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IMPLICATIONS OF CHANGING FACTOR PRICES
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THE KOREAN PLYWOOD INDUSTRY'S PRODUCTION COSTS

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IMPLICATIONS OF CHANGING FACTOR PRICES AND PRODUCTION TECHNOLOGY ON THE KOREAN PLYWOOD INDUSTRY'S PRODUCTION COSTS

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ABSTRACT

IMPLICATIONS OF CHANGING FACTOR PRICES AND PRODUCTION TECHNOLOGY ON THE KOREAN PLYWOOD INDUSTRY'S PRODUCTION COSTS

By

Hyun Deok Seok

The Korean plywood industry was developed as a strategic industry in the 60's and grew until the end of the 70's. The industry's success was due to rising demands for plywood in domestic and world markets, continuing supplies of inexpensive tropical logs and other inputs, and the government's commercial policies which maintained strong protection for domestic target industries.

However, several economic shocks caused a major contraction of the Korean plywood industry. These started with the oil crisis of the early 70's and were followed later by Indonesia's tropical log export ban, declining export markets and diminishing governmental assistance. In the near future, the industry will face even more severe competition in the domestic plywood market as well due to a new trade policy of decreasing protectionism.

Productivity and cost effectiveness are crucial in competitive markets. To provide insight for making the plywood industry more competitive in international and domestic markets, the industry's production behavior and cost structure are investigated in this study.

The primary objective of this study is to investigate factors causing contraction of the Korean plywood industry. The second objective is to analyze the industry's adjustment methods and processes (e.g., factor substitutions, technological changes, and structural changes) following altered circumstances.

To address these objectives, the transcendental logarithmic cost function with labor, capital, material, and energy for the industry is estimated using annual time series data for the period of 1966-87. Several models based on the production technology are estimated. The best model is selected using the likelihood ratio test. The test for technological change and structural changes of the production function are also conducted.

Major findings are: (1) production costs were most sensitive to log prices; (2) the industry showed a material-using technological change bias; and (3) material is substitutable with all other inputs.

Implications of this study are: (1) because material cost is a main factor affecting total production costs, the long-run log supply should be carefully assessed; and (2) producing more highly processed plywood should be considered to enhance the Korean plywood industry's comparative advantages.

This study is dedicated to my
grandfather, Mr. Ki Won, Seok.

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CHAPTER 1

INTRODUCTION

1.1. Background

After the end of Japanese rule in 1945, the Korean government sought to establish a strong economy in order to satisfy the consumptive demands of a rapidly increasing population. Moreover, a rapid rise in unemployment also became a major concern of the government. The need for a concrete national defense, to prevent any possible invasion attempt from North Korea, also required a stable and strong economy. However, the inefficient and inadequate administration of Sungman Lee's regime, political and social instabilities, and the extensive destruction occasioned by the Korean War (1950-1953) decimated the Korean economy again (Brown 1973).

After the war, rehabilitation of the Korean economy was initiated in 1954 with the aid of international economic agencies.[1] Development of import-substitution industries became one of Korea's major economic policies, strategically designed to revive a nearly suffocated economy (Kuznets 1977). Although major industries showed higher growth rates than those of average developing countries in some years,

[1] The International Cooperation Administration (ICA) and the United Nations Korean Reconstruction Agency (UNKRA) were major agencies.

the economy started to show signs of stagnation in 1959. Because of the unbalanced development of industries, declining foreign aid, and political and social instability, economic growth did not occur until the early 1960's.[2] Even then the economy remained at essentially the same stage as the prewar level, due to the lack of natural resources, low capital and technology accumulation, weak industrial structure, and the slow economic progress which compounded existing problems.

The appearance of Chung Hee Park's regime (in 1961) brought a new economic era to Korea. One major accomplishment of the first phase of his economic development plan (1962-1966) was the switch from development of import-substitution industries to development of export-led industries (Government of the Republic of Korea 1966; Kuznets 1977).

Sixty-seven percent of the area of South Korea is covered by wilderness mountain areas which were once heavily forested. However, after both massive extraction of forest resources by the Japanese during their rule in Korea (1910-1945), and subsequent destruction of much of the remaining forests during the Korean War, little remained intact in the mountain areas. Consequently, forest resources and

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[2] The excessive expansion of production capacities in consumer goods industries and the failure to establish industries which would have provided intermediate goods to the consumer goods industry became major obstacles to the growth of the whole economy.

industries were not important factors in the Korean economy.

However, the rise to power of Park's government caused the forest sector to become an important part of the Korean economy. The initiation of massive planting and conservation practices in the mountain areas resulted in one of the most successful reforestation projects in the world. Selection of the plywood industry as a strategic industry for the revival of the Korean economy in the late 1960's also contributed to the overall development of the forest sector. The success of the plywood industry initiated the development of other major forest industries such as furniture and musical instrument industries.

The plywood industry was developed as a strategic industry 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 contributor 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 harshness of competition in the world plywood market, caused mainly by the appearance of the South Seas countries in that market, suppressed the Korean plywood industry more than ever. The problem was compounded by inefficient production processes resulting from 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.

This information can be used by policymakers and other interested in natural resource-using industries.

1.2. 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). 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.

The primary objective of this study is to investigate the causes of the contraction of the Korean plywood industry. The second objective of the study is to analyze the industry's adjustment methods and processes following altered circumstances (e.g., factor substitutions, technological changes, and structural changes). 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:

1) What was the major cause of the contraction? Did increased factor prices cause increases in production costs resulting in less competitiveness in the world market? For example, what was the effect of increased 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 producing plywood in Korea?

2) To be more competitive in the world market, how has the Korean plywood industry faced the altered circumstances? In other words, 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? For instance, did industry substitute a labor input for an energy input when the price of energy increased? 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? It is clear that these questions regarding structural changes and input substitutions must be addressed in order to reveal adjustment behaviors of the industry following altered situations.

To address these objectives and related questions, the transcendental logarithmic cost function for the industry (see chapter 4), which is a flexible form of a cost function, is applied and estimated by using the annual time series data for the period of 1966-87. In addition, the test for structural changes of the production function is conducted in order to investigate the second objective of the study. To select the best model which is based on the production technology, the log likelihood ratio test is conducted.

1.3. Scope and Limit of the Study

This study deals only with the production behavior of the Korean plywood industry. Therefore, commercial policy issues related to the Korean plywood industry are not analyzed. A discussion of commercial policies, however, is presented in chapter 2. There are two major reasons for excluding the issues of commercial policies from this study. First, the effects of those policies are already quantified and included in the cost performances of the industry, even though those effects are not separately quantified. Second, it is very difficult to quantify the effects of those policies correctly due to the lack of data and information regarding the commercial policies applied to the Korean plywood industry. However, the exclusion of commercial policy issues may limit the usefulness of this study in terms of policy implementation and evaluation.

Although the Korean plywood industry has more recently begun to produce a variety of plywood products, this study considers plywood as a single commodity. The main reasons for this aggregation are: (1) the Korean plywood industry mainly produced unprocessed plywood (raw panel) in most of the years for the sample period; and (2) due to the lack of data availability, it is difficult to get a separate cost of production for the processed plywood. The aggregation of the commodities may limit the usefulness of the study in some cases.

This study includes only four inputs (namely, capital, labor, energy, and material). Although these inputs comprise more than 95% of total production costs, the inclusion of only these four factors in the analysis may limit the usefulness of this study in some applications (The Korea Development Bank and Economic Planning Board, various years). The main reason for excluding other inputs (e.g., water) is that these inputs are not significant in the total production costs and these inputs cannot be classified in terms of the common classification of the production factors for the industry.

The study considers for the period 1966-1987 mainly because of data availability. However, this may affect the results of econometric analysis and consequently may limit the usefulness of the study in some applications.

1.4. The Dissertation Plan

This study of the Korean plywood industry has six chapters. The general status of the study, background, information, objectives, scope, and limitations are presented in this chapter. The second chapter provides general information on the Korean plywood industry, including its historical development, its current situation, and the conditions of the domestic plywood market. This provides a foundation for understanding the industry and its output market. The third chapter focuses on a review of previous studies of forest products industries in the Korean and North American regions, including studies of industry production behavior. Given this study's objectives, it provides a basis for selecting the econometric models used. The fourth chapter covers the functional forms of the model used for the present study, including a description of the tests relevant to this study. Estimation methods and processes of the employed model, and results of the estimations are presented in the fifth chapter. Conclusions and policy implications are presented in the final chapter. All related data are presented in the Appendix.

CHAPTER 2

OVERVIEW OF THE KOREAN PLYWOOD INDUSTRY

2.1. Introduction

In order to fulfill the objectives of this study, a general understanding of the industry and its performance throughout the sample period is required. In addition, the conditions of the plywood market should be reviewed in order to understand how its mechanisms affect the industry's performance. Therefore, the primary intent of this chapter is to provide a description of the Korean plywood industry and the domestic plywood market by presenting the establishment, development, expansion, and contraction of the Korean plywood industry throughout its history. In addition, a description of the conditions of the domestic plywood market and a history of the commercial policies implemented for the industry and its market are presented in this chapter.

2.2. History of the Korean Plywood Industry

The history of the Korean plywood industry is presented in four parts, which are grouped by time periods and the concomitant shape of the industry. First, the establishment and initial development of the industry--here depicted as an import-substitution industry--are presented. The second part discusses the continuing development and success of the industry throughout the '70s. In this period, the Korean plywood industry was classified as an export-led industry. The third part describes the contractions of the industry after the late '70s. And finally, the historical review focuses on the reshaping process of the industry following its massive decline.

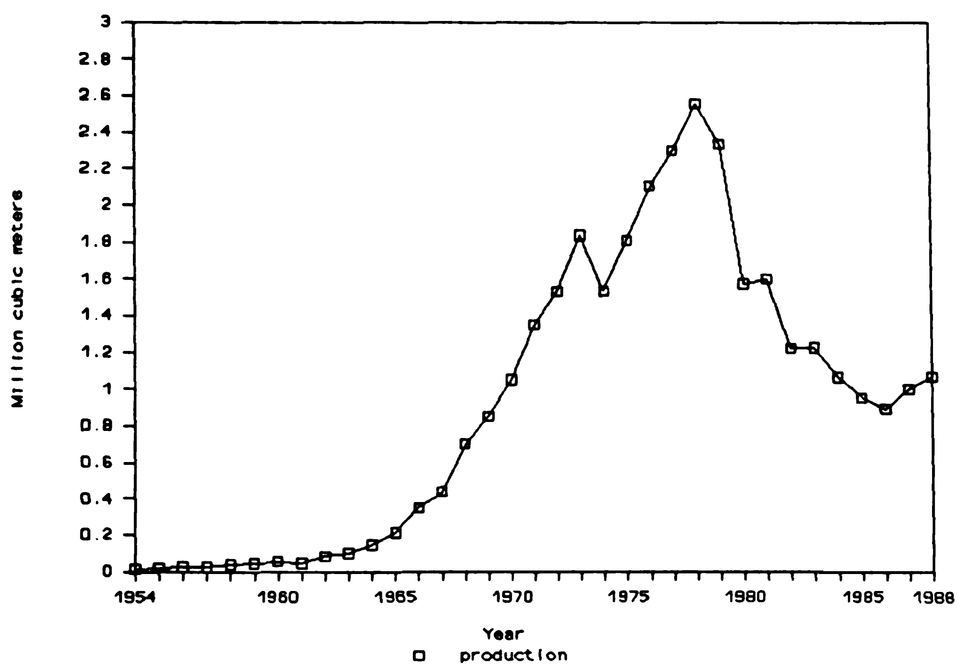
2.2.1. Establishment and Initial Development of the Korean Plywood Industry in the Period 1954-1960

The history of the Korean plywood industry began when Dae-Sung Timber Ltd. was established in 1936. However, due to the lack of data from the period of its establishment to the end of the Korean War, the early stage of the plywood industry, including the history of its establishment and initial expansion, is unknown. However, we can assume that Korea's production technologies were comparable to Japan's, and that the produced merchandise was limited to raw panels, since the Korean plywood industry was controlled by the Japanese at that time (Song and Son 1978).

After the Korean War (1950-1953), the Korean plywood industry expanded significantly as a result of construction booms which boosted demand for the plywood. To meet this postwar demand for plywood, the industry reconstructed its facilities, developed advanced technologies, and expanded its production structure. To this end, production increased from 15.79 thousand cubic meters (M^3) in 1954 to 55.20 thousand M^3 in 1960, and the annual rate of production increase for the same period was 19.58% (see Figure 2-1). In 1957, the Korean plywood industry began to supply plywood to the in-country United Nations forces. Exports to the United Nations forces continued for several years. In 1959, Sung-Chang Enterprise Co. Ltd. exported plywood to the United States for the first time.

Until the early 1960's, the Korean plywood industry expanded its production capacities and satisfied domestic consumption needs. Without industry expansion, plywood would need to be imported. Therefore, the first period of its history, 1954-60, includes the establishment and successful development of the Korean plywood industry as an import-substitution industry.

Figure 2-1. Production of Plywood in Korea, 1954-1988.



Note: Data are 4mm basis.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

2.2.2. Success of the Korean Plywood Industry as an Export-led Industry in the Period 1961-1979

The Korean plywood industry entered a new era after being named as a strategic export-led industry by the Korean government in 1964. From that time on, its production capacity expanded significantly and operating rates were kept high until 1979 (see Table A-1 in Appendix A).

The major expansion of the Korean industry in this period can be explained by several reasons. First, the continuous expansion of the Korean economy created additional domestic demands for plywood via construction booms. This was a result of the success of several economic development plans started by the First Korea Economic Development Plan in 1962. Second, the industry's export market had expanded remarkably with the assistance of the Korean government and the industry's great eagerness to export plywood. Third, the demand for plywood in the world market had increased steadily during this period (see Table A-4). Fourth, inexpensive and plentiful natural tropical logs, a major factor in plywood manufacturing, had been continuously available from the South Sea countries.[3] This yielded consistently huge value-added opportunities for the industry. Finally, since many construction companies

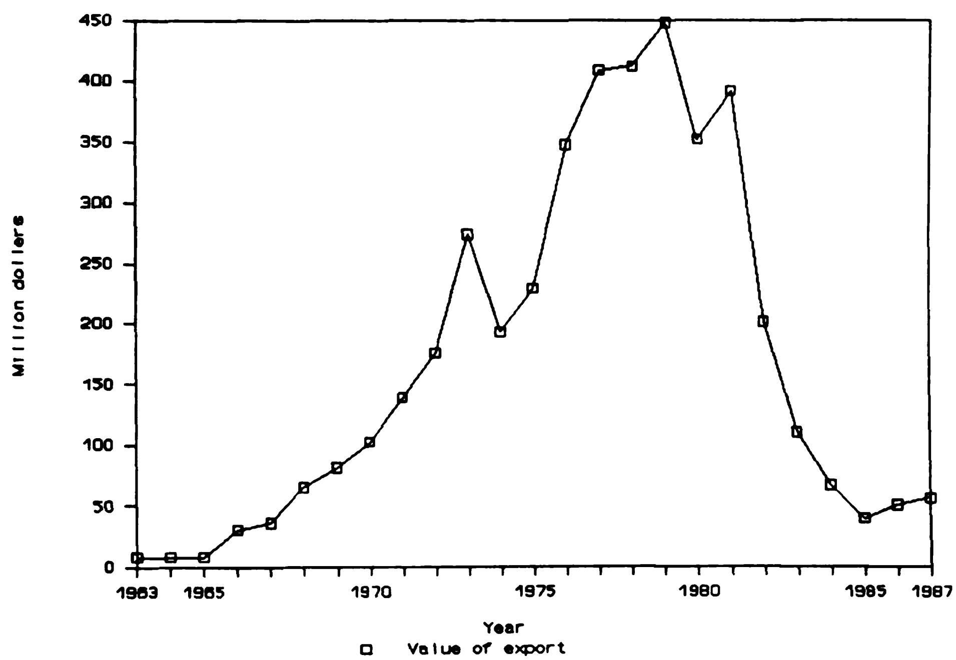
[3] Indonesia and Malaysia were the major suppliers of tropical logs to Korea.

serviced construction activities in Middle Eastern countries such as Saudi Arabia and Iraq, plywood exports to these countries become more significant at that time (see Table A-2).

Production of plywood increased from 353.7 thousand M^3 in 1966 to 2,559.3 thousand M^3 in 1978. Export values for the same period expanded from 30.6 million to 394.1 million U.S. dollars (see Figure 2-2). The production capacities of the plywood industry expanded from 360.2 thousand M^3 in 1966 to 2,734.2 thousand M^3 in 1978.

However, during this second period of the industry's history, the first oil shock in 1973 created a major shrinkage of plywood industry since (1) it caused higher production costs through higher oil prices, and (2) it brought on stagnation in the global economy. Consumption of plywood in the domestic and world market was significantly reduced, and the Korean plywood industry suffered financial problems related to over-investment in facilities and unsold commodities. Therefore, the export values of plywood declined 33% in 1974 from the previous year. Consequently, production decreased from 1,840.2 thousand M^3 in 1973 to 1,534.5 thousand M^3 in 1974.

Figure 2-2. Value of Plywood Exports from Korea, 1963-1987.



Note: Values are nominal U.S. dollars.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

The industry recovered its expansion momentum in 1975, and reached record highs for exports in 1979 and for production in 1978. The industry also became a major producer and exporter among the plywood production and export countries at the end of the '70s (see Table A-4 and A-5). In addition, the Korean plywood industry became a major contributor to the Korean economy and became the largest industry acquiring foreign currencies, which were a significantly important factor in accumulating capital for the development of the Korean economy (The Bank of Korea, various years. the Korea Economic Statistics Yearbook).

