Returns to Scale, Technical Change and the Demand for Factors in Korean Water Transport Industry

*Ho Soo Nah**

한국수상운송산업의 규모의 경제, 기술변화 그리고 생산요소수요

나 호 수

요 약

본 논문에서는 1970년 부터 1989년의 기간에 한국의 수상운송산업에서 규모의 경제가 존재했었는지 그리고 기술변화는 어떤 형태로 야기되어 왔는지를 살펴 보고 각 생산요소의 자체 및 교차탄력성을 측정하고자 한다. 특히 해운합리화조치의 결과는 실증분석에서 어떻게 나타나고 있는지에 관심을 둔다. 실증결과는 기술변화의 측정치가 계속 음의 값을 보여 오다가 80년 중반 이후에 양의 값을 가짐을 보여 준다. 또한 규모의 경제는 존재하나 그 정도가 계속 감소되어 왔음을 보여 준다. 이러한 결과는 한국수상운송산업의 성장과정의 측면에서 도출되는 직관적인 생각과 일치되는 것으로 해석할 수 있다. 그리고 노동 및 자본 절약적 기술변화와 중간재 사용적 기술변화가 야기되었음을 보여 준다.

1. Introduction

Since the 1960s Korean government has adopted the export-oriented strategy of economic development and Korean economy has experienced phenomenal economic growth and export expansion[1]. As a result of successful economic growth, the volume of export and import has grown very rapidly and the demand for freight transportation has increased at a formidable pace. In this situation Korean government acknowledged the necessity to transport this export and

* Department of International Trade, College of Social Sciences, Korea Maritime University, Pusan, Korea

1) For the recent study of Korean economy, see Kuznets(1988). This study indicates the export expansion as a reason of rapid economic growth.

import timely and stably and to protect the water transportation industry which remained in the infant industry in the 1960s. By virtue of this protective policy of the water transportation industry, the volume of Korean ships increased very rapidly in the 1970s[2]. Facing with the worldwide economic recession in the early 1980s, Korean water transport industry had some difficulties in competing with foreign firms because of the weakened competitiveness of this industry. To overcome this difficult state of Korean firms, Korean government started the so-called rationalization of Korean water transport industry in 1984. In this paper we explore the technology structure of Korean water transport industry on an aggregate level and estimate numerous parameters derived from a flexible cost function. From these parameters we calculate the own and cross-elasticities of substitution and factor price, and measure the degree of economies of scale and technical change.

Intuitively we can think that this industry enjoyed the considerable benefits from the rapid expansion of scale in the 1970s, but experienced the inefficiency of capital due to the excessive quantitative expansion of capital neglecting the qualitative improvement of capital structures. Therefore we can expect that the benefit of economies of scale has been lessened gradually. We are also concerned with the comparison of technical change before and after the rationalization of this industry.

This paper's organization is as follows. In section 2, we describe the theoretical model to analyze our concerns. In section 3, we present the empirical results, that is, parameter estimates, various elasticities, the measures of technical change and bias, and the degree of returns to scale.

2. The Theoretical Model

We employ the translog cost function which is developed by Christensen, Jorgenson and Lau(1973). This function is a second-order Taylor expansion around an arbitrary point of a function. We assume one output and n inputs. The translog cost function is described as follows[3].

$$\begin{aligned} ln\ C &= \alpha_0 + \alpha_t T + 1/2\ \alpha_{tt}\ T^2 + \alpha_y\ ln\ Y + 1/2\ \alpha_{yy}(ln\ Y)^2 \\ &+ 1/2 \sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij}\alpha_{yt}\ ln\ P_i\ ln\ P_j + \sum_{i=1}^{n} \alpha_{it}\ \alpha_{ty}\ ln\ P_i\ ln\ Y \\ &+ \sum_{i=1}^{n} \alpha_{yt}\ ln\ P_i\ ln\ Y + \sum_{i=1}^{n} \alpha_{it}\ T\ ln\ P + \alpha_{yt}\ T\ ln\ Y \end{aligned} \quad (1)$$

