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CODEN: IAASCA **ORIGINAL ARTICLE**

Relative Efficiency Analysis of Container Ports in Middle East using DEA-AP

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ABSTRACT
The aim of this study, is evaluating of relative efficiency of major container port in Middle East for the period of 2011-2013. Required information was collected from scientific resources and inputs and outputs data were collected from statistical yearbook of the Iran's ports and maritime organization and formal website of each foreignport. Firstly in this study Relative Efficiency of Ports were evaluated via one basic model of DEA-technique namely BCC-O. Then ports were ranked based on the achieved results. To rank ports with the 100% efficiency Anderson-peterson method was used. Based on the results of output- oriented BCC modelthatrepresentspure technical efficiency, ports of Bushehr, Jebel Ali, Khorfakkan and Alexandria have the highest coefficient of efficiency and Bandar Imam Khomeini have been the weakest port in three yearsin this respect. Most of Ports in considered period operated, under variablereturns to scale, and only ports of Khorafkan and Alexandria, have been operated underconstantreturns to scale. In theperiod2011-2013, the average of pure technical efficiency has was calculated 73percent. Finally, virtual ports were proposed as template for inefficient ports to improve efficiency.
***Key words**: maritime transportation, container ports, Middle East, efficiency, data envelopment analysis*

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INTRODUCTION

The globalization of the world economy has led to an increasingly important rolefor transportation. In particular, container transportation plays a key role in this process;largely because of the numerous technical and economic advantages it possesses over traditional methods of transportation. Standing at the crucial interface of seaand inland transportation, the significance of the container port and its production capabilities cannot be ignored[1].

The maritime transport services have benefited the economy of many regions of the world because more than 80 percent of the world trade volume is carried by ships. Maritime transport is thus an efficiency facilitator of the world trade [2].This role has become moreapparent and crucial in today's expanded and diversified world trade system. Maritime transport was,and currently is, the backbone of development for many countries [3]. Theadvantage of maritime transport is the speed, comfort, safety, and the possibility and ability to handle heavy traffic of goods and passengers at relatively low prices.Compared with traditional port operations, containerization has greatly improved port production performance. To reap economies of scale and of scope, liner shipping companies and container ports are respectively willing to deploy dedicated containerships and efficient container handling systems. As a consequence, port productivity has been greatly enhanced. At the same time, many container ports no longer enjoy the freedom yielded by a monopoly over the handling of cargoes from within theirhinter land; they are not only concerned, therefore, with whether they can physically handle cargo, but also whether they can

compete for cargo. This inter-port competition, under the orthodox microeconomic framework, is believed to provide an incentive to improve port performance. Under such a competitive environment, port performance measurement is not only a powerful management tool for port operators, but also constitutes a most important input for informing regional and national port planning and operations. This critical dependence of the competitiveness of a container port on thelevel of efficiency it offers is a recurrent finding in empirical studies of port choice, but is most recently and persuasively evidenced [4].
Seaports, serving as the interface between maritime and inland transportation, play a significant role in the economic development of a region. Production capabilities and the performance measurement of seaports have always been a major issue in seaport management. Besides functioning as a powerful management tool for seaport operators, seaport performance measurement also functions as an important input for regional and national seaport planning and operations. One of the important aspects Constant of seaport performance measurement is the efficiency and for evaluation of efficiencythe popular method of Data Envelopment Analysis (DEA) is used [5].
This study aims to benchmark the efficiency of the Middle East container seaports using the Data Envelopment Analysis (DEA) method and to investigate the changes in the pure technical efficiency, scale efficiency and nature of returns to scale, over the period 2011 to 2013. The following section will mainly review the literature on port efficiency. Next, the Data Envelopment Analysis (DEA) framework will be discussed. The empirical results and the analysis will be presented and discussed in the fourth section. The final section summarizes and concludes.

METHODOLOGY

Data Envelopment Analysis (DEA)

The basic concept of efficiency measurement is the ratio of total outputs to total inputs. Charnes et al. [6] were the first to introduce the *DEA* as a multi-factor productivity analysis module for measuring the relative efficiencies on making units (*DMU*s). This model cannot support imperfectly competitive markets. To overcome this limitation, Banker *et al*. [7] described *BCC* model, this model estimates its productivity level at the given scale of operation and identifies return to scale. The goal is to select a set of inputs and outputs that are relevant to the evaluation of performance and for which a moderate statistical relationship exists.
In *DEA*-*CCR* model all observed production combinations can be scaled up or down proportionally, and in *DEA*-*BCC* model the variables allow return to scale and is graphically represented by a piecewise linear convex frontier. The *DEA* is normally applied to analyze the cross section data, where time is ignored and *DMU* are compared with the others at the same period. In this paper, we propose the output-oriented *DEA* model to maximize the output while the given current inputs remain the same. The mathematical expression of the *DEA* models as follow:
1) *CCR* Model [6].
Max $y_j=\theta$
s.t