2.2.3. Contraction of the Industry in the Early 1980s

The Korean plywood industry faced a dark future after 1979, when the conditions of the major input markets altered dramatically. Starting in 1979, the Korean plywood industry confronted a tropical log export-ban from Indonesia which was the largest supplier of tropical logs to the Korean plywood industry at that time (see Table A-13). In addition, there was a downturn in plywood demand from both domestic and world markets, and financial problems due to the major elimination of the assistance programs of the Korean government (see part 2.4. in this chapter). The industry was further damaged after facing the second oil shock and a 36% devaluation of domestic currency in 1980.

Sky-rocketing prices of tropical logs and oil increased production costs, and eventually reduced the comparative advantages of the Korean plywood industry in the world market. Furthermore, the appearance of the South Sea countries, particularly Indonesia, in the world plywood market, and the shrinkage of this market due to the second oil shock in the late '70s created a significant reduction of the Korean plywood industry's share in the world market. In the domestic market, the industry suffered similarly reduced demand for plywood due to the shrinkage of a downturn in the Korean economy.

The Dong-Myung Timber Co., which owned the largest production capacities among plywood firms in the world at that time, disappeared in 1977. Soon after, the Korea Timber Co. and the Kyung-Dong Timber Co. in 1980, and the Sam-Sin Timber Co. and the Sin-Sin Timber Co. in 1981 all went bankrupt (Seoul Newspaper 1990). Further failures of plywood firms continued until 1986.

Production decreased from 2559.3 thousand M^3 in 1978 to 893.3 thousand M^3 in 1986, while exports decreased significantly from 1,308.0 thousand M^3 in 1979 to 171.1 thousand M^3 in 1986. Also, production capacity decreased from 2,734.2 thousand M^3 to 1,516.6 thousand M^3 in 1986.

However, the domestic consumption fluctuated during the same period, decreasing in the first three years and increasing in later years (see Figure 2-3).

2.2.4. Reconstruction of the Korean Plywood Industry

The Korean plywood industry faced a difficult situation in the late '70s and early '80s, and only the most financially sound firms could survive. The remaining twelve firms adjusted their production structures in order to survive any severe setback. Related firms such as resource development firms were absorbed to develop more versatile management (Seoul Newspaper 1990). More advanced technologies were developed for greater efficiency in the production process, and more value-added products such as processed plywood were produced.[4] Greater efforts were made to find new sources of tropical logs in order to secure a permanent supply.[5]

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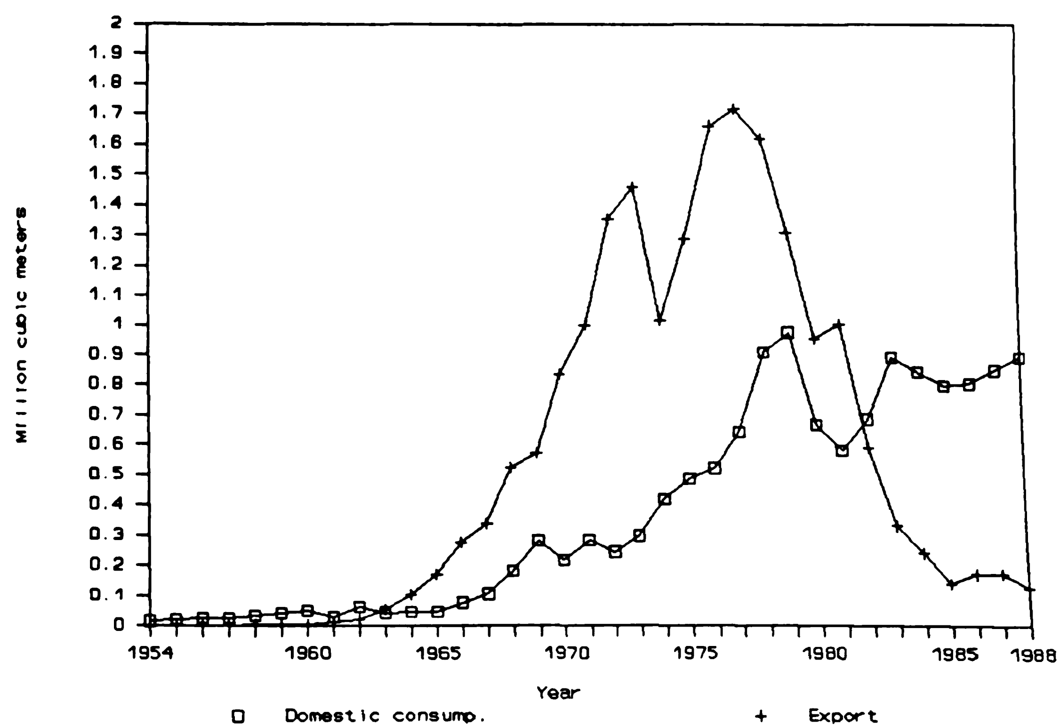
[4]The major processed plywoods are prefinished, overlaid, printed, and cosmetic.

[5]For example, Eagon Industry Cooperation Ltd. recently acquired a license to develop approximately 340 *thousand ha* of forest land from the government of the Solomon Islands (Seoul Economics Newspaper 1990).

Figure 2-3. Domestic Consumption and Export in Korea, 1954-1988.



Note: Data are 4mm basis.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

As a result of these changes, production has tended to increase in recent years, although production capacity has remained constant.

2.3. Structure of the Korean Plywood Market and Performance of the Korean Plywood Industry

The production, domestic consumption, and exports of plywood are reviewed for understanding the structure of the Korean plywood industry.

Production of plywood increased from 353.7 thousand M^3 in 1966 to 1,001.9 thousand M^3 in 1987. However, it did not show an increase for every year of the period 1966-1987. Production had continuously increased from 353.4 thousand M^3 in 1966 to 2,559.3 thousand M^3 in 1978 with an average annual growth rate of 16.45%. During the period 1966-78, only 1974 and 1975 showed a decrease in production, due to the first oil shock. Subsequently, however, production started to decrease from the year 1978, and continued until 1987. The production of plywood decreased from 2,559.3 thousand M^3 in 1978 to 1001.9 thousand M^3 in 1987. A commonly held view is that the production shrinkage in this period was due to the loss of export markets and the diminishing competitiveness of Korean plywood. This, in turn, was related to increased prices of tropical logs and oil, which had sky-rocketed as a result of the natural log export ban from Indonesia and the second oil shock in 1979. Quantification of these relationships are part of the focus of this study.

Domestic consumption of plywood increased steadily from 76.8 thousand M^3 in 1966 to 850.0 thousand M^3 in 1987. However, these trends are significantly different from that of production. Domestic consumption had increased from 1966 to 1979 with an annual growth rate of 6.6%. However, after the year 1979, the supply decreased for the next three consecutive years. Unlike the production trend, domestic consumption increased again after 1983, while total production decreased in the same period. Since plywood has been consumed mainly as an intermediate good, its demand can be explained by the activities of final demands. The input-output tables of the industry, published by the Bank of Korea (the Bank of Korea 1973 and 1975), indicate that the construction industry has been a predominant consumer of plywood, comprising more than 70% of the demand, followed by electronics and furniture industries (Song and Son 1978). Therefore, the number of permits authorized by the Korean government for building construction can be a major explanation for domestic plywood consumption trend (see Table A-12).

Export of plywood significantly increased from 276.9 thousand M^3 in 1966 to 1,618.0 thousand M^3 in 1978, which is the largest annual plywood export. After 1978, plywood exports began to decline and reached 172.2 thousand M^3 in 1987. The main reasons for this decline are: (1) increased production costs, and (2) the appearance of Indonesia as a major competitor in the world plywood market. The value of plywood exports had become nearly parallel to the fluctuations in the physical quantities of plywood exports. The value of plywood exports hit their peak of almost one-half billion dollars in 1979.

2.3.1. Major Export of Plywood by Region and Country

The U.S. had been a predominant importer of Korean plywood until the early '80s. It imported more than 80% of total plywood exports from Korea until 1972. After that, its share declined significantly to 69% in 1975, and eventually to less than 10% in 1984. It is evident that the U.S. market had been a major contributor to the success of the Korean plywood industry in the world market. Therefore, the loss of the U.S. market to the South Sea countries (especially Indonesia) explained the loss of almost the entire export market to the Korean plywood industry. Only the United States, Canada, Japan, and Saudi Arabia were major importers of Korean plywood.

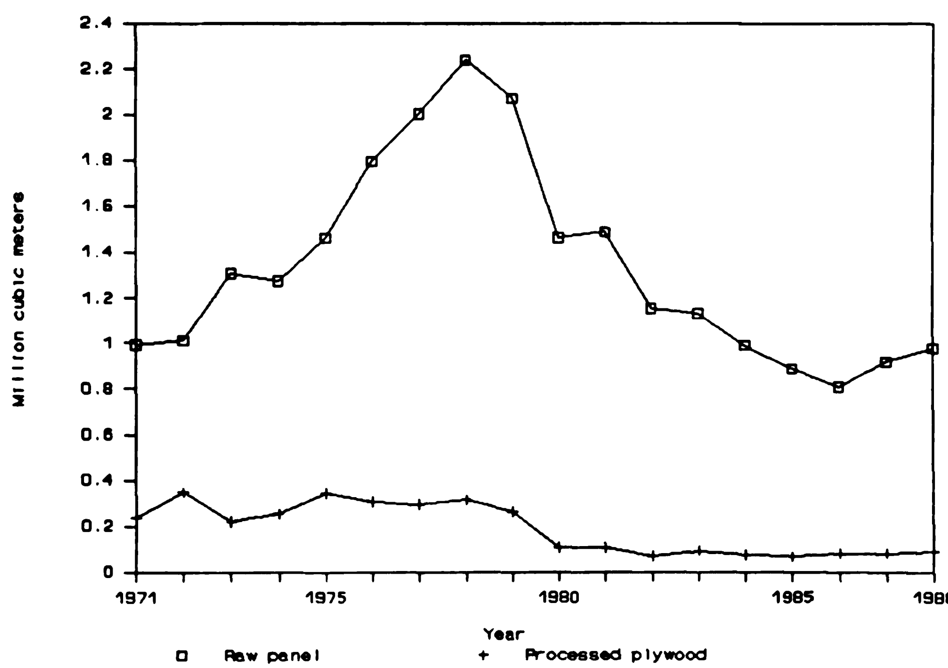
2.3.2. Production, Domestic Consumption, and Export of Plywood by Kinds

Plywood is classified into two major products classes, namely, raw panel and processed plywood. The Korean plywood industry produced and supplied these two products for both the domestic and world markets in the sample period.

2.3.2.1. Production, Domestic Consumption, and Export of Raw Panels

Raw panels have been major products of the Korean plywood industry since its establishment. For many years after 1971, the shares of raw panels of total plywood production were more than 90% (see Figure 2-4). However, its share decreased after the major contraction of the industry in the early '80s. Its share in total production decreased from 94% in 1970 to approximately 78% in 1988.

Figure 2-4. Production of Raw Panel and Processed Plywood in Korea, 1971-1988.

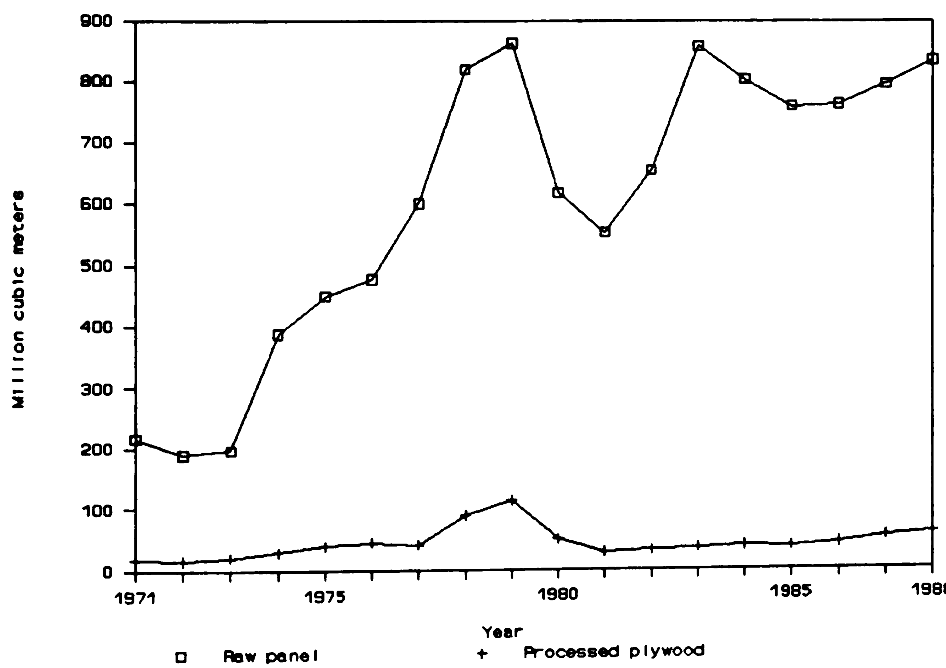


Note: Data are 4mm basis.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

In the domestic market, the share of raw panels was dominant in most years. Its share increased slightly from 92.5% in 1970 to 93.5% in 1988 (see Figure 2-5). Accordingly, the share of raw panels of total exports has proportionately decreased (see Figure 2-6).

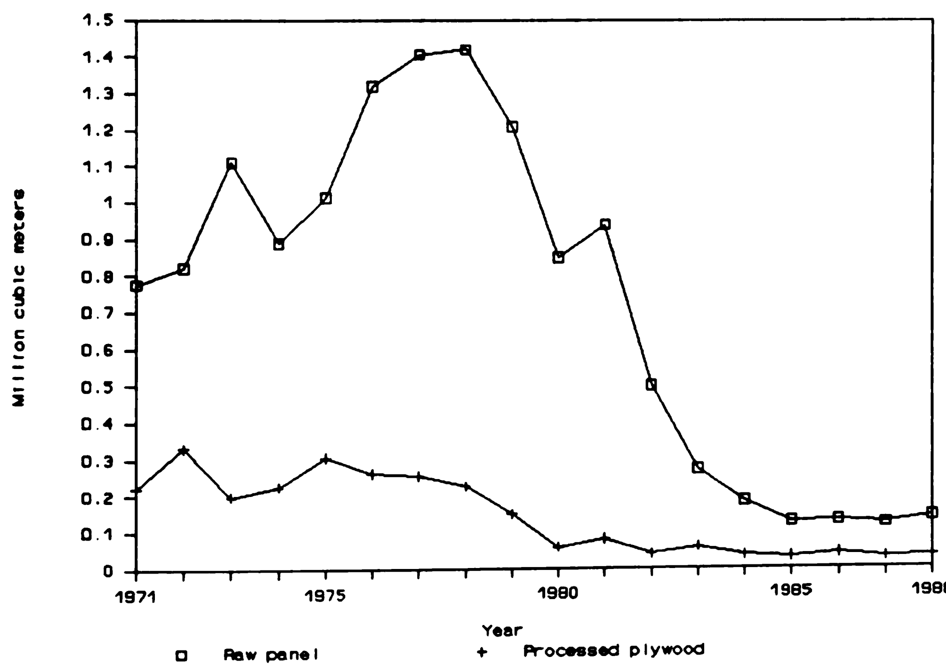
Raw panels are classified into four products by their thickness, namely, "below 3.5 *mm*", "3.5-5.9 *mm*", "6.0-11.9 *mm*", and "over 12.0 *mm*". Among them, the "3.5-5.9 *mm*" size panel was the major product until the early '80s. Its share of total production was more than 50% until 1980. However, after 1980, the "over 12.0 *mm*" size panel became a major product by showing an increase in its share growth. In 1989, the "over 12.0 *mm*" size occupied 69% of total production, while the "3.5-5.9 *mm*" size had only an 8% share (see Table A-6). The trends of total production, domestic consumption, and export of raw panel by kind were very similar for the sample period (see Table A-6, A-8, and A-10).

Figure 2-5. Domestic Consumption of Raw Panel and Processed Plywood in Korea, 1971-1988.



Note: Data are 4mm basis.
Source: Korea Plywood Industries Association. various years. Statistics of Plywood.

Figure 2-6. Export of Raw Panel and Processed Plywood in Korea, 1971-1988.



Note: Data are 4mm basis.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

2.3.2.2. Production, Domestic Supply, and Export of Processed Plywood

Processed plywood has never been a major product of the Korean plywood industry. In most years of the sample period, it occupied only 3.6-24.6% of total plywood production. However, its relative significance in the plywood market has tended to grow in recent years. The share of processed plywood grew from 7.2% in 1979 to 22.4% in 1988.

The proportion of domestic consumption of the processed plywood showed consistency over the sample period. Its share of the total domestic supply showed was in single digits throughout the sample period except for 1979. The share of processed plywood of total exports shows an increasing trend in recent years.

Processed plywood is classified mainly as four products, namely, prefinished, overlaid, printed, and cosmetic plywood. Among them, prefinished plywood was the major product until the mid-'70s (see Table A-7). Since then, overlaid plywood has become the major product; it comprised 64% of processed plywood production in 1988. Similarly, prefinished plywood was a major commodity for domestic and export markets until the mid-'70s. However, overlaid plywood has become a major commodity in both domestic and world markets in more recent years.

2.3.3. Maximum Production Capacity, Investment, Value Added, and Rate of Operation

The trend in production capacity parallels the trend of production. Production capacity increased annually until 1979 due to the success of exports in the world market. Then, it began to decline steadily until 1987 due mainly to the diminishing export market and consequent bankruptcy of plywood firms until 1987.

Investment had risen steadily until 1979, the year in which it peaked. Subsequently, it decreased more significantly than it rose (see Table A-16). This can be attributed to the success and subsequent shrinkage of the industry caused by several economic shocks (see the history of plywood in the first part of this chapter).

The industry enjoyed a steady increase of value-added until 1978 except for the year 1974, and the largest value-added in 1978 and 1984 (nominal terms). The drop in 1974 may be explained by the first oil shock in 1973. After 1978, it decreased sharply in the following two years. The skyrocketed price of oil and tropical logs in 1979 could explain this downturn. After that, the amount of value-added steadily recovered in most years because of the financially sound firms that had remained in the industry.

