International Review of Business Research Papers
Vol.3 No.2 June 2007, Pp. 486 - 503

Efficiency Analysis and Ranking of Major Container Ports in Northeast Asia: An Application of Data Envelopment Analysis

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The Northeast Asia is emerging as the third hub of world economy next to EU and NAFTA. Neighboring countries in the region enter into keen competition to take the lead in global supply chain network. This competition is accelerated by the fast growing Chinese economy. Under these circumstances, it is necessary for container ports not only to extend the facilities but also to improve the operational efficiency for gaining competitive advantage over their rivals. By applying DEA models, we attempt to measure the operational efficiency of the 19 major container ports in the Northeast Asia. This analysis of operational efficiency reveals the causes of inefficient operation and also suggests how to overcome the drawbacks. An additional analysis for ranking the container ports was conducted using the super-efficiency model. According to the results of this study, eight container ports are operated efficiently among which Hongkong is ranked top as the most efficient port in the Northeast Asia. Two Korean container ports, both Busan and Gwangyang show relatively low operational efficiency compared to their rival ports. To become efficient, they need to improve either cut their labor and capital (inputs) or increase their TEU (output) of the two ports.

Field of Research: International Trade and Transportation Logistics

1. Introduction

For the globalization and regional economic integration of world economy, there have been keen competitions among countries to take the initiative in global supply chain network. Especially, in the Northeast Asia, which is emerging as the 3rd hub of

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world economy next to EU and NAFTA, several countries including Korea, China, Japan, Taiwan, Singapore and Hongkong have competitively accelerated the advance. Recently, in order to foster Busan and Gwangyang as the hubs of container development of major container ports to occupy the quantity of goods transported in ports, Korea has plans to build 30 berths at Busan New Port and 33 berths at Gwangyang Port by 2011.

However, as many shipowners have turned to the hub & spoke system that ships touch at a few of key container ports and link the other container ports through feeder services, some low efficient container ports should be degraded to feeder container ports. Under this circumstance, to take the prior positions as major container ports and to keep the competitive advantages, it is necessary that these ports should not only extend their facilities, but also maximize the efficiency of their own operations.

In this study, we attempt to measure the efficiency of major container ports in the Northeast Asia including the ports of Busan and Gwangyang, to find out the present states and drawbacks of these container ports, and finally to suggest solutions for removing the drawbacks. The main purposes of this study are 1) to analyze the efficiency of the competitive 19 container ports in the Northeast Asia, 2) to identify the causes and degrees of inefficiency, and 3) to establish the standards of benchmarking to improve the efficiency and to suggest the way of improvement.

To achieve these purposes, we use DEA (Data Envelopment Analysis) models to measure the relative efficiency of each container port. DEA can evaluate the efficiency of each port from the overall points of views through taking relations between multiple inputs and outputs into account, whereas previous studies evaluated just the partial efficiency by considering individual input factors such as the productivity of crane, the capacity of yard and quay.

This study is organized as follows. In section 2, we introduce DEA model and the review of previous studies on measurement of port efficiency. In section 3, we present the results of empirical study conducted on 19 container ports in the Northeast Asia. We then conclude our study in section 4.

2. Literature Review

We have reviewed the literature on studies that have applied DEA method to analyze port efficiency as shown in table 1.

Roll and Hayuth(1993) first tried to use DEA model in analyzing the efficiency of container ports. They evaluated the efficiency of 20 virtual ports through DEA-CCR model with 3 inputs and 4 outputs. Martinez-Budria et al.(1999) classified 26 container ports in Spain into three groups according to the level of complexity based on data from 1993 to 1997 and then evaluated the efficiency of those ports through DEA-BCC model with 3 inputs and 1 outputs. The result showed that the higher the complexity, the higher the efficiency. Tongzon(2001) evaluated the efficiency of 4 Australian and 12 other international container ports in 1996, using the DEA-CCR and DEA-additive models with 6 inputs and 2 inputs. Valentine and Gray(2001) also applied the DEA-CCR model with 2 inputs and 2 outputs to examine the efficiency of 31 container ports out of the world's top 100 container ports in 1998. Using both DEA-CCR and BCC models, Park and De(2004) evaluated the efficiency of 11 Korean container ports with 2 inputs and 4 outputs. Park(2005) performed DEA/Window analysis on 11 Korean container terminals during the five years from 1999 to 2002. Song and Sin(2005) also evaluated the efficiency of 53 international major container ports using DEA-CCR model based on data from 1995 and 2001.

