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THE TEST OF TECHNOLOGY CHANGE, FACTOR SUBSTITUTION AND PRODUCTION STRUCTURE ADJUSTMENT OF THE KOREAN PLYWOOD INDUSTRY

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I. Interoduction

The major question regarding the competitiveness of any industry is mainly derived from the cost performances of manufacturing goods. The cost performance of the industry can be explained from input mixtures, the availability of technology, and levels of outputs. To improve productivity, the industry should cost- effectively mix inputs into its production structure, depending on available technologies (Nicholson 1985). This implies that the industry needs to substitute a less expensive input for a more expensive input when one can be substituted for the other. Furthermore, the industry needs to develop technologies toward using more inputs which become less expensive, while saving inputs which are highly priced. Also, development of technologies could be a significant component enhancing cost effectiveness.

The Korean plywood industry has faced remarkably altered circumstances of input markets during the past three decades. Owing to the expansion of the Korean economy, the opportunity costs of the labor factor rose significantly. The oil crises of the 1970's caused the price of the energy input to skyrocket. Finally, significantly reduced supplies of tropical logs due to export restrictions by the Southeast Sea countries consequently resulted in a substantial price increase for tropical logs.

Previous research has not directly addressed the contraction of the Korean plywood industry, though it is believed that the altered

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circumstances of factor markets were major contributors. Therefore, this study addresses the following questions:

To be more competitive in the world market, what are the major adjustments that the Korean industry made when it faced different situations? Did they substitute specific inputs for other inputs due to the changed prices of inputs? Or, did they develop a technology toward using a certain input, while saving other inputs? Or, did the Korean plywood industry change its production structure to dilute the impact of changed conditions of input markets?

The objective of the study is to analyze the industry's adjusting methods and processes, such as factor substitutions, technological changes, and structural changes, following altered circumstances.

II. Study Methods

The cost function employed for this study is based on duality theory and consists of a transcendental logarithmic function (translog function). The Translog function is one of several possible flexible functional forms. The major advantage of flexible functional forms as compared to other ordinary functional forms, such as the Cobb-Douglas or the CES function, is that they can estimate the parameters of interest without a priori restriction on these parameters. Since many flexible forms are available and have very similar properties, choosing a proper flexible form for the research of interest is an important issue.[1] According to Pope(1984), three principles must be considered for selecting functional forms: (1) the form must be flexible enough to describe behavior; (2) it should accommodate microeconomic theory; and (3) it should be rather parsimonious with readily interpretable results and ease of econometric implementation. Lau (1974) described two principles for selecting the functional form: (1) the functional form must be capable of approximating an arbitrary function to the desired

[1] Flexible form are classified based on the method of approximation: namely, Taylor's series and Fourier series methods. The main difference between them is that Taylor's series is a local approximation, while the Fourier series is a global approximation. The generalized Leontief(GL), the translog(TL), the generalized Cobb-Douglas(GCD), the generalized square root quadratic(GSRQ), and the generalized BOX-COX(GBC) forms fall into the first class, while the Fourier flexible form falls into the second class.

order of precision; and (2) it must result in estimation forms that are linear in their parameters. Finally, Fuss et al. (1978) provided five criteria for choosing the functional form: (1) parsimony in parameters, (2) ease of interpretation, (3) computational ease, (4) interpolative robustness within the sample, and (5) extrapolative robustness outside the sample. Since the translog cost function well satisfies the criteria of selection functional forms suggested by Pope (1984), Lau (1974), and Fuss et al. (1978), it is employed for this study.

1. Model

The nonhomothetic, nonhomogeneous and nonunitary elasticity of substitution of transcendental logarithmic cost function for the Korean plywood industry can be expressed as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_Q \ln Q + 0.5\alpha_{QQ}(\ln Q)^2 + \alpha_T T + 0.5\,\alpha_{TT} T^2 \\ & + \sum_i \alpha_i \ln P_i + 0.5 \sum_i \sum_j \alpha_{ij} \ln P_i \ln P_j + \sum_i \alpha_{Ti} T \ln P_i \\ & + \sum_i \alpha_{Qi} \ln Q \ln P_i \quad \text{for} \quad i, j = L, M, E, K. \end{aligned} \tag{1}$$

where C is a total production cost, Q is an aggregate industry output, P_i is the price of inputs (i.e., P_l, P_m, P_e, and P_k is the price of labor, logs, energy and capital, respectively), T is a time trend that will be used as a proxy for technological changes, and α's are estimated coefficients. L, M, E, and K represent labor, material, energy, and capital, respectively. In order to form symmetry of cross-partial derivatives, the following condition should be met:

$$\alpha_{ij} = \alpha_{ji} \quad \text{for} \quad i \neq j \tag{2}$$

According to neoclassical production theory, the cost function must be homogenous of degree one with respect to factor prices (Varian 1984). Therefore, the following conditions are imposed on the parameters of the translog cost function:

$$\sum_i \alpha_i = 1, \ \sum_i \alpha_{Qi} = 0, \ \sum_i \alpha_{Ti} = 0, \ \sum_i \alpha_{ij} = \sum_j \alpha_{ij} = \sum_i \sum_j \alpha_{ij} = 0 \quad \text{for} \quad i \neq j \tag{3}$$

2. Estimation of Biased Technological Progress

According to the Shephard's Lemma (Shephard 1953 and Diewart 1971), factor demand functions can be obtained by differentiating the cost function with respect to factor prices. Therefore, for the ith input Xi:

$$\frac{\partial C}{\partial P_i} = X_i = X_i(Q, P_i) \ \text{ for } \ i, j = K, L, M, E. \tag{4}$$

Therefore, the factor demand function for the logarithmic cost function is:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} \tag{5}$$

Then substituting equation (4) into equation (5),

$$\frac{\partial \ln C}{\partial \ln P_i} = X_i \frac{P_i}{C} = S_i \tag{6}$$

In order to get a linear form of the factor share (S_i) equations, equation (1) must be differentiated with respect to the log of factor prices ($\ln P_i$):

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} = X_i\frac{P_i}{C} = S_i = \alpha_i + \sum_j \alpha_{ij}\ln P_i$$
$$+\alpha_{Qi}\ln Q + \alpha_{Ti}T \ \text{ for } \ i, j = K, L, M, E. \tag{7}$$

A technological change bias is defined as the influence of technological progress on factor shares when factor prices and output are held constant. In this equation (7), the parameter α_{Ti} indicates the change of the factor share with respect to the time when factor prices have remained constant. Therefore, it is possible to apply the Hicksian definition of technological change bias (Binswanger 1974) to equation (7). The technological change bias can be estimated as follows:

$$\delta_i = \frac{\partial S_i}{\partial T}\frac{1}{S_i} = \alpha_{iT}\frac{1}{S_i} \tag{8}$$

If the value of δ_i is positive, technological change is assumed to be factor-using. If the value of δ_i is negative, technological change is assumed to be factor-saving. If the value of δ_i is not significantly different from zero, there is no indication of technological change bias.[2]

3. Allen- Uzawa Partial Substitution Elasticities and the Price Elasticities of Derived Demands for Factors

The substitution among factor inputs within a certain stage of a technology is explained by the Allen-Uzawa partial substitution elasticities. These elasticities can be calculated from the cost function as follows (Allen 1938, Uzawa 1962): [3]

$$\sigma_{ij} = \frac{\alpha_{ij}}{S_i S_j} + 1 \qquad \text{for} \quad i \neq j \tag{9}$$

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[2] A technological change is factor-using when changes leads to use of a greater proportion of a certain input.
An advantage of defining the technological change according to the equation is that it can be applied to more than two factors.

[3] The allen elasticity of substitution is derived from the cost function C (Uzawa 1962)

$$A_{ij}(y, p) = \frac{C(y, p)\, C_{ij}(y, p)}{C_i(y, p)\, C_j(y, p)}$$

Where subscripts are partial derivatives, y is output quantity and p is the vector of input prices.
From Shephard's Lemma (Shephard 1953),

$$X_i = C_i(y, p),$$

where X_i is the optimal quantity of the ith input, therefore

$$A_{ij}(y, p) = \frac{\sigma_{ij}(y, p)}{S_j(y, p)},$$

where $\sigma_{ij}(y, p)$ is the (constant-output) cross-price elasticity of demand and $S_j(y, p) = p_j c_j(y, p)/c(y, p)$ is the share of the jth input total cost (Blackorby and Russell 1989).

$$\sigma_{ii} = \frac{\alpha_{ii}}{S_i^2} - \frac{1}{S_j} + 1 \tag{10}$$

where σ_{ij} and σ_{ii} are the Allen-Uzawa partial substitution elasticities, and S_i and S_j are shares of factors i and j of the production costs. The price elasticity of derived demand for a particular factor, given constant output and constant prices for all other factors, can be derived from the partial substitution elasticities as follows (Allen 1938):

$$\mu_{ij} = S_j \sigma_{ij}, \quad \forall ij \tag{11}$$

where μ_{ij} is the price elasticity of derived demand for factor i with respect to the price of factor j, σ_{ij} is the Allen-Uzawa partial substitution elasticity, and S_j is the share of factor j of the production costs.

