International Journal of Energy Sector Management

Inter-group performance of oil producing countries: a meta and global frontier analysis

Kwaku Ohene-Asare, Victor Sosu Gakpey, Charles Turkson,

Inter-group performance of oil producing countries: a meta and global frontier analysis

Kwaku Ohene-Asare
Department of Operations and Management Information Systems, University of Ghana Business School, Legon, Ghana

Victor Sosu Gakpey
Airport Operations, Ghana Airports Company Limited, Accra, Ghana, and

Charles Turkson
Department of Operations and Management Information Systems, University of Ghana Business School, Legon, Ghana

Abstract

Purpose – The purpose of this study is to compare the production efficiencies and frontiers differences of oil-producing countries (OPCs) in four inter-governmental organizations (IGOs) in the international petroleum industry with the aim of providing such countries understanding of group characteristics that help maximize their supply interests.

Design/methodology/approach – The empirical analysis is based on 14 years of panel data covering the period from 2000 to 2013. In all 46 unique countries who are members of four IGOs relevant to the international petroleum industry are examined on individual and group bases. The authors use both metafrontier analysis and global frontier difference in examining the group average and group frontiers, respectively.

Findings – Groups with high inter and intra-group collaborations which ensure exchange of information, organizational learning and innovation tend to do better than groups with even higher hydro-carbon endowment. Additionally, hydro-carbon resource endowment may not be the solution to group inefficiency without higher endowment in human capital, economic stability, technology and infrastructure.

Practical implications – Choice of inter-governmental organizational membership should be based on the level of inter- and intra-group collaborations, human capital endowment among others and not mere historic links or even resource endowment.

Originality/value – This is among the few studies to compare and rank IGOs. Specifically, it is among the first studies to analyze the petroleum production efficiencies of IGOs involved in the international petroleum industry. This study assesses the performance differences among OPCs with the aim of identifying for OPCs the characteristics of inter-governmental groups that are beneficial to efficiency in upstream petroleum activities.

Keywords Data envelopment analysis, Petroleum products, Global frontier differences, Intergovernmental organizations, Technology gap ratios

Paper type Research paper

International Journal of Energy Sector Management
Vol. 12 No. 3, 2018
pp. 426-448

1750-6220
DOI 10.1108/IJESM-07-2017-0006

1. Introduction

The oil and gas industry plays an important role in the economic growth and development of most economies and have become an integral part of global economic life (Kashani, 2005; Barros and Assaf, 2009; Murphy and Hall, 2011; Ramachandra *et al.*, 2005). The sector supports such industries as energy, transportation, industrialized agriculture, steel and plastic pipe production, health care and chemical industries that generate income and employment (Francisco *et al.*, 2012; Ismail *et al.*, 2013). The importance of oil and gas means oil-producing countries (OPCs) play crucial roles in the supply of crude oil and natural gas (Managi *et al.*, 2006). OPCs, through the production and export of oil and gas, hold substantial amount of the world petroleum reserves, production and marketing (Ike and Lee, 2014). Out of the 1,492,164 million barrels of world-proven crude oil reserves in 2016, for example, 81.5 per cent was owned by Organization of the Petroleum Exporting Countries (OPEC) member states alone (OPEC, 2017).

At the forefront of the state involvement in the industry are inter-governmental organizations (IGOs) which are coalitions of countries aimed at improving the bargaining power of member countries. In the industry, IGOs like the OPEC, Organization of Arab Petroleum Exporting Countries (OAPEC) and International Energy Agency (IEA) are influential in forging global policy pertaining to the industry. Though these IGOs are influential parties, few studies have assessed the performance of IGOs in terms of petroleum supply (Dike, 2013; Ike and Lee, 2014; Ramcharran, 2002), as well as with the consideration that OPCs in different groups may not have the same production technologies in petroleum production and exploration and hence may not be easily comparable. Productive efficiencies of different OPCs may not be comparable because of differences in production opportunities as a result of membership of different IGOs. Group policies and restrictions, like production quotas, differences in stock of human, physical or financial capital, as well as differences in economic infrastructure and resource endowment, have the potential of affecting efficiencies of member states (Ike and Lee, 2014; O'Donnell *et al.*, 2008).

Even in the general literature on IGOs, not necessarily in the petroleum industry, most studies on IGOs concentrate on one particular IGO in their assessment. Taylor *et al.* (2010), Shahabinejad *et al.* (2013), Muldoon *et al.* (2011) and Gorton and Davidova (2004) have concentrated on intra-group performance assessment considering efficiency only in that particular IGO of interest. A few studies like those of Abu-Alkheil *et al.* (2012), Drakos (2003) and 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 have been little inter-group comparison to identify and rank IGOs with respect to a particular phenomenon under study. There is therefore room for this study to build literature by conducting an inter-group performance assessment which is lacking in literature. We do not yet know what kinds of IGOs thrive in the oil and gas industry and why they do.

This study contributes to the oil and gas efficiency literature by examining performance differences between different IGOs in petroleum supply. It examines differences in the production opportunities available to OPCs in different IGOs with the aim of identifying whether membership of particular groups provide some advantages over others. This is done by assessing inter-group meta-efficiency, technology gap ratios (TGR) and frontier differences of OPCs using a bootstrap-based data envelopment analysis (DEA) (Charnes *et al.*, 1978) based on metafrontier analysis (Battese *et al.*, 2004; O'Donnell *et al.*, 2008) and the global frontier differences – GFD (Asmild and Tam, 2007). Next, for robustness check, the study tests the differences in the distribution of meta-efficiency levels and frontier estimates (Li, 1996; Simar and Zelenyuk, 2006). The rest of the study is organized as follows: Section 2 presents theoretical and empirical literature, this is followed by Section 3 which is dedicated to the methods and data from which findings are presented in Section 4. Section 5 is for discussions and conclusions. It makes policy prescriptions on the essence of inter and intra group collaborations in enhancing productive efficiencies of member states.

2. Literature review

2.1 Theories on inter-group performance

The theories on inter-group performance help explain why the performance of different blocs of countries may differ. Two main theoretical views are used to explain inter-group performance. These are the game theory (Von Neumann and Morgenstern, 1944) and resource-based theory (RBT) (Penrose, 1959).

2.1.1 Game theory. The theory explains decisions individuals or a group of players take to win a game when competing with one or more opponents (Von Neumann and 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 taken 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-theoretic 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 *et al.*, 2012; Yin *et al.*, 2012). In other words, game theory studies games that are mathematical models of relationships and interactions among multiple players, each trying to advance their self-interest by choosing among a set of strategies (Yin *et al.*, 2012; Weibull, 1997).

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

The theoretical views of game theorists are therefore very important in assessing and understanding the competition and collaboration between various IGOs in the international petroleum industry. IGOs use 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.

Table I. Outcomes of inter and intra group collaboration

Intra-group collaboration	Inter-group collaboration: Low		Inter-group collaboration: High	
Low	Low exchange of information within and between groups results in: Organizational learning not supported Information asymmetries not addressed	I	Low exchange of information within group renders between group collaboration irrelevant leading to: Organizational learning not supported Information asymmetries not addressed	II
High	High exchange of information within group but low exchange between group results in: Organizational learning/innovation Information asymmetries not addressed	III	High exchange of information within and between group results in: Organizational learning/innovation Information asymmetries addressed	IV

Source: Adapted from Rigby *et al.* (2013)

2.1.2 Resource-based theory. RBT studies the differences in outcomes in respect of resources owned (Peteraf and Barney, 2003). Theory defines the organization's uniqueness and position in competitive situations in the environment (Hoopes *et al.*, 2003). Its emphasis is on differences in efficiency (Peteraf and 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; Wernerfelt, 1984; Miles, 2012). The RBT of strategy (RBT) hinges on the argument that entities with valuable, rare, special and inimitable resources have the potential of achieving superior performance (Wiklund and Shepherd, 2003; Bharadwaj, 2000; Barney, 1991; Barney, 1995; Amit and Schoemaker, 2012). RBT uses the internal characteristics and resources of entities to explain their heterogeneity in strategy and performance (Camisón and Villar-López, 2014). Basically, RBT assumes that there are underlying production heterogeneities or differences across entities (Dobbin and Baum, 2000; Peteraf, 1993; Barney, 1991).