Table 1: The Applications of DEA method on ports efficiency

Authors	DEA Models	Data Description	Inputs	Outputs
Roll and Hayuth (1993)	DEA with CCR model	Hypothetical numerical example of 20 ports	manpower, capital, cargo uniformity	cargo throughput, level of service, user's satisfaction, ship calls
Martinez-Budria et al. (1999)	DEA with BCC model	26 Spanish ports, 1993-1997	labor expenditures, depreciation charges, other expenditures	total cargo throughput, revenue for the rent of port facilities
Tongzon (2001)	DEA with CCR and Additive DEA models	4 Australian and 12 other international ports for 1996	number of cranes, number of container berths, number of tugs, terminal area, delay time, labor	annual container throughput, ship working rate
Valentine and Gray (2001)	DEA with CCR model	31 world ports for the year 1998	total length of berth, container berth length	container throughput, total cargo throughput
Park and De (2004)	DEA with CCR and BCC models	11 Korean seaports for the year 1999	berthing capacity(number of ships), cargo handling(tones)	cargo throughputs, number of ship calls, revenue, consumer satisfaction
Park (2005)	DEA/Window analysis	11 Korean container terminals, 1999-2002	Total length of quay, number of cranes, size of yard areas, size of labor force, LPC(Lifts Per Calls), NBP(Net Berth Productivity)	cargo throughput, terminal capacity
Song and Sin (2005)	DEA with CCR model	53 container ports in the world, 1995-2001	Berth length, total area, CFS area, hours of working, G/C and yard equipments	total TEU
Current study	DEA with CCR, BCC, and super-Efficiency models	19 container ports in the Northeast Asia for the year 2004	total berth length, terminal area, number of quay cranes, number of yard equipments	container throughput

All the studies mentioned above utilized various DEA models and input and output factors based on their plan of studies. However, it would make sense in the practical level to identify the relative ranking of efficiency among all of the ports being compared so as to establish standards for benchmarking. Therefore, in this study, we attempt to identify the ranking of efficiency on container ports by using the concept of super-efficiency suggested by Anderson and Petersen (1993).

3. Methodology

DEA is a linear programming (LP) based deterministic and non-parametric method for measuring the relative efficiency of DMUs (Decision Making Units) with multiple inputs and outputs. The DEA models most widely used in practice are the CCR and the BCC models. The main difference between the two models is in the assumption for returns to scale (RTS). In fact, the CCR model assumes constant returns to scale (CRS), whereas the BCC model allows for variable returns to scale (VRS). DEA models can be distinguished according to whether they are input-oriented or output-oriented (i.e. either minimizing inputs for a given level of output, or maximizing output for a given level of input). In this study, we use output-oriented CCR and BCC models to analyze how to produce the maximum possible container throughput from a given fixed quantity of resources.

3.1 CCR Model

Charnes, Cooper and Rhodes(1978) extended Farrell's(1957) work in the measurement of technical efficiency and first introduced the term data envelopment analysis, known as the CCR model. Here we give a brief introduction to the model.
We assume that there are n DMUs, where each DMU produces s outputs by utilizing m inputs. For the i^{th} DMU these are represented by the column vectors x_i and y_i respectively. The $m \times n$ input matrix, X, and the $s \times n$ output matrix, Y, represent the data for all n DMUs. Then, relative efficiency of the i^{th} DMU can be found by solving the following fractional programming problem:

$$\max_{u,v} (u' y_i / v' x_i), \quad s.t.\ u' y_j / v' x_j \le 1, \quad j = 1,2,\cdots,n, \quad u,v \ge 0 \qquad (1)$$

where u is a $s \times 1$ vector of output weights and v is a $m \times 1$ vector of input weights (the prime denotes a transposed vector). This fractional programming problem can be easily transformed into the following equivalent linear programming problem:

$$\max_{u,v} (u' y_i) \quad s.t.\ v' x_i = 1, \quad u' y_j - v' x_j \le 0, \quad j = 1,2,\cdots,n, \quad u,v \ge 0 \qquad (2)$$