4. Test for Production Structure Changes

Change of production structure is tested for investigating how the industry responded the altered input markets. To do this, a dummy variable is included in the translog cost model (i.e., equation (1)). Therefore, the translog cost function with a dummy variable (D) is as follows:

$$\begin{aligned} \ln C &= \alpha_0 + \alpha_Q \ln Q + 0.5\alpha_{QQ}(\ln Q)^2 + \alpha_T T + 0.5\,\alpha_{TT} T^2 \\ &+ \sum_i \alpha_i \ln P_i + 0.5 \sum_i \sum_j \alpha_{ij} \ln P_i \ln P_j + \sum_i \alpha_{Ti} T \ln P_i \\ &+ \sum_i \alpha_{Qi} \ln Q \ln P_i \quad \text{for} \quad i, j = L, M, E, K. \end{aligned} \tag{12}$$

If the coefficient of dummy variable is significantly different from zero at the satisfactory level of confidence, the production structure is changed.

5. Definition and Computation of the Data

Total costs of production (C) are obtained from the *Report on Mining and Manufacturing Census*, published by the Korea Development Bank and Economic Planning Board. Total output (Q) is obtained from *The Statistics Yearbook*, published annually by the Korean Plywood Manufacturers' Association. Since the cost of tropical logs comprised more than 95 percent of total costs of materials(*Report on Mining and Manufacturing Census*, various years), the prices of the tropical log are used for the material prices. The prices of tropical imported logs are taken from *The Price Statistics Summary*, published by the Bank of Korea.

The price of energy (E) is represented by the proportionally averaged price of Bunker-C oil and electricity because both comprised more than 95 percent of energy costs during the sample period (*Report on Mining and Manufacturing Census*, various years). The prices of Bunker-C oil and electricity are obtained from *The Price Statistics Summary*, published by the Bank of Korea. The price of labor (L) is obtained by dividing total labor compensation by the total number of the labor force hired; these figures are taken from the *Report on Mining and Manufacturing Census*, published by the Korea Development Bank and Economic Planning Board. The price of capital (K) can be estimated as the rate of return on fixed assets. The rental value of a firm's stocks can be calculated as if the stocks were rented based on the opportunity cost concept. However, no opportunity cost can be driven for the machinery and equipment in forest industries because they may not be used for other purposes after purchased. Therefore, the firm's rate of return can substitute its opportunity cost, which is considered a basis for calculating the rental value of a firm's stocks, for the forest industry (Nautiyal and Singh 1983; Singh and Nautiyal 1984).[4]

The data for dummy variable (D) are expressed by 0 or 1. After 1979, the data are expressed as 1, while 0 is used for the years until

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[4] Several methods for calculating capital price are employed by previous studies. (1) The rental value of capital, which is defined as the annual expenditure per dollar of capital stock, was employed by Banskota *et al.* (1985). (2) The implicit price method, which is measured by the firm's rate of return(the rental price of capital) as its opportunity cost, is used by Singh and Nautiyal(1985, 1984), Nautiyal and Singh (1985, 1983), and Meil and Nautiyal(1988). (3) Wear(1989) used a quasi-rent on the capital stock as a capital price. Then, the rental price of capital is :

$$P_k = (VA - P_L L) / K$$

where P_k is price of capital, VA is value added, P_L is price of labor, L is labor, and K is capital. Among these methods, the second method is used for this study because of availability of the data.

1979. The share of each input (SE, SK, SM, and SL) is calculated by dividing the costs of each of the inputs by total costs.

6. Estimation Method

Since the large number of coefficients to be estimated, The translog cost function can not be estimated efficiently by ordinary least squares because of multicollinearity. To resolve this problem, the cost and share equations together (e.g., Berndt and Wood, 1975) assuming constant returns to scale can be estimated for reducing the number of coefficients to be estimated. However, this method only can be used for the constant returns to scale case. Therefore, a multivariate regression system which estimates cost function and its share equations jointly (Christensen and Greene, 1976) can effectively remove possible multicollinearity among regressors by acquiring additional information from its share equations.

