Technical Change and Returns to scale
in the Korean Shipping Industry

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한국해운산업의 기술변화및 규모의 경제에 관한 연구

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국문요약

본 논문에서는 1968년부터 1988년의 기간에 한국의 해상운송산업에서 규모의 경제가 존재했었는지 그리고 기술변화는 어떤 형태로 야기되어 왔는지를 살펴 보고 특히 해운합리화조치로 인한 실증분석의 결과에 우선적인 관심을 둔다. 실증결과는 기술변화의 측정치가 계속 음의 값을 보여 오다가 80년 중반 이후에 양의 값을 가짐을 보여 준다. 또한 규모의 경제는 70년대 말까지는 존재하다가 80년대 이후 규모의 불경제를 보여주고 있다. 이러한 결과는 한국해운산업의 양적성장과 질적성장의 동시적인 추구가 필요함을 보여준다.

1. Introduction

There are two kinds of stratagies by which less-developed countries are able to enhance their economies to industrialised economies. The one is import substitution strategy and the other, export-promotion strategy. The former is referred to as inwrad-looking strategy, while the latter is referred to as outward-looking strategy[1].

Since the 1960s Korean government has adopted the outward-looking strategy of economic development. As a result of that, Korean economy has experienced phenomenal economic growth and export expansion[2]. Its choice might be a forceful one in that there were deficient resources in South Korea.

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1) Sometimes the word "looking" is replaced by the word "oriented". See the chapter 11 the Kenen (1989)'s book for these two kinds of development strategies.
2) For the recent study of Korean economy, see Kuznets(1988). This study indicates the export expansion as a reason of rapid economic growth.

Together with 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 import timely and stably and to protect the shipping industry which remained in the infant industry in the 1960s. In particular, at that time Korean government officials felt that the growth of shipping services industry would make good contributions to earning the foreign income to be utilized in developing the Korean economy. The Korean government have pursued many protective policies to increase the productive capacity of the Korean Shipping Industry[3]. By virtue of this protective policy of shipping industry, the volume of Korean ships has increased very rapidly in the 1970s[4]. Facing with 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 Shipping Industry on an aggregate level and estimate numerous parameters derived from a flexible cost function. From these parameters we calculated the own-and cross-elasticities of substitution and price for factors, 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, measures of technical change and the degree of returns to scale.

2. The 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[5].

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3) For the process of growth of the Korean Shipping Indastry, see Lee(1990).

4) For the Protective policy of Korean Water Transport Industry, See Pak, Shin and Nah(1989).

5) 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.

$$\ln C = \alpha_0 + \alpha_t T + \frac{1}{2}\alpha_{tt}T^2 + \alpha_y \ln Y + \frac{1}{2}\alpha_{yy}(\ln Y)^2$$

$$+ \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}\alpha_{yt}\ln P_i \ln P_j + \sum_{i=1}^{n}\alpha_{ti}\alpha_{ty}\ln P_i \ln Y$$

$$+ \sum_{i=1}^{n}\alpha_{yt}\ln P_i \ln Y + \sum_{i=1}^{n}\alpha_{ti}T\ln P + \alpha_{yt}T\ln Y \tag{1}$$

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.

$$S_i = \partial \ln C / \partial \ln P_i$$

$$= \alpha_i + \alpha_{ii}\ln P_i + \sum_{j=1}^{n}\alpha_{ij}T \ln P_i + \alpha_{yt}T \ln Y \tag{2}$$

where i=1, 2, ……, n and S_i is the cost share of i‑th input.

Following Diewert(1971), a cost functin dual to a production function will exist if it satisfies adding up condition and symmetry condition as follows : (i) $\Sigma S_i = 1$(adding up condition) (ii) $a_{ij} = a_{ji}$(symmetry condition), i=1, 2, ……, n.

Considering data constraint of 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 contions and this linear homogeneity conditions, we can obtain the following three resultant equations used in estimating the technology parameters in Korean water transportation industry.

$$\ln C = \alpha_0 + \alpha_y \ln Y + \frac{1}{2}\alpha_{yy}(\ln Y)^2 + \alpha_t T + \frac{1}{2}\alpha_{tt}T^2 + \alpha_{yt}T \ln Y$$

$$+ \alpha_k \ln(P_k/P_m) + \alpha_l \ln(P_l/P_m) + \frac{1}{2}\alpha_{kk}\{\ln(P_k/P_m)\}^2$$

$$+ \frac{1}{2}\alpha_{ll}\{\ln(P_l/P_m)\}^2 + \alpha_{kl}\ln(P_k/P_m)\ln(P_l/P_m)$$