Thus, production processes and resources are different from a group to another group. Therefore, entities 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 entities of varying capabilities are able to compete in the same marketplace and, at least, breakeven (Dobbin and Baum, 2000; Peteraf, 1993). Accordingly, the main assumption of RBT is that only entities with certain resources and capabilities with special characteristics will gain competitive advantage and, therefore, achieve superior performance (Camisón and Villar-López, 2014). 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 petroleum industry. Size of oil and gas reserves; human, technical and technological competencies of member states; and 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 Efficiency in the petroleum industry

There has been quite a number of efficiency-related research in the petroleum industry, substantially among the issues of ownership (Ike and Lee, 2014; Wolf, 2009; Ohene-Asare *et al.*, 2017), privatization (Hawdon, 2003; Kashani, 2005) and environmental efficiency (Ismail *et al.*, 2013; Sueyoshi and Goto, 2012). Additionally, as 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. Kim *et al.* (1999) and Hawdon (2003) have all attempted such comparison, except that these studies focused on gas distribution to the neglect of crude oil. Similarly, these papers that have attempted international comparison only focused on the downstream activities of the industry. Although the body of literature in the petroleum industry is substantial, there 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 include Hawdon (2003) who analyzed the efficiency of the gas industry of 33 countries and Kim *et al.* (1999) who examined 28 natural gas transmission and distribution companies operating in eight countries.

2.3 Group performance and efficiency

Studies regarding group performance and efficiency of IGOs have been heavily skewed toward banking, energy efficiency and health. For example, whereas Abu-Alkheil *et al.* (2012) concentrated on bank efficiency of OAPEC and Gulf Cooperation Countries (GCC), Marius Andrieş and Căpraru (2012), Casu and Molyneux (2003), Claeys and Vander Vennet (2008) and Košak *et al.* (2009) 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 Former Soviet Union (FSU) and Central and Eastern European (CEE) countries. Just like banking, several studies can be cited for energy efficiency (Adetutu, 2014; Al-Rashed and León, 2015; Goldthau and Witte, 2011; Filippini and Hunt, 2011) and health (Adler-Milstein *et al.*, 2014; Retzlaff-Roberts *et al.*, 2004; Oderkirk *et al.*, 2013; Al-Essa *et al.*, 2015). Other research issues like education (Afonso and St Aubyn, 2005; Afonso and St. Aubyn, 2006), agriculture, (Vlontzos *et al.*, 2014; Gorton and Davidova, 2004), insurance (Donni and Fecher, 1997), railways (Oum and Yu, 1994), postal service, environment and policy (Selowsky and Martin, 1997) have also been considered by other studies.

Although these studies have recorded differences in the level of efficiency of individual members of various IGOs (Vlontzos *et al.*, 2014; Oderkirk *et al.*, 2013), together, 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 that purposely targeted energy-focused IGOs like OPEC, OAPEC and IEA (Adetutu, 2014; Al-Rashed and León, 2015; Behname, 2012; Goldthau and Witte, 2011) rather looked at issues like banking efficiency and energy 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 petroleum industry. It is also evident in literature that most studies on IGOs concentrate on one particular IGO in their assessment, thus concentrating on intra-group performance (Taylor *et al.*, 2010; Gorton and Davidova, 2004). A few studies like those of Abu-Alkheil *et al.* (2012), Aristovnik (2012), Selowsky and Martin (1997) and Drakos (2003) 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 under study. There is therefore room for this study to build literature in conducting an inter-group performance comparison.

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 Organization for Economic Corporation and Development (OECD) countries from 1963 to 1992. Regression-based estimation approaches like the Translog Cost Function (Adetutu, 2014; Claeys and Vander Vennet, 2008) and Auto Regressive Distributed Lag (Sari and 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 26 OECD countries from 1980 to 2008. Their paper does not conduct inter-IGO comparison, as the focus was only on OECD. Most of the reviewed literature used in this study have applied a number of models, some in combination to estimate efficiency of groups or IGOs; however, there is rare evidence regarding global frontier or metafrontier 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.

3. Methods and data

In this section, we present our methods used in making deductions about inter-group performance differences among IGOs in the production and supply of petroleum resources. We primarily use DEA-based metafrontier and global frontier analysis which are subsequently discussed in the subsections. We present in Figure 1 a summary of the analysis process

The first step is the data, the input and output variables that are used to model the production processes of these OPCs and which will be the basis for the comparison. We present the variables used and the OPCs in 3.4.2 and 3.4.3. In all, three input variables and two output variables on each of the 46 unique OPCs that belong to the four IGOs are gathered for the purpose of this study. The next step is the metafrontier analysis. This is presented in Section 3.1. It involves three main steps. First the efficiencies of all OPCs are estimated based on a pooled frontier that does not distinguish between the groups: this is the meta efficiency scores. The second step is to separate the OPCs into their unique groups and group efficiencies computed for each OPC. The ratio of the meta efficiency scores to the group efficiency scores is the Technology Gap Ratio which measures the similarity between group performance and best practice frontiers in the industry. The meta efficiency scores and Technology Gap Ratios of the various IGOs are compared statistically to see if differences exist.

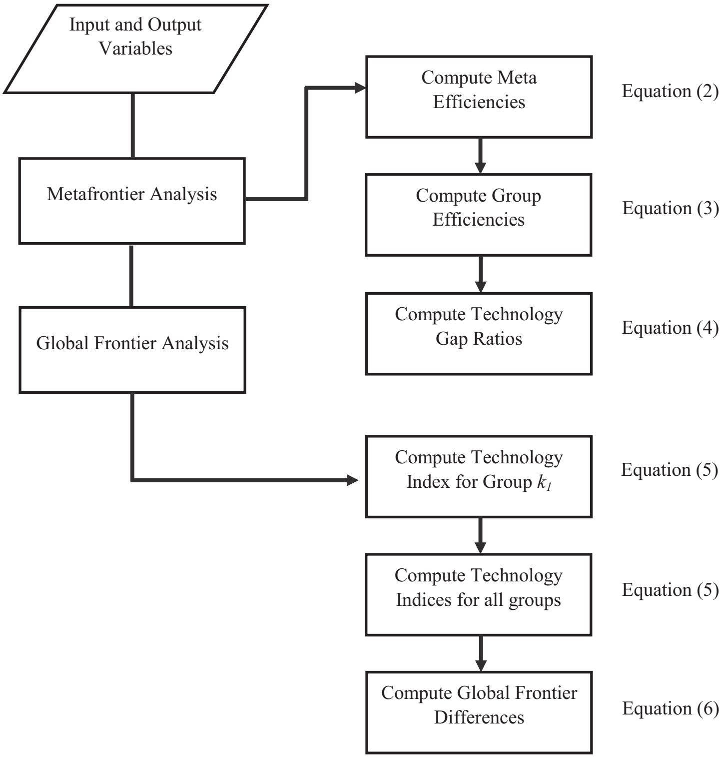

Figure 1.
Summary of analysis process

The next process is the global frontier analysis which is presented in section 3.2. While the metafrontier analysis allows for the examination of the average technology gap ratios at the state level, the GFDs allow for examining differences in production possibility frontiers at the group level. With this, efficiencies of all OPCs irrespective of group is computed relative to the frontier of only one group k. The geometric mean of this score becomes the Technology Index for that group k. This process is repeated for all K groups. The GFD between group k_1 and k_2 is the ratio of the technology indices (TIs) of these two groups.

