Asia Pacific Journal of Advanced Business and Social Studies
ISBN (eBook): 978 0 9943656 7 5 | ISSN : 2205-6033
Year: 2018 , Volume: 4, Issue: 1

EVALUATING THE COMPETITIVENESS OF QINZHOU PORT ON THAILAND-GUANGXI ROUTE UNDER PAN-BEIBU GULF ECONOMIC COOPERATION

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Abstract

This paper aims to, through Data Envelopment Analysis (DEA), analyze the efficiency and competitive position of the Qinzhou Port, compared with the rest eight ports of containerization in Pan-Beibu Gulf Economic Cooperation (PBGEC) region. Based on the introduction, a literature review is presented thereafter. We innovatively adopt the Charnes, Cooper and Rhodes (CCR) model, Banker, Charnes and Cooper (BCC) model to determine the overall efficiency, pure technical and scale efficiency, and then the Super Efficiency model has been used to indicate the efficiency ranking of the 9 ports in the PBGEC. The result implies that the Qinzhou port exists input redundancy and insufficient output due to its scale efficiency. Also, Qinzhou port is posed in an inferior position in its competitiveness. Further research is needed for how to overcome such weakness and then enhance the overall efficiency and competitiveness accordingly. At the end of this paper, limitations and recommendations are also presented.

Keywords: Qinzhou Port, Pan-Beibu Gulf Economic Cooperation (PBGEC), Data Envelopment Analysis.

1. Introduction

As a new sub-regional cooperation project within the frame of China- Association of Southeast Asian Nations (ASEAN) free trade zone, Pan-Beibu Gulf Economic Cooperation (PBGEC)has been posed as a hot issue for both China and ASEAN. As an initiative to create the costal industrial areas making full advantages in maritime transport with neighboring countries, China takes Qinzhou port as one of gateways for Thailand and Guangxi.

The evaluation of the competitiveness of Qinzhou port is critically important. From a nation's perspective, maritime transport becomes very important to the nation's integration. Over 90% of international trade is through transporting by sea, and over 60% China-ASEAN trade is through port logistics (Zou, 2012). In order to support trade oriented economic development, seaports have to improve port competitiveness by ensuring that seaport services are provided on an internationally competitive basis (Tongzon, 2001). Thus, a seaport with strong competitiveness is an important factor to a nation's international competitiveness. While, in terms of the significance of sea ports, Qinzhou Port, in particular, is the only foreign trade container port in Guangxi, the container hub in Beibu Gulf. From October, 2015, all of foreign trade container routes of other ports of Guangxi are transferred to the Qinzhou port except fruit routes. Bulk in Fangcheng port and Beihai port of Guangxi. In the past of 2015, the throughput of Qinzhou port reached 6.51 million tons, of which the throughput of container is 942,000 TEUs. So, Qinzhou port is the busiest container port in Guangxi (Qinzhou Municipal Bureau of Statistics, 2016), which paves the way for the Beibu Gulf port into an international shipping hub in Southeast Asia.

 DOI : 10.25275/apjabssv4i1ss7

However, evaluation of the container port competitiveness is not an easy case. Competitiveness is rather flexible and can be used for numerous different purposes in basic economic units (company, sector, region, country, and macro-region) (Vuković, 2012). In order to evaluate the seaport competitiveness, one of the most important tools to measure seaport competitiveness is the efficiency (Voorde and Winkelmans, 2001; Cruz, 2012).Therefore, this paperis to analyze the competitiveness of Qinzhou port in Data Envelopment Analysis (DEA) method through efficiency. For such purpose, what are to be compared and analyzed are Qiangzhou port and the rest 8 ports, namely, Hong Kong port, Thailand's Laem Chabang Port, Guangdong's Guangzhou port, Shenzhen port, Zhanjiang port, Zhuhai port, Hainan's Haikou port and Yangpu port.

The paper includes 5 sections. After the introduction, section 2 presents the review on the assessment method applied in port competitiveness. Section 3 explains the DEA method. Following section 4 are the data and result analysis of Qinzhou port competitiveness under DEA method. And section 5 summarizes the main result accordingly.

2. Literature Review

A variety of methods have been applied to evaluate port competitiveness. These studies can also be categorized into those that utilize subjective evaluation method and objective evaluation method. The former carries evaluation based on learned and experienced of human being to determine the weight of the index, and the latter confirms the weight of the index based on information and importance provided by index data itself.

