Modeling the Efficiency of the Mobile Industry in the Middle East Using Data Envelopment Analysis

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Abstract

This paper is the first to present a detailed modeling framework for measuring and comparing the relative efficiencies of mobile operators in the Middle East. Partial Factor Productivity together with three different DEA models, the CCR, the BCC and the A&P, using multiple inputs and outputs, are implemented to measure the efficiency of 16 mobile operators in nine different countries in the Middle East. The paper offers quantifiable suggestions on the improvements which the relatively inefficient mobile operators have to abide with to be able to compete with their regional counterparts. Seven mobile operators were found to have been functioning at full efficiency while 9 were operating inefficiently. The most efficient mobile operator among the 16 was Avea Turkey, followed by Etsialat UAE, Wataniya Kuwait, Turkcell Turkey, Mobily Saudi Arabia, Orange Israel and finally du UAE.

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1   Introduction

The world is currently witnessing the information economy era where continuous information has become the main resource for competition. Telecommunications is the only guarantor of such information. In fact, telecommunications is an essential catalyst for economic growth as per the International Telecommunications Union's (ITU)[3] empirical studies conducted in 1984 [1] and 1999 [2]. It boosts economic growth through its integration in every sector of the economy; agriculture, infrastructure, education, health, business, as well as the governmental sector. It succeeded in removing several obstacles from the everyday economical processes. It shortens geographical distances, allows for a faster flow of information and is a main driver for cost reduction. Telecommunications has become a must for participating in the competitive world markets and for attracting investments. The mobile sector is one of the major corner-stones of the telecommunications systems which play a major role in conducting, organizing and managing processes in various sectors of the economy: large amounts of cross-border information flow, reduction in transaction and transport costs, stimulation in consumer demand for world-class brands, services and products [3].

With the introduction of the mobile phones in the early 1990's, the face of telecommunications has drastically changed.   In 1996, the number of new mobile subscribers was greater than the number of new fixed-line subscribers, and in 1998 the number of new mobile users was twice that of the fixed ones. The turning point in the mobile industry's history was in 2002 when the number of mobile subscribers has surpassed the number of fixed-line subscribers worldwide [4]. That was also the case of the mobile industry in the Middle East that witnessed in addition to the fast growth, significant technological developments and fierce competition due to the issuance of multiple mobile licenses. The competitive pressures have led the mobile operators to focus on improving their services and products and cutting their costs to better manage and maintain their profits. Working at optimal level of efficiency and productivity becomes indispensable when operating in a gradually saturated market such as the Middle Eastern one.

Currently, there is an increasing concern among organizations to study the level of efficiency with which they operate relative to their competitors. Efficiency is an important aspect to measure because all the resources used by organizations are scarce. Inputs such as labor, raw materials, time and energy are not very abundant anymore. This is why organizations should try to conserve and use them in the best possible manners. Efficiency is concerned with the optimal use of these

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[3] The United Nations specialized agency for information and communication technologies (ICTs).

scarce resources to produce outputs of a given quality. Efficiency can be assessed in terms of technical efficiency, allocative efficiency, productive efficiency, dynamic efficiency, cost efficiency, social efficiency and distributive efficiency. The most common concept of efficiency is the technical efficiency. A unit is said to be technically efficient if it is producing the maximum amount of output while using the minimum amount of inputs. Efficiency is an important factor in the determination of productivity. Productivity is usually expressed in the form of partial factor productivity or total factor productivity.

One commonly used model for efficiency measurement is the partial factor productivity (PFP) that considers a single input and a single output. However, partial factor productivity is subject to the weakness that it fails to measure the total productivity with multiple inputs and outputs. Moving from partial factor productivity to total factor productivity by combining all inputs and all outputs helps to avoid accrediting gains of production to one input that should be attributable to another input but faces at the same time several difficulties such as choosing the inputs and outputs and consequently assigning weights for each of them to reach a single output to input ratio. A model that does not require a common set of weights and prior assumption of the production function is the data envelopment analysis (DEA).

DEA is a non-parametric linear-programming (LP) based technique that converts multiple input and output measures into a single comprehensive measure of relative efficiency. DEA is a methodology directed to frontiers and not to central tendencies. It uncovers the relationships between the inputs and outputs. It does not keep them hidden like other modeling instruments such as statistical regression where a regression plane is fit through the center of the data. In DEA, the organization under study is called a decision making unit (DMU). The definition of DMU has been intentionally left unrestricted to allow the use of DEA over a wide range of applications. A DMU is considered any entity responsible for converting inputs into outputs and whose performance is to be measured. DEA is concerned in measuring relative efficiency, whereby, a DMU is to be rated as 100% or fully efficient if and only if the performances of other DMUs do not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs [5]. This definition of relative efficiency avoids the necessity of assuming weights for the factors of production or specifying the relations that are supposed to exist between them.

