarises the research process and findings. Based on the findings, conclusions are drawn which are used to make recommendations for practice, policy and further research.

6.1 Summary of study

The main aim of this study was to examine the production and supply efficiency of OPCs belonging to four IGOs in the international oil industry. Many oil and gas efficiency related studies have been conducted, but little knowledge on inter-country and group level efficiency exist. The contributions of this research is first to add to the literature in the international oil and gas industry by exploring knowledge on the performance of OPCs. In addition to this, the study does not only assesses the nexus between OPCs performance and their association with a particular IGOs but also does inter-IGO performance using two DEA estimating techniques- the Metafrontier Analysis (Battese et al., 2004) and the Global Frontier Differences (Asmild, Paradi, Reese, & Tam, 2007) approaches. The within group (intra IGO) and again between groups (inter IGO) comparison have seen little or no consideration by most authors in the oil and gas industry. The study employed the metafrontier approach which interestingly caters for the challenge of group heterogeneity, and the global frontier difference which compares the frontiers of the various groups in the international oil and gas industry for the first time. Also, the Simar-Zelenyuk adapted Li test, Simar and Wilson (2002) test of returns to scale and other innovative modelling approaches are used to ensure robust research conclusions. Output-orientation was used for all modelling processes. This model allowed management to distinguish results based on policy and strategy and industry knowledge regarding increasing production levels from a given level of resource.

Data used was source from the U.S Energy Information Association's web site and the World Bank's World Development Indicators database. In all 53 OPCs from the four IGOs in the international oil and gas industry for the 14-year period from 2000 to 2013 were sampled. The scope of the database comprises country level data on oil and gas reserves and production outputs. The main findings identified in the study are:

i. The production technology of oil and gas producing nations that were sampled, seems to exhibit a constant return to scale rather than variable return to scale.
ii. From the intra group assessment;
    a. Although some members of the FSU have appreciable levels of efficiency, most members of this IGO have high levels of group and meta-inefficiencies. There is high discrepancies between the group and meta-efficiencies of the FSU states.

    b. IEA states are low inefficiencies and similar levels of group and meta-efficiency scores. Additionally, assessment of their technology gap ratios (TGRs) show that most IEA states have high TGRs.

    c. The performance of members of the OAPEC bloc is seen to be moderate to high for almost all the member countries. Although some member states have quite high results, a few other states are low. This show some level of dispersion in the performance of member states.

d. OPEC member states produce the highest levels of oil outputs. This is encouraging since they also are the highest endowed IGO in terms of oil reserves. This notwithstanding they seem to have quite high meta and group inefficiency levels. However, the levels of inefficiencies for the group and meta scores are quite similar for most OPEC states.

iii. For the inter group assessment:

a. By comparing the averages and distributions of the groups, IEA states on average were the best performers followed by OAPEC, OPEC and FSU in that order. The average levels of meta-efficiency and technology gap ratios of IEA were seen to be significantly larger than the averages of the other IGOs

b. This was also confirmed from the Global Frontier analysis since the best performing countries in the IEA are seen to significantly outperform even the best performing countries in the other three IGOs. IEA and OAPEC production frontiers were seen to be consistently better than both the OPEC and FSU frontiers for all 14 years.

6.2 Conclusions of the study

The study through its findings has identified some interesting issues that need careful consideration in the performance assessment and benchmarking of oil producing countries and IGOs related to the international oil industry.

First, the issue of scale of operation and its possible effects on productive capabilities of OPCs in the industry was examined using the test of returns to scale property of the production frontier in the international oil and gas industry. Results show that size does not matter in this industry since constant returns to scale was observed for the industry for each of the years examined. This means that all oil producing countries in the international oil industry examined are operating at optimal production scales. Countries need not bother about either increasing their productive capacities or reducing it in order to improve supply efficiencies since their current production levels are of the appropriate scale. This also means that rate of change in reserve capacities (inputs) is consistent with changes in their production levels (outputs) (Asmild et al., 2013). Oil producing countries are of similar production capacities irrespective of the size of the country's oil and gas resource endowment. This is probably because of the capital intensive nature of oil and gas exploration and production activities (Szilas, 1985).

Second issue of concern pertains to the intra group performance assessments. FSU states were seen to be underperformers with only few lower inefficiencies and higher TGRs. On the other hand, IEA states were mostly seen as consistent performers since most of them had high TGRs. For OAPEC and OPEC states, their performance were mostly mixed. Whereas some member states were high performers, a few others were not that good. However, for both OPEC and OAPEC, number states who were generally high performers outweighed those who were not that good. The low performance of the FSU states could be partly as a result of the level of infrastructural investment in the region and partly due to the low level of cooperation by member states in the production efforts. It can be argued that the low level of capital investment and technology, linked with the lack of cooperation could be the cause of the disparities in the performance within the IGO. This is evident in the very high meta-inefficiencies and group inefficiencies exhibited by the countries in the IGO. The IEA's consistent performance and a high intra-group scores mean that member countries are all performing very close to the frontier in a very similar manner. This is an indication that countries in IEA may be producing using the best state of knowledge in the industry. There high performance may be due to intra group collaboration of members and the vibrant nature of this IGO especially in seeking international expertise to develop the IEA.