The method of estimating seemingly unrelated equations, which was introduced by Zellner, cannot estimate invariantly in which an equation is deleted in the share equations (Zellner 1962).[5]

The iterative Zellner-Efficient estimation (IZEF) - equivalent to a maximum likelihood iterative technique - can provide invariant estimators in the equation deleted (Dhrymes 1973). However, a further gain in efficiency can be achieved by combining IZEF and the two-stage least squares (2SLS) to form the iterative three-stage least squares (I3SLS). The I3SLS has been used by many economists (e.g., Berndt and Wood, 1975; Christensen and Greene, 1976; Nautiyal and Singh, 1985, 1986). Therefore, the I3SLS method will be used for estimating the Korean plywood industry's translog cost function.

III. Results

The estimates of the translog cost function model for the Korean Plywood Industry are presented at the Appendix.

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[5] Since the share equations are added up as one, estimating all share equations and the cost function together will be the estimation of the singular system.

1. Result of Estimation of the Technological, Change Bias

Technological change biases are estimated by using average factor share values and time as a proxy for technological change. Estimates presented in Table 1 are used to determine if technological changes are capital-saving, labor-saving, energy- using, and/or material-using. Only material-using technological change is indicated because it alone is significant at the 10 % level. Material-using technological changes may be due to the use of inexpensive and plentiful supplies of tropical logs from the Southeast countries for most years of the sample period. As a result, the industry tended to use more materials. The technological change bias is an important factor in the input demand and income distributions. For example, if the technology changes material-using direction, the demand for the material will be increased and consequently the material sector will earn more income. In a competitive industry, decisions regarding demand for inputs are based theoretically on the equality of the marginal rate of technical substitution of inputs to the factor price ratio. Since the factor price ratios are assumed to be constant, material-using technological changes indicate that the demand for material will increase proportionally as the output level increases. Results of material-using technological changes are the same as those of other studies (e.g., Merrifield and Singleton (1986)). Material-using technological changes are expected since the industry enjoyed inexpensive prices for tropical logs for most of the sample period. However, since the material price has significantly increased over the

TABLE 1 Technological Change Bias

Factor	Technological change bias
Material	0.004* (0.002)
Labor	-0.025 (0.014)
Energy	0.018 (0.019)
Capital	-0.098 (0.055)

* indicates 10 % significance level.

Notes: 1. Figures in the parentheses are the standard errors of the estimates.

2. Elasticities are calculated based on the average factor shares over time.

3. The standard errors are calculated by S.E.(δ_i) = S.E(α_{Ti})/S_i.

past 10 years, the industry should develop technology to save more materials in order to reduce production costs.

2. The Allen Partial Elasticities of Substitution and Elasticity of Input Demand

Table 2 presents the Allen partial elasticities of substitution estimates for all factors. Most elasticities are statistically insignificant. This implies that the substitution or complement among inputs is not available in many cases. All of the own Allen partial elasticities are less than zero.

Labor, energy, and capital are all complementary with material.[6] Among them, capital has the largest value of the elasticity (1.66) followed by energy (0.98) and labor (0.30). The results of the Allen partial elasticities of substitution indicate that no substitute is available for the material input. As expected, this implies that the industry actually did not substitute other inputs for material input. Since the material cost comprised a significant portion of the production costs, the non- substitutability of the

TABLE 2 The Allen Partial Elasticity of Substitution Estimates

Input	Labor	Energy	Material	Capital
Labor	-2.21	-3.76	0.30*	-2.15
	(1.66)	(2.22)	(0.11)	(4.84)
Energy	-3.76	-11.90**	0.98**	0.52
	(2.22)	(2.00)	(0.15)	(2.52)
Material	0.30*	0.98**	-0.09**	1.66**
	(0.11)	(0.15)	(0.01)	(0.47)
Capital	-2.15	0.52	1.66**	-11.00
	(4.84)	(2.52)	(0.47)	(11.25)

* indicates 10 % significance level.
** indicates 5 % significance level.

Notes: 1. Figures in the parentheses are the standard errors of the estimates.
2. Elasticities are calculated based on the average factor shares .
3. The standard errors are calculated by $S.E.(\sigma_{ij}) = S.E(\alpha_{ij})/S_i S_j$.

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6 If the value of elasticity between inputs is positive, they are complements. If the value of elasticity is negative, they are substitutes each other.

material input caused even more severe production cost increases. When industries face rising prices of a certain input, they should try to substitute other inputs for that input. If substitution is impossible, the industry then has to bear all the costs of the increased prices of the input. Therefore, non-substitutability of the material factor was also a reason for the Korean plywood industry's loss of competitiveness.