Since there is a complete absence of academic work measuring and comparing the performance of mobile operators in terms of productivity and efficiency in the Middle East, and despite the complication and difficulty in getting data for the mobile operators in such a region where only few are publicly listed, this paper is the first to do so using the PFP and DEA models for sixteen mobile operators in nine different countries in the Middle East during the year 2011.

The paper proceeds as follows. Section 1 explores the literature review of efficiency measurement. The data and the selection of the appropriate input and output factors together with the implementation of the PFP and DEA models are systematically assessed in section 2. The three DEA models, namely the basic CCR, the BCC and the A&P, are also applied in section 2. The results of the PFP and DEA models are depicted in section 3. The paper then concludes the empirical findings.

2   Literature Review

Researchers have been attracted to measure productivity and efficiency in the mobile industry using several methods. The methods used included partial productivity, data envelopment analysis, Tobit regression, sensitivity analysis, Malmquist index approach, total factor productivity, and other measurements.

Hsiang-Chih Tsai (2006) [6] performed a study on 39 of Forbes[4] 2000 ranked leading global telecom operators from America, Asia- Pacific, Europe and Africa to measure the productivity efficiency ratings of those operators and to check if the top ranked Forbes operators have the top ranked efficiency measures. The study applied the DEA using three methods, the traditional radial method known as the CCR model, developed by Charnes, Cooper and Rhodes in 1978, the A&P model developed by Anderson and Peterson in 1993 and the efficiency achievement measure that was proposed by Chiang and Tzeng in 2000. The DEA efficiency scores showed that eight companies out of the 39 were operating at full efficiency. The DEA efficiency scores obtained of the 39 companies were then compared with their relative EBITDA margin, Return on Assets (ROA), Total Asset Turnover, and Profitability and their Forbes 2000 ranking. The results showed that the DEA ranking, the Forbes ranking and the four quantitative financial performance indicators ranking are significantly different. The DEA ranking showed a higher correlation with the total asset turnover ranking. And the EBITDA margin ranking, the ROA ranking and the profitability ranking revealed a higher correlation with each other. Whereas the Forbes ranking showed a lower correlation with the ROA ranking, the profitability ranking, and the DEA ranking.

Another study was performed to explore the impact of industrial policy on

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[4] Forbes is an American media and publishing company headed by Steve Forbes, best known for *Forbes Magazine*. Forbes provides daily news coverage on business, technology, financial markets, personal finance, sports and a wide array of other topics. Forbes is also widely known for its lists of billionaires, world's richest people, world's leading companies and the richest celebrities, among others. Forbes was founded in 1917.

the efficiency and productivity of 24 major Asia-Pacific telecom firms under the circumstance of competition and privatization [7]. The time period covered the years 1999 through 2004. In the first stage the researchers applied the data envelopment analysis to measure the efficiency scores of the units focusing on technical efficiency, pure technical efficiency and scale efficiency, taking into consideration the returns to scale status. In the second stage, the inefficiency scores obtained from the DEA were regressed using the Tobit regression method against four environmental factors: market concentration, public ownership, fixed assets ratio and fixed line revenue ratio. In the third stage, the Malqumist productivity index was used to evaluate the longitudinal total factor productivity (TFP). The results showed that 12 out of the 24 firms improved their productivity while 11 firms declined. The growth in productivity was due to technical growth rather than to efficiency change. The study concluded that firms wishing to increase their efficiency and productivity should rely on technological improvements.

Comparing Operational Efficiency among Mobile Operators in Brazil, Russia, India and China [8] is a study that examined the operational efficiency among 10 mobile operators in the BRIC region between the years 2002 and 2006. The efficiency measure was done through PFP and the DEA decomposed into pure technical efficiency and scale efficiency. Four mobile operators from Brazil and two mobile operators from each of Russia, India and China were analyzed. A sensitivity analysis was then applied which showed how the DEA efficiency scores of the ten operators varied when deleting one of the three inputs each at a time. The study revealed similar results for both methods the PFP and DEA. The Brazilian operators which had the highest average productivity factors had as well the highest efficiency scores. And the two Indian operators which had the least efficiency scores had the lowest average productivity ratios.

Furthermore, DEA was used to measure the operational efficiency of six mobile operators in Japan and Korea between the years 2002 and 2006 [9]. In addition to the DEA, the study applied the partial factor productivity. The analysis was taken further through the Tobit regression to be able to determine the factors that are influencing the overall technical efficiency of the mobile operators under study. The results demonstrated that the Japanese operators are more efficient than the Korean ones. This was mainly due to the higher usage of data services in Japan than in Korea and the unsuccessful implementation of the WCMDA (Wideband Code Division Multiple Access) in the early stage in Korea. The Tobit regression showed that the geographical area, the quality of service, the degree of competition, the 3G network type, the ratio of 3G subscribers, and the ratio of data service revenues all had a significant effect on the efficiency of operators. The study performed on the Indian mobile telecom operators using DEA and sensitivity analysis [10] on 126 operators showed that the older operators lie on the efficiency frontier and act as benchmarks for the younger ones. A sensitivity analysis was then performed. It showed that the private operators are more

efficient than the state-owned ones. Many operators proved to be distinctly inefficient and require improvements to increase their efficiency.