3.1 Metafrontier analysis

Metafrontier analysis in DEA, attributed to the works of Battese *et al.* (2004), O'Donnell *et al.* (2008), allows for comparison across heterogeneous groups (Battese and Rao, 2002; O'Donnell *et al.*, 2008). This involves the measurement of efficiency scores for individual groups (group efficiency), as well as for the entire dataset irrespective of group (meta-efficiency). Therefore, on the assumption that N countries produce m non-negative outputs $\left(\text{denoted by } y \in \Re_{+}^{m}\right)$, using s non-negative inputs $\left(\text{denoted by } x \in \Re_{+}^{s}\right)$, the production possibility set can be defined as:

$$T = \{(x, y) \in \Re_{+}^{m+s} | x \text{ can produce } y\} \tag{1}$$

Now, based on the assumptions of DEA, such as ray unboundedness, monotonicity and convexity, the CRS output-oriented Farrell (1957) technical efficiency score, $TE_0\ (x, y)$, of a given OPC (x_0, y_0) relative to metafrontier can be computed by solving the following linear programming problem:

$$TE_0^M(x,y) = \text{Max}\left\{\varphi_0^M(x,y)\ \middle|\ \begin{array}{ll} \sum_{j=1}^{N} \lambda_j x_{ij} \le x_{i0} & \forall i = 1, 2, \ldots, s \\ \sum_{j=1}^{N} \lambda_j y_{rj} \ge \varphi\, y_{r0} & \forall r = 1, 2, \ldots, m \\ \lambda_j \ge 0 & j = 1, 2, \ldots, N \end{array}\right. \tag{2}$$

Therefore, $TE_0^M(x,y)$ is the output-oriented efficiency score that measures the proportional increment in the output of a DMU necessary to be efficient given the level of input. For output-orientation, an OPC is considered inefficient if $TE_0^M(x,y) > 1$, but it is considered efficient if and only if $TE_0^M(x,y) = 1$ (Fare *et al.*, 1994). However, because of the existence of sub-groups K in the meta-technology and the possibility of technological heterogeneities across groups, k group-specific technical efficiency, $TE_0^k(x,y)$, can be formulated for each OPC relative to its group frontier. This is defined in equation (3) as:

$$TE_0^k(x,y) = \text{Max}\left\{\varphi_0^k(x,y)\ \middle|\ \begin{array}{l} \sum_{j=1}^{n_k} \lambda_j^k x_{ij}^k \le x_{i0} \qquad \forall i = 1, 2, \ldots, s \\ \sum_{j=1}^{n_k} \lambda_j^k y_{rj}^k \ge \varphi\, y_{r0} \qquad \forall r = 1, 2, \ldots, m \\ \lambda_j^k \ge 0; \quad j = 1, 2, \ldots, n_k; \quad k = 1, 2, \ldots, K \end{array}\right. \tag{3}$$

Based on the meta-efficiency and the group efficiency scores, a technology gap ratio of OPC_o in group k can be computed as the ratio of $TE_0^M(x,y)$ to $TE_0^k(x,y)$.

$$\mathrm{TGR}_0^k(x,y) = \frac{TE_0^M(x,y)}{TE_0^k(x,y)} \tag{4}$$

This measure, which takes values between zero and unity, measures the diversion from the available technology, irrespective of group because of membership of the particular group *k*.

3.2 Global frontier analysis

The GFDs 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 and Tam, 2007). This examines the overall rather than the individual changes in the frontier of various groups (Asmild *et al.*, 2013). This means that this model can draw conclusions about performance differences for the entire sample. It is better, as 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 GFDs, 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 countries relative to the frontier of a particular group *k*. This is defined as:

$$\mathrm{TI}^k(x_j,y_j) = \left(\prod_{\substack{j=1,\ldots,N\\ k=1,\ldots,K}} TE^k\left(x_j^K,y_j^K\right)\right)^{1/N} \tag{5}$$

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

$$\mathrm{GFD}^{k_1,k_2} = \frac{\mathrm{TI}^{k_2}(x_j,y_j)}{\mathrm{TI}^{k_1}(x_j,y_j)} = \frac{\left(\prod_{\substack{j=1,\ldots,N\\ k=1,\ldots,K}} TE^{k_2}\left(x_j^K,y_j^K\right)\right)^{1/N}}{\left(\prod_{\substack{j=1,\ldots,N\\ k=1,\ldots,K}} TE^{k_1}\left(x_j^K,y_j^K\right)\right)^{1/N}} \tag{6}$$

This is the ratio of the geometric mean of the efficiencies of all countries relative to k_2 frontier to the geometric mean of the efficiencies of all countries relative to k_1 frontier. The efficiency scores are computed using similar model formulation to that already presented in equation (2). The GFD $>$ 1 indicate that Group 1 frontier is on average better that Group 2 frontier. When GFD = 1 then Group 1 frontier is not better than Group 2 frontier. Finally, if GFD $<$ 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 GFD is preferred.

3.3 Testing of differences in the distribution of efficiency scores

The study uses the Simar–Zelenyuk-adapted Li test (SZAL) to statistically explore differences in the distribution of efficiency or frontier estimates between different IGOs in the oil and gas industry (Li, 1996; Simar and 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 (Simar and Zelenyuk, 2006) and is very useful since there are 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 $\{TE^{B,j} : j = 1,\ldots, N\}$ represent 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:

$$\begin{aligned} H_0 &: f_A(TE^A) = f_B(TE^B) \\ H_a &: f_A(TE^A) \neq f_B(TE^B) \end{aligned} \tag{7}$$

The null hypothesizes the existence of equal distribution of scores across the two groups. The alternate hypothesis expects there to be significant differences in the distribution of scores across the two groups. It should be noted that this test is a pairwise test. 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. A bootstrap algorithm is used to generate p-values for this test based on the empirical distribution of scores. This bootstrap algorithm, as well as the test statistic of the Simar–Zelenyuk-adapted Li-test, can be seen by reference to Kenjegalieva *et al.* (2009), Simar and Zelenyuk (2006).

3.4 Data description

3.4.1 Inter-governmental organizations. Intergovernmental organizations 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 and Ward, 2008; Holland, 1998). 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 toward the petroleum industry. In this study, we focus on four IGOs, three of which are at the forefront of forging global policy. These are OPEC, OAPEC and IEA. The FSU is also included in this study to capture the dynamics of such IGOs without clear collaboration and formality in organization.

OPEC is a permanent intergovernmental organization headquartered in Vienna, Austria (OPEC, 2012). Currently, OPEC comprises 14 members (OPEC, 2018) with their main objective to co-ordinate and unify petroleum policies among member countries to secure fair and stable prices for petroleum producers (OPEC, 2012; Fuinhas *et al.*, 2015). The organization aims to ensure an efficient, economic and regular supply of petroleum to consuming nations; and a fair return on capital to those investing in the industry (OPEC, 2012). The organization phases a challenge of member states not respecting the output policies established (Goldthau and 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).

OAPEC is a regional IGO concerned with the development of the petroleum industry by fostering cooperation among its members (OAPEC, 2015). Membership comprises 11 Arab oil exporting countries. 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 petroleum 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 IEA was established as an autonomous organization of the OECD after an agreement of the International Energy Program in 1974 with membership of 16 countries and its secretariat in Paris (Colgan *et al.*, 2012). Currently, IEA membership stands at 29. 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 in oil supply through the release of emergency oil stocks to the markets (IEA, 2014). The IEA works with other international organizations and forums in the energy field. It engages in active discussions with producer countries and other IGOs in the oil and gas industry particularly at the International Energy Forum (IEA, 2014). In addition, the IEA collaborates with the International Renewable Energy Agency 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.

The post-Soviet states, also collectively known as the FSU, are the 15 independent states that emerged from the Union of Soviet Socialist Republic in its dissolution in December 1991 (Minescu *et al.*, 2008). The dissolution of the Soviet Union took place as a result of general economic stagnation, even regressing the inter-republic economic connections, leading to even more serious breakdown of the post-Soviet economies (Easterly and Fischer, 1994). Although the FSU is not a traditional IGO like OPEC 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; Bhattacharyya, 2007). 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 US energy information administration (EIA) recognize their influence in their annual statistical reports.

