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A Trend Analysis on Scale Efficiency of the Port of Gwangyang: 1994-2004*

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목 차

Key Words : The Port of Gwangyang, Scale efficiency, Trend analysis, DEA, CCR, BCC, Malmquist

Abstract

The purpose of this paper is to analyze the trend on scale efficiency of the Port of Gwangyang from 1994 to 2004 using CCR, BCC, and Malmquist index approaches. The main results are as follows. First, scale efficiency shows a 50% similar[5(94/95, 95/96, 97/98, 2001/2002, 2003/2004) out of 10] pattern to technical efficiency change. Second, total factor productivity increased at 48.57% rate of growth on average in 6 out of 10 periods except 96/97, 97/98, 99/2000, and 2000/2001. 2003/2004 period is the one period experiencing rapid total factor productivity changes, mainly due to technical progress. Third, the ranking order of accumulative indices is scale efficiency change, TFP change, efficiency change, technical change, and pure efficiency change. The main policy implication of this paper is that according to the CCR, BCC, and Malmquist results, the Port of Gwangyang should develop the plan for enhancing the 5 Malmquist indices with following the management way of benchmarking ports.

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I. Introduction

After opening in July 1998, the Port of Gwangyang has set up a development plan consisting of three stages spanning to 2011. After completing it, container terminals in the Port of Gwangyang will come to a total of 33 berths capable of handling 9,330,000 TEU per annum and it will then rank top 10th container port in the world.1)

However, these days, because of the rapid development of Chinese ports and opening the Busan New Port, the Port of Gwangyang is seriously challenged.

In evaluating the performance and efficiency of a marine terminal, it is a common practice to compare its actual throughputs with its optimum throughputs, where throughputs may be measured as the tonnage or number of cargoes and containers handled by the terminal for a specified time period. Thus whether the performance of the terminal is evaluated to be good or poor will depend upon the determined optimum throughput.2)

In order to support trade oriented economic development, port authorities have increasingly been under pressure to improve port efficiency by ensuring that port services be provided on an internationally competitive basis. Ports form a vital link in the overall trading chain and, consequently, port efficiency is an important contributor to a nation's international competitiveness. Thus monitoring and comparing one's port with others in terms of overall efficiency has become an essential part of many countries' microeconomic reform programmes.3)

When we measure the efficiency of seaport, scale efficiency under returns to scale4) becomes very important, because scale efficiency can measure the exact situation of seaport more correctly.5) Scale efficiency under RTS(return to scale) approaches is not

1) S. W. Lee(2006), "Competition among Hub Ports and the Strategy for Co-opetition of Gwangyang Port," *Proceedings of the 4th International Conference Gwanyang Forum*, The Korean Association of Shipping and Logistics, April 19-21, p.43.

2) W.K. Talley(1988), " Optimum Throughput and Performance Evaluation of Marine Terminals," *Maritime Policy and Management*, Vol.15, No.4, p.327.

3) J. Tongzon(2001), " Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis," *Transportation Research Part A*, Vol.35, pp.113-114.

4) The returns to scale(RTS) is defined as the ratio of the maximum proportional expansion of outputs to a given proportional expansion of inputs. RTS is increasing, constant, or decreasing depending upon whether output increases by that same amount(constant), by less than that amount(decreasing)and by more than that amount(increasing).(Tone and Sahoo, 2005, p.264).

5) Scale efficiency relates to a possible divergence between actual and ideal production size which coincides with the long-run competitive equilibrium under CRTS. A scale-efficient producer will choose the input and output combination which will be on the production or cost frontier.(T.F. Wang, K. Cullinane, and D.W. Song, *Container Port Production and Economic*

new but very useful for measuring the performance and efficiency of seaports in a competitive environment, because scale efficiency under RTS and relative rankings are a powerful management tool for port operators and should be a s starting point for regional and national studies of seaport operations.

The purpose of this paper is to investigate the trend of scale efficiency of Port of Gwangyang using DEA(Data Envelopment Analysis) and Malmquist methods for 11 years(1994-2004) and is to make policy implications to enhance the efficiency of the port of Gwangyang. The main reason to measure the trend of scale efficiency by using DEA and Malmquist methods which can show the relative efficiency change compared to the other ports is to verify whether current extension investment programs for the Port of Gwangyang by Korean government are producing the expected results in terms of the dynamic trend efficiency. The empirical results relating to scale efficiency can also be useful to the authority of Gwangyang Port that they can detect the problems preventing this port from achieving full efficiency in terms of inputs and outputs elements. In addition, no study deals with this topic in Korea by using DEA and Malmquist methods.

The paper is organized as follows. Secton II presents the survey of previous studies briefly according to the scholars. Section III proposes a basic concept of CCR, BCC and Malmquist DEA methods and produces the result of empirical analysis. Section IV concludes with the brief summary of this paper.

II. Survey of Previous Studies

Previous studies, using DEA for measuring efficiency of seaport for productivity and efficiency of seaports, have been widely published during the recent 10 years. Roll and Hayuth(1993), Tongzon(2001), Valentine and Gray(2002), Cullinane, Song, and Gray(2002), Wang, Cullinane, and Song(2005) have examined the productivity of container ports. In Korea, Oh and Park (2001), Han(2002) presented the meaurement of productivity with international competition power. Roll and Hayuth(1993), Tongzon(2001) and Valentine and Gray(2002) used DEA methods for measuring the efficiency and productivity of Australian and other international ports. Recently, as the most comprehensive analysis, Wang, Cullinane and Song(2005) shows an applicability of the several DEA models[basic DEA, FDH(free disposal hull), Window, alternative

Efficiency, Palgrave Macmillan, 2005, p.5).

DEAs] and stochastic frontier approaches to the measurement of container port efficiency by using cross-sectional and panel data. A summary of previous studies is shown in <Table 1>.