OAPEC countries' performances are moderately high, signifying that members of the IGO are not too far from the frontier in terms of the group efficiency. This is evident in the small differences between the meta-efficiencies and group efficiencies giving an indication that countries in this IGO are producing using close to the best technology in the industry to a large extent. This notwithstanding few members are a distant from the frontier and requires improvement. This could be that these states may not be following the laid down policies in the group and that group policies and guidelines may not actively drive members to the same direction. OPEC states show a lot of differences in their performance, indicating that some countries are using similar state of knowledge in the industry while others fail to take advantage of the best available state of knowledge in their production efforts. Even though member states produce the highest levels of oil outputs. Issues of internal collective action challenges and the rise of new producers can explain the differences in their performance (Goldthau & Witte, 2011). Group policies may not be as effective as it was previously with the rise of new and powerful non-member players like USA and China.

Finally, for the inter-group performance assessment, whereas IEA was seen as the best performer in the industry, FSU was seen to be not as improved as all the other IGOs in the international oil industry that were assessed. OAPEC and OPEC came second and third respectively on the TGRs ranking. IEA frontier was the best performer in the study over the 14 years period from 2000 to 2013 outperforming OAPEC, OPEC and the FSU in terms of meta-efficiency and group efficiency. It is also evident in the TGR. The same situation was observed when the production frontiers of these four groups were compares. The IEA frontier was seen to be the best in the industry that sets the pace for all other groups. Second was the OAPEC frontier. Whereas the OPEC production frontier comes closely third with that of the OAPEC frontier, both groups' frontier are a distant away from the current state of knowledge employed by IEA members. FSU had the lowest production frontier in the international oil industry. IEA's performance could be as a result of both the high intra-group collaboration and even higher inter-group (external) collaborations. The result is therefore high exchange of information that results in better organizational learning and innovation by members and addressed all information asymmetries and bottlenecks that may hinder the progress of the production and supply capabilities of member states.

6.3 Recommendations of the study

Based on the findings and conclusions of this study some essential recommendations can be proffered on policy, practice and future research. This will assist oil producing countries, policy makers in the industry, investors, oil related IGOs in the international oil industry and academics to better appreciate the dynamics of the international oil industry.

Recommendations on Policy

a. Due to the fact that constant returns to scale was observed, OPCs are seen to be producing at optimal production sizes. This means that policy makers should not concentrate on developing policies that bother on capacity expansion or reduction as current levels are adequate.

b. FSU states should put in more efforts to formalise their association with clearer policy guidelines that enshrine better collaboration among member states.

c. IEA was seen to be the best IGO. Whiles this is good, the IGO should strive for more collaborations especially with the other IGOs in this industry. Other IGOs like

OAPEC and OPEC can use IEA as a benchmark when developing operational targets.

d. Countries that are yet to join an IGO can take a close look at the activities of IEA in ensuring both internal and external collaborations. Choice of an IGO to join should be guided by the level of collaboration among member states and the technical capabilities of external collaborators.

Recommendations on Practice

a. Management of the production activities in these countries should ensure that current optimal levels are maintained. This is because, whereas these countries may not be facing scale inefficiencies now, it is very possible that future production capacities may result in higher costs due to large operation.

b. FSU states should be more open to international collaboration instead on focusing on internal capabilities as was observed in literature. Close association with higher performing states and organizations can better streamline their activities and reduce their inefficiencies.

c. Whereas OAPEC and OPEC were among the best performers, individual members experienced different levels of performance. Organizational policies and guidelines should be better institutionalised. Efforts should be directed towards ensuring that member countries adhere to these policies that work.

Recommendations on Further Research

a. To develop greater understanding, further research in productive efficiencies or any frontier performance criteria in the industry should adopt a constant returns to scale model especially when assessing the performance of these OPCs under consideration.

b. While Social network theory believes that common backgrounds among actors ensure close collaboration, for FSU states, this common ancestry does not seem to improve their performance. Future research should delve more into precise ties that can improve efficiencies in the international oil industry and how countries with adversarial histories can be joined towards a common productive goal.

c. Further research is desirable to develop greater insight of how production quotas and other regulatory guidelines of some IGOs, such as OPEC, affects the performance of individual countries.

d. OPCs were examined at the composite country level. It would be interesting for further research to shed more insight on how domestic dynamics and macroeconomic conditions translate to performance.

e. Further research can explore how various IGOs in the industry handle price volatilities that affect the performances of different IGOs.