Alternatively, the same solution can be obtained by solving the dual problem of formula (2). The dual to the above multiplier form is the envelopment form, which is shown below:

$$\min_{\theta,\lambda} \theta, \quad s.t. -y_i + Y\lambda \geq 0, \quad \theta x_i - X\lambda \geq 0, \quad \lambda \geq 0 \cdots\cdots (3)$$

where θ is a scalar representing the efficiency score for the i^{th} DMU and λ is a $n \times 1$ vector of constants. Because θ is associated with the input constraints, this model is often referred to as the input-oriented model. Similarly, the output-oriented CCR model can be written as follows:

$$\max_{\phi,\lambda} \phi, \quad s.t. -\phi y_i + Y\lambda \geq 0, \quad x_i - X\lambda \geq 0, \quad \lambda \geq 0 \cdots\cdots (3)'$$

Input-oriented efficiency scores range between 0 and 1.0, and whereas output-oriented efficiency scores range from 1.0 to infinity, in both cases 1.0 is efficient. For the output-oriented model, we define the efficiency score as the inverse of the estimated score (i.e. $1/\phi$).

3.2 BCC Model

Banker, Charnes and Cooper(1984) extended the CCR model to allow for variable returns to scale by adding the convexity constraint $e'\lambda = 1$ to the original formula and is referred to as the BCC model. The formulations of the input-oriented and output-oriented BCC models are as follows, respectively:

$$\min_{\theta,\lambda} \theta, \quad s.t. -y_i + Y\lambda \geq 0, \quad \theta x_i - X\lambda \geq 0, \quad e'\lambda = 1, \quad \lambda \geq 0 \cdots\cdots (4)$$

$$\max_{\phi,\lambda} \phi, \quad s.t. -\phi y_i + Y\lambda \geq 0, \quad x_i - X\lambda \geq 0, \quad e'\lambda = 1, \quad \lambda \geq 0 \cdots\cdots (4)'$$

where e is the $n \times 1$ unit vector. The efficiency computed from the BCC model is pure technical efficiency, whereas the one from the CCR model is the aggregate measure of technical and scale efficiency. Therefore, scale efficiency can be defined to be CCR efficiency over BCC efficiency ($SE_i = E_{i,CCR} / E_{i,BCC}$). $SE = 1$ indicates scale efficiency and $SE < 1$ indicates scale inefficiency.

Scale inefficiency is due to either increasing or decreasing returns to scale, which can be determined by comparing the BCC score with that estimated under non-increasing returns to scale (NIRS). The NIRS DEA model is formulated by substituting the $e'\lambda = 1$ restriction in the above BCC model with $e'\lambda \leq 1$ as shown below:

$$\min_{\theta,\lambda} \theta, \quad s.t. -y_i + Y\lambda \geq 0, \quad \theta x_i - X\lambda \geq 0, \quad e'\lambda \leq 1, \quad \lambda \geq 0 \cdots\cdots (5)$$

$$\max_{\phi,\lambda} \phi, \quad s.t. -\phi y_i + Y\lambda \geq 0, \quad x_i - X\lambda \geq 0, \quad e'\lambda \leq 1, \quad \lambda \geq 0 \cdots\cdots\cdots (5)'$$

If the NIRS efficiency score is unequal to the BCC efficiency score, then increasing returns to scale exists for that DMU. If the two scores are equal, then decreasing returns to scale exists.

