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Relative Efficiencies of ASEAN Container Ports based on Data Envelopment Analysis

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ABSTRACT

Ports play a critical role in the economies of many countries in the ASEAN region. Efficient ports facilitate a country's imports and exports, and the "relative efficiency" of a port is evaluated based on its efficiency compared to others in its group. This study analyzes the relative efficiencies of 50 ASEAN container ports and terminals. These ports are categorized according to their container handling system and location (those located in a riverbank connected to the sea are called "inland seaports" and those by the seaside are called "seaports"). The traditional output-oriented data envelopment analysis method is applied, and measures of super-efficiency constant returns to scale are estimated in order to compare the units situated on the efficiency frontier. The findings may support port managers in the ASEAN region to make decisions on whether to increase container traffic. In addition, policymakers may consider the evaluation results in deciding whether to improve the trans-ASEAN transport network and ASEAN trade competitiveness.

1. Introduction

Ports' efficiency has become increasingly important topic. As connecting links between different transport modes in the global logistics chain, container terminals are vital to the efficiency of the whole chain. Beyond its pivotal role in the global trade network, the efficiency of container ports and terminals is also a key issue for operators due to intensifying port and terminal competition worldwide.

Because of their position in the logistics chain, the level of port efficiency greatly affects a country's productivity and competitiveness (Wu and Goh, 2010). Port markets used to be perceived as monopolistic due to the exclusive and immovable geographic locations of the ports and the unavoidable concentration of port traffic. However, the rapid development of international container and intermodal transportation has drastically changed the market structure from that of a monopoly to that of fierce competition in many parts of the world (Cullinane and Wang, 2007). Along with these trends, the economy is becoming more regional (Rex el al., 2015; UNCTAD, 2015). A recent example is the establishment of the ASEAN Economic Community (AEC) in 2015. The AEC offers opportunities in the form of a market of US$2.6 trillion and over 622 million people. As of 2014, the AEC was collectively the third largest economy in Asia and the seventh largest in the world and accounted for 14% of world container throughput. As ASEAN has designated 47 main ports in the trans-ASEAN transport network, these ports face a number of challenges in providing more efficient shipping network services given the varying levels of port infrastructure development (ASEAN, 2011).

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Thus, it is necessary to analyze the efficiency and productivity of these ports in order to pursue the realization of the ASEAN Single Shipping Market (ASSM).

This study evaluates the relative efficiency of 50 ASEAN container ports and terminals. The objective of the research is to highlight the most efficient ports in the sample according to their type (inland or sea) and their container yard equipment. Such categorization is necessary because, to apply the data envelopment analysis (DEA) method, we need to compare homogenous units. The traditional DEA output-oriented models are applied to determine the target values of the outputs for each port. The important contributions of this study include providing a benchmarking analysis based on the DEA method and assisting decision makers in their ports' development operations and the improvement of the trans-ASEAN transport network

2. Literature Review

Production optimization has been analyzed by many researchers. Debreu (1951) establishes the first measure of productive efficiency with his concept of the coefficient of resource utilization. Farrell (1957) proposes a similar method of measuring efficiency by including multiple inputs and outputs. The so-called input-based Farrell efficiency can be defined as the maximum proportional contraction of all inputs that allows the production of the same amount of output. In the opposite case, the output-oriented Farrell efficiency measures the proportional expansion of all outputs with a given amount of inputs. There are two types of efficiency: allocative (cost) and technical. The former represents the optimal combination of inputs and outputs under the assumption that the producer wants to minimize costs, whereas the latter is associated with the effectiveness with which a given set of inputs is used to produce an output. The main drawback of the Farrell efficiency is the attribution of weights to the inputs and outputs. To overcome this problem, Charnes, Cooper, and Rhodes (CCR) (1978) define an optimization method based on mathematical programming. They created the DEA method with constant returns to scale (CRS), or the so-called DEA-CCR. This method allows the measurement of the relative efficiency of decision-making units (DMUs) without attributing any predetermined weights or conducting any time series analyses. This method is extended by Banker, Charnes, and Cooper (BCC) (1984) to include variable returns to scale (VRS) and is also known as DEA-BCC. Since then, the DEA method has been extended in multiple ways, incorporating, for example, dummy or categorical variables, discretionary and non-discretionary variables, nonparametric Malmquist indices, etc. This study applies the traditional DEA method to determine the most efficient ports in the ASEAN region. As DEA is suited for the comparison of homogenous units such as container ports, a common feature of port benchmarking studies is the use of operational data due to the difficulty of obtaining a port's costs and prices (Bichou, 2013). Thus, this study focuses on technical efficiency measurements.