Subjective evaluation method involves in Delphi method (Jafari et al., 2013), fuzzy comprehensive evaluation method and analytic hierarchy process (Yeo and Song, 2003; Song and Yeo, 2004; Yuen et al.,2016; Rudjanakanoknad et al., 2014; van Dyck and Ismael, 2015). Such method has the advantages of good applicability, operability and simplicity. However, its result may go far away from subjectivity since people were involved in the process of determining appraisal index and weight and influenced by the evaluator's cognitive ability and literacy levels.

Objective evaluation method includes DEA (Cullinane and Wang, 2010), factor analysis method (Yeo et al., 2008; Grosso and Monteiro, 2009) and principal component analysis (Tongzon and Heng, 2005). The objective evaluation method gives the weight of index objectively based on the information and importance provided by index data, which prevents the subjective effect from the evaluator.

Moreover, there have been many empirical studies of measuring port efficiency by using DEA, a simple and feasible scientific method suitable for evaluating port competitiveness through avoiding subjectivity and arbitrariness. Generally, DEA is a method of linear programming which uses the input, and output of productive processes in order to calculate the relative efficiency of each DMU (Polyzos and Niavis, 2013). Table 1 summaries the DEA method used in ports in recent 10 year. Most of the previous studies measured efficiency based on CCR model and BCC model. In this study, we are to use the CCR and BCC model to determine overall efficiency, pure technical, scale efficiency and adopt the Super Efficiency model to give the efficiency ranking of the 9 ports.

Table 1: Summary of the DEA Method Used in Ports

Author (year)	DMU	Method	Input variables	Output variables
Al-Eraqi et al. (2008)	22 seaports in the middle east and east African region	CCR, BCC	Berth length, storage area, handling equipment	Throughput (tons)
Liu et al. (2008)	45 container terminals in mainland	BCC	Quay length, quayside gantry crane, rubber-	Throughput (TEU)

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	China		tyred gantry crane	
Min and Park (2008)	11 container terminals	BCC	Gantry cranes, terminal quay length, yard areas, size of labor force	Throughput (TEU), terminal capacity (TEU)
Wu and Lin (2008)	21 leading ports from G7, BRIC and N-11 countries	CCR, BCC	Terminal area, total quay length, number of quayside gantries, number of straddle carries	Number of containers
Jiang and Li (2009)	12 seaports from China, Korea and Japan	DEA	Import/export by customs, GDP by regions, berth length, crane numbers	Throughput (TEU)
Sharma and Yu (2009)	70 container terminals	DEA	quay length (total quay length of a container terminal), terminal area , quay cranes,transfer cranes(yard cranes) , straddle carriers , reach stackers	Container throughput
Wu and Goh (2010)	20 largest container ports	CCR, BCC	Terminal area, total quay length, number of pieces of equipment	Container throughput
Gao et al. (2010)		DEA	Quay berth number, warehouse area, storage yard area, port aggregate investment, cargo gear number, traveling bridge number	Container throughput, cargo throughput
Cullinane and Wang (2010)	25 leading container ports	DEA	Quayside gantry (number), yard gantry (number), straddle carrier (number)	Container throughput, terminal length, terminal area
Eraqi et al. (2010)	22 cargo seaports in the region of east Africa and middle east	BCC, CCR, Super efficiency	Berth length, terminal area, equipment units	Ships call, cargo throughput (tons)
Nigra (2010)	57 worldwide seaports (of which 21 Iberian portso	BCC, Super efficiency	Capital expense, employees, operational expenses	General cargo, dry bulks/solid bulks, liquid bulks, passengers

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Kamble et al. (2010)	12 major Indian seaports	BCC	Storage facilities, number of berths, number of cargo handling equipments	Average total turnaround time (days), average output per ship berth day (tons)
Wu et al. (2010)	77 terminals from 56 global container ports	CCR, BCC	Capacity of cargo handling equipment, number of berths, terminal area, storage capacity	Container throughput
Hung et al. (2011)	31 container ports in Asia-Pacific region	BCC, CCR	Terminal area, ship-shore container gantry crane, container berth, terminal length (the length of berths at which container ships anchor)	Container throughput
Munisamy and Singh (2011)	69 major Asian container ports	CCR, BCC, Super efficiency	Berth length, terminal area, total reefer points, total quayside cranes(and/or Mobile cranes), total yard equipment	Total throughput (TEU)
Wanke et al. (2011)	25 major Brazilian port terminals	CCR, BCC	Terminal area, size of parking lot for incoming trucks/parking lot (in number of trucks), number of shipping berths	Aggregate throughput per year (in tons), number of loaded shipments per year
Zhang et al. (2011)	23 container terminals	DEA	Number of berths, berth length, land size, quay crane, yard gantries	Throughput (TEU)
Demirel et al. (2012)	16 container terminals of Mediterranean	BCC, CCR	Quay length, terminal area, quay cranes 9indclidng both ship-to-shore and the mobile quay cranes used mainly by small container terminals), yard equipment, maximum draft	Throughput (TEU)
Kim (2012)	19 European container ports	DEA	Length of berths, terminal area, number if cranes, working hours	Throughput (TEU)