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APPENDIX A

Taxonomy of Papers on Efficiency of IGO states

No.	Author	Issue	Methods	Sample	Industry	IGO
1.	Abu-Alkheil, Burghof & Khan, (2012)	Bank efficiency	DEA	40 Banks in UK, Turkey, GCC state & Malaysia (2005-2008)	Banking	OAPEC GCC
2.	Adetutu (2014)	Energy efficiency	Modified Translog Cost Function	4 OPEC Countries (1972–2010)	Energy	OPEC
3.	Adler-Milstein J, et al.(2014)	Health efficiency	Conceptual	20 OECD countries	Health	OECD
4.	Afonso & Aubyn (2004)	Education and Health efficiency	FDH DEA	24 OECD Countries	Education/ Health	OECD
5.	Al-Rashed & León (2015)	Energy efficiency	Energy coefficient	OPEC countries (2010)	Energy	OPEC
6.	Al-Rubaie, Salek & Walker (2015)	Efficiency of pharmaceuticals	Regression	30 responses were from 17 international, 7 GCC, 3 non-GCC Arab, and 3 Asian	Health	OAPEC GCC
7.	Andrieş and Căpraru (2012)	Competition and Bank efficiency	SFA Regression	27 EU Countries (2001- 2009)	Banking	EU
8.	Arestis, Chortareas & Desli (2006)	Efficiency of economy	DEA	26 OECD Countries (1963–1992)	Economy	OECD
9.	Aristovnik (2012)	Educational efficiency	DEA	27 EU and OECD Countries (1999–2007)	Education	EU OECD
10.	Arnade (1994)	Agricultural Efficiency and Productivity	DEA	77 countries EU, USA, Australia & New Zealand (1961 - 1987)	Agriculture	EU, etc.
11.	Asongu (2013)	Financial efficiency	Regression	11 AU Countries (1981 - 2009)	Economy	AU

12.	Behname (2012)	Bank efficiency	DEA Regression	8 OPEC Countries (1995-2009)	Banking	OPEC
13.	Bosseboeuf et al (1997)	Energy efficiency	Energy intensity ratio and technico-economic approach	9 EU member countries (1970 - 1993)	Energy efficiency	EU
14.	Çakır, Perçin & Min (2015)	Efficiency of the postal services	DEA	25 OECD Countries (2010)	Postal Service	OECD
15.	Casu & Girardone (2004)	Bank efficiency	SFA DEA Malmquist	5 EU Countries (1990s)	Banking	EU
16.	Casu & Girardone (2006)	Bank efficiency	Panzar and Rosse model DEA	EU-15 Countries (1997–2003)	Banking	EU
17.	Casu & Molyneux (2003)	Bank efficiency	DEA Tobit Regression	5 EU Countries (1993 - 1997)	Banking	EU
18.	Claeys &Vennet (2008)	Bank efficiency	Translog Cost Function	1130 banks from 31 European countries (1994-2001)	Banking	EU
19.	Dike (2013)	Measuring the security of energy exports demand in OPEC economies	REED index	12 OPEC Countries (2009)	Oil	OPEC
20.	Donni & Fecher (1997)	Efficiency and productivity of the insurance industry	DEA and Malmquist	15 OECD Countries (1983-1991)	Insurance	OECD
21.	Drakos (2003)	Bank efficiency	Regression	10 CEE and FSU Countries (1993–1999)	Banking	FSU CEE
22.	Fare, Grosskopf, Norris and Zhang (1994)	Productivity Growth, Technical Progress, and Efficiency Change	DEA Malmquist	17 OECD Countries (1979-1988)	Economy	OECD
23.	Filippini & Hunt (2009)	Energy efficiency	SFA	29 OECD Countries	Energy	OECD

				(1978 - 2006)		
24.	Fredriksson, Vollebergh and Dijkgraaf (2004)	Energy efficiency	Regression	12 OECD Countries (1982–1996)	Energy	OECD
25.	Fu et al. (2015)	Economy	Regression	China and G20 member countries	Economy	G20
26.	Geller, Harrington, Rosenfeld, Tanishima, Unander (2006)	Energy efficiency	Energy intensity	10 OECD Countries (1973-1998)	Energy	OECD
27.	Goldthau & Witte (2011)	Performance in energy	Review	OPEC (1960-2009)	Oil	OPEC
28.	Gorton & Davidova (2004)	Farm productivity and efficiency	DEA SFA	6 CEE countries	Agriculture	CEE
29.	Gupta & Verhoeven (1999)	Efficiency of government expenditure	FDH	37 Countries in Africa Union (1984–1995)	Education/ Health	AU
30.	Hori (2012)	Energy efficiency	Energy intensity	OECD and Non-OECD countries	Energy	OECD
31.	Jollands et al (2010)	Energy efficiency	Review/Policy	G8 (2008)	Energy	G8
32.	Košak, Zajc and Zorić (2009)	Bank efficiency	SFA	5 New EU Member States (1996 – 2006)	Banking	EU
33.	Krishnasamy & Ahmed (2009)	Efficiency and Productivity of economy	Metafrontier MPI	26 OECD Countries (1980-2008)	Economy	OECD
34.	Mamatzakis, Staikouras and Koutsomanoli-Filippaki (2008)	Bank efficiency	SFA	10 E U Countries (1998–2003)	Banking	EU
35.	Meier et al.(2013)	Fuel energy	Review	6 IEA members	Bioenergy	IEA

