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Efficiency of the 26 major container ports in 2015: comparative analysis with different models

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Abstract

This paper estimates and compares the technical efficiency of the container ports using data envelopment analysis (DEA) and stochastic frontier analysis (SFA) models and check the role of the characteristics of infrastructure on container port efficiency. The comparisons are based on cross-sectional data for 26 world's major container ports in 2015 using an input variables related to the characteristics of port infrastructure, such as: the total quay length (meter), the maximum alongside depth (meter), the total terminal area (square meter) and the storage capacity (thousand TEU/year). The DEA-BCC results show that 16 container ports have more than 0.5 score efficiency while with the SFA models all container ports achieved score efficiency more than 0.5.

Keywords: Technical efficiency; DEA; SFA; world's major container ports.

1. Introduction

Container ports efficiency is an imperative indicator for competitiveness and growth. The emergent international sea traffic and shifting technology in the maritime transport industry are obliged to provide progressive technology. They are being forced to improve port efficiency to provide comparative advantages that will attract more traffic. Thus, the global container transportation system has developing rapidly since its inauguration in the 1960s, this being due to the continued increase in the size of container ships, the automation in cargo handling systems and the continued specialization of container terminals [1].

According to Cullinane et al. [2] containerization has stimulated shipping services globalization through the emergence of alliances and acquisitions in the liner industry. In the literature of transport studies, there are two intentions to study economic performance: gross measures of productivity and shift measures of technical change [3]. This study is established to evaluate the technical efficiency of the major container port in 2015. It is expected to realize the DEA-CCR, DEA-BCC, half normal and truncated normal distribution for the SFA with cross-sectional data. It is required to analyze the extent to which the results are sensitive to the specification of the production function and to the estimation method used (DEA and SFA).

The background of this study is to estimate the technical efficiency of the world's major container port. According to the estimation, we try to answer the following questions: are the characteristics of the infrastructure influencing the efficiency of the container port? Does the number of the throughput produced is the most important in the case of the container port, i.e. what is the most important the quality of the infrastructure or the number of the throughput produced in the efficiency of the container port? Another contribution of this study is to specify where the most efficient container ports are located? Do the different models (DEA; SFA) produce similar efficiency rankings of container ports?

To answer all these questions, this paper is structured as follow: section 2 educates the survey literature concerning international container ports efficiency. Section 3, represents

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the methodology and results. Section 4, represents the conclusion.

2. Literature review

Schøyen and Odeck [4] concluded that the DEA approach is more popular than SFA. Then, it has been used more recently in applications across studies and dominates the literature. Most of the previous studies accept container throughput (TEUs) as the output variable of efficiency measurement. The most inputs used are physical variables. Even so, the variations in crane and handling technology are apprehended in diverse literature according to Bichou [5].

The study of the container ports is related to the international geographical location. The sample with international ports is more significant. However, the samples are usually chosen among the top container ports by throughput (TEUs). The focusing on these kinds of samples, founded that is composed of the huge container ports. These views are expressed by several studies such as [6] and [7].

The majority of the literatures studies are regional for example the studies [8], [9], [10], [11], [12], [13], [14] and [15] takes the case of Asian container ports and specially china ports which prove that the interesting container port are located in the Asian country and china ports occupied the first rank after 2010. A number of studies in container ports educate the European container ports case as the studies [5], [16] and [10].

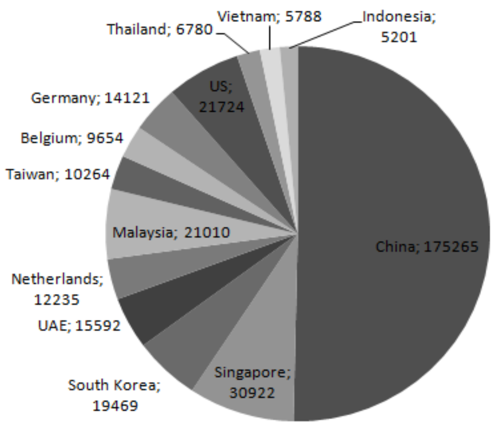
The analysis of researchers showed also a various result. For instance, the studies [8], [10] and [14] used DEA models with cross-sectional data, they found a small average efficiency less than 0.5 in some cases. Furthermore, the studies [4], [13] and [15] used panel data and found an average efficiency more than 0.8, which demonstrate the important effect of the type data for improving efficiency measurement.

3. Methodology and results

The measurement of container ports efficiency used data envelopment analysis (DEA) and stochastic frontier analysis (SFA) models. The output variable selected is the number of containers in TEUs. The selected input variables are the total quay length (meter), the maximum alongside depth (meter), the total terminal area (square meter) and the storage capacity (thousand TEU/ year). These variables are selected according to the available data for the various container ports.

