ANALYZING THE TECHNICAL EFFICIENCY USING DATA ENVELOPMENT ANALYSIS METHOD: THE CASE OF GULF COOPERATION COUNCIL COUNTRIES

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Abstract

Given the importance of technical efficiency for production process, the current study is measuring the technical efficiency in the Gulf Cooperation Council countries over the period 2009-2016. For this purpose, the study will employ the nonparametric model uses the linear programming by Data Envelopment Analysis (DEA) to calculate technical efficiency. Results revealed that Kuwait is operating by optimal size production in both frontiers, constant returns to scale (CRS), and variable returns to scale (VRS) and so it is considered as the benchmark for the rest of the Gulf Cooperation Council countries. On the other hand, the results showed that Bahrain, UAE, Oman and KSA do not operate within optimal size, which restrain them to perform the overall technical efficiency and scale efficiency.

Keywords: scale efficiency, economic growth, Gulf Cooperation Council

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1. Introduction

The world nowadays facing liberalization of foreign trade and economic openness within the concept of globalization, while the framework of economic competition was expanding in production between countries. Competition is no longer restricted to the local markets of a single country, but rather to the level of international markets among countries. Thus, the achievement of economic competition between countries requires an efficient management of resources with the ability to introduce a new product and achieving a larger volume of exports. This can be carried out through maximizing the benefit of available modern technology and reducing the cost of production, in addition to learn from international experiences in the field of production, especially in the industrial sector as an engine of economic growth that can create sufficient value added to productive units.

The concept of technical competence is one of the economic concepts that have received the attention of many economic sectors such as agriculture, industry, the banking system, transportation, and others. Measuring the technical efficiency of the economy is one of the indicators upon which it based to determine the methods of achieving economic growth.

A low level of technical efficiency for an individual country would imply that a higher level of economic development could achieved by efficiently producing more output with the same level of inputs. In contrast, a highly efficient country should lie more on technical progress and innovative activity in order to achieve higher economic growth. It seems, therefore, that identifying the sources of technical inefficiency is of particular importance to promote economic growth (Dimelis & Papaioannou, 2011).

Therefore, technical efficiency considered necessary condition for building a more sustainable modern economy. The purpose of this study is to explore and analyze the technical efficiency in the Gulf Cooperation Council (GCC) countries during the period (2009 - 2016).

2. Theoretical background and literature review

The concept of efficiency established in 1951 in the study of Koopmans (1951), which noted that "the product is technically efficient if the increase in production of a particular product requires a reduce production of another product at least or adding one more input at least.

The study of Farrell (1957) is the first attempt to measure economic efficiency. His study indicates that economic efficiency consists of two parts. **First:** *technical efficiency* (TE), means the ability to achieve the best level of production using the available inputs. It is the ratio of actual production to optimal production, or the ratio of actual inputs to the level of optimal inputs. If this ratio is less than one, this indicates a decrease in technical efficiency. **Second:** *allocative Efficiency*, means the ability to use the optimal mix "Optimal Combination" of production inputs to achieve production at the lowest cost.

Stigler (1960) defines technical efficiency as the relationship between inputs and outputs, measured as follows: actual outputs / maximum outputs from available resources. Optimal efficiency is achieved when this ratio is equal to one, and this is achieved when the marginal output of the factors of production is equal to the cost of each factor. According to Carlsson (1972), technical efficiency is defined as producing the maximum amount of output because of using a given amount of input or maximizing the production of available inputs.

The concept of efficiency has remained unchanged since its inception, and there has been no modification to this concept. In the study of Porcelli (2009), efficiency is defined as: **First**, *technical efficiency* measures the actual output ratio to the potential output by assuming a given input or measuring the proportion of inputs used in production to the optimum level to be used of those inputs, assuming a given output. **Second**, *allocative efficiency* refers to the ability to combine inputs and outputs using optimal ratios in the light of prevailing prices. For example, testing actual costs versus optimal production costs, or the optimum profit for an enterprise. In the definition of Amornkitvikai (2011), efficiency means the production of a given output with the lowest possible level of inputs, or the ability of an enterprise to use the optimal mix of inputs, considering production technology and input prices.

