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Technical efficiency comparison of container ports in Asian and Middle East region using DEA

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ABSTRACT

With the instigation of China Pakistan Economic Corridor (CPEC), the strategic significance of South Asian and Middle Eastern ports have been vitalized. The aim of this study is to compare the technical efficiency of less explored South Asian & Middle Eastern ports with the East Asian ports and determine ways for their efficiency enhancement and management optimization. The cross sectional data for the year 2018 was collected for 15 container ports each of South & Middle Eastern and East Asian region and arranged into input and output variables. The data was analyzed through the DEA-CCR and DEA-BCC model. Results indicate that only one port each from UAE and India among the Middle & South Asian ports were found efficient on CCR model with the number of efficient ports on BCC model increased by 47%. While, in East Asian region two ports of China and one of South Korea were found efficient on CCR model, with 33% increase on BCC model. Lianyungang port was the most prominent among the efficient ports being highly benchmarked. The average efficiency for East Asian region (CCR: 0.524, BCC: 0.901) remained similar to that of South Asian and Middle East Region (CCR: 0.517, BCC: 0.906).

1. Introduction

Ports are considered vital to an efficient supply chain and a well-organized transport system (Meersman & Van de Voorde, 2013). A seaport with a developed hinterland connectivity is an asset for linking the demand market to supply market (Schøyen & Odeck, 2017). The growth in the prominence of seaports as a facilitator in the international transport is palpable. The trade through sea has augmented by 5% over the last two decades and is double the rate at which the world GDP is growing (Odeck & Bråthen, 2012).

A growth rate of this magnitude is appearing to be a test of the seaport capacity. Researchers have a concern as if the seaports were proficient enough to suffice the transport and logistics growth (Odeck & Bråthen, 2012). In order to attract more business, there is a severe competition between the container ports subject to their efficiency (Heng, 2004; Luo, Liu, & Gao, 2012; Yuen, Zhang, & Cheung, 2013). Competition among ports is pivotal to a better performing industry (Cullinane, Wang, Song, & Ji, 2006). The latest developments in the global trade has brought manifold increment in the prominence of container transport. The volume of global container transport has increased by 10%, almost three times as that of the world GDP (Odeck & Bråthen, 2012).

This growth in container transport is attributed to the various methodical and monetary benefits it has as compared to the conventional sea transportation. Seaports appear to be the most integral and prominent part of the containers transport system, as being at the interface of ocean and land (Chao, Yu, & Hsieh, 2018). The utility of the standardized container shapes and sizes have increased the system efficiency manifold, as it could be exchanged and transferred expediently in the multimodal transport industry. To get a better edge in the competitive port market and enhance their efficiency, various ports have been incorporating modern equipment and IT systems. These modern equipment ensures smooth container shipping operations in the multimodal transport system (Neylan, 2015).

Containerization have introduced new horizons of competition to the port industry which were lacking in the traditional systems. Prior to the incorporation of modern standard containers, the port market had a serious monopolistic structure subject to their prominent geographic & strategic locations and manifold increment in the vessel traffic (Cullinane & Wang, 2006). Conversely, modern intermodal containerized transport system has subsided these monopolies and brought about a fierce competition in the

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market where contiguous ports have to compete in terms of better facilities and services (Cullinane, Fei, & Cullinane, 2004).

An analysis of the present day literature indicates that researchers have been using Data Envelopment Analysis (DEA) and other frontier methods like the Stochastic Frontier Analysis (SFA) to assess and compare the performance of container ports with each other and the set touchstones. These methods not only give an insight into the Technical Efficiency (TE) and port performance, but also reveal the sectors in which these ports lack behind and require improvements in order to be able to compete in the modern port market (Odeck & Bråthen, 2012).

The development of the Chinese container ports in the coastal areas are a result of the modifications and unobstructed connectivity brought about over the last 30 years. These modifications laid the bases for a smoother and well organized container shipment and the whole foreign trade. Moreover, it upheaved the economies of contiguous cities. The Chinese coastal ports have been home to massive construction which not only subsided the deficiency in their capacity, but also some of the ports are augmented with capacity higher than demanded by the vessel traffic they deal with. Also, the 12th five-year plan have diverted the port efficiency to be more intensive and enhanced (Dan, Weixin, & Feng, 2013).

A broad evaluation of the concerned literature states that most of the studies on port efficiency have been focused on the European ports (Munisamy & Jun, 2013). Studies conducted on the Asian ports are very limited, specifically those on South Asian and Middle Eastern countries. Container ports in the Middle East are of vital prominence as they serve a connectivity between the goods transferred between East and West (Al-Eraqi, Mustafa, Khader, & Barros, 2008). Similarly, the ports in or at the shores of Hormuz strait are of critical prominence, since this strait is considered one of the busiest in the world. A study of the twelve costal container ports of India states that only six of these were efficient enough to handle the vessels traffic at hand, while rest of the ports required improvements and modifications in their systems to enhance their capacity to the required level (Kamble, Raoot, & Khanapuri, 2010).

A study on the container ports of Pakistan based on game theory stated that there was a monopolistic trend in these ports, such that the ports and their private operators had higher profit taking with the lack of a positive competitive environment. A concession contract was termed advantageous to both the port authorities and users in order to ensure the smooth functioning and efficiency of the port (Saeed & Larsen, 2010). In another study conducted on the Karachi port trust, various factors were evaluated that would affect the choice of selecting a port. The results indicated that service quality, handling efficiency and capacity along the charges were among the most significant factors for port selection and increasing the business opportunity (Saeed, 2009).