Table 3 shows own and cross-partial elasticities of factor demand estimates. Labor demand is inelastic for the price of material. Energy demand is inelastic for the price of material and its own price. Material demand is inelastic for the prices of energy and capital input. Also material demand is inelastic for its own price. Only capital demand is elastic for the price of material.

3. Test of Structural Changes

The result of production structure change test shows that the coefficient of the dummy variable is highly significant at a 1 % level of significance. Therefore, the industry changed its production

TABLE 3 Own and Cross Partial Elasticity of Factor Demand Estimates

	Price			
Input	Labor	Energy	Material	Capital
Labor	-0.21	-0.02	0.25**	-0.04
	(0.15)	(0.06)	(0.09)	(0.04)
Energy	-0.35	-0.50**	0.82**	0.01
	(0.20)	(0.08)	(0.12)	(0.07)
Material	0.02	0.03**	-0.08**	0.03**
	(0.03)	(0.01)	(0.02)	(0.01)
Capital	-0.20	0.02	1.39**	-0.22
	(0.63)	(0.25)	(0.39)	(0.23)

* indicates 10 % significance level.
** indicates 5 % significance level.
Notes: 1. Figures in the parentheses are the standard errors of the estimates.
2. Elasticities are calculated based on the average factor shares .
3. The standard errors are calculated by S.E.(μ_{ij}) = S.E(α_{ij})/S_i .

structure when it faced the altered conditions of the material market in 1979. Since the coefficient of the dummy variable was negative, the industry adjusted its production structure to reduce production costs. The results indicated the industry have changed their production structures in order to dilute the impacts of highly priced materials. However, if we assume all of the individual firms had similar production structures, it may be inferred that the industry changed its production structure when it faced the heightened prices of tropical logs starting in 1979.

IV. Summary and Conclusion

This study was conducted to analyze technology change, factor substitutability, and structure change of the Korean plywood industry.

The transcendental logarithmic cost function was selected to analyze the production behavior of the Korean plywood industry by using the annual time series data for the period of 1966-87.

The major findings of the study are: (1) The technological change is only material-using for the Korean plywood industry because all technological change biases but material-using are not statistically significant.

(2) The Allen partial elasticities of substitution estimates for all factors showed that all the own Allen partial elasticities are less than zero. Labor, energy, and capital are all complementary with material. Capital has the largest value of the elasticity (1.66), followed by energy (0.98) and labor (0.30). The estimation results of the Allen partial elasticities of substitution indicate that the other inputs are not substitutable for material input. This implies that rising costs of the material input can not be absorbed due to the non-substitutability among production inputs. Therefore, non-substitutability of material input can be a major contributing cause to the industry's contraction in the early 80s because material costs occupied the largest portion of the production costs.

(3) The own and cross partial elasticities of the factor demand were calculated. Demand for labor is inelastic for the price of material. Demand for energy is inelastic for the price of material and its own price. Demand for material is inelastic for the prices of energy

and capital input and its own price.. The demand for capital is elastic for the price of material. The elasticities of factor demand are important in terms of production costs.

(4) Tests for production structure changes with respect to the tropical log price change in 1979 were conducted. The results show that the coefficient of the dummy variable is highly significant at a 1% level of significance.

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APPENDIX

A1. Estimates of the Translog Cost Function Model for the Korean Plywood Industry

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
α_0	122.84** (19.52)	α_{lk}	-0.006** (0.001)	α_{eq}	0.006* (0.002)
α_Q	7.63** (2.55)	α_{lm}	-0.06** (0.01)	α_{mq}	0.003 (0.005)
α_{QQ}	-4.55** (0.65)	α_{le}	-0.02* (0.009)	α_{kq}	0.002* (0.001)
α_t	-0.31** (0.07)	α_{kk}	-0.014* (0.007)	α_{lt}	-0.002* (0.001)
α_{tt}	0.004** (0.002)	α_{km}	0.01* (0.005)	α_{et}	0.0007 (.0008)
α_l	-0.02 (0.06)	α_{ke} α_m	0.01 (0.02)	α_{mt}	0.003 (0.001)
α_e	0.19** (0.03)	α_{mm}	0.06** (0.01)		
α_m	0.87** (0.09)	α_{me}	-0.01 (0.008)		
α_k	-0.04 (0.03)	α_{ee}	0.02** (0.003)		
α_{ll}	0.06** (0.01)	α_{lq}	-0.01** (0.003)		

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