<Table 1> Summary of Previous Studies

Classification \ Scholar	Roll and Hyuth(1993)	Tongzon(2001)	Oh and Park (2001)
Analyzed Country	Israel	World	World, East-North Asia
Analyzed Ports	20 Hypothetical Ports	World Container Port	28 Container Ports
No. of Sample	20	16	28
Analyzed Model	DEA Model: CCR model Outputs: cargo throughput, level of service, user's satisfaction, ship calls Inputs: manpower, capital, cargo uniformity	DEA Model: CCR and Additive DEA Model Outputs:Cargo Throughput, Ship Working rate Inputs: No. of crane, No. of container berth , No. of tugs Terminal area, Delaytime, Labor	DEA Model: CCR and BCC 1. Inputs:Length of berth, No. of G/C, CY Area ,CFS Area 2. Outputs: Total Cargo handled, Port Fees

Classification \ Scholar	Valentine and Gray(2002)	Cullinane, Song, and Gray(2002)	Han(2002)
Analyzed Country	Europe and East-North Asia	Asia	Asia
Analyzed Ports	12 ports in Europe and East-North Asia Area	15 container ports in Asia	25 Asian ports
No. of Sample	12	15	38
Analyzed Model	A. Cluster Anlaysis 1.organisational structure 2. ownership B. DEA Analysis 1. Inputs: No. of Containers, Total length of berth, Container berth length 2. Outputs: Total tons throughput	Stochastic Frontier Model 1. inputs: terminal quay length, terminal area, number of cargo handling equipment 2. outputs: container throughput in TEUs	log-linear production of the Cobb-Douglas Type 1. dependent variable: number of container throughput, terminal efficiency represented by berth utilization 2. independent variable: location, no. of shipping lines' direct call service. level of economic activitymeasured by each countries' GNP, gross crane productivity, berth surface, yard throughput

Classification \ Scholar	Barros and Athanassiou(2004)	Wang, Cullinane and Song(2005)	Park (2006.4)
Analyzed Country	2(Greece and Portugal)	30	1(South Korea)
Analyzed Ports	6	top 30 container ports	26
No. of Sample	18	62 in cross-sectional data in 2001, 240 panel data from 1992 to 1999	286 panel data from 1994 to 2004
Analyzed Model	1. Inputs : Ships, Movements of freight, Total cargo handled, Container handled	1. Inputs: Terminal length, Terminal area, Quayside gantry, Yard gantry, Straddle carrier 2. Outputs: Container throughput	1. Inputs: Berthing capacity, Cargo handling Capacity 2. Outputs: Cargo throughput, Number of ship calls

III. An Empirical Analysis by Using CCR, BCC, and Malmquist

Efficiency can simply be expressed as a ratio of output to input provided that the product only produces one output. Therefore, in multiple inputs and outputs cases, efficiency then begins to resemble the sum of weighted outputs over the sum of weighted inputs.6)

Productivity and efficiency are the two most important concepts in measuring performance. The productivity of a producer can be loosely defined as the ratio of output(s) to input(s). If production has multiple outputs and inputs, productivity refers to total factor productivity that involves all factors of production. Efficiency can be defined as relative productivity over time or space, or both.7) However, because of several factors which should be considered, the limits on the productivity of a container terminal may be imposed by either physical or institutional factors or a combination of both. Dowd and Leschine(1990, p.111) show the general components for measuring the productivity of container ports. Also, Wang, Cullinane, and Song(2005,pp.81-87) define the input and output variables more carefully after critically reviewing the previous studies.

After a theoretical summary of the 2 basic models of DEA, i.e., CCR and BCC models, introduced in this section, the Malmquist index used frequently for vertical analysis will be shown for panel analysis.

1. CCR and BCC Models8)

Data envelopment analysis (DEA), developed by Charnes, Cooper and Rhodes(1978), uses linear programming to measure relative efficiency among similar decision-making units (DMUs) incorporating multiple inputs and outputs.

Suppose we have a set of n peer DMUs, which produce observed multiple output vector $\mathbf{Y}$, by utilizing observed multiple input vector $\mathbf{X}$, respectively. Then, the production possibility set $\mathbf{F}$ is defined as (1).

$$\mathbf{F} = \{(\mathbf{Y}, \mathbf{X}) \mid \mathbf{X} \text{ can produce } \mathbf{Y}\} \tag{1}$$

6) Valentine, and Gray (2002), p.167.

7) More detailed explanation on the definition of "productivity" and "efficiency", refer to Wang et al.(2002), p.4.

8) Park(2003.12),pp.39-41.

An efficient frontier(or production technology) can be represented with a set of DMUs which satisfy Pareto efficiency conditions among production possibility set. This efficient frontier needs the following two basic assumptions(Shephard, 1970).

First, the efficient frontier should be satisfied with convexity assumption of production possibility set $\mathbf{F}$. The convexity assumption means that, for a DMU with a single input A and single output B, respectively, if $(y^A, x^A) \in \mathbf{F}$ and $(y^B, x^B) \in \mathbf{F}$, then $(\lambda y^A + (1-\lambda)y^B, \lambda x^A + (1-\lambda)x^B, 0 \le \lambda \le 1) \in \mathbf{F}$.

Second, the efficient frontier should be satisfied with free disposability assumption of inputs and outputs. The free disposability assumption means that, for inputs, if $(y^A, x^A) \in \mathbf{F}$ and $x^B \ge x^A$, then $(y^A, x^B) \in \mathbf{F}$, and, for outputs, if $(y^A, x^A) \in \mathbf{F}$ and $y^B \le y^A$, then $(y^B, x^A) \in \mathbf{F}$.