A different form of DEA was applied on the Malaysian telecommunications sector to compare its performance before and after privatization. The study was applied only on one operator in Malaysia, Telekom Malaysia, through two dimensions, its fixed line business and its overall business. The period under study was from 1968 until 2007. Since only the performance of one operator was being analyzed and the purpose was to compare its performance over time, the time series DEA analysis was applied. The time series DEA approach treats each year's data as a different decision making unit and compares them to each other. The results showed that the performance after the company has been privatized was better than the performance before privatization. A similar study was performed on one single operator, Korea Telecom, but to measure the impact of competition on its efficiency as a public enterprise and one of the biggest telecommunications service providers in Korea [11]. Besides the time series DEA, PFP was used. The PFP showed mixed results and did not help the researchers to draw the needed conclusion for their study. The DEA results showed an improvement in overall efficiency due to an improvement in allocative efficiency and not in technical efficiency. This implied that when monopolistic firms face external competition they tend to respond by reducing input cost and excessive capital but need time to improve their technical efficiency.

Banker, Cao, Menon, and Natarjan (2010) [12] studied the productivity growth of the U.S. mobile telecom industry. 16 out of the top 25 U.S. mobile operators were put under study from the year 2000 until 2002. DEA was used to measure the productivity. The results of the study showed that there was significant growth in productivity of the telecom industry in the U.S and that technological advancement almost exclusively contributed to this growth. Moreover, the operators that were early movers had better productivity improvement and technological progress and the same applied for the national operators in comparison with the regional ones.

Giokas and Pentzaropoulos (2000) [13] measured the efficiency of 36 telecommunications centers of Hellenic Telecommunications Organization in Greece. The inputs selected were number of technical personnel, administrative, operations, accounting and finance personnel, general duties, special status and temporary personnel and installed network capacity. The outputs selected were tariff units for automatic local, trunk, and international telephony and number of new connections and transfer of telephone lines. Out of the 36 telecommunications centers, 15 were operating efficiently.

The development and growth in DEA is evidence to its acceptance as a valuable model for measuring efficiency in the mobile sector. The below section will first apply the PFP method and then measure the efficiency of the mobile operators in the Middle East using the DEA model.

3   Implementation of the PFP and DEA to the Mobile Operators in the Middle East

3.1 Input - Output Factors

As showed in section 1, no common set of factors of production has been used when measuring efficiency in the mobile sector. We will make sure in this paper that the inputs and outputs relate to the objectives of the DMUs, which are the mobile operators, are consistent across DMUs and are quantifiable. This is the most challenging step especially that few of the operators are publicly listed, and thus obtaining their financial and operational data was hard and costly.   We will use 3 input factors and 2 output factors as illustrated in Table 1.

Table 1: Input and Output Factors

Input	Output
Total number of employees (Emp) Total Assets (TA) CAPEX	Total Revenue (TR) EBITDA

The input factors chosen are the total number of employees, total assets and capital expenditures. Since labor is an essential input in the production function of any mobile operator, the number of employees was chosen. The capacity a mobile operator has is represented by its total assets. Total assets are all assets owned by the operator, including current assets, fixed assets, intangible assets and deferred tax assets. The mobile communication industry is capital intensive, and the operator's capital expenditures (CAPEX) are necessary for the construction of its network. The CAPEX invested affects call quality, coverage, transmission speed and network capacity. This is why CAPEX was chosen as an input factor in our study. It represents the total expenditures for the purchase of property, equipment and other assets.

As for the output factors, one can use the amount of service produced by the operators which is measured in terms of number of voice minutes, number of SMS and the data volume produced from GPRS and 3G. But those figures are not obtainable for most of the operators we are studying. Instead, we used the revenue and earnings made by the operators as output factors: total revenue, and earnings before interest, taxes, depreciation and amortization (EBITDA) were selected.

Given the fact that the input and output values should be positive, operating profit (EBIT) and net income were excluded as output variables because of their negative values for 4 mobile operators in 2011.

3.1.1.   Number of DMUs

One of the restrictions when constructing a DEA model is the total number of DMUs, and the number of inputs and outputs to be selected. The basic requirement in DEA is that the number of DMUs exceeds three times the number of input plus output variables.

$$n > 3(m+s) \tag{1}$$

where:
 n is the number of DMUs
 m is the number of inputs
 s is the number of outputs
The 16 selected DMUs in our study with 3 input and 2 output factors met the above condition $\{16 > 3(3+2)\}$.

