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應用 DEA/AR 模式評估港埠經營效率之研究－以基隆、臺中及高雄三港為例：評論意見

APPLYING THE DEA/AR MODEL TO EVALUATION OF THE OPERATIONAL EFFICIENCY OF PORTS－ AN EMPIRICAL STUDY OF KEELUNG, TAICHUNG, AND KAOHSIUNG PORTS: A COMMENT

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摘　要

應用資料包絡分析法於評估廠商之績效時，有若干細節應特別留意，本文對於林彬等人 (2006) 發表於本刊第 35 卷第 4 期頁 391-414 的文章提供若干評論意見，按該文中作者應用資料包絡分析法與限定權重範圍模式以評估臺灣三個主要港埠的經營效率，本文指出該文在變數選取、規模效率衡量、視窗分析及文獻回顧等方面的若干缺失，期盼能使資料包絡分析法之應用更為洽當及更為清晰。

關鍵詞：資料包絡分析法 (DEA)；限定權重範圍 (AR)；港埠效率

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ABSTRACT

This paper provides critical remarks and remedies to a recent article published in this Journal, volume 35, number 4, page 391-414, by Lin, Yu and Yang (2006). In their article, the authors employed the data envelopment analysis (DEA) and assurance region (AR) approaches to investigate the operational efficiency for three major ports in Taiwan. The present paper points out the faults or errors found in their article in terms of variable selection, scale efficiency measurement, window analysis, and some erroneous statements in literature reviews. It is hoped that this will make more appropriate and much clearer the DEA applications to port's performance evaluation.

Key Words: *Data envelopment analysis (DEA), Assurance region (AR), Port efficiency*

1. INTRODUCTION

In a recent article, Lin, Yu and Yang [1] (hereafter LYY) employed the data envelopment analysis (DEA) and assurance region (AR) models to investigate the operational efficiency of three major ports in Taiwan. Since it was originally developed by Charnes, Cooper and Rhodes [2] (CCR) and succeeded by Banker, Charnes and Cooper [3] (BCC), DEA approach and its modified models have been successfully applied to the relative efficiency evaluation throughout different industries, including private and public sectors. The previous studies measured the relative efficiency of port's operation usually only by using DEA models. It is the first time to see the application of both DEA and AR models to efficiency measurement for the ports in Taiwan. Therefore, one of the contributions of LYY's [1] paper is that it enhanced the practicability of DEA.

However, due perhaps to misunderstanding of characteristics of port industry, some problems have appeared in their article. The present paper will systematically point out the faults or errors found in their article, in terms of variable selection, scale efficiency measurement, usage of window analysis, and some erroneous statements in literature reviews. It is hoped to make more appropriate and much clearer in the application of DEA to port's performance evaluation.

2. COMMENTS

2.1 Variable Selection

In their article, LYY [1] applied the DEA/AR models to investigate the operational efficiency of three major ports in Taiwan. Four input variables have been used in the evaluation: (1) number of employee of port authority, (2) expenditure, (3) total tonnage of tug ship, and (4) the length of berth. To account for output measures, they selected total revenue (TR), total tonnage of incoming ships (TIS), and total tonnage of commodities handled (TCH) by port as three variables. However, at least two problems arise in the aspect of variable selection.

When conducting an efficiency measurement, the first and most important step is to determine the input and output variables to be included in analysis. In this stage special attention should be given as impertinent selection of variables could reduce the distinction between the compared decision making units (DMUs) and lead into biased results. On the one hand, a DMU converts the resources to produce outputs, as such all the inputs and outputs should be included in the analysis (Boussofiane *et al*. [4]). On the other hand, some variables may be repeating virtually the same or similar information, and some others may not be regarded as crucial. Introduction of too many (especially, the redundant) variables oftentimes tend to shift the compared DMUs toward the efficiency frontier, resulting in a relatively large number of DMUs with high efficiency scores (Golany and Roll [5]). Thus, before conducting the DEA-based analyses, one needs to check and select variables very carefully.

In the port operation context, since there are essentially two categories of port services, namely marine and terminal services, the total revenue (TR) generally comes from marine services rendered to incoming ships and cargo (including break-bulk commodities and containers) handling services. The former depends strongly upon the charge rates and the gross register tonnage of incoming ships, while the latter is highly correlated with the charge rates and the total cargo and number of containers handled by port (TCH). Thus, one would reasonably suspect that the results evaluated by LYY [1] could be biased due to following two standpoints. First of all, choosing TR, TIS and TCH as the output variables simultaneously in the analysis would be redundant since TR is indeed repeating virtually the same information as TIS and TCH. The problem led by redundant selection is same as choosing total revenue and number of hamburgers sold as two output variables in measuring efficiency for fast food restaurants. Moreover, since the adjustment of port charge rates, exchange rate between different currencies, negotiation terms, could be the affecting factors of the total revenue, but not necessarily efficiency. As Sherman [6] pointed out that profit (as well as revenue) measure was not a good indicator of how efficiently resources were used to provide customer services.

Secondly, the terminal services in the ports of Keelung, Taichung and Kaohsiung in fact consists of break-bulk commodities and containers. Taking Keelung port as an example, it handled bulk commodities and containers by 88,911 thousand tons and 1,918,597 TEUs in Year 2002 [7], respectively. In their case study, however, LYY [1] focused only on the handling of bulk commodities (88,911 thousand tons, see Table 5 in page 403 in LYY’s article), while the other important throughput, number of containers handled (in terms of TEU) is neglected. Thus, it suggests that the selection of output variables may be problematic since one important output variable is missing in their analysis.