The number of studies available in the literature analyzing the efficiency of container ports in the South Asia and Middle East is very limited. Specifically, for Pakistani ports there have been no such study which could evaluate their technical efficiency. Moreover, the extensive literature review conducted in this study concluded that there has been no such study which could associate the technical efficiency of various container ports in this region. Furthermore, with Belt and Road Initiative by China, a significant portion of Chinese trade with Europe and central Asian countries would be diverted to the route through Pakistan by means of CPEC project. This will result in the initiation of a new trend of competition in these container ports.

This study is intended to analyze the technical efficiency of 15 prominent container ports in the South Asia and Middle East region. Similarly, the technical efficiency of 15 noticeable container ports of East Asia will also be evaluated. The technical efficiency of East Asian container ports will be compared against that of South Asia and Middle East for a specific set of variables. This comparison would reveal the set of areas for specific ports which needs to be improved, as how other ports in this study have worked on that and have augmented their efficiency. This study is of vast practical importance for various container ports, port authorities, supply chains and governments as it would recommend the set of improvements required in order to make the transport system more efficient.

2. Literature review

The efficiency of ports has a profound effect on the international trade and is therefore under vast practical and academic evaluation. Due to its multifaceted prominence and applicability, its various perspectives are explored. Various studies have evaluated the port efficiency from user's inclination and selection perception. In this aspect of efficiency, factors affecting the port attractiveness and user's choice are elaborated employing multinomial logistics regression (Niavis & Tsekeris, 2012).

Port performance is subject to various indicators for its effective management and efficiency optimization. These indicators or performance factors are termed as choice variables, which are organized by port authorities to attain their desired economic goals (Talley, 2006). These performance affecting factors could be employed in port efficiency evaluation from various perspectives (UNCTAD, 1976). Some of the key performance indicators used abundantly are efficiency, productivity, utility and expediency indicators (Suárez-Alemán, Sarriera, Serebrisky, & Trujillo, 2016).

Among the quantitative efficiency assessment techniques, the most abundantly used methods are ratio analysis, parametric and non-parametric estimation parameters. However, the latter two methods are most commonly used. These two techniques are differentiated by the way efficiency is estimated in these methods. The parametric estimator is evaluated through a stochastic frontier based on Translog and Cobb-Douglas description. While the non-parametric frontier is assessed through the DEA analysis. The technical efficiency results obtained through the use of these two methods would represent resemblance if the ports sample selected had similarities (Cullinane et al., 2006).

An extended literature is available on the port efficiency assessment. To evaluate the container throughput as efficiency indicator, various input variables like number of quay cranes available, the area and length of the port selected along the straddles are used. The results indicated that public ports were more efficient as compared to the private ports (Cullinane, Song, & Wang, 2005). The port management faces immense pressure in order to enhance their cost & time utility and hence electability (Kamble et al., 2010).

Some of these studies are focused at the augmentation of logistics at a country level (Abdur Razzaque, 1997), while some of these studies are focused at logistics optimization at regional levels (Goh & Ang, 2000). The regional logistics optimization studies have been further classified into intra-regional and inter-regional logistics optimization studies (Bookbinder & Tan, 2003). A classification of the literature based on the methodology adopted, sample size used, input and output variables opted and the regions under study have been presented in Table 1.

A study focused at the ASEAN region applied the output oriented model to the 50 container terminals in the region to determine their relative efficiencies (Kutin, Nguyen, & Vallée, 2017). Similarly, a study focused at the performance of inland water ports employed a Bayesian approach to determine their performance (Hossain et al., 2019). Numerous authors have explored the literature available on the port efficiency measurement. The most in-depth and comprehensive reviews have been presented by Odeck and Bråthen (2012).

Table 1
Data envelopment analysis techniques in ports.

Author/Year	Region and No. of Ports	Model (DEA)	Inputs	Outputs
Cullinane, Song, Ji, and Wang (2004)	Global 25 Container terminals 1992 to 1999	Window, CCR and BCC	Berth length Terminal area No. of berth Cranes No. of yard cranes No. of straddle carriers	TEU
Jiang and Li (2009)	China, Japan and Korea 12 ports 2007	DEA	Import/Export Regional GDP Berth size No. of Crane	TEU
Kamble et al. (2010)	India 12 Ports 2010	Output oriented BCC	Storage yards, No. of berths & cargo handling equipment	Avg. total turnaround time Avg. output/ship berth day
De Oliveira and Cariou (2011)	Global 122 Iron Ore & Coal Ports 2005	Input oriented DEA CCR & BCC	Depth Length Stockpile Loading rates	Throughput(MT)
Dan et al. (2013)	China 19 container ports 2010	Three stage (Input Oriented BCC)	Berth length Handling equipment & staff quantity	TEU
Bergantino, Musso, and Porcelli (2013)	Global 30 Ports 1995 to 2009	Three stage (Input Oriented BCC)	Berth length No. of terminals Port area Handling equipment	TEU
Wilmsmeier, Tovar, and Sanchez (2013)	Latin America, Caribbean and Spain 10 ports 2005 to 2011	Non parametric DEA	Berth area Ship-to-shore crane & labor capacity	TEU
Almawsheki and Shah (2015)	Middle East 19 ports 2012	Input oriented CRR	Berth area Quay length Quay crane Handling equipment	Throughput
Li, Kyu-seok, Ki-Chan, and Young-Mo (2015)	Northeast Asia 16 ports	DEA CCR DEA BCC	No of berths Berth length Depth No of Cranes Terminal area	Throughput(TEU)
Zheng and Park (2016)	Korea and China 2014 30 ports	DEA CCR DEA BCC	Berth length Yard area No of QC No of TC	Throughput(TEU)
Rajasekar and Deo (2018)	India 8 Ports 1993 to 2011	DEA Additive CCR & BCC	No. of berths Berth length No. of equipment No. of employs	Total traffic Container throughput
Zarbi, Shin, and Shin (2019)	Iran 2008 to 2017 5 ports	DEA Windows	Quay wall length No of berths No of gantry cranes Yard space	Throughput(TEU)
Dong, Li, and Gajpal (2019)	Maritime Silk Road 10 Ports	DEA CCR DEA SBM	No of berths Berth length No of Quay Crane	TEU