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 and Bauer, 2004).

3.4.2 Inputs and outputs. Three inputs and two outputs are selected for the efficiency estimation process. Oil reserves, gas reserves and total labor force employed were chosen as inputs to generate natural resources of oil and gas. Choice of these variables was motivated by previous literature that has considered reserves, labor and production levels as a good representation of the production process in the upstream petroleum industry (Eller *et al.*, 2011; Ohene-Asare *et al.*, 2017; Kashani, 2005). The two outputs, oil and gas production are physically generated from the oil and gas reserves using human resources. These variables are selected because the issue under consideration is how OPCs are achieving maximum outputs obtainable given their available inputs. 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 OPCs.

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 resources are converted into outputs that generate significant revenue (Wolf, 2009). 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). Finally, labor is a critical resource in the production process. It is a key factor of production in production theory. The petroleum industry is both labor- and capital-intensive process. These variables were sourced from the US EIA and the World Development Indicators database of World Bank. The labor force is estimated as the labor force of a country as a proportion of the contribution of the industry to Gross Domestic Product.

3.4.3 Data. In all, 53 OPCs across the period from 2000 to 2013 are used to draw inferences. All 12 members of OPEC as at the study period, 20 of the 29 members of IEA, 10 of the 15 members of FSU and all 11 members of OAPEC qualified for the study. They were selected because of data availability for both oil and natural gas operations. A few members of IEA and FSU were either exclusively oil producing or natural gas extracting not both. We focused on OPCs with both oil and gas operations. Additionally, seven members of OPEC were also members of OAPEC, therefore, if the duplicates are corrected the effective number of IGOs becomes 46 unique countries. After data cleaning because of missing data, 737 observations were useful. Descriptive statistics and correlations of the pooled dataset are presented in Table II.

From Table II, all inputs from the table are positively and significantly associated with both outputs. Correlations between inputs and outputs are significant at the 1 per cent level therefore the isotonicity property of DEA which requires that an output should not decrease with an input increase (Dyson *et al.*, 2001; Honma and Hu, 2008; Wanke *et al.*, 2015) is not violated. The intuition for the positive associations is that employing more inputs is expected to lead to higher production levels. Finally, there are relatively weaker correlations among the inputs. Even the correlation between the oil reserves and labor force is not statistically significant (r = -0.032, $p > 0.05$). The weak correlations among the inputs is also an encouraging sign in DEA estimations, as 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. Also, test of the returns to scale property of the production frontier using the mean of ratios as proposed by Simar and Wilson (2002) revealed that the production frontier exhibits constant returns to scale for all 14 years.

Variable	Symbol	Mean	SD	$y1$	$y2$	$x1$	$x2$	$x3$
Oil produced	y_1	1628.59	2679.15	1				
Gas produced	y_2	2309.03	4749.99	0.673**	1			
Oil reserves	x_1	33.87	63.28	0.749**	0.157**	1		
Gas reserves	x_2	133.63	296.81	0.526**	0.618**	0.261**	1	
Labor force	x_3	15561972	25022196	0.435**	0.764**	−0.032	0.280**	1

Note: $^{**}p < 0.01$

Table II.
Descriptive statistics and correlations between inputs and outputs

4. Findings

4.1 Metafrontier analysis

Starting with the metafrontier analysis, the average meta-efficiency, group-efficiencies and TGRs of OPCs in each IGO are presented and ranked in Table III. IGOs are ranked based on their TGRs to identify the best performing ones in order of importance. As 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 and Dermine, 2003; Dietsch and Lozano-Vivas, 2000). It can however be noted that, whereas OAPEC member states are on average producing at about 75 per cent (1/1.3332 = 0.75) of their potential capacity, FSU states are only producing at 44 per cent (1/2.2928 = 0.44) of their potential production capacity. IEA and OPEC states are producing at 61 and 66 per cent of their potential production capacities respectively.

Meta-efficiencies are quite high indicating more inefficiencies, as most scores are away from the efficiency score of 1. IEA (1.9163) is the only IGO with an average meta-efficiency score that is quite similar to their average group efficiency score. The differences between the average 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 average 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 is 0.8486. 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 0.3817 of the state of knowledge available in the international petroleum industry. Also, the TGRs of all IGOs except FSU (0.3817) are above 0.6057. This means that, given the inputs, IEA is producing at 84.86 per cent close to the available state of production technology in the international petroleum industry. OAPEC and OPEC are producing at 63.27 and 60.57 per cent respectively.

What is not obvious in these inter-group comparisons 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 IV. The performances of the four IGOs are first compared using traditional point estimate 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. While these tests are well known, it only compare point estimates and neglect the distribution of the entire dataset (Li, 1996; Simar and Zelenyuk, 2006). To cater for this weakness, the SZAL test, which uses kernel density estimators to compare the distribution of the scores are also used here.

The first pairwise comparison is between the scores of FSU and IEA. This is a comparison of the two extremes, as previous results from Table III revealed that FSU has the highest meta-inefficiency scores of 6.0071 and lowest TGR of 0.3817, while IEA had the best meta-efficiency score and TGR of 1.9163 and 0.8486, respectively. Statistical comparisons for all three tests reveal significant differences in the meta-efficiencies and TGRs of FSU and IEA at the 0.1 per cent significance level. IEA member states significantly

IGO	Meta efficiencies	Group efficiencies	TGR	Rank
FSU	6.0071	2.2928	0.3817	4
IEA	1.9163	1.6262	0.8486	1
OAPEC	2.1071	1.3332	0.6327	2
OPEC	2.5092	1.5197	0.6057	3

Table III. Inter-IGO metafrontier results

Table IV. Pairwise comparisons of inter-IGO performance

IGOs	Index	*t*-test	Mann–Whitney	SZAL
FSU - IEA	Meta Eff.	6.28 (0.000)***	31737 (0.000)***	27.47 (0.000)***
	TGR	−22.01 (0.000)***	3064 (0.000)***	66.89 (0.000)***
FSU – OAPEC	Meta Eff.	6.12 (0.000)***	16437 (0.000)***	16.13 (0.000)***
	TGR	−9.83 (0.000)***	3560 (0.000)***	33.02 (0.000)***
FSU – OPEC	Meta Eff.	5.71 (0.000)***	16255 (0.000)***	17.46 (0.000)***
	TGR	−8.65 (0.000)***	5318 (0.000)***	19.18 (0.000)***
IEA – OAPEC	Meta Eff.	−2.49 (0.013)*	19648 (0.188)	2.60 (0.005)**
	TGR	11.98 (0.000)***	34324 (0.000)***	33.26 (0.000)***
IEA – OPEC	Meta Eff.	−5.99 (0.000)***	18716 (0.001)**	2.89 (0.002)**
	TGR	12.18 (0.000)***	37122 (0.000)***	34.41 (0.000)***
OAPEC - OPEC	Meta Eff.	−3.81 (0.000)***	10848.5 (0.038)*	2.30 (0.011)*
	TGR	0.87 (0.383)	13311 (0.345)	13.38 (0.000)***

Notes: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; values in parenthesis () are the p-values

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 petroleum industry.

Next, results for IEA are compared with that of OAPEC. 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 ($t = -2.49$, $p < 0.05$), Mann–Whitney shows no statistically significant differences in the ranks of these two IGOs ($U = 19648$, $p = 0.188$). 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 ($l = 2.60$, $p < 0.01$). 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 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 2 which shows the kernel density distribution of the TGRs of the four IGOs. From Figure 2 it is clear that whereas the distribution of scores for IEA seem to gain more density toward the score of 1.0, that of OAPEC seem to peak between 0.4 and 0.6.