$$\sum_{k=1}^{n} \lambda_k \ y_{rk} \geq \theta y_{rj}$$

$$\sum_{k=1}^{n} \lambda_k \ x_{ik} \leq x_{ij}$$

θ free; $\lambda_k \geq 0$; k=1,2,…,n; r=1,2,…,s; i=1,2,…,m
And 2) *BCC* Model, [7] is defined by adding equations (2) to expression (1) above.

Where *n* is number of *DMU*, θ_j is the efficiency of the jth*DMU*, *xik*are *i-th*inputs of the *k-th* *DMU*, *yrk are* the outputs of *k-th DMU* and *λk*is weight of *k-th DMU*. The *DEA*-technique requires a large number of medium-sized linear programming problems to be solved. The two models, described previously, the first is called *CCR* model (constant return to scale) which is a scale efficiency and technical efficiency, and the second is called *BCC* model (variable return to scale) which is a pure technical and scale efficiency [8].

Returns to Scale

A DMU is said to operate at constant returns to scale (CRS) when there is proportional increase or decrease of the output to input resources. If the DMU increase by less than proportional change, then it is deemed as operating at decreasing returns to scale (DRS). On the other hand, if the DMU increase by more than the proportional change, then it operates at the increasing returns to scale (IRS). Both of the DRS and IRS fall under the variable returns to scale (VRS).

Anderson-Peterson Model(A&P)

Basic DEA models cannot easily present ranking of efficient units. AP concept is in fact a criterion for ranking of efficient units. Ranking level assigned to efficient units in AP model is equal to or greater than 1. Residual levels obtained from efficiency value using AP model indicates the increase in input levels and the DMU with more input consumption may has more efficiency[31].

Max $y_j=\theta$

s.t

$\sum_{k=1}^{n} \lambda_k \, x_{ik} + s_i^- = x_{ij}$ i=1,2,…,m

k≠j

$\theta y_{rj} \sum_{k=1}^{n} \lambda_k \, y_{rk} + s_r^+ = 0$ r=1,2,…,s

k≠j

$$\sum_{k=1}^{n} \lambda_k = 1$$

k≠j

$\lambda_k, s_i^-, s_r^+ \geq 0$; θ آزاد در علامت k=1,2,...,n و k≠j

Variable Selection and Sample

The container throughput in twenty equivalent units (TEU) is the most common and appropriate indicator on determining the port's production efficiency and is popularly used in the previous efficiency comparison studies as the sole output of port production. It is strongly related to the need for cargo-related facilities and services. This study uses container throughput as the single output.

In production theory, vital inputs are labor, land and equipment. Almost all previous studies, take into account the total berth length and the total terminal area as land input. However, only container berth and multipurpose berth will be taken into consideration in this study. Due to the difficulty of collecting labor information, a labor proxy variable will be derived based on the suggestion of Notteboom *et al*. [10] that highlights the close relationship between the number of gantry cranes and the number of dock workers in a container terminal. Thus, this study uses yard and quay equipment to proxy labor.

Table 1 provides a summary of the input and output variables definitions which will be used in DEA-BCC model in the empirical part of this study. All the variables used in this study have been aggregated from each terminal to port level by summing up the quantity of the equipment from each terminal for a particular port.

This study considers the container seaports in Middle East region for performance benchmarking. Data on container seaports from these regions are collected primarily based on the International Containerization Year Book for a period of 3 years spanning from 2011 to 2013. The total number of seaports analyzed in this study is 12. They are located in 5 countries i.e. Islamic Republic of Iran, United Arab Emirates, Saudi Arabia, Oman, Egypt (see appendix table for the list of ports studied).Using this data, can form data envelopment analysis for each container port and their relative efficiency achieved. After forming desired models with data of these ports, these models were calculated with DEA Solver Pro software and the efficiency of ports and their rankings were based on output oriented BCC method. Then, for ports that have the efficiency coefficient 1 to the AP model was implemented in Lingo software. These Results have shown in Table 3:

In addition the ability of DEA, to calculate the relative efficiency of decision maker units and ultimately their ranking, this model can introduce units as reference units for each of the inefficient units. These reference units,indeed, as patterns for inefficient units to be efficient units by closing their inputs or outputs to reference units.

