A Study on the Cost Structure of the Korean Water Transport Industry

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I. Introduction

In terms of recent changes in foreign and domestic situations of the water transport industry, Korea has recently faced many types of dilemma. To solve these chronic problems Korean government has attempted reorganization and rationalization of this industry. The governmental objective of this policy is to prevent excessive competition and unnecessary duplication of efforts among many firms of water transportation under severe world situation of this industry and to increase the efficiency of this industry. Especially Korean government has thought that this industry would be governed by scale economies and this reform would increase the efficiency of this industry. In the light of this situation overriding issues are the existence of scale economies,the level and bias of technical progress, and the extent of substitutability among factors. This study deals with these issues and attempts to elicit some implications from the resulting findings. The present study employs the transcendental logarithmic(briefly translog) cost function approach developed by Christensen, Jorgensen and Lau(1973) to estimate the production structure of this industry during the 1969-1985 period.[1]

1) See J.K. Kwon and M. Williams(1982) for the analysis of Korean manufacturing sector. In this paper they use the translog cost function to examine the structure of Korean manufacturing.

The important properties of this functional form allow for scale economies and technical progress changing with time trend, and impose no a priori restriction among factors.[2)]

In addition, this function can measure the impacts of technical change on distribution of factor income. This paper's organization is as follows : In section II we introduce methodological procedure and theoretical aspects of translog cost function. Section III gives data sources, estimation method and empirical results. The last section summarizes some findings and explores some policy implications.

II. Methodological Procedure

The translog production function is a second-order Taylor approximation around an arbitrary point of expansion and generalizes the Cobb-Douglas and CES specifications. We assume there exist n factors of production(x_1, $x_2 \cdots\cdots x_n$) and one gross output Q. The translog production function is as follows :

$$\ln Q=\beta_0+\sum_{i=1}^{n}\beta_i \ln x_i+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln x_i \ln x_j$$

$$+\beta_t T+\frac{1}{2}\beta_{tt}T^2+\sum_{i=1}^{n}\beta_{ti}T\ln x_i \quad\cdots\cdots(1)$$

It is shown that a well-behaved cost minimizing technology may be described sufficiently by a joint cost function in lieu of a production function. A distinct cost function yields a distinct production function and vice-versa.[3)]

We use the translog cost function as dictated by data availability, the ease of implementation and multi-collinearity problem which is inherent in production function approaches. Thus, the joiut cost function corresponding to the above production function (1) is as follows.

2) See H.S. Nah(1983) for the properties of translog production and cost function.

3) Diewert(1971) explained very exactly the dual relation between cost and production function.

$$\ln C=\alpha_0+\alpha_t T+\frac{1}{2}\alpha_{tt}T^2+\alpha_y \ln Y+\frac{1}{2}\alpha_{yy}(\ln Y)^2+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}\ln P_i \ln P_j+$$

$$\sum_{i=1}^{n}\alpha_{yi}\ln Y \ln P_i+\sum_{i=1}^{n}\alpha_{ti}\, T \ln P_i+\alpha_{ty}\, T \ln Y \quad \cdots\cdots(2)$$

, where C is total cost, Pi is i-th input price and Y is output. We can obtain additional informations on the parameter of the function (2) by Shephard's Lemma. These are the cost share equations of each input.

$$S_i=\frac{\partial \ln C}{\partial 1_n P_i}=\alpha_i+\alpha_{ii}\ln P_i+\sum_{j=1}^{n}\alpha_{ij}\ln P_i+\alpha_{ti}T+\alpha_{yi}\ln Y \cdots\cdots(3)$$

, where $i=1,2,\cdots\cdots n$, 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 safisfies adding up condition and symmetry condition as follows :

(i) $\sum_{i=1}^{n} S_i=1$ ……(4)

(adding up condition)

(ii) $\alpha_{ij}=\alpha_{ji},\quad i, j=1,2,\cdots\cdots,n$ ……(5)

(symmetry condition)

The first restriction implies that the covariance matrix is singular ; however this implies that the likelihood function is undefined. This problem is overcome by dropping one equation for joint estimation.

It is shown that the maximum likelihood estimates or non-linear least square estimates are invariant to the deleted equation. To represent the technology exactly, the well-behaved cost function must satisfy the following requirements.

(i) linear homogeneity in factor prices[4)]:

$$\sum_{i=1}^{n}\alpha_i=1\,;\ \sum_{i=1}^{n}\alpha_{ij}=\sum_{j=1}^{n}\alpha_{ij}=\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}=0\,;$$

$$\sum_{i=1}^{n}\alpha_{yi}=0\,;\ \sum_{n=1}^{n}\alpha_{ti}=0 \quad \cdots\cdots(6)$$

4) The condition of constant returns to scale is $\alpha_Y=1$ and $\alpha_{YY}=0$

(ii) monotonicity with respect to input prices[5] :

$$\frac{\partial \ln C}{\partial \ln P_i} = \alpha_i + \sum_{i=1}^{n} \alpha_{ij} \cdot \ln P_i + \alpha_{yi} \ln Y + \alpha_{ti} T > 0 \quad \cdots\cdots (7)$$

(iii) concavity in input prices (This requires the Hessian matrix of second partial derivatives with respect to factor prices to be negative semi-definite). This concavity may be verified by testing the negative semi-difiniteness of the matrix of elasticities of substitution.