3.1.2.   Isotonicity Test

Another restriction is the isotonicity principle which the input and output factors have to comply with. Increasing an input should result in an increase in the value of an output and not cause a decrease. To determine this isotonicity property we performed a correlation analysis on the input and output variables already selected. Table 2 depicts the correlation coefficients obtained and shows that all the coefficients are greater than 0.5, indicating a positive high correlation between the input and output variables. Only the correlation coefficient between EBITDA and CAPEX is 0.46, slightly below 0.5, but still indicating a positive and acceptable correlation coefficient.

Table 2: Pearson Correlation between Inputs and Outputs

r	TR	EBITDA
TA	0.96	0.79
CAPEX	0.67	*0.46
Number of Employees	0.86	0.70

3.2. Sample and Data Collection

Table 3 depicts the 16 operators that we included in our sample and compares them in terms of the total number of mobile subscribers, the number of 3G[5]

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[5] Third generation of mobile telecommunications technology. 3G allows mobile operators to offer high speed internet service.

Table 3: A Comparison between the Mobile Operators' Subscribers Number and
Market Share

Country	Operator	Total number of mobile subscribers	Number of 3G subscribers	Market Share
Turkey	Turkcell	34,500,000	18,500,000	53%
Saudi Arabia	STC	25,969,406	10,203,292	46%
Saudi Arabia	Mobily	23,032,657	11,057,603	41%
Turkey	AVEA	12,800,000	3,725,000	20%
UAE	Etisalat	7,800,000	3,779,417	60%
UAE	du	5,216,000	2,122,179	40%
Israel	Cellcom	3,349,000	3,349,000	34%
Israel	Orange	3,176,000	1,826,909	32%
Oman	Omantel	2,819,858	605,178	59%
Jordan	Orange	2,694,000	900,000	35%
Palestinian Territories	Jawwal	2,425,000	0	84%
Kuwait	Wataniya	1,957,713	1,026,758	38%
Oman	Nawras	1,933,061	255,393	41%
Kuwait	Viva	1,047,000	627,054	20%
Qatar	Vodafone	797,000	302,468	28%
Palestinian Territories	Wataniya	464,964	0	16%

Source: GSMA[6]- GSMA Intelligence[7]

subscribers and the market share.

The circumstances and conditions of the mobile sector in the Middle East
differ between the countries. Over the past years, the region has undergone a wave
of market liberalization. Several operators have been privatized and the issuance
of new licenses has given way to new entrants. However, the degrees of

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[6] GSM Association (GSMA) - Founded in 1987, The GSM Association (GSMA) is a
global trade association representing more than 700 GSM mobile phone operators across
217 territories and countries of the world. More than 180 manufacturers and suppliers
support the Association's initiatives as associate members.

[7] GSMA Intelligence is part of GSM Media LLC. It provides coverage and data of all
1,140 mobile operators, 3,505 networks and 236 countries from 1979–present with
five-year forecasts and analysis on the mobile ecosystem. https://gsmaintelligence.com/

liberalization vary between the markets. Some are currently witnessing fierce competition such as in Jordan, Kuwait, Saudi Arabia and Israel. While the competition level remains low in countries like Palestine, Qatar, and UAE. Subject to the different regional economical and political situations and the global mobile trends, the mobile operators in the Middle East are forced to operate at full efficiency to maintain and possibly increase their profits and markets shares. This was enough to justify the objectives of our paper.

The data for the above input and output factors were collected from the mobile operators' published financial statements and the 2011 end of year reports. The major challenge was with obtaining the number of employees. Interviews were held with the operators whose number of employees is not publicly stated[8]. All the financial figures collected where converted from the operators' reported currencies to US dollar as per the exchange rate of 16 February, 2013.

Table 4 shows the statistical summary of the data collected. For the number of employees, the median was used instead of the mean because one company among the 16, STC Saudi Arabia, has a huge number of employees relative to the others (21,000 employees).

Table 4: Statistical Summary of Input and Output Variables

	n	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
Employees *(person)*	16	4,333	2,726	405	21,000	5,405
TA *($, million)*	16	5,491.70	1,808.64	283.24	29,699.71	8,317.17
CAPEX *($, million)*	16	495.91	254.59	44.36	2,063.67	592.82
TR *($, million)*	16	2,369.38	1,240.02	73.08	9,991.93	2,840.03
EBITDA *($, million)*	16	805.13	352.85	1.77	3,623.22	1,025.29

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[8] Those operators are Wataniya Kuwait, Wataniya Palestine, Vodafone Qatar, STC Saudi Arabia and Etisalat UAE.