36.	Muldoon et al (2011)	Health efficiency	Regression	192 UN Countries (2001-2008)	Health	UN
37.	Oderkirk, Ronchi & Klazzinga (2013)	Health efficiency	Regression	20 OECD countries (2011-2012)	Health	OECD
38.	Oum & Yu (1994)	Efficiency of Railways	DEA TFP Tobit regression	19 OECD Countries (1978-89**)**	Railways	OECD
39.	Ramcharran (2002)	Efficiency and Oil production responses to price changes	Griffin's Model	12 OPEC Countries (1973-1997)	Oil	OPEC
40.	Reiche (2010)	Energy efficiency	Review/Policy	6 GCC countries	Energy	OAPEC GCC
41.	Retzlaff-Roberts, Chang & Rubin (2003)	Technical efficiency in health care	DEA	29 OECD Countries (1998)	Health	OECD
42.	Sari & Soytas (2009)	Efficiency	Auto Regressive Distributed Lag (ARDL) Approach,	5 OPEC Countries (1971–2002.)	Economy	OPEC
43.	Selowsky & Martin (1997)	Policy Performance	Regression	25 CEE & FSU (1990-1995)	Economy	CEE FSU
44.	Shahabinejad, Mehrjerdi & Yaghoubi (2013)	Productivity	SFA	44 Asian Countries (2000-2010)	Economy	ASEAN
45.	Sharma & Thomas (2008)	R&D efficiency	DEA	22 UN member Countries (2004)	R&D	UN
46.	Staníčková & Skokan (2012)	Efficiency	DEA	27 EU Countries (2000 -2010)	Economy	EU
47.	Taylor (2010)	Energy efficiency	Review	16 IEA countries	Energy	IEA
48.	Vlontzos et al (2014).	Agricultural energy and environmental efficiency	DEA	25 EU Countries (2001–2008)	Agriculture	EU

IEA – OAPEC – FSU EU AU ASEAN UN GCC CEE

APPENDIX B

CHRONOLOGICAL TAXONOMY OF EFFICIENCY STUDIES IN OIL AND GAS INDUSTRY

NO.	AUTHOR (YEAR)	ISSUES RESEARCH	METHOD	INPUTS	OUTPUTS	SAMPLE/STUDY PERIOD	Product	SECTOR
1.	Al-Obaidan and Scully (1991)	Ownership and efficiency	SFA	• Total assets	• Total revenue • Barrels of crude oil produced + barrels of crude oil refined	44 oil companies (1979-1983)	Oil and Gas	Upstream
2.	Al-Obaidan and Scully (1993)	Backward Vertical Integration	Aigner-Chu deterministic frontier	• Total assets	• Total revenue	55 oil companies (1979-1982)	Oil and Gas	Upstream
3.	Thompson Dharmapala, Rothenberg and Thrall (1994)	DEA/ AR and Profitability	DEA	• Total Cost • Proved reserves (combined)	• Additions to reserves (combined) • Sales of production from reserves	14 integrated oil companies in US (1980-1987)	Oil and Gas	Upstream
4.	Al-Obaidan and Scully, (1995)	Multinationality	SFA	• Total assets	• Total revenue . Barrels crude oil produced + barrels crude oil refined	44 oil companies (1976-1982)	Oil and Gas	Upstream
5.	Price and Weyman-Jones (1996)	Privatization	DEA SFA	• Number of employees • Length of gas Mains Transmission	• Domestic gas sales • Industrial gas sales • Commercial gas sales	12 distribution regions in UK (1977-78 to 1990-91)	Gas	Downstream

				and distribution system	• Number of Customers • Gas using appliances sold			
6.	Lee, Park and Kim. (1996)	International Comparison	Edgeworth Index	• Capital • Labour •Administration	• Gas deliveries	28 natural gas transportation utilities in 8 countries (1987-1995)	Gas	Downstream
7.	Thompson, Dharmapala, Diaz, Gonzalez-Lima and Thrall(1996)	Conceptual Paper	DEA	• Total production costs • Total proven reserves of crude • Total exploratory and development wells drilled • Total proven reserves of natural gas	• Oil Production• Gas Production	30 oil companies (1983-1985)	Oil and Gas	Upstream
8.	Thompson, Dharmapala, Rothenberg and Thrall (1996)	Application od DEA AR and CR	DEA	• Expenditure in exploration • Crude oil reserves • Natural gas reserves	• Crude oil discovered proved reserves • Natural gas discovered proved reserves	14 integrated oil companies in US (1980-1991)	Oil and Gas	Upstream
9.	Kim, Lee, Park and Kim, (1999)	International Comparison, Determinants of Productivity	Multilateral Tornqvist Managerial Index System Analysis Non-parametric Efficiency Analysis	• Labour • Capital (Assets) • Administration	• Total volume of gas supplied • Revenue from gas transportation	28 Natural Gas transmission and distribution companies operating 8 countries (1987-1995)	Gas	Downstream
10	Hawdon (2003)	Regulation	DEA	• Employment • Length of	• Gas Consumption	Country-level Dataof 33	Gas	Downstream