In the Table 5 shadow price each reference unit of inefficient units are represented. Through the aid of shadow prices Ports can be calculated the combined Virtual container ports. Combined Virtual Ports represent the coordinates of inputs and outputs of inefficient ports for becoming efficient ports. To obtain the combined virtual ports must shadow prices of reference Ports multiplied by corresponding coordinates the input and output of corresponding reference coordinates ports and then combine the resulting weighted inputs and outputs.

RESULT

Descriptive Statistics

Table 2 displays the descriptive statistics for the input and output variables used to calculate the efficiency scores. On average, all the input and output variables are showing an upward trend from 2011 to 2013. This indicates that container seaports in Middle East are developing and expanding within the observed periods. Besides, the enhancement and development of the ports' capacity have improved the total container throughputs.

DEA Results

The result of the pure technical efficiency within the observed period, from year 2011 to 2013, of each container seaport in Middle East is presented in the Table3.

Table 1: Definition of Output and Input Variables for DEA model TatT

Variable	**Description**
Output Throughput	Total container seaport throughput (TEU)
Inputs Berth Berth length Terminal Area Quay & Yard Gantry	 Total number of berth Total berth length (m) Total terminal area (m^2) Total number of quayside cranes, mobile cranes, quay gantry, mobile gantry and the ship shore container gantry, yard gantries

Table2. Descriptive statistics for input -output variables, Middle East container ports, 2011-2013

		2011	2012	2013
No of berth	Minimum	2	2	2
	Maximum	23	23	23
	Mean	8.66	8.66	9
	SD	5.99	6.20	6.39
Berth Length (m)	Minimum	388	388	388
	Maximum	7875	7875	7875
	Mean	2080.25	2166.41	2333.08
	SD	2004.83	2034.98	2038.28
Terminal Area (m2)	Minimum	13	13	13
	Maximum	508	508	508
	Mean	107.08	112.08	115.41
	SD	132.26	131.99	132.30
No of Quay & Yard Gantry	Minimum	3	4	4
	Maximum	261	261	261
	Mean	60.41	65.91	68.91
	SD	71.30	71.27	70.92
Total Container Throughputs (TEU)	Minimum	102000	86000	55000
	Maximum	13000000	13270000	13641000
	Mean	2837083.3	2945166.7	291408.3
	SD	3410678.4	3500920	3601163.3

SUMMARY AND CONCLUSION

According to the results of the implementation of output-oriented BCC model, the ports of Bushehr, Khorfakkan, Jebel Ali and Alexandria have the highest efficiency and the port of Imam Khomeini, in this respect, is presented the weakest performance. The results of the AP model.

Table 3: DEA Efficiency Results of Middle East Container ports

ports		2011	2012	2013
Imam Khomeini	VRS	0.102	0.094	0.161
	RTS	IRS	IRS	IRS
Bushehr	VRS	1	1	1
	RTS	IRS	IRS	IRS
Khorramshahr	VRS	1	0.22	0.199
	RTS	IRS	IRS	IRS
Shahidrajaee	VRS	0.775	0.493	0.523
	RTS	DRS	DRS	IRS
Jabel Ali	VRS	1	1	1

	RTS	DRS	DRS	DRS
Khorfakkan	VRS	1	1	1
	RTS	Constant	Constant	Constant
Salalah	VRS	0.940	0.831	0.798
	RTS	DRS	DRS	DRS
Sohar	VRS	0.467	0.995	1
	RTS	IRS	IRS	IRS
Dammam	VRS	0.453	0.347	0.538
	RTS	DRS	DRS	IRS
Jaddeh	VRS	0.600	0.652	0.628
	RTS	DRS	DRS	DRS
Port said	VRS	1	0.763	0.744
	RTS	DRS	DRS	DRS
Alexandria	VRS	1	1	1
	RTS	Constant	IRS	Constant

Show that the port of Jebel Ali in years of 2011 and 2013 and Port Khorfakkan in year of 2012 were the most efficient ports. As seen in Table 2,in the period of mining, most of ports operated under variable returns to scale.It can be concluded that the managers of these ports with expanding the capacity of own inputs, saw an increase in output and thereby increase their efficiency. Since the BCC model represents pure technical efficiency, so coefficient of this model for each port, represent operational inefficiency. This means that the managers of these ports should focus on improving management approaches and handling of the operations. With a particular focus on Iran's container ports, the ports of Khorramshahr, shahidRajaee and especially the port of Imam Khomeini were operation inefficient and only port of Bushehr in this respect has been efficient in every three years. In addition, the reference ports of inefficient ports were calculated with their shadow price. for example , Bandar Imam Khomeini by pattern of port of Bushehr with the shadow price of (0.890) and port of Khorfakkan with the shadow price of (0.190) price can be localized in 2013 to achieve pure technical efficiency.

