

■ 論 文 ■

An Analysis of the Efficiency of the Global Logistics Industry with Data Envelopment Analysis and a Tobit Model

세계 물류산업의 효율성에 관한 연구

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요 약

세계화를 통해 글로벌 공급사슬은 더욱 복잡해지고, 고객들은 모든 물류서비스를 통합적으로 제공받을 수 있는 기업에 대한 의존도가 높아짐에 따라 고객들은 물류 기업에 대해서 가격뿐만 아니라 운영적 측면에서 높은 효율성을 요구하고 있다.

이에 본 연구에서는 자료포락분석(Data Envelopment Analysis)을 중심으로 전세계 물류산업의 효율성의 추이와 비효율성에 영향을 미치는 요소들에 대한 연구를 진행하였다. 그 결과를 요약하면, 5개년간 세계의 물류산업의 효율성은 높아지는 추세를 보이고 있었으며, 비효율성은 규모에 의한 비효율성보다는 순수기술효율성에 의해 나타난 비효율성에 의해서 나타나고 있었다.

비효율성에 영향을 미치는 외부적인 요소를 살펴보면, 우선 세계화는 비효율성에 영향을 주고 있다. 세계화의 요소 중에서는 경제적인 요소보다는 전반적인 세계화 정도가 더 영향을 미쳤으며, 인프라와 관련되어서는 인력, 금융적 지원, 기반 등 소프트웨어적 측면의 영향력이 더 유의했으며, 법제도적인 측면에서는 집행의 투명성, 법제도의 효과가 유의하게 영향을 미치는 것을 밝혀냈다.

According to the demand for services, a single point contract between a user and provider spreads over the industry, and the relationship between them is a main issue. The user wants to make a deal with the contributor which can provide the effective services to the user.

This study is to estimate the efficiency of global logistics industry with Data Envelopment Analysis, by nations from 2001 to 2005. Furthermore, it tries to estimate the inefficiency affected by macro factors, and proves the association between them using Tobit model.

Global logistics industry has made growth both externally and internally more than doubled for the last 5years. Technical inefficiency of global logistics industry is more influenced by pure technical inefficiency than inefficiency of scale. Therefore, technical efficiency can be increased by decreasing pure technical inefficiency.

Through this study, it found that the logistics industry got influenced to its efficiency by high price of oil, and courier and transportation service market is formed stably. Furthermore, it advocates policy planners to consider effectiveness and clearness of policy which influence to inefficiency of logistics industry. Also, it found that labor and financial support can give critical effect.

I. Introduction

1. Background and purpose

Globalization has certainly permeated and affected supply chains in terms of coverage and complexity. As global supply chains become more complex, customers are increasingly relying on single firms that provide the full range of logistic service activities, leading to consolidation in the industry as firms attempt to achieve economies of scale and scope.

Such suppliers are better able to integrate raw material supply with finished product delivery and provide cost-efficient, door-to-door logistics service on a worldwide basis. This level of integration reportedly improves service reliability and reduces costs for customers.

As a result of demand for integrated services, many firms that maintain core competencies in specific transport segments increasingly provide logistics as a key value-added service.

To meet this type of demand, a single point contract between a user and a provider with a comprehensive industry coverage is required, and the user wants to make a deal with the contributor which can provide the logistics services to the user as effectively and efficiently as possible.

Given the importance of efficiency in the delivery of logistics services, this study aims to estimate and compare the efficiency of logistics service providers operating across a range of countries using Data Envelopment Analysis (DEA) 2001 to 2005. Furthermore, it tries to explain their efficiency or inefficiency levels in terms of macroeconomic factors using Tobit model. From these analyses, it attempts to draw out some industry strategy recommendations which can enhance their levels of efficiency.

II. Literature Review

1. Methodologies

Data Envelopment Analysis (DEA) is a non-

parametric optimization decision-making technique that has been widely used for performance analysis in public and private sectors. DEA estimates the technical efficiency of individual decision making units (DMUs) within a group relative to the other DMUs in the group.

The DEA method has an advantage over other parametric techniques in that it allows for the use of multiple outputs and inputs. The method can be input-oriented or output-oriented; the former tries to minimize the amount of inputs for the production of a given amount of output, while the latter tries to achieve the maximum output for a given amount of inputs.

In order to determine the influence of additional variables on DEA technical efficiency results, several statistical tools, parametric and non-parametric have been proposed. Regression analysis and analysis of variance are frequently applied to investigate the relationship between the efficiency score and other variables.