2) For the protective policy of Korean transport industry, see Pak, Shin and Nah(1989).
3) For the studies of Korean economy using translog function, see Kwon and Williams(1982), Kwon(1986) and Kim and Pak(1989). These studies deal with manufacturing sectors.

where C is total cost, P_i and P_j are i-th and j-th factor prices, Y is output and T is technology index which is assumed to shift uniformly following the time path. From the equation (1) we can obtained the derived demand for factors using Shephard's Lemma. These are obtained in the form of cost share equations of each input as follows.

$$S_i = \partial\ ln\ C / \partial\ ln\ P_i$$
$$= \alpha_i + \alpha_{ii}\ ln\ P_i + \sum_{j=1}^{n} \alpha_{ij}\ T\ ln\ P_i + \alpha_{yt}\ T\ ln\ Y \qquad (2)$$

where $i=1, 2 \cdots n$ and S_i is the cost share of i-th input.

Following Diewert(1971), a cost function dual to a production function will exist if it satisfies adding up condition and symmetry condition as follows : (i) $\sum_{i=1}^{n} S_i = 1$ (adding up condition) (ii) $\alpha_{ij} = \alpha_{ji}$ (symmetry condition), $_{i,j=1,2\cdots n}$.

Considering the data constraint of the Korean water transport industry, we assume three factors, that is, capital(K), labor(L) and materials(M). We also assume linear homogeneity in factor prices. Using the adding up condition, symmetry conditions and these linear homogeneity conditions, we can obtain the following three resultant equations which are used in estimating the technology paramters in the Korean water transportation industry.

$$\begin{aligned} ln\ C = & \alpha_0 + \alpha_y\ ln\ Y + \alpha_{yy}\ (ln\ Y)^2 + \alpha_t T + \alpha_{tt}\ T^2 + \alpha_{yt}\ T\ ln\ Y \\ & + \alpha_k\ ln\ (P_k/P_m) + \alpha_l\ ln\ (P_l/P_m) + \alpha_{kk}\{ln(P_k/P_m)\}^2 \\ & + \alpha_{ll}\{ln\ (P_l/P_m)\}^2 + \alpha_{kl}\ ln\ (P_k/P_m)\ ln\ (P_l/P_m) \\ & + \alpha_{ky}\ ln\ (P_k/P_m)\ ln\ Y + \alpha_{ly}\ ln\ (P_l/P_m)\ ln\ Y \\ & + \alpha_{kt}\ T\ ln\ (P_k/P_m) + \alpha_{lt}\ T\ ln\ (P_l/P_m) \end{aligned} \qquad (3)$$

$$\begin{aligned} S_k = & \alpha_k + \alpha_{kk}\ ln\ (P_k/P_m) + \alpha_{kl}\ ln\ (P_l/P_m) \\ & + \alpha_{ky}\ ln\ (P_k/P_m)\ ln\ Y + \alpha_{ky}\ T\ ln\ Y \end{aligned} \qquad (4)$$

$$\begin{aligned} S_l = & \alpha_l + \alpha_{ll}\ ln\ (P_l/P_m) + \alpha_{kl}\ ln\ (P_k/P_m) \\ & + \alpha_{ly}\ ln\ (P_l/P_m)\ ln\ Y + \alpha_{ly}\ T\ ln\ Y \end{aligned} \qquad (5)$$

For the other six parameters (α_m, α_{mm}, α_{km}, α_{lm}, α_{my} and α_{mt}) adding up conditions and linear homogeneity conditions are used[4].

Uzawa(1962) has derived the Allen partial elasticities(AES) of substitution between input i and j as

4) These six parameters are obtained as the following equations.