Table 4: Anderson-peterson Results of Middle East Container ports

ports		2011	2012	2013
Imam khomeini	VRS	0.102	0.094	0.161
Bushehr	VRS	1.74	1.64	1.3
Khorramshahr	VRS	1.32	0.22	0.199
Shahidrajaee	VRS	0.775	0.493	0.523
Jabel Ali	VRS	3.043	2.8	2.99
Khorfakkan	VRS	1.816	2.961	1.728
Salalah	VRS	0.940	0.831	0.798
Sohar	VRS	0.467	0.995	1.105
Dammam	VRS	0.453	0.347	0.538
Jaddeh	VRS	0.600	0.652	0.628
Port said	VRS	1.059	0.763	0.744
Alexandria	VRS	1.539	1.324	1.4

Table5.reference ports and their shadow prices

ports	2011	2012	2013
Imam khomeini	Khorramshahr(0.326) Bushehr(0.256) Khorfakkan(0.416)	Bushehr(0.6) Khorfakkan(0.4)	Bushehr(0.809) Khorfakkan(0.190)
Khorramshahr	-	*Bushehr(0.95)* *Khorfakkan(0.05)*	Bushehr(0.976) Khorfakkan(0.023)
Shahidrajaee	Jabel Ali(0.033) Khorfakkan(0.966)	Jabel Ali(0.075) Khorfakkan(0.924)	Bushehr(0.119) Khorfakkan(0.88)
Salalah	Khorfakkan(0.833) Port Said(0.166)	Jabel Ali(0.038) Khorfakkan(0.961)	Jabel Ali(0.038) Khorfakkan(0.961
Sohar	Bushehr(1)	Bushehr(1)	-
Dammam	Khorfakkan(0.944) Port Said(0.055)	Jabel Ali(0.071) Khorfakkan(0.928)	Bushehr(0.198) Khorfakkan(0.801)

Jaddeh	Jabel Ali(0.298) Khorfakkan(0.198) Port Said(0.502)	Jabel Ali(0.351) Khorfakkan(0.648)	Jabel Ali(0.351) Khorfakkan(0.648)
Port Said	-	Jabel Ali(0.082) Khorfakkan(0.917)	Jabel Ali(0.173) Khorfakkan(0.826)

SUGGESTIONS

Reviewing the results, it is clear that the majority of ports including three Iranian ports, the relative efficiency are not in good and knowing that the coefficient of efficiency of the implementation of the BCC model shows pure technical efficiency, we can conclude that port inefficient in management of operations and how to use your inputs. Thus, the following suggestions in elderly:

1. Long-term contract with the port operator with strong management, so that the port operator with protection of long-term contract can perform any desired investments.
2. Optimize uptime or downtime of equipment
3. The use of mechanized systems for container operations and port systems to reduce dependence on manpower in port operations
4. Inspection and repair of worn-out equipment
5. Increase and expand of inputs for ports which operate under increasing return to scale.

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Appendix

Port	Year	Inputs				Output
		berth (number)	Berth length (m)	Terminal Area (m^2)	Terminal Area (number)	Throughput (Thousand Teu)
Imam Khomeini	2011	5	1050	40	12	147
	2012	5	1050	40	12	162
	2013	5	1050	40	12	142
Bushehr	2011	2	388	13	4	231
	2012	2	388	13	4	200
	2013	2	388	13	4	190
Khorramshahr	2011	6	860	23	3	102
	2012	6	860	23	5	86
	2013	6	860	23	5	55
Shahidrajaee	2011	7	1697	103	32	2762
	2012	8	1807	103	61	2318
	2013	8	1807	103	61	1763
Jabel Ali	2011	23	7875	508	261	13000
	2012	23	7875	508	261	13270
	2013	23	7875	508	261	13641

Khorfakkan	2011 2012 2013	5 5 6	1200 1200 2000	70 70 70	24 24 46	3230 3996 3800
Salalah	2011 2012 2013	7 7 7	2505 2505 2505	76 87 87	84 97 97	3201 3620 3340
Sohar	2011 2012 2013	2 2 2	520 520 520	28 28 28	12 12 12	108 199 200
Dammam	2011 2012 2013	6 7 7	1440 1680 1680	72 116 116	52 70 70	1492 1622 1659
Jaddeh	2011 2012 2013	17 19 19	4166 4645 4645	219 224 224	128 132 132	4010 4738 4561
Port said	2011 2012 2013	13 13 16	2150 2150 3350	106 106 146	90 90 104	4272 3631 4100
Alexandria	2011 2012 2013	7 7 7	1112 1317 1317	27 27 27	23 23 23	1490 1500 1508