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Azevedo et al. (2012)	10 Iberian container terminals	BCC	Container cranes, terminal area, quay length	Container throughput
Lu and Wang (2012)	31 major container terminals	BCC, CCR, Super efficiency	Yard area, quay crane, yard crane, yard tractor, berth length	Container throughput
Lu and Wang (2012)	31 container terminals (14China ports an 17 Korea ports)	CCR, BCC	Yard area per berth, number of quayside cranes per berth, number of terminal cranes per berth, number of yard tractor per berth, berth length, water depth	Container throughput per berth
Niavis and Tsekeris (2013)	30 seaports in the wider region of south-eastern Europe	DEA, Super efficiency	Number of berth, length of quays, number of cranes used by each port for container handling	Total throughput (TEU)
Pjevcev et al. (2012)	5 Serbia river ports of Danube river	DEA	Total area of warehouses, quay length, number of cranes	Port throughput (tons)
Bichou (2012)	420 container terminals	CCR, BCC	Terminal area, max draft, length overall, quay crane index, yard-stacking	Throughput (TEU)
Infante and Gutiérrez (2013)	33 ports/terminals in the Asian Pacific region	CCR, BCC	Total number of gantry, terminal area, total berth length of the terminals	TEUs handled
Lu and Park (2013)	28 major East Asia container terminals	CCR	Yard area, quay crane, terminal crane, yard tractor, berth length	Throughput (TEU)
Mokhtar and Shah (2013)	6 major container terminals in Malaysia	CCR, BCC	Total terminal area, maximum draft in meter, berth length in meter, quay crane index, yard stacking index, vehicles, number of gate lanes	Throughput (TEU)
Munisamy and Jun (2013); Munisamy and Wang (2013)	69 major container ports in Asia	DEA	Berth length, terminal area, total reefer points, total quayside	Total throughput (TEU)

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			cranes, total yard equipment	
Munisamy and Jun (2013)	30 Latin America container seaports	BCC, CCR	Berth length, terminal area, quay equipment, yard gantry, sophisticated equipment (reach stackers, straddle carriers), general equipment 9forklifts and yard tractors)	Container throughput
Grilo (2013)	11 terminals of Portuguese ports	CCR, BCC	Total quay length, number of berths, quay depth, storage area, number of cranes	Cargo throughput (ton)
Olapojuand Aloba (2013)	Lagos seaports	DEA	Terminal area, berth number, berth length	Ship traffic, cargo throughput
Polyzos and Niavis (2013)	30 Mediterranean ports	CCR, Super efficiency	Length of quays, number of ship to shore cranes	Number of TEUs that were moved
Shin and Jeon (2013)	8 terminals of south Korea	BCC, CCR	Quay length, number of container cranes, area of container yard	Container throughput and CO_2 emission
SchøyenandOdeck (2013)	24 container ports from Norway, all Nordic countries, United Kingdom	BCC, CCR	Berth length, terminal area, yard gantry cranes, straddle carriers	Container handling trucks, container throughput
Yuen et al. (2013)	21 major container terminals in China, Busan, Singapore and Kaohsiung	DEA	Number of berths, total berth length, land size (port land area), number of quay cranes, yard gantries	Cargo throughput (TEU)
Rajasekar et al. (2014)	Major ports in India	CCR, BCC	Number of berth, berth length, number of equipments, number of employees	Container throughput)TEU), total traffic
Akgül et al. (2015)	15 leading container ports in Turkey	CCR	Number of quay cranes, terminals area, storage capacity, quay length	Throughput (TEU)
Almawshe and Shah	19 container	CCR	Terminal area,	Throughput (TEU)