$\alpha_m = 1 - \alpha_k - \alpha_l,\ \alpha_{km} = -\alpha_{kk} - \alpha_{kl} = -\alpha_{ll} - \alpha_{kl},$

$\alpha_{my} = -\alpha_{ky} - \alpha_{ly},\ \alpha_{mt} = -\alpha_{kt} - \alpha_{kt},\ \ \alpha_{mm} = -\alpha_{my} - \alpha_{mm}.$

$$\sigma_{ij}=C\ C_{ij}/C_i\ C_j,\quad _{i,j=K,L,M} \tag{6}$$

where C is cost function, $C_i=\partial C/\partial P_i$ and $C_{ij}=\partial^2 C/\partial P_i \partial P_j$.

By definition, $\sigma_{ij}=\sigma_{ji},\ _{i,j=K,L,M.}$[5] In the translog cost function the AES's are given as follows.

$$\sigma_{ii}=(\alpha_{ii}+S_i^2-S_i)/S_i^2,\quad _{i=K,L,M} \tag{7}$$

$$\sigma_{ij}=(\alpha_{ij}+S_i\ S_j)/S_iS_j,\quad _{i,j=K,L,M} \tag{8}$$

These AES's are not constrained to be constant but may vary with the values of the cost shares. The price elasticities of demand for factors are defined as follows.

$$\varepsilon_{ij}=\partial\ ln\ x_i/\partial\ ln\ P_j,\quad _{i,j=K,L,M} \tag{9}$$

where x_i is i-th input level and output and all the other inputs are fixed. Allen(1938) showed that the AES's are analytically related to the price elasticities of demand for factors of production as follows.

$$\varepsilon_{ij}=S_i\ \sigma_{ij},\quad _{i,j=K,L,M} \tag{10}$$

In our model we assume the non-constant returns to scale. To calculate the measure of returns to scale, we have to estimate the output elasticitiy of cost(ε_{cy}).

$$\begin{aligned}\varepsilon_{cy}&=\partial\ ln\ C/\partial\ ln\ Y\\ &=\alpha_y+\alpha_{yy}\ ln\ Y+\alpha_{yk}\ ln\ P_k+\alpha_{yl}\ ln\ P_l\\ &\quad+\alpha_{ym}\ ln\ P_m+\alpha_{yt}\ T\end{aligned} \tag{11}$$

The measure of returns to scale(RTS) is given as follows.

$$RTS=1-\varepsilon_{cy} \tag{12}$$

We can measure the rate of technical change (ROTC) and its biases (BOTC).

$$\begin{aligned}ROTC&=-\partial\ ln\ C/\partial\ T\\ &=-(\alpha_t+\alpha_y\ ln\ Y+\alpha_{kt}\ ln\ P_k+\alpha_{lt}\ ln\ P_l)\end{aligned} \tag{13}$$

$$BOTC=\partial\ S_i/\partial\ T=\alpha_{it},\quad _{i=K,L,M} \tag{14}$$

Total factor produtivity growth(TFPG) is defined as the negative of the change in average cost with input prices held constant. It can be shown that total factor productivity growth has the

5) This holds good because $C_{ij}=C_{ji}$, which is called Young's theorem.

following relationship with the output elasticity of cost(ε_{cy}) and the rate of technical change(ROTC).[6]

$$TFPG = (1-\varepsilon_{cy})\partial \ ln \ Y/\partial \ T + ROTC \tag{15}$$

Assuming constant returns to scale means that RTS=0 or $\varepsilon_{cy}=1$. Therefore total factor productivity growth is equal to the rate of technical change. But if returns to scale are either increasing ($\varepsilon_{cy}<1$) or decreasing ($\varepsilon_{cy}>1$), then total factor productivity growth will differ from the rate of technical change.