3.3 Super-efficiency Model.

The CCR and BCC models divide the DMUs into inefficient and efficient ones. However, as all efficient DMUs receive the same efficiency score of 1, it is not possible to distinguish between the efficient DMUs. To overcome this problem, Andersen and Petersen (1993) proposed the super-efficiency ranking method for only efficient DMUs. The super-efficiency measures how much can the inputs be increased (or the outputs decreased) while not become inefficient.

The super-efficiency model is identical to the DEA model described above, but a DMU under evaluation is excluded from the reference set. This allows a DMU to be located above the efficient frontier i.e. to be super-efficient. Therefore, the super-efficiency score for efficient DMU can in principle take any value greater than or equal 1. This procedure makes a ranking of efficient DMUs possible (i.e., the higher the value the higher the rank). On the while, the scores for inefficient DMUs remain the same as in the standard models.

Figure 1 provides an input-oriented illustration of the super-efficiency model (Lovell and Rouse, 2003). The efficient frontier consists of the line segments connecting DMUs A, B and C. If DMU B is excluded from the reference set, the effect is to construct a new frontier consisting of the broken line segments connecting DMU A and C. The super-efficiency of DMU B becomes OB*/OB > 100%. This implies that DMU B could increase both inputs and still remain efficient.

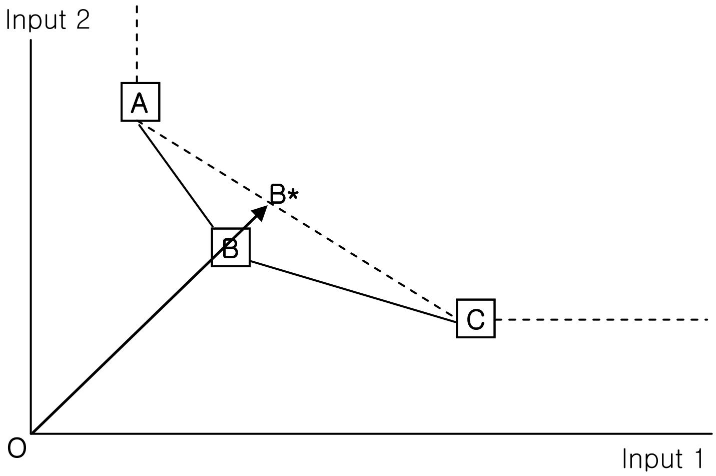

Figure 1. Evaluating the super-efficiency of DMU B

4. Empirical Analysis

In this study, we employ DEA model to analyze and compare the efficiency of the major competitive container ports in the Northeast Asia. DMUs (Decision Making Units) consist of total 19 container ports, including two (Busan, Gwangyang) in Korea, eight (Shanghai, Shenzhen, Qingdao, Ningbo, Tianjin, Xiamen, Guanzhou, Dalian) in China, five (Tokyo, Yokohama, Nagoya, Osaka, Kobe) in Japan, two (Kaohsiung, Keelung) in Taiwan, Hongkong and Singapore. As the facilities and scales of these container ports are similar, selected DMUs are adequate for the analysis of this study. To apply DEA model, the common inputs and outputs of each container port should be appropriately selected for this analysis. As the selection of inputs and outputs is directly related with the validity of the model, it requires close attention to maximize the discrimination power of the model with the selected inputs and outputs (Nyhan and Martin, 1999). Labor and capital are two generic inputs for the analysis of efficiency. To quantitatively measure the labor and capital, we use the number of quay and yard equipments as proxies of labor and the total berth length and terminal area as those of capital. TEU is used as the only output in this analysis as it is an index of competitiveness of a container port. Although there is no optimal way to decide the number of inputs and outputs, it is appropriate that the relationship among the numbers of DMUs, inputs and outputs should fulfill this condition, $n \geq \max[m \times s, 3(m+s)]$ where n is the number of DMUs, m is the number of inputs and s is the number of outputs (Cooper et al., 1999; Boussofiane et al., 1991; Banker et al., 1984).