$$+ \alpha_{ky}\ln(P_k/P_m)\ln Y + \alpha_{ly}\ln(P_l/P_m)\ln Y$$

$$+ \alpha_{kt}T\ln(P_k/P_m) + \alpha_{lt}T\ln(P_l/P_m) \tag{3}$$

$$S_k = \alpha_k + \alpha_{kk}\ln(P_k/P_m) + \alpha_{kl}\ln(P_l/P_m)$$

$$+ \alpha_{ky}\ln(P_k/P_m)\ln Y + \alpha_{ky}T\ln Y \tag{4}$$

$$S_l = \alpha_l + \alpha_{ll}\ln(P_l/P_m) + \alpha_{kl}\ln(P_k/P_m)$$

$$+ \alpha_{ly}\ln(P_l/P_m)\ln Y + \alpha_{ly}T\ln Y \tag{5}$$

For the other six parameters. a_m, a_{mm}, a_{km}, a_{lm}, a_{my} and a_{mt}. adding up conditions and linear

homogeneity conditions are used[6]

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

$$\sigma_{ij} = CC_{ij}/C_i\ C_j, \qquad i,j = K, L, M \tag{6}$$

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. $\sigma_{ij} = \sigma_{ji}$. $i, j = K, L$ and M[7]. In translog cost function the AES's are given as follows.

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

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

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.

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

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.

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

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}).

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

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

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

We can measure the rate of technical change(ROTC).

$$ROTC = -\partial \ln C /\partial T$$
$$= -(\alpha_t + \alpha_{yt}\ln Y + \alpha_{kt}\ln P_k + \alpha_{lt}\ln P_l + \alpha_{mt}\ln P_m + \alpha_{tt}\ T) \tag{13}$$

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6) These six parameters are obtained as the following equations.
  $\alpha_m = 1 - \alpha_k - \alpha_l, \alpha_{km} = -\alpha_{kk} -\alpha_{kl}, \alpha_{lm} = -\alpha_{ll} -\alpha_{kl}$,
  $\alpha_{my} = -\alpha_{ky} -\alpha_{ly}, \alpha_{mt} = -\alpha_{kt} -\alpha_{lt}, \alpha_{mm} = -\alpha_{my} -\alpha_{mm}$.

7) This holds good because $C_{ij} = C_{ji}$. which are called Young's theorem.

3. Empirical Implementation

The data used to estimate the cost structure and derived demands for factors cover the period 1970–1988 for the Korean shipping industry. Those data consist of output, and the prices and cost shares of these factor services. As a proxy of output in this industry, we use the total volumes of oversea and coastal freight transportation measured in terms of ton–km, which are obtained in the 'Main Statisics of Korean Economy' published annually by Economic Planning Board. We use the wholesale price indices of materials for materiasl prics, 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'.

As rental prices of capital, we utilized the user cost of capital which is estimated by the e-quation $P_k = (r + d - dp)$, where r is weighted various interest rates concerning the purchas of ships, d is deprecition rate and dp is the price increase of capital. 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 the 'Analyses of Business Management'.

1) Parameter estimates

The estimation method of this model is full information maximum likelihood estimation

Table 1 Full information maximum likelihood parameter estimates of translog cost function for the Korean Shipping Industry in 1968–1988[a]

Parameter		Parameter		Parameter	
a_0	−8.659	a_m	0.486	a_{ky}	−0.021
	(−1.357)		(3.779)		(−0.534)
a_t	1.066	a_{kk}	−0.003	a_{ly}	0.013
	(1.402)		(−0.054)		(1.058)
a_{tt}	−0.066	a_{11}	0.046	a_{my}	0.008
	(−1.485)		(2.259)		(0.257)
a_y	−2.490	a_{mm}	−0.008	a_{kt}	0.001
	(−0.737)		(−0.122)		(0.067)
a_{yy}	−0.738	a_{k1}	−0.025	a_{lt}	−0.012
	(−0.789)		(−1.175)		(−3.516)
a_k	0.231	a_{km}	0.028	a_{mt}	0.011
	(1.378)		(0.540)		(1.219)
a_1	0.282	a_{1m}	−0.021	a_{yt}	0.265
	(5.462)		(−1.175)		(1.286)
log of likelihood function 154.329					

a) The ratio of parameter estimates to asymptotic standard errors are given in parentheses.

method. For parameter computation, we use the software package of TSP, version 4.0.

Table 1 Shows those parameter estimates.

The fitting of this model is good. In particular, the t-values of the more important coefficients such as a_k, a_1, a_m and a_t are statistically significant. But some t-values of estimated coefficients are statistically insignificant.

2) Elasticities of substitution and price for factors

Table 2 present the own- and cross-elasticities of substitution for capital, labor and materials. The own elasticities of substitution for all factors have negative signs, which is consistent with production theory.