3. Research methodology

A DEA technique has a number of merits over the conventional regression based production function approach. Based on these approaches, this study like various other studies available in literature adopts DEA for analysis. Some of the prominent merits of DEA includes its ability to handle various inputs and outputs with different units. It does not require any assumption of a functional form relating inputs to outputs. It can be applied to profit as well as non-profit making entities. Also, it sets targets for inefficient DMUs to make them efficient and identifies slacks in inputs and outputs. Moreover, it estimates a single efficiency score, identifies input excesses along output and provides benchmarks to monitor the performance of inefficient firms. Apart from that, it does not require a prior judgment to the relative importance of the various outputs or knowledge of input prices.

3.1. DEA-CCR

Since the cost and price related data of ports is difficult to find, its efficiency is measured based on the operational or technical data. DEA is an approach which utilizes the technical data in order to determine efficiency of Decision Making Units (DMUs), devoid of any need of monetary or cost related data (Bichou, 2013). DEA incorporates the input and output data of all the DMUs and determines their efficiency with respect to the minimal possible input and maximum possible output (Thanassoulis, 2000). It determines the efficacies and benchmarks for optimized practices with given resources (Cook, Tone, & Zhu, 2014).

While using DEA it shall first be determined if the purpose is to optimize input or output. If purpose of the analysis was to identify factors which over utilize the resources, then input focused models are the best choice which would ultimately determine the inputs to be decreased. However, if the purpose is to boost output, then an output focused model shall be employed (Cook et al., 2014). In this study the purpose is to determine the least possible input for an already defined fixed output. So, the model used will be input oriented.

This section devises the way of how to apply DEA for this study to determine the technical efficiency of the selected ports. Suppose we have n number of ports (DMUs) that incorporate k number of inputs to result in l number of productivities. Moreover, it also needs to be determined that $x_{pq} > 0$ is the amount of input variable p being used by the qth DMU, while $y_{rq} > 0$ is classified as the output or product being given by the qth DMU. The data used could further be classified as panel or cross sectional data, difference between the two could be elaborated as the former stands for data of several years, while later represents data of a single year. The mathematical expression for DEA-CCR is illustrated as,

$$\theta* = \min \theta \quad (1)$$

$$s.t. \sum_{q=1}^{n} x_{pq}\lambda_q \leq \theta x_{po} \quad p = 1, 2, 3, \ldots, k \quad (2)$$

$$\sum_{q=1}^{n} y_{rq}\lambda_q \geq y_{ro} \quad r = 1, 2, 3, \ldots, l \quad (3)$$

$$\lambda_q \geq 0 \quad r = 1, 2, 3, \ldots, l \quad (4)$$

x_{po}, y_{ro}, are the pth input and rth output of the DMU o under study;

λ_q stands for those variables which indicate the effect of prominent factors which of efficient DMUs are used as reference by other DMUs to compare their efficiency with.

$\theta*$, is the comparative technical efficiency of DMU o.

3.2. DEA-BCC model

The DEA-CCR model is associated with a limitation that it considers the return to scale as constant and cannot discern technical efficiency from that of scale efficiency. Due to this reason, if the production is variable return to scale oriented, the results obtained may picture some actually efficient DMUs as inefficient. To counter this issue, (Banker, Charnes, & Cooper, 1984) came up with an alternative proposition considering the variables return to scale with additional block fundamentals.

$$\max h_0 = \sum_{r=1}^{s} u_r y_{r0} + u_0$$

$$s.t \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_0 \leq 0, \quad j = 1, 2, 3, \ldots, n$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$u_r, x_{i0} \geq \varepsilon, \forall, r, i$

Now as the u_0 is not bound to the conditional limitation, hence it demonstrates return to scale aspects of the 'j-th' DMU. Now depending upon the value of u, the DMU varies, if $u_0 = 0$, it reflects the DMU to be under the highest optimal conditions of production. While, for $u_0 > 0$, it is decreasing because for production scale it is considered higher than that of optimal. Similarly, for $u_0 < 0$, the DMU is increasing return to scale as for production scale it is lower as compared to optimal.

In this study, the cross sectional data of various ports or DMUs will be compared against each other for data of a single year and their efficiency is calculated and benchmarked. The model used to achieve this are DEA-CCR and DEA-BCC. Panel data is considered to be more suitable as it determines the vigorous behavior of the port efficiency with the passage of time. However, the limitation associated with this study is the scarcity of data and the hardships associated in obtaining this type of data. These hardships are attributed to the difficulty in political issues, handling and unviable data collection and handling resources specifically in the Middle Eastern and South Asian region.

In DEA analysis, the efficiency of an individual port is determined and compared against the other ports in the group. Those ports which have maximum efficiency are meant to compose the frontiers of the group, reference to which the efficacies of the rest of the group are measured. These ports fixed as frontiers are non-functional and do not have the parametric properties, hence it can be defined by and measured in ordinary units like numbers, meters, square meters, and hectares.