Shephard(1970) provided an another functional representation of production technology as a definition of distance function as expressed in (2).

$$\mathrm{D}(\mathbf{Y}, \mathbf{X}) = \min\{\theta \mid (\mathbf{X}, \mathbf{Y}/\theta) \in \mathbf{F}\} \tag{2}$$

Where, $\mathrm{D}(\mathbf{Y}, \mathbf{X})$ is an output oriented distance function.9) This set can be described mathematically by its sections. Therefore, an input oriented distance function is defined as $\max\{\theta \mid (\mathbf{Y}, \mathbf{X}/\theta) \in \mathbf{F}\}$. For estimation of such a distance function, Aigner and Chu(1968) originally introduced a nonparametric technique named linear programming. And then Charnes, Cooper and Rhodes(1978) suggested DEA methodology as shown in (3), in which an optimal solution is the reciprocal of Farrell(1957)'s technical efficiency estimates.

$$\text{Min} \quad \theta - \varepsilon \sum_{r=1}^{s} s_r^+ - \varepsilon \sum_{i=1}^{m} s_i^-$$

s.t.

$$x_{ij_0}\theta - \sum_{j=1}^{n} x_{ij}\lambda_j - s_i^- = 0, \quad i = 1, 2, \cdots, m,$$

9) This set can be described mathematically by its sections. Therefore, input oriented distance function is defined as $\max\{\theta \mid (\mathbf{Y}, \mathbf{X}/\theta) \in \mathbf{F}\}$.

$$\sum_{j=1}^{n} y_{rj}\lambda_j - y_{rj_0} - s_r^+ = 0, \quad r = 1, 2, \cdots, s,$$

$$\lambda_j,\ s_i^-,\ s_r^+ \geq 0, \qquad \forall j,\ r,\ i. \tag{3}$$

where, we assume n units, each using m inputs to produce s outputs. We denote by y_{rj} the level of the rth output ($r = 1, 2, \cdots, s$) from unit j ($j = 1, 2, \cdots, n$) and by x_{ij} the level of the jth input ($j = 1, 2, \cdots, m$) to the jth DMU.

And ε is a very small positive number that prevents the weights from vanishing (formally, ε should be seen as a non-Archimedean constant), s_i^-, s_r^+ represent the slack variables, λ_j are variables whose optimal values will define an efficient production possibility minimizing inputs DMU_0 without detriment to its output levels. As a result, the optimal solution of θ represents the estimated efficiency of DMU_0.

Equation (3) is called as CCR model, which is added constant returns to scale condition of efficient frontier to above two basic assumptions. Where, the constant returns to scale condition means that, for $k > 0$, if $(\mathbf{Y}, \mathbf{X}) \in \mathbf{F}$, then $(k\mathbf{Y}, k\mathbf{X}) \in \mathbf{F}$.

Another DEA model, which is usually referred to as the BCC model is proposed by Banker, Charnes and Cooper(1984). This model is expressed by adding convexity constraint such as $\sum_{j=1}^{n} \lambda_j = 1$ to traditional CCR model. As a result, BCC model can estimate separately pure technical efficiency and scale efficiency, on the assumption that the variable returns to scale in production technology exist.

2. Malmquist Model

The purpose of a Malmquist-type productivity index is to measure the productivity and efficiency changes over time. The basic idea of Malmquist index is to exploit the relation between distance functions of different time periods as ratios.

Caves, Christensen and Diewert(1982) defined an Malmquist productivity index as a ratio of distance function between periods t and t+1(as presented in (4). This index is based on output oriented Malmquist index.

$$M_{O,j}^{t,t+1} = D_O(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1}) / D_O(\mathbf{Y}_j^{t},\mathbf{X}_j^{t}), \quad j=1,\ 2,\cdots,n. \tag{4}$$

After that, Fare, Grosskopf, Lindgren and Roos(1995) show this index can be solved using linear programming. They employed the geometric mean of the two output oriented Malmquist index to expand the above measure of productivity change.

$$M_{O,j}^{t,t+1} = \left[\frac{D_O^t(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1})}{D_O^t(\mathbf{Y}_j^{t},\mathbf{X}_j^{t})} \bullet \frac{D_O^{t+1}(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1})}{D_O^{t+1}(\mathbf{Y}_j^{t},\mathbf{X}_j^{t})} \right]^{1/2}$$

$$= \frac{D_O^{t+1}(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1})}{D_O^t(\mathbf{Y}_j^{t},\mathbf{X}_j^{t})} \bullet \left[\frac{D_O^t(\mathbf{Y}_j^{t},\mathbf{X}_j^{t})}{D_O^{t+1}(\mathbf{Y}_j^{t},\mathbf{X}_j^{t})} \bullet \frac{D_O^t(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1})}{D_O^{t+1}(\mathbf{Y}_j^{t+1},\mathbf{X}_j^{t+1})} \right]^{1/2}$$

$$,t=1,\ 2,\cdots,T-1, \quad j=1,\ 2,\cdots,n. \tag{5}$$

The first term on the right-hand side measures the magnitude of technical efficiency change between periods t and $t+1$. Also, The second term measures the shift(technical change) in the efficient frontier between periods t and $t+1$. Obviously, theses indexes should be interpreted as "equal to 1" means remains, "less than 1" means declines, "more than 1" means improves.

3. Comparison of Three Models

In <Table 2>, for comparison, we note the characteristics of three models according to some criteria. As shown in this table, each models have some difference between assumptions, frontier type, analyzing technique, and estimated efficiency results. The CCR and BCC models are the two DEA models that are widely studied and applied. The main difference between BCC and CCR models is that the former allows for a variable returns to scale, assumption, while the latter is applicable solely to situations where constant returns to scale are assumed. Accordingly, the production frontiers in these models are different. The advantage of two models lies in the fact that the results can provide each DMU with information on to what maximum extent it is likely to improve its performance, or to what extent, it can improve its performance compared with its most similar efficient counterpart.[10] CCR model provides information on pure technical and scale efficiency taken together, BCC model identifies technical efficiency alone. Malmquist model is to measure the productivity and efficiency changes over time. Therefore it gives us information on the dynamic change of efficiency.