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

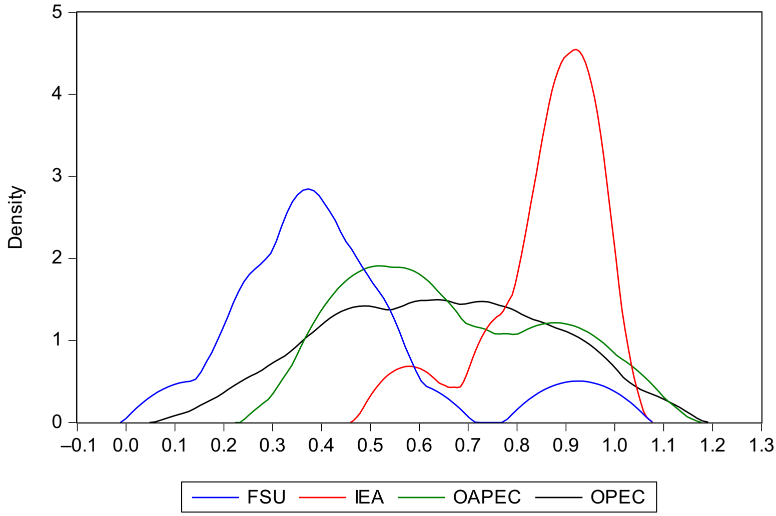

Figure 2.
Distribution of technological gap ratios

Table IV 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, questions remain whether there are statistically significant differences. Just like previous comparisons, scores of OAPEC and OPEC are statistically compared on all three tests 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 = 0.87, p = 0.383) and ranks (U = 13311, p = 0.345) 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 = 13.38, $p < 0.001$). This can be inferred from Figure 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, while 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.

4.2 Global frontier differences

This measures performance based on the production frontiers rather than average efficiencies. First, TI are estimated for all the IGOs. This is then followed by an assessment of the frontier differences. If the TI is less than 1, it means that the frontier is worse than most observations since on average other 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 V for each year from 2000 to 2013. The average for the pooled dataset is also included.

Table V. Technology indices for the IGOs

Year	Tech indices (OPEC)	Tech indices (IEA)	Tech indices (FSU)	Tech indices (OAPEC)
2000	0.76285	1.95127	0.60600	1.02614
2001	0.75169	1.98658	0.61070	1.00069
2002	0.76011	2.01982	0.62169	0.98068
2003	0.84802	2.03534	0.64190	1.00340
2004	0.79012	1.96082	0.60276	0.95621
2005	0.77051	1.90790	0.59017	0.91812
2006	0.76774	1.93495	0.59833	0.91415
2007	0.77331	2.15939	0.63381	0.98010
2008	0.74753	2.18157	0.63885	0.98017
2009	0.78701	2.13726	0.64222	0.96278
2010	0.77807	2.12755	0.65562	0.96216
2011	0.83750	2.26267	0.72035	1.04981
2012	0.80934	2.15908	0.69886	0.98903
2013	0.85030	2.26530	0.72382	1.04325
Pooled	0.78744	2.07394	0.64022	0.98254

It is obvious from Table V 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. IEA's worse TI of 1.9079 is even higher than OAPEC's best of 1.04981. 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. While the TI of OPEC ranges from 0.7475 to 0.8503, FSU have had the lowest levels of the technological indices having achieved their highest index of 0.7238 in 2013. FSU's largest TI is even lower than the lowest of OPEC. For the pooled dataset, on average, whereas IEA has the highest average of 2.07394 and OAPEC has a score of 0.98254, OPEC and FSU have scores of 0.78744 and 0.64022, respectively.

While the TI gives 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 GFD approach of Asmild and Tam (2007) gains utility. The TIs are used in the estimation of the GFDs between the different groups. Results of the GFD are presented subsequently. GFD measures and provides the overall conclusions about whether one group frontier is superior to the other (Asmild and 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 shifts 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 (6). Results are presented in Table VI.

Table VI. Global frontier differences

IGO	OPEC	IEA	FSU	OAPEC
OPEC	1.0000			
IEA	2.6338	1.0000		
FSU	0.8130	0.3087	1.0000	
OAPEC	1.2478	0.4738	1.5347	1.0000

These scores are based on the pooled scores although GFDs can be computed for individual years. It was observed that the pooled results are not that different from the annual GFDs. From Table VI, it is evident that when compared to the OPEC frontier, IEA and OAPEC are 163.38 per cent ([2.6338 − 1] × 100) and 25.78 per cent ([1.2478 − 1]× 100), respectively, better than OPEC frontier, whereas FSU on average is 18.7 per cent ([1 − 0.8130]× 100) worse than OPEC frontier. Compared to the IEA frontier, FSU recorded the worse overall performance with respect to the IEA frontier. FSU frontier was, on average, 69.13 per cent ([1 − 0.3087]× 100) worse than IEA's frontier. This was closely followed by OPEC which had a GFD of 0.3797 signifying that OPEC frontier was on average 62.03 per cent worse than IEA's frontier. The closest group to the state of technology employed by IEA was OAPEC, which had a frontier 52.62 per cent worse than IEA's. GFD results relative to the FSU frontier shows it is the least performing one since all other IGOs have better performing production frontiers. The final of the GFD comparisons is relative to the OAPEC frontier. These scores are reported in Table VI. OAPEC's frontier shows some interesting results. Whereas on average, OAPEC's frontier seems better than the OPEC (0.8014) and FSU (0.6516) frontiers, it is not better than that of IEA (2.1106).

5. Discussions and conclusions

5.1 Discussions

From both the metafrontier and GFD assessments, IEA is seen to have higher efficiencies and production frontier relative to the three other IGOs. This may be because of fact that the IEA is made up of 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 IGOs (Bamberger and Scott, 2004; Jollands *et al.*, 2010; Colgan *et al.*, 2011; Duffield, 2012). The RBT purports that the way an organization is structured combined with its resources, can better enhance its performance. This is justified by the empirical works which give credence to the importance of these resource characteristics for performance (Sirmon *et al.*, 2011; Crook *et al.*, 2008). 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 and Scott, 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). IEA can be situated in quarter IV of Table I which sees strong intra and inter-group collaboration resulting in organizational learning, innovation and disruption of information asymmetries.

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 because of their close links with each other and their occupation of the same geographical location. OAPEC sponsored ventures also help them to keep pace with developments and succeed in enhancing their performance in the industry (OAPEC, 2010). Stronger and more strategic 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 per cent 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. There is a link between organization resources and performance. The more resource endowed an organization is, the better its performance. Unlike IEA, OAPEC and OPEC seem to experience comparative challenge in their collaboration efforts although they have high resource endowment. Institutional bottlenecks, failure of members to conform to production quotas and other policy initiatives can have a negative effect on group performance.

OPEC's frontier follows OAPEC as the next best production frontier with scores better than that of FSU. The composition of membership 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 and Witte, 2011). It stands to reason that their better performance as compared with FSU may be a result of this collaborations, solidarity and other factors favoring the group in the coalition among member countries (Mikdashi, 1974). Good strategic collaboration within a particular group, as well as between that group and others, allows for group learning and innovation which can enhance the group's performance.

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 required for positive utility to countries in the petroleum 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, as differences in the individual goals may not stimulate 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, as economic benefits from higher production levels may not be realized by the producing organizations. Additionally, it is possible that because most oil produced in this region is heavy (Goldemberg, 2000; EIA, 2013), it is a contributory factor to their inefficiencies. Heavy oil requires enhanced oil recovery techniques. This stands to reason that because higher production technology is required for exploring heavy oil, intra-group collaborations in terms of technology and research, as well as reducing the transactional cost, will be beneficial. Therefore, the poor performance can be associated with lack of collaboration in technology and research in the IGO (Goldemberg, 2000). FSU is clearly placed in quarter I of Table I where there is low collaboration both within and with other IGOs. The finding is that as was expected.