This study uses cross-sectional data for the year 2004 reported from

Containerisation International Year Book 2006 to get the reliability of the results, and the other data are collected through websites and publicity booklets of the container ports and revised into the data for the analysis to increase the accuracy of information. Descriptive statistics for variables in DEA estimation are shown in table 2.

Table 2: Descriptive statistics for input and output variables

Variables	Minimum	Maximum	Mean	Standard Deviation
Berth Length (m)	1,110	10,475	4,569.32	2,305.69
Terminal Area (m^2)	339,000	4,039,822	1,803,884.84	964,919.76
Number of Quay Cranes	15	118	39.158	27.53
Number of Yard Equipments	28	385	122.579	98.45
Container Throughput (TEU)	1,320,000	21,984,000	6,794,148.37	6,553,074.62

4.1 Efficiency Analysis

After applying output-oriented CCR model and BCC model to the selected inputs and outputs, the results of efficiency analysis on the 19 container ports are shown in Table 3. To practically improve the efficiency of container ports, increasing changeable outputs may be more appropriate than decreasing the given inputs. Therefore, this study selected the output-oriented model and used both CCR model and BCC model simultaneously to pure technical efficiency and scale efficiency separately. DEA Excel Solver, the widely used DEA software, is used for the analysis. As shown in table 3, the efficiency indices of Shanghai, Shenzhen, Xiamen, Hongkong and Kaohsiung are equal to 1 in CCR model, and the other three container ports of Ningbo, Tianjin and Keelung are added in BCC model. Therefore, total eight container ports turned out to have been operating efficiently. On the other hand, container ports of which efficiency indices are not equal to or smaller than 1 are relatively inefficient in operation compared with the efficient container ports on the efficiency frontier. The inefficient container ports have a group of ports as the reference sets for benchmarking.

The results of the comparison among the nations of the container ports show that the efficiency of China and Taiwan are relatively higher than those of other nations, while the container ports in Japan are less efficient. The efficiency index of Busan Port in Korea is above the average, and that of Gwangyang port is below the average indicating that the two container ports show significant differences even in the same country.

The technical efficiency in CCR model, shown in table 3, can be classified into pure technical efficiency and scale efficiency. By using this concept, we can find whether the cause of the inefficiency is from pure technical inefficiency or from scale inefficiency. Shanghai, Shenzhen, Xiamen, Hongkong and Kaohsiung that both pure technical efficiency and scale efficiency are equal to 1 are considered as operating at the most productive scale size (MPSS). It is said that, as the container ports of Ningbo, Tianjin and Keelung which are efficient on BCC model but inefficient on CCR model have been efficiently operated except the effect of scale, the major causes of inefficiency are from scale inefficiency. The three container ports should require the close consideration on whether inputs should be increased or decreased. But the results indicate that these container ports should enhance their own efficiency by increasing their input level as these have IRS characteristics. Because the container ports of Busan, Guanzhou, Yokohama and Singapore, which show DRS characteristics, have been operated by the inputs over optimal scale, the consideration on the decrease of inputs or the increase of outputs is required. In the cases of the container ports of which both pure technical efficiency and scale efficiency is less than 1, both can be the causes of inefficiency. However, it is considered that as pure technical efficiency is less than scale efficiency, pure technical factors have given more mischievous effect on their own whole efficiency rather than scale factors.