The sample comprises the major 26 container ports in 2015 according to the containers traffics measured in TEUs. The data of the throughput are collected from the Lloyd's Ports of the World (2016), for the other variables the data are collected according to the annual statistics report of container port (2015), the annual statistical of the China Ports Association (2015) and the various official websites of container ports. Figure 1 describes the division of throughput.

Fig 1 division of the throughput (TEUs, 000) in 2015 between the countries



According to the figures 4 the distribution of throughput (TEUs, 000) containers varies between countries and regions. The region of Asia, especially the China countries, handled the most number on containers in 2015.

The results achieved according to the Ordinary Least Square (OLS) and the maximum likelihood

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(MLE) estimates of the parameters production function were obtained from the software frontier 4.1. Table 1 shows that the maximum-likelihood estimate of the parameter of the total quay length input are -0.278 and -0.282 for the half vs. truncated normal distributions respectively. The coefficient of the total quay length was found to be insignificant similarly in the two distributions. The coefficients of the variables maximum alongside depth, total terminal area and the total container storage capacity are observed as significant in the two cases. Thus, the container ports production is affected by the different factors.

For both the half-normal and the truncated-normal distribution, $\gamma=\sigma_U^2/(\sigma_V^2+\sigma_U^2)$ is estimated at 0.406 and 0.50 levels, respectively, that is mean 40.6 percent of random variations in the half normal distribution in container port production are due to the inefficiency. Also, 50 percent of random variations in the truncated normal distribution in container ports production are owed to the inefficiency. The estimates of σ^2 amount of 0.192 and 0.194 for half vs. truncated normal distributions respectively. They are significant in the both cases of half vs. truncated normal distributions.

The estimate of the η (named (Mu) in the table 3) parameter is found negative (i.e. η= -0.321). The parameter η is negative, demonstrating that the distribution of the inefficiency effects is concerted in the order of zero, as compared with half-normal distribution.

The values of the log likelihood function for the two distribution production functions are 0.166 and 0.165, respectively as table 1 present. There is a little difference between the two results not exceed 0.001.

Table 1 The OLS and the MLE of the Stochastic Frontier Function.

Variables/ parametres	*OLS*	*MLE*	
		half normal	*Truncated normal*
Constant	-0.212 (-0.265)	-0.179 (-0.283)	-0.208 (-0.636)
X_1	-0.280 (-0.121)	-0.278 (-0.123)	-0.282 (-0.435)
X_2	0.158 (0.674)	0.156 (0.895)	0.157 (0.606)
X_3	0.566 (0.168)	0.563 (0.184)	0.567 (0.634)
X_4	0.167 (0.425)	0.165 (0.487)	0.166 (0.392)
(σ^2)	0.236	0.192	0.194
Gamma (γ)		0.406	0.500
Mu		0	-0.321
Eta		0	0
log likelihood		0.166	0.165

Note: y= throughput (TEU, 000s); x_1= total quay length (meter); x_2= maximum alongside depth (meter); x_3= total terminal area (square meter); x_4= storage capacity (thousand TEU, 000s/year); t-ratios: are shown in parentheses;

The largest value DEA vs. SFA of mean efficiency is 0.616 and 0.876 respectively, which found a difference around to 0.26. In the same previous studies (Lie and Lih, 2005) found a value approximate to 0.766 for the DEA and 0.934 for the SFA in 2002 for 27 international container ports. Cullinane et al. [16] found a value of mean efficiency rough to 0.783 for the DEA and to 0.790 for the SFA for 57 top container ports which 30 ranked the top in 2001. In addition, the height value is 0.866 founded by [18] according to a Cobb-Douglas production function. The depth value efficiency is 0.484 estimated by Munisamy and Singh [8] with DEA model. The results of the studies of Infante and Gutierrez [11], Ding et al., [13] founded a great difference between the DEA-BCC and DEA-CCR models more than 0.3.

The truncated distribution of the term error is able to improve container ports efficiency. Correspondingly, Almawsheki and Muhammad [14] concluded that among the 19 container terminals studies only 3 terminals such as Jebel Ali, Salalah and Beirut are efficient, the others

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terminals are inefficient. Besides, Niavis and Tsekeris [10] studied 30 seaports in South-Eastern Europe they founded a value around to 0.66 with the DEA-BCC and to 0.61 with scale efficiency scores.

Table 2. Efficiency estimates obtained from the DEA and the SFA.