3. Empirical Results

The data used to estimate the cost structure and derived demands for factors cover the period 1970-1989 for the Korean water transportation industry. Those data consist of output, factor prices and cost shares of these factor services. As a proxy of output in this industry, we use the total volumes of overseas and coastal freight transportation measured in terms of ton-km, which are obtained in the 'Main Statistics of Korean Economy' published annually by Economic Planning Board. We use the wholesale price indices of materials for the price of materials which are obtained in the 'Economic Statistics Yearbook' published by Bank of Korea. As there are no confident wage data of this industry, we use labor costs per employee which are calculated in the 'Analyses of Business Management'. For the rental prices of capital, we calculate the ratios of capital cost to total cost. Capital cost is obtained from the value added minus total labor cost. For the resultant rental price indices of capital, we use the wholesale price indices multiplied by the rental prices. The cost shares of capital, labor and materials are calculated from the data of 'Analyses of Business Management'.

1) Parameter estimates

The estimation method of this model is full information maximum likelihood estimation method. For parameter computation, we use the software package of TSP, version 4.0.

Table 1 shows those parameter estimates.

6) For this relationship, see Levy and Jondrow(1986).

<Table 1> **Full information maximum likelihood parameter estimates of translog cost function for the Korean water transport industry in 1970-1989[a)]**

Parameter		Parameter		Parameter	
α_0	2.177	α_m	0.492	α_{ky}	−0.007
	(0.006)		(0.549)		(−0.014)
α_t	−0.161	α_{kk}	0.058	α_{ly}	0.030
	(−0.005)		(1.810)		(0.273)
α_{tt}	0.005	α_{ll}	0.015	α_{my}	−0.024
	(0.003)		(1.260)		(−0.062)
α_y	8.528	α_{mm}	0.173	α_{kt}	−0.002
	(0.029)		(3.272)		(−0.040)
α_{yy}	4.279	α_{kl}	0.050	α_{lt}	−0.007
	(0.033)		(1.978)		(−0.466)
α_k	0.268	α_{km}	−0.108	α_{mt}	0.009
	(0.244)		(−2.901)		(0.186)
α_l	0.240	α_{lm}	−0.065	α_{yt}	−0.412
	(0.918)		(−2.989)		(−0.027)
log of likelihood function	127.437				
ln C-equation[b)] :		R^2	0.989	D.W.[c)]	1.284
S_k-equation :		R^2	0.996	D.W.	1.704
S_l-equation :		R^2	0.997	D.W.	1.023

a) The ratio of parameter estimates to asymptotic standard errors are given in parentheses.
b) R^2's are calculated as unity minus the ratio of the sum of squared residuals to the sum of squared dependent variables.
c) D.W.'s mean Durbin-Watson Statistics.

The fitting of this model is quite good. The approximate R^2's are very high. But many t-values of estimated coefficients are statistically insignificant. Durbin-Watson statistics show that the autocorrelations of disturbance in each equation are inconclusive or rejected.

2) Elasticities of substitution for factors

Table 2 present the own-and cross-elasticities of substitution for capital, labor and materials. The own elasticities of substitution for labor are highest, those of materials are lowest and those of capital are in the middle. This implies that Korean firms in this industry are very sensitive to the fluctuation of labor price, whereas they are not sensitive to the price fluctuation of materials. This shows the inflexibility of the exogenous price change of materials and the easiness to adjust labor demands because of weak labor unions.

The cross-elasticities of substitution show that each factor has a substitutable relationship with other factors. In particular the substitution between capital and labor is very strong. This result seems to have some relation with the inflexibility of the cost of materials.

<Table 2> **The own-and cross-elasticities of substitution of factors for the Korean water transport industry in 1970-1989**