Table 3: Estimation results for Efficiency scores

Container Ports (DMU)		DEA-CCR model		DEA-BCC model		SE	RTS
		TE	Reference set (λ)	PTE	Reference set (λ)		
1	Busan	0.826	3(0.342) 4(0.509) 12(0.197)	0.830	3(0.391) 4(0.274) 11(0.088) 12(0.247)	0.995	DRS
2	Gwangyang	0.344	8(0.550) 12(0.233)	0.411	7(0.357) 8(0.643)	0.835	IRS
3	Shanghai	1.000	3(1.000)	1.000	3(1.000)	1.000	CRS
4	Shenzhen	1.000	4(1.000)	1.000	4(1.000)	1.000	CRS
5	Qingdao	0.574	11(0.407)	0.645	8(0.258) 11(0.286) 13(0.456)	0.890	IRS
6	Ningbo	0.904	3(0.082) 4(0.138) 12(0.139)	1.000	6(1.000)	0.904	IRS
7	Tianjin	0.853	3(0.115) 4(0.024) 12(0.253)	1.000	7(1.000)	0.853	IRS
8	Xiamen	1.000	8(1.000)	1.000	8(1.000)	1.000	CRS
9	Guanzhou	0.482	3(0.018) 4(0.199) 8(1.351)	0.498	4(0.342) 8(0.645) 12(0.013)	0.969	DRS
10	Dalian	0.461	3(0.274) 11(0.037)	0.473	8(0.906) 11(0.094)	0.975	IRS
11	Hongkong	1.000	11(1.000)	1.000	11(1.000)	1.000	CRS
12	Kaohsiung	1.000	12(1.000)	1.000	12(1.000)	1.000	CRS
13	Keelung	0.947	4(0.110) 11(0.031)	1.000	13(1.000)	0.947	IRS
14	Tokyo	0.491	11(0.210) 12(0.228)	0.591	8(0.851) 11(0.146) 12(0.003)	0.831	IRS
15	Yokohama	0.249	4(0.313) 8(0.564) 12(0.517)	0.253	4(0.394) 8(0.075) 12(0.531)	0.985	DRS
16	Nagoya	0.346	4(0.240) 8(0.015) 12(0.299)	0.382	8(0.691) 11(0.054) 12(0.255)	0.907	IRS
17	Osaka	0.321	4(0.014) 8(0.237) 12(0.555)	0.325	4(0.016) 8(0.397) 12(0.472) 13(0.115)	0.988	IRS
18	Kobe	0.243	4(0.208) 11(0.143) 12(0.306)	0.258	8(0.508) 11(0.178) 12(0.314)	0.940	IRS
19	Singapore	0.803	4(0.242) 11(1.017)	0.937	11(1.000)	0.857	DRS

a) TE: Technical Efficiency, PTE: Pure Technical Efficiency, SE: Scale Efficiency

b) RTS: Returns to Scale (IRS: Increasing, DRS: Decreasing, CRS: Constant)

4.2 Ranking Analysis by Super-efficiency Model

Although CCR and BCC models provide a method to dichotomize container ports into efficient and inefficient DMUs, it is impossible to determine the relative rankings among the efficient DMUs. When there are several efficient ports (efficiency index=1) like in this study, it is difficult to tell which port is more efficient to what extent than other ports. To overcome this limitation, we attempt the ranking analysis of container ports using the super-efficiency model. The results are shown in table 4. In order to decide the rank of each container port in the view of overall technical efficiency, it attempts to measure super-efficiency scores in output-oriented CCR model.