2.3.4. Tropical Log Import, Log Price, and Major Suppliers of Tropical Logs

Volume of tropical log imports for manufacturing plywood increased steadily for most years until 1977. However, the volume of log imports decreased after Indonesia began to restrict log exports in 1979 (see Table A-14). The tropical log export restriction by Indonesia caused a higher import price of logs and eventually burdened the plywood industry. Indonesia had supplied more than 60% of the total number of logs imported by Korea in most of the years before 1979. However, Korea has not imported any logs from Indonesia since 1985. Since 1980, Malaysia has become a major supplier of logs to Korea, and now supplies more than 60% of the total number of imported tropical logs in Korea. Papua New Guinea has been the second largest supplier of tropical logs to Korea since 1982.

2.3.5. Price of Plywood

The nominal price of plywood steadily increased in most years except for the period of 1978-80 (see A-15). The rapid price increases during that period indicate that the sharp rise in log and oil prices was a major factor. The real price of plywood did not increase in most years except 1973. A sharp increase in 1973 can have been a result of the first oil-shock.

2.4. Commercial Policies on the Plywood Industry

Since the plywood industry developed with assistance of the Korean government's commercial policies during most years in the sample period, a review of those historically implemented commercial policies is required to understand the Korean plywood industry. This part of the study reviews the history of those commercial policies in order to provide a better understanding of the industry. Most of this review section is based on the studies by Kim (1988) and Song and Son (1978).

When the plywood industry initiated its exports to the U.N. forces in Korea in 1957, the government began to facilitate the development of the industry. The amount of governmental assistance was nevertheless insignificant until the industry was named as a target-industry in 1964. However, specific data on the commercial policies applied to the plywood industry were available only for the period 1967-1969 (Song and Son 1978). Therefore, the information on the general commercial policies of all the target industries will be reviewed together.

2.4.1. Commercial Policies on the Export-led Industries in Korea

Given Korea's poor natural resources endowment and lack of accumulated capital, expansion of trade--especially exports--was considered the best way of developing its infant economy. Therefore, the major objective of successive economic development plans initiated in 1962 was expansion of commodity export. To fulfill this objective, the Korean government supported those industries with a greater possibility of acquiring foreign currency through adequate commercial policies.[6]

The major commercial policies aimed at developing and encouraging exportation can be divided into several categories, namely, tax policy, financial policy, and trade policy. The major contribution of this assistance through commercial policies was to reduce the production costs of commodities and consequently increase the competitiveness of Korean industries in world markets.

Tax policies included tax exemptions and discounts on direct and indirect taxes, and are referred to as domestic taxes in this paper. The major assistance from the trade

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[6] Examples of this kind of industry are the footwear, plywood, cement, and fabric industries.

policy was from the reduction and exemption of the tariff.[7] The value amount of assistance per unit of export over the period 1967-1975 indicated that these two policies contributed the greatest amount of the assistance for the industries (Song and Son 1978). Assistance from these policies comprised more than 67% of the total assistance over the period of 1967-1975, and increased up to 90% in 1975. After 1975, these two policies became even more significant due to the reduction and termination of other policies.

The government also assisted the industries through its financial policies. The major form of financial policy was a loan-aid policy. The industry was indirectly subsidized by discounted interest rates on the loaned capital. Also, it was comparatively easier for the target-industries to receive loans than for other industries. The loans came from all sorts of sources, including funds accumulated by the government, commercial banks and imported capital. However, this policy had never been a major assistance to the industry, and became even more insignificant after 1971.

Another method of assistance was an indirect subsidy by

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[7] The tariff policy indicated the complete, or partial exemption of tariffs on intermediate goods, while imposing extremely high rates of tariff on processed goods, mainly to protect the domestic manufacturers. This policy is commonly called "tariff escalation".

means of discounted energy prices for the targeted industry. However, it was never a major assistance policy because it usually provided less than 1% of the total assistance for the industries.

2.4.2. Export Assistance Programs for the Plywood Industry

All commercial policies for the target industries were essentially applied to the plywood industry. However, due to the uniqueness of the plywood industry in comparison to other industries, the amount of assistance was different in some cases.

The export assistance programs for the plywood industry can be classified into three sub-programs, namely, a domestic tax and tariff policy, a capital-loan policy, and an allowance of conversion factor in plywood production.

2.4.2.1. The Tariff Policy

In the early years of the sample period, no tariff was applied on imported logs originally intended for the manufacture of plywood for exports. Only 50% of the original tariff rates were applied to the domestic usage of imported logs until 1975. However, this 50% tariff-exemption was not effective after the implementation of a tariff-reimbursement program in 1975. This program stipulated that the tariffs would be paid initially, but could be completely reimbursed after the industry had exported plywood manufactured from the imported logs within one year of their importation. In contrast, the tariff previously had been strictly imposed on plywood for most years. This policy was a manifestation of the Korean government's so-called "tariff-escalation" policy, used to protect domestic plywood manufacturers.[8]

The tariffs on imported capital from abroad were completely exempted until early 1974 to induce foreign investments in the domestic industry. Also, this policy stimulated the expansion of production facilities and increased comparative advantages through reducing fixed costs. However, it was no longer effective after the new policy was established in 1974. The government imposed tariff on imported capital goods after 1974, but the payments could be deferred up to three years.

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[8] "Tariff-escalation" means that tariff rates are escalated when the imported products are highly processed. The main purpose of this policy is to provide more value-adding activities to manufacturing in one's own country.

2.4.2.2. Domestic Tax Policies

All indirect taxes were exempted for plywood exporters. Half of the income tax had been exempted until 1973, when the exemption of direct taxes was terminated. After 1973, several reserve-loan programs, which were specially intended to encourage plywood exports, were indirectly substituted for the direct-tax exemption program. The government also allowed higher depreciation rates for the plywood industry, which were from 1.15 to 1.5 times higher than other non-target industries. This policy partially compensated the loss of the direct-tax exemption program by reducing the burden of direct taxes.

2.4.2.3. Financial Export Assistance Program

The government assisted the plywood industry through discounting interest rates on foreign trade loans. Also, it secured lower interest rates on the loaned capital from abroad (see Table A-18). However, the difference in interest rates between commercial loans and trade loans had been reduced since the early '70s, and has almost equalized in recent years.

2.4.2.4. Conversion Factor Policy

The government allowed a higher conversion loss rate (in other words, a lower conversion factor) in plywood manufacturing.[9] The conversion loss rate was 43-49% until 1974, and 41-43% after that. Because of these highly allowed loss rates, the industry could utilize the unused imported logs originally intended for export, but which are actually the remainder from the difference between the government-set conversion loss rates and the actual ones. This policy thereby allowed the industry to use imported logs for domestic demand, not for exports. Eventually, it provided the industry extra profits from the sale of products, made by untaxed imported logs to the domestic markets. Because actual conversion factors were around 50% in many cases, the industry could use about 10% of its imported logs for domestic demand.[10] Ironically, this policy was considered the most important assistance policy

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[9] "Conversion factor" is the ratio (as a %) between the volume before and after processing. For example, the ratio of log volume before being used to manufacture plywood and after is the conversion factor of manufacturing plywood (Society of American Foresters 1983).

[10] In contrast, the conversion factor would have been 51-59 % in the case of the 43-49 % conversion loss rates. Again, the conversion factor would have been 57-59 % if the conversion loss rates had been 41-43 %.

since it contributed the largest profits to the plywood industry (Song and Son 1978).

2.5. Summary and Conclusion

The history of the Korean plywood industry was reviewed based on selected periods of growth and decline. The industry was established with government assistance to serve the needs of the Korean economy. It expanded with the growth of domestic and world economics, improving domestic and world markets of inputs and outputs, and Korean government assistance. During this period, production, industry capacity, and exports of the plywood industry increased significantly. However, the industry suffered a major contraction during the early of '80s due to significant alterations of input market conditions and the loss of the world plywood market to its competitors.

Production, export, and production capacity of the industry significantly decreased during this period because of closure of many individual firms. After that, the industry maintained the same level of production and domestic consumption. However, the industry continued to lose shares in the export market.

Since the industry was established, developed, and expanded with the assistance of Korea's commercial policies, the commercial policies which were implemented on the plywood industry were reviewed. Tax policy, loan policy, and the allowance policy of the conversion factor were major assistance programs. Among these programs, the conversion factor policy provided a major impact.

CHAPTER 3.

LITERATURE REVIEW

A few studies of Korean forest products industries and numerous studies of North American forest products industries have been completed. A review of selected studies is presented in this chapter. Only those investigating production behavior, including factor demand, factor substitution, production structure, economies of scale, and technological change, are discussed. The review is limited to Canadian and U.S. studies on production behavior and to Korean forest products studies because: (1) this study's focus is on the production behavior of the Korean plywood industry, and (2) numerous studies of the North American forest industries are not related directly to production behavior. However, most of the previous studies of the Korean forest industries will be reviewed since only a handful of studies were conducted.

3.1. Studies of the Korean Forest Products Industries

Several studies of the Korean forestry industry have been conducted by Korean foresters. These studies have focused primarily on the market structures and behaviors of forest products. Several studies have examined domestic timber markets, timber demands, and demands for timber exports (Yoo *et al*. 1985, Shim *et al*. 1982, and Kim and Park 1980). Others have focused the pulp and paper industry and its market (Youn 1988, Chung and Chung 1984, and Lee 1982). In addition, Kim (1989) compared the development processes of the Korean and Japanese forest products industries.

Few studies focused primarily on the production behaviors of the Korean forest industry. S. Kim (1984) employed the Cobb-Douglas and Constant Elasticity of Substitution (CES) production functions to study the production behavior of the plywood industry.[11] He used

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[11]For the production function Q=f(K,L), when the elasticity of substitution equals to one, the function is the Cobb-Douglas production function (Douglas 1934). The mathematical form is :

$$Q = f(K,L) = A\, K^{a}\, L^{b}$$

where A, a, and b are all positive constants. Also a+b=1 indicates the Cobb-Douglas function has constant returns to scale.

The constant elasticities of substitution (CES) production function is :

$$Q=\gamma\,[\delta K^{-\rho}+(1-\delta)\,L^{-\rho}]^{-\frac{1}{\rho}} \quad \text{where } \gamma>0,\ 0\le\delta\le1,\ \rho=>-1$$

γ is an efficiency parameter, δ is a distribution parameter

ρ is a substitution parameter.

The CES production function includes elasticity of substitution values of 1, 0, and infinity as special cases the Cobb-Douglas production function for estimating economies of scale, and the CES production function for estimating the elasticities of substitution between two inputs (labor and capital). The major findings of this study were: (1) the Korean plywood industry was characterized by diseconomies of scale, and (2) the elasticity of substitution between labor and capital was inelastic for the Korean plywood industry. These results conflicted with those of Song and Son (1978).

Song and Son (1978) studied the development process of the Korean plywood industry and concluded that the industry had elastic substitution capabilities between labor and capital regardless of the size of the firms. Also, the economies of scale were positive for the Korean plywood industry. They employed the Cobb-Douglas production function and a variant form of the CES production to estimate the economies of scale and the elasticities of substitution between two production factors (labor and capital). However, both studies included only capital and labor as production inputs, while energy and material were not considered.

N. Kim's (1984) used the Cobb-Douglas production function, including two factors (labor and capital) for the

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(Arrow *et al.* 1961).

study of the production technology. Results of this study showed that the industry enjoyed increasing economies of scale for all locations.

3.2. Studies of the Production Behaviors and Structures of the U.S. and Canadian Forest Products Industries

Numerous studies have been conducted of the Canadian and U.S. forest products industries. These studies cover many industries including pulp and paper, lumber, plywood, and sawmill industries. Given this study's objectives, only the studies of the forest products industries' production behaviors are reviewed in this section.

Production structures of the U.S. and Canadian forest products industries have been studied in order to understand the roles played by factor demands, production structures, economies of scale, and technological changes.[12] Economists who engaged in the above types of studies includes: Buongiorno and Lu (1989), Wear (1987, 1989), Meil and Nautiyal (1988), Meil *et al.* (1987), Abt (1987), Martinello (1985, 1987), Merrifield and Singleton (1986), Nautiyal and Singh (1985, 1986), Borger and Buongiorno

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[12] Production structure refers to a certain modelled types of production function such as a homogeneous or homothetic function.

(1985), Banskota *et al.* (1985), Merrifield and Haynes (1983, 1985), Stier (1980, 1985), Singh and Nautiyal (1984, 1986), Buongiorno *et al.* (1983), Greber and White (1982), Mohr (1980), Field and Grebenstein (1979), Jorgenson *et al.* (1987), and Tsurumi (1970). These studies can be classified by several categories such as models employed, study objectives, industries, and regions. For purposes of this review, studies will be discussed based on industry groups (i.e., lumber, pulp and paper, sawmill, solid wood, and multiple industries).

3.2.1. Lumber Industry

Abt (1987) conducted an analysis of regional factor demand in the U.S. lumber industry by using the translog cost function.[13] The study estimated the restricted cost function to decompose factor demands. The findings of the study were that the fixed-factor assumption was violated in this case.

Meil, Singh, and Nautiyal (1987) analyzed the dynamic cost structure of the British Columbia interior softwood lumber industry, using a variable cost approach. The study

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[13]Translog cost function is explained in chapter 4.

assumed variable cost minimization instead of total cost minimization of industry's production process. Therefore, they used a model which combined the translog cost function of Christensen *et al.* (1973, 1976) with the dynamic interrelated factor demand theory (Nadiri and Rosen 1969, 1973; Mohr 1980) to decompose the short-run and long-run cost functions of the industry.[14] The major findings were: (1) demand for variable inputs in the regional industry were interrelated, (2) significant economies of scale and technological progress were found, (3) the technological progress was found to be both wood-using and labor-saving, (4) all inputs were found to be substitutable, except for wood and energy, and (5) labor productivity was positive, while wood and energy productivities were negative.

Nautiyal and Singh (1985) studied the production structure of the Canadian lumber industry by employing a nonhomothetic translog cost function for the period 1965-1981. They included four inputs (labor, capital, material (roundwood), and energy) in their model. They tested the homotheticity and homogeneity of the production function and

[14]Dynamic interrelated factor demand functions allow the interaction among variables in the input demand functions over time. Therefore, this model allows differentiation of the input demand along with the length of time.

also estimated factor substitution, factor demand elasticity, and the effects of factor costs on the production cost of the plywood. The results of the study showed that: (1) the production structure of the industry was homothetic and homogenous, while the assumption of unitary elasticity of substitution among inputs was refuted, (2) the price of material had a major impact on the average production cost, and (3) substantial economies of scale were found in the production process of the industry.

Singh and Nautiyal (1986) studied the long-term productivity of and demand for inputs in the Canadian lumber industry from the period of 1955 to 1982 by employing the translog cost function which was specially imbedded by a cross-stock adjustment process in the cost share equations. The least-costs in the production process, which were calculated by removing the short-run adjustment, were used to estimate the long-run productivity of the inputs. The results of the study showed that: (1) factor demands in the Canadian lumber industry are interrelated, (2) the Canadian lumber industry experienced economies of scale, and (3) only labor productivity increased among inputs.

3.2.2. Pulp and Paper Industry

Borger and Buongiorno (1985) employed the variable translog cost function to calculate annual indices of total productivity growth of the paper and paperboard industry in the U.S. for the period 1958-1981.[15] This study disaggregated the paper industry and paperboard industry, unlike other studies. Study findings suggested that: (1) the industry showed short-run economies of scale and long-run diseconomies of scale; (2) derived demands for energy, labor, and materials appeared inelastic; (3) substitutability existed between energy and materials and between labor and materials, but not between labor and energy; and (4) the average productivity growth of the paper industry was three or four times faster than that of the paperboard industry between 1958 and 1981.

Buongiorno, Farimani, and Chuang (1983) employed a generalized Cobb-Douglas production function and mark-up pricing to investigate price formation for the U.S. paper and paperboard industry over the period from January 1967 to

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[15] A variable cost function includes only variable costs in the cost function.

June 1979.[16] The results of the study showed that: (1) capital costs had been predominantly important in setting prices, and (2) technological changes did not significantly affect the price of paper for the sample period, except for labor-saving technological changes.

Martinello (1985) employed the translog cost function to estimate factor substitution, technological change, and returns to scale for three Canadian industries, including the pulp and paper industry, during the period of 1963-1982. The result of this study showed that technological change is capital-using and labor-saving for all industries.

Mohr (1980) studied the long-term structure of production, factor demand, and factor productivity in several U.S. manufacturing industries, including food and beverages, textile mill products, paper and related products, chemical and allied products, rubber and plastic products, and motor vehicles and equipment. He combined the duality theorem of Shepherd, the translog production function, and the dynamic interrelated factor demand model of Nadiri and Rosen to build a model, called a partial

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[16] The price of output is computed by a mark-up procedure. This is that the price of output (P) is set by the average unit cost of production (UC) and by a market-up factor (m) (Buongiorno *et al.* 1983):

$P = m\ UC.$

adjustment model, for decomposing the cyclical and secular influences of the production process of several industries.[17] In other words, he segregated the long-run least-cost, and the short-run costs of production by removing the adjustment process. Also, he estimated the long-run and short-run productivities of the inputs for those industries.

Nautiyal and Singh (1986) studied the long-term productivity and factor demand in the Canadian pulp and paper industry by using the translog cost function specially imbedded by the interrelated dynamic adjustment process for the study, which is the same model for their earlier study of the Canadian lumber industry in 1985. The study found that: (1) the long-term structure of production is homothetic; (2) all inputs in the production process are substitutes in the long-term; and (3) there is no productivity growth in the long-run.

Stier (1985) employed the translog cost function, including three inputs, to investigate the implications of factor substitution, economies of scale, and technological

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[17] The partial adjustment model is designed to decompose the differences of factor demands in a long-term and short-term situation. Since the input demands are usually interrelated by the change of time, the responds of industry's factor demand are mixed with various lagged adjustment. The partial adjustment model is useful to verify these differences.

change for the cost of production in the United States pulp and paper industry in the period 1948-1976. The results of the study showed that: (1) the prices of the material, labor, and capital led to increases in the plywood price, while output expansion did not yield price increases due to the existence of economies of scale in the production process, and (2) the industry showed labor-saving, wood-using, and capital-using technological advances.