SFA					
Ports	*CCR*	*BCC*	*scale*	*Half normal*	*Truncated normal*
Shanghai	1.000	1.000	1.000	0.998	0.999
Singapore	0.461	1.000	0.461	0.995	0.996
Shenzhen	1.000	1.000	1.000	0.998	0.999
Ningbo	0.227	0.233	0.976	0.980	0.984
Hong kong	0.219	1.000	0.219	0.886	0.889
Busan	0.132	0.247	0.534	0.870	0.873
Guangzhou	0.128	0.189	0.677	0.920	0.924
Qingdao	0.125	0.159	0.782	0.955	0.957
Dubai	0.084	0.196	0.430	0.883	0.885
Tianjin	0.142	0.540	0.263	0.803	0.806
Rotterdam	0.397	1.000	0.397	0.882	0.887
Port klang	0.234	1.000	0.234	0.778	0.783
Kaohsiung	0.276	0.632	0.436	0.761	0.762
Antwerp	0.200	0.268	0.745	0.975	0.978
Dalian	0.395	0.483	0.818	0.990	0.991
Xiamen	0.524	0.701	0.748	0.894	0.897
Tanjung pelepas	0.064	0.079	0.807	0.897	0.900
Hamburg	0.416	1.000	0.416	0.856	0.864
Los angeles	0.142	0.363	0.392	0.763	0.769
Long beach	0.395	0.558	0.707	0.851	0.857
Leam chabang	0.217	0.735	0.295	0.866	0.887
New york	0.126	0.242	0.521	0.854	0.863
Yingkou	0.263	0.546	0.481	0.759	0.767
Ho chi minh	0.636	1.000	0.636	0.763	0.765
Bremen	0.324	0.838	0.387	0.756	0.758
Tanjung	0.331	1.000	0.331	0.718	0.722
Mean	0.325	0.616	0.565	0.871	0.876

Comparing across models, the truncated normal-SFA and DEA-BCC achieved the highest value efficiency. Shanghai is the largest container port in the worldwide, handling around 36.537 million TEUs in 2015. It was the most efficient container ports in this research accompanied with Singapore, Shenzhen, Ningbo and Dalian. These five container ports achieved scale efficiency more than 0.8 with DEA models and height value with the SFA models more than 0.9. Moreover, as it is seen these best four ports are china container ports.

To compare the results with similar application in the literature, it found that the study of Cullinane and Wang [7] reveal that the two container ports of Keelung and Colombo were found to be highly efficient during the whole study period (1992-1999). This contrasts with the results for world container ports such as Rotterdam, Hamburg and Antwerp that have a large container throughput and face strong competition from other ports. The results of Munisamy and Singh [8] reveal that the Chinese container ports are efficient, these ports are Xiamen, Yantian, Lianyungang, Tianjin and Guangzhou. The same authors conclude that China follows the global trend in engaged liner services at ports.

The study of Wang and Cullinane [18] show that Rotterdam, Hamburg, Antwerp, Bremen/Bremerhaven, Los Angeles and Long Beach are classed as the most competitive ports. They demonstrated that the ports of Rotterdam, Hamburg and Antwerp have invested actively in port facilities and infrastructure in order to increase the capacity and improve the productivity of their container handling capability.

The analysis of the study of Lie and Lih [19] shows that among the 27 ports, operating efficiency scores of Hong Kong is the highest. Their study shows the distinction of performance with different models. Hyun et al. [20] found that the ports of Shanghai, Hong Kong and Qingdao revealed to be the most efficient from 21 Asian container ports acceding to the data of 2011.

The container ports are more efficient in 2015, this study found the best mean efficiency (0.876) still 2015, which prove that the container ports improve their infrastructure. The competitiveness

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of these ports is highly relevant for increasing the investments in infrastructure characteristics, which makes them dependent on the quality and efficiency of their hinterland connections.

The stochastic models show that the sample of container ports selected has relatively access to transport infrastructure, which makes it's the competitive container ports in the world. The prioritization of expanding the existing infrastructure and starting new construction projects leading to an efficient container port. Subsequently, the comparisons of this research with the last researches demonstrate the difference in results.

In addition, many large container ports in Asia are independently operated under the control of a single port authority. For example, many container terminals in Shanghai are operated by themselves respectively under the control of Shanghai International Port Group (SIPG). Similarly, there are several container terminals in Busan port operated by themselves separately under the control of Busan Port Authority (BPA). Which improve their efficiency and maximize handling throughput.

4. Conclusion

This paper studied the technical efficiency of the major container ports using the DEA and SFA models. Moreover, examined the comparability between container ports ranking efficiencies and it compares also with the results of literature studies. The models are estimated with the error components model specification. As well, the results indicated that the input variables included in the technical efficiency effects have a significant influence on container ports production. In addition, the average of efficiency scores of SFA model with truncated normal distribution is the highest which, equal to 0.876. Thus, with the DEA-BCC and DAE-CCR models achieved a mean efficiency is equal to 0.616, 0.325, respectively. It is found that the total average scores SFA method is better than the DEA method in measuring container ports efficiency. The DEA and SFA application explain the technical efficiency and identify if the variables characterized the port infrastructure have an effect on the handling of the containers. The comparison founded that the port of Shanghai, Singapore, Shenzhen, Ningbo and Dalian are the most efficient container ports, according to the four models used for evaluation, which explain the best infrastructure of these container ports with a great number of containers.

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