THE ANALYSIS OF IMPACTS OF FACTOR PRICES ON THE PRODUCTION COSTS OF THE KOREAN PLYWOOD INDUSTRY

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I. Introduction

The plywood industry was developed as a strategic industry in Korea early 1960's mainly because it was labor-intensive. The industry continuously expanded its capacity until the end of the 1970's, and at one point earned the largest amount of foreign currency of any single commodity among export goods. The expansion was due to;(1) booming construction activities in Korea and Middle Eastern countries at that time which boosted demand for plywood; and (2) continuing supplies of inexpensive tropical logs from the Southeast Sea countries which made plywood manufacturing more profitable. Moreover, the government's commercial policy, which maintained strong protectionism for domestic target industries such as plywood, textiles, fertilizers, and footwear, was a major contributer to the expansion of the plywood industry (Government of the Republic of Korea 1971).

However, several economic shocks created disasters for the plywood industry in the early 1980's. Major shocks included the oil crisis of the early 1970's and later followed by the tropical log export ban by Indonesia and sluggish construction activities in domestic and Middle Eastern countries' construction markets. Also, the increasing harness of competition in the world plywood market, caused mainly by the appearance of the South Sea countries in that market, suppressed the Korean plywood industry more than ever. The problem was compounded by inefficient production processes resulting from

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the Korean government's protectionist policies. These successive shocks resulted in both a major loss of export markets and the huge shrinkage of the plywood industry.

In the near future, the industry will face even more severe competition in the domestic plywood market as well. This is the result of the Korean government's new trade policy of decreasing protectionism. In order to make the Korean plywood industry more competitive in international and domestic markets, the production behavior and cost structure of the industry should be investigated, since productivity and cost effectiveness are chiefly what make it competitive.

II. Objectives of the Study

Since the late 1970's, the production scale of the Korean plywood industry has shrunk significantly due in large part to loss of export markets. This implies that the Korean plywood industry has been losing its competitiveness in the world plywood market, and its loss of competitiveness brings further concerns in the domestic plywood market as protectionism is removed.

The major question regarding the competitiveness of any industry is usually 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).

The Korean plywood industry has faced remarkablely 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 crisis 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 Indonesia consequently resulted in a substantial price increase for tropical logs.

The objectives of this study are to investigate the effects of factor price changes on the production cost of the plywood industry in Korea. Previous research has not directly addressed the contraction of the Korean plywood industry, though it is believed that the altered circumstances of factor markets were major contributors. Therefore, this study addresses the following questions:

What was the effect of changed prices of tropical logs on the production performances of the Korean plywood industry? Has labor cost been a significant factor in modifying the cost performances of manufacturing plywood in Korea? What are other influential input prices which may affect the cost of production plywood in Korea?

III. Study Methods

The objectives of this study are to investigate the effects of input prices on the production costs of the Korean plywood industry. In order to address these objectives and related questions, the production structure of the industry must be investigated. A production or cost function can be used to analyze the production structure of the industry. The cost function is used for this study because of duality theory and the theoretical and empirical advantage of the cost function over the production function.[1]

To provide the best approximation of the production structure, a certain functional form should be used. Among functional forms, including conventional functional forms (i.e., Cobb-Douglas and CES function) and flexible forms (i.e., the Generalized Leontief, the Translog, the Generalized Cobb-Douglas, the Generalized Square Root Quadratic, the Generalized Box-Cox, and the Fourier function), the Translog cost function is employed for this study.[2] Since the

[1] From the mathematical principle of duality, problems of constrained maximization are related to problems of minimization which are constrained by the constraints of the maximization problem. An example adequate for this study is that a firm's fundamental problem of maximizing profits used given inputs is dual to minimizing costs to produce given outputs (Nicholson 1985).

Duality theory provides a very useful tool for economists because they can choose a cost function or production function, depending on the circumstances. Therefore, the choice of a cost or a production function for a given study does not alter the answers to the question but provides convenience to researchers.

[2] Flexible forms 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.

flexible forms are superior to the conventional forms theoretically, a flexible form is chosen for the study.[3] The choice of translog function among flexible forms is based on the principles of selecting functional forms, which are suggested by Pope(1984), Lau(1974), and Fuss et al. (1978).[4]

1. Model

The Translog cost function for the Korean plywood industry includes four inputs – namely, material(tropical logs for plywood), energy, capital, and labor – in the investigation of the effects of input costs on the production costs. Annual data for the industry during the 1966-87 period are used.