One of the reasons for which the DEA-CCR and DEA-BCC is considered more suitable for application is its ability to determine the wholesome technical and scale efficiency. The results are defined such that if the value of theta = 1, the port is considered to be the fully efficient. However, if the value of theta < 1, it is said to be inefficient (Charnes, Cooper, & Rhodes, 1978). Hence, if the value is less than 1, it means that the inputs are not used properly and are wasted to certain portion subject to various reasons.

3.3. Data collection and variables

The criterion adopted for selection of the ports comprised of the following main dimensions.

1. The port shall have been operated for a significant number of years.
2. It should be the prominent and main terminal/port of the country.
3. A significant amount of data should be available for the prospective ports and terminals at their official websites and other reliable government sources.

The sources of data incorporated for this study have been listed as follows with their concerned references and links.

1. Data from the official website and publications of the respective ports considered for this study (Busan Port, 2019)
2. Yearly statistics published by china ports and harbors association (Chinaports, 2019)
3. Yearly statistics published by Ministry of Finance, Pakistan (PMF, 2018)
4. Data collected by direct contact with terminal operators as well as site visits

The cross sectional data for all the selected ports was collected and arranged into number of berths, number of cranes, berth length and berth depth as the input variables, while the TEUs as output variable. The test was run using MATLAB R2018a accompanied by a toolkit of DEA-CCR. The analysis was again run using Excel Solver 2016 edition supported by the DEA frontier. Moreover, the results were further validated by running the same test through a Chinese software (Max-DEA) for DEA-CCR analysis.

4. Results and discussion

For the successful and reliable conduction of this study, fifteen prominent container ports from each of the two regions under study were selected. The names and abbreviation of these profound container ports have been presented in Table 2.

Table 2
DMUs names and abbreviations.

No.	East Asian region			Middle East and South Asian region		
	Area	Port	Abbr	Area	Port	Abbr
1	Mainland China & Taiwan	Shanghai International Port Group	SIPG	UAE	Jebel Ali Container Port	JACT
2		Port of Nansha	PNS		Zayed Port (Fujairah & Khalifa)	ZPF&K
3		Port of Dalian	PDL	Pakistan	Karachi Port Trust	KPT
4		Port of Qingdao	PQD		Port Qasim Authority	PQA
5		Port of Lianyungang	PLYG	Iran	Shahid Rajaee Port	SRP
6		Port of Xingang	PXG		Emam Khomeini	EK
7		Port of Shenzhen	PSZ		Bandar Abbas	BA
8		Port of Xiamen	PXM	India	Jawaharlal Nehru Port Trust (jnpt & nsict)	JNPT
9		Ningbo Zhoushan	NBZ		Hazira Port	HP
10		Port of Keelung	PKL		Port Pipavav	PP
11		Port of Taichung	PTC		Mundra Port	MP
12	South Korea	Incheon Port Authority	IPA	Oman	Aden Container Port	ACT
13		Port of Gwangyang	PGY		Hodeidah Container Port	HCT
14		Busan New Container Port	BNCT	Yemen	Port Salalah	PS
15	Japan	Port of Hakata	PHKT		Sohar Port & Freezone	SPF

Table 3
Statistical characteristics.

Region	Variables	Minimum	Maximum	Mean	Std. deviation
East Asian Region	TEU	128,064	42,010,000	14,895,705.27	12,349,313.04
	Cranes	9	142	44.93333333	35.2409394
	Berth Length	1214	12,067	4608.9	3098.062495
	Number of Berths	4	39	14.53333333	8.765734153
	Draught	13.3	20	16.01333333	1.979129198
Middle East and South Asian Region	TEU	110,890	15,000,000	2,692,274.733	3,736,761.42
	Cranes	5	66	18.93333333	15.19617746
	Berth Length	450	6700	1920.8	1476.498861
	Number of Berths	2	28	8.066666667	7.304271418
	Draught	9.5	17.5	14.31333333	2.283752134

A comparative analysis of the statistical characteristics for the selected input variables have been shown in Table 3, indicating that the East Asian ports have better facilities and resources as compared to Middle East & South Asia ports.

4.1. *East Asian region*

This section compares and analyzes the technical efficiency of 15 container ports each from East Asian and South Asian along Middle Eastern countries. Firstly, the 15 container ports or DMUs of East Asia are being evaluated for their technical efficiency. The results indicate that out of the 15 DMUs only three of them are efficient. Namely, only Shanghai International Port Group, Port of Lianyungang and Busan New Container port are the efficient ports, meaning that only 20% ports are efficient. While the remaining 12 container ports are inefficient making it 80% of the total.

Further classifying the results, it could be seen from Table 4 that only two other port have a value between 0.8 and 1, while four of the container ports are having their theta values between 0.5 and 0.8. Only one container port has theta values between 0.2 and 0.5, while 5 container ports have the lowest theta values of lower than 0.2. The results of technical efficiency are depicted in Table 4.

In BCC analysis the number of efficient ports or terminals is increased as compared to the CCR analysis, which is a demonstration of the lower total technical efficiency subject to the scale inefficiency. Terminals depicted as efficient in 2018, are SIPG, PLYG, BNCT, PXM and PHKT are efficient with the score of 1. It covers up 33% of all the considered terminals in this scenario. Overall, the number of terminals confirmed as efficient in BCC model which justifies the statement that scale inefficiency is the reason beyond lower CCR efficiency. Terminals with a score of 1 in both BCC and CCR models are SIPG, PLYG and BNCT and hence considered the most efficient terminals.