The importance of studying and improving efficiency has been highlighted in industrial countries in general and developing countries in particular in their close relationship to the exploitation of economic resources. Economic progress in any country depends on two main factors: First, technical efficiency in the employment of inputs. Second, capital investment efficiency represented in machinery, equipment and raw materials. The well-being of society is based on maximizing outputs with minimal inputs, where high productivity in the production of any commodity expresses the possibility of producing the same amount of the commodity using less resource, thereby diversifying production from other commodities (Coelli et al, 2005).

Alomari and Saqfalhait (2016) used panel data to study the impact of technical efficiency on the performance of listed Jordanian pharmaceutical companies for the period (2007-2012). They found that there is a positive relation between technical efficiency and profitability, while profit margins are low in low-efficiency companies.

Margono et al (2011) found that economic growth in Indonesia is low and not sustained due to low technical efficiency. Lau and Brada (1990) concluded that technical efficiency had positive effect on industrial performance and hence economic growth in China. Ali and Hamid (1996) found that technological progress and technical efficiency contribute significantly and positively to economic growth.

3. Methods of measuring technical efficiency

Technical efficiency can be measured using the two most common forms of applied economics*: parametric* and *nonparametric* model. The *parametric model* is used in the regression analysis of the production function in the traditional way. Greene (2002) points out that the "Frontier Production Function" is an extension of the regression model that best represents the production function, through which the production level is estimated using available inputs. One of the most important features of the parametric model is that it is used in the Returns to Scale test and helps to determine the impact of the change in efficiency at the production level (Sena, 2003). The disadvantages of this model are its inability to identify sources of low efficiency, and regression results give a general indicator of efficiency by comparing the actual output with potential output level (Ogundari, 2008).

The *nonparametric model* uses the linear programming by Data Envelopment Analysis (DEA). In practice, this analysis evaluates each decision-making unit (DMU) compared with the best DMUs or the so-called "Best Practice for each DMU. Where inefficient DMUs are evaluated against the efficient DMUs, and therefore efficient DMUs will enveloped the inefficient DMUs (Soares et. al, 2017). The objective of this model is to estimate the production frontier of DMUs that use the same inputs to achieve output, where production frontier estimated based on efficient DMUs - the comparison of each DMU with the benchmark in terms of production scale. The main advantages of this analysis are to determine the best performance among different DMUs;

to defining the worst performance among different DMUs; to assist in the process of redistributing inputs needed to raise efficiency levels; to assist in determining the degree of inefficiency in performance; and to determine the level of change in efficiency over time. Given the advantages of this method in the analysis, it will be used in this study to calculate technical efficiency.

The DEA method has been applied since 1978 (Charnes et al., 1978), which has its roots from Farrell (1957). The DEA concedes as the best method to determine benchmark, because it is distinguished by identifying the best counterpart units for inefficient units, based on multiple inputs and outputs. Efficiency measurement in this method does not require availability of inputs or output prices, nor does it require input and output from the same unit of measurement, as there are no restrictions on the use of a particular form of production function (Sena, 2003). This method of measurement can be used when the size of data is relatively small (Coelli et al., 2005).

The DEA method assuming that the production frontiers either constant returns to scale CRS, or variable returns to scale VRS. The CRS was formulated in the study of Charnes et al. (1978), it's known as CCR and called the *Overall Technical Efficiency*, where the production frontier can be determined based on this assumption. The VRS was formulated in a study of Banker et al. (1984), it's known as BCC and called *Pure Technical Efficiency*, indicating the ability of the DMU to achieve the best production using available inputs.