	σ_{kk}	σ_{mm}	σ_{ll}	σ_{km}	σ_{kl}	σ_{lm}
1970	−1.770	−0.285	−3.763	0.278	1.896	0.350
1971	−1.802	−0.272	−3.894	0.281	1.937	0.343
1972	−1.736	−0.280	−3.979	0.295	1.925	0.323
1973	−1.757	−0.265	−4.210	0.304	1.982	0.304
1974	−2.137	−0.169	−5.252	0.276	2.441	0.258
1975	−2.394	−0.128	−5.619	0.230	2.733	0.252
1976	−2.335	−0.129	−5.841	0.249	2.751	0.223
1977	−2.053	−0.193	−4.877	0.280	2.292	0.285
1978	−2.179	−0.181	−4.722	0.249	2.330	0.317
1979	−2.398	−0.147	−4.935	0.207	2.533	0.322
1980	−2.185	−0.154	−5.562	0.275	2.557	0.233
1981	−2.228	−0.126	−6.550	0.289	2.869	0.131
1982	−2.225	−0.125	−6.606	0.291	2.882	0.125
1983	−2.731	−0.019	−5.736	0.141	3.077	0.276
1984	−2.551	−0.103	−5.966	0.199	2.979	0.234
1985	−2.637	−0.088	−6.280	0.183	3.170	0.211
1986	−2.475	−0.081	−7.626	0.251	3.461	0.043
1987	−2.404	−0.093	−7.302	0.263	3.272	0.071
1988	−2.290	−0.107	−7.214	0.287	3.127	0.065
1989	−2.262	−0.116	−6.868	0.287	2.994	0.100

3) Price elasticities of factors

In Table 4, The own-price elasticities of factors are presented.

<Table 3> **The own-price elasticities of factors for the Korean water transport industry in 1970-1989.**

	ε_{kk}	ε_{mm}	ε_{ll}
1970	−0.511	−0.148	−0.728
1971	−0.512	−0.144	−0.731
1972	−0.509	−0.146	−0.733
1973	−0.510	−0.142	−0.738
1974	−0.519	−0.104	−0.751
1975	−0.516	−0.083	−0.753
1976	−0.517	−0.084	−0.754
1977	−0.518	−0.114	−0.748
1978	−0.519	−0.109	−0.746
1979	−0.516	−0.093	−0.748
1980	−0.519	−0.097	−0.753
1981	−0.518	−0.082	−0.753
1982	−0.518	−0.082	−0.753
1983	−0.501	−0.062	−0.753
1984	−0.510	−0.069	−0.754
1985	−0.506	−0.060	−0.754
1986	−0.513	−0.056	−0.747
1987	−0.515	−0.064	−0.750
1988	−0.518	−0.072	−0.750
1989	−0.518	−0.077	−0.752

We can observe that materials are not only very insensitive but also become more insensitive to the price change of materials. But those of capatal and labor have maintained their early values steadily.

Table 4 shows the cross-price elasticities of factors. In this table we can observe that the elastcities between materials and other factors are relatively low and those between capital and labor are relatively high. In particular the effects of capital and labor price changes on materials are very low. Probably this is due to the exogenous property of materials in Korean economy.

<Table 4> The cross-price elasticities of factor demands for the Korean water transportation industry in 1970-1989

	ε_{km}	ε_{mk}	ε_{kl}	ε_{lk}	ε_{ml}	ε_{lm}
1970	0.144	0.080	0.367	0.547	0.068	0.181
1971	0.148	0.078	0.364	0.550	0.064	0.181
1972	0.154	0.068	0.355	0.565	0.060	0.169
1973	0.163	0.088	0.348	0.576	0.053	0.162
1974	0.170	0.067	0.349	0.592	0.037	0.159
1975	0.149	0.049	0.366	0.588	0.034	0.164
1976	0.162	0.055	0.355	0.609	0.029	0.145
1977	0.167	0.071	0.351	0.578	0.044	0.169
1978	0.150	0.059	0.368	0.554	0.050	0.192
1979	0.131	0.045	0.384	0.545	0.049	0.204
1980	0.173	0.065	0.346	0.607	0.031	0.146
1981	0.188	0.067	0.330	0.667	0.015	0.086
1982	0.190	0.068	0.329	0.672	0.014	0.081
1983	0.097	0.026	0.404	0.564	0.036	0.189
1984	0.134	0.040	0.376	0.596	0.030	0.158
1985	0.126	0.035	0.380	0.609	0.025	0.145
1986	0.174	0.052	0.339	0.718	0.004	0.030
1987	0.179	0.056	0.336	0.701	0.007	0.048
1988	0.192	0.065	0.325	0.707	0.007	0.043
1989	0.190	0.066	0.328	0.686	0.011	0.066

4) Output elasticities of cost, returns to scale, rates of technical change and total factor productivity growth

From the table 5 the interesting points can be described as follows.