Translog cost function for the Korean plywood industry can be expressed as follows:

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

where C is a total production cost, Q is an aggregate industry output, P_i and P_i are the price of inputs, T is a time trend that will be used as a proxy for technological changes, and α are estimated coefficients. L, M, E, and K represent labor, material, energy, and capital, respectively.

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[3] The major advantage of these 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.

[4] 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 order of precision; and (2) it must result in estimation forms that are linear in their parameters.

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.

In order to form symmetry of cross-partial derivatives, the following condition should be met:[5]

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

According to neoclassical production theory, the cost function must be homogeneous of degree one with respect to factor prices (Varian 1984). Therefore, the following conditions are imposed on the parameters of the translog cost function for symmetry and homogeneity (Merrifield and Haynes 1985):

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

2. Tests for the Production Structure

Since the translog cost function for the Korean plywood industry does not constrain a certain production structure such as an homotheticity, homogeneity, or unitary elasticity of substitution, these production structures will be tested to select the best model which is based on the production technology by using the likelihood ratio test.[6]

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[5] Young's therom and continuity of the cost function provide the symmetry condition of cross-partial derivatives.

[6] A production function is homogeneous of degree r if all inputs in the production function are changed proportionally, output changes by the rth power of that changes. In mathematical form, if $f(x_1, \ldots, x_n)$ is homogeneous of degree r,

$$f(tx_i \ldots tx_n) = t^r f(x_i, \ldots, x_n)$$

where t is constant(Silberberg (1981)).

Therefore, homogeneity in the production function indicates the degree of production change when the factor amounts change.

The homotheticity production function shows that the slopes of isoquant curves are invariant in all radial expansions. This means that the output elasticities for all factors are the same at any point in the expansion path. In other words, if the production function is homothetic, the expansion of the output does not affect the combinations of factors used (Silberberg 1981).

Formally, homothetic function is

$$y = h(x_1, \ldots, x_n) = F(f(x_1, \ldots, x_n)$$

where $F' = 0$ and $f(x_1, \ldots, x_n)$ is a homogeneous function (Silberberg 1981)

The likelihood ratio test is designed to test the validity of the restriction by comparison of the likelihood functions. That is, if an imposed restriction is valid, the value of the likelihood function with the imposed restriction will not be significantly different from the value of the likelihood function without imposition of the restriction. The likelihood ratio test is as follows:

$$LR = -2[L(\tilde{\beta}, \tilde{\alpha}^2) - L(\hat{\beta}, \hat{\alpha}^2)] \sim \chi^{2m}$$

where $L(\tilde{\beta}, \tilde{\alpha}^2)$ is the maximum of the log likelihood function when the restrictions are imposed, $L(\hat{\beta}, \hat{\alpha}^2)$ is the maximum of the log likelihood function when the restrictions are not imposed, and m is the number of restrictions (Kmenta 1986).

If a cost function is a separable function in output and factor prices, the production structure of industry is homothetic. Therefore, α_{Qi} should not be significantly different from zero in the translog cost function (Christensen and Greene 1976). If the elasticity of cost with respect to output is constant, a homothetic function is homogeneous (Christensen and Greene 1976). Therefore, if α_{Qi} and α_{QQ} are zero, the production function is homogeneous. The elasticities of substitution between factors are unitary if second-order terms in the prices are not available in the cost function (Christensen and Greene 1976). Therefore, in order that the elasticity of substitution is unity, α_{ij} should not be significantly different from zero. Further information on derivations of the restrictions for homotheticity and homogeneity are available from Diewert (1974). For this study, homotheticity, homogeneity, and constant elasticity of substitution are tested for the production structure of the Korean plywood industry.

