Tung Oil: On Economic Analysis.

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TUNG OIL: AN ECONOMIC ANALYSIS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Economics

by

Randolph George Kinabrew
B.A., Mississippi College, 1937
M.A., Louisiana State University, 1947
August, 1950
MANUSCRIPT THESES

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ACKNOWLEDGMENT

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This study was undertaken to determine the causes and effects of the decrease in the price of tung oil during the post-war period.

The major portion of the material has been presented in two parts: Chapters II, III, and IV explain Part I, while Part II contains Chapters V, VI, VII, and VIII. Chapter I is more or less a presentation of the general plan followed in Parts I and II. A general summary of the thesis is the subject of Chapter IX.

The development of the tung oil industry in the United States and the current producing processing, and marketing practices of the domestic industry were presented in Chapter II. The topics included in the study of the domestic industry were (1) origin of the domestic industry, (2) experimental development, (3) the domestic tung growing area, (4) soil and drainage requirements, (5) scientific and technological development of the domestic industry, and (6) the structure of the industry.

A description of the Chinese tung oil industry is found in Chapter III. The phases of the industry described include the following: (1) the producing area, (2) harvesting methods, (3) drying and pulverizing methods, (4) expressing methods, (5) Chinese transporting and marketing
practices, (6) tung oil production, (7) quality of Chinese tung oil, (8) Chinese consumption, and (9) export trade. Chinese producing and processing methods are crude and appear to be inefficient. The greatest portion of Chinese exports go to the United States.

Recent developments of tung oil in countries other than the United States and China are presented in Chapter IV. Countries in which tung oil is being produced include Latin America, Africa, India, Japan, Australia, and Russia. Countries in Latin America in which tung oil is being produced are Argentina, Brazil, and Paraguay. Tung trees growing in Latin America are relatively young.

In Chapter V, some of the characteristics and uses of tung oil are discussed. The material was presented under the following major topics: (1) physical properties of tung oil, (2) uses of tung oil, and (3) domestic consumption of tung oil. The principal consumers of tung oil are the paint and varnish industry, linoleum and oilcloth industry, and the printing ink industry.

Chapter VI is a statistical presentation of production and consumption of drying oils in the United States. The study is broadened to include other oils used interchangeably with tung oil in the manufacture of drying-oil products. The relative importance of drying oils is discussed under the following heads: (1) availability of
drying oils in the United States, (2) the tariff status of drying oils, (3) government price support programs for drying oils, (4) relative prices of drying oils, and (5) consumption of drying oils in the United States.

Chapter VII is a treatment of the economic aspects of producing drying oils. The purpose of the chapter has been to determine the responsiveness of the supply of the various drying oils to changes in prices and to make a comparison of the time required to effect a change in the supply of the various drying oils as a result of changes in the price.

Economic aspects of the demand for drying oils is the subject matter of Chapter VIII. An attempt is made to describe the market situations in which tung nuts and tung oil are sold and to relate them to economic theory. The nature of the demand for drying oils is presented. The demand for drying oils is derived from the demand for products which are made from drying oils, such as paint, varnish, linoleum, oilcloth, printing ink, and core oil. An effort is made to determine the degree of competition prevailing in the market situations through which tung oil is distributed. It appears that the highest degree of competition prevails in the markets nearest the producer and that the degree of competition decreases as the products move toward the consumer. The effect of changes in the demand for tung oil are presented, together with the
effect of changes in the supply of tung oil on the price.

As shown in Chapter IX, factors which influenced the price of tung oil from about 1940 to 1948 have been listed as (1) characteristics and uses of tung oil, (2) the availability of drying oils in the United States, (3) consumption of drying oils in the United States, (4) economic aspects of producing drying oils, and (5) the nature of the demand for drying oils.
TUNG OIL: AN ECONOMIC ANALYSIS
CHAPTER I

INTRODUCTION

Tung oil is a drying oil of vegetable origin used principally in the preparation of paints, varnishes, and related materials. It is obtained from the kernels of tung nuts which are grown on species of the spurge family of plants. Traditionally, the growing of tung trees has been confined to China; however, recent years have witnessed the development of tung orchards on a commercial basis in other parts of the world, notably the United States and South America. The United States is the principal consuming country and ranks second in production. However, the domestic industry produces only about one-tenth of the amount consumed annually. The production of the oil could be greatly encouraged by a tariff.