<Table 2> Comparison of Three Models

Models / Classifications	CCR	BCC	Malmquist
Assumptions	Convexity Free disposability Constant returns to scale	Convexity Free disposability Variable	Similar to BCC
Type of frontier	Ray from the origin	Piecewise linear	Frontier change over time
Analyzing Technique	LP(Simplex)	LP(Simplex)	LP(Simplex)
Estimated Efficiency	CCR efficiency score < BCC efficiency score		>1, then improves <1, then declines

4. Empirical Analysis and Explanation

This paper focused on a trend analysis of scale efficiency of the Port of Gwangyang from 1994 to 2004 using CCR, BCC, and Malmquist models. Therefore, Data for an empirical analysis come from the Statistical Yearbook of Maritime Affairs and Fisheries produced by the Ministry of Maritime Affairs and Fisheries. In this section, first, the results of CCR and BCC models of DEA using cross-sectional data will be shown. Second, the results of Malmquist model will be analyzed under the CRS and VRS. Third, the trend of scale efficiency will be shown including domestic competition power according to the efficiency rankings.

(1) Variables and Summary Statistics for the Sample

According to the definition by Dowd and Leschine(1990, p.111) and Wang, Cullinane, and Song(2005,pp.81-87), this paper should have adopted the detailed variables for empirical analysis. In Korea, the Statistical Yearbook of Maritime Affairs and Fisheries annually published by the Ministry of MAF shows official statistics for seaports' input and output variables. Although the objective of this paper is to analyze the trend of scale efficiency of the Port of Gwangyang compared with other 25 Korean ports, this

10) More detailed explanation on the characters of CCR, BCC model, refer to Wang et al.(2005), pp.40-45; Wang et al.(2002), pp.7-11, p.16; Cullinane et al.(2006),p. 361.

paper has a limitation in part from data for empirical analysis. Inputs are berthing capacity, and cargo handling capacity. Outputs are import and export cargo throughputs and number of ship calls. Important statistics relating to the sample are summarized in <Table 3>.

<Table 3> Summary Statistics for the Sample

Variables and Statistics	Outputs		Inputs	
	Import and export cargo throughputs (1000 R/T)	Number of ship calls (number)	Berthing capacity (1000 DWT)	Cargo handling capacity (1000 DWT)
Mean	28624.87	11996.70	487.05	15059.89
Standard error	2750.60	1059.93	44.73	1411.18
Median	6758.5	4359.00	97.5	5649.00
Mode	619	2051.00	33.00	817.00
Standard deviation	46516.85	17924.98	756.48	23865.20
Kurtosis	2.58	5.99	2.77	5.24
Skewness	1.92	2.43	1.90	2.35
Range	219733.00	97169.00	3189.00	121841.00
Minimum	27.00	160.00	1.00	1.00
Maximum	219760.00	97329.00	3189.00	121842.00
Count	286	286	286	286

(2) CCR and BCC Analysis[11)]

The efficiency results with RTS of input and output oriented CCR and BCC models from 1994 to 2004 for Gwangyang Port out of 26 international trade ports in Korea are shown in <Table 4>. DEA-Solver by Cooper , Seiford and Tone(1999) was used. In <Table 4>, various comments are in order. First, the input-oriented model aims at reducing the input amounts by as much as possible while keeping at least the present output levels. Second, the output-oriented model maximizes output levels under at most the present input consumption. In general, input-oriented model is recommended, because of efficiency scores which show the 1 or below. It is easy to compare the efficiency scores among seaports compared with those of output-oriented model.[12)] If

11) More detailed explanation, refer to the followings.
Tongzon(2001), pp.116-119; Banker, Charnes and Cooper(1984), pp.1078-1092; Charnes, Cooper and Rhodes(1978), pp.429-444.

12) Input-oriented model is closely related to operational and managerial issues, whilst ouput-oriented model is more related to port planning and strategies. More detailed

the Port of Gwangyang is found inefficient, such a careful case by case examination of characteristics is called for, before an inefficiency diagnosis can be confirmed.[13)]

The main empirical results are as follows.

First, the Port of Gwangyang is inefficient in terms of input-oriented CCR under CRS before 1997 compared to the rapid increase of efficiency after 1998.

Second, scale efficiency scores under input-oriented CCR show below 43% before 1997 compared to those of the rapid increase over 62% after 1998.

Third, rankings of scale efficiency under input-oriented CCR are better than those of output-oriented BCC efficiency scores.

Fourth, scale efficiencies result from CCR efficiency score/ BCC efficiency score. The scale efficiency of the Port of Gwangyang shows continuously decreasing returns to scale. It means that output increases by less than increased input amount.

<Table 4> The Port of Gwangyang's Efficiency and RTS Change of Input and Output oriented CCR and BCC Models from 1994 to 2004 Using Cross-Sectional Data

Item / Year	input-oriented CCR under CRS	input-oriented CCR under VRS	output-oriented BCC under CRS	output-oriented BCC under VRS	Scale efficiency under input-oriented CCR	Scale efficiency under output-oriented BCC	Returns to Scale
1994	0.100160	0.748234	9.984060	1.052173	0.133861(26)	9.48899(26)	Decreasing
1995	0.11528	0.75658	8.67426	1.17416	0.152376(24)	7.38766(24)	Decreasing
1996	0.22220	0.51701	4.500421	1.14889	0.429782(23)	3.91720(26)	Decreasing
1997	0.23419	0.79707	4.27013	1.22048	0.29381(24)	3.49874(25)	Decreasing
1998	0.48573	0.77623	2.05877	1.27537	0.62575(17)	1.61426(17)	Decreasing
1999	0.46687	0.82627	2.14192	1.15305	0.56504(20)	1.85762(22)	Decreasing
2000	0.39046	0.85299	2.56110	1.07222	0.45775(22)	2.388605(25)	Decreasing
2001	0.31957	0.68570	3.12925	1.06167	0.466041(22)	2.94748(26)	Decreasing
2002	0.40298	0.51971	2.48151	1.08318	0.775403(9)	2.29095(23)	Decreasing
2003	0.41497	0.64613	2.40982	1.08819	0.642236(18)	2.21452(23)	Decreasing
2004	0.474907	0.69424	2.10567	1.20472	0.684068(15)	1.74786(21)	Decreasing

(3) Malmquist Analysis

<Table 5> shows the Port of Gwangyang's several efficiency changes including scale efficiency. DEAP(Coelli, 1996) was used for Malmquist index calculation. Estimations

explanation, refer to Wang et al.(2005), pp.87-88.