The efficiency results for both CCR and BCC models have been summarized in Table 4 for this scenario. It is evident from the table that the overall average efficiency for CCR model is 0.524785, which is much lower than that of the BCC model having a value of 0.900696. Moreover, it could be summarized that the scale efficiency of the terminals in this scenario is relatively higher.

The high efficiency of Shanghai and Busan port is attributed to the reasons that these are the main ports of China and South Korea respectively. Furthermore, they are equipped with high quality resource management, better hinterland connectivity and state of the art machinery and equipment. While the Lianyungang port of China has a higher efficiency because of the better business and resource handling. The poor efficiency of the other ports could be attributed to reasons opposite of these.

4.1.1. *Benchmarking*

Results of the benchmarking depicts that how many of the efficient ports have been used as a reference. Benchmarking could be elaborated from two perspectives, from the perspective of efficient ports it showcases that how many inefficient ports have been using them as a reference of efficiency benchmark. While from the perspective of inefficient ports, it depicts which efficient ports have been they referring to or using as a scale to measure and evaluate their efficiency.

Looking at the results displayed in Table 4, it could be concurred that Shanghai port has been used 7 times as a benchmark. Since Shanghai port is a hub and a huge portion of the China's trade is being dealt here. It has state of the art machinery in appropriate quantity and has focused on the effective management of their resources along efficient traffic container handling. That is why Shanghai port has been used by 7 different ports as a benchmark.

The port of Lianyungang has been used ten times as benchmark. Since Lianyungang port is not of the key hub ports of China, yet

Table 4
Efficiency scores of DMUs.

No.	DMU name	CRS efficiency	VRS efficiency	Sum of lambdas	Benchmarks	RTS
1	SIPG	1.00000	1	1.000	7	Constant
2	PLYG	1.00000	1	1.000	10	Constant
3	BNCT	1.00000	1	1.000	4	Constant
4	NBZ	0.89179	0.9025	1.095	1, 2	Increasing
5	PSZ	0.80790	0.826849	0.966	2	Increasing
6	PNS	0.75637	0.815324	0.899	1, 2	Increasing
7	PXG	0.70609	0.844543	0.776	1, 2	Increasing
8	PQD	0.56221	0.674317	0.783	1, 2	Increasing
9	PXM	0.50367	1	0.481	1, 2	Increasing
10	PDL	0.35336	0.754803	0.457	2, 3	Increasing
11	IPA	0.15373	0.966555	0.157	1, 2	Increasing
12	PGY	0.07113	0.840374	0.083	3	Increasing
13	PHKT	0.05208	1	0.043	3	Increasing
14	PTC	0.00797	0.989726	0.007	1, 2	Increasing
15	PKL	0.00548	0.895442	0.006	2, 3	Increasing
Average efficiency	0.524785	0.900696				

it is a highly efficient port. Its efficiency is a function of its well organized operations, highly effective resource management and utilization with effective and optimized container handling. These are the reasons this port has been used as a benchmark by ten out of the twelve inefficient container ports.

The port of Busan is the most prominent and main port of South Korea. It has a very high number of ship arrivals and traffic handling among the busiest ports in the world. It has been provided with the latest technologies and equipment available in the market. These are the reasons it has been used four times as a benchmark by other ports for their efficiencies. The obvious reasons for it being benchmarked is its business and facilities, rather than its paramount resource and input management.

4.1.2. Return to scale

The purpose of this study is also the evaluation of return to scale of the selected container ports. Return to scale efficiency of a container is a function of its sum of lambdas. For a DEA-CCR model, if the summation of the lambdas is equal to 1, it is termed as the constant return to scale (CRS). If the summation of the lambdas is less than 1, it is stated to be as increasing return to scale (IRS). While, in case of the sum of lambdas higher than 1, the port efficiency is said to be decreasing return to scale (DRS) (Wanke, Barbastefano, & Hijjar, 2011).

Looking at Table 4, the results of the ports under investigation states that all the three efficient ports are constant return tom scale. While all the inefficient ports have their sum of lambdas lower than 1 and are increasing return to scale. All the return to scale ports if increase their inputs will have an output increased more than the proportionality found in input and output. Moreover, the outputs could also be augmented by optimizing the scale of operations of these ports, and the scale of operation could be enhanced by bringing about an expansion in it and through improved connectivity and relationship between shipping organizations.

4.2. Middle East and South Asian region

In comparison, looking at the efficiency results of the South Asian and Middle Eastern container ports, only two ports are efficient. The efficiency of the Jebel Ali is for the reason that it is one of the prominent ports of the region and serves as a main hub for the UAE's shipping business. It has strong collaboration with regional shipping organizations. This port has a very efficient management and utilization of input resources. The results of technical efficiency are tabulated in Table 5.

Similarly, the other efficient port is Jawaharlal Nehru Port Trust. It is one of the prominent and busiest port of India and South Asia. Its high efficiency is attributed to the proper management of its input resources moreover, it has a higher hinterland connectivity and strong shipping networks. Being one of the main and busiest port of the country it has been provided with latest machinery, equipment and IT management systems.