Table 4: Ranking of the container ports by super-efficiency scores

Container Ports	Efficiency Scores (CCR)	Amount of inefficiency for each input and/or output					Super-efficiency Scores (Ranking)
		Berth Length	Terminal Area	Quay Cranes	Yard Equipments	Container Throughputs	
Busan	0.826	0 (0.00%)	0 (0.00%)	0 (0.00%)	-25 (-13.12%)	2,407,279 (21.06%)	0.826(9)
Gwangyang	0.344	-1,527 (-41.26%)	-536,211 (-39.04%)	0 (0.00%)	0 (0.00%)	2,520,189 (190.92%)	0.344(16)
Shanghai	1.000	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.077(5)
Shenzhen	1.000	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.092(4)
Qingdao	0.574	-1,841 (-36.10%)	0 (0.00%)	-3 (-8.10%)	-13 (-8.61%)	3,816,306 (74.25%)	0.574(11)
Ningbo	0.904	0 (0.00%)	-544,421 (-37.37%)	0 (0.00%)	0 (0.00%)	423,649 (10.58%)	0.904(7)
Tianjin	0.853	0 (0.00%)	0 (0.00%)	0 (0.00%)	-6 (-11.25%)	654,781 (17.17%)	0.853(8)
Xiamen	1.000	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.131(3)
Guanzhou	0.482	0 (0.00%)	-934,914 (-38.49%)	0 (0.00%)	0 (0.00%)	3,549,616 (107.30%)	0.482(13)
Dalian	0.461	0 (0.00%)	-295,992 (-19.68%)	-7 (-28.38%)	0 (0.00%)	2,581,568 (116.75%)	0.461(14)
Hongkong	1.000	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.306(1)
Kaohsiung	1.000	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.279(2)
Keelung	0.947	-2,333 (-73.08%)	0 (0.00%)	-16 (-64.15%)	0 (0.00%)	116,859 (5.64%)	0.947(6)
Tokyo	0.491	-805 (-20.04%)	0 (0.00%)	0 (0.00%)	-20 (-17.33%)	3,476,262 (103.52%)	0.491(12)
Yokohama	0.249	0 (0.00%)	0 (0.00%)	-2 (-3.90%)	0 (0.00%)	8,194,994 (301.55%)	0.249(18)
Nagoya	0.346	0 (0.00%)	0 (0.00%)	-1 (-4.91%)	0 (0.00%)	4,070,695 (188.86%)	0.346(15)
Osaka	0.321	0 (0.00%)	0 (0.00%)	-6 (-21.56%)	0 (0.00%)	4,249,256 (211.50%)	0.321(17)
Kobe	0.243	-1,000 (-18.68%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	6,781,273 (311.52%)	0.243(19)
Singapore	0.803	-999 (-9.54%)	0 (0.00%)	-6 (-5.33%)	0 (0.00%)	5,059,544 (24.56%)	0.803(10)

The results show that the super-efficiency scores of Shanghai, Shenzhen, Xiamen, Hongkong and Kaohsiung of which all efficiency indices are equal to 1 are 1.077, 1.092, 1.131, 1.306 and 1.279 respectively. Therefore, Hongkong Port is evaluated as the most efficient. On the other hand, as the super-efficiency scores of the inefficient container ports are the same as the efficiency indices in CCR model, Kobe Port is the most inefficient. While the inefficiency on inputs and outputs in efficient container ports are all zero, there are too much inputs or too little output in inefficient container ports. In the case of Kobe Port, which shows the lowest scores 0.243, it should decrease 1,000m(18.68%) of its berth length or increase 6,781,273 TEU(311.52%) of its container throughput to reach to the 100% efficiency. In the meantime, two container ports of Busan and Gwangyang in Korea ranked the 9th and the 16th showing weak competitiveness among container ports in the Northeast Asia.

4.3 How to improve the efficiency of the container ports of Busan and Gwangyang

As we discussed earlier, the container ports of Busan and Gwangyang turned out to be inefficient. Therefore, we need to figure out what causes inefficiency and how to improve the efficiency of the container ports of Busan and Gwangyang. By following Table 3, we can see that the efficiency score of Busan Port is 0.830, which is less than 0.995 of the scale efficiency score. Therefore it might be true that the inefficiency could be caused by the pure technical efficiency rather than the scale efficiency. Consequently, Busan Port needs to take the benchmarking on the reference set such as Shanghai(0.391), Shenzhen(0.274), Kaohsiung(0.247), Hongkong(0.088) to figure out how to improve its efficiency, where the values in parenthesis stand for weight(λ). Note that Shanghai has the highest weight of 0.391, and thus Busan Port should consider Shanghai as the most favorable port for benchmarking.

Now, in order to evaluate the target values for input and output factors which make Busan Port efficient, we need to project the actual values for input and output factors onto the efficient frontier and express them as the positive combination of DMUs in the reference set. The target values for input and output factors in the ports of Busan and Gwangyang are shown in Table 5. According to Table 5, it can be seen that Busan Port should decrease 9.39% of yard equipments and increase 20.43% of the container throughput in order to be efficient.