5.2 Conclusions

On the basis of little inter-country and inter-IGO comparison literature on the international petroleum industry, this study examined four IGOs in the industry in terms of production efficiencies and GFDs of member states. 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. 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. IEA's performance could be as a result of both the high intra-group collaboration and even higher inter-group (external) collaborations together with strong Western-industrialized market economy structures. Therefore, high exchange of information that results in better organizational learning and innovation by members is achieved and all information asymmetries and bottlenecks that may hinder the progress of the production and supply capabilities of member states addressed.

Therefore, IGOs like FSU should put in more efforts to formalize their association with clearer policy guidelines that enshrine better collaboration among member states. Close association with higher performing states and organizations can better streamline their activities and reduce their inefficiencies. Whereas OAPEC and OPEC were among the best performers, individual members experienced different levels of performance. Organizational policies and guidelines should be better institutionalized. Efforts should be directed toward ensuring that member countries adhere to these policies that work.

While theory supports the view that common background among actors ensures close collaboration, for FSU states, this common ancestry does not seem to improve their performance. Further research can explore which kinds of ties can improve efficiencies in the international petroleum industry and how countries with adversarial histories can be joined toward a common productive goal. Further research can explore how production quotas and other regulatory guidelines of some IGOs, such as OPEC, affect the performance of individual countries. OPCs were examined at the composite country level. It would be interesting to examine how domestic dynamics and macroeconomic conditions translate to performance. Further research can explore how various IGOs in the industry handle price volatilities in the industry and how low-price environments affect the performances of different IGOs.

This study makes a number of contributions, this notwithstanding there are some limitations in terms of data and scope. Countries used for assessment were drawn from the list of members of four IGOs – OPEC, IEA, OAPEC and FSU. However, a few were eliminated because they produced either only oil or only gas. While this is a limitation, majority of members of these IGOs produce both oil and gas. Additionally, a larger sample covering all OPCs in the world would have been appropriate but it is difficult to access because of data scarcity. 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 petroleum producing members of these other IGOs are also members of the four IGOs that are currently under study.

References

Abu-Alkheil, A.M., Burghof, H.P. and Khan, W.A. (2012), “Islamic commercial banking in Europe: a cross-country and inter-bank analysis of efficiency performance”, *International Business & Economics Research Journal (Iber)*, Vol. 11 No. 6, pp. 647-676.

Adetutu, M.O. (2014), “Energy efficiency and capital-energy substitutability: evidence from four OPEC countries”, *Applied Energy*, Vol. 119, pp. 363-370.

Adler-Milstein, J., Ronchi, E., Cohen, G.R., Winn, L.A.P. and Jha, A.K. (2014), “Benchmarking health IT among OECD countries: better data for better policy”, *Journal of the American Medical Informatics Association*, Vol. 21 No. 1, pp. 111-116.

Afonso, A. and St Aubyn, M. (2005), “Non-parametric approaches to education and health efficiency in OECD countries”, *Journal of Applied Economics*, Vol. 8, pp. 227-246.

Afonso, A. and St. Aubyn, M. (2006), “Cross-country efficiency of secondary education provision: a semi-parametric analysis with non-discretionary inputs”, *Economic Modelling*, Vol. 23 No. 3, pp. 476-491.

Aguilera, R.F. (2012), “The economics of oil and gas supply in the former soviet union”, *International Journal of Global Energy Issues*, Vol. 35 No. 6, pp. 480-493.

Al-Essa, R.K., Al-Rubaie, M., Walker, S. and Salek, S. (2015), “The pharmaceutical companies assessment and experience with the centralised procedure”, *Pharmaceutical Regulatory Environment*, Springer, New York.

Al-Rashed, Y. and León, J. (2015), “Energy efficiency in OPEC member countries: analysis of historical trends through the energy coefficient approach”, *OPEC Energy Review*, Vol. 39 No. 1, pp. 77-102.

Amit, R. and Schoemaker, P.J. (2012), “Strategic assets and organizational rent”, *Strategic Management Journal*, Vol. 14 No. 1, pp. 33-46.

Arestis, P., Chortareas, G. and Desli, E. (2006), “Financial development and productive efficiency in OECD countries: an exploratory analysis*”, *The Manchester School*, Vol. 74 No. 4, pp. 417-440.

Aristovnik, A. (20120, “The impact of ICT on educational performance and its efficiency in selected EU and OECD countries: a non-parametric analysis”, Available at SSRN 2187482.

Asmild, M. and Tam, F. (2007), “Estimating global frontier shifts and global malmquist indices”, *Journal of Productivity Analysis*, Vol. 27 No. 2, pp. 137-148.

Asmild, M., Hollingsworth, B. and Birch, S. (2013), “The scale of hospital production in different settings: one size does not fit all”, *Journal of Productivity Analysis*, Vol. 40 No. 2, pp. 197-206.

Bamberger, C.S. and Scott, R. (2004), *IEA: The First 30 Years*, International Energy Agency, Organisation for Economic Co-operation and Development, New York.

Barney, J. (1991), “Firm resources and sustained competitive advantage”, *Journal of Management*, Vol. 17 No. 1, pp. 99-120.

Barney, J.B. (1995), “Looking inside for competitive advantage”, *Academy of Management Perspectives*, Vol. 9 No. 4, pp. 49-61.

Barros, C.P. and Assaf, A. (2009), “Bootstrapped efficiency measures of oil blocks in Angola”, *Energy Policy*, Vol. 37 No. 10, pp. 4098-4103.

Battese, G.E. and Rao, D.S.P. (2002), “Technology gap, efficiency, and a stochastic metafrontier function”, *International Journal of Business and Economics*, Vol. 1, pp. 87-93.

Battese, G.E., Rao, D.S.P. and O’donnell, C.J. (2004), “A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies”, *Journal of Productivity Analysis*, Vol. 21 No. 1, pp. 91-103.

Behname, M. (2012), “The compare of concentration and efficiency in banking industry: an evidence from the OPEC countries”, *Eurasian Journal of Business and Economics*, Vol. 5.

Bharadwaj, A.S. (2000), “A resource-based perspective on information technology capability and firm performance: an empirical investigation”, *MIS Quarterly*, Vol. 24 No. 1, pp. 169-196.

Bhattacharyya, S.C. (2007), “Energy sector management issues: an overview”, *International Journal of Energy Sector Management*, Vol. 1 No. 1, pp. 13-33.

Biermann, F. and Bauer, S. (2004), “Assessing the effectiveness of intergovernmental organisations in international environmental politics”, *Global Environmental Change*, Vol. 14 No. 2, pp. 189-193.

Camisón, C. and Villar-López, A. (2014), “Organizational innovation as an enabler of technological innovation capabilities and firm performance”, *Journal of Business Research*, Vol. 67 No. 1, pp. 2891-2902.

Canhoto, A. and Dermine, J. (2003), “A note on banking efficiency in Portugal, new vs. Old banks”, *Journal of Banking & Finance*, Vol. 27 No. 11, pp. 2087-2098.

Casu, B. and Molyneux, P. (2003), “A comparative study of efficiency in european banking”, *Applied Economics*, Vol. 35 No. 17, pp. 1865-1876.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), “Measuring the efficiency of decision-making units”, *European Journal of Operations Research*, Vol. 2 No. 6, pp. 429-444.

Claeys, S. and Vander Vennet, R. (2008), “Determinants of bank interest margins in Central and Eastern Europe: a comparison with the west”, *Economic Systems*, Vol. 32 No. 2, pp. 197-216.

Colgan, J., Keohane, R. and Van De Graaf, T. (2011), "Institutional change in the energy regime complex", *Political Economy of International Organizations Meeting, Zurich*, 27-29.

Colgan, J.D., Keohane, R.O. and Van de Graaf, T. (2012), "Punctuated equilibrium in the energy regime complex", *The Review of International Organizations*, Vol. 7 No. 2, pp. 117-143.

Crook, T.R., Ketchen, D.J., Combs, J.G. and Todd, S.Y. (2008), "Strategic resources and performance: a Meta-analysis", *Strategic Management Journal*, Vol. 29 No. 11, pp. 1141-1154.