Tobit regression is an alternative to ordinary least squares regression (OLS) and is employed when the dependent variable is bounded from below or above or both, with positive probability pileup at the interval ends, either by being censored or by being corner solution. That is if the range is given by the interval $[a; b]$, observed $y < a$ is recorded as $y = a$, and likewise observed $y > b$ is recorded as $y = b$. In the corner solutions the observations are by nature limited from below or above or both with a positive probability at the 'corners' (interval ends).

DEA scores are limited to the interval $[0; 1]$ and accordingly only have a positive probability to attain one of the two corner values. As two-limit Tobit has been used regularly in modeling of DEA scores it is thus still included in the comparison of possible models of DEA scores.

2. Previous Researches

1) DEA in the logistics industry

Data Envelopment Analysis (DEA) has previously

been applied in a number of industries such as financial, medical and welfare, and transportation industry to investigate productivity growth or performance improvement.

Min and Joo(2006) argued that the operational efficiency of third party logistics providers dictates their competitiveness and survival. They estimated the operational efficiency using Data Envelopment Analysis for US-based 3PL providers and proposed that the ineffective providers should benchmark the best performing corporation to survive in intensive competition.

Oum et al.(2005) measured and compared 10 major North American airlines' performance during the 1990-2001 period by measuring and investigating residual TFP, cost competitiveness, and average yields. They founded that Performing well in both productive efficiency and pricing needed to the airlines for being successful.

Weber et al.(2004) estimates efficiency and productivity in the US trucking and warehousing industry in the 48 contiguous states during the 1994-2000 period by using Data Envelopment Analysis. In the paper, if all inefficiency by the states were to be reduced, trucking accidents involving fatalities could have been eliminated three to four per state per year, while simultaneously increasing industry income.

2) DEA and Second stage analyses

Scheraga(2004) examined the relationship between the strategic focus of airline customer service activities and operational efficiency. Operational efficiency was measured by means of data envelopment analysis. Efficiency measures were related to strategically focused expenditures on operations, passenger services, and ticketing, promotion, and sales by means of a tobit analysis. He suggested that focused expenditures on operations and passenger services had a negative impact on operational efficiency. At the same time, focused expenditures on ticketing, sales, and promotion had a positive impact on the efficiency.

Sheraga(2004) investigated the structural drivers of operational efficiency as well as the financial posture of airlines on the eve of September 11th. At the second stage of the analysis, it was found that relative operational efficiency does not inherently imply superior financial mobility. He proposed that airlines need to have a process which allows the redirection of financial and other resources so that they can continue to operate in a dynamic environment characterized by unexpected events.

Oum and Yu(1994) measured the productivity efficiency of the railway systems in nineteen OECD countries and analyzed it in order to identify the effects of both public subsidies and degree of managerial autonomy on efficiency. A second stage process was used. DEA was the first stage to measure the gross efficiency index from the panel data of the nineteen railways over the 1978-89 period. Tobit regression decomposed the effects of the public subsidies and degree of administrative independence on efficiency as the second stage. The empirical results implied productive efficiency of railway systems may be significantly enhanced by an institutional and regulatory framework which provides a greater freedom for managerial decision-aking.

In the existing research related with efficiency of logistics industry, one function such as air and marine transport, and warehousing in logistic services dominated over the study in the United States and Europe. Relating to infrastructure, investigations of efficiency on management of airport or seaport in the prominent regions were the main subjects. Exploring of companies connected to logistics services, however, could not be found in an easy way.

III. Analysis and Results

1. Selection of variables

1) Variables of DEA

One of the main problems with DEA techniques is the correct selection of inputs and outputs. Other

difficulties are the homogeneity assumption and the flexibility of restrictions regarding the weights. The greater the number of factors included in the analysis, the lower the level of discrimination. To avoid this problem several approximations can be found in the literature. Sun (2002) compute correlations between inputs and outputs and examine input-output relations through multiple regression models.

Banker et al.(1984) showed that the numbers of DMU must exceed three times when number of inputs adds to this of outputs.

The 'rule of thumb' suggested by Dyson (2001) suggests that to achieve a reasonable level of discrimination, the practitioner needs the number of units to be at least $2m \times s$ where $m \times s$ is the product of the number of inputs and outputs.