			Bootstrapping	pipelines	• Number of Customers	countries (1998, 1999) Gas Industry		
11	Ismail, Tai, Kong, Law, Shirazi and Karim (2003)	Environmental Efficiency	DEA	• Assets • Employee Numbers	• Revenue	17 Oil Companies (2008)	Oil and Gas	Upstream
12	Kashani (2005)	Regulation	DEA SFA Regression	•Construction Cost • Variable Cost • Water depth • Revenue depth • Number of partners	• Oil Production • Gas Production	66 oil and gas fields, 67 oil fields. United Kingdom. (1974-1991)	Oil and Gas	Upstream
13	Kashani (2005)	State Intervention	DEA SFA Regression	• Construction Cost • Variable Cost• Water depth • Revenue depth • Number of partners	• Oil Production • Gas Production	37 Gas Fields in Norway. (1972-2000)	Oil and Gas	Upstream
14	Managi, Opaluch, Jin and Grigalunas, (2005)	Technology Change	Regression	• Drilling distance per exploratory well • Drilling distance per development well • Total number of exploratory and development wells • Price of oil & gas • Water depth	• Quantity of oil and gas reserves discovered in barrels of oil equivalent	370 Drilling wells in gulf of Mexico-US (1947-1998)	Oil and Gas	Upstream

15	Managi, Opaluch, Jin and Grigalunas (2006)	Technology Change	SFA	• Oil reserves• Water depth • 5 yrs. ex drill mills ratio • Gas reserves	• Porosity	370 Drilling wells in gulf of Mexico-US (1947-1998)	Oil and Gas	Upstream
16	Barros and Assaf (2009)	Bootstrapping	DEA Bootstrapping Bootstrapped truncated regression	•Operational cost • Investment Premium • Taxes	• Gross production	9 Angolan oil Blocks (2002-2007)	Oil	Upstream
17	Barros and Managi (2009)	Growth Accounting vs Productivity Method	DEA	•Operational cost • Investment premium• Taxes	• Gross production	9 Angolan oil blocks (2002-2007)	Oil	Upstream
18	Wolf (2009)	Ownership and efficiency	Regression	• Oil and gas reserves • OPEC membership (Binary) • Total assets • State ownership Percentage • Ratio of oil and gas reserves • Number of employees	• Annual oil and gas production • Revenues • Net income	87 oil firms (1987-2006)	Oil and Gas	Upstream
19	Eller, Hartley and Medlock (2011).	Ownership	DEA SFA	• Oil reserves • Number of employees• Natural gas reserves	• Revenues	78 oil firms (2006)	Oil and Gas	Upstream
20	Francisco ,de Almeida and de Silva (2012)	Environmental Efficiency	DEA	• Amount of water consumed • Percentage of Idleness	• Processed oil • Effluents (Undesirable)	10 Brazilian Refineries (2004)	Oil and Gas	Downstream

					• Age of Refinery (Uncontrollable)			
21	Sueyoshi and Goto (2012)	Conceptual Paper: Environmental Efficiency and Ownership	DEA	• Amount of Oil Reserves • Amount of Gas Reserves • Total operating cost • Number of employees	• Oil Production • Gas Production• CO2 emission (Undesirable)	19 oil firms. (2005-2009)	Oil and Gas	Upstream
22	Sueyoshi and Goto (2012)	Conceptual Paper: Environmental Efficiency and Ownership	DEA	• Amount of Oil Reserves • Amount of Gas Reserves • Total operating cost • Number of employees	• Oil Production• Gas Production • CO2 emission (Undesirable)	19 oil firms. (2005-2009)	Oil and Gas	Upstream
23	Barros and Antunes (2014)	Productivity Change. Malmquist vs Luenberger	Luenberger Productivity Indicator	•Operational cost • Taxes	• Production of oil • Investment premium	9 Angolan oil Blocks (2002-2008)	Oil	Upstream
24	Ike and Lee, H. (2014)	Ownership	DEA Slack Based MPI Regression	• Oil reserves • Gas reserves • Number of employees	• Oil production • Gas Production	38 oil companies (2003-2010)	Oil and Gas	Upstream