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(2015)	terminals in the middle eastern region		quay length, quay crane, yard equipment, maximum draft	
Baran and Górecka (2015)	18 leading container ports ranked in 2012	CCR, BCC	Number of berths, terminal area, storage capacity in TEU, quay length	Annual throughput (TEU)
Ding et al. (2015)	21 coastal small and medium sized-port container terminals in China	CCR, BCC	Terminal length, handling equipment quantity, staff quantity	Container throughput
Lu et al. (2015)	20 world's container ports	CCR, BCC, Super efficiency	Yard area, quay crane, terminal crane, yard tractor, berth length	Container throughput
Nguyen et al. (2015)	43 largest Vietnamese ports	DEA	Berth length, terminal areas, warehouse capacity, cargo handling equipment	Cargo throughput
da Cruz and de Matos Ferreira (2016)	10 Iberian seaport	CCR, BCC	Labor, fixed asset, turnover, ships handled	Cargo throughput
Jang et al. (2016)	21 container ports in Asia	CCR, BCC, SBM	Number of berth, length of berth, terminal area, gantry crane	Cargo volume (TEU)
Tetteh et al. (2016)	China and 5 west African countries	DEA	Number of berths, number of cranes, length of quay	Vessel calls(gross tons), port throughput (TEU)
Zheng and Park (2016)	30 major container terminals in Korea and China	CCR, BCC	Berth length, yard area, number of quay cranes, number of yard cranes	Throughput (TEU)
Schøyen and Odeck (2017)	6 largest Norwegian container ports against 14 similar small- and medium-sized ports in the Nordic countries and UK	DEA	Berth length, terminal areas, number of yard gantrycranes, straddle carries, container handling trucks	Container units (TEU)

Note: CCR: Charnes, Cooper and Rhodes model; BCC: Banker, Charnes and Cooper model; DEA: Data Envelopment Analysis; G7: America, France, Italy, Canada, Germany, Japan, and the England; BRIC: Brazil, Russia, India, China; N11: South Korea, Indonesia, Vietnam, the Philippines, Pakistan, Bangladesh in Asia, Nigeria and Egypt in Africa, Mexico in North America, Iran in the Middle East, and Turkey

As indicated in the Table 1, there have been many empirical studies on measuring port efficiency by using DEA in the literature. The models mostly used to apply the DEA method are the CCR model and BCC model. However, it should be pointed out that few studies have been less investigated the competitiveness of Qinzhou port. In particular, the studies that combined with DEA method used in Qinzhou port cannot be found.

3. Methodology

3.1 Data Envelopment Analysis

DEA is a multi-factor productivity analysis for measuring the relative efficiencies on Decision Making Units (DMUs). In this study, the DEA-CCR and DEA-BBC models are to be adopted for analysis the relative efficiency of the sample ports, both input and output oriented. Because the above models are given a value of 1 for all efficiency DMUs, it is unable to establish any further distinctions among the efficiency DMUs. Therefore, the DEA-Super Efficiency model is to be used to rank the ports, and the new efficiency value can thus be greater than 1.

Assuming that there are n DMUs, where each DMU_j (j=1,⋯, n) produces s output y_{rj}(r = 1,⋯, s) by utilizing m inputs x_{ij}(i= 1,⋯, m).

Then it has a linear programming dual of CCR model as follows:

$$\text{Min}\theta - \varepsilon\left[\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^-\right] \quad (1)$$

Subject to: $$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{ij}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{rj}$$

$$\lambda_j \geq 0, s_r^+, s_i^- \geq \varepsilon \geq 0.$$

Where: y_{rj} is rth outputs of the jth DMU;

x_{ij} is$i$th inputs of the jth DMU;

ε is a small positive number;

λ_{j_i} is a weight of jth DMU;

s_r^+ is a slack variable of rth output;

s_i^- is a slack variable of $i$thinput.