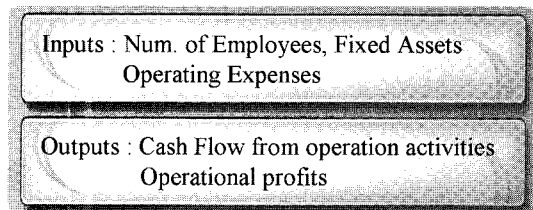
(1) Available input and output measures

The data for inputs and outputs used in this study comes from two different sources. DART (Data Analysis, Retrieval and Transfer) System recorded by the Korean Financial Supervisory Service is employed to collect the annually financial data of 192 Korean firms during the period of 2001-2005. In addition, OSIRIS¹⁾ presented by Bureau van Dijk²⁾ is used to compile the fiscal facts of 394 global corporations in the same period.

Three different factors are chosen as inputs for this study. Due to the labor-intensive nature of the logistics industry, a company's number of employees is selected. Operating expenses is another input because operating expenses include many elements of variable costs such as fuel, personnel cost, maintain costs, and insurance fee. Properties and equipment constituting a firm's fixed assets are viewed as resources for logistics firms (especially asset-based). The former can add value by utilizing facilities such as warehousing and

freight services. The latter is an indicator of a firm's capacity to meet customers' needs.

On the output side, the overall performance of logistics companies can be measured by operating profits that best reflect the operational efficiency of Decision Making Units. Cash flows from operating activities is one of outputs since they provide an index of gauging the value of a company. Even though a company obtains a profit, it can still fail to pay when the cash flows are not sufficient.



<Figure 1> Variables of DEA

2) Variables of Tobit regression.

(1) Independent Variables

To investigate the factors affecting a firm's level of inefficiency, the following set of hypotheses and variables are selected.

- ① The degree of globalization of each country decreases the inefficiency.

Globalization index³⁾ announced by A.T.Kearney and ForeignPolicy are employed in the variable to closely examine the relationship between globalization and the inefficiency.

Trade and FDI indexes in globalization reports are chosen as another independent variables. Also the international organization index is included in the metrics as it represents an organization's activities that promote interactions with members in various fields and which are applied by global standard.

- ② The capability of infrastructures of individual

1) OSIRIS is a comprehensive database of listed companies around the world. It contains a wide range of financial and complementary information.

2) Bureau van Dijk Electronic Publishing is one of Europe's leading electronic publishers of business information.

3) www.ForeignPolicy.com

nation diminishes the inefficiency.

Airport, seaport, and complementary resources scores, surveyed by United States International Trade Commission in 2005, are applied to represent the second factor. The airport score summarizes the speed and cost of processing cargo through airports, both overall and for individual cargo procedures. The seaport score reviews the speed and cost of processing cargo through seaports, both overall and for individual cargo procedures, including the cost of repositioning equipment. The complementary resources score captures the presence of complementary resources such as labor, financing, and inland transport.

③ The degree of regulatory declines the inefficiency.

To investigate the third hypothesis, the regulatory, security burden, and customs scores surveyed by United States International Trade Commission in 2005 are considered. The regulatory score captures the presence or absence of certain restrictions, their impact on costs and productivity, the degree of transparency of regulation, and the degree to which foreign firms receive the same treatment as domestic firms. The security burden score depicts the effect of security procedures on efficiency. The customs score includes all information on the quality, efficiency, and cost of customs procedures, whether or not it is specific to airports, seaports or even to any other mode.

(2) Dependent Variables

Dependent variable is the inefficiency score which results from 1 minus technical efficiency. The relationship between annual inefficiency and the factors are not the main point this categorized nation, which headquarters of listed companies are located is more important in the study.

2. The results

1) Analysis of efficiency

(1) Descriptive Statistics on Data

Before analysing the results of this study, < Table 1 > shows the basic statistical properties of the selected global logistics companies' annual input and output variables.

An average change of input variables shows that all input variables have grown up externally with constant increase. Number of employees increased from 6750 in 2001 to 7405 in 2005, operating cost increased to \$1330 million from \$960 million, and fixed asset also increased from \$1020 million in 2001 to \$1400 million in 2005.

An average change of output also shows growth; operating revenue increased to \$140 million in 2005 from \$60 million in 2001, and cash flow through business activities doubled from \$80 million to \$160 million.