3.3. PFP and DEA

3.3.1.   Partial Factor Productivity (PFP)

Even if the PFP fails to measure total productivity, it plainly gives productivity indicators easy to understand. This study calculated and compared six indicators:

1. Revenue per employee (RPE): the ratio of total revenue to the number of employees.
2. Revenue per total asset (RPA): the ratio of total revenue to the total assets.
3. Revenue per capital expenditure (RPC): the ratio of total revenue to the capital expenditure.
4. EBITDA per employee (EPE): the ratio of EBITDA to the number of employees.
5. EBITDA per total asset (EPA): the ratio of EBITDA to the total assets.
6. EBITDA per capital expenditure (EPC): the ratio of EBITDA to the capital expenditure.

Table 5: PFP ratios

Output Input	TR	EBITDA
Number of Employees	RPE	EPE
TA	RPA	EPA
CAPEX	RPC	EPC

3.3.2.   Data Envelopment Analysis (DEA)

Following the application of the PFP to measure the productivity, three DEA models, the CCR[9], BCC[10] and the A&P[11] are applied to measure the relative technical efficiency of the 16 mobile operators under study. The input-oriented model that measures how much less inputs a mobile operator can employ to produce the same amount of output, is selected in this paper. In fact, a mobile operator has better control over its inputs. The outputs in the mobile sector may be driven by factors beyond the control of the operator such as market factors and competition.

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[9] Refers to the development of the first DEA model by Charnes, Cooper and Rhodes.

[10] In 1984, Banker, Charnes and Cooper proposed an extension on the CCR (CRS) model to account for variable returns to scale (VRS). The model they proposed is called the BCC model.

[11] The A&P model is a modified DEA model proposed by Anderson and Peterson.

1.   The Basic CCR Model

Efficiency is measured as a ratio of weighted sum of outputs to weighted sum of inputs. The efficiency formula applied to this study is translated into the following:

$$Efficiency(E) = \frac{u_1(TR) + u_2(EBITDA)}{v_1(Emp) + v_2(TA) + v_3(CAPEX)} \quad\quad (2)$$

Where:

u_1 is the weight given to the total revenue output

u_2 is the weight given to the EBITDA output

v_1 is the weight given to the number of employees input

v_2 is the weight given to the total assets input

v_3 is the weight given to the capital expenditure input

Without knowing the values of u_1, u_2, v_1, v_2, v_3 equation 2 is solved by rewriting it in the form of linear programming as done by Charnes, Cooper and Rhodes [14]. One of the main advantages of DEA is that it does not require prior assumptions of the production function or the weights of the factors of production.

Maximize $E_1 = u_1$ (TR) + u_2 (EBITDA)   *for mobile operator 1*   (3)
Subject to:
- v_1 (Emp) + v_2 (TA) + v_3 (CAPEX) = 1   *for mobile operator 1*
- $\sum u_1$ (TR) + u_2 (EBITDA) - $\sum v_1$ (Emp) + v_2 (TA) + v_3 (CAPEX) ≤ 0 *for all mobile operators*
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$

2.   The BCC Model

The CCR model shown in equation (3) only takes into account constant returns to scale (CRS). However, mobile operators are not always operating at optimal scale and are subject to variable returns to scale (VRS). To overcome the constraint of the CCR model, we will implement the BCC model which introduces an extra variable, u_o, representing the variable returns to scale. The linear programming formula in the BCC model becomes as follows:

Maximize $E_1 = u_1$ (TR) + u_2 (EBITDA) – u_o *for mobile operator 1*   (4)
Subject to:
- v_1 (Emp) + v_2 (TA) + v_3 (CAPEX) = 1   *for mobile operator 1*
- $\sum u_1$ (TR) + u_2 (EBITDA) - $\sum v_1$ (Emp) + v_2 (TA) + v_3 (CAPEX) - $u_o \leq 0$ *for all mobile operators*
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$
- u_o free in sign (its sign will indicate how the returns to scale are varying)

The results of both the CCR and the BCC models will be compared. If they are similar, this means there is no scale efficiency.

Scale Efficiency

Scale Efficiency is expressed as the ratio of Overall Technical Efficiency divided by Pure Technical Efficiency.

$$SE = \frac{OTE}{PTE} \tag{5}$$

Once the CCR and the BCC results are obtained, the Scale Efficiency of the 16 mobile operators will be calculated. Knowing that the CCR model provides the OTE value and the BCC model provides the PTE value, the Scale Efficiency of each mobile operator is obtained from the following formula:

$$SE = \frac{CCR}{BCC} \tag{6}$$

3.   The Modified DEA Model

The CCR and BCC models evaluate the relative efficiencies of the mobile operators and allow for the calculation of the scale efficiency, but do not rank the efficient DMUs. To overcome this weakness in the CCR and BCC models, the study will then apply the A&P model [15] to be able to differentiate between the efficient DMUs. The purpose of implementing the three different DEA models is to capture the entirety of the mobile operators' performance.