The BCC model adds the convexity restriction ($\sum_{j=1}^{s}\lambda_j = 1$) based on formula (1). The linear programming dual of BCC model is represented by:

$$\text{Min} \; \theta - \varepsilon\left[\sum_{r=1}^{s} s_r^+ + \sum_{r=1}^{m} s_i^-\right] \quad (2)$$

Subject to: $$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{ij}$$

 DOI : 10.25275/apjabssv4i1ss7

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^{+} = y_{rj}$$

$$\sum_{j=1}^{s} \lambda_j = 1$$

$$\lambda_j, s_r^{+}, s_i^{-} \geq 0$$

The Super Efficiency model is formulated in the following form similar to the above two models:

Min θ (3)

Subject to: $\sum_{j=1, j\neq j_0}^{n} \lambda_j x_j + s_i^{-} = \theta x_{ij}$

$$\sum_{j=1, j\neq j_0}^{n} \lambda_j y_j - s_r^{+} = y_{rj}$$

$$\lambda_j, s_r^{+}, s_i^{-} \geq 0$$

3.2. Input and Output Variables

There have been many empirical studies on measuring port efficiency by using DEA in the literature. The input and output variables used in these studies are presented in Table 1.

To avoid having too many DMUs with efficiency values being equal to 1, which would lower the discriminatory power of DEA, Norman and Stoker (1991) suggested that the number of DMUs should be at least twice the sum of input and output variables. Because the present study had nine ports, adopting this suggestion would mean that the sum of input and output variables could not be greater than four (Golany and Roll, 1989). Accordingly, the number of berth, berth length (meter), and terminal area (square meter) are considered as input variables, and container throughput (TEU) is used as the output variables in this study. The summary of input and output variables as shown in table 2.

Table 2: input and output variables used in the DEA model

Variables	Description	Measurement unit
Input:		
Number of berths	Total container berths in container port	Number
Berth length	Total container berth length of container port	Meter
Terminal area	total area of container terminals in container port	Hectare
Output:		
Container throughput	Total container throughput in TEU	10, 000 TEU/year

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3.3 Data Collection

Necessary information and data have been collected through precious literature, telephone interview, statistical yearbook, official websites from ports and the port authority and the other specialized websites.

Table3:Data for DEA Model for Year 2015

DMU: Port	Input 1: Number of berths (number)	Input 2: Berth length (m)	Input 3: Terminal area (hectare)	Output: Container throughput (10,000 TEU)
Qinzhou	4	2300	158	94.2
Shenzhen	39	16943	792	2420.45
Guangzhou	68	13241	899.86	1762.49
Zhanjiang	2	678	67.8	60.12
Zhuhai	24	5078	228.6	133.77
Haikou	3	786	30	127.13
Yangpu	9	1696	23.1445	27.16
Hong Kong	24	7694	279	2011.4
Laem Chabang	11	4640	256.6757	679.4

Source: China Ports Year Book 2016; China Statistical Yearbook 2016; Port of Hong Kong in Figures 2015; BSAA Annual Report 16-17; telephone interview; office websites of government, terminal, port and port authority

4. Results and Discussion

In this study, both the CCR and BCC models are applied to the MaxDEA software. The super efficiency model isapplied to the EMS1.3 software.

4.1 Input Oriented CCR Model

Table 4shows the relative efficiency ranking of 9 ports under input oriented CCR model. Hong Kong port's efficiency performs the best (the score is 1), other ports efficiency value are less than 0.8, and Zhuhai port performs the worst (0.101). Such score of the Qinzhou port is 0.281.

As the table shows, under the input oriented CCR model, Hong Kong port is efficiency (efficiency value=1). In the table, proportionate movement represents input redundancy value and slack movement indicates the insufficient output value and projection denotes the efficiency target value. The projection results provide a performance improvement target for inefficiency ports. That is, Qingzhou port should achieve 9420 thousand TEU with 1 berth, 360 meter berth length and 13 ha terminal area.

Hong Kong port relative efficiency value is 1, target and actual values are the same, and it has advantages in the PBGEC. In order to analyze the inefficiency port problem in terms of input, Table 5 makes a percentage difference in comparison with the target value and actual value (original data).

There is a large gap between the target value and original data. This shows that the efficiency of inputs being used is not appropriate, a serious input crowding in the port on the given level of input. A relatively large percentage difference in the ports except Shenzhen port, Laem Chabang port and Haikou port.The degree of input crowing is more than 25%. Yangpu port is the highest crowding degree port with berth input crowding value is 96.4%. It is obvious that degree of resource waste is serious.

 DOI : 10.25275/apjabssv4i1ss7

4.2 Output Oriented CCR Model

The relative efficiency ranking of input-oriented CCR and output-oriented CCR are the same, but output-oriented CCR gives the target value (projection) of output (container throughput). Therefore, it is necessary to show the calculating results of output-oriented CCR.