The CRS hypothesis is appropriate in the DEA only when all DMUs are operating by optimal scale (Coelli et al., 2005). However, in fact, there are many barriers that prevent some DMUs from achieving optimal scale such as imperfect competition (Pannu et al. (2011); Alemdar and Oren (2006)), because the operating size of the DMUs response to the input's productivity, which can be increasing, decreasing, or maximum. Using either CRS or VRS, technical efficiency scores can be calculated either in Input Oriented or Output Oriented. The results of the CRS and VRS models can be used to calculate the *relative technical efficiency* scores which known as the Scale efficiency (SE).

If the DMU is operating optimally (optimal size), the TE^{VRS} will be equal or close to the TE^{CRS}. Means, the TE scores can be determined by the CRS assumption. If the DMU is not operating optimally, the TE^{VRS} will exceeds the TE^{CRS}, and the DMU will be inefficient if TE^{VRS} equals (one). That's why the SE has been calculated, where the SE is defined as the capacity of the enterprise to produce within its size (Kao & Lu, 2011).

The relative technical efficiency (SE) is calculated by dividing the TE^{CRS} on TE^{VRS}. If the DMU operates by the optimal size (operating on the production frontier), the TE^{CRS} will be equal to TE^{VRS}, this also indicates that the degree of scale efficiency (SE) equals (one). If the DMU does not operate optimally, the TE^{VRS} will be greater than the TE^{CRS}, which makes the degree of (SE) less than one, and here are two possibilities: **First,** the DMU operates by increasing returns to scale (IRS). Therefore, the level of production must increase by increasing inputs and operate at a larger scale until technical efficiency is achieved. **Second,** the DMU operates by decreasing returns to scale (DRS) and therefore reduce the production level and operate in a smaller size and fewer inputs to achieve technical efficiency.

The inefficiency can be explained by the production elasticity, calculated by dividing Marginal Production (MP), on the average production (AP). If the AP at its maximum, the production elasticity will equal (one), so the DMU operates by CRS and achieves overall and relative technical efficiency. If the AP was increasing, the production elasticity will exceed one, and the MP in this case will exceed the AP, indicating that the DMU operates by increasing returns to scale (IRS). If the AP is decreasing, the production elasticity will be (smaller than one), and the MP in this case will be smaller than the AP, meaning that the DMU operates by decreasing returns to scale (DRS). (Erbetta & Rappuoli, 2003). In both cases (IRS and DRS), the DMU may be inefficient, where the degree of efficiency depends on the difference between TE^{CRS} and TE^{VRS}.

4. Methodology

4.1. Data

The study used a panel data for the six GCC countries over the period (2009-2016). The following inputs were included for the analysis: total number of labors in each country, dollar value of total capital in each country measured by 2010 prices, and total production of crude oil per year for each country as a natural resource. The output is real value of Gross Domestic Product GDP measured by 2010 prices. These data were obtained from the World Bank database.

4.2. Measuring the technical efficiency of the GCC countries using DEA analysis

After applying the DEA model, the results are shown in Table 1. The TE scores of using the output-oriented approach of each country in each year, applying the two models (CRS, VRS).

Table 1

Technical Efficiency Scores in GCC Countries Using Output Oriented Approach

CRS Model

Year	*Bahrain*	*Kuwait*	*Oman*	*Qatar*	*KSA*	*UAE*
2009	0.734	1.000	0.657	0.980	0.614	0.730
2010	0.736	1.000	0.657	0.990	0.612	0.729
2011	0.735	1.000	0.654	1.000	0.629	0.728
2012	0.740	1.000	0.657	0.999	0.618	0.729
2013	0.737	1.000	0.657	0.998	0.608	0.729
2014	0.737	1.000	0.658	0.998	0.606	0.730
2015	0.738	1.000	0.659	1.000	0.604	0.729
2016	0.739	1.000	0.659	1.000	0.600	0.729
Average	***0.737***	***1.000***	***0.657***	***0.996***	***0.611***	***0.729***
Max.	***0.740***	***1.000***	***0.659***	***1.000***	***0.629***	***0.730***
Min.	***0.734***	***1.000***	***0.654***	***0.980***	***0.600***	***0.728***
St.d	***0.001***	***0.000***	***0.001***	***0.006***	***0.009***	***0.001***