3.2.3. Lumber Industry

Banskota *et al.* (1985) used a translog cost function for the analysis of the production structure of the Alberta sawmill industry. Unlike other studies, which used the translog cost function, this study used cross-sectional data. Results of the study showed that: (1) significant factor substitutions were presented, and (2) positive scale economies were found across mills.

Field and Grebenstein (1979) estimated capital-energy substitutions for numerous U.S. industries, including the lumber industry, employing the translog cost function. The results of the study demonstrated that for some industries energy and capital inputs were complements, while for other industries they were substitute. However, he concluded that these inputs were substitutes for all sectors.

3.2.4. Other Solid Wood Industries

Wear (1987) used the translog cost function to analyze the production structure of the U.S. solid wood products industries. He found that the assumption of output separability, general output homogeneity, linear output homogeneity, and Hicks-neutral technological progress were refuted. He also found that the industry experienced timber- and labor-saving and capital-using technological changes during the sample period.

Wear (1989) studied structural change and factor demand in Montana's solid wood products industries for the period of 1958-1978. He used a quadratic normalized cost function to estimate demands of stumpage and labor in the Montana wood products industries and tested for a structural change in the demands for labor and stumpage.[18] Study results showed that structural change has occurred since 1978, most likely in the period of the 1979-1983 downturn in wood products markets.

Greber and White (1982) employed Sato-Batavia methods to analyze technical change and productivity growth in the U.S. lumber and wood products industry by considering biased

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[18]The quadratic normalized function is one of many flexible functional forms.

technical changes during the period 1951-1973.[19] Study finding showed that the industry experienced labor-saving biased technological changes.

Jorgenson *et al.* (1987) used translog production functions to study U.S. economic growth and productivity for the period 1948-79. The paper, lumber, and furniture industries were included in the study.

Martinello (1987) estimated factor substitution, technical change and returns to scale for British Columbia wood products industries, including the plywood industry, for the period 1963-79. He employed the translog cost function, including three factors (capital, materials, and labor) for this study. Unlike other studies, he estimated capital services from aggregate capital stock and energy consumption data. The major findings of this study were: (1) all inputs were substitutable, (2) the technical changes were capital using, labor saving, and material-using or neutral in all industries, and (3) all industries experienced increasing average cost over the sample years.

Meil and Nautiyal (1988) employed the variable translog cost function to investigate the production structure and factor demand of four major softwood lumber production

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[19]The Sata-Batavia methods is a functional form which is intended to estimate technical change biases. This method is developed by Sato (1970), and revised by Batavia (1979).

regions over the time period of 1968-1984. Unlike previous studies, which used the translog cost function to investigate the production structure of the Canadian lumber industry, this study examined only the softwood lumber industry. Also, this study tested inter- and intra-regional homogeneity of production function. The results of the study showed that: (1) different production structures were present in the different regions, (2) different mill sizes of the same region showed different production behaviors, and (3) most mills throughout the regions showed material- and energy-using and labor-saving technological changes.

Buongiorno and Lu (1989) employed a mark-up model of price formation to investigate the reasons for changes in the prices of forest products for four solid-wood industries and three pulp and paper industries in the U.S. for the period 1958-84. The findings of the study showed that price changes were mainly influenced by changes in the unit variable cost of production and changes in demand. Also, labor productivity was not increased for any industry.

Merrifield and Singleton (1986) used a dynamic capital adjustment model to conduct a dynamic cost and factor demand analysis of the Pacific Northwest lumber and plywood industries for the period 1954-80. The results of this study showed that own- and cross-price elasticities of derived demand generally increased as the industry adjusted the long-run capital levels. The input requirement elasticities indicated constant proportions of stumpage requirements to output levels in both industries, relatively constant proportions of labor to output in only the plywood industry, and relatively volatile employment levels in the lumber industry.

Merrifield and Haynes (1983) established a market model for the Pacific Northwest forest products industry to estimate the effects of exogenous demand and supply shifts on the final good market. Markets were developed for softwood lumber and plywood products, and for inputs such as labor, capital, and stumpage. The system of market equations then were solved to estimate the effects of a market condition on other markets.

Merrifield and Haynes (1985) employed a homothetic translog cost function including four inputs (labor, capital, energy, and stumpage) to analyze cost performance of the lumber and plywood industries in two Pacific Northwest regions during the period 1950-79. They estimated derived demand for inputs, factor substitution, and technology changes. The findings show that: (1) some regions enjoyed scale economies over the sample period, (2) little technological progress had been observed during the sample period, and (3) the industry experienced cost savings by substitution possibilities among inputs and changing factor mixes following technological advances.

Stier (1980) employed a homothetic translog cost function for ten U.S. forest industries including the sawmill and paper industries to investigate their production structures for the period 1958-74. He included only labor and capital inputs in his model. Results showed that technological progress was neutral in the wooden container and building paper industries, while other industries were labor-saving.

Tsurumi (1970) employed the CES production function for twelve Canadian manufacturing industries, including the paper industry, to estimate the production structures of those industries.

3.3. Conclusion

The review of the previous studies of the Korean forest industries leads to several conclusions: (1) few studies have been conducted on the production behaviors of the Korean forest products industries, (2) these studies employed simple models such as the Cobb-Douglas and CES function to investigate the production performance of the industries, and (3) these studies included fewer inputs--at most two factors--in their investigations even though more than two inputs are important in the production process. Therefore, more comprehensive studies, using models that include more inputs in the production process are needed to analyze Korean forest products industries.

The translog function was the most popular model for investigating production behaviors of the forest products industries in North America, such as production structure, economies of scale, factor substitution, and cost performance. The popularity of this function is due to its superior flexibility relative to any other normal functional forms such as the Cobb-Douglas and CES functional forms for investigating production behaviors (see Chapter 4 for a more detailed explanation). The translog function was employed in the studies by Abt (1987), Banskota (1985), Borger and Buongiorno (1985), Field and Grebenstein (1979), Jorgenson *et al.* (1987), Martinello (1987, 1985), Meil and Nautiyal (1988), Meil *et al.* (1987), Merrifield and Haynes (1985), Mohr (1980), Nautiyal and Singh (1986), Singh and Nautiyal (1985), Stier (1985, 1980), and Wear (1989). Some studies used a dynamic concept of translog function, but the majority of the studies employed a static concept. While a majority of the above studies employed a translog cost function, a couple of these studies used a translog production function.

In the review of both Korean and North American studies of forest products industries, significant differences were found in methods and objectives between the studies conducted in these two areas (i.e., Korea and North America). Most studies investigated factor substitutability, factor demand, economy of scale, bias of technological progress, and the effects of input costs on production costs irrespective of whether a translog function or other function was used. Few studies of the Korean forest products industries have been undertaken; they should be more comprehensively investigated by employing more flexible, comprehensive models.

CHAPTER 4

STUDY METHODS

The objectives of this study are to investigate the effects of input prices on the production costs of the Korean plywood industry and to analyze the industry's adjustment methods in the production process following altered conditions of the input markets.

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 advantages of the cost function over the production function (see 4.2.1. for further description).

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. Since the flexible forms are superior to the conventional forms theoretically, a flexible form is chosen for the study (see 4.2.2. for more details). 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) (full descriptions are provided in 4.2.3. in this chapter).

4.1. Overview of Methods Selected

The cost function employed for this study is based on duality theory and consists of a transcendental logarithmic function (translog function). It is one of several possible flexible functional forms for the Korean plywood industry and 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 1966-1987 period are used. The translog cost function is also used to estimate factor substitutions, demand elasticities, and technological bias changes. The likelihood ratio test is employed for investigating the production technology of the Korean plywood industry. Structural changes in the production process of the industry are tested.

4.2. Model

4.2.1. Duality Theory and Cost Function

According to duality theory, a well-behaved cost function is considered a dual to the production function (Shephard 1953, 1970).[20] The choice of the cost function over the production function provides several advantages. Advantages come from the fact that the cost function uses factor prices, while the production function uses factor quantities.[21] The use of factor prices tends to be convenient because they are potentially observable and more readily available. Therefore, the cost function is easier to estimate than the production function in econometrics. In addition, factor demand functions can be easily derived

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[20] 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.

[21] The cost function is expressed by factor prices and output quantities, while the production function is expressed by factor quantities.

from the cost function. For this study, therefore, the cost function is employed.

4.2.2. Flexible Functional Forms

In order to investigate factor demand elasticities, a system of equations relating factor shares and total cost expenditures to factor price and output level should be estimated. Moreover, a functional form for the model must be chosen to estimate the demand elasticities of certain inputs. Since a system of equations is derived from either a production function or cost function, the problem of specifying a system of equations is the problem of approximating the production or cost function. In other words, econometrically, a functional form is needed that provides the best approximation of the elasticities of input demands. The development of flexible functional forms provides approximations of elasticities of interest without *a priori* constraints on these elasticities. A flexible functional form is defined as follows: if function "f" can provide a second-order (differential) approximation to an arbitrary twice continuously differential function of "f^*" at "x^*", it is a flexible functional form (Diewert 1971). Most flexible functional forms used in the application of the duality theory are second order approximations. Two different definitions of second order approximation were presented by Lau (1974): first, Diewert's definition is that a function $G(y)$ is a second order approximation to a function $F(y)$ at y_0 if the first and second derivatives of the two functions are equal at y_0, that is,

$$G(y_0)=F(y_0)$$

$$\left[\frac{\partial G}{\partial y_i}\right]_{y=y_0}=\left[\frac{\partial F}{\partial y_i}\right]_{y=y_0}$$

$$\left[\frac{\partial^2 G}{\partial y_i \partial y_j}\right]_{y=y_0}=\left[\frac{\partial^2 F}{\partial y_i \partial y_j}\right]_{y=y_0}$$

where function G and F are twice differentiable.

; and second, the definition by Cristensen *et al.* (1973, 1976) is that a function $G(y)$ is a second order approximation to a function $F(y)$ if

$$G(y_0)=F(y_0)$$

and

$$|G(y)-F(y)|\leq\frac{K\|y-y_0\|^3}{\|y_0\|^3},$$

for all y in a prescribed neighborhood of y_0, where K is a constant for a given y_0 and the neighborhood.

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.

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. Therefore, a flexible functional forms is most appropriate for this study.

4.2.3. Choice of Flexible Functional Forms

Since many flexible forms are available and have very similar properties, the issue of choosing a certain flexible form for the research of interest has been a growing one among economists.

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. 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.

The issue of choosing flexible functional forms has been continually investigated by numerous empirical studies. The studies by Wohlgenant (1984), Pollak *et al.* (1984), Pope (1984), King (1984), Guilkey *et al.* (1983), Gallant (1981), Caves and Cristensen (1980), Applebaum (1979), Berndt and Khaled (1979), Wales (1977), and Berndt *et al.* (1975) were among them. The results of these studies showed that no consensus of superiority for a particular flexible forms was revealed. Although the Fourier series method is superior to the Taylor's series on a theoretical basis (Gallant 1982), the results of empirical studies showed that it actually provided a greater oscillation in estimated elasticities (Chalfant, 1984).[22]

4.3. Translog Cost Function for the Korean Plywood Industry

Since the translog function well satisfies the criteria of selecting functional forms suggested by Pope (1984), Lau (1974), and Fuss *et al.*(1978), it is employed for this study.

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

$$lnC=\alpha_0+\alpha_Q lnQ+0.5\alpha_{QQ}(lnQ)^2+\alpha_T T+0.5\alpha_{TT}T^2$$

$$+\sum_i \alpha_i lnP_i+0.5\sum_i\sum_j \alpha_{ij}lnP_i lnP_j+\sum_i \alpha_{Ti}T lnP_i$$

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22 Theoretically, the Fourier series is superior to the Taylor's series because the former has the capability in principle to approximate globally the true price and income elasticities (Gallant 1981), while the latter does not.

The Fourier form is desirable with regard to the unbias of estimators, but not with regard to the variance of estimators (Chalfant 1984 and Pope 1984).

The results of the study by Chalfant (1984) showed that the Fourier series failed to satisfy the desired curvature restrictions on the cost function because the estimated own-elasticities of substitution were positive about one-fourth of the time. Also, the study by Wohlgenant (1984) showed wide variations in estimated elasticities by the Fourier series method.

$$+\sum_{i}\alpha_{Qi}\ln Q\ln P_i+\alpha_{TQ}T\ln Q \quad for \quad i,j=L,M,E,K. \qquad (1)$$

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:[23]

$$\alpha_{ij}=\alpha_{ji} \quad for \quad i\neq j \quad (2)$$

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 for symmetry and homogeneity (Merrifield and Haynes 1985):

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

$$\sum_i \alpha_i=1,\ \sum_i \alpha_{Qi}=0,\ \sum_i \alpha_{Ti}=0,\ \sum_i \alpha_{ij}=\sum_j \alpha_{ij}=\sum_i \sum_j \alpha_{ij}=0$$

$$for \quad i \neq j \quad (3)$$

4.4. 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 by using the likelihood ratio test.[24]

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[24] A production function is homogeneous of degree *r* if all inputs in the production function are changed proportionally, output changes by the *r*th 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

$$y=h(x_1,\ldots,X_n)=F(f(x1,\ldots,X_n))$$

where $F' = 0$ and $f(x_1,\ldots, X_n)$ is a homogenous 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:

$$LR = -2[L(\beta,\tilde{\sigma}^2)-L(\beta,\hat{\sigma}^2)] \sim \chi_m^2 \qquad (4)$$

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

$$Let\ \ \tilde{\sigma}^2=\frac{1}{n}\sum\tilde{\mu}_t^2,\ \ \hat{\sigma}^2=\frac{1}{n}\sum\hat{\mu}_t^2,\quad then,$$

$$LR = -2[-\frac{n}{2}\log(2\pi\tilde{\sigma}^2)-\frac{1}{2\tilde{\sigma}^2}\sum\tilde{\mu}_t^2 + \frac{n}{2}\log(2\pi\hat{\sigma}^2)+\frac{1}{2\hat{\sigma}^2}\sum\hat{\mu}_t^2] \qquad (4a)$$

where $\hat{\mu}_t$ is the residuals of the estimated restricted equation and $\tilde{\mu}_t$ is the residual of the unrestricted model (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 homogenous (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.

4.5. 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 *i*th input X_i:

$$\frac{\partial C}{\partial P_i}=X_i=X_i(Q,P_i) \quad for \quad i,j=K,L,M,E. \quad (5)$$

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

$$\frac{\partial lnC}{\partial lnP_i}=\frac{\partial C}{\partial P_i}\frac{P_i}{C}. \qquad (6)$$

Then substituting equation (5) into equation (6),

$$\frac{\partial lnC}{\partial lnP_i}=X_i\frac{P_i}{C}=S_i. \qquad (7)$$

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 ($logP_i$):

$$\frac{\partial}{\partial}\frac{lnC}{lnP_i}=\frac{\partial}{\partial}\frac{C}{P_i}\frac{P_i}{C}=X_i\frac{P_i}{C}=S_i=\alpha_i+\sum_j\alpha_{ij}(lnP_i)$$

$$+\alpha_{Qi}lnQ+\alpha_{Ti}T \quad for \quad i,j=K,L,M,E. \quad (8)$$

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 (8), 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 (8).

The technological change bias can be estimated as follows:

$$\delta_i = \frac{\partial S_i}{\partial T}\frac{1}{S_i} = \alpha_{iT}\frac{1}{S_i} \qquad (9)$$

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.[25]

[25] 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.

4.6. 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):[26]

$$\sigma_{ij}=\frac{\alpha_{ij}}{S_i S_j}+1 \qquad for \quad i\neq j \quad (10)$$

$$\sigma_{ii}=\frac{\alpha_{ii}}{S_i^2}-\frac{1}{S_i}+1 \qquad (11)$$

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[26] 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 $S_j(y,p)=p_jC_j(y,p)/C(y,p)$ is the share of the jth input total cost (Blackorby and Russell 1989).

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):

$$\mu_{ij}=S_j\sigma_{ij}, \quad \forall ij \quad (12)$$

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.

4.7. 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:

$$\ln\overline{C}=\ln\frac{C}{Q}=\ln C-\ln Q=\alpha_0+\ln Q(\alpha_Q-\alpha_{QT}T-1)+0.5\alpha_{QQ}(\ln Q)^2+\alpha_T T$$

$$+0.5\alpha_{TT}T^2+\sum_i \alpha_i lnP_i+0.5\sum_i\sum_j \alpha_{ij}\ln P_i \ln P_j$$

$$+\sum_i \alpha_{Ti}T lnP_i+\sum_i \alpha_{Qi}\ln Q \ln P_i. \qquad (13)$$

The elasticities of average costs with respect to input costs can be derived by differentiating equation (8) with respect to the log of factor prices (Merrifield and Haynes 1985):

$$E\bar{C}_i=\frac{\partial \ln \bar{C}}{\partial \ln P_i}=\alpha_i+\sum_i \alpha_{ij}\ln P_j+\alpha_{ii}\ln P_i+\sum_i \alpha_{Ti}T$$

$$+\sum_i \alpha_{Qi}\ln Q \quad for \quad i\neq j \quad (14)$$

4.8. Test for Production Structure Changes

Change of production structure is tested for investigating how the industry responded the increased material prices in the beginning of 1979. 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:

$$lnC=\alpha_0+\alpha_Q lnQ+0.5\alpha_{QQ}(lnQ)^2+\alpha_T T+0.5\alpha_{TT}T^2$$

$$+\sum_i \alpha_i lnP_i+0.5\sum_i\sum_j \alpha_{ij} lnP_i lnP_j+\sum_i \alpha_{Ti} T lnP_i$$

$$+\sum_i \alpha_{Qi} lnQ lnP_i+\alpha_{QT} T lnQ+\alpha_D D \quad for\ i,j=L,M,E,K. \quad (15)$$

If the coefficient of dummy variable is significant at the satisfactory level of confidence, the production structure is changed. A negative sign on the dummy variable would indicate a shift to less costly production. A positive sign would indicate more costly production.