As compered to East Asian ports, the percentage of the efficient ports in South and Middle East is 13.33% as only two ports out of 15 are efficient, which is much lower. While the percentage of inefficient ports is higher with a value of 86.67% with 13 container ports being inefficient. Apart from that 4 container ports same in number as that of East Asian ports, are having efficiency values between 0.5 and 0.8, while only 1 container port could make it between 0.8 and 1 of the efficiency value, which were 2 for the East Asian region. Moreover, the number of container ports with efficiency values between 0.2 and 0.5 are 7, which was only 1 in East Asian region. While, the number of port with theta values lower than 0.2 are only 2 in this region, which were 5 in the East Asian region being much higher.

Similarly, for the South Asian and Middle Eastern region, the number of efficient ports on BCC model increased to 7 which is a 47% increase. While the most efficient terminals having a score of 1 on both CCR and BCC models are JACT and JNPT. The overall average efficiency for CCR and BCC models depicts a huge difference with the scale efficiency again holding a higher value of 0.905939.

4.2.1. Benchmarking

Looking at the results of benchmarking, it could be seen that all of inefficient ports that are 13 out of 13 have been using Jebel Ali port as their benchmark, which is not only a hub in the region but also an example of effective and optimized input resource management. While eight out of 13 inefficient ports have been using Jawaharlal Nehru Port Trust as their benchmark to compare their level of efficiency with. This port is also one of the prominent ports of the country and region and serves as shipping hub. It is associated with the most efficient utilization of the input resources, and sets a very feasible benchmark for the inefficient container ports of the region.

4.2.2. Return to scale

The return to scale results for the South Eastern and Middle Eastern container ports are showing the same trend as that of the East Asian container ports. The two efficient DMUs are constant return to scale, while the remaining thirteen inefficient container ports have their lambda summation value lower than one, being considered as increasing return to scale (IRS). Similarly, an increment in the input at these ports will result in outputs higher than proportion.

In order to determine the possible ways to improve the technical efficiency of inefficient ports, the comparative results could be

Table 5
Efficiency scores of DMUs.

No.	DMU name	CRS efficiency	VRS efficiency	Sum of lambdas	Benchmarks	RTS
1	JACT	1.00000	1	1	13	Constant
2	JNPT	1.00000	1	1	8	Constant
3	PS	0.91140	0.991376	0.539	1, 2	Increasing
4	MP	0.81156	0.897739	0.506	1, 2	Increasing
5	SRP	0.68640	1	0.104	1	Increasing
6	PQA	0.52556	0.897654	0.072	1	Increasing
7	BA	0.48108	0.780887	0.456	1, 2	Increasing
8	KPT	0.45901	0.854451	0.176	1, 2	Increasing
9	HP	0.43534	1	0.062	1, 2	Increasing
10	PP	0.38120	1	0.18	1, 2	Increasing
11	ZPF&K	0.35200	0.724489	0.107	1	Increasing
12	HCT	0.31319	1	0.033	1, 2	Increasing
13	SPF	0.22706	0.609163	0.055	1	Increasing
14	ACT	0.09523	1	0.045	1, 2	Increasing
15	EK	0.08132	0.833333	0.007	1	Increasing
Average efficiency	0.517357	0.905939				

employed. The variables selected for the study shall be compared for both the inefficient ports and those efficient ports which have been used as benchmark. This comparison would indicate the possible areas of improvement in the variables under consideration. The quantity, resource allocation and policy on use could pave ways for effective resource utilization in the efficient ports.

Determining and evaluating the technical efficiency of ports is a complex domain and involves the intricate role of various variables. These variables or the factors that affect the efficiency and performance of a port terminal can range from the availability of resources, availability of proper business activities, effective operations, effective use of resources and the design, availability along implementation of a wide range of policies which affect the working of a port in one way or another. In concurrence to such diverse background of the affecting factors, this study has aimed at the consideration and amalgamation of the most prominent efficiency factors which were consistent and available for all of the ports under consideration. Moreover, the operations and functionality of a port and terminal is also multifaceted. A port may serve many strategic, commercial, state and military purposes. However, in this study, only the commercial throughput and the resources along policies associated with it were taken into consideration.

Since, CPEC and Pakistan are one of the most protuberant dimension of the BRI. In this regard, it is important to discuss the commercial and military aspect of the Pakistani Ports. Both Karachi Port Trust and Port Qasim authority have some military uses associated with them. However, due to the sensitive nature and security concern, the military operations and uses are kept apart and segregated from the commercial uses. Moreover, in accordance with criteria set for this study, only the commercial throughput and associated resources, management and operations have been taken into account. Another concern in this domain is the effect of increasing traffic at Pakistani' Ports concomitant to the geopolitical, BRI and CPEC stimuli. However, the most positive and noteworthy aspect in this regard is the high potential deep water Gwadar Port. The Gwadar port is the main emphasis and consideration of both the Chinese and Pakistani governments, when it comes to the handling of additional traffic initiated and diverted by the BRI. Therefore, attributed to the strategic, geographical and commercial prominence associated with the Gwadar Port, both the Chinese and Pakistani governments are very optimistic toward its capacity to handle such upsurge in the traffic. Therefore, the authors did not consider the effect of military use on the commercial operations, performance and efficiency of Pakistani Ports. However, it is an important and interesting topic to assess and evaluate the effect of military use on the commercial performance of such ports.