We can also see from Table 3 that Gwangyang Port has the efficient score of 0.411 and has Xiamen(0.643) and Tianjin(0.357) as the reference set. Moreover, by following Table 5, we know that, in order for Gwangyang Port to be efficient, it should be able to handle 3,208,236 TEU by increasing 143.04% of container throughput. The main reason for which Gwangyang Port has such a low throughput seems that there is still the lack of know-how and technology in Gwangyang because it just opened in 1998, as well as the inconsistent policies of government related to the lack of SOC and the delay of industrial complex development. Therefore, Gwangyang Port seems to need more time to get its international competitive power through accumulating know-how and technology.

Table 5: Efficient Targets for the ports of Busan and Gwangyang

Container Ports	Efficiency Scores	Input and Output	Actual	Target	Potential Improvement(%)	Reference set (λ)
Busan	0.830	Berth Length	5,973	5,973	0	Shanghai(0.391) Shenzhen(0.274) Kaohsiung(0.247) Hongkong(0.088)
		Terminal Area	2,923,069	2,923,069	0	
		Quay Cranes	52	52	0	
		Yard Equipments	189	171	-18(-9.39%)	
		TEU	11,430,000	13,764,730	2,334,730(20.43%)	
Gwang-yang	0.411	Berth Length	3,700	1,589	-2,111(-57.07%)	Xiamen(0.643) Tianjin(0.357)
		Terminal Area	1,373,503	818,357	-555,146(-40.42%)	
		Quay Cranes	15	15	0	
		Yard Equipments	39	39	0	
		TEU	1,320,000	3,208,236	1,888,236(143.05%)	

5. Conclusions

The competition among the container ports in the Northeast Asia has been increased by the rapid growth of China's economy. It is therefore necessary for these container ports to strengthen their own competitive powers through the improvement of operational efficiency for achieving competitive advantages against their rivals.

In this study we evaluated not only the relative efficiency of the major 19 container ports in the Northeast Asia using DEA models so that we would be able to identify the current level of efficiency for each container port, but also the ranking of all the container ports considered in this study by using super-efficiency model. We then suggested a way of improving operational efficiency of inefficient container ports. According to the result of CCR model, 5 container ports of Shanghai, Shenzhen, Xiamen, Hongkong and Kaohsiung turned out to be relatively efficient, compared with the others. We also applied BCC model to figure out what causes inefficiency and found that the inefficiency of the container ports of Ningbo, Tianjin and Keelung was caused by the scale inefficiency, whereas the inefficiency of the other container ports was caused by the technical inefficiency.

On the other hand, the container ports of Busan and Gwangyang in Korea, turned out to be relatively inefficient, compared with their rivals. Therefore, the container ports of Busan and Gwangyang would be required to improve their input and output structure through benchmarking for Shanghai and Xiamen, respectively. Moreover, it might be one of possible alternatives to try to improve the operational efficiency of the whole container ports in Korea through reorganizing two container ports as specific role and service oriented container port based on their competitiveness.

This study has a significant implication in the sense that it tried to utilize quantitative models, DEA model and Super-efficiency model, for evaluating and ranking operational efficiency of competitive container ports in the Northeast Asia. As we mentioned earlier, DEA models allow us to evaluate the current level of efficiency of each container port and to identify the strength and weakness of each container port and eventually to suggest an efficient way of benchmarking to inefficient container ports. super-efficiency model also allows us to evaluate the ranking of container ports in terms of their efficiency.

Despite of the above implication, we still need to conduct further studies as follows. Firstly, we just used 4 inputs and 1 output in our DEA model to measure the operational efficiency of the container ports. This is a very restrictive model and it is therefore required to conduct various studies for models with various inputs and outputs. Secondly, although we just conducted the cross-sectional analysis in this study because of the limitation of data, it is also required to perform DEA/Window analysis with time-series data in order to see how the efficiency for container ports will change in the future periods of time.

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