13) H. Tulkens(1993), "On FDH Efficiency Analysis: Some Methodological Issues and Applications to Retail Banking, Courts, and Urban Transit," *Journal of Productivity Analysis,* Vol.4, pp.192-193.

for annual performance of the Port of Gwangyang during the period of 1994 and 2004 are presented in <Table 5> and plotted in [Figure 1].

In <Table 5>, technical efficiency change, technical change, pure efficiency change, scale efficiency change and total factor productivity change are listed. Technical efficiency improved in 6 out of 10 periods except 98/99, 99/2000, 2000/2001 and 2002/2003. There was positive technical change in the Port of Gwangyang during 4(98/99, 99/2000, 2000/2001, and 2002/2003) out of 10 periods under CRS. Technical progress has occurred at - 3.3%(calculation: 1 minus 0.967), on average, annual growth rate, with 2003/2004 recording by 230% rate of growth, and 99/2000 by 13.6%. If VRS are assumed, technical efficiency in 5 out of 10 periods remained high level including 54.2% rate of growth during 96/97. However, 95/96 recorded a rapid fall in efficiency, 2000/2001, 2001/2002 and 2003/2004 recorded a 20%-30% fall in efficiency, while 97/98 had experienced a slight fall in efficiency. Scale efficiency shows a 50% similar[5(94/95, 95/96, 97/98, 2001/2002, 2003/2004) out of 10] pattern to technical efficiency change. Total factor productivity increased at 48.57% rate of growth on average in 6 out of 10 periods except 96/97, 97/98, 99/2000, and 2000/2001. 2003/2004 period is the one period experiencing rapid total factor productivity change, mainly due to technical progress. 96/97, 97/98, 99/2000 and 2000/2001 are the reversed cases.

The annual means of the Malmquist indices for the Port of Gwangyang are shown in <Table 5>. They are consistent with those from Malmquist indices mean of all ports for whole periods except pure efficiency change and total factor productivity change.

From [Figure 1], 5 Malmquist indices have shown no particular pattern in the rise and fall except the high efficiency change in 2000/2001, and the high technical change and TFP in 2003/2004 which should be noted.

The average total factor productivity indexes for 3[The Port of Incheon(1.083), The Port of Busan(1.139), and The Port of Gwangyang(1.105)] main container ports in Korea shows similar results. In each case, there has been an increase in the level of total factor productivity. However, we should be very careful when we compare the TFP of the different ports as they do each have individual characteristics that make this difficult.

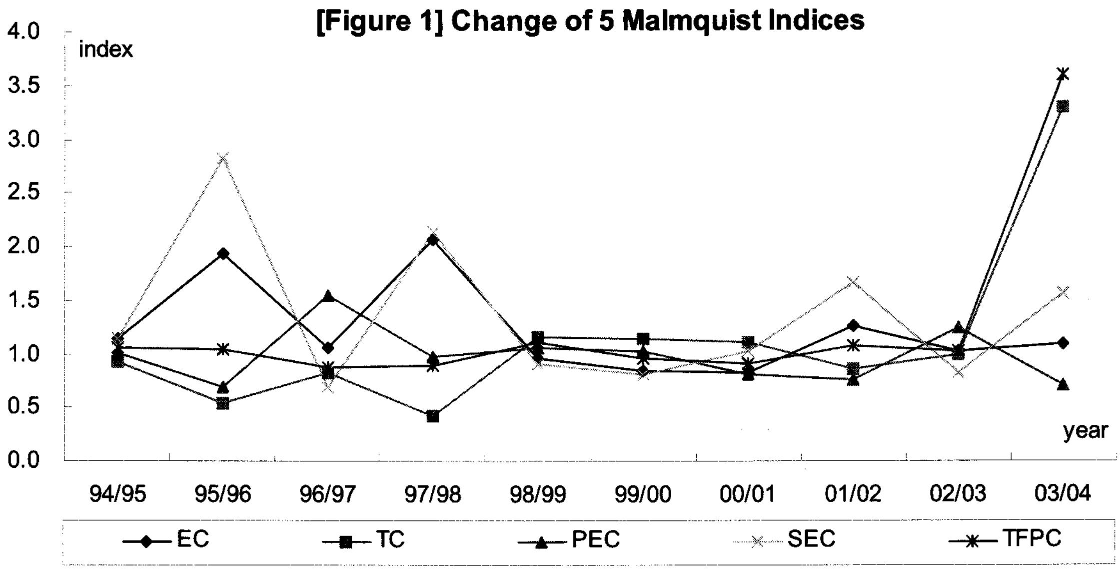
The five accumulative indices from [Figure 2] have shown no certain patterns of rise and fall over the sample periods, but a general trend was upward tendency. Especially high rate of growth has shown after the Port of Gwangyang has opened in 1998. The ranking order of accumulative indices is scale efficiency change, TFP change, efficiency change, technical change, and pure efficiency change.