APPENDIX C

DESCRIPTIVE STATISTICS BY TIME

		N	Mean	Std. Deviation	Minimum	Maximum	ANOVA F	ANOVA Sig.
Oil Reserves	2000	52	27.55	58.04	0.01	263.50	0.216	0.998
	2001	52	27.91	57.71	0.01	261.70		
	2002	52	28.05	57.70	0.01	261.75		
	2003	52	31.91	61.29	0.01	261.80		
	2004	52	33.11	62.32	0.01	261.90		
	2005	52	33.44	62.44	0.01	261.90		
	2006	52	33.88	63.51	0.01	266.81		
	2007	51	34.85	63.26	0.01	262.30		
	2008	51	35.29	64.16	0.01	266.75		
	2009	52	34.91	63.82	0.01	266.71		
	2010	52	35.26	62.99	0.01	262.40		
	2011	52	37.53	67.02	0.01	262.60		
	2012	49	39.56	71.33	0.01	267.02		
	2013	52	41.33	74.70	0.01	297.57		
	Total	723	33.87	63.28	0.01	297.57		
Gas Reserves	2000	52	106.04	260.35	0.04	1700.00	0.137	1.000
	2001	52	110.27	263.90	0.02	1700.00		
	2002	52	115.42	267.30	0.02	1680.00		
	2003	52	116.63	267.06	0.02	1680.00		
	2004	52	135.44	305.83	0.04	1680.00		
	2005	52	135.01	306.20	0.04	1680.00		
	2006	52	136.56	308.04	0.04	1680.00		
	2007	51	140.24	310.52	0.04	1680.00		
	2008	51	140.68	308.99	0.07	1680.00		
	2009	52	138.72	307.69	0.07	1680.00		
	2010	52	145.75	311.72	0.04	1680.00		
	2011	52	147.21	311.89	0.04	1680.00		
	2012	49	155.20	328.04	0.04	1680.00		
	2013	52	149.12	321.10	0.04	1688.00		
	Total	723	133.63	296.81	0.02	1700.00		
Labour Force	2000	52	14236015.56	24214013.86	303604.00	147134193.00	0.070	1.000
	2001	52	14369218.42	24276345.89	319802.00	148216979.00		
	2002	52	14555641.44	24403122.85	335376.00	149007489.00		
	2003	52	14757966.10	24552424.66	355406.00	149705300.00		
	2004	52	14968418.56	24714179.17	382853.00	150729170.00		
	2005	52	15214033.67	24985272.40	424303.00	152676462.00		
	2006	52	15417363.88	25232314.85	477508.00	154694540.00		
	2007	51	15813970.04	25671774.47	540749.00	155976570.00		
	2008	51	16029800.27	25890710.46	605930.00	157724796.00		
	2009	52	16021090.44	25686856.43	664212.00	157889958.00		
	2010	52	16182553.33	25653982.28	707016.00	157464257.00		
	2011	52	16351310.33	25683846.47	731901.00	157635584.00		
	2012	49	17361678.67	26375113.98	741723.00	158786582.00		
	2013	52	16706223.83	25903640.65	738890.00	159144632.00		
	Total	723	15561972.32	25022196.20	303604.00	159144632.00		

Oil Production	2000	52	1463.53	2376.25	0.39	9475.75	0.120	1.000
	2001	52	1450.19	2344.96	0.33	9156.64		
	2002	52	1420.02	2308.82	0.31	8998.43		
	2003	52	1488.37	2512.56	0.35	10076.81		
	2004	52	1596.69	2658.80	0.25	10796.24		
	2005	52	1646.90	2751.14	0.28	11496.31		
	2006	52	1646.07	2705.06	0.30	11098.44		
	2007	51	1669.42	2695.40	0.28	10748.62		
	2008	51	1721.25	2793.66	0.24	11428.60		
	2009	52	1655.06	2656.51	0.22	10314.71		
	2010	52	1703.70	2779.79	0.22	10908.35		
	2011	52	1714.87	2907.60	0.22	11469.90		
	2012	49	1846.31	3101.30	0.22	11840.68		
	2013	52	1792.97	3095.59	0.21	12342.77		
	Total	723	1628.59	2679.15	0.21	12342.77		
Gas Production	2000	52	1945.14	4385.98	0.46	24174.00	0.155	1.000
	2001	52	1975.79	4411.85	0.57	24501.00		
	2002	52	2001.99	4416.89	0.35	23941.00		
	2003	52	2053.45	4509.73	0.71	24119.00		
	2004	52	2137.78	4572.80	0.71	23970.00		
	2005	52	2216.74	4562.44	0.53	23457.00		
	2006	52	2272.76	4631.64	0.35	23535.00		
	2007	51	2403.20	4771.08	0.35	24664.00		
	2008	51	2485.87	4867.01	0.35	25636.00		
	2009	52	2380.94	4713.91	0.35	26057.00		
	2010	52	2519.17	4988.60	0.25	26836.00		
	2011	52	2599.57	5276.69	0.21	28479.00		
	2012	49	2734.64	5412.11	0.00	29542.00		
	2013	52	2629.20	5359.24	0.00	30005.00		
	Total	723	2309.03	4749.99	0.00	30005.00		

APPENDIX D

SUMMARY OF TUKEY HSD RESULTS

Summary of Tukey HSD Results for FSU

Country	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
Meta Efficiency Scores							
Turkmenistan	14	1.336127					
Belarus	14	2.008064					
Uzbekistan	14	2.718953					
Russia	14	2.900439					
Azerbaijan	14	3.842545					
Kazakhstan	14	4.585289					
Ukraine	14	5.001232					
Kyrgyzstan	14		26.211315				
Georgia	14		26.412623				
Tajikistan	14			73.502855			
Group Efficiency Scores							
Belarus	14	1.124731					
Uzbekistan	14	1.142826					
Turkmenistan	14	1.226900					
Kazakhstan	14	1.305782					
Russia	14	1.326069					
Azerbaijan	14	1.569428					
Ukraine	14	1.645614					
Georgia	14		7.668168				
Kyrgyzstan	14		9.191870	9.191870			
Tajikistan	14			10.217240			
Technological Gap Ratios							
Tajikistan	14	.142701					
Georgia	14		.291215				
Kazakhstan	14		.310537				
Ukraine	14		.328497				
Kyrgyzstan	14		.354955	.354955			
Uzbekistan	14			.425406	.425406		
Russia	14				.456646		
Azerbaijan	14				.485949	.485949	
Belarus	14					.562084	
Turkmenistan	14						.926923