<Table 1> Statistical Description on Input and Output Data

			2001	2002	2003	2004	2005
I N P U T	Number of employees	Max	371,000	375,890	375,096	384,000	502,545
		Min	1	1	1	1	1
		Ave.	6,750	6,818	6,681	7,039	7,405
	Operating Cost (mil. USD)	Max	27,688	39,794	45,965	53,691	47,726
		Min	25	87	24	30	35
		Ave.	960	1,094	1,176	1,323	1,330
	Fixed Asset (mil. USD)	Max	30,009	30,866	31,405	32,299	33,295
		Min	53	68	72	162	291
		Ave.	1,028	1,133	1,230	1,331	1,400
O U T P U T	Cash Flow (mil. USD)	Max	3,795	4,646	5,881	7,361	5,514
		Min	0.0001	0.0001	0.0001	0.0001	0.0001
		Ave.	86	111	126	159	166
	Operating Revenue (mil. USD)	Max	3,962	4,096	4,473	5,513	6,143
		Min	0.0001	0.0001	0.0001	0.0001	0.0001
		Ave.	62	77	89	121	140

It shows that global logistics industry has made growth both externally and internally.

(2) Overall Efficiency

Below <Table 2> shows the averages of technical efficiency, pure technical efficiency, and scale efficiency of the logistics companies which have performed continuous business activities from 2001 to 2005. The efficiencies was calculated as the arithmetic mean.

<Table 2> Efficiency by year

	TE	PTE	SE
2001	0.245	0.384	0.638
2002	0.205	0.338	0.607
2003	0.294	0.469	0.627
2004	0.135	0.309	0.437
2005	0.220	0.288	0.764
Ave.	0.220	0.358	0.614

Technical efficiency can be calculated by CCR Model which assumes CRS (Constant Return to Scale). Technical efficiency in 2001 measured by CCR Model is 0.245 which means that management efficiency of the industry all over the world is only 24.5% and 75.5% is the inefficiency they have.

The reason for decreased efficiency in 2002 is due to the effect of World Trade Center terror on September 11, 2001, and the reason of such decrease in 2004 is due to increased oil price caused by Iraq War(Doganis, 2006). The reason why overall technical efficiency was low until 2005 is because it included inefficiency from failing economies of scale while accomplishing it as the critical factor to Asset-based companies.

Pure Technical Efficiency measured through BCC Model, which assumes VRS (Variable Return to Scale), signifies that the removal of the inefficiency of scale from technical efficiency. It showed efficiencies as low as 38.4% in 2001, 33.8% in 2002, 46.9% in 2003, 30.9% in 2004, and 28.8% in 2005.

In analyzing technical efficiency, pure technical

efficiency, and scale efficiency with the mean value in five years, technical efficiency is 0.220, which means that 78% of inefficiency existed. This indicates that 78% of input can be saved by efficient management while 78% of inefficient output exists.

Pure technical efficiency is 0.358 which means it has 64.2% inefficiency. Scale efficiency is the quotient of technical efficiency by pure technical efficiency, which resulted in 0.614; therefore it still has remaining 38.6% inefficiency.

Because efficiency of scale has been bigger than pure technical efficiency for the last five years, technical inefficiency of global logistics companies is more influenced by pure technical inefficiency than inefficiency of scale. Therefore, technical efficiency can be increased by decreasing pure technical inefficiency.

It can be founded that the average standard deviation of technical efficiency is 0.0582 from year to year standard deviation of efficiency value. When one looks into it more specifically, it can be seen that the efficiency declination of scale is 0.1165, which is big, and it seems that the declination appeared by decreasing efficiency of small and medium sized companies.

(3) Efficiency by Nations

Below <Table 3> shows the value of technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) of nations. There were 32 nations of companies in the study however, 13 countries, which had less than five companies in the nation, were excluded from the study. The efficiencies are the arithmetic means categorized into nations in which company's headquarter located.

Denmark received the highest TE and PTE averages in the 5 years. Norway ranked the highest in SE.

2) Results from Tobit Model

It operated jointly significance test by selecting

<Table 3> Efficiency of Nations

	TE	PTE	SE
Canada	0.188	0.360	0.522
US	0.181	0.336	0.539
Denmark	0.440	0.630	0.698
France	0.185	0.321	0.576
Germany	0.142	0.347	0.409
Italy	0.248	0.331	0.749
Netherlands	0.198	0.394	0.503
Norway	0.335	0.396	0.846
Sweden	0.167	0.367	0.455
Switzerland	0.138	0.344	0.401
UK	0.203	0.338	0.601
China	0.301	0.402	0.749
HongKong	0.311	0.462	0.673
Japan	0.163	0.225	0.724
Taiwan	0.216	0.314	0.688
Malaysia	0.262	0.358	0.732
Singapore	0.264	0.400	0.660
Thailand	0.303	0.430	0.705
Korea	0.226	0.399	0.566

various related factors to prove the assumption, and set the basic assumption like this to approve.

$$H_0 : \beta_j = \beta_i = \dots = \beta_k = 0$$

$$H_1 : \text{at least one of } \beta \text{ is not } 0$$

A negative coefficient means positive effect to the efficiency, since each independent variable is related with the inefficiency.