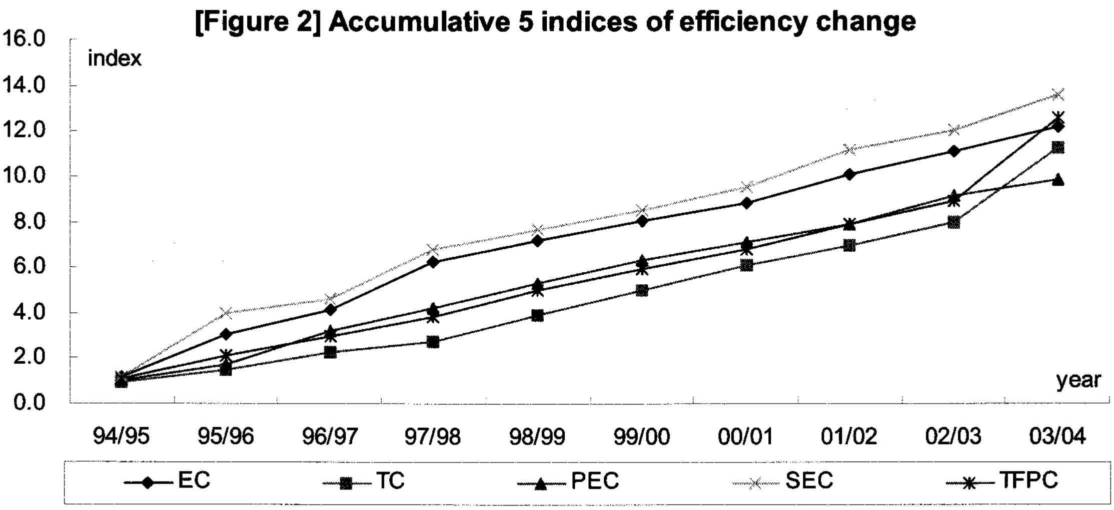
The high growth rate of efficiency change in 97/98 and scale efficiency change in

95/96, and 97/98, and technical change and TFP change in 2003/2004 should be noted. The 1.24% of TFP growth per year during the sample period was indicated. The increase of efficiency change was due to the opening of the Gwangyang port. The related increase can be explained partly by the increase of throughput and the usage of new port equipment.

<Table 5> The Port of Gwangyang's Malmquist Efficiency Change from 1994 to 2004 by Using Panel Data

Year	Item	Technical Efficiency Change (CRS)	Technological Change	Pure Technical Efficiency Change (VRS)	Scale Efficiency Change	Total Factor Productivity Change
1994/1995	M Index	1.151	0.916	1.011	1.138	1.054
	Mean	0.997	0.842	1.015	0.982	0.839
1995/1996	M Index	1.927	0.538	0.683	2.821	1.036
	Mean	1.401	0.643	1.153	1.215	0.901
1996/1997	M Index	1.054	0.826	1.542	0.684	0.871
	Mean	1.133	0.898	1.141	0.993	1.017
1997/1998	M Index	2.074	0.426	0.974	2.130	0.883
	Mean	1.169	0.601	1.068	1.094	0.702
1998/1999	M Index	0.961	1.160	1.064	0.903	1.115
	Mean	0.972	1.148	0.924	1.052	1.116
1999/2000	M Index	0.836	1.136	1.032	0.810	0.950
	Mean	0.996	1.010	1.068	0.933	1.006
2000/2001	M Index	0.818	1.112	0.804	1.018	0.910
	Mean	0.920	1.139	0.963	0.955	1.048
2001/2002	M Index	1.261	0.856	0.758	1.664	1.080
	Mean	1.065	1.047	0.956	1.115	1.115
2002/2003	M Index	1.030	0.995	1.243	0.828	1.025
	Mean	1.001	0.945	0.985	1.016	0.946
2003/2004	M Index	1.092	3.301	0.702	1.556	3.604
	Mean	0.927	1.571	0.860	1.078	1.455
Mean	M Index Mean of Port of Gwangyang for Total Period	1.163	0.967	0.951	1.223	1.124
	M Index Mean of All Ports for Total Period	1.050	0.950	1.009	1.040	0.998





V. Conclusion

This paper has used the CCR, BCC, and Malmquist index approaches for measuring the trend analysis on the scale efficiency of the Port of Gwangyang from 1994 to 2004 using 2 inputs and 2 outputs.

The main empirical results are as follows.

First, the Malmquist efficiency of the Port of Gwangyang has shown the upward tendency in terms of technical efficiency change, scale efficiency change, and total factor productivity change. However, technical change, and pure efficiency change have been declined, although technical change was rapidly increased in 2003/2004. High scale efficiency in 95/96, 97/98, 2001/2002, and 2003/2004 produced this results.

Second, scale efficiency shows a 50% similar[5(94/95, 95/96, 97/98, 2001/2002, 2003/2004) out of 10] pattern to technical efficiency change. Scale efficiency change mainly comes from the positive CRS technical efficiency change in 94/95, 95/96, 96/97, and 97/98 with positive VRS pure efficiency change in 99/2000, and 2002/2003.

Third, total factor productivity increased at 48.57% rate of growth on average in 6 out of 10 periods except 96/97, 97/98, 99/2000, and 2000/2001. 2003/2004 period is the one period experiencing rapid total factor productivity changes, mainly due to technical progress in 98/99, 99/2000, 2000/2001, and 2003/2004.

Fourth, the ranking order of accumulative indices is scale efficiency change, TFP change, efficiency change, technical change, and pure efficiency change according to the Malmquist index mean of the Port of Gwangyang for total period in <Table 5>.

The policy implications of this paper are as follows.

First, an effect of pure technical efficiency change(average:0.951) and scale efficiency change(average:1.223) on technical efficiency change(CRS technology) is positive. Scale efficiency is more effective than pure technical efficiency in terms of influential power to the CRS technology. Therefore to enhance the technical efficiency in the Port of Gwangyang, port authority manager should introduce the policy which can manage the usage of input and output elements more efficiently after identifying the sources of input and output inefficiency.

Second, the 12.4% of average growth rate in the total factor productivity change mainly comes from the 16.3% of technical efficiency change instead of -3.3% of technological change. Therefore, to enhance the total factor productivity of the Port of Gwangyang by inducing the positive technological change, port authority manager should remove the institutional barriers to the diffusion of knowledge on innovations for input and output elements in the port.