Dietsch, M. and Lozano-Vivas, A. (2000), "How the environment determines banking efficiency: a comparison between French and Spanish industries", *Journal of Banking & Finance*, Vol. 24 No. 6, pp. 985-1004.

Dike, J.C. (2013), "Measuring the security of energy exports demand in OPEC economies", *Energy Policy*, Vol. 60, pp. 594-600.

Dobbin, F. and Baum, J.A.C. (2000), "Introduction: economics meets sociology in strategic management", in Baum, J.A.C. and Dobbin, F. (Eds), *Economics Meets Sociology in Strategic Management*, Emerald Group Publishing Limited, Bingley.

Donni, O. and Fecher, F. (1997), "Efficiency and productivity of the insurance industry in the OECD countries", *The Geneva Papers on Risk and Insurance – Issues and Practice*, Vol. 22 No. 4, pp. 523-535.

Dorussen, H. and Ward, H. (2008), "Intergovernmental organizations and the Kantian Peace: a network perspective", *Journal of Conflict Resolution*, Vol. 52 No. 2, pp. 189-212.

Drakos, K. (2003), "Assessing the success of reform in transition banking 10 years later: an interest margins analysis", *Journal of Policy Modeling*, Vol. 25 No. 3, pp. 309-317.

Duffield, J.S. (2012), "The return of energy insecurity in the developed democracies", *Contemporary Security Policy*, Vol. 33 No. 1, pp. 1-26.

Dyson, R.G., Allen, R., Camanho, A.S., Podinovski, V.V., Sarrico, C.S. and Shale, E.A. (2001), "Pitfalls and protocols in DEA", *European Journal of Operational Research*, Vol. 132 No. 2, pp. 245-259.

Easterly, W. and Fischer, S. (1994), "What we can learn from the soviet collapse", *Finance and Development*, Vol. 31 No. 2.

EIA (2013), *International Energy Outlook 2013*, US Energy Information Administration, Washington.

Eller, S.L., Hartley, P.R. and Medlock, K.B. (2011), "Empirical evidence on the operational efficiency of national oil companies", *Empirical Economics*, Vol. 40 No. 3, pp. 623-643.

Fare, R., Grosskopf, S., Norris, M. and Zhang, Z. (1994), "Productivity growth, technical progress, and efficiency change in industrialized countries", *American Economic Review*, Vol. 84, pp. 66-83.

Farrell, M.J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society. Series A (General)*, Vol. 120 No. 3, pp. 253-290.

Filippini, M. and Hunt, L.C. (2011), "Energy demand and energy efficiency in the OECD countries: a stochastic demand frontier approach", *The Energy Journal*, Vol. 32 No. 2, pp. 59-80.

Francisco, C.A.C., De Almeida, M.R. and Da Silva, D.R. (2012), "Efficiency in Brazilian refineries under different DEA technologies", *International Journal of Engineering Business Management*, Vol. 4, pp. 1-11.

Fuinhas, J.A., Marques, A.C. and Quaresma, T.N. (2015), "Does oil consumption promote economic growth in oil producers? Evidence from OPEC countries", *International Journal of Energy Sector Management*, Vol. 9 No. 3, pp. 323-335.

Goldemberg, J. (2000), *World Energy Assessment: Energy and the Challenge of Sustainability*, United Nations Publications, New York.

Goldthau, A. and Witte, J.M. (2011), "Assessing OPEC's performance in global energy", *Global Policy*, Vol. 2, pp. 31-39.

Gorton, M. and Davidova, S. (2004), "Farm productivity and efficiency in the CEE applicant countries: a synthesis of results", *Agricultural Economics*, Vol. 30 No. 1, pp. 1-16.

Hawdon, D. (2003), "Efficiency, performance and regulation of the international gas industry – a bootstrap DEA approach", *Energy Policy*, Vol. 31 No. 11, pp. 1167-1178.

Holland, G.L. (1998), "The role of intergovernmental organizations in coastal zone management", *Ocean & Coastal Management*, Vol. 39 Nos 1/2, pp. 25-31.

Honma, S. and Hu, J.L. (2008), "Total-factor energy efficiency of regions in Japan", *Energy Policy*, Vol. 36 No. 2, pp. 821-833.

Hoopes, D.G., Madsen, T.L. and Walker, G. (2003), "Guest editors' introduction to the special issue: why is there a resource-based view? Toward a theory of competitive heterogeneity", *Strategic Management Journal*, Vol. 24 No. 10, pp. 889-902.

IEA 2014, *World Energy Outlook 2014*, International Energy Agency, Paris.

Ike, C.B. and Lee, H. (2014), "Measurement of the efficiency and productivity of national oil companies and its determinants", *Geosystem Engineering*, Vol. 17 No. 1, pp. 1-10.

Ismail, Z., Tai, J.C., Kong, K.K., Law, K.H., Shirazi, S.M. and Karim, R. (2013), "Using data envelopment analysis in comparing the environmental performance and technical efficiency of selected companies in their global petroleum operations", *Measurement*, Vol. 46 No. 9, pp. 3401-3413.

Jollands, N., Waide, P., Ellis, M., Onoda, T., Laustsen, J., Tanaka, K., De T'serclaes, P., Barnsley, I., Bradley, R. and Meier, A. (2010), "The 25 IEA energy efficiency policy recommendations to the G8 gleneagles plan of action", *Energy Policy*, Vol. 38 No. 11, pp. 6409-6418.

Kashani, H.A. (2005), "State intervention causing inefficiency: an empirical analysis of the Norwegian continental shelf", *Energy Policy*, Vol. 33 No. 15, pp. 1998-2009.

Kenjegalieva, K., Simper, R., Weyman-Jones, T. and Zelenyuk, V. (2009), "Comparative analysis of banking production frameworks in Eastern European financial markets", *European Journal of Operational Research*, Vol. 198 No. 1, pp. 326-340.

Kim, T.Y., Lee, J.D., Park, Y.H. and Kim, B. (1999), "International comparisons of productivity and its determinants in the natural gas industry", *Energy Economics*, Vol. 21 No. 3, pp. 273-293.

Košak, M., Zajc, P. and Zorić, J. (2009), "Bank efficiency differences in the new EU member states", *Baltic Journal of Economics*, Vol. 9 No. 2, pp. 67-89.

Krishnasamy, G. and Ahmed, E.M. (2009), "Productivity growth analysis in OECD countries", *Korea and the World Economy*, Vol. 10, pp. 225-244.

Lauber, T.B., Decker, D. and Knuth, B. (2008), "Social networks and community-based natural resource management", *Environmental Management*, Vol. 42 No. 4, pp. 677-687.

Li, Q. (1996), "Nonparametric testing of closeness between two unknown distribution functions", *Econometric Reviews*, Vol. 15 No. 3, pp. 261-274.

Madhani, P., M. (2010), "Salesforce compensation: game theory", *SCMS Journal of Indian Management*, Vol. 7, pp. 72-82.

Managi, S., Opaluch, J.J., Jin, D. and Grigalunas, T.A. (2006), "Stochastic frontier analysis of total factor productivity in the offshore oil and gas industry", *Ecological Economics*, Vol. 60 No. 1, pp. 204-215.

Marius Andrieş, A. and Căpraru, B. (2012), "Competition and efficiency in EU27 banking systems", *Baltic Journal of Economics*, Vol. 12 No. 1, pp. 41-60.

Mikdashi, Z. (1974), "Cooperation among oil exporting countries with special reference to Arab countries: a political economy analysis", *International Organization*, Vol. 28 No. 01, pp. 1-30.

Miles, J., A. (2012), *Management and Organization Theory: A Jossey-Bass Reader*, John Wiley & Sons, New York.

Minescu, A., Hagendoorn, L. and Poppe, E. (2008), "Types of identification and intergroup differentiation in the Russian Federation", *Journal of Social Issues*, Vol. 64 No. 2, pp. 321-342.