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

$$D_{ij} = \frac{C\, C_{ij}}{C_i C_j} \quad \cdots\cdots (8)$$

, 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 $D_{ij} = D_{ji}$, $i, j = 1, 2, \cdots\cdots n$. With the translog cost function the AES's are as follows.

$$D_{ii} = (\alpha_{ii} + S_i^2 - S_i) / S_i^2, \quad i = 1, \cdots\cdots n \quad \cdots\cdots (9)$$

$$D_{ij} = (\alpha_{ij} + S_i S_j) / S_i S_j, \quad i, j = 1, 2 \cdots\cdots n \quad \cdots\cdots (10)$$

These AES's are not constrained to be constant but may vary with the values of the cost shares. The price elasticity of demand for factors of production E_{ij} is conventionally defined as

$$E_{ij} = \partial \ln x_i / \partial \ln P_j, \quad i, j = 1, 2 \cdots\cdots n \quad \cdots\cdots (11)$$

,where output quantity and all other input prices are fixed.

Allen(1938) has shown that the AES's are analytically related to the price elasticities of demand for factors of production as follows.[7]

$$E_{ij} = S_j D_{ij}, \quad i, j = 1, 2 \cdots\cdots n \quad \cdots\cdots (12)$$

5) For later discussion we can see that this momotonicity hold good in the cost structure of Korean water transport industry.

6) It hold good because $C_{ij} = C_{ji}$.
This relation is called Young's theorem.

7) We note that $D_{ij} = D_{ji}$, but $E_{ij} \neq E_{ji}$ generally.

Moreover we can also estimate returns to scale. These estimates(RTS) are derived from cost／output elasticity estimate(E_{cy}).

$$E_{cy} = \partial 1_n C / \partial 1_n Y$$

$$= \alpha_y + \alpha_{yy} \ln Y + \sum_{i=1}^{n} \alpha_{yi} \ln P_i + \alpha_{ti} T \quad \cdots\cdots (13)$$

$$RTS = 1 - ECY^{8)} \quad \cdots\cdots (14)$$

We can estimate the level and bias of technical change.[9]

$$TP = -\partial \ln C / \partial T$$

$$= -(\alpha_t + \alpha_{ty} \ln Y + \Sigma\, \alpha_{ti} \ln P_i + \alpha_{tt} T), \quad i = 1,2 \cdots\cdots n \quad \cdots\cdots (15)$$

(the level of technical change)

$$BTP = \partial S_i / \partial T = \alpha_{ti}, \quad i = 1,2 \cdots\cdots n, \quad \cdots\cdots (16)$$

(the bias of techical progress).

III. Data, Estimation and Empirical Results

Data consists annual time-series for Korean water transportation industry, 1969-85. They are measures of aggregate output, total cost and prices of labor, capital and materials. The data for employee remuneration, total cost and income share of capital, labor and materials are available from Business Statistics of Bank of Korea. But there does not exist capital price of water transport industry, so I use capital price of Korean manufacturing as a proxy variable, and also aggregate price index of materials in water transport industry are not available. So I use petroleum products price as a proxy variable of material price.

In order to estmate the parameters of the translog cost function, we eatimate simultaneously the cost function (2) and the cost share equations (3) as a multivariate

8) If RTS>0, this industry has economies of scale, if RTS<0, it has diseconomies of scale, and if RTS=0, it has constant returns to scle.

9) Minus sign of TP means that technical progress helps to reduce the cost of this industry.

10) If $\alpha_{Ti} > 0$, technical progress takes place to increase the income share of input i.

regression, subject to the symmety and input homogeneity restrictions, using an iterative Zellner's estimation procedure.

Now we examine the empirical results.

Parameter estimates for the cost function outlined in the previous section are reported in Table 1.

Table 1. Translog Cost Function Parameters[11)]

Parameter	estimate	Paı ameter	estimate
α_0	10.66430(4.30)	α_{LK}	0.0354(2.05)
α_M	0.2427(2.77)	α_T	-0.4814(-1.38)
α_L	0.2812(7.05)	α_{TT}	0.0355(1.47)
α_K	0.4761(4.83)	α_{TY}	0.0729(0.71)
α_Y	2.0118(1.36)	α_{TM}	0.0318(5.17)
α_{YY}	0.1963(0.44)	α_{TL}	-0.0121(-4.16)
α_{MM}	0.0913(3.18)	α_{TK}	-0.0197(-2.82)
α_{LL}	0.0224(1.90)	α_{YM}	-0.1335(-4.76)
α_{KK}	-0.0010(-0.02)	α_{YL}	0.0338(4.07)
α_{ML}	-0.0578(-5.10)	α_{YL}	0.09970(3.18)
α_{MK}	-0.0335(-1.04)		

$R^2=0.9891$ D.W.=2.29, S.S.R.=0.2042

These estimates are used to compute estimates of own-and cross-price elasticities and factor substitution, and they are also used to determine the contributions of scale econ - omies, level and bias of technical progress.