Soil and climatic considerations have limited the area in which tung trees may be grown successfully in the United States to six southeastern states, namely, Florida, Georgia, Alabama, Mississippi, Louisiana, and Texas. This limitation, however, can hardly affect the expansion of tree plantings.

Significance of the Industry

The sale of tung nuts does not make a very significant
contribution to the total annual income of the producing states. In 1949, the farm value of tung nuts sold in the principal producing states was as follows: Mississippi, $1,946,000; Louisiana, $1,037,000; Florida, $990,000; and Georgia and Alabama, $132,000. In as much as tung orchards have been developed on cut-over timber land and in other areas which have become submarginal for other purposes, the income from the sale of nuts - $4,105,000 in 1949 - approximates a net increase to annual income.

From the standpoint of income diversification, the development of a stable tung oil industry in the South can be helpful to farmers in the productive area as a stabilizer of farm incomes. Most significantly, in periods of low income and declining prices for agricultural commodities, a stable tung oil industry tends to stabilize income of the region and nullify, to some extent, the downward swing of the business cycle. There is the possibility of a source of tung oil stimulating further industrialization of the South. An abundant supply of gum rosin is obtained annually from pine trees situated in the same general region in which tung oil is produced. A very good grade of varnish may be made

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from a combination of rosin, tung oil, and a suitable coloring pigment. To the extent that sources of raw materials do influence the location of paint and varnish establishments, further development and stabilization of the tung oil industry would make the South a low-cost area for that industry. Still other typically southern industries which use large quantities of tung oil annually are the wallboard industry and certain phases of the textile industry. Wallboard and other building material may be treated with tung oil to make it waterproof and more durable. Certain textile goods, such as tents, awnings, and outer garments may be made waterproof by use of tung oil. The existence of these materials in the same or adjacent areas offers interesting possibilities of relocation of industries as the tung oil industry becomes better established.

From the standpoint of farm management, growing tung trees has some desirable features and helps to diversify farm income. "The widest benefit and greatest advantage that tung offers, is that of crop diversification." Small orchards, not exceeding four or five acres, may be maintained by the ordinary farm family as a cash crop to supplement income from other farming operations. In addition, as the harvesting and marketing period for tung nuts is from November

through May, it offers an off-season source of income and
does not interfere with other crops harvested in spring and
early fall. Even though the trees may be damaged by live-
stock grazing in tung orchards, the extent of damage is not
considered sufficient to be prohibitive.

The Problem

The domestic tung oil industry has been expanding
since its beginning on a commercial basis in 1932. During
the 1930-1940 period, expansion was at a normal rate and
the price of tung oil, though varying according to a seasonal
pattern, was maintained at a profitable level. Tung oil
price quotations were higher than quotations for other drying
oils.

During the war-period, the price of all drying oils
increased considerably. From 1940 to 1941, the average
annual price of tung oil increased from 26.3 cents per pound
to 32.2; linseed oil, from 9.7 to 10.7 cents; soybean oil,
from 4.8 to 8.5 cents; oiticica oil, from 18.9 to 20.2; and
menhaden fish oil, from 7.1 to 10.1 cents. Castor oil de-
creased from 15.6 cents to 15.2. Considering the 1940
average annual price as the base, the maximum war-time per-
centage change in the average annual price of the principal
commercial drying oils was as follows:
Drying oil prices during the postwar period present a distorted pattern. For the first year of the postwar period, 1946, tung oil was the only one of the representative drying oils to suffer a price decline from a wartime peak. The percentage average price change from the wartime high to the postwar low was as follows:

- **Tung oil**  \(\$\) 50.57%
- **Linseed oil**  \(\$\) 68.82%
- **Soybean oil**  \(\$\) 145.83%
- **Citric oil**  \(\$\) 38.62%
- **Menhaden oil**  \(\$\) 83.10%
- **Castor oil**  \(\$\) 17.97%

Price ranges for the same oils are presented graphically in Chart I for the years 1940 through 1949. By reference to the chart, it appears that the price position of tung oil has experienced a serious set-back relative to other drying oils on the American market. Within a short period of about four years, the price of tung oil has declined to the 1941 level; while the price of other oils
not only remained at relatively high postwar levels but ac-
tually increased with the end of hostilities and the re-
moval of government price ceilings. The primary problem
presented by this situation, therefore, is to determine the
cause or causes of the decrease in the competitive position
of tung oil and to show how they have brought about this
effect. How is tung oil produced in the United States,
China, and other countries? What are the characteristics
and uses of tung oil? What are the most common drying oils
and in what respect do they compete with tung oil? What
are the economic aspects of producing drying oils? What is
the nature of the demand for tung oil?

Method of Approach

The tung oil industry in the United States is rela-
tively new, and its peculiar features are not as generally
understood as in the case of some of the more common agricul-
tural commodities. In order to present the characteristics
of tung oil and the industry, this analysis is divided into
two parts. Part I, consisting of Chapters II through IV, is
descriptive and historical in nature. It is felt that a de-
scription of the industry in each of the principal tung-pro-
ducing areas in the world - China and the United States -
will serve to place the domestic industry in its proper
perspective in respect to world trade. Chapter II is devoted
to a description of the industry in the United States. An
effort is made to point out, with as few technicalities as possible, the most important cultivating and marketing practices, as well as technological and scientific improvements. In Chapter III which gives an account of the industry in China, in order to facilitate comparison, the same general pattern is followed. Emphasis is placed on producing, harvesting, and marketing practices, as well as "the state of the arts" in the Chinese industry. Chapter IV gives an account of current and potential sources of tung oil in other countries. This chapter is included because of its importance in a long-run economic analysis, rather than for its past and present importance. Emphasis is placed upon developmental activities and possibilities of future growth in South America, Africa, and other scattered areas where tung trees may be grown with a fair degree of success. Throughout Part I, reference is made frequently to historical developments not as a primary method of approach, but as a means of establishing a general sequence of chronological events in the entire industry. It is well known that industries tend to take on different characteristics as they progress from infancy to maturity. This fact is of importance in analyzing the competitive aspects of a commodity which must compete with commodities produced by other industries occupying different levels of maturity.

Part II, including Chapters V through VIII, consists of analytical material. The primary purpose is to establish,
by inductive and deductive methods, the underlying economic forces determining the market situations in which the most important commercial drying oils are exchanged and to set forth the most logical effects of the different market situations upon price. The accomplishment of this purpose involves an analysis of both supply of and demand for drying oils and tung oil in particular. A fundamental hypothesis is that differences in the manner in which drying oils originate have a direct bearing upon their relative abilities to compete successfully in the market. Therefore, supply occupies a prominent place in the analysis. Because the demand is of a derived nature and industrial consumers, through chemical research, are able to make substitutions with apparent ease, the burden falls upon the producer to make alterations in quantities offered in order to avoid unfavorable price movements or to obtain the advantage of favorable price changes from other causes. A comparison of the degrees of elasticity of supply of competing drying oils is regarded as a useful method of analysis. No attempt is made to calculate the exact degree of elasticity of supply of any of the oils, but conditions which influence elasticity of supply are presented.

Physical characteristics and commercial uses of tung oil are presented in Chapter V. Since tung oil is used in preparation of various types of coating materials, it is felt that a presentation of the special industrial areas in
which those coating materials are used would be helpful in understanding the extent and nature of tung oil consumption in the United States. Basically, the chapter is a descriptive background for part of the analytical material in Chapter VIII, which is an analysis of the demand for drying oils. For clearness of presentation, the chapter is divided into five sections, (1) availability of drying oils in the United States, (2) comparative prices, (3) tariff status of competing oils, (4) government price support, and (5) consumption of drying oils.