4   Findings

4.1.PFP Results

The results of the six indicators adopted in this study are illustrated in Table 6. It can be anticipated that Turkcell Turkey, Etisalat UAE, Avea Turkey and Wataniya Kuwait will be evaluated as fully efficient in the DEA analysis since they achieved at least one highest single-output-single-input ratio score. Nevertheless, there is a high probability that other mobile operators will be fully efficient as well when evaluating the efficiency using a multiple input and multiple output ratios. The PFP failed to provide a single numeric judgment for the productivity of the 16 mobile operators under study. The results did not show that one single operator has the highest ratios and thus is the most productive. On the contrary, each operator shows a different level of productivity depending on the measured indicator.

Table 6: Partial Factor Productivity Results

Operators	RPE ($,thousand/person)	RPA	RPC	EPE ($,thousand/person)	EPA	EPC
Orange Jordan	263.68	0.622	11.282	104.43	0.247	4.468
Mobily Saudi Arabia	1,297.24	0.535	5.183	482.24	0.199	1.927
STC Saudi Arabia	475.81	0.336	4.842	107.76	0.076	1.097
Viva Kuwait	702.42	0.742	3.250	3.75	0.004	0.017
Wataniya Kuwait	865.58	1.179	0.547	394.73	0.538	0.250
Nawras Oman	502.19	0.658	0.724	263.77	0.345	0.380
Omantel Oman	259.57	0.421	12.544	113.43	0.184	5.482
Jawwal Palestine	425.00	0.477	8.718	191.52	0.215	3.929
Wataniya Palestine	178.25	0.258	0.464	8.64	0.013	0.022
Vodafone Qatar	806.46	0.141	3.667	71.84	0.013	0.327
Avea Turkey	645.65	1.840	3.856	79.61	0.227	0.476
Turkcell Turkey	1,564.81	0.280	9.587	490.97	0.088	3.008
Etisalat UAE	587.04	0.451	13.596	324.95	0.250	7.526
du UAE	808.02	0.735	6.859	266.09	0.242	2.259
Cellcom Israel	229.08	0.717	11.770	77.86	0.244	4.000
Orange Israel	204.92	0.842	12.750	65.11	0.268	4.051

*Note: RPE- Revenue Per Employee. RPA- Revenue Per Total Asset. RPC- Revenue Per CAPEX
EPE- EBITDA Per Employee. EPA- EBITDA Per Total Asset. EPC- EBITDA Per CAPEX

4.2. Data Envelopment Analysis (DEA) Results[12]

The input orientation was selected for the CCR, the BCC and the A&P as justified in section 1. Since all three models assume convexity, the convex structure is selected along with the radial distance. The radial distance measures the DMU's efficiency score depending on its proportional distance from the efficiency frontier.

1. CCR Model Results

The DEA scores showed that 7 mobile operators are fully efficient and had a CCR score equal to 1, as displayed in Table 7. Turkcell Turkey, Etisalat UAE, Avea Turkey and Wataniya Kuwait are fully efficient, in addition to, Mobily Saudi Arabia, du UAE and Orange Israel. On the contrary, 9 operators, Cellcom Israel, Orange Jordan, Nawras Oman, Omantel Oman, Jawwal Palestine, Viva Kuwait, STC Saudi Arabia, Vodafone Qatar and Wataniya Palestine, are operating on a relatively less efficient level. Their CCR efficiency scores varied between 0.964 and 0.232.

Table 7: CCR Model Efficiency Results

Operator	*CCR*	Benchmarks
Mobily Saudi Arabia	1.000	2
Wataniya Kuwait	1.000	5
Avea Turkey	1.000	2
Turkcell Turkey	1.000	2
Etisalat UAE	1.000	6
du UAE	1.000	4
Orange Israel	1.000	5
Cellcom Israel	0.964	Orange Israel, Etisalat UAE, du UAE
Orange Jordan	0.955	Orange Israel, Etisalat UAE, du UAE, Wataniya Kuwait
Nawras Oman	0.934	Orange Israel, Etisalat UAE, Wataniya Kuwait
Omantel Oman	0.924	Orange Israel, Etisalat UAE
Jawwal Palestine	0.861	Orange Israel, Etisalat UAE, du UAE, Wataniya Kuwait
Viva Kuwait	0.842	Mobily Saudi Arabia, Wataniya Kuwait, Avea Turkey
STC Saudi Arabia	0.606	Turkcell Turkey, Etisalat UAE, du UAE
Vodafone Qatar	0.515	Turkcell Turkey
Wataniya Palestine	0.232	Mobily Saudi Arabia, Wataniya Kuwait, Avea Turkey

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[12] The DEA results were generated using the Efficiency Measurement System, EMS 1.3, software.