(1) Elasticities of Substitrtion

Table 2 shows own-and cross-elasticities of factor substitution and Table 3 shows own -and cross-price elasticities. As one would expect, the own-price elasticities of demand

11) The value of the parenthesis in table 1 is t-value.

and the own-elasticities of substitution are all negative, which is required to assure the concavity of this function and implies that each factor is a substituatable factor for the other factors. Labor input is rather weak substitute for materials and rather strong substitute for capital.

Table 2. Own-and Cross-elasticities of Substitution

D_{MM}	D_{LL}	D_{KK}	D_{ML}	D_{MK}	D_{LK}	
1970	-0.61	-3.58	-2.39	0.41	0.78	1.62
1975	-0.13	-7.67	-6.51	0.13	0.38	4.09
1980	-0.33	-5.25	-3.58	0.33	0.76	2.21
1985	-0.27	-7.10	-3.44	0.09	0.78	2.66

Table 3 : Own-and Cross-Price Elasticities

E_{MM}	E_{LL}	E_{ML}	E_{MK}	E_{LK}	E_{KM}	E_{KL}	E_{LM}	E_{KM}	E_{KL}
1970	-0.31	-0.69	-0.71	0.08	0.23	0.48	0.21	0.40	0.31
1975	-0.10	-0.65	-9.88	0.01	0.09	0.55	0.10	0.53	0.35
1980	-0.21	-0.70	-0.79	0.04	0.17	0.49	0.21	0.49	0.29
1985	-0.19	-0.67	-0.78	0.01	0.18	0.60	0.06	0.53	0.25

(2) Homotheticity

The cost function is homothetic if the optimal combination is independent of the scale of output so that the expansion path is linear. To be homothetic, all the factor price-output interaction parameters, α_{Yi} must be zero. However our estimates indicate statistically significant, so we can reject the hypothesis, $\alpha_{Yi}=1$. Therefore our cost function is non-homothetic for factor prices.

(3) Scale Economies and Technical Change

Table 4 shows the elasticity of cost with respect to output (E_{CY}), returns to scale (1-E_{CY}), technical progress (TP) and bias of technical change. According to this table we can see that Korean water transport industry has substantial diseconomies of scale and the degree of diseconomies of scale has strenghtened gradually. In addition, we can know that as time goes on, the rate of technical progress decreases and in 1980s this industry has recorded negative rate of technical progress.

Table 4 Cost/output Elasticity, Returns to scale and Technical Progress

	E_{CY}	$1-E_{CY}$	TP
1970	1.80	-0.80	0.46
1975	2.12	-1.12	0.25
1980	2.89	-1.89	0.06
1985	3.31	-2.30	-0.10

These facts are in accordance with the fact that since 1982, water transportation industry has faced severe economic stagnation. Next we examine the impacts of technical progress on the income share of factor.

$\alpha_{TM}>0$, $\alpha_{TK}<0$ and $\alpha_{TL}<0$ means that technical progress is material-using, capital-

This means that material prices encourage substitution of other factors for materials.

saving and labor-saving.

By contrast, as technical change is capital-using and labor-using, the increases in the prices of these imputs tend to encourage technical progress.

IV. Summary and Conclusion

We have examined the cost structure of Korean water transport industry. Our findings are summarized as follows:

1) Labor is a substitutable factor for materials and capital.

2) The cost function of Korean water transport inductry is non-homothetic.

3) Since 1969, Korean water transport industry has experienced diseconomies of scale.

4) Since 1982, this industry has experienced negative rate of technical progress.

5) Technical progress is labor-saving, capital-saving and materical-using.

On the whole our findings seem to be in accordance with our practical experiences.

Korean economy has experienced many difficult problems because of the deficit operation of water transport industry. These phenomena have aggravated since the world stagnation in 1982. Korean government has alttemped the reorganization of this industry to achieve more efficient operation and to prevent excessive competition. But we cannot expect the short-term effect of this policy. We note that this policy should be based on the market mechanism. Our result implies that Korean water transport industry should have maintained appropriate scale of this economy and the expansion of scale cannot guarentee the cost reduction of this industry. Also in 1980's this industry has not achieved positive technical progress. Therefore policy authority should encourage technical innovation and improvement of effectiveness of this industry. We can also know that material-using, capital-saving and labor-saving technical progress has taken place in this industry. This means that as technical progress happens, more use of capital and labor help to reduce the cost of this industry, but materials tend to increase the cost of this industry due to technical progress. This implied this industry should substitute labor and capital for materials to reduce the total cost. In spite of data constraint and shortcomings of specification and estimation of this model, we can obtain some significant findings in this industry. These findings and implications should be used to encourage efficient operation of this industry and optimal decision making of government and private firms.

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