3. Impact of Factor Prices on the Average Costs of Production

The impact of input costs on the average cost of production can be estimated from the Korean plywood industry's translog cost function equation. The average cost function of the industry can be expressed as:

$$\begin{aligned} \ln AC = \ln(C/Q) = \ln C - \ln Q = \alpha_0 + \ln Q(\alpha_q - \alpha_{QT}T - 1) + 0.5\alpha_{QQ}(\ln Q)^2 \\ + \alpha_T T + 0.5\alpha_{TT}T^2 + \sum_i \alpha_i \ln P_i + 0.5 \sum_i \sum_j \alpha_{ij} \ln P_i \ln P_j \\ + \sum_i \alpha_{Ti} T \ln P_i + \sum_i \alpha_{Qi} \ln Q \ln P_i \end{aligned}$$

The elasticities of average costs with respect to input price can be derived by differentiating equation with respect to the log of factor prices (Merrifield and Haynes 1985):

$$EAC_i = \partial \ln AC / \partial \ln P_i = \alpha_i + \sum_i \alpha_{ij} \ln P_j + \alpha_{ij} \ln P_j$$
$$+ \sum_i \alpha_{Ti} T + \sum_i \alpha_{Qi} \ln Q \quad \text{for } i \neq j$$

4. Definition and Computation of the Data

The definition and computation of the data for each variable along with the source of information are presented below.

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), which is the total quantity of plywood produced, is measured in physical units. It is obtained from The Statistics Yearbook, published annually by the Korean Plywood Manufacturers' Association.

The price of materials (M) is represented by the prices of the tropical log which are used for manufacturing plywood, and it is 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 since they 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

[7] Several methods for calculating capital price were employed in 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),

fixed assets.[7]

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

5. Estimation Method

The translog cost function can be estimated by employing ordinary least squares. However, due to the large number of coefficients to be estimated, the potential problem of multicollinearity presents itself.

Therefore, the translog cost function and its share equations should be jointly estimated as a multivariate regression system (Christensen and Greene 1976). This method can effectively remove possible multicollinearity among regressors of the cost function by providing additional information from its share equations (Singh and Nautiyal 1985). Although Zellner introduced the method of estimating seemingly unrelated equations for the cost equations and its share equation, this method cannot produce invariant estimates in which an equation is deleted in the share equations(Zellner 1962).[8]

The iterative Zellner-efficient estimation (IZEF), which is equivalent to a maximum likelihood iterative technique, can provide invariant estimators in the equation deleted (Kmenta and Gilbert 1986, Dhrymes 1973). A further gain in efficiency will be achieved by combining IZEF and the two-stage least squares (2SLS) to form the iterative three-stage least squares(I3SLS) (Singh and Nautiyal 1985).

The I3SLS estimators can be obtained as follows (Kmenta 1986): the residual from the initially estimated three-stage least squares equations is used to estimate new variances and covariances

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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..

[8] 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.

of the structural disturbances. These estimators will replace the previous estimators of the three-stage least squares formula. This process can be repeated until the values of the estimated structural coefficients are stable.[9] This method has been used by many economists(e.g., Berndt and Wood 1975; Christensen and Greene 1976; Sherif 1983; Nautiyal and Singh 1985, 1986; Singh and Nautiyal 1985). Therefore, this method will be used for estimating the Korean plywood industry's translog cost function and its share equations.

In this study, the capital share equation is omitted arbitrary in order to avoid singularity problem. All remaining equations are assumed to have normally distributed stochastic disturbance terms with zero mean and finite variance. Also, the errors are correlated across equations contemporaneously, but are assumed independent across time.

IV. Results

1. Results of the Production Structure Test

Results of the likelihood ratio tests (Table 1) show that all imposed restrictions were rejected at a 5% level of significance.[10] That is, the calculated values of χ^2 fall outside critical values for models 2~4. Therefore, homothetic, homogeneous, and unitary elasticities of substitution production structures for the Korean plywood industry were not valid. In other words, the production structure of the Korean plywood industry was nonhomothetic, and nonhomogenous with

Table 1 Test Statistics for the Production Structure

	Model 1	Model 2	Model 3	Model 4
Number of restrictions	None	3	4	6
Log of likelihood function	41.03	6.82	6.22	12.51
Critical χ^2(5%)		7.81	9.48	12.59
Calculated χ^2		68.42	69.62	57.04

Model 1 is the unrestricted translog cost function.
Model 2 is the homothetic cost function.
Model 3 is the homogeneous cost function.
Model 4 is the unitary elasticity of substitution cost function.

[9] The asymptotic properties of this method are the same as those of the ordinary three-stage least squares estimates.