2. BCC Model Results

To take variable returns to scale into consideration, we ran the BCC model. The results changed dramatically and the majority of the DMUs were evaluated as fully efficient. The only two inefficient operators under the BCC model were Cellcom Israel and Nawras Oman.

Table 8: BCC Model Efficiency Results

Operator	BCC	Benchmarks
Mobily Saudi Arabia	1.000	0
Wataniya Kuwait	1.000	1
Avea Turkey	1.000	0
Turkcell Turkey	1.000	0
Etisalat UAE	1.000	1
du UAE	1.000	1
Orange Israel	1.000	1
Orange Jordan	1.000	2
Omantel Oman	1.000	0
Jawwal Palestine	1.000	1
Viva Kuwait	1.000	0
STC Saudi Arabia	1.000	0
Vodafone Qatar	1.000	0
Wataniya Palestine	1.000	1
Nawras Oman	0.996	Orange Jordan, Wataniya Kuwait, Jawwal Palestine, Wataniya Palestine
Cellcom Israel	0.966	Orange Israel, Etisalat UAE, du UAE, Orange Jordan

3. Scale Efficiency Results

The results from the BCC model differed from the CCR results indicating the existence of scale efficiency. Table 9 illustrates that the relative inefficiency the mobile operators showed under the CCR model is due to scale inefficiency rather than pure technical inefficiency. PTE purely reflects the mobile operator's managerial performance to organize its inputs in the production process. Whereas, SE indicates the management's ability to choose the optimum size and scale of production that will attain the needed level of production. The scale inefficiency the inefficient mobile operators showed is due to the size of the operator which is either too large and is not taking full advantage of scale or too small for its scale of operations. Only Nawras Oman and Cellcom Israel have a PTE<1 indicating inefficiency in their managements' performance and their inability to utilize resources in an optimal manner.

Table 9: OTE, PTE and SE results

Operator	OTE *(CCR)*	PTE *(BCC)*	SE
Mobily Saudi Arabia	1.000	1.000	1.000
Wataniya Kuwait	1.000	1.000	1.000
Avea Turkey	1.000	1.000	1.000
Turkcell Turkey	1.000	1.000	1.000
Etisalat UAE	1.000	1.000	1.000
du UAE	1.000	1.000	1.000
Orange Israel	1.000	1.000	1.000
Cellcom Israel	0.964	0.966	0.997
Orange Jordan	0.955	1.000	0.955
Nawras Oman	0.934	0.996	0.938
Omantel Oman	0.924	1.000	0.924
Jawwal Palestine	0.861	1.000	0.861
Viva Kuwait	0.842	1.000	0.842
STC Saudi Arabia	0.606	1.000	0.606
Vodafone Qatar	0.515	1.000	0.515
Wataniya Palestine	0.232	1.000	0.232
Mean	0.865	0.998	0.867

SE=OTE/PTE

Table 10: A&P Model Results

Ranking	Operator	Score
1	Avea Turkey	2.086
2	Etisalat UAE	1.846
3	Wataniya Kuwait	1.623
4	Turkcell Turkey	1.567
5	Mobily Saudi Arabia	1.338
6	Orange Israel	1.153
7	du UAE	1.145
8	Cellcom Israel	0.964
9	Orange Jordan	0.955
10	Nawras Oman	0.934
11	Omantel Oman	0.924
12	Jawwal Palestine	0.861
13	Viva Kuwait	0.842
14	STC Saudi Arabia	0.606
15	Vodafone Qatar	0.515
16	Wataniya Palestine	0.232

4. A&P Results

The results of the CCR model identified the 7 DMUs with full relative overall technical efficiency and gave each of them a score equal to 1 without differentiating between them. To be able to rank the efficient DMUs, the A&P model was ran using the 'Superefficiency' field. Table 10 shows that the most efficient mobile operator among the 16 is Avea Turkey, followed by Etsialat UAE, Wataniya Kuwait, Turkcell Turkey, Mobily Saudi Arabia, Orange Israel and finally du UAE.

5   Discussion and Conclusion

The most important objective of efficiency measurement is improvement. The DEA is a useful model for planning the improvements for the 9 inefficient DMUs. We have been able to measure the efficiency scores of the mobile operators using the three different DEA models. In this section we quantify[13] the needed improvements to optimize the output of this study. Since we are concerned with the input orientation, the needed improvements mainly focus on a decrease in the inputs used by the mobile operators to maintain the same level of output, as shown in Table 11.

The values in Table 11 are the target amount of inputs which the mobile operators should be using to become fully efficient. The report showed that the target values for the 7 fully efficient operators are the same as their actual ones. For the 9 inefficient mobile operators, the target values were compared with the actual ones to show the improvements they need to undergo in order to maximize their efficiency and reach the efficiency frontier (Table 12).