First, the effect of scale expansion has been lessened rapidly. It seems that at the early stage of economic growth, the effects of scale expansion on cost reducement were very high, but gradually capital inefficiency has increased because of excessive quantitative expansions of capital without qualitative improvement of this industry. It is interesting that scale expansions provide this industry with the cost reducement.

Second, rates of technical change had had negative values by 1986 and have had positive values since 1987. In the mid-1980s those values are improved very rapidly, which is due to the rationalization and reorganization of this industry by the strong leads of government.

<Table 5> **The output elasticities of cost, returns to scale, rates of technial change and total factor productivity growth for Korean water transport industry In 1970-1989.**

	ε_{cy}	RTS	ROTC	TFPG
1970	−1.742	2.742	−0.794	n.a.
1971	−1.265	2.265	−0.713	−0.190
1972	−1.123	2.123	−0.665	−0.369
1973	−0.578	1.578	−0.577	−0.184
1974	−0.856	1.856	−0.571	−0.508
1975	−0.833	1.833	−0.534	−0.339
1976	−0.725	1.725	−0.489	−0.266
1977	−0.296	1.296	−0.412	−0.130
1978	−0.185	1.185	−0.367	−0.211
1979	0.184	0.816	−0.297	−0.132
1980	−0.227	1.227	−0.303	−0.302
1981	−0.043	1.043	−0.250	−0.096
1982	0.606	0.394	−0.122	−0.043
1983	0.555	0.445	−0.153	−0.083
1984	0.526	0.474	−0.090	−0.046
1985	0.333	0.667	−0.073	−0.039
1986	0.411	0.589	−0.031	0.040
1987	0.508	0.492	0.014	0.075
1988	0.613	0.387	0.059	0.109
1989	0.282	0.718	0.063	0.762

Third, total factor productivity growth had negative values from 1970 to 1985, but since 1986 it has had positive values. We can interpret the total factor productivity as the sum of the effects of scale expansion and technical change. These two effects have reverse effects on the average cost. Therefore during the period 1970-1985 negative technical change effects predominated the effects of scale change, but in 1986 vice versa. Since 1987 two effects have the same directions in the effects of cost diminution. This result is in accordance with our intuitive thinking.

Fourth, parameter estimates show that this industry have experienced capital-saving, labor-saving and materials-using technical change. But these tecnical biases are very modest.

4. Conclusion

We attempted to estimate the cost structure and the derived demands for factors in the Korean water transportation industry. The important and interesting points are summarized as follows.

First, the own-elasticities of substitution and the own-price elasticities of materials are relatively low, but those of labor are a little high.

Second, the interactions between capital and labor are strong, whereas those between materials and other factors are weak.

Third, Returns to scale have existed in this industry, but the benefits from the scale expansion have been lessened.

Fourth, while technical regress had taken place by the mid-1980s, technical progress has taken place since the mid-1980s.

Fifth, total factor productivity had been lowered by the mid-1980s due to the predominance of technical change effects over scale effects, but since that time total factor productivity has grown a little rapidly.

Sixth, policy implication from this empirical result is that policy authority should make efforts to maintain the appropriate scale of this industry and give some incentives to improve the viability of this industry in the long run. Temporary incentives rather may undermine the competitiveness of this industry. Each firm has to increase the human investment to improve the quality of labor and take pains to elevate the management ability and efficient operations of productive factors.

There are some suggestions for further studies.

First, there is a need to increase the number of factors. Two kinds of capital, labor and materials can be used in this model.

Second, the more appropriate data are required to explore the exact policy implications.

Third, this model should be expanded including the process of dynamic optimization.

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