4.9. Data

4.9.1. 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. All values are nominal.

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. The unit is 100 thousand won.

Total output (Q), which is the total quantity of plywood produced, is measured in physical units (thousand M^3, 4mm basis). 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. The cost of tropical logs is the most significant of all costs of materials, comprising more than 95 percent of total costs (Report on Mining and Manufacturing Census, various years). The prices of tropical imported logs, which is measured in 100 thousand won per M^3 with 4mm basis, 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 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 unit of energy price is 100 thousand won per KWH and liter.

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 unit of labor price is 100 thousand won per person in a year.

The price of capital (K) can be estimated as the rate of return on fixed assets. From an opportunity cost standpoint, the rental value of a firm's stocks can be calculated as if the stocks were rented. Since the machinery and equipment in forest industries may not be used for other purposes after purchased, there will be no opportunity cost for other usages. Therefore, the firm's rate of return can be its opportunity cost (Nautiyal and Singh 1983; Singh and Nautiyal 1984).[27]

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

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[27]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), 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.

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

Data are presented in Appendix B.

4.9.2. Data Sources

The sources of the data for this study are as follows: The Korea Economic Statistics Yearbook, published by the Bank of Korea, The Yearbook of Foreign Trade Statistics, published by the Office of Customs Administration, Report on Mining and Manufacturing Census published by the Korea Development Bank and Economic Planning Board, The Price Statistics Summary, published by the Bank of Korea, The Statistics Yearbook, published annually by the Korean Plywood Manufacturers' Association, and Monthly Statistical Bulletin, published by the Bank of Korea.

4.10. 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 equation and its share equation, this method cannot produce invariant estimates in which an equation is deleted in the share equations (Zellner 1962).[28]

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 1968, 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

[28]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.

variances and covariances 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.[29] 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.

Since share equations have same parameters with the translog cost function (e.g., α_L, α_{LL}, α_{LE}, α_{LM}, α_{LK}, and α_{TL}), the parameters estimated in the share equations will replace the parameters in the translog cost function. However, the parameters which are not included in the share equations (e.g., α_0, α_Q, and α_{QQ}) will be used.

In this study, the capital share equation is omitted arbitrary in order to avoid singularity problem. All remaining equations (i.e., cost equation and three share equations) are assumed to have normally distributed stochastic disturbance terms with zero mean and finite variance. Also, the errors are correlated across equations

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

contemporaneously, but are assumed independent across time.

Micro TSP computer program (version 5.1a, Quantitative Micro Software, McGraw-Hill) will be used for estimation since it includes I3SLS estimation method.

CHAPTER 5

CONDUCT AND RESULTS OF ANALYSIS

This chapter presents all functional forms estimated for the study. The forms are classified into five models based on types of restrictions regarding production structures (e.g., homothetic and homogeneous production structures). Estimated results of the models are presented and used for the selection of the best model. Calculation of some elasticities (e.g., elasticities of substitution) and analysis of production structure changes also presented in this chapter.

5.1. Estimated Translog Cost Function and Its Share Equations

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

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_Q \ln Q + \alpha_M \ln M + \alpha_E \ln E + \alpha_L \ln L + \alpha_K \ln K + \alpha_T T \\ & + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{LL}(\ln L)^2 + 0.5\alpha_{MM}(\ln M)^2 + \alpha_{QT} T \ln Q \\ & + 0.5\alpha_{EE}(\ln E)^2 + 0.5\alpha_{KK}(\ln K)^2 + 0.5\alpha_{TT}T^2 + \alpha_{EL}\ln L \ln E \\ & + \alpha_{LK}\ln K \ln L + \alpha_{LM}\ln L \ln M + \alpha_{EM}\ln E \ln M + \alpha_{EK}\ln E \ln K \\ & + \alpha_{MK}\ln M \ln K + \alpha_{TL} T \ln L + \alpha_{TE} T \ln E + \alpha_{TM} T \ln M + \alpha_{TK} T \ln K \\ & + \alpha_{QL}\ln Q \ln L + \alpha_{QE}\ln Q \ln E + \alpha_{QM}\ln Q \ln M + \alpha_{QK}\ln Q \ln K \qquad (16) \end{aligned}$$

where C is a production cost, Q is an aggregate industry output, L, M, K, and E are the prices of input labor, material, capital and energy, respectively; T is a time trend used as a proxy for technological changes, and all α are estimated coefficients.[29]

Factor share equations are obtained from differentiation of the translog cost function with respect to the natural logarithm of factor prices (see chapter 4 for the derivation). Share equations for all factors are as follows:

$$S_L = \alpha_L + \alpha_{LL}\ln L + \alpha_{LE}\ln E + \alpha_{LM}\ln M + \alpha_{LK}\ln K + \alpha_{TL}T + \alpha_{QL}\ln Q \quad (17)$$

$$S_E = \alpha_E + \alpha_{EE}\ln E + \alpha_{EL}\ln L + \alpha_{EM}\ln M + \alpha_{EK}\ln K + \alpha_{TE}T + \alpha_{QE}\ln Q \quad (18)$$

$$S_M = \alpha_M + \alpha_{MM}\ln M + \alpha_{ML}\ln L + \alpha_{ME}\ln E + \alpha_{MK}\ln K + \alpha_{TM}T + \alpha_{QM}\ln Q \quad (19)$$

$$S_K = \alpha_K + \alpha_{KK}\ln K + \alpha_{KE}\ln E + \alpha_{KM}\ln M + \alpha_{KL}\ln L + \alpha_{TK}T + \alpha_{QK}\ln Q \quad (20)$$

For symmetry of cross partial derivatives, the

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[29] The trend variable (T) is called technological change by many authors including such as Stier (1980), and Meil *et al.*(1988). However, T may reflect many factors (e.g., stages in the development of the industry). Therefore, interpretation of the trend variable as a proxy for technological change in this study must proceed cautiously.

following condition should be met:

$$\alpha_{ij}=\alpha_{ji}, \quad for \quad i \neq j \qquad (21)$$

where i and j are K, L, M, and E.

The cost function must be homogenous of degree one with respect to factor prices. Therefore, the following conditions are imposed on parameters of the translog cost function:

$$\sum_i \alpha_i=1, \quad \sum_i \alpha_{Ti}=0, \quad \sum_i \alpha_{Qi}=0,$$

$$\sum_i \alpha_{ij}=\sum_j \alpha_{ij}=\sum_i \sum_j \alpha_{ij}=0 \quad for \quad i \neq j \qquad (22)$$

Since the deletion of any one of the four share equations provides the invariant estimates by using the iterative three-stage least squares (I3SLS), the capital equation will be removed arbitrarily for this study. The prime reason for eliminating the capital share equation is to avoid a singularity of the variance-covariance matrix.

After all restrictions (i.e., equations 21 and 22) are applied, the translog cost and its share equations can be rewritten as follows:

$$\ln C = \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M-\ln K) + \alpha_E(\ln E-\ln K)$$
$$+ \alpha_L(\ln L-\ln K) + \alpha_T T + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{LL}(\ln L-\ln K)^2$$
$$+ 0.5\alpha_{MM}(\ln M-\ln K)^2 + 0.5\alpha_{EE}(\ln E-\ln K)^2 + 0.5\alpha_{TT}T^2$$
$$+ \alpha_{EL}(\ln L-\ln K)(\ln E-\ln K) + \alpha_{LM}(\ln L-\ln K)(\ln M-\ln K)$$
$$+ \alpha_{EM}(\ln E-\ln K)(\ln M-\ln K) + \alpha_{TL}T(\ln L-\ln K) + \alpha_{TE}T(\ln E-\ln K)$$
$$+ \alpha_{TM}T(\ln M-\ln K) + \alpha_{QL}\ln Q(\ln L-\ln K) + \alpha_{QE}\ln Q(\ln E-\ln K)$$
$$+ \alpha_{QM}\ln Q(\ln M-\ln K) + \alpha_{QT}T\ln Q \qquad (23)$$

$$S_L = \alpha_L + \alpha_{LL}(\ln L-\ln K) + \alpha_{LE}(\ln E-\ln K) + \alpha_{LM}(\ln M-\ln K) + \alpha_{TL}T + \alpha_{QL}\ln Q \qquad (24)$$

$$S_E = \alpha_E + \alpha_{EE}(\ln E-\ln K) + \alpha_{EL}(\ln L-\ln K) + \alpha_{EM}(\ln M-\ln K) + \alpha_{TE}T + \alpha_{QE}\ln Q \qquad (25)$$

$$S_M = \alpha_M + \alpha_{MM}(\ln M-\ln K) + \alpha_{ML}(\ln L-\ln K) + \alpha_{ME}(\ln E-\ln K) + \alpha_{TM}T + \alpha_{QM}\ln Q \qquad (26)$$

The translog cost function (equation 23) and its share equations (equations 24, 25, and 26), except the share equation of the capital (equation 20), are estimated together. This model is referred to as Model 1 for this study.

5.2. Test for Production Structure

Production structures of the industry, such as hometheticity, homogeneity, unitary elasticities of substitution and technological change bias are investigated.

From the original restriction-free (see above) model, restrictions are sequentially applied to examine different models.[30]

5.2.1. Homothetic Production Function

If α_{iQ} are zero, the production function of the industry is homothetic. Therefore, the homothetic translog cost function can be written as follows:

$$\begin{aligned}\ln C = {} & \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M - \ln K) + \alpha_E(\ln E - \ln K) \\ & + \alpha_L(\ln L - \ln K) + \alpha_T T + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{LL}(\ln L - \ln K)^2 \\ & + 0.5\alpha_{MM}(\ln M - \ln K)^2 + 0.5\alpha_{EE}(\ln E - \ln K)^2 + 0.5\alpha_{TT}T^2 \\ & + \alpha_{EL}(\ln L - \ln K)(\ln E - \ln K) + \alpha_{LM}(\ln L - \ln K)(\ln M - \ln K) \\ & + \alpha_{EM}(\ln E - \ln K)(\ln M - \ln K) + \alpha_{TL}T(\ln L - \ln K) + \alpha_{TE}T(\ln E - \ln K) \\ & + \alpha_{TM}T(\ln M - \ln K) \qquad (27)\end{aligned}$$

$$S_L = \alpha_L + \alpha_{LL}(\ln L - \ln K) + \alpha_{LE}(\ln E - \ln K) + \alpha_{LM}(\ln M - \ln K) + \alpha_{TL}T \qquad (28)$$

$$S_E = \alpha_E + \alpha_{EE}(\ln E - \ln K) + \alpha_{EL}(\ln L - \ln K) + \alpha_{EM}(\ln M - \ln K) + \alpha_{TE}T \qquad (29)$$

$$S_M = \alpha_M + \alpha_{MM}(\ln M - \ln K) + \alpha_{ML}(\ln L - \ln K) + \alpha_{ME}(\ln E - \ln K) + \alpha_{TM}T \qquad (30)$$

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[30]These restrictions for each production structure are explained in the chapter 4.

Equations 27, 28, 29, and 30 are simultaneously estimated to test the homothetic production technology. The results of the estimation are used for the log likelihood test. This model is named Model 2 for this study.

5.2.2. Homogeneous Production Function

If α_{QQ} and α_{iQ} are zero, the production function of the industry is homogeneous. Therefore, the homogeneous translog cost function can be written as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M - \ln K) + \alpha_E(\ln E - \ln K) \\ & + \alpha_L(\ln L - \ln K) + \alpha_T T + 0.5\alpha_{LL}(\ln L - \ln K)^2 \\ & + 0.5\alpha_{MM}(\ln M - \ln K)^2 + 0.5\alpha_{EE}(\ln E - \ln K)^2 + 0.5\alpha_{TT}T^2 \\ & + \alpha_{EL}(\ln L - \ln K)(\ln E - \ln K) + \alpha_{LM}(\ln L - \ln K)(\ln M - \ln K) \\ & + \alpha_{EM}(\ln E - \ln K)(\ln M - \ln K) + \alpha_{TL}T(\ln L - \ln K) + \alpha_{TE}T(\ln E - \ln K) \\ & + \alpha_{TM}T(\ln M - \ln K) \end{aligned} \tag{31}$$

$$S_L = \alpha_L + \alpha_{LL}(\ln L - \ln K) + \alpha_{LE}(\ln E - \ln K) + \alpha_{LM}(\ln M - \ln K) + \alpha_{TL}T \tag{32}$$

$$S_E = \alpha_E + \alpha_{EE}(\ln E - \ln K) + \alpha_{EL}(\ln L - \ln K) + \alpha_{EM}(\ln M - \ln K) + \alpha_{TE}T \tag{33}$$

$$S_M = \alpha_M + \alpha_{MM}(\ln M - \ln K) + \alpha_{ML}(\ln L - \ln K) + \alpha_{ME}(\ln E - \ln K) + \alpha_{TM}T \tag{34}$$

Equations 31, 32, 33, and 34 are simultaneously estimated to test the homogeneous production technology. Results of the estimation are used for the log likelihood test. This model is named Model 3 for this study.

5.2.3. Unitary Elastic Production Function

The elasticities of substitution between factors are unitary when α_{ij} is zero. After the restriction of $\alpha_{ij}=0$ is applied to the original translog cost equation (i.e., model 1), a new equation for the unitary elasticities of the substitution production function can be written as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M-\ln K) + \alpha_E(\ln E-\ln K) \\ & + \alpha_L(\ln L-\ln K) + \alpha_T T + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{TT}T^2 \\ & + \alpha_{TL}T(\ln L-\ln K) + \alpha_{TE}T(\ln E-\ln K) + \alpha_{TM}T(\ln M-\ln K) \\ & + \alpha_{QL}\ln Q(\ln L-\ln K) + \alpha_{QE}\ln Q(\ln E-\ln K) + \alpha_{QM}\ln Q(\ln M-\ln K) \end{aligned} \tag{35}$$

$$S_L = \alpha_L + \alpha_{TL}T + \alpha_{QL}\ln Q \tag{36}$$

$$S_E = \alpha_E + \alpha_{TE}T + \alpha_{QE}\ln Q \tag{37}$$

$$S_M = \alpha_M + \alpha_{TM}T + \alpha_{QM}\ln Q \tag{38}$$

Equations 35, 36, 37, and 38 are estimated together along with the obtained log likelihood function in order to test the unitary elasticities of substitution among factors. This model is called Model 4 for this study.

5.3. Test for the Hicks Neutral Technological Change

The Hicks neutral technological change will be tested by applying restrictions (α_{Ti}=0) on Model 1. Therefore, the new equations after restrictions are imposed are as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M-\ln K) + \alpha_E(\ln E-\ln K) \\ & + \alpha_L(\ln L-\ln K) + \alpha_T T + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{LL}(\ln L-\ln K)^2 \\ & + 0.5\alpha_{MM}(\ln M-\ln K)^2 + 0.5\alpha_{EE}(\ln E-\ln K)^2 + 0.5\alpha_{TT}T^2 \\ & + \alpha_{EL}(\ln L-\ln K)(\ln E-\ln K) + \alpha_{LM}(\ln L-\ln K)(\ln M-\ln K) \\ & + \alpha_{EM}(\ln E-\ln K)(\ln M-\ln K) + \alpha_{QL}\ln Q(\ln L-\ln K) \\ & + \alpha_{QE}\ln Q(\ln E-\ln K) + \alpha_{QM}\ln Q(\ln M-\ln K) + \alpha_{QT}T\ln Q \end{aligned} \tag{39}$$

$$S_L = \alpha_L + \alpha_{LL}(\ln L-\ln K) + \alpha_{LE}(\ln E-\ln K) + \alpha_{LM}(\ln M-\ln K) + \alpha_{QL}\ln Q \tag{40}$$

$$S_E = \alpha_E + \alpha_{EE}(\ln E-\ln K) + \alpha_{EL}(\ln L-\ln K) + \alpha_{EM}(\ln M-\ln K) + \alpha_{QE}\ln Q \tag{41}$$

$$S_M = \alpha_M + \alpha_{MM}(\ln M-\ln K) + \alpha_{ML}(\ln L-\ln K) + \alpha_{ME}(\ln E-\ln K) + \alpha_{QM}\ln Q \tag{42}$$

The equation 39, 40, 41, and 42 are estimated simultaneously. Results of estimation are used for the likelihood ratio test. This model is named Model 5.

5.4. Test for Structural Changes

In order to perform the test for a production structure change, a dummy variable is included in the "best" translog cost function, which is selected using the log likelihood test. Therefore, the new equations are as follows:

$$\begin{aligned}\ln C = {} & \alpha_0 + \ln K + \alpha_Q \ln Q + \alpha_M(\ln M-\ln K) + \alpha_E(\ln E-\ln K) \\ & + \alpha_L(\ln L-\ln K) + \alpha_T T + 0.5\alpha_{QQ}(\ln Q)^2 + 0.5\alpha_{LL}(\ln L-\ln K)^2 \\ & + 0.5\alpha_{MM}(\ln M-\ln K)^2 + 0.5\alpha_{EE}(\ln E-\ln K)^2 + 0.5\alpha_{TT}T^2 \\ & + \alpha_{EL}(\ln L-\ln K)(\ln E-\ln K) + \alpha_{LM}(\ln L-\ln K)(\ln M-\ln K) \\ & + \alpha_{EM}(\ln E-\ln K)(\ln M-\ln K) + \alpha_{TL}T(\ln L- \ln K) \\ & + \alpha_{TE}T(\ln E-\ln K) + \alpha_{TM}T(\ln M -\ln K)+ \alpha_{QL}\ln Q(\ln L-\ln K) \\ & + \alpha_{QE}\ln Q(\ln E-\ln K) + \alpha_{QM}\ln Q(\ln M-\ln K) +\alpha_{QT}T\ln Q + \alpha_D D \quad (43)\end{aligned}$$

$$S_L = \alpha_L + \alpha_{LL}(\ln L-\ln K) + \alpha_{LE}(\ln E-\ln K) + \alpha_{LM}(\ln M-\ln K) + \alpha_{TL}T + \alpha_{QL}\ln Q \quad (44)$$

$$S_E = \alpha_E + \alpha_{EE}(\ln E-\ln K) + \alpha_{EL}(\ln L-\ln K) + \alpha_{EM}(\ln M-\ln K) + \alpha_{TE}T + \alpha_{QE}\ln Q \quad (45)$$

$$S_M = \alpha_M + \alpha_{MM}(\ln M-\ln K) + \alpha_{ML}(\ln L-\ln K) + \alpha_{ME}(\ln E-\ln K) + \alpha_{TM}T + \alpha_{QM}\ln Q \quad (46)$$

where D is a dummy variable for the material input.