In other words, the 9 inefficient mobile operators need to decrease their input levels by the above percentages and maintain the same 2011 level of output to become fully efficient.

In our model we assumed all DMUs as being homogenous, but this in fact may not always be true. In addition, and due to the non-transparency of the mobile operators in terms of internal management strategies and input capacities, it was not possible to have the weights allocated to the factors of production prior to running the models. Another limitation we faced is the inability to measure the absolute efficiency of a DMU. Despite these limitations, this paper provided a framework for measuring and comparing the relative efficiencies of mobile operators in the Middle East and for offering suggestions on the improvements which the relatively inefficient mobile operators have to abide with to be able to

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[13] The DEA Frontier will be used http://www.deafrontier.net .

Table 11: Target Report Generated by the DEA Frontier

DMU No.	DMU Name	Efficient Input Target		
		Number of Employees	TA	CAPEX
1	Cellcom Israel	6,989	2,234,386,129	136,042,441
2	Orange Israel	7,891	1,920,577,000	126,828,000
3	Orange Jordan	2,104	891,565,023	49,187,602
4	Mobily KSA	4,121	9,997,680,221	1,031,368,759
5	STC KSA	12,722	17,993,300,168	1,250,255,037
6	Viva Kuwait	397	376,023,108	85,881,599
7	Wataniya Kuwait	997	7,321,57,987	1,576,677,729
8	Nawras Oman	952	727,167,895	660,626,751
9	Omantel Oman	1,268	1,567,833,610	52,619,974
10	Jawwal Palestine	783	698,000,170	38,185,639
11	Wataniya Palestine	95	65,834,067	36,638,977
12	Vodafone Qatar	208	1,168,129,709	34,068,903
13	Avea Turkey	2,700	947,316,600	452,061,858
14	Turkcell Turkey	3,071	17,186,699,999	501,256,000
15	Etisalat UAE	11,150	14,520,553,527	481,426,400
16	du UAE	2,984	3,282,623,335	351,539,300

Table 12: Needed Improvements for the Inefficient Mobile Operators

	Employees	Total Asset	CAPEX
Cellcom Israel	-3.6%	-3.6%	-3.6%
Orange Jordan	-4.5%	-4.5%	-4.5%
Nawras Oman	-6.6%	-6.6%	-6.6%
Omantel Oman	-53.9%	-7.6%	-7.6%
Jawwal Palestine	-13.9%	-13.9%	-13.9%
Viva Kuwait	-15.8%	-15.8%	-15.8%
STC Saudi Arabia	-39.4%	-39.4%	-39.4%
Vodafone Qatar	-48.5%	-49.5%	-61.7%
Wataniya Palestine	-76.8%	-76.8%	-76.8%

compete with their regional counterparts. Mobile operators are confronting a lot of challenges, and operating as efficiently as possible is becoming very crucial.

Challenges are related to severe competition. Competition is coming from mobile operators among themselves and from external parties such as voice over IP (VoIP) providers and internet service providers (ISP). VoIP providers are hindering the mobile operators' revenues from international voice calls, whereas the ISPs are threatening the mobile operators' broadband revenue. This is why operators are going to compete for data packages and international traffic. Prices are falling, and mobile operators in highly penetrated markets will start to re-price service packages to win customers regardless if it is profitable or not. In response to competition, mobile operators are in the process of rolling out Long Term Evolution (LTE) hoping to get a premium price form the upgrade of customers from 3G to LTE. However, LTE will not bring the anticipated revenue. Amidst the fierce competition, mobile operators will be forced to reduce their LTE prices as well. Operators will try to limit their losses by earning revenue from new value added services (VAS).   VAS might help in compensating part of the revenue, but it will be unlikely for it to replace all the lost revenue. The greatest value that mobile operators will gain from VAS will be more of a marketing image rather than financial gain. There does not seem to be a new technology which will be able to create new revenue for mobile operators. For this reason, investors in the telco industry should be careful. They have previously enjoyed high returns, but the share prices will start to decrease. Mobile operators have invested a lot of money to obtain licenses and are now forced to offer low prices for their services. To be able to compensate for the high licenses prices paid; mobile operators will have two solutions: either massive cost cutting or consolidation. The consolidation the mobile market will witness will be of two types: light consolidation where two

or more operators build an infrastructure together, or the classic consolidation where two or more operators will be merged into one.

Taking the above challenges into account, mobile operators, globally and in the Middle East, do not have a choice but to be operating in the most efficient manner to be able to generate the highest revenue possible from the industry. Financial ratios do not reflect efficiency; only models similar to the proposed DEA are able to evaluate efficiency and suggest quantifiable improvements. The operators' managements and regulators are now urged to apply similar models in order to guarantee and optimize their continuity.

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