VRS Model

Year	*Bahrain*	*RTS*	*Kuwait*	*RTS*	*Oman*	*RTS*	*Qatar*	*RTS*	*KSA*	*RTS*	*UAE*	*RTS*
2009	1.000	IR	1.000	CR	0.701	IR	1.000	IR	0.969	DR	0.947	DR
2010	0.993	IR	1.000	IR	0.691	IR	0.999	IR	0.973	DR	0.950	DR
2011	0.975	IR	1.000	DR	0.689	IR	1.000	CR	1.000	DR	0.962	DR
2012	1.000	IR	1.000	DR	0.684	IR	0.999	CR	1.000	DR	0.972	DR
2013	0.949	IR	1.000	DR	0.681	IR	0.999	CR	0.994	DR	0.982	DR
2014	0.931	IR	1.000	DR	0.680	IR	0.999	CR	1.000	DR	1.000	DR
2015	0.934	IR	1.000	DR	0.677	IR	1.000	IR	1.000	DR	0.995	DR
2016	0.927	IR	1.000	DR	0.676	IR	1.000	CR	1.000	DR	1.000	DR
Average	***0.964***		***1.000***		***0.685***		***0.999***		***0.992***		***0.976***	
Max.	***1.000***		***1.000***		***0.701***		***1.000***		***1.000***		***1.000***	
Min.	***0.927***		***1.000***		***0.676***		***0.999***		***0.969***		***0.947***	
St.d	***0.031***		***0.000***		***0.008***		***0.001***		***0.013***		***0.021***	

Scale Efficiency (SE)

Year	*Bahrain*	*Kuwait*	*Oman*	*Qatar*	*KSA*	*UAE*
2009	0.734	1.000	0.938	0.980	0.633	0.771
2010	0.741	1.000	0.951	0.991	0.629	0.768
2011	0.754	1.000	0.950	1.000	0.629	0.757
2012	0.740	1.000	0.960	1.000	0.618	0.750
2013	0.776	1.000	0.965	0.999	0.612	0.742
2014	0.791	1.000	0.967	0.999	0.606	0.730
2015	0.791	1.000	0.973	1.000	0.604	0.733
2016	0.797	1.000	0.976	1.000	0.600	0.729
Average	***0.765***	***1.000***	***0.960***	***0.996***	***0.616***	***0.747***
Max.	***0.797***	***1.000***	***0.976***	***1.000***	***0.633***	***0.771***
Min.	***0.734***	***1.000***	***0.938***	***0.980***	***0.600***	***0.729***
St.d	***0.026***	***0.000***	***0.012***	***0.007***	***0.012***	***0.016***

Note: RTS denotes to Returns to scale; IR is increasing returns to scale, CR is constant returns to scale and DR is decreasing returns to scale. KSA denotes for Saudi Arabia and UAE is United Arab Emirates.

Source: World Bank Database

Based on Table 1, the scores of TE in the two models CRS and VRS show that Kuwait is operating by optimal size, because the scores of TECRS equals TEVRS. Thus, Kuwait achieves the Overall TE and Pure TE within the CRS and VRS assumptions, and it is considered as the benchmark for the rest of the GCC countries.

The rest of the GCC countries distributed according to its allocation from Kuwait, it can be ranking according to the average technical efficiency as shown in Table 2.