Again, the above equations (43, 44, 45, and 46) are estimated together and the model is named Model 6.

5.5. Summary and Results of Model Estimation

Estimation results for the six models are presented in the Table 5-1. The estimators are used to derive some important figures (e.g., elasticities) in the following sections.[31]

5.6. Results of the Production Structure Test

Results of the likelihood ratio tests show that all imposed restrictions were rejected at a 5% level of significance (see Table 5-2).[32] That is, the calculated values of X^2 fall outside critical values for models 2-5. 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 nonhomogeneous with nonunitary elasticity of substitution.

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[31] As noted throughout this dissertation, substitution of inputs in the production process and elasticity of derived demand for inputs provide important implications on the industry's cost performance and income distribution of the input sectors.

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

Table 5-1. Estimates of an Unrestricted and Restricted Translog Cost Function Models for the Korean Plywood Industry.

Parameters	Model					
	1	2	3	4	5	6
α_0	122.84** (19.52)	-46.85 (33.59)	15.52 (32.98)	80.59** (16.74)	-0.87 (23.99)	455.09** (15.08)
α_Q	7.63** (2.55)	5.60** (1.54)	1.72** (0.23)	-10.18** (2.39)	-15.87 (2.63)	-3.73 (1.97)
α_{QQ}	-4.55** (0.65)	-0.57* (0.22)	-	0.13 (0.27)	0.92* (0.39)	-8.70** (0.48)
α_t	-0.31** (0.07)	0.36** (0.08)	0.42** (0.07)	0.035* (0.018)	-0.11** (0.01)	-0.58** (0.05)
α_{tt}	0.004** (0.002)	0.005* (0.002)	0.005* (0.002)	0.007** (0.001)	0.007** (.0009)	-.0006 (0.001)
α_l	-0.02 (0.06)	-0.07 (0.08)	-0.07 (0.08)	0.14** (0.03)	0.028 (0.06)	-0.02 (0.06)
α_e	0.19** (0.03)	0.21** (0.04)	0.21 (0.04)	-0.005 (0.02)	0.17** (0.03)	0.19** (0.04)
α_m	0.87** (0.09)	0.88** (0.08)	0.88 (0.08)	0.86** (0.04)	0.80** (0.08)	0.87** (0.08)

Table 5-1 Continued.

Parameters	Model					
	1	2	3	4	5	6
α_k	-0.04 (0.03)	-0.02 (0.03)	-0.02 (0.03)	0.005 (0.006)	0.002 (0.007)	-0.04 (0.03)
α_{11}	0.06** (0.01)	0.05* (0.02)	0.05 (0.02)	-	0.04** (0.007)	0.07** (0.02)
α_{1k}	-0.006** (0.001)	0.003* (0.001)	0.003* (0.001)	-	0.003* (0.001)	-0.014 (0.01)
α_{1m}	-0.06** (0.01)	-0.06** (0.01)	-0.06** (0.01)	-	-0.04** (0.006)	-0.06** (0.01)
α_{1e}	-0.02* (0.009)	-0.003 (0.007)	-0.003 (0.007)	-	-0.003 (0.006)	-0.006 (0.005)
α_{kk}	-0.014* (0.007)	-0.006 (0.007)	-0.006 (0.007)	-	-0.006 (0.007)	0.003 (0.002)
α_{km}	0.01* (0.005)	0.01** (0.005)	0.01** (0.005)	-	0.01** (0.005)	0.01** (0.005)
α_{ke}	0.01 (0.02)	-0.007 (0.01)	-0.007 (0.01)	-	-0.007 (0.01)	0.01 (0.02)

Table 5-1 Continued.

Parameters	Model					
	1	2	3	4	5	6
α_{mm}	0.06^{**} (0.01)	0.06^{**} (0.01)	0.06^{**} (0.01)	-	0.04^{**} (0.008)	0.06^{**} (0.01)
α_{me}	-0.01 (0.008)	-0.01 (0.008)	-0.01 (0.008)	-	-0.01^{*} (0.008)	-0.01 (0.008)
α_{ee}	0.02^{**} (0.003)	0.02^{**} (0.004)	0.02^{**} (0.004)	-	0.02^{**} (0.003)	0.02^{**} (0.003)
α_{1q}	-0.01^{**} (0.003)	-	-	-0.01 (0.005)	-0.01^{**} (0.003)	-0.01^{**} (0.003)
α_{eq}	0.006^{*} (0.002)	-	-	0.005 (0.003)	0.006^{*} (0.002)	0.006^{*} (0.002)
α_{mq}	0.003 (0.005)	-	-	-0.001 (0.006)	0.002 (0.005)	0.002 (0.005)
α_{kq}	0.002 (0.001)	-	-	0.006 (0.003)	0.002 (0.001)	0.002 (0.001)
α_{1t}	-0.002^{*} (0.001)	-0.002^{*} (0.001)	-0.002^{*} (0.001)	0.002^{**} (.0004)	-	-0.002^{*} (0.001)

Table 5-1 Continued.

Parameters	**Model**					
	1	**2**	**3**	**4**	**5**	**6**
α_{et}	0.0007 (.0008)	0.0006 (0.001)	0.0006 (0.001)	0.001^{**} (.0003)	-	0.0007 (.0008)
α_{mt}	0.003 (0.001)	0.003 (.0002)	0.003 (.0002)	-0.002^{**} (.0005)	-	0.003 (0.001)
α_{kt}	-0.001^{*} (.0005)	-0.001^{*} (.0005)	-0.001^{*} (.0005)	-0.001 (0.001)	-	-0.001^{*} (.0005)
α_D	-	-	-	-	-	-2.53^{**} (0.11)
R^2	0.99	0.97	0.97	0.98	0.98	0.99
Adjusted R^2	0.98	0.90	0.91	0.96	0.92	0.93
DW	2.36	1.94	1.51	1.53	1.61	1.87

*: indicates 10% significance level.
**: indicates 5% significance level.
Note: (1) Numbers in parentheses are the standard errors of the estimates.
(2) Model 1 is the unrestricted translog cost function.
(3) Model 2 is the homothetic cost function.
(4) Model 3 is the homogenous cost function.
(5) Model 4 is the unitary elasticity of substitution cost function.
(6) Model 5 is the Hicks neutral technology change bias model.
(7) Model 6 is for the structural change test.

Table 5-2. Test Statistics for the Production Structure.

	Model 1	Model 2	Model 3	Model 4	Model 5
Number of restrictions	None	3	4	6	3
Log of likelihood function	41.03	6.82	6.22	12.51	8.76
Critical x^2 (5%)		7.81	9.48	12.59	7.81
Calculated x^2		68.42	69.62	57.04	64.54

Note: Descriptions of models are presented in the chapter 4 and chapter 5.

Nonhomotheticity and nonhomogeneity of production structure imply that the relative composition 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.

5.7. 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.[33]

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

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

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 (data available from author).

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 (σ_{ij}) 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 (see Table 5.5.). Therefore, the concavity 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.

5.8. Effects of Input Prices on Average Production Cost

Table 5-3 presents the elasticities of average cost with respect to factor prices. 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 (see Appendix 5). Nautiyal and Singh (1985) estimated average 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 costs of the Korean plywood industry were extremely sensitive to the price of the material.

Table 5-3. Elasticities of Average Cost with Respect to Factor Prices.

Input price	**Elasticities**
Labor	0.0950
Energy	0.0425
Material	0.8428
Capital	0.0195

5.9. Result of Test and Estimation of the Technological Change Bias

Results (Table 5-2) of the likelihood ratio test indicate that the calculated value of x^2 (i.e., 64.54) is within the rejection region (i.e., 11.34). Therefore, the test for Hicks neutral technological changes shows that the industry had biased technological changes, since the assumption of the Hicks neutral technological change was rejected at a 1% level of significance.

Technological change biases are then estimated by using average factor share values and time as a proxy for technological change. Estimates presented in Table 5-4 are used to determine if technological changes are capital-saving, labor-saving, energy-using, and/or material-using.[34] Only material-using technological change is indicated because it alone is significant at the 5% level. Material-using technological changes may be due to the use of inexpensive and plentiful supplies of tropical logs for most years of the sample period. As a result, the industry tended to use more materials.

A study by Martinello (1987) found that the British

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[34]As mentioned in chapter 4, if the indicator of the technological change bias has a negative value, the technological change bias is factor-saving. If it is positive, the technological change bias is factor-using.

Columbia plywood industry had capital-using, labor-saving, and material-neutral changes. Haynes and Merrifield (1985) indicated that the plywood industries in the western region of the Pacific Northwest had labor-saving and structure-using changes, while the eastern region's industries had equipment-saving technological changes. For the Pacific Northwest plywood industries, labor-saving, capital-using, and stumpage-using technological changes were found by Merrifield and Singleton (1986). Moreover, Greber and White (1982) discovered that the U.S. wood products industry also exhibited labor-saving technological changes.

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

Table 5-5 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.

Table 5-4. 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 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 over time.
3. The standard errors are calculated by $S.E.(\delta_i) = S.E(\alpha_{Ti})/S_i$.

Labor, energy, and capital are all substitutable with material.[34] 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 substitutes are available for the material input, which has the greatest impact on the average plywood production costs. Substitutability of material input indicated that the industry tried to reduce production costs through substitution of inputs, however substitutability is physically limited in the actual plywood manufacturing process because plywood is made mostly of wood.

Table 5-6 shows own and cross-partial elasticities of factor demand estimates. Labor quantity demanded is inelastic for the price of material. Quantity demanded 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. Also the demand for material is inelastic for its own price. The demand for capital is elastic for the price of material.

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[34]If the value of elasticity between inputs is negative, they are complements. If the value of elasticity is positive, they are substitute each other.

Table 5-5. 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 5 % significance level.

Note: 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 $S.E.(\sigma_{ij}) = S.E(\alpha_{ij}) / S_i S_j$.

Table 5-6. Own and Cross Partial Elasticity of Factor Demand Estimates.

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

** indicates 5% significance level.

Note: 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 $S.E.(\mu_{ij}) = S.E(\alpha_{ij})/S_i$.

5.11. Test of Structural Changes

The result of production structure changes (Table 5-1) shows that the coefficient of the dummy variable is highly significant at a 1 % level of significance. Therefore, the industry changed its production structure when it faced the altered conditions of the material market in 1979. Since the value of the coefficient for the dummy variable was negative, the industry adjusted its production structure to reduce production costs.

CHAPTER 6

SUMMARY AND CONCLUSION

This study was conducted to analyze the production structure and cost performance of the Korean plywood industry. The objectives of the study were: (1) to investigate the impact of input prices on the production costs of the Korean plywood industry, and (2) to analyze the industry's adjustment methods and processes following altered circumstances (e.g., factor substitutions, technological changes, and structural changes). In more detail, the following questions were presented: (1) What input costs were the major causes of increasing production costs? For example, what was the effect of the increased prices of tropical logs on the production costs of the industry? Has the cost of labor been a significant factor in modifying the cost performance of manufacturing plywood in Korea? What other input prices may affect the production cost of the plywood industry? (2) To be more competitive in the world market, how has the Korean plywood industry adapted to external shocks? In other words, what are the major adjustments that the Korean industry made when it faced different situations? Did it substitute specific inputs for other inputs due to the changed prices of inputs? Or, did it 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 the changed conditions of input markets? In order to reveal the adjustment behaviors of the industry, these questions regarding structural changes and input substitutions were addressed.

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. To select the best econometric model based on production technology and to investigate technological change bias, the likelihood ratio test was used. A test for structural changes of the production function was also conducted.

6.1. Findings and Implication of the Analysis

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 nonhomogeneous 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. In other words, the output elasticities for all inputs are not invariant at any level of production along a radial expansion path. This means that the relative compositions of inputs, holding all input prices invariant, will be different at a certain production level from that of other production levels. This provides an important implication for the factor demand because the relative demand of inputs will change as the level of output changes.

Using the likelihood ratio test as the criterion, Model 1 was selected as the best model. Model 1 is an unrestricted model. The conditions for the well-behaved cost function, which are homogeneity, positivity, continuity, and concavity, were investigated for Model 1. All four of these necessary and sufficient conditions were fulfilled for Model 1; therefore, the Model 1 is a well-behaved cost function.

(2) 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 elasticities are 0.8428, 0.095, 0.0425, and 0.0195 for material, labor, energy, and capital, respectively. If the price of material changes 1%, then the average cost of plywood production will change approximately 0.85%. Other elasticities are interpreted in the same manner.

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. During the late 70's, the price of tropical logs significantly increased. Because of the significant impact of tropical log prices on plywood production costs, the almost two-fold increase in the prices of tropical logs caused a significant increase in plywood production costs at that time. 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.

(3) The test for Hicks neutral technological change showed that the industry had a technological change bias. Results of the likelihood ratio test indicated that the assumption of the Hicks neutral technological change was rejected. The rejection of this assumption implies that the marginal rate of the technical substitution of inputs for other inputs will change along with the changes in output levels.

The technological change bias is estimated by using (1) the average value of a factor share and (2) time as a proxy for technological change. The technological change is material-using for the Korean plywood industry. 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 relative demand for the material will be increased and consequently the material sector will earn proportionally more income. Other technological change biases are not statistically significant. 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 past 10 years, the industry should develop technology to save more materials in order to reduce production costs.

(4) 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 substitutable for 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 substitutable for material inputs. However, the substitution between logs and other inputs may not be effective and may be limited in the actual plywood manufacturing process. Engineering studies would be necessary to determine the physical limits of substitutability.

(5) 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.

(6) 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. The results can be interpreted in two ways: first, the production structure might have changed because many plywood mills were closed, even though the remaining mills maintained their production structures; or second the remaining firms might 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.

6.2. Implications of this Study

These findings have important implications for the Korean plywood industry.

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.

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 producing 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 contracting 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.[35] (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.[36]

6.3. Scope and Limits of the Analysis

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

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

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

of the analysis are presented below.

First, the analysis results revealed that the material market had been a major factor affecting the shape of the Korean plywood industry throughout its history. However, the material market was treated as an exogenous factor, and therefore was not analyzed in this study. The major reason for excluding the material market was that this market has been controlled by major tropical log-supplying countries. Consequently, the omission of a material market analysis may limit the usefulness of the present study.

Furthermore, several limits of this analysis may have been incurred from including the trend (T) variable in the cost equation. Since the trend variable can be the explanatory variable for the several development stages of the Korean plywood industry (as well as concealing other trends), the assumption of the trend variable as only a proxy of technological progress in this study may not provide information exclusively regarding technological progress. Also, the trend variable may not explain any specific technological changes. For example, it cannot specifically indicate how the technology changed and what kinds of technology were involved. Therefore, the use of the trend variable as a bias technological change indicator in the study may provide only limited information regarding specific technological changes in the industry's development progress.

In the product markets, product prices can explain the competitiveness of the industry. Further, the relationships between the price of merchandise and its production costs addresses how the industry creates profits. However, the exclusion of the issue of plywood prices and production cost relationships from this study may result in limited information regarding the industry's ability to be competitive in the plywood market.

Another important consideration is that, several Korean-owned plywood firms are located in tropical-log producing countries such as Indonesia. These plywood firms face significantly different input-market conditions in comparison to the domestic plywood firms. They use less expensive material (with possibly even better quality) and labor than do the domestic firms. The exclusion of these Korean-owned plywood firms from this analysis may limit implications for the future Korean plywood industry.

Moreover, since the dummy variable for the test of production structure change only explains the shift of the intercept of the total cost equation, it may not fully address specific production structure changes. Interpretation of the shift, therefore, reflected the effects on the cost function rather than concerning production structure changes.

Finally, owing to the plywood industry's history, the trend of the industry can be divided into two major periods. From its establishment to its peak (1978), the industry continued to expand. Subsequently, the industry contracted until recent years. The analysis of these two different stages as a single progress may provide less information in comparison to an analysis which conducts a separate analysis for both periods. Since the short sample period (i.e., small data sets) did not allow for a separate analysis for this study, a separate analysis for both periods could be conducted in the future.

6.4. Further Studies

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. Further study may utilize different concepts of time in the analysis. Since this study used a comparative static analysis, a dynamic analysis could be conducted in further studies. Also, only one of the flexible functional forms was used for this study, the use of other flexible forms could be pursued. More specific suggestions on these topics are presented in the remainder of this chapter.

Policy issues should be examined for a more comprehensive understanding of the industry's production performance. Since the industry was developed with government assistance, a study of policy issues would be an important factor in understanding how the industry behaved in the production process. Effects of the protectionist policy on the industry can be evaluated in more detail. How did it affect the production performance of the industry? Did it hurt the industry's productivity and cost effectiveness or not? How did it affect the industry's production performance and cost efficiency when the industry faced different conditions in its input markets? Next, effects of these commercial policies on income distribution among producers and consumers should be investigated. In other words, who gains and who loses from these protectionist policies? If there are losers and gainers, what is the extent of the losses and gains? How did the protectionist policy for the plywood industry affect the country's economy? These questions are important to answer in evaluating the effects of commercial policies on the industry and on the whole economy.