Third, the increase of total factor productivity is mainly due to the CRS efficiency and technological progress. However, in view of the average level, the CRS efficiency change is more than 1, and technological progress is less than 1. That is to say, the direction of CRS efficiency and technological progress is opposite. Therefore, to improve the technological progress, port authority manager should introduce the total management plan for input and output elements, because the technological progress will come from the positive movement of production frontier itself by inducing the new technology according to the time path.

Fourth, according to the target analysis and finding out benchmarking ports from the CCR and BCC analysis, the Port of Gwangyang should develop the plan for efficient usage of inputs and outputs(especially number of ship calls, because slacks were found), and follow the port management ways of benchmarking ports(the Ports of Daesan, Okpo, and Woolsan) for enhancing the scale efficiency including 4 Malmquist indices.

The limitations of this paper are as follows.

First, an empirical work in seaports is usually hindered by lack of appropriate statistical information. Several sets of input-output models are needed for finding out the exact elements or factors affecting the scale efficiency of the Port of Gwangyang.

Second, empirical results are not analyzed more closely by adding the real situation in the seaport.

Third, parametric stochastic frontier methodology conducted by Wang, Cullinane, and Song(2005) should be done to compare the results of this paper more exactly.

The next study will deal with these subjects.

<References>

1. Banker, R. D., A. Charnes and W. W. Cooper(1984), "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," *Management Sciences*, Vol. 30, pp.1078-1092.
2. Bennathan, E. and A. Walters(1979), *Port Pricing and Investment Policy for Developing Countries*, Oxford Univ. Press.
3. Callen, J.L.(1990), "Efficiency Measurement in the Manufacturing Firm", *Journal of Productivity Analysis*, Vol. 2, pp.5-13.
4. Charnes, A. and W. W. Cooper(1980), "Management Science Relations for Evaluation and Management Accountability," *Journal of Enterprise Management*, Vol. 2, No. 2.
5. Charnes, A., W. W. Cooper and E. Rhodes(1978), "Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, Vol. 2, pp.429-444.
6. Culliname, K. and D.W. Song(1998), "Container Terminals in South Korea: Problems and Panaceas," *Maritime Policy and Management*, Vol. 25, No. 1, pp.63-80.
7. Cullinane, K., D.W. Song, and R. Gray(2002), "A Stochastic Frontier Model of the Efficiency of Major Container Terminals in Asia: Assessing the Influence of Administrative and Ownership Structures," *Transportation Research PART A*, Vol36, pp.743-762.
8. Dowd, T. J.(1984), "Container Terminal Leasing and Pricing," *Maritime Policy and Management*, Vol. 11, No. 4, p.280.
9. Dowd, T. J. and T. M. Leschine(1990), "Container Terminal Porductivity: A Perspective," *Maritime Policy and Management*, Vol. 17, No. 2, pp.108-109.
10. Farrel, M. J.(1957)"The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society, Series A, Part 3.*
11. Fleming, D. K.(1997), "World Container Port Rankings," *Maritime Policy and Management*, Vol. 24, No. 2, pp.175-181.
12. Frankel, E. G.(1991), "Port Performance and Productivity Measurement," *Ports and Harbors*, Vol. 36, No. 7, September, pp.11-13.
13. Ha, D.W.(1996), *An Analysis of Competition Surroundings among the Main Container Ports of East-North Area*, Marine Industry Research Institute, December.
14. Han, C.H.(2002), "An Empirical Study on the Determinants fo Port Performance and Effciency," *Proceedings of the 2nd International Gwangyang Port Forum and Int'l Conference for the 20th Anniversary of Korean Association of Shipping Studies*, Korean Association of Shipping Studies, April 24-26, pp.247-259.
15. Humphrey, D. B.(1993), "Cost and Technical Change: Effects from Bank Deregulation," *Journal of Productivity Analysis*, Vol. 4, pp.9-34.
16. Jansson, J. O. and D. Shneerson(1982), *Port Economics*, MIT Press.
17. Jun, I.S., Kim, H.S., and Kim, B.J., *An Enhancement Plan for International Competition Power of Korea's Container Ports*, Marine Industry Research Institute, December 1993, pp.219-258.

18. Lee, J.W.(2001), " Challenges Faced in Container Port Development in Asia and the Pacific Region," *Proceedings of 16th International Conference of The Korea Port Economic Association*, July 6-7, pp.47-48.

19. Lee, S.W.(2006), "Competition among Hub Ports and the Strategy for Co-opetition of Gwangyang Port," *Proceedings of the 4th International Conference Gwanyang Forum*, The Korean Association of Shipping and Logistics, April 19-21, pp.34-59.

20. Mairesse, J. and E. Kremp(1957), "A Look at Productivity at the Firm Level in Eight French Industries," *Journal of Productivity Analysis*, Vol. 4, pp.211-234.

21. Monie, G. De(1987), "Measuring and Evaluating Port Performance and Productivity," *UNCTAD MONOGRAPHS on PORT MANAGEMENT*, No.6, International Association of Ports and Harbors, September, pp.2-11.

22. Oh, S.D. and Park, R.K.(2001), "A Method of Measuring the International Competitiveness of Container Ports: A DEA Approach, Focused on Productivity Analysis," *Journal of Korea Port Economic Association*, Vol.17, No.1, May, pp.27-51.

23. Park, R.K.(2003), "A Measurement Way on the Effectiveness of Port Investment: Congestion Model Approach," *Journal of Korea Port Economic Association*, Vol.19, No.2, pp.33-53.

24. Park, R.K.(2006), " A Trend Analysis on the Scale Efficiency of the Port of Gwangyang," *Proceedings of the 4th International Conference Gwanyang Forum*, The Korean Association of Shipping and Logistics, April 19-21, pp.615-631.

25. Petersen, N. C., "DEA on a Relaxed Set of Assumptions," *Management Science*, Vol. 36, No. 3, pp.305-314.

26. Roll, Y. and Y. Hayuth(1993), "Port Performance Comparision Applying Data Envelopment Analysis(DEA)," *Maritime Policy and Management*, Vol. 20, No. 2, pp.153-161.