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 materials price flucuation. This shows the inflexibility of exogenous materials price change 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 materials is very strong. This result seems to have some relation with the inflexibility of materials cost.

Table 2 The own- and cross- elasticities of substitution of factors for the Korean shipping industry in 1968-1988.

	σ_{KK}	σ_{LL}	σ_{MM}	σ_{LM}	σ_{MK}	σ_{LK}
1968	-2.81489	-3.08495	-0.83971	0.79749	1.19223	0.48383
1969	-2.19871	-3.14506	-1.01177	0.77390	1.17634	0.55682
1970	-2.09637	-3.17049	-1.04746	0.76780	1.17374	0.56686
1971	-2.20555	-3.18972	-0.99738	0.77180	1.17547	0.54857
1972	-2.22207	-3.21140	-0.98548	0.77133	1.17533	0.54264
1973	-2.21000	-3.25314	-0.97959	0.77849	1.17417	0.53732
1974	-2.23423	-3.31949	-0.95444	0.76575	1.17328	0.52236
1975	-2.68623	-3.42845	-0.79782	0.77541	1.18164	0.43394
1976	-2.89394	-3.52737	-0.73434	0.77507	1.18508	0.37988
1977	-2.91128	-3.66258	-0.70773	0.76677	1.18308	0.34422
1978	-3.01930	-3.83190	-0.66098	0.75736	1.18299	0.27967
1979	-3.47155	-3.89395	-0.58550	0.76227	1.19419	0.17893
1980	-3.55297	-4.10372	-0.54627	0.74552	1.19284	0.08284
1981	-2.90424	-4.29269	-0.60758	0.70748	1.17216	0.12848
1982	-3.00322	-4.43282	-0.56197	0.68193	1.17152	0.00056
1983	-3.06284	-4.46648	-0.52777	0.65152	1.17028	-0.13570
1984	-3.15282	-4.37361	-0.49653	0.62330	1.17049	-0.28045
1985	-3.03281	-3.97967	-0.48947	0.56997	1.16484	-0.42662
1986	-3.03552	-3.58396	-0.47773	0.53949	1.16367	-0.54075
1987	-3.33272	-3.37758	-0.43738	0.53775	1.17083	-0.70517
1988	-3.16146	-3.13397	-0.45304	0.51749	1.16593	-0.69213

It is interesting that capital and labor are substitutable factors in 1970s, but complementary factors in 1980s.

Table 3. The own-price elasticities of factors for the Korean Shipping Industry in 1968 – 1988.

	ε_{KK}	ε_{LL}	ε_{MM}
1968	− 0.74595	− 0.56763	− 0.46268
1969	− 0.69369	− 0.56611	− 0.51044
1970	− 0.68307	− 0.56540	− 0.51937
1971	− 0.69438	− 0.56485	− 0.50675
1972	− 0.69603	− 0.56419	− 0.50366
1973	− 0.69483	− 0.56285	− 0.50212
1974	− 0.69723	− 0.56050	− 0.49544
1975	− 0.73643	− 0.55604	− 0.44970
1976	− 0.75149	− 0.55131	− 0.42888
1977	− 0.75268	− 0.54370	− 0.41970
1978	− 0.75986	− 0.53199	− 0.40287
1979	− 0.78631	− 0.52698	− 0.37364
1980	− 0.79054	− 0.50613	− 0.35735
1981	− 0.75220	− 0.47863	− 0.38247
1982	− 0.75881	− 0.44180	− 0.36397
1983	− 0.76265	− 0.39752	− 0.34939
1984	− 0.76824	− 0.35280	− 0.33549
1985	− 0.76073	− 0.27990	− 0.33227
1986	− 0.76090	− 0.23355	− 0.32685
1987	− 0.77875	− 0.21335	− 0.30755

Table 4. The cross-price elasticities of factor damands for the Korean Shipping Industry in 1968 – 1988.