5. Conclusion

This study is aimed to impart an understandable evaluation of the technical and scale efficiency, and assess the efficiency of South Asian, Middle Eastern and East Asian ports. Attributed to the massive exports and imports of China and South Korea, their ports have high volumes of business handling. While, in comparison the South Asian and Middle Eastern ports have very low volumes of business. With the initiation of CPEC & BRI, and transfer of Chinese business toward South Asia, specifically Pakistan. The business dimensions along the efficiency of ports will be subject to a change. Ports near the Hormuz Strait in the South Asian and Middle Eastern countries have been less explored in literature. The busiest and yet efficient ports and terminals of the East Asian countries presents practical guidelines for effective operations and optimized management. Their successful business handling and efficiency is subject to modern technology, availability of resources and effective management. These ports do not increase their business operations and volumes at the cost of customer satisfaction and quality of service. Their comparison with the South Asian and Middle Eastern ports will provide a deeper practical understanding to their limitations and shortcomings and pave ways for effective management under increased business and overload.

The South Asian and Middle Eastern ports were taken into one sample group, while the East Asian ports were taken in a separate sample group. The sample size was limited to 15 container ports in each group. The port's technical and scale efficiencies were analyzed using the DEA- CCR and DEA-BCC models. The results reveal that among the East Asian ports, only three of 15 container ports were found efficient. Namely, the Shanghai International Port Group, Port of Lianyungang and Busan New Container Port are the efficient ports both on the CCR and BCC models. The number of efficient ports in BCC analysis increased by 33% as compared to CCR.

The efficiency of Shanghai port and Busan port is attributed to the facts that these are the main ports of China and Korea respectively, having the highest amount of regional business. These ports also have better facilities and latest technology along efficient resource utilization. The port of Lianyungang is not the main port of country and yet efficient, that is its efficiency is so prominent that this has been used ten times as a benchmark by the inefficient container ports of the group. Its policies and practices of operations and management impart far better and practical insights into overload and excessive throughput handling. The Lianyungang port is a role model for the small and less busy ports of the South Asian and Middle Eastern ports having limited resources.

On the other hand, amongst the selected Middle Eastern and South Asian ports, only Jebel Ali container port of UAE and Jawaharlal Nehru Port Trust of India are efficient on both CCR and BCC models. The number of efficient ports on BCC model is 47% higher than that of the CCR model.

The success and efficiency of these ports is attributed to their large business market, better hinterland connectivity, being major port of the country and an effective resource management. All the remaining inefficient ports were found return to scale which is a positive sign on their performance being considered on a move toward development. Furthermore, among the efficient ports of a group being used as benchmark for efficiency and productivity, the Jebel Ali container port is the highest benchmarked.

The higher amount of TEUs handling by East Asian container ports is one of the basic reasons initiating better resource utilization and the increment or maximization of the available variables. With the Belt and Road Initiative by China, the competition in the South Asian ports will augment and intensify. Ports in this region are return to scale and with the increase in international business are expected to augment in efficiency. The study of the South Asian ports as a function of time, policies and type of government needs to be explored in future.

Conflict of interest

Authors declare that there is no conflict of interest in publishing this research article.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajsl.2020.04.004.

References

Abdur Razzaque, M. (1997). Challenges to logistics development: the case of a third world country-Bangladesh. *International Journal of Physical Distribution & Logistics Management*, *27*(1), 18–38.

Al-Eraqi, A. S., Mustafa, A., Khader, A. T., & Barros, C. P. (2008). Efficiency of Middle Eastern and East African seaports: Application of DEA using window analysis. *European Journal of Scientific Research*, *23*(4), 597–612.

Almawsheki, E. S., & Shah, M. Z. (2015). Technical efficiency analysis of container terminals in the middle eastern region. *The Asian Journal of Shipping and Logistics*, *31*(4), 477–486.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, *30*(9), 1078–1092.

Bergantino, A. S., Musso, E., & Porcelli, F. (2013). Port management performance and contextual variables: Which relationship? Methodological and empirical issues. *Research in Transportation Business & Management*, *8*, 39–49.

Bichou, K. (2013). An empirical study of the impacts of operating and market conditions on container-port efficiency and benchmarking. *Research in Transportation Economics*, *42*(1), 28–37.

Bookbinder, J. H., & Tan, C. S. (2003). Comparison of Asian and European logistics systems. *International Journal of Physical Distribution & Logistics Management*, *33*(1), 36–58.

"Busan Port," http://www.bnctkorea.com.

Chao, S.-L., Yu, M.-M., & Hsieh, W.-F. (2018). Evaluating the efficiency of major container shipping companies: A framework of dynamic network DEA with shared inputs. *Transportation Research Part A: Policy and Practice*, *117*, 44–57.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429–444.

"Chinaports," http://www.chinaports.com/ports/.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1–4.

Cullinane, K., & Wang, T.-F. (2006). Data envelopment analysis (DEA) and improving container port efficiency. *Research in Transportation Economics*, *17*, 517–566.

Cullinane, K., Fei, W. T., & Cullinane, S. (2004). Container terminal development in Mainland China and its impact on the competitiveness of the port of Hong Kong. *Transport Reviews*, *24*(1), 33–56.

Cullinane, K., Song, D.-W., Ji, P., & Wang, T.-F. (2004). An application of DEA windows analysis to container port production efficiency. *Review of Network Economics*, *3*(2)

Cullinane, K., Song, D.-W., & Wang, T. (2005). The application of mathematical programming approaches to estimating container port production efficiency. *Journal of Productivity Analysis*, *24*(1), 73–92.

Cullinane, K., Wang, T.-F., Song, D.-W., & Ji, P. (2006). The technical efficiency of container ports: Comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part A: Policy and Practice*, *40*(4), 354–374.

Dan, L., Weixin, L., & Feng, P. (2013). The efficiency measurement of coastal container terminals in China. *Journal of Transportation Systems Engineering and Information Technology*, *13*(5), 10–15.