[10] All models are also rejected at the level of significance at 1%.

nonunitary elasticity of substitution.

Nonhomotheticity and nonhomogeneity of production structure imply that the relative compositive of the inputs in the production process can be changed when the output level changes. In other words, if the output level increases autonomously (holding all input prices constant), the slope of isoquants along a radial expansion will be changed from the original tangency (Silberberg 1981). Equivalently, the output elasticities for all inputs are not invariant at any level of production along a radial expansion path. This means that the relative composition of inputs (holding all input prices invariant) at a certain production level will be different from that of other production levels.

2. Validation of the Best Model

Given the results of the likelihood ratio test, Model 1 is considered as the best model since no other models are valid. The conditions for a well-behaved cost function (i.e., homogeneity, positivity, continuity, and concavity) were investigated for Model 1.[11]

First, the condition of homogeneity in input prices was imposed *a priori* on the estimated cost function. Therefore, homogeneity condition was fulfilled.

Second, the positivity condition will be met if the fitted values of all input shares are positive. From the results of estimation, this condition was successfully fulfilled since all the fitted values for shares were positive.

Third, the concavity condition will be satisfied if the Hessian matrix of the second-order partial derivatives is symmetric and negative semidefinite (Fuss 1977). The equivalent condition for the concavity condition is that the symmetric matrix of the Allen elasticities of substitution is negative semidefinite (Mohr 1980). A sufficient condition for fulfilling the above condition is that all of the own Allen partial elasticities of substitution are less than zero, namely $\sigma_{ij} < 0$. Estimation results show that all of the own Allen partial elasticities of substitution are less than zero. Therefore, the concavity

[11] These four conditions are the necessary and sufficient conditions for the well-behaved cost function (Varian 1984).

condition was fulfilled for this model.

Fourth, the continuity condition also will be satisfied, if the cost function fulfilled the concavity condition (Varian 1984). It did so as indicated above: thus, the continuity condition was satisfied for this model.

Therefore, all four necessary and sufficient conditions (i.e., homogeneity, positivity, continuity, and concavity) for a well-behaved cost function were fulfilled for the best model, Model 1.

3. Effects of Input Prices on Average Production Cost

The elasticities of average cost with respect to factor prices from the Model 1, which is the best model based on the likihood ratio tests, are presented (Table 2). The price of material has the highest elasticity value, followed by labor, energy, and capital. Therefore, material has the greatest effect on production costs, followed by labor, energy, and capital. The results differ from those of Merrifield and Haynes (1985) of the Pacific Northwest region of the United States, which showed that labor had the highest value of elasticity, followed by energy or structure depending on the locations of the industries. Nautiyal and Singh (1985) estimated averge cost elasticities for the Canadian lumber industry. Their results revealed that roundwood had the greatest elasticity (0.57), followed by labor (0.24), energy (0.17), and capital (0.02). Compared to other regional plywood industries in the previous studies, the differences of elasticities among inputs are much larger for the Korean plywood industry. This implies that production cost of the Korean plywood industry were extremely sensitive to the price of the material.

V. Findings and Implication of the Analysis

Table 2 Elasticities of Average Cost with Respect to Factor Prices

Input price	Elasticities
Labor	0.0950
Energy	0.0425
Material	0.8428
Capital	0.0195

The major findings of the study are:

(1) Regarding the production structure of the Korean plywood industry, results of the likelihood ratio test show that all imposed restrictions(i.e., homotheticity, homogeneity, and unitary elasticity of substitution) were rejected at a 5% level of significance. Therefore, homothetic, homogenous and unitary elasticities of substitution production structures for the Korean plywood industry were not valid for the study period. In other words, the production structure of the Korean plywood industry was nonhomothetic and nonhomogenous with nonunitary elasticity of substitution.

Nonhomotheticity and nonhomogeneity of the production structure imply that the relative composition of the inputs in the production process can be changed when the output level changes. Equivalently, if the output level increases autonomously (holding all input prices constant), the slope of isoquants along a radial expansion will be changed from the original tangency. This provides an important implication for the factor demand because the relative demand of inputs will change as the level of output changes.