	ε_{KM}	ε_{MK}	ε_{KL}	ε_{LK}	ε_{ML}	ε_{LM}
1968	0.65692	0.31594	0.08903	0.12822	0.14674	0.43941
1969	0.59347	0.37114	0.10023	0.17568	0.13930	0.39043
1970	0.58198	0.38244	0.10109	0.18470	0.13692	0.38070
1971	0.59724	0.37008	0.09714	0.17271	0.13667	0.39214
1972	0.60069	0.36815	0.09533	0.16997	0.13551	0.39422
1973	0.60186	0.36916	0.09296	0.16983	0.13296	0.39391
1974	0.60003	0.36614	0.08820	0.16301	0.12930	0.39749
1975	0.66605	0.32395	0.07038	0.11897	0.12576	0.43707
1976	0.69212	0.30774	0.05937	0.09865	0.12114	0.45266
1977	0.70158	0.30587	0.05110	0.08900	0.11382	0.45470
1978	0.72103	0.29772	0.03883	0.07038	0.10515	0.46161
1979	0.76209	0.27048	0.02422	0.04053	0.10316	0.48645
1980	0.78032	0.26541	0.01022	0.01843	0.09195	0.48769
1981	0.73787	0.30359	0.01433	0.03328	0.07888	0.44536
1982	0.75876	0.29600	0.00006	0.00014	0.00797	0.44166
1983	0.77473	0.29140	− 0.01200	− 0.03379	0.05799	0.43131
1984	0.79086	0.28521	− 0.02262	− 0.06834	0.05028	0.42114
1985	0.79074	0.29218	− 0.03001	− 0.10701	0.04009	0.38691
1986	0.79614	0.29169	− 0.03524	− 0.13555	0.03516	0.36910
1987	0.82329	0.27358	− 0.04454	− 0.16478	0.03397	0.37813
1988	0.81110	0.28351	− 0.04234	− 0.16830	0.03165	0.36000

In table 3. The own-price elasticities of factors are presented.

We can observe that capital is not only relatively sensitive. but also stable in comparison with other factors. But those of material and labor have the low and fluctuated values. Therefore we can think that capital adjustment has been flexible to adapt to the change of market conditions.

Table 4 shows the cross-price elasticities of factors. In this table we can observe that the elasticities between labor and other factors are relatively low and also that those between capital and materials are relatively high. From this result. we think that labors in Korean shipping Industry are relatively inflexible. In particular the effects of labor price changes on the other factors are very low. This seems to be due to the exogenous inflexiblity of materials in Korean Shipping Industry.

3) Output elasticities of cost, returns to scale, and rates of technical change

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

First. at the early period of Korean economic growth this industry experienced returns to scale. and rapidly the benefits of scale expansion were lessened. and since late 1980s it has revealed diseconomies of scale. This phenomena seems to be due to the fact that at the ear-

Table 5. The output elasticities of cost, returns to scale, rates of technical change and total factor productivity growth for the Korean water transport industry in 1970-1989.

	ε_{CY}	RTS	ROTC
1968	0.35353	0.64647	-0.07363
1969	0.30485	0.69515	-0.12033
1970	0.59383	0.40617	-0.04614
1971	0.37264	0.62736	-0.15404
1972	0.38539	0.61461	-0.17917
1973	0.95579	0.04421	-0.00669
1974	1.19590	-0.19590	0.04023
1975	0.96452	0.03548	-0.07010
1976	0.92071	0.07929	-0.11072
1977	0.84332	0.15668	-0.16670
1978	0.92159	0.07841	-0.16477
1979	1.17993	-0.17993	-0.10138
1980	1.27268	-0.27268	-0.10108
1981	1.21079	-0.21079	-0.15520
1982	1.36989	-0.36989	-0.12749
1983	1.66740	-0.66740	-0.04932
1984	1.99656	-0.99656	-0.03842
1985	2.29387	-1.29387	-0.11709
1986	2.50769	-1.50769	-0.16506
1987	2.78639	-1.78639	-0.23350
1988	2.93433	-1.93433	-0.25673

ly stage of economic growth, the effects of scale expansion on cost reducement were very high, but gradually capital inefficiency has tended to increase because of excessive quantitative expansions of capital without qualitative improvement of this industry. It is interesting that the effects of scale expansions have changed rapidly and finally overturned to the worse states.

Second, rates of technical change had been negative values by 1984 and have been positive values since 1985. 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. This results are consistent with the findings of Nah(1991).

4. Conclusion

We attempted to estimate technical change and the returns to scale for in Korean Shipping Industry. The important and interesting points are summarized as follows.

First. The own elasticities of substitution for labor are highest, those of materials are lowest and those of capital are in the middle.

Second. The cross – elasticities of substitution show that each factor has a substitutable relationship with other factors.

Third, the elasticities between labor and other factors are relatively low and also that those between capital and materials are relatively high.

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

Fourth. at the early period of Korean economic growth this industry experienced returns to scale, and rapidly the benefits of scale expansion were lessened, and since late 1980s it has revealed diseconomies of scale.

Fifth. rates of technical change had been negative values by 1984 and have been positive values since 1985. In the mid – 1980s those values are improved very rapidly.

Finally, we have the following policy implications from this empirical result, that is, 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 have to increase the human investment to improve the quality of labor and take pains to elevate 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 into a model including the process of dynamic optimization.

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