Similar problem exhibited due to choosing the total expenditure and number of employee as two input variables in their analysis. In Taiwan, ports are operated by government and each port authority has to report its annual financial statements to Ministry of Transportation and Communications (MOTC). In ports' financial statements, the total expenditure generally contains the item of wages, thus it would be double counted or redundant selected if one chooses the total expenditure and number of employees as two input variables. Moreover, since a large amount of expenditure may come from capital investment in facilities construction (such as berth) and equipment procurement (such as gantry, crane, and tugs), therefore, choosing expenditure, number of tugs, and length of berth as input factors simultaneously in the analysis could be one of source of problem. Again, it is suspected that the results might be significantly biased since the impertinent input variable is used in the analysis. In addition, since the true value of currency differs from year to year, the most important thing is to discount the revenue and expenditure to the common bases (base year) when using them as input and output measures. Without discounting, the results will be seriously biased since the revenue and expenditure in any year cannot be compared directly with the same measures in the other year.

The scientific definitions of input and output variables are critical to the application of DEA. The specification of erroneous or ill-defined variables inevitably leads to the wrong conclusions emerging (Cullinane and Wang [8]). The selection of input and output variables should reflect the actual objectives and process of port production as accurately as possible (Norman and Stoker [9]). Basically, the ports analyzed in LYY [1] share the common objective of increasing outputs. It is thus suggested to choose the number of containers handled and total tonnage of commodities handled as two output variables in the analysis since the two outputs form the basis for the revenue generation of a port. As for input variables, based on the comment discussed above, the expenditure should be excluded from the input variable set. In addition, the speed of movement of cargoes and containers between ship and shore crucially decides the efficiency of a port. This movement relies heavily upon such equipments as gantry and crane. Thus the number of gantry will be an important input variable in port efficiency evaluation. To sum up, it is thus suggested to select number of employee, total tonnage of tug ship, number of gantry, and the length of berth as input variables.

2.2 Scale Efficiency

LYY [1] adopted CCR/AR-I and BCC/AR-I to evaluate the technical efficiency (TE) and pure technical efficiency (PTE) for three ports in Taiwan, respectively. Then, they further measured scale efficiency by using the ratio of TE to PTE. In fact, one can easily calculate the scale efficiency simply by the quotient of TE to PTE since the derivation has been done by Banker [10]. It should be noted that, however, the relationship between CCR and BCC models (that is, scale efficiency) is no longer guaranteed when the different weight restrictions are introduced into the so-called CCR/AR-I and BCC/AR-I models. In other words, without any proof, the scale efficiency measured by simply dividing TE by PTE could be problematic, since the weights are restricted in DEA/AR models. As Tone [11] showed that, by the addition of weight restriction, the status of returns to scale may suffer a change.

2.3 Window Analysis

The window analysis, firstly proposed by Charnes *et al.* [12], enables us to assess the performance of a DMU over time by treating it as a different entity in each time period. However, special attention should be paid when adopting window analysis method to measuring the performance over time, since one of basic assumption implied in DEA method is that each DMU produces outputs by using inputs and applying common technology (frontier). Relative shorter period (usually one to three years) allows us to assume that there has been no technological change in the period considered. If this assumption was not implied, one cannot pool all observed data in one model. This could be one of reasons of using monthly data in Charnes et al. [12], who assessed the performance of maintenance units in the U.S. air forces by taking data of three months in each window. In their window analysis, however, LYY [1] pooled the data of six years in a DEA/AR model. This could be the source of problem, since without any evidence or hypothesis testing, one would reasonably suspect that there may unavoidably have significant technological change (frontier shift) in port operation in each of these periods of six years (1995 ~ 2000, 1996 ~ 2001, and 1997 ~ 2002).

2.4 Some Erroneous Statements

To avoid misleading, one should be very carefully in reviewing literatures. In the Subsection 2.1 of their article, LYY [1] reviewed some previous studies and stated that Farrell [13] firstly proposed to use production frontier for measuring technical efficiency and price efficiency under the assumption of single output and then constructed the basic theory of efficiency measurement by using mathematical programming model (line 3 from bottom, page 394). In fact, to find out the production frontier and then measure the efficiency for an observed point (*i.e*. DMU), Farrell [13] proposed to solve a system of algebraic equations, rather than programming technique. Similar problem exhibited in the Subsection 2.2, in their article, LYY [1] stated that "Thompson *et al.* [14] used AHP method to find out the upper and lower bounds of weights, and then analyzed efficiency of bank in Japan" (line 1, page 397). There are, however, at least two errors in this statement. Firstly, Thompson *et al*. [14] investigated the bounds of weights by setting restrictions on the rations of the shadow prices, rather than by AHP method. Secondly, Thompson *et al*. [14] indeed utilized DEA/AR model to analyze the comparative site evaluations for locating a high-energy physics lab in Texas, rather than to analyze banking efficiency of Japan.

As for the methods for establishing bounds of weights, LYY [1] stated that there are two methods can be used to determine the bounds of weights. It should be noted that, however, at least five methods have been developed to aid the estimation of such bounds, for more detail, refer to Cooper *et al*. [15]

3. SUMMARY

In their application of DEA/AR approaches to measuring the operational efficiency of three ports in Taiwan, LYY [1] have presented a battery of faults relating to variable selection, scale efficiency measurement, usage of window analysis, and literature reviews. The current paper attempts to shed some light upon the application of DEA/AR to the ports performance measurement. The major contribution of this commentary paper is to critique the problematic points appeared in LYY's [1] paper and to propose correct means to remedy; thus, it can make the application of DEA more accurate and much clearer. Besides, the systematic reporting of such problems would be a significant aid to the improvement of DEA practice in the port industry.

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