The scope of the study is extended in Chapter VI to include other oils which are used in the United States for drying purposes. Greater emphasis is placed upon economic analysis in this chapter than formerly in as much as some use is made of material contained in previous chapters. The purpose of the chapter is to determine the relative importance of the principal drying oils with which tung oil must compete as an article of commerce. The order of presentation includes a section on each of the following topics: desirable qualities, comparative indices of drying properties, and availability of drying oils. The oils included in the chapter are segregated on the basis of their availability in quantities sufficient to influence the tung oil market. Major consideration is given to domestic production and imports of those oils which currently are produced in quantities of commercial importance, and those which do possess good drying
properties but are not available in commercial quantities are treated in a limited way.

Chapter VII consists of analytical material from the standpoint of producing drying oils, tung oil in particular. It seems that supply should occupy an important position in the entire analysis because of the effect which substitutions have upon market price if rapid and worthwhile modifications can not be made in supply. The rate of industrial expansion and development, the responsiveness of supply to price changes, and the time required for changes to be made in supply as a result of price changes are developed for each of the principal drying oils. A comparison of the oils on the basis of the above factors reveals the resourcefulness of production techniques and methods to cope with dynamic market situations. That industry which can contract production when prices are falling and increase production sufficiently and quickly when prices are rising is in a favorable competitive position, other things being equal. In order to develop these aspects of supply, price and time elasticity of supply must be considered. Therefore, a consideration of cost of production of different oils and production time-periods are underlying factors which influence responsiveness of supply.

Certain inherent differences in plants and trees from which vegetable oils are obtained are brought into the analysis in Chapter VII. Basic differences between annual and perennial crops are included.
Chapter VIII is devoted to a consideration of demand for drying oils with primary consideration given to the demand for tung oil. The primary purpose of the chapter is to establish the character of demand for tung oil, to show in what respect it differs from the demand for other oils, and to set forth relevant economic principles—changes in supply and demand—which are potent price-determining devices.

The basic problem of the chapter is to make an application of price determining doctrines to the reality of the tung oil market. This determination is done, first, by isolating the various phases or component parts of the drying oil market and evaluating them individually as to their effect upon price, and second, by considering the tung market in its entirety and illustrating the effect of changing conditions of both supply and demand upon the price of tung oil.

The concluding chapter is an exercise in synthesis in which all previous chapters are considered collectively and conclusions arrived at deductively and evaluated.
PART I

INDUSTRIAL DEVELOPMENT, PRACTICES, AND TECHNIQUES
CHAPTER II

THE DOMESTIC TUNG OIL INDUSTRY

Tung production in the United States is confined to a relatively small area in certain portions of the states of the Gulf Coast Region. The growing of tung nuts is limited to that region because of the unfavorable climatic and soil conditions which prevail in other parts of the United States. Processing and refining operations are carried on in or near the producing area because a high percentage of the total weight of the basic raw material is eliminated in the processing operation. High costs of handling, storing, and shipping tung nuts out of the producing area are avoided at least in part by processing them near the source of supply and shipping the oil to industrial consumers in tank cars or steel drums.

Origin of Tung Oil Production in the United States

Tung trees were introduced into the United States on an experimental basis for the first time about the beginning of the present century. The first plantings came from China. In 1908, L. S. Wilcox, United States Consul General at Hankow, China, sent some tung seeds to a person in the San Joaquin Valley in California to be planted in that
region. At about the same time, the consul general sent some of the seeds to the United States Department of Agriculture in Washington. Those seeds were sent to experimenters in the warmer regions of the United States. The initial efforts to establish tung groves in this country were unsuccessful. It was, therefore, recognized that further knowledge of the nature of the tung tree was necessary.