Table 1 provides an overview of DEA use in the literature to evaluate the relative efficiencies of container terminals and ports. In this list, the sample size generally varies between 10 and 70 DMUs, and Bichou (2013) is the only study that analyzes a considerable number of terminals, i.e., 420. The most commonly applied DEA methods are the traditional ones, DEA-CCR and DEA-BCC. In the literature, the selected inputs are usually the terminal area, the quay length, the number of container berths, the number of quay cranes, and the number of employees. In order to compare homogenous units using similar technologies, some authors include other specific indicators regarding the port's infrastructure, such as the number of tugs, the number of straddle carriers, the number of reach stackers, etc. The most suitable indicator to evaluate the ports' production is the annual container throughput in TEUs, as the main purpose of any container terminal is to handle as many containers as possible. Another potential output indicator is the number of ship calls. Two studies use non-conventional indicators as inputs or outputs. Hai-bo and He-zhong (2009) evaluate the allocative efficiencies of 13 port companies in China by taking into account net permanent assets and total employees as production factors and the main business revenues as output. The study conducted by Guimaraes et al. (2014) evaluates the environmental performances of 15 Brazilian container terminals using total energy consumption, the consumption of non-renewable energy, sewage emissions, office supply consumption, CO_2 emissions, and water consumption as inputs and container throughput as an output.

By using DEA-BCC, DEA-CCR, and panel data, the empirical results of Bichou (2013) show that most of the container terminals clearly utilize a VRS production technology. Similarly, Hung et al. (2010) conclude that the overall technical inefficiencies of Asian container ports are primarily due to pure technical inefficiencies rather than scale inefficiencies. Only 26% of Asian container ports are regarded as efficient. This result also suggests that port managers should focus first on improving their management practices to meet the market requirements of container ports, and then container ports can be subject to improvements in their scale efficiencies. Cullinane and Wang (2007) conduct a rather arbitrary dichotomous classification of the sample between large and small ports on the basis of a cut-off throughput of 1 million TEUs per annum. Their findings suggest an association between large ports and decreasing returns to scale and between small ports and increasing returns to scale. In Tongzon (2001), the underutilization of labor is highlighted as a primary source of inefficiency for 11 of 12 ports in the sample. Wanke (2013) shows, based on a two-stage network DEA model to calculate the physical infrastructure and shipment consolidation efficiency levels, that just 7 out of 27 (25.9%) ports achieved 100% efficiency in the first stage of physical infrastructure efficiency. The results of DEA-CCR for 19 container terminals in the Middle East show that 84.21% of the terminals are inefficient (Almawsheki and Shah, 2014). Li, Luan and Pian (2013) assess the efficiency of coastal container terminals in China via a three-stage DEA model. The overall coastal container terminal efficiency is relatively low because of scale inefficiency, and there is a vast regional difference in terminal efficiency across different port groups. In addition, there is serious input excess in coastal container terminals in China of approximately 35%. Finally, in the assessment of terminal efficiency, the environment and statistical noise both affect the efficiency value (Li, Luan and Pian, 2013).

The main conclusions of the literature review are as follows: a) there is a need to find appropriate criteria to categorize container terminals; b) the sample sizes in these studies range from 11 to 420 container terminals; c) the output most commonly used by researchers is the annual container throughput; d) for a small sample with homogenous ports, it is appropriate to apply only DEA-CCR; and e) for a larger sample with ports of different sizes, both DEA-CCR and DEA-BCC should be applied.