In the table 6, the results give the optimized resource allocation target value to ports, such as Qinzhou port should reduce 1017.667 meter berth length (input 2), 111.5 ha terminal area (input 3) to increase 24.1033 million TEU (proportionate movement value of output) and then achieve 335.233 thousand TEU (projection movement value of output). Other inefficiency port can be analyzed similarly. Also, the efficiency target value and original data are to be compared in Table 7. Apparently, the inefficiency ports can achieve a large output at the current level of input. For instance, Qinhzou port can realize DEA efficiency when it enlarges 71.9% container throughput at the current level.

Table 6: Relative Efficiency Calculation Results under Output Oriented CCR

Port	Slack movement (Input 1)	Slack movement (Input 2)	Slack movement (input 3)	Proportionat e movement (output)	Projection movement (output)
Hong Kong	0	0	0	0	2011.4
Shenzhen	0	-4440.25	-338.625	848.075	3268.525
Laem Chabang	0	-113.583	-128.801	242.492	921.892
Haikou	-0.548	0	-1.498	78.35	205.48
Guangzhou	-26.697	0	-419.715	1699.032	3461.522
Zhanjiang	0	-36.833	-44.55	107.497	167.617
Qinzhou	0	-1017.667	-111.5	241.033	335.233
Yangpu	-7.009	-1057.743	0	139.696	166.856
Zhuhai	-8.16	0	-44.461	1193.744	1327.514

Note: The proportionate movement of input and slack movement of the output value are 0. Here will not be listed.

4.3 Input Oriented BCC

Through contrasting Table 4withTable 8, relative efficiency values under output-oriented BCC have a big change. There are 5 ports are DEA efficiency: Zhanjiang, Yangpu, Shenzhen, Hong Kong and Haikou ports. The inefficiency ports' relative efficiency values are generally higher, only Zhuhai port's relative efficiency value below 0.5.

The relative efficiency result details of other inefficiency ports are summarized in the Table 8. Proportionate movement and slack movement values are very small compared to the values of CCR model. Compared the port ranking of CCR model (consider constant returns to scale), Laem Chabang port and Guangzhou port drop in ranking under the BCC (variable returns to scale), we hold that these two ports are not achieving DEA efficiency the reason is the scale of ports is expanding rapidly but a good integration of resources is not done yet. On the other hand, the Laem Chabang port and Guangzhou port have a huge potential.

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4.4 Output Oriented BCC

Table 9 is the relative efficiency ranking under output-oriented BCC model. The relative efficiency scores with small gaps compared to the scores of input-oriented BCC. The relative efficiency value is between 0.1-0.8, Zhuhai port is the smallest one with the score 0.103.

To analyze the gap between the original data and the target value (projection value) which the port achieve DEA efficiency is required. It is found that there are large gaps between the original data and the target value. The target value of Qinzhou port is 2.5 times than the original value. The target value of Zhuhai port even up to 9.7 times. It is worthy of pointing out that if Guangzhou port achieves DEA efficiency, its output will have greatly increased, thus enhancing its competitiveness.

Table 9: Relative Efficiency Results under Output-Oriented BCC Model

Port	Score	Input 1	Input 2	Input 3	Output		
		Slack movement	Slack movement	Slack movement	Original	Proportionate movement	Projection
Zhanjiang	1	0	0	0	60.12	0	60.12
Yangpu	1	0	0	0	27.16	0	27.16
Shenzhen	1	0	0	0	2420.45	0	2420.45
Hongkong	1	0	0	0	2011.4	0	2011.4
Haikou	1	0	0	0	127.13	0	127.13
Laem Chabang	0.791	0	-1091.818	-102.476	679.4	178.971	858.371
Guangzhou	0.781	-35.004	0	-313.193	1762.49	494.234	2256.724
Qinzhou	0.397	0	-984.182	-71	94.2	143.309	237.509
Zhuhai	0.103	-7.953	0	-43.894	133.77	1164.073	1297.843

4.5. Technical Efficiency and Scale Efficiency

To calculate and analyze the ports' aggregate efficiency, pure technical efficiency and scale efficiency and obtain the results are shown in the Table 10.

The Hong Kong port has the efficiency advantage in the competition (pure technical efficiency and scale efficiency are achieved DMU efficiency).

Shenzhen port, Haikou port, Zhanjiang port and Yangpu port's pure technical efficiency value are 1, scale efficiency value is between 0.3-0.8. But besides Shenzhen port shows decreasing return to scale, the other ports exhibit increasing return to scale. It is indicated that Haikou, Zhanjiang and Yangpu ports enlarge the operational scale will have returns to scale increasing effect, and then competitiveness will be strengthened. Conversely, Shenzhen port should reduce the scale of operation.