(1) Effects of Globalization

Inefficiency decreases as globalization proceeds from below table. But just economical or political globalization did not influence much. In other words, globalization influences(GI) all sectors such as culture, politic and society.

(2) Effects of infrastructures

Physical factors such as airport, seaport out of

<Table 4> Effects of globalization

	Coef.	Std.Err.	t	P> t
Trade	0.0016	0.0010	1.62	0.121
Int'l Org.	0.0010	0.0011	0.88	0.388
FDI	0.0009	0.0010	0.91	0.374
GI	-0.0023	0.0013	-1.85	0.078
Cons.	0.7329	0.0390	18.80	0.000

various infrastructures also influence to inefficiency. But infrastructures related with software such as labor, financial service influence more.

<Table 5> Effects of infrastructures

	Coef.	Std.Err.	t	P> t
Airport	0.0378	0.0321	1.18	0.252
Seaport	0.0207	0.0369	0.56	0.580
Comp.	0.340	0.0143	-2.38	0.026
Cons.	0.6257	0.1079	5.80	0.000

(3) Effects of regulatory

The degree of transparency of regulation, the degree to which foreign firms receive the same treatment as domestic firms, and the impact on costs and productivity make bigger effect than policy related with just simple security or customs.

<Table 6> Effects of regulatory

	Coef.	Std.Err.	t	P> t
Regulatory	-0.0454	0.0169	-2.69	0.013
Burden of Security	0.0123	0.0160	0.77	0.450
Customs	0.0139	0.0194	0.72	0.481
Cons.	0.7077	0.0957	7.40	0.000

(4) Implications from Results

Firstly, inefficiency of logistics industry is influenced by effectiveness and clearness of policy and treatment of foreign companies. Therefore, policy planner should focus on the effectiveness, let logistics companies perform efficiently, and reduce uncertainty by raising the degree of transparency of regulation.

Secondly, although inefficiency of logistics industry is influenced by physical factors, it is influenced more by software such as labor and financial support. So support is needed for logistics companies to run their business smoothly by increasing investment on software.

Thirdly, although globalization of companies is important, effort to increase efficiency by sharing globalization's profit through globalization of one country is necessary. It needs to diffuse not only

economic integration but also political engagement, technological connectivity, and personal contact point to do so.

IV. Conclusions

Data Envelopment Analysis is used in this study to measure the efficiency of the logistics industry across several countries for the period of 5 years. The results showed that the industry has grown which more than doubled for the past 5 years. The study also revealed that the overall TE is 0.220 which means that it has been 78% inefficient. PET is 0.358 which means that 64.2% of inefficiency exists. Scale Efficiency is the value of Technical Efficiency divided by Pure Technical Efficiency which is 0.614 and thus it has 38.6% of inefficiency remaining.

Because Scale Efficiency has been bigger than Pure Technical Efficiency for the last 5 years, Technical Inefficiency of the logistics industry is caused more by Pure Technical Inefficiency than the inefficiency of scale. Therefore, Technical Efficiency can be increased by decreasing its Pure Technical Inefficiency.

In case of efficiency by nation, Denmark has the highest in TE and PTE and Norway has the highest in SE.

As a result of assessing the factors influencing the inefficiency of logistics companies through Tobit model, it was found that the general level of globalization, complement score and regulatory score do have a significant influence on inefficiency.

The general level of globalization should be high enough in economic integration with the world economy as well as society, politics and culture. Although airport and seaport are important to the industry, software such as labor, financial service influence more. Indirect factors such as effectiveness and clearness of policy are more important than direct and specific factors such as tariff and burden of security in policy.

Through this study, it advocates that policy planners should consider effectiveness and clarity of policy which influence the efficiency level of the logistics industry. Also, it found that labor and financial support can have a significant impact on efficiency. Based on these findings, the Korean government authorities should cultivate men of ability and propel financial support to be a developed country in the industry.

The major limitation of this study is that it is only based on secondary data without taking into account the likely effects of such principal events as September 11 or the rapid escalation in the price of aviation fuel. In addition, the study was conducted to include only those factors which influence inefficiency and the present condition of efficiency, but short of setting up a forecasting model.

Future possible research is to explore other ways to measure efficiency by using stochastic frontier analysis or using a production function except DEA so that a comparative study of their respective results can be made. Moreover, further study can be done to investigate further the relationship between principal events and microscopic factors, how principal events can influence efficiency and to set up a forecasting model.

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