Muldoon, K.A., Galway, L.P., Nakajima, M., Kanters, S., Hogg, R.S., Bendavid, E. and Mills, E.J. (2011), "Health system determinants of infant, child and maternal mortality: a cross-sectional study of UN member countries", *Globalization and Health*, Vol. 7 No. 1, p. 10.

Murphy, D.J. and Hall, C.A.S. (2011), "Energy return on investment, peak oil, and the end of economic growth", *Annals of the New York Academy of Sciences*, Vol. 1219, pp. 52-72.

O'Donnell, C., Rao, D.S.P. and Battese, G. (2008), "Metafrontier frameworks for the study of firm-level efficiencies and technology ratios", *Empirical Economics*, Vol. 34 No. 2, pp. 231-255.

OAPEC (2010), *Annual Report*, OAPEC, Kuwait.

OAPEC (2015), *Current Developments in the World and Arab Energy Industry*, OAPEC, Kuwait.

Oderkirk, J., Ronchi, E. and Klazinga, N. (2013), "International comparisons of health system performance among OECD countries: opportunities and data privacy protection challenges", *Health Policy*, Vol. 112 Nos 1/2, pp. 9-18.

Ohene-Asare, K., Turkson, C. and Afful-Dadzie, A. (2017), "Multinational operation, ownership and efficiency differences in the international oil industry", *Energy Economics*, Vol. 68, pp. 303-312.

OPEC (2012), *Statute*, OPEC, Vienna.

OPEC (2014), *Annual Statistical Bulletin*, OPEC, Vienna.

OPEC (2017), *OPEC Annual Statistical Bulletin 2017*, Organization of the Peroleum Exporting Countries, Vienna.

OPEC (2018), "Member countries", available at: www.opec.org/opec_web/en/about_us/25.htm (accessed 8 January 2018).

Otsuki, T. (2013), "Nonparametric measurement of the overall shift in the technology frontier: an application to multiple-output agricultural production data in the Brazilian amazon", *Empirical Economics*, Vol. 44 No. 3, pp. 1455-1475.

Oum, T.H. and Yu, C. (1994), "Economic efficiency of railways and implications for public policy: a comparative study of the OECD countries' railways", *Journal of Transport Economics and Policy*, Vol. 1, pp. 121-138.

Penrose, E.T. (1959), *The Theory of the Growth of the Firm*, Oxford University Press, Oxford.

Peteraf, M.A. (1993), "The cornerstones of competitive advantage: a resource-based view", *Strategic Management Journal*, Vol. 14 No. 3, pp. 179-191.

Peteraf, M.A. and Barney, J.B. (2003), "Unraveling the resource-based tangle", *Managerial and Decision Economics*, Vol. 24 No. 4, pp. 309-323.

Ramachandra, T.V., Loerincik, Y. and Shruthi, B.V. (2005), "Intra-and inter-country energy intensity trends", *Journal of Energy and Development*, Vol. 31, pp. 43-84.

Ramcharran, H. (2002), "Oil production responses to price changes: an empirical application of the competitive model to OPEC and non-OPEC countries", *Energy Economics*, Vol. 24 No. 2, pp. 97-106.

Rasmussen, E. (1989), *Games and Information*, Basil Blackwell, Oxford.

Retzlaff-Roberts, D., Chang, C.F. and Rubin, R.M. (2004), "Technical efficiency in the use of health care resources: a comparison of OECD countries", *Health Policy*, Vol. 69 No. 1, pp. 55-72.

Rigby, J., Dewick, P., Courtney, R. and Gee, S. (2013), "Limits to the implementation of benchmarking through KPIs in UK construction policy: insights from game theory", *Public Management Review*, Vol. 16 No. 6, pp. 782-806.

Rogner, H.H., Aguilera, R., F., Archer, C., L., Bertani, R., Bhattacharya, S.C., dusseault, M., B., Gagnon, L., Harbel, H., Hoogwijk, M., Johnson, A., Rogner, M., L., Wagner, H., Yakushev, V., Arent, D., J., Bryden, I., Krausmann, F., Odell, P., Schillings, C. and Shafiei, A. (2012), "Energy resources and potentials", in Johansson, T. B., Patwardhan, A., Nakicenovic, N., Gomez-Echeverri, L. and Zou, J. (eds) *Global Energy Assessment: Toward a Sustainable Future*, Cambridge University Press, New York.

Sari, R. and Soytas, U. (2009), "Are global warming and economic growth compatible? Evidence from five OPEC countries?", *Applied Energy*, Vol. 86 No. 10, pp. 1887-1893.

Selowsky, M. and Martin, R. (1997), "Policy performance and output growth in the transition economies", *The American Economic Review*, Vol. 87 No. 2, pp. 349-353.

Shahabinejad, V., Mehrjerdi, M.R.Z. and Yaghoubi, M. (2013), "Total factor productivity growth, technical change and technical efficiency change in asian economies: decomposition analysis", *Iranian Journal of Economic Studies*, Vol. 2, pp. 47-69.

Simar, L. and Wilson, P.W. (2002), "Non-parametric tests of returns to scale", *European Journal of Operational Research*, Vol. 139 No. 1, pp. 115-132.

Simar, L. and Zelenyuk, V. (2006), "On testing equality of distributions of technical efficiency scores", *Econometric Reviews*, Vol. 25 No. 4, pp. 497-522.

Sirmon, D.G., Hitt, M.A., Ireland, R.D. and Gilbert, B.A. (2011), "Resource orchestration to create competitive advantage breadth, depth, and life cycle effects", *Journal of Management*, Vol. 37 No. 5, pp. 1390-1412.

Sueyoshi, T. and Goto, M. (2012), "Data envelopment analysis for environmental assessment: Comparison between public and private ownership in petroleum industry", *European Journal of Operational Research*, Vol. 216 No. 3, pp. 668-678.

Taylor, P.G., D'ortigue, O.L., Francoeur, M. and Trudeau, N. (2010), "Final energy use in IEA countries: the role of energy efficiency", *Energy Policy*, Vol. 38 No. 11, pp. 6463-6474.

Trestian, R., Ormond, O. and Muntean, G.M. (2012), "Game theory-based network selection: Solutions and challenges", *Ieee Communications Surveys & Tutorials*, Vol. 14 No. 4, pp. 1212-1231.

Vlontzos, G., Niavis, S. and Manos, B. (2014), "A DEA approach for estimating the agricultural energy and environmental efficiency of EU countries", *Renewable and Sustainable Energy Reviews*, Vol. 40, pp. 91-96.

Von Neumann, J. and Morgenstern, O. (1944), *Theory of Games and Economic Behavior*, Princeton University Press, Princeton, NJ.

Wanke, P., Barros, C.P. and Faria, J.R. (2015), "Financial distress drivers in Brazilian banks: a dynamic slacks approach", *European Journal of Operational Research*, Vol. 240 No. 1, pp. 258-268.

Weibull, J.W. (1997), *Evolutionary Game Theory*, MIT Press, New York.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, Vol. 5 No. 2, pp. 171-180.

Wiklund, J. and Shepherd, D. (2003), "Research notes and commentaries: knowledge-based resources, entrepreneurial orientation, and the performance of small and medium-sized businesses", *Strategic Management Journal*, Vol. 24 No. 13, pp. 1307-1314.

Wolf, C. (2009), "Does ownership matter? The performance and efficiency of state oil vs Private oil (1987–2006)", *Energy Policy*, Vol. 37 No. 7, pp. 2642-2652.

Yin, Z., Jiang, A.X., Tambe, M., Kiekintveld, C., Leyton-Brown, K., Sandholm, T. and Sullivan, J.P. (2012), "Trusts: scheduling randomized patrols for fare inspection in transit systems using game theory", *AI Magazine*, Vol. 33 No. 4, p. 59.

Corresponding author
Kwaku Ohene-Asare can be contacted at: kohene-asare@ug.edu.gh