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Laem Chabang port, Guangzhou port and Zhuhai port's pure technical efficiency value below their scale efficiency, indicating that the major cause of inefficiency is pure technical inefficiency. That is, the output is appropriate at the current level of input.

Relatively, Qinzhou port's pure technical efficiency value higher than scale efficiency value means that the major cause of inefficiency is scale efficiency. A large throughput needs the large scale to support. Qinzhou port should pay attention to the production scale.

Table 10: Technical Efficiency Value and Scale Efficiency Value

Port	CRS	VRS	Scale	RTS
Hong Kong	1	1	1	Constant
Guangzhou	0.509	0.512	0.994	Increasing
Laem Chabang	0.737	0.817	0.902	Increasing
Shenzhen	0.741	1	0.741	Decreasing
Zhuhai	0.101	0.160	0.631	Increasing
Haikou	0.619	1	0.619	Increasing
Qinzhou	0.281	0.596	0.471	Increasing
Zhanjiang	0.359	1	0.359	Increasing
Yangpu	0.163	1	0.163	Increasing

Note: CRS: aggregate efficiency (technical efficiency) based on constant return to scale; VRS: pure technical efficiency based on variable return to scale; scale: scale efficiency=CRS/VRS; RTS: returns to scale (increasing, decreasing and constant)

 DOI : 10.25275/apjabssv4i1ss7

Table 4: Relative Efficiency Scores under Input-Oriented CCR Model

Port	Score	Number of berths			Berth length			Terminal area			Container throughput		
		Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection
Hong Kong	1	0	0	24	0	0	7694	0	0	279	0	0	2011.4
Shenzhen	0.741	-10.119	0	28.881	-4396.153	-3288.151	9258.697	-205.498	-250.763	335.739	0	0	2420.45
Laem Chabang	0.737	-2.893	0	8.107	-1220.492	-820.67	2598.838	-67.515	-94.921	94.239	0	0	679.4
Haikou	0.619	-1.144	-0.339	1.517	-299.703	0	486.297	-11.439	-0.927	17.634	0	0	127.13
Guangzhou	0.509	-33.377	-13.593	21.03	-6499.13	0	6741.87	-441.682	-213.704	244.474	0	0	1762.49
Zhanjiang	0.359	-1.283	0	0.717	-434.818	-13.211	229.971	-43.482	-15.979	8.339	0	0	60.12
Qinzhou	0.281	-2.876	0	1.124	-1653.704	-285.963	360.333	-113.602	-31.331	13.066	0	0	94.2
Yangpu	0.163	-7.535	-1.141	0.324	-1419.934	-172.174	103.892	-19.377	0	3.767	0	0	27.16
Zhuhai	0.101	-21.582	-0.822	1.596	-4566.303	0	511.697	-205.565	-4.48	18.555	0	0	133.77

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Table 5: The Percentage Difference Comparison between Target and Actual Values under Input-Oriented CCRModel

DMU	Port	Shenzhen	Laem Chabang	Haikou	Guangzhou	Zhanjiang	Qinzhou	Yangpu	Zhuhai
Input1	Projection	28.881	8.107	1.517	21.03	0.717	1.124	0.324	1.596
	Origin	39	11	3	68	2	4	9	24
	Difference	25.95%	26.30%	49.43%	69.07%	64.15%	71.90%	96.40%	93.35%
Input2	Projection	9258.697	2598.838	486.297	6741.87	229.971	360.333	103.892	511.697
	Origin	16943	4640	786	13241	678	2300	1696	5078
	Difference	45.35%	43.99%	38.13%	49.08%	66.08%	84.33%	93.87%	89.92%
Input3	Projection	335.739	94.239	17.634	244.474	8.339	13.066	3.767	18.555
	Origin	792	256.6757	30	899.86	67.8	158	23.1445	228.6
	Difference	57.61%	63.28%	41.22%	72.83%	87.70%	91.73%	83.72%	91.88%

Table 7: The Percentage Difference Comparison between Target and Actual Values under Output-Oriented CCRModel