Table 2

Ranking of GCC countries by average technical efficiency

Country	Pure Technical Efficiency (TE^{VRS})	Order	Relative Technical Efficiency (SE)	Order
Bahrain	0.964	Fifth	0.765	Fourth
Kuwait	1	First	1	First
Oman	0.685	Sixth	0.960	Third
Qatar	0.999	Second	0.996	Second
KSA	0.992	Third	0.616	Sixth
UAE	0.976	Fourth	0.747	Fifth

Source: World Bank Database

Qatar is the nearest country for Kuwait in the two models CRS and VRS, meaning that Qatar approximately achieves the Overall TE and Pure TE. Thus, it operates by optimal size since there are no significant differences in technical efficiency between the two models (CRS, VRS).

KSA, UAE and Bahrain are the third, fourth and fifth respectively, according to its pure TE, but they do not operate by optimal size. Therefore, the SE of KSA falls to 62%, and it was the last country in GCC ranking. SE of UAE falls to 75% as the fifth country, and SE of Bahrain falls to 76.5% having the fourth order. By looking to returns to scale for those three countries (KSA, UAE and Bahrain), it show that KSA and UAE have DRS, meaning these two countries are using inputs more than the desired level, and they should reduce their inputs (L,K and Crude Oil) by a given output (GDP), or increasing the output level by a given inputs, that may increasing the SE. Bahrain has IRS, meaning that its inefficiency results from using input slower than the desirable level, or producing output (GDP) lower than the desired level by a given inputs. Therefore, Bahrain should increase its inputs and output to achieve SE.

The results displayed in Table 1 also indicate that Oman operates by acceptable size since there are a slightly significant differences in technical efficiency between the two models (CRS, VRS). It was the sixth country in pure TE, but it has the third order between the GCC countries according to SE. Moreover, Oman operates by IRS, meaning that its inefficiency results from using input slower than the desirable level, or producing output (GDP) lower than the desired level by a given input. Therefore, Oman should increase its inputs and output to achieve SE.

One of the advantages of DEA analysis calculates the slack or projection of inputs and output that can help us to make recommendations for the DMUs to achieve Overall TE (Size Efficiency). After analysing the TE scores for the GCC countries, the projections of output were as Table 3 shows.

Table 3

The required changes of GDP for GCC countries to achieve SE

Year	Bahrain	Kuwait	Oman	Qatar	KSA	UAE
2009	36%	0	52%	2%	62%	37%
2010	35%	0	52%	1%	63%	37%
2011	36%	0	52%	0	59%	37%
2012	35%	0	52%	0.14%	62%	37%
2013	35%	0	52%	0.19%	64%	37%
2014	35%	0	52%	0.20%	65%	37%
2015	35%	0	51%	0.01%	65%	37%
2016	35%	0	51%	0	67%	37%

Source: DEA analysis

The results of table (3) indicate that most of GCC countries like Bahrain, UAE, Oman and KSA, do not operating within optimal size. That prevent them to achieve Overall TE and SE, but instead they may be achieving Pure TE because their scores of TEVRS exceeds TECRS. That means those countries can be technically efficient independently within their current size.

5. Conclusion

The basics of economic efficiency are based on the fact that resources are scarce. Therefore, the importance of studying and improving efficiency has been highlighted in industrial countries in general and developing countries in particular in their close relationship to the exploitation of economic resources. Such efficiency became more necessary in the production process to maximize the total factor productivity.

In order to minimize inputs, maximize production and economic profitability, this study aims to measure the technical efficiency in the GCC countries over the period (2009-2016). For this purpose, the study employs the nonparametric model (the DEA) to calculate technical efficiency. The DEA method assuming that the production frontiers either constant returns to scale CRS, or variable returns to scale VRS.

Results reveal that Kuwait is operating by optimal size production in both frontiers CRS, VRS and so it is considered as the benchmark for the rest of the GCC countries. On the other hand, the results show that Bahrain, UAE, Oman and KSA do not operate within optimal size which restrain them to perform the overall technical efficiency and scale efficiency. Instead, they may perform pure technical efficiency which means that those countries can be technically efficient independently within their current size.

The study recommends investigating the technical efficiency in other sectors and other countries.

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