27. Roll, Y. and A. Sachish(1981), "Productivity Measurement at the Plant Level," *Omega*, Vol. 9, No. 1, pp.37-42.

28. Sachish, A.(1996), "Productivity Functions as A Managerial Tool in Israel Ports," *Maritime Policy and Management*, Vol. 23, No. 4, pp.341-369.

29. Schonfeld, P. and S. Frank(1986), "Optimizing the Use of a Containership Berth," *Tansportation Research Record*, No. 984, pp.56-62.

30. Seiford, L. and R. M. Thron(1990), "Recent Development in DEA," *Journal of Econometrics*, Vol. 46, pp.7-38.

31. Siegal, I. H.(1980), *Company Productivity: Measurement for Improvement*, W. E. Upjohn Institute for Employment.

32. Suykens, F.(1987), "Some Remarks Productivity in Seaports," *Ports and Harbors*, Vol. 32, No. 12, Dec., pp.14-23.

33. Talley, W. K., "Optimum Throughput and Performance Evaluation of Marine Terminals," *Maritime Policy and Management*, Vol. 15, No. 4, pp.327-331

34. Talley, W. K.(1986), "A Comparison of Two Methodologies for Selecting Transit Performance Indicators," *Transportation*, Vol. 13, pp.201-210.

35. The Federation of Korea Industries(1997), *The Enhancement Assignment for Competition Power of*

Ports, Industry Policy 97-3, September 20.

36. Tone, K. and B.K. Sahoo(2005), "Evaluating Cost Efficiency and Returns to Scale in the Life Insurance Corporation of India Using Data Envelopment Analysis," *Scoio-Economic Planning Sciences,* Vol. 39, pp.261-265.
37. Tongzon, J.(2001), "Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis," *Transportation Research, Part A,* Vol. 35, pp.113-128.
38. Tulkens, H.(1993), " On FDH Efficiency Analysis: Some Methodological Issues and Applications to Retail Banking, Courts, adn Urban Transit," *The Journal of Productivity Analysis,* Vol. 4, pp.183-210.
39. Valantine, V.C. and R. Gray(2002), " Competition of Hub Ports: A Comparison between Europe and the Far East," *Proceedings of the 2nd International Gwangyang Port Forum and Int'l Conference for the 20th Anniversary of Korean Association of Shipping Studies, Korean Association of Shipping Studies,* April 24-26, pp.161-176.
40. Walter, A.(1975), "Marginal Cost Pricing in Ports," *The Logistics and Transportation Review,* Vol. 11, pp. 297-308.
41. Wang, T.F., K. Cullinane and D.W. Song(2005), *Container Port Production and Economic Efficiency,* Palgrave Macmilllan.
42. Wang, T.F., D.W. Song and K. Cullinane(2002), "The Applicability of Data Envelopment Analysis to Efficiency Measurement of Container Ports," *IAME Panama 2002 Conference Proceedings,* International Association of Maritime Economists, November 13-15, pp.1-21.

< 요 약 >

광양항의 규모효율성 추세분석: 1994-2004

박노경

본 논문은 1994년-2004년까지 2개의 투입물(접안능력, 하역능력)과 2개의 산출물(수출입화물처리량, 입출항척수)을 이용하여 DEA방법(CCR, BCC)과 맴퀴스트지수방법에 의거하여 광양항의 규모효율성의 추세를 분석하였다.

실증분석의 주요한 결과는 다음과 같다.

첫째, 광양항의 맴퀴스트효율성은 기술적 효율성, 규모효율성, 총요소생산성변화측면에서 상승하는 추세를 보였주었다. 그러나 기술변화는 2003년과 2004년 사이에 급격하게 증가하였음에도 불구하고 기술변화와 순수효율성변화는 하락하였다. 95/96, 97/98, 2001/2002, 2003/2004년의 높은 규모효율성이 그 원인이 되었다. 둘째, 규모효율성은 기술적 효율성변화와 10개년의 기간 중에서 50% 수준에서 유사한 추세를 보였다. 그러한 규모효율성변화는 94/95, 95/96, 96/97, 97/98년의 규모수확불변하의 기술적 효율성변화와 99/2000, 2002/2003년의 규모수확가변하의 순수 효율성변화에 기인한다. 셋째, 총요소생산성은 6개년의 기간에서 48.57%의 성장률로 증가하였는데, 그 주요한 원인은 98/99, 99/2000, 2000/2001, 2003/2004년의 기술적 진보에 기인하였다. 넷째, 누적 맴퀴스트지수의 순위는 규모효율성변화, 총요소생산성변화, 종합효율성변화, 기술적변화, 순수효율성변화의 순서였다.

본 논문의 정책적인 함의는 다음과 같다.

첫째, 순수기술적 효율성변화와 규모효율성변화가 기술적 효율성변화에 미친 효과는 긍정적이었다. 규모수확불변 하에서 규모효율성이 순수기술효율성변화보다도 더욱 영향력이 컸다. 따라서, 광양항의 기술적효율성을 증대시키기 위해서는 항만당국이 투입-산출요소의 비효율적 요인을 확인한 후에 효율적으로 관리하는 방안을 마련해야만 한다.둘째, 총요소생산변화에서의 12.4%의 평균성장율은 16.3%의 기술적효율성에 기인한다. 따라서 총요소생산성을 증대시키기 위해서는 항만당국은 투입-산출요소를 획기적으로 사용하는 방안에 대한 지식을 확산시키는데 제도적 장애요인을 제거하여야만 한다. 셋째, 광양항은 규모효율성을 높이기 위해서는 DEA분석을 통해서 발견된 벤치마킹항만들(대산항,옥포항,울산항)의 항만관리방법을 도입해야만 한다.

□ 주제어: 광양항, 규모효율성, DEA, CCR, BCC, 맴퀴스트지수