De Oliveira, G. F., & Cariou, P. (2011). A DEA study of the efficiency of 122 iron ore and coal ports and of 15/17 countries in 2005. *Maritime Policy & Management*, *38*(7), 727–743.

Dong, Z., Li, W., & Gajpal. (2019). Evaluating the environmental performance and operational efficiency of container ports: an application to the maritime silk road. *IJERPH*, *16*(June (12)), 2226. http://dx.doi.org/10.3390/ijerph16122226

Goh, M., & Ang, A. (2000). Some logistics realities in Indochina. *International Journal of Physical Distribution & Logistics Management*, *30*(10), 887–911.

Heng, W. (2004). *Port privatization, efficiency and competitiveness: Some empirical evidence from container ports/terminals*.

Hossain, N. U. I., et al. (2019). Metrics for assessing overall performance of inland waterway ports: A bayesian network based approach. *Complexity*, *2019*(May), 1–17. http://dx.doi.org/10.1155/2019/3518705

Jiang, B., & Li, J. (2009). DEA-based performance measurement of seaports in northeast Asia: Radial and non-radial approach. *The Asian Journal of Shipping and Logistics*, *25*(2), 219–236.

Kamble, S. S., Raoot, A. D., & Khanapuri, V. B. (2010). Improving port efficiency: A comparative study of selected ports in India. *International Journal of Shipping and Transport Logistics*, *2*(4), 444–470.

Kutin, N., Nguyen, T. T., & Vallée, T. (2017). Relative efficiencies of ASEAN container ports based on data envelopment analysis. *The Asian Journal of Shipping and Logistics*, *33*(July (2)), 67–77. http://dx.doi.org/10.1016/j.ajsl.2017.06.004

Li, D., Kyu-seok, K., Ki-Chan, N., & Young-Mo, A. (2015). A comparative analysis of terminal efficiency in Northeast Asia container ports. *Journal of Navigation and Port Research*, *39*(1), 55–60.

Luo, M., Liu, L., & Gao, F. (2012). Post-entry container port capacity expansion. *Transportation Research Part B: Methodological*, *46*(1), 120–138.

Meersman, H., & Van de Voorde, E. (2013). Port management, operation and competition: a focus on North Europe. In *The handbook of maritime economics and business, Informa Law from Routledge*. pp. 921–936.

Munisamy, S., & Jun, O. B. (2013). Efficiency of Latin American container seaports using DEA. In *Presented at the Proceedings of 3rd Asia-Pacific business research conference* (pp. 25–26).

Neylan, P. (2015). *Forecast development of world container traffic*.

Niavis, S., & Tsekeris, T. (2012). Ranking and causes of inefficiency of container seaports in South-Eastern Europe. *European Transport Research Review*, *4*(4), 235–244.

Odeck, J., & Bråthen, S. (2012). A meta-analysis of DEA and SFA studies of the technical efficiency of seaports: A comparison of fixed and random-effects regression models. *Transportation Research Part A: Policy and Practice*, *46*(10), 1574–1585.

Pakistan Ministry of Finance. (2018). . pp. 194–206. *Transportation and communication* (Vol. 13) Ministry of Finance.

Rajasekar, T., & Deo, M. (2018). The size effect of Indian major ports on its efficiency using Dea-Additive models. *IJAME*.

Saeed, N. (2009). An analysis of carriers' selection criteria when choosing container terminals in Pakistan. *Maritime Economics & Logistics*, *11*(3), 270–288.

Saeed, N., & Larsen, O. I. (2010). Container terminal concessions: A game theory application to the case of the ports of Pakistan. *Maritime Economics & Logistics*, *12*(3), 237–262.

Schøyen, H., & Odeck, J. (2017). Comparing the productivity of Norwegian and some Nordic and UK container ports-an application of Malmquist productivity index. *International Journal of Shipping and Transport Logistics*, *9*(2), 234–256.

Suárez-Alemán, A., Sarriera, J. M., Serebrisky, T., & Trujillo, L. (2016). When it comes to container port efficiency, are all developing regions equal? *Transportation Research Part A: Policy and Practice*, *86*, 56–77.

Talley, W. K. (2006). Port performance: An economics perspective. *Research in Transportation Economics*, *17*, 499–516.

Thanassoulis, E. (2000). DEA and its use in the regulation of water companies. *European Journal of Operational Research*, *127*(1), 1–13.

UNCTAD. (1976). *Port performance indicators*.

Wanke, P. F., Barbastefano, R. G., & Hijjar, M. F. (2011). Determinants of efficiency at major Brazilian port terminals. *Transport Reviews*, *31*(5), 653–677.

Wilmsmeier, G., Tovar, B., & Sanchez, R. J. (2013). The evolution of container terminal productivity and efficiency under changing economic environments. *Research in Transportation Business & Management*, *8*, 50–66.

Yuen, A. C., Zhang, A., & Cheung, W. (2013). Foreign participation and competition: A way to improve the container port efficiency in China? *Transportation Research Part A: Policy and Practice*, *49*, 220–231.

Zarbi, S., Shin, S.-H., & Shin, Y.-J. (2019). An analysis by window DEA on the influence of international sanction to the efficiency of iranian container ports. *The Asian Journal of Shipping and Logistics*, *35*(December (4)), 163–171. http://dx.doi.org/10.1016/j.ajsl.2019.12.003

Zheng, X. B., & Park, N. K. (2016). A study on the efficiency of container terminals in Korea and China. *The Asian Journal of Shipping and Logistics*, *32*(December (4)), 213–220.