DMU	Port	Shenzhen	Laem Chabang	Haikou	Guangzhou	Zhanjiang	Qinzhou	Yangpu	Zhuhai
Output	Origin	2420.45	679.4	127.13	1762.49	60.12	94.2	27.16	133.77
	Projection	3268.525	921.892	205.48	3461.522	167.617	335.233	166.856	1327.514
	Difference	25.95%	26.30%	38.13%	49.08%	64.13%	71.90%	83.72%	89.92%

Table8:The Relative Efficiency Results of Inefficiency Ports under Input-Oriented BCC Model

DMU		Input 1			Input 2			Input 3		
Port	Score	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection
Laem Chabang	0.817	-2.018	0	8.982	-851.159	-884.165	2904.676	-47.084	-74.762	134.829
Qinzhou	0.596	-1.616	0	0.384	-929.062	-570.4	800.538	-63.823	-22.689	71.489
Guangzhou	0.512	-33.173	-13.601	21.226	-6459.539	0	6781.461	-438.991	-214.762	246.107
Zhuhai	0.16	-20.17	-0.756	3.074	-4267.657	0	810.343	-192.12	-5.602	30.877

Asia Pacific Institute of Advanced Research (APIAR) DOI : 10.25275/apjabssv4i1ss7

4.6. Super Efficiency

Table11: Super Efficiency Model Results

Port	VRS-SE value	Ranking	CRS-SE value	Ranking
Shenzhen	Big	1	0.7405	2
Hong Kong	2.3516	2	1.8427	1
Haikou	1.9351	3	0.6187	4
Zhanjiang	1.5	4	0.3587	6
Yangpu	1.2962	5	0.1628	8
Laem Chabang	0.8166	6	0.7370	3
Qinzhou	0.5961	7	0.2810	7
Guangzhou	0.5122	8	0.5092	5
Zhuhai	0.1596	9	0.1008	9

Note: VRS-SE value: super efficiency value from a variable return to scale; CRS-SE value: super efficiency value from a constant return to scale

With respect to the relative efficiency ranking, the BCC model has 5 efficiency ports, but it is not possible to differentiate the five ports since the ports efficiency score is 1. Therefore, it is necessary to use super efficiency model to rank the ports.

The ports ranking based on constant returns to scale and variable returns to scale are shown in Table 11. Shenzhen port's super efficiency value shows as Big based on variable returns to scale. It means that Shenzhen port is DEA efficiency, whether to increase input or decrease output. However, it is relative in the sample ports.

The ranking under variable returns to scale has changed. Shenzhen port ranks first, followed by Hong Kong port. Zhanjiang port move up two places to No 4 and Yangpu port move 3 places to No 5 respectively, shows the strong competitiveness. On the contrary, Laem Chabang port and Guangzhou port dropped 3 places to No 6 and No 8 respectively. Qinzhou port ranking does not change. Zhuhai port is ranked in the bottom shows the weak competitiveness. High concentration of super efficiency value illustrates the intense competition level of ports of PBGEC.

Conclusion

In this paper, the relative efficiency and competitive position of Qinhzou port, the maritime route between Thailand and China, are researched through the comparison with the rest 8 ports under PBGEC. The conclusion could be presented thereafter. The results of input and output oriented CCR model show that Qinzhou port efficiency score is 0.281, and the results of input and output oriented BCC model indicate that Qinzhou port efficiency scores are 0.596 and 0.397 respectively, both of which reveal that Qinzhou port exists input redundancy and insufficient output in the sample ports. In addition, the pure technical efficiency and technical efficiency results also imply that the main cause of Qinzhou port inefficiency relies on scale efficiency. Moreover, the ranking of the super efficiency model indicates that Qinzhou port performs with weak competitiveness.

There are some limitations of this study in following aspects. Firstly, due to the data of sample ports were difficult to obtain, this study just consider the cross-sectional data of year 2015. Secondly, as DEA analysis calculates the relative efficiency based on the selected samples, in this study we concentrate on the 9 container ports of PBGEC for the year 2015, so the DEA results probably would be different if the sample ports were different or new data of another year are included.

 DOI : 10.25275/apjabssv4i1ss7

And the implication for further study could be summarized. Upcoming research should apply panel data to evaluate the efficiency of the sample ports with larger sample ports and variables. And various research objects should be widely applied. Additionally, container terminals comparison between two or more countries also should be applied to further research. Further, for the feasibility of this research for the policy makers, how to enhance the overall competitiveness of Qinzhou port should be taken in no time.

 DOI : 10.25275/apjabssv4i1ss7

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