Summary of Tukey HSD Results for IEA States

Country	N	Subset for alpha = 0.05								
		1	2	3	4	5	6	7	8	9
Meta Efficiency Scores										
Norway	14	1.26								
France	14	1.29	1.29							
Netherlands	14	1.32	1.32							
Denmark	14	1.33	1.33							
Japan	14	1.39	1.39	1.39						
US	14	1.47	1.47	1.47						
Canada	14	1.47	1.47	1.47						
UK	14	1.48	1.48	1.48						
NZ	14	1.82	1.82	1.82	1.82					
Greece	14	1.90	1.90	1.90	1.90					
Hungary	14		1.95	1.95	1.95	1.95				
Czech Republic	14			2.07	2.07	2.07				
Austria	14				2.38	2.38	2.38			
Slovakia	14				2.46	2.46	2.46	2.46		
Spain	14				2.48	2.48	2.48	2.48		
Turkey	14					2.62	2.62	2.62		
Australia	14					2.63	2.63	2.63		
Germany	14						3.01	3.01		
Italy	14							3.07		
Group Efficiency Scores										
UK	14	1.15								
Netherlands	14	1.16								
Canada	14	1.16								
Norway	14	1.16								
France	14	1.17								
Denmark	14	1.19	1.19							
Japan	14	1.28	1.28	1.28						
US	14	1.30	1.30	1.30						
NZ	14	1.33	1.33	1.33						
Spain	14	1.39	1.39	1.39	1.39					
Turkey	14	1.54	1.54	1.54	1.54					
Greece	14		1.77	1.77	1.77	1.77				
Hungary	14			1.79	1.79	1.79	1.79			
Czech Republic	14				1.97	1.97	1.97	1.97		
Austria	14					2.26	2.26	2.26	2.26	
Slovakia	14						2.38	2.38	2.38	
Germany	14							2.40	2.40	
Australia	14							2.47	2.47	
Italy	14								2.77	
Poland	14									3.59
Technological Gap Ratios										
Spain	14	0.58								
Turkey	14	0.59								
NZ	14		0.76							

UK	14		0.78							
Canada	14		0.80	0.80						
Germany	14		0.80	0.80	0.80					
US	14			0.88	0.88	0.88				
Netherlands	14				0.88	0.88				
France	14					0.90	0.90			
Poland	14					0.90	0.90			
Italy	14					0.91	0.91			
Denmark	14					0.91	0.91			
Hungary	14					0.92	0.92			
Japan	14					0.92	0.92			
Norway	14					0.93	0.93			
Greece	14					0.93	0.93			
Australia	14					0.95	0.95			
Austria	14					0.95	0.95			
Czech Republic	14					0.95	0.95			
Slovakia	14						0.97			

Summary of Tukey HSD Results for OAPEC

Country	**N**	**Subset for alpha = 0.05**					
		1	**2**	**3**	**4**	**5**	**6**
Meta Efficiency Scores							
Kuwait	14	1.200795					
Qatar	14	1.281469					
Bahrain	14	1.308595					
Saudi Arabia	14	1.419018	1.419018				
Algeria	14	2.497571	2.497571	2.497571			
Tunisia	13		2.689048	2.689048			
Libya	13		2.708792	2.708792			
Syria	14			3.020070	3.020070		
Egypt	14			3.624552	3.624552		
Iraq	14				4.319599		
Group Efficiency Scores							
Saudi Arabia	14	1.095871					
Kuwait	14	1.132239					
Bahrain	14	1.142174					
Algeria	14	1.163587					
Qatar	14	1.172159					
Tunisia	13	1.250483					
Libya	13	1.441912	1.441912				
Syria	14	1.616586	1.616586				
Egypt	14		1.929254	1.929254			
Iraq	14			2.468775			
Technological Gap Ratios							
Tunisia	13	.464449					
Algeria	14	.466356					
Egypt	14		.526895				

Libya	13		.527096				
Syria	14		.567047	.567047			
Iraq	14			.572819			
Saudi Arabia	14				.777449		
Bahrain	14					.873982	
Qatar	14						.916989
Kuwait	14						.944147