According to the results of this study, the future outlook for the Korean plywood industry may be bleak for several reasons. First, the industry relies heavily on the condition of the material market over which it has no control. What if the tropical log market changes dramatically again? Can the industry survive? This is of major concern to the industry because imported tropical logs are a major input of plywood production. Second, the difficulty for the industry will be increased if protectionism is removed in the future since countries such as Indonesia produce tropical logs in their backyard and have cheaper labor inputs. Therefore, comparative advantage issues should be considered at this stage in order for the industry to survive in the future. Since the findings of this study confirm that the industry is very vulnerable to tropical log market conditions, Korea may not have a comparative advantage in the production of plywood anymore, although it might have had it at one time. The differences between now and the '70s in terms of input markets and government policies are very significant. The price of tropical logs is much higher now than it was 15 years ago. Also, the availability of tropical logs is limited, and labor costs is getting more expensive nowadays. Most export assistance programs are no longer available for the plywood industry, and domestic markets may erode because protective tariff rates are currently much lower. The industry has also had much more difficult times in the world plywood market since Indonesia entered this arena.

Should plywood manufacturing continue in Korea? Is production plywood economically desirable in terms of efficient allocation of national resources? The answer may be negative based upon current input market conditions, the political climate, world plywood markets, and domestic plywood market considerations.

In order to overcome these problems, several options can be pursued: (1) The supply of logs should be considered and secured for the long run through finding and contraction other supply sources. (2) Substitution among different types of logs should be pursued in order to compensate for future shortages of tropical logs. Temperate logs from North America may be the best source of substitution for tropical logs. Growing trees in Korea may be substitutable for tropical logs in the future.[12] (3) The industry needs to convert its major products from the less processed plywood to the more highly processed plywood. The third option should be considered seriously because: (a) Korea has accumulated improved technologies for manufacturing plywood for over 30 years. (b) Competing with newer plywood manufacturing countries, which own inexpensive materials and labor factors(e.g., Indonesia), in the highly processed plywood market may not be as difficult as in the minimally processed plywood market. Also, competing with incumbent countries in the highly processed plywood market may not be impossible because Korea still owns cheaper labor and similar levels of technologies.[13]

VI. Summary and Conclusion

The study was conducted to analyze the production structure and cost performance of the Korean plywood industry. The objectives of the study was to investigate the impact of input prices on the production

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[12] Since logs in Korea are small, technology similar to the U.S. southern pine plywood industry's may be appropriate (Leefers 1981).

[13] Eagon Industrial Corp. LTD was successful in exporting highly processed plywood products in recent years.

costs of the Korean plywood industry.

Based on study objectives and a review of relevant literature and theory, the transcendental logarithmic cost function was selected to analyze the behavior of the Korean plywood industry. It is a "flexible form" cost function, which was applied and estimated by using the annual time series data for the period of 1966-87. Using the likelihood ratio test as the criterion, Model 1, which is an unrestricted model, was selected as the best model.

Effects of the input prices on the average production cost of the outputs were investigated. The elasticities of average costs with respect to factor prices showed that the elasticity associated with material price is the highest, followed by energy, capital, and labor. The estimates for elasticities imply that the cost of material was a dominant factor affecting plywood production costs. Therefore, the production costs of the plywood industry were mainly determined by the prices of materials. Hence, increased import prices of tropical logs in the late '70s, were a major factor in the loss of competitiveness by the Korean plywood industry in the world market, and in the subsequent contraction of the industry after the late '70s.

Since the cost of material is a dominant factor in forming production costs, the industry should find alternatives for reducing production costs. Further exploration of alternative sources of tropical logs should be continued. The other possibility is a substitution of temperate logs for tropical logs even though using temperate logs for plywood manufacturing would be still more costly. To save material inputs, the industry should enhance its utilization rates of logs through technological progress and by using more efficient machinery.

There are several limitations of this analysis. These resulted mainly from the finite scope of the study and capabilities of the model employed.

Further studies can be conducted based on alternative objectives and research methods. For example, implications of commercial policies on the industry's production performance could be studied. High priority should be given to investigating the comparative advantage of manufacturing plywood in Korea. The possible substitution of temperate logs for tropical logs in the plywood manufacturing process also should be investigated. The possible major adjustment behaviors of the industry, such as production structure change, input substitutions, and technological change, when it faced the altered circumstances, can be addressed in the further study.

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