The issue of comparative advantage is important to investigate in further studies. Does the Korean plywood industry have comparative advantages over other countries in certain plywood products? The answer to these questions may provide a better answer as to whether the industry should be expanded and the direction of the expansion.

Since the industry relies heavily on tropical log markets, the economic feasibility of substituting temperate logs for tropical logs may be an important issue. To avoid further shocks from the tropical log markets, the industry should find alternative material inputs.

Since this study employed a static analysis, which assumed an instantaneous adjustment of factor uses, the usefulness of this study may be limited. The reason for using a comparative static analysis in this study is that one year is a long enough period to completely adjust the industry's production process, and only annual data were used. In the real world, when conditions in input markets change, the industry may not be able to adjust its input mixtures instantaneously. It may not have enough time to adjust its production processes, or it may be reluctant to change its input mixtures because of extra transaction costs, its conservativeness, or the uncertainties of future input markets. In the long run, however, the industry may indeed have enough time to adjust its production process when it faces changing input prices. Therefore, a dynamic analysis divides a short-run from a long-run situation in the industry's response to such price changes by changing its production process. The separation of the short-run from the long-run situation in the analysis may be more appropriate in many cases. Therefore, dynamic analyses can be pursued in future studies.

Further study may be conducted using different types of flexible forms. The use of different flexible forms may bring about a better conclusion in some cases because a particular flexible form may perform better on certain data. However, seeking better flexible functional forms requires tremendous time and efforts. A further study of the application of the Fourier flexible form may bring a better estimation of the functional form since it has a global approximation property, which is considered to be better than a local approximation property on a theoretical basis.

APPENDIX A

Data for the Korean Plywood Industry

Table A-1. Production, Production Capacity, Export, and Domestic Consumption, 1954-1988 (1000 M^3, 4mm basis).

Year	production		Export		Domestic consumption
	Capacity	Level	Total	U.N. Force	
1954	n.a.	15.8	0.0	0.0	15.8
1955	n.a.	22.3	0.0	0.0	22.3
1956	n.a.	24.9	0.0	0.0	24.9
1957	n.a.	27.1	1.4	1.4	25.6
1958	n.a.	38.7	3.6	3.6	35.1
1959	n.a.	46.9	4.0	3.9	42.8
1960	n.a.	55.2	5.6	5.5	49.5
1961	50.6	45.0	14.9	5.4	30.0
1962	91.5	83.7	21.7	1.4	62.0
1963	124.0	99.0	55.02	0.3	44.0
1964	177.1	148.0	103.4	0.4	44.5
1965	250.9	215.3	169.7	0.2	45.5
1966	360.2	353.7	276.9	1.8	76.8
1967	442.9	440.0	334.5	0.2	105.5
1968	744.1	703.9	523.7	3.4	180.1
1969	1084.5	853.4	571.7	2.7	281.6
1970	1177.5	1053.3	835.5	0.1	217.8
1971	1527.0	1351.5	994.3	0.1	357.1
1972	1705.9	1535.9	1343.0	0.0	192.6
1973	2123.3	1840.2	1435.0	0.0	404.3
1974	2394.0	1534.5	1014.0	0.0	520.1
1975	2454.0	1810.7	1289.0	0.0	520.9
1976	n.a.	2107.1	1663.0	0.0	443.6

Table A-1. Continued.

Year	production		Export		Domestic consumption
	Capacity	Level	Total	U.N. Force	
1977	n.a.	2305.2	1717.0	0.0	587.3
1978	2734.2	2559.3	1618.0	0.0	940.4
1979	2790.0	2338.3	1308.0	0.0	1029.9
1980	2343.6	1576.6	953.8	0.0	622.8
1981	2281.8	1600.6	1004.0	0.0	596.2
1982	1933.6	1224.0	590.3	0.0	633.6
1983	1899.4	1226.6	330.3	0.0	896.3
1984	1748.0	1063.9	240.3	0.0	823.6
1985	1748.0	955.5	140.6	0.0	796.8
1986	1516.6	893.3	171.1	0.0	804.9
1987	1160.6	1001.9	172.2	0.0	850.0
1988	1155.0	1068.7	129.4	0.0	893.8

Note: n.a. = not available.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-2. Export of Plywood by Year and Area, 1967-1988 (1000 M^3, 4mm basis. Million dollars ($)).

Year	North America		Asia		Middle East	
	Quantity	Value	Quantity	Value	Quantity	Value
1967	382.12	39.7	20.31	1.6	0.00	0.0
1968	653.79	67.4	1.82	0.3	0.00	0.0
1969	560.01	77.4	35.82	3.9	0.00	0.0
1970	742.18	87.5	89.88	12.3	0.00	0.0
1971	940.45	124.7	50.44	6.3	0.00	0.0
1972	1086.90	153.2	123.62	20.4	0.00	0.0
1973	851.36	185.8	366.87	97.0	3.98	1.2
1974	677.19	124.9	288.41	27.8	0.82	0.3
1975	969.39	174.4	150.29	23.7	17.15	3.0
1976	1056.50	217.4	119.97	14.0	78.90	19.1
1977	1081.80	274.0	75.03	8.9	76.63	22.7
1978	988.14	235.3	74.33	13.0	177.96	41.8
1979	729.60	254.5	40.18	15.9	236.33	74.1
1980	438.85	156.3	46.87	16.1	257.42	88.1
1981	386.32	136.1	62.94	22.9	320.18	107.4
1982	199.35	63.5	3.39	1.2	274.98	84.9
1983	84.52	28.9	1.23	0.3	158.36	47.5
1984	22.13	7.7	0.52	0.1	124.73	34.8
1985	9.63	2.9	0.71	0.2	61.45	14.4
1986	25.44	8.2	11.38	3.1	10.90	2.8
1987	7.89	3.5	32.33	11.0	354.89	0.1
1988	1.75	1.6	5.02	2.6	0.00	0.0

Table A-2. Continued.

Year	Europe		Central and South America		Others	
	Quantity	Value	Quantity	Value	Quantity	Value
1967	0.00	0.0	0.00	0.0	0.00	0.0
1968	0.00	0.0	0.00	0.0	0.00	0.0
1969	0.00	0.0	0.00	0.0	0.93	0.2
1970	1.75	0.2	0.00	0.0	1.64	0.2
1971	1.49	0.2	0.00	0.0	0.52	0.1
1972	9.60	4.5	0.00	0.0	2.60	0.3
1973	20.87	5.7	0.00	0.0	7.33	2.3
1974	8.22	2.7	1.41	0.4	5.73	2.2
1975	78.83	17.8	1.12	0.3	66.96	10.2
1976	276.40	64.8	0.00	0.0	131.32	26.4
1977	236.96	59.1	6.32	1.5	218.36	46.6
1978	344.55	96.3	6.44	1.6	27.71	6.1
1979	288.45	109.6	0.52	0.2	13.43	6.1
1980	153.19	58.0	0.56	0.2	56.95	22.0
1981	168.40	64.9	3.39	1.2	63.35	22.7
1982	32.74	13.0	8.82	2.5	71.20	26.1
1983	29.65	11.5	13.21	3.5	43.45	16.9
1984	11.98	4.3	12.05	2.8	69.04	27.5
1985	6.44	2.7	1.75	0.5	60.78	22.8
1986	28.38	10.6	2.12	0.3	92.85	31.0
1987	34.82	17.1	14.06	4.8	82.70	33.9
1988	23.32	16.6	4.58	2.5	94.53	36.9

Note: All values are nominal values.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-3. Total Value and Unit Value of Plywood Exports in Korea, 1966-1987 (Million \$, \$/M^3).

Year	Plywood Export	
	Total value	Unit value
1966	30.6	111
1967	41.3	117
1968	67.7	109
1969	81.5	115
1970	100.2	125
1971	131.3	125
1972	178.4	147
1973	292.0	207
1974	158.3	187
1975	229.4	182
1976	341.7	214
1977	412.8	240
1978	394.1	257
1979	460.4	345
1980	340.7	372
1981	355.2	367
1982	191.2	313
1983	108.6	316
1984	77.2	316
1985	43.5	313
1986	56.0	296
1987	70.4	318

Note: Values are nominal values.
Source: Food and Agriculture Organization of the United Nations (FAO). Various years. Yearbook of Forest Products.

Table A-4. Major Plywood Producing Countries, 1965-1988 (1000 M^3, 4mm basis).

Year	World	Korea	USA	Canada	Japan	Indo-nesia
1965	20312	118	10606	1384	2097	3
1966	25577	353	13208	1803	3101	3
1967	26559	440	13059	1868	3778	3
1968	29884	703	14509	1959	4743	4
1969	30839	821	13635	2004	5893	7
1970	32959	847	14078	1851	7058	7
1971	36595	1048	16184	2066	7340	7
1972	39835	1214	17746	2202	7748	4
1973	42278	1459	18054	2451	8596	9
1974	36150	1233	15172	2085	7443	n.a.
1975	34133	1436	14579	2051	6168	8
1976	38609	1671	16727	2442	7120	8
1977	41453	2289	17981	2660	7476	279
1978	42030	2560	17056	2807	8016	424
1979	42774	2338	17128	2510	8532	624
1980	39383	1575	14857	2338	8000	1011
1981	40302	1599	16300	2086	7096	1552
1982	38891	1423	14803	1850	6742	2487
1983	44092	1491	18169	2270	7291	3138
1984	44000	1326	18425	2050	7083	3600
1985	44791	1229	18580	2190	7033	4615
1986	47657	1111	20484	1877	6824	5750
1987	50997	1179	21500	2221	7340	6400
1988	51135	1269	21315	2162	7260	6560

Source: FAO. Various years. Yearbook of Forest Products.

Table A-5. Major Plywood Exporting Countries, 1965-1988 (1000 M^3, 4mm basis).

Year	World	Korea	Japan	China	Indo-nesia	Canada
1965	2005	72	357	158	0	217
1966	2781	277	377	283	0	330
1967	3021	311	337	308	0	401
1968	3832	600	425	412	0	429
1969	4191	709	393	521	0	400
1970	4477	822	322	589	0	369
1971	4981	1028	327	810	0	342
1972	5733	1195	270	951	0	429
1973	6498	1322	155	953	0	471
1974	4923	1030	123	685	0	341
1975	5185	1258	116	758	1	313
1976	5995	1623	133	768	1	249
1977	6496	1703	262	946	17	388
1978	7175	1605	197	1240	70	499
1979	6979	1297	152	1091	117	493
1980	6623	946	104	868	245	548
1981	7296	1068	107	951	760	408
1982	6859	642	94	822	1232	413
1983	7859	348	100	867	2106	434
1984	8083	211	83	601	3021	474
1985	8835	127	78	556	3964	473
1986	9628	171	54	505	4607	337
1987	11632	176	29	544	5648	330
1988	12807	100	19	501	6372	479

Source: FAO. Various years. Yearbook of Forest Products.

Table A-6. Production of Raw Panel by Thickness in Korea, 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Below 3.5mm	3.6mm-5.9mm	6.0mm-11.9mm	Over 12.0mm
1971	992.53	24.86	923.90	8.35	35.42
1972	1011.54	14.67	930.93	9.57	56.37
1973	1309.17	98.47	1071.50	23.99	115.21
1974	1276.69	108.85	863.97	44.31	259.56
1975	1464.15	64.11	1121.65	53.10	225.29
1976	1798.00	44.09	1235.89	117.53	400.49
1977	2006.53	62.66	1363.51	118.85	461.51
1978	2241.08	33.93	1369.99	185.11	652.05
1979	2073.16	16.72	1228.06	172.27	656.11
1980	1467.22	27.93	767.42	139.31	532.56
1981	1490.73	52.60	743.02	151.47	543.64
1982	1152.78	75.15	463.38	133.02	481.23
1983	1132.12	99.30	382.95	97.58	552.29
1984	988.90	91.48	307.40	74.71	515.31
1985	887.36	123.09	241.38	73.02	449.87
1986	809.58	219.13	156.84	54.54	379.07
1987	919.22	268.59	121.56	73.52	455.55
1988	977.20	266.71	109.46	53.44	547.59

Note: Data for 1971, 1972, and 1973 are based on panel surface basis.

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-7. Production of Processed Plywood by Kinds in Korea, 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Prefinish	Overlaid	Printed	Cosmetic
1971	238.97	199.33	34.98	2.82	1.83
1972	347.91	260.55	54.56	21.91	10.88
1973	220.11	112.70	64.84	20.24	22.31
1974	256.32	103.42	48.65	27.65	76.59
1975	344.69	134.94	91.09	43.67	74.97
1976	307.05	88.34	123.59	38.04	57.07
1977	296.39	78.85	145.16	24.39	47.98
1978	315.97	46.74	167.69	33.29	68.23
1979	262.59	42.74	136.78	13.89	69.17
1980	107.75	10.19	62.87	1.95	32.72
1981	108.32	14.35	62.87	1.44	29.65
1982	69.99	8.30	34.93	3.27	23.48
1983	93.32	8.60	53.45	3.84	27.42
1984	73.95	7.41	39.72	2.17	24.65
1985	67.17	7.62	38.66	3.27	17.60
1986	82.82	9.40	44.01	4.76	24.63
1987	81.70	6.54	47.07	3.21	24.87
1988	90.46	9.26	57.40	9.10	14.68

Note: Data for 1971, 1972, and 1973 are based on panel surface basis.

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-8. Domestic Consumption of Raw Panel by Thickness in Korea 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Below 3.5mm	3.6-5.9mm	6.0-11.9mm	Over 12.0mm
1971	216.81	10.14	180.33	6.25	20.08
1972	190.29	5.16	166.28	3.90	14.93
1973	197.00	14.80	143.87	9.14	29.17
1974	387.94	36.55	197.46	22.57	131.35
1975	449.26	35.16	229.57	28.77	155.75
1976	477.08	22.56	250.02	36.87	167.62
1977	600.18	21.54	300.34	35.55	242.73
1978	820.04	13.70	431.08	55.74	319.18
1979	863.16	5.11	463.35	48.57	346.11
1980	618.08	8.94	296.67	37.94	274.52
1981	552.77	31.49	228.47	41.41	251.39
1982	654.15	59.72	230.91	50.12	313.38
1983	858.74	83.66	249.48	64.61	460.98
1984	803.24	79.59	227.10	54.50	442.03
1985	759.05	117.39	178.85	61.97	400.84
1986	762.16	193.70	126.08	48.78	393.58
1987	795.96	264.69	88.00	54.15	389.10
1988	834.99	251.44	104.06	42.41	437.28

Note: A, B, C, and D are "below 3.5*mm*", "3.6-5.9*mm*", "6.0-11.9*mm*", and "over 12.0*mm* " respectively. Data are based on 4 mm panel. Data for 1971, 1972, and 1973 are based on panel surface basis.

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-9. Domestic Consumption of Processed Plywood by Kinds in Korea, 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Prefinish	Overlaid	Printed	Cosmetic
1971	17.74	13.87	2.14	0.19	1.54
1972	15.49	11.85	1.03	0.80	1.81
1973	20.70	9.35	2.21	3.23	5.91
1974	29.25	10.21	4.05	1.55	13.44
1975	39.19	4.02	7.70	2.22	25.25
1976	45.02	4.55	14.61	20.70	5.16
1977	41.17	3.86	12.96	18.44	5.91
1978	88.79	4.29	23.85	23.42	37.23
1979	112.53	26.99	26.16	10.23	49.15
1980	49.57	1.74	23.31	0.50	24.02
1981	28.05	2.21	9.27	0.25	16.32
1982	31.41	1.21	8.90	1.22	20.08
1983	34.89	1.15	12.35	0.68	20.71
1984	38.48	1.75	15.65	0.51	20.57
1985	37.04	1.14	19.71	0.61	15.58
1986	41.98	2.65	18.97	3.55	16.81
1987	53.25	3.92	29.11	2.36	17.86
1988	57.76	6.39	36.80	2.60	11.97

Note: Data for 1971, 1972, and 1973 are based on panel surface basis.

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-10. Export of Raw Panel by Thickness in Korea, 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Below 3.5mm	3.6-5.9mm	6.0-11.9mm	Over 12.0mm
1971	775.72	14.71	743.57	2.09	15.32
1972	821.25	9.50	764.64	5.66	41.43
1973	1112.17	83.66	927.62	14.85	86.03
1974	888.74	72.29	666.51	21.74	128.20
1975	1014.89	28.94	892.08	24.33	69.53
1976	1320.91	21.52	985.87	80.66	232.85
1977	1406.35	41.11	1063.16	83.30	218.76
1978	1421.04	20.22	938.91	129.04	332.85
1979	1209.99	11.60	764.70	123.69	309.99
1980	849.13	18.98	470.74	101.37	258.02
1981	937.95	21.10	514.54	110.05	292.24
1982	498.63	15.42	232.46	82.90	167.84
1983	273.37	15.64	133.46	32.97	91.28
1984	185.66	11.89	80.30	20.20	73.25
1985	128.30	5.70	62.53	11.05	49.00
1986	131.24	25.43	30.75	5.75	69.31
1987	123.25	3.89	33.55	19.36	66.43
1988	141.99	15.27	5.39	11.03	110.29

Note: Data for 1971, 1972, and 1973 are based on panel surface basis.
Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-11. Export of Processed Plywood by Kinds in Korea 1971-1988 (1000 M^3, 4mm basis).

Year	Total	Prefinish	Overlaid	Printed	Cosmetic
1971	221.23	185.45	32.83	2.63	0.30
1972	332.42	248.69	53.52	21.10	9.10
1973	199.41	103.34	62.63	17.01	16.42
1974	227.07	93.20	44.60	26.09	63.17
1975	305.49	130.91	83.39	41.45	49.73
1976	262.03	83.78	108.98	17.34	51.91
1977	255.22	74.99	132.19	5.95	42.08
1978	227.17	42.45	143.83	9.87	31.01
1979	150.05	15.74	110.62	3.65	20.03
1980	58.17	8.45	39.55	1.45	8.71
1981	80.27	12.13	53.59	1.18	13.35
1982	38.57	7.09	26.02	2.05	3.41
1983	58.43	7.44	41.10	3.16	6.72
1984	35.47	5.65	24.10	1.65	4.09
1985	30.12	6.47	18.95	2.66	2.03
1986	40.83	6.75	25.03	1.20	7.84
1987	28.45	2.61	17.96	0.85	7.02
1988	32.69	2.86	20.60	6.50	2.72

Note: Data for 1971, 1972, and 1973 are based on panel surface basis.