Summary of Tukey HSD Results for OPEC

Country	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
Meta Efficiency Scores								
Kuwait	14	1.2008						
Qatar	14	1.2815	1.2815					
Saudi Arabia	14	1.4190	1.4190					
Ecuador	12	1.4951	1.4951					
Angola	14	1.5313	1.5313	1.5313				
UAE	14		2.2333	2.2333	2.2333			
Algeria	14			2.4976	2.4976			
Libya	13				2.7088			
Iraq	14					4.3196		
Venezuela	14						5.4929	
Nigeria	14						5.6513	
Iran	14							8.4099
Group Efficiency Scores								
Algeria	14	1.0824						
Saudi Arabia	14	1.0943						
Kuwait	14	1.1304						
Qatar	14	1.1929						
Angola	14	1.1953						
UAE	14	1.2031						
Ecuador	12	1.2042						
Libya	13	1.3733						
Venezuela	14		2.0420					
Iran	14			2.5250				
Iraq	14			2.7189				
Nigeria	14				3.3197			
Technological Gap Ratios								
Iran	14	0.3043						
Venezuela	14		0.3740					
Algeria	14		0.4351					
Libya	13			0.5189				
UAE	14			0.5835	0.5835			
Nigeria	14				0.5895			
Iraq	14				0.6331			
Saudi Arabia	14					0.7762		
Angola	14					0.7811		

Ecuador	12					0.8092		
Qatar	14						0.9292	
Kuwait	14						0.9427	

APPENDIX E

QUARTILE ANALYSIS OF METAFRONTIER SCORES

Country	IGO	Meta Efficiencies	Group Efficiencies	TGR	Rank	Quartile
Slovakia	IEA	2.2430	2.1672	0.9662	1	1st
Czech Republic	IEA	1.8292	1.9230	0.9512	2	1st
Austria	IEA	2.3571	2.2408	0.9506	3	1st
Australia	IEA	2.5025	2.3667	0.9457	4	1st
Kuwait	OAPEC	1.1972	1.1299	0.9438	5	1st
Kuwait	OPEC	1.1972	1.1282	0.9424	6	1st
Greece	IEA	1.8586	1.7283	0.9299	7	1st
Qatar	OPEC	1.2729	1.1826	0.9290	8	1st
Norway	IEA	1.2524	1.1629	0.9285	9	1st
Turkmenistan	FSU	1.3249	1.2247	0.9244	10	1st
Japan	IEA	1.3818	1.2702	0.9192	11	1st
Qatar	OAPEC	1.2729	1.1669	0.9167	12	1st
Hungary	IEA	1.8614	1.7059	0.9165	13	1st
Italy	IEA	3.0119	2.7236	0.9043	14	2nd
France	IEA	1.2901	1.1651	0.9031	15	2nd
Denmark	IEA	1.3178	1.1886	0.9020	16	2nd
Poland	IEA	3.9728	3.5796	0.9010	17	2nd
Netherlands	IEA	1.3123	1.1573	0.8819	18	2nd
US	IEA	1.4600	1.2827	0.8786	19	2nd
Bahrain	OAPEC	1.3046	1.1399	0.8738	20	2nd
Ecuador	OPEC	1.4769	1.1941	0.8085	21	2nd
Germany	IEA	2.9925	2.3907	0.7989	22	2nd
Canada	IEA	1.4636	1.1617	0.7938	23	2nd
Angola	OPEC	1.5269	1.1925	0.7810	24	2nd
Saudi Arabia	OAPEC	1.4135	1.0949	0.7746	25	2nd
Saudi Arabia	OPEC	1.4135	1.0934	0.7735	26	2nd
UK	IEA	1.4797	1.1413	0.7713	27	3rd
NZ	IEA	1.7235	1.2943	0.7510	28	3rd
Iraq	OPEC	4.2290	2.6755	0.6326	29	3rd
Nigeria	OPEC	5.5772	3.2812	0.5883	30	3rd
Turkey	IEA	2.5924	1.5230	0.5875	31	3rd
Iraq	OAPEC	4.2290	2.4220	0.5727	32	3rd
Spain	IEA	2.4080	1.3765	0.5716	33	3rd
UAE	OPEC	2.1083	1.1957	0.5671	34	3rd
Syria	OAPEC	2.5099	1.4184	0.5651	35	3rd
Belarus	FSU	2.0023	1.1233	0.5610	36	3rd
Libya	OAPEC	2.4402	1.2840	0.5262	37	3rd
Egypt	OAPEC	3.5822	1.8823	0.5255	38	3rd
Libya	OPEC	2.4402	1.2646	0.5182	39	3rd
Algeria	OAPEC	2.4920	1.1606	0.4657	40	4th
Tunisia	OAPEC	2.6699	1.2394	0.4642	41	4th

Russia	FSU	2.8920	1.3199	0.4564	42	4th
Azerbaijan	FSU	3.2583	1.4763	0.4531	43	4th
Algeria	OPEC	2.4920	1.0820	0.4342	44	4th
Uzbekistan	FSU	2.7007	1.1421	0.4229	45	4th
Venezuela	OPEC	5.4166	2.0236	0.3736	46	4th
Kyrgyzstan	FSU	24.6788	8.7513	0.3546	47	4th
Ukraine	FSU	4.9945	1.6374	0.3278	48	4th
Iran	OPEC	8.3536	2.5220	0.3019	49	4th
Kazakhstan	FSU	4.3545	1.3011	0.2988	50	4th
Georgia	FSU	24.7591	7.2097	0.2912	51	4th
Tajikistan	FSU	68.0373	9.6844	0.1423	52	4th