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-12. Building Construction Permits in Korea 1966-1988 (1000 units, Million M^2).

Year	Number of building	Floor area
1966	36.8	4507
1967	57.3	5888
1968	67.9	7717
1969	75.1	9572
1970	92.9	10787
1971	89.1	9619
1972	74.1	8701
1973	117.3	16572
1974	128.2	16884
1975	120.9	18420
1976	111.5	17985
1977	142.4	22342
1978	149.7	30818
1979	129.3	27505
1980	104.4	25727
1981	75.0	20846
1982	101.5	29798
1983	126.5	39693
1984	101.5	39563
1985	95.4	38217
1986	100.1	43543
1987	114.0	47982
1988	137.1	59770

Source: The Korea Economic Statistics. Various years. The Bank of Korea.

Table A-13. Import of Tropical Log for Plywood Manufacturing in Korea, 1965-1988 (1000 M^3, 4mm basis, Million $).

Year	Philippine		Malaysia		Indonesia		Papua New Guinea	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1965	161	5.53	350	11.90	0	0.00	0	0.00
1966	277	9.40	430	15.25	0	0.00	0	0.00
1967	418	14.65	574	22.31	0	0.00	0	0.00
1968	376	13.02	878	33.01	5	0.21	0	0.00
1969	907	32.23	1048	41.38	65	1.68	0	0.00
1970	813	30.50	1195	47.46	262	10.40	0	0.00
1971	898	38.39	1189	49.32	764	34.37	0	0.00
1972	305	11.44	1320	37.36	1354	41.58	0	0.00
1973	218	12.46	1450	82.16	1537	86.54	0	0.00
1974	91	6.18	1289	87.28	1623	108.20	0	0.00
1975	94	4.82	1502	74.82	1980	99.44	0	0.00
1976	19	1.01	1744	109.90	2716	185.80	0	0.00
1977	0	0.00	1488	88.99	3768	252.10	0	0.00
1978	37	1.86	1220	78.33	3812	264.90	0	0.00
1979	5	0.45	1524	189.60	3133	397.20	0	0.00
1980	23	3.06	1715	226.20	1590	240.20	28	2.68

Table A-13. Continued.

Year	Philippine		Malaysia		Indonesia		Papua New Guinea	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1981	138	16.83	3044	342.30	431	56.81	229	24.34
1982	195	24.17	2466	279.50	73	10.14	321	33.56
1983	64	7.28	2132	192.30	84	8.93	308	23.78
1984	4	0.42	1545	155.30	29	2.96	438	38.85
1985	0	0.00	1676	145.30	0	0.00	352	26.72
1986	0	0.00	1974	162.70	0	0.00	414	34.72
1987	0	0.00	1727	201.00	0	0.00	236	24.78
1988	0	0.00	1964	265.10	0	0.00	268	30.38

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-14. Quantity, Value, and Unit Value of Tropical Log Imports in Korea, 1965-1988 (1000 M^3, 4mm basis. 1000 $. $/$M^3$).

Year	Total quantity	Total value	Unit Value
1965	511	17430	34.11
1966	707	24646	34.86
1967	992	36962	37.26
1968	1259	46243	36.73
1969	2020	75289	37.27
1970	2270	88360	38.93
1971	2851	122077	42.82
1972	2979	90368	30.34
1973	3205	181158	56.52
1974	3003	201663	67.15
1975	3576	179079	50.08
1976	4479	296864	66.28
1977	5256	341171	64.91
1978	5069	345172	68.09
1979	4662	587324	125.98
1980	3356	472188	140.70
1981	3842	440372	114.62
1982	3055	347401	113.72
1983	2588	232291	89.76
1984	2016	197568	98.00
1985	2028	172050	84.84
1986	2388	197430	82.68
1987	1963	225854	115.06
1988	2232	295521	132.40

Note: All values are nominal values.
Source: Korea Plywood Industries Association. Various years. Statistics of plywood.

Table A-15. Plywood Price Index, Nominal Plywood Price, Deflated Plywood Price, and Log Price Index in Korea, 1966-1987.

Year	Plywood Price Index	Nominal Plywood Price	Deflated Plywood Price	Log Price Index
1966	11.3	169	1495	14.5
1967	12.2	171	1401	14.5
1968	12.4	175	1411	14.2
1969	12.5	176	1408	14.4
1970	15.7	202	1286	14.5
1971	16.9	220	1301	14.7
1972	19.0	252	1326	18.5
1973	19.1	252	1319	24.9
1974	22.9	700	3056	35.2
1975	30.8	780	2532	35.5
1976	32.3	820	2538	40.4
1977	35.6	890	2500	46.5
1978	40.6	1000	2463	50.5
1979	59.4	1563	2631	75.9
1980	100.0	2401	2401	100.0
1981	102.8	2442	2375	99.5
1982	112.3	2673	2380	96.7
1983	114.0	2709	2376	87.3
1984	116.9	2791	2387	97.3
1985	116.0	2750	2370	99.4
1986	113.1	2755	2435	110.6
1987	117.0	2800	2393	117.8

Note: unit for nominal and real plywood price is won/4mm*1.2m*4m).
Source: The Bank of Korea. Various years. The Price Statistics Summary.

Table A-16. Investment and Value-added of the Plywood Industry in Korea, 1966-1987 (million won).

Year	Investment	Value added
1966	1311.0	2840.7
1967	2395.4	2872.3
1968	3406.1	7365.7
1969	4005.2	8149.8
1970	7916.2	12192.7
1971	4820.9	16125.8
1972	4117.3	25381.1
1973	n.a.	43382.8
1974	5860.5	15896.5
1975	4834.0	35796.5
1976	15646.4	59737.1
1977	7782.9	67770.4
1978	24508.0	99496.0
1979	54714.0	70995.0
1980	17794.0	45978.0
1981	32997.0	69154.0
1982	8079.0	71833.0
1983	13314.0	99067.0
1984	20852.0	94804.0
1985	9446.0	75562.0
1986	5332.0	73141.0
1987	19145.0	90493.0

Note: All values are nominal terms
Source: Economic Planning Board. various years. Report on Mining and Manufacturing Survey (Census).

Table A-17. Log Import Price by Year and Month in Korea, 1978-1987 ($\$/M^3$, 4mm Basis).

	Year									
Mon.	**'78**	**'79**	**'80**	**'81**	**'82**	**'83**	**'84**	**'85**	**'86**	**'87**
1	67	83	150	108	114	99	92	92	79	103
2	68	96	142	116	77	92	95	94	84	106
3	69	113	145	115	124	86	93	91	86	102
4	71	118	160	120	116	88	99	89	86	102
5	71	119	158	115	114	85	109	85	84	101
6	70	121	151	115	114	87	112	86	87	101
7	68	135	146	115	113	85	115	84	87	102
8	73	152	132	112	108	85	109	84	84	114
9	75	160	133	111	106	90	102	82	85	121
10	79	168	128	106	106	92	98	79	84	132
11	82	167	125	103	104	94	93	75	88	138
12	87	156	113	107	99	96	89	73	90	134

Source: Korea Plywood Industries Association. Various years. Statistics of Plywood.

Table A-18. Interest Rates on Loans and Discounts of Deposit Money Banks in Korea 1965-1986 (%).

Year	Discounts on Commercial Bills	Loans on Foreign Trade Bills	Loans for Supplies in Foreign Currency
9/30/1965	24.0	6.5	6.5
6/29/1967	24.0	6.0	6.0
10/1/1968	26.0	6.0	6.0
6/1/1969	24.6	6.0	6.0
6/18/1970	24.0	6.0	6.0
6/28/1971	22.0	6.0	6.0
1/17/1972	19.0	6.0	6.0
8/3/1972	15.5	6.0	6.0
10/2/1972	15.5	6.0	6.0
2/9/1973	15.5	6.0	6.0
5/14/1973	15.5	7.0	7.0
1/24/1974	15.5	9.0	9.0
11/12/1974	15.5	9.0	9.0
12/7/1974	15.5	9.0	9.0
4/17/1975	15.5	7.0	7.0
10/1/1975	19.0	7.0	7.0
8/2/1976	18.0	8.0	8.0
7/1/1977	16.0-19.0	8.0	8.0
10/4/1977	16.0-19.0	8.0	8.0
6/16/1978	19.0	9.0	9.0
12/7/1978	19.0	9.0	9.0
9/7/1979	19.0	9.0	9.0
1/12/1980	25.0	12.0	12.0
6/5/1980	24.0	12.0	12.0
8/1/1980	24.0	12.0	12.0

Table A-18. Continued.

Year	Discounts on Commercial Bills	Loans on Foreign Trade Bills	Loans for Supplies in Foreign Currency
9/16/1980	22.0	12.0	12.0
11/8/1980	20.0	12.0	12.0
12/29/1981	17.0	12.0	n.a.
1/14/1982	16.0	12.0	n.a.
3/29/1982	13.5	11.0	n.a.
6/28/1982	10.0	10.0	n.a.
1/23/1984	10.0-10.5	10.0	n.a.
11/5/1984	10.0-11.5	10.0	n.a.
4/19/1985	10.0-11.5	10.0	n.a.
10/11/1985	10.0-11.5	10.0	n.a.
3/24/1986	10.0-11.5	10.0	n.a.

Note: n.a. is not available
Source: The Bank of Korea. Various years. The Korea Economic Statistics Yearbook.

Table A-19. Tariff Rates for Plywood and Tropical logs in Korea 1962-1988 (%).

Year	Tropical log	Plywood
1964	10	50
1965	10	50
1966	10	50
1967	10	50
1968	10	50
1969	10	50
1970	10	50
1971	10	50
1972	10	50
1973	10	50
1974	10	50
1975	10	40
1976	10	40
1977	10	30
1978	10	30
1979	10	30
1980	5	30
1981	5	30
1982	5	30
1983	5	30
1984	5	30
1985	5	30
1986	5	30
1987	5	30
1988	5	20

Source: Korea Institute of Customs Research. Various years. Tariff Schedules of Korea.

APPENDIX B

Data Used in Models

Table B-1. Prices of capital (K), labor (L), energy (E), and Material (M), 1966-1987 (All prices are nominal. All units are explained in the Chapter 4.).

Year	K	L	E	M
1966	0.484407	0.852418	0.0000398	0.094631
1967	0.913536	1.138369	0.0000425	0.102316
1968	0.986445	1.126305	0.0000424	0.103395
1969	0.910612	1.580108	0.0000430	0.113492
1970	0.426790	1.800681	0.0000477	0.123276
1971	10128383	2.052087	0.0000507	0.159800
1972	0.955351	2.238292	0.0000625	0.121006
1973	1.113081	2.886905	0.0000664	0.224681
1974	0.350249	3.338426	0.0001230	0.325025
1975	0.640947	4.302174	0.0003000	0.242378
1976	0.720160	5.708486	0.0003210	0.320791
1977	0.811697	7.860019	0.0003440	0.314168
1978	1.406132	10.68375	0.0003530	0.329578
1979	0.707345	12.85207	0.0003870	0.609749
1980	0.507162	15.70455	0.0009420	0.928477
1981	0.514131	16.92934	0.0011910	0.802917
1982	0.592594	18.35648	0.0011720	0.851502
1983	0.795369	21.18800	0.0011430	0.714016
1984	0.807151	25.38539	0.0011550	0.810852
1985	0.799182	27.25720	0.0011020	0.755221
1986	0.772319	29.12372	0.0011280	0.722456
1987	0.831276	32.26252	0.0010010	0.911585

Table B-2. Total Cost (C), Quantity of Products Produced (Q), Trend (T), and Dummy (D), 1966-1987 (Total cost is nominal. All units are explained in the Chapter 4.).

Year	C	Q	TR	D
1966	105191.3	445.2	1	0
1967	97908.48	553.8	2	0
1968	181834.5	885.9	3	0
1969	347097.1	821.0	4	0
1970	439185.3	1055.4	5	0
1971	442914.8	1231.5	6	0
1972	555110.3	1359.4	7	0
1973	1244070.0	1529.2	8	0
1974	1189163.0	1533.0	9	0
1975	1399569.0	1808.8	10	0
1976	1987098.0	2105.0	11	0
1977	2544434.0	2302.9	12	0
1978	2944334.0	2557.0	13	0
1979	4346424.0	2335.7	14	1
1980	3858808.0	1574.9	15	1
1981	4454513.0	1599.0	16	1
1982	2984348.0	1222.7	17	1
1983	3199217.0	1225.4	18	1
1984	3283477.0	1062.8	19	1
1985	2981914.0	954.5	20	1
1986	2842481.0	892.4	21	1
1987	3573072.0	1000.9	22	1

Table B-3. Share of Capital (SK), Labor (SL), Energy (SE), and Material (SM), 1966-1987.

Year	SK	SL	SE	SM
1966	0.019512	0.077396	0.026631	0.876459
1967	0.011239	0.092084	0.021115	0.875559
1968	0.014372	0.097576	0.037826	0.850225
1969	0.009024	0.100848	0.027176	0.862950
1970	0.039029	0.094157	0.029684	0.837128
1971	0.019359	0.079870	0.030560	0.870209
1972	0.028715	0.085493	0.039831	0.845958
1973	0.018797	0.062677	0.025751	0.892773
1974	0.022899	0.072155	0.045142	0.859801
1975	0.023942	0.072744	0.055211	0.848101
1976	0.029220	0.090093	0.052222	0.828463
1977	0.026250	0.100278	0.049552	0.823918
1978	0.016822	0.122907	0.041673	0.818596
1979	0.011546	0.095091	0.035861	0.857500
1980	0.011746	0.087223	0.061262	0.839766
1981	0.015097	0.082998	0.055765	0.846137
1982	0.020308	0.098316	0.051026	0.830348
1983	0.019466	0.108038	0.051531	0.820963
1984	0.017885	0.114144	0.053680	0.814289
1985	0.015853	0.121509	0.051943	0.810693
1986	0.016658	0.121485	0.052243	0.809613
1987	0.021326	0.113020	0.041350	0.824301

Table B-4. Total Labor Cost, Total Labor, Total Capital Cost, and Total Fixed Asset, 1966-1987 (1000 won, nominal term).

Year	Total labor cost	Total labor	Total capital cost	Total fixed asset
1966	814145	9551	205250.9	5864314
1967	901589	7920	110048.4	3144240
1968	1774269	15753	261342.2	7466922
1969	3500414	221153	313243.4	8949812
1970	4135266	22965	1714107	28568460
1971	3537593	17239	857467.8	14291131
1972	4745852	21203	1594041	26567359
1973	7797533	27010	2338525	38975430
1974	8580528	25398	2723173	45386226
1975	10181095	23665	3350964	55849400
1976	17902386	31361	5806489	82949845
1977	25515195	32462	6679381	83492264
1978	36188000	33872	4953102	70758608
1979	41331000	32159	5018411	100000000
1980	33658000	21432	4532868	90657360
1981	36972000	21839	6725320	130000000
1982	29341000	15984	6060893	120000000
1983	34564000	16313	6227732	120000000
1984	37479000	14764	5872750	120000000
1985	36233000	13293	4727456	94549121
1986	34532000	11857	4735152	94703044
1987	40383000	12517	7620224	110000000

Table B-5. Material Cost, Fuel Cost, Power Cost, and Total Energy Cost, 1966-1987 (1000 won, nominal term).

Year	Material cost	Cost of fuels	Cost of power	Total energy cost
1966	9219596	125016	155129	280145
1967	8572472	66270	140470	206740
1968	15460032	369836	317977	687813
1969	29952781	464712	478569	943281
1970	36765468	563430	740263	1303693
1971	38542856	642850	710720	1353570
1972	46960035	1078578	1132532	2211110
1973	111067200	1781483	1422235	3203718
1974	102244400	2239651	3128564	5368215
1975	118697600	4877140	2850114	7727254
1976	164623800	6443723	3933391	10377114
1977	209640500	7863829	4744466	12608295
1978	241022000	7081000	5189000	12270000
1979	372706000	8382000	7205000	15587000
1980	324050000	14208000	9432000	23640000
1981	376913000	13352000	11489000	24841000
1982	247805000	6514000	8714000	15228000
1983	262644000	7419000	9067000	16486000
1984	267370000	7281000	10345000	17626000
1985	241742000	5660000	9829000	15489000
1986	230131000	5937000	8913000	14850000
1987	294529000	5930000	8845000	14775000

Table B-6. Fuel Cost Share, Power Cost Share, Bunker-C Price, and Power Price, 1966-1987 (nominal term).

Year	Fuel cost share (%)	Power cost share (%)	Price of Bunker-C (won/liter)	Price of power (won/KWH)
1966	44.62	55.38	3.56	4.32
1967	32.05	67.95	3.60	4.55
1968	53.76	46.24	3.60	4.98
1969	49.26	50.74	3.69	4.89
1970	43.21	56.79	4.06	5.31
1971	47.49	52.51	4.79	5.32
1972	48.77	51.23	6.38	6.12
1973	55.60	44.40	7.11	6.06
1974	41.72	58.28	17.47	8.66
1975	63.11	36.89	38.74	15.10
1976	62.09	37.91	41.00	17.52
1977	62.37	37.63	43.00	20.14
1978	57.70	42.30	46.00	20.72
1979	53.77	46.23	46.00	30.30
1980	60.10	39.90	124.00	49.28
1981	53.74	46.26	168.00	62.35
1982	42.77	57.23	182.00	68.76
1983	45.00	55.00	172.77	66.50
1984	41.30	58.70	185.76	66.10
1985	36.54	63.46	185.76	66.64
1986	39.97	60.03	185.76	64.21
1987	40.13	59.87	157.35	61.74

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