A second shipment of tung seeds was sent by Mr. Wilcox in 1905 to the Bureau of Plant Industry. The seeds were planted in Chico, California, where the experiment proved to be more successful than formerly. Many seedlings were produced; and they were sent to State experimental stations, cemeteries, and city parks located in milder regions of the country which were thought to be suitable for growing tung trees. A great many of the seedlings were set out in Alabama at Fairhope, Robertsdale, and Batesville; in Georgia at Cairo, Augusta, and Thomasville; in Florida at Gainesville, Tallahassee, and St. Petersburg; in Mississippi at Biloxi, London, and Lucedale; in Louisiana at Bolivar,

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2 S. E. Green, T. E. Ashley, C. F. Potter, and Ernest Angelo, Tung Culture in Southern Mississippi, Bulletin 409, Agricultural Experimental Station, State College, Mississippi, (Oct., 1944), p. 3.
Fayetteville, and Alexandria; in South Carolina at Bennetsville and in Texas near Houston. From the early experiments, it was found that the *Aleurites fordi* species could be grown successfully only in the Southern States and that the *Aleurites montana* species is more adaptable to the more tropical regions. Subsequently, cultivation experiments became widespread in the Gulf Coastal Region.

Five of the seedlings sent from Chico, California, were given to the superintendent of the cemetery at Tallahassee, Florida, who planted them in the cemetery there. In the autumn of 1906, Mr. William R. Raynes of Tallahassee, transplanted the seedlings to what was regarded as a more favorable location. Only one of the seedlings lived and grew to maturity. Sufficient seedlings were obtained from this tree in 1912 by Mr. Tement Ronalds to plant a 4-acre orchard near Tallahassee. It was the first tung-bearing orchard in this country; and from it, a crop of tung nuts was obtained sufficient to conduct the first trial expression of tung oil in the United States.

**Experimental Developments**

In an effort to obtain the cooperation of the leaders of the Paint Manufacturers of the United States and the National Varnish Manufacturers Association in developing a

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3 Concannon, *op. cit.*, p. 63
4 Ibid., p. 63.
domestic tung oil industry, Dr. Fairchild presented an account of the early experiments and results to those leaders in 1918. They were favorably impressed with the possibilities of developing a domestic supply because of the disadvantages of their dependence upon China for their tung oil requirements. As a result of these pioneering efforts of Dr. Fairchild, a representative of the two national organizations, Henry A. Gardner, visited the Gulf States during the next two years and conducted an investigation. He submitted a formal report on the possibilities of developing the industry in 1921. 5

The American Tung Oil Corporation was formed in 1923 as a non-profit concern and financed by the paint and varnish manufacturers for the purpose of encouraging the growth of tung trees on a commercial scale. Experiments on tung tree culture were conducted on a 200-acre farm near Gainsville, Florida, and the results were distributed to prospective tung growers. 6 This experiment constituted the beginning of real and active progress in developing a domestic industry. Even then it was evident that further development could be accomplished by extensive commercial plantings of tung trees and economical harvesting of the nuts and expression of the oil.

5 Ibid., p. 64.
6 Ibid., p. 64.
During the next few years many failures occurred because of improper location of groves, poor soil selections, and neglect of the trees. Many ill-advised promotional adventures characterized the pioneer days of the industry. Such promotional organizations sold many acres of land which were not suitable for successful cultivation of tung trees. Large financial losses occurred when land of this type was abandoned or applied to other uses.

Initial progress was very slow because of lack of proper technical and scientific information on such things as soil and climatic requirements, planting methods, cultivation practices, fertilization, and expressing processes. In the course of time such information was supplied through research and publications of the United States Department of Agriculture, state experimental stations, and some private organizations interested in developing the industry.

The first commercial crop of tung nuts was obtained from tung orchards in Florida in 1932. 60,000 pounds of oil were produced in that year. Adverse weather conditions affected the crop yields from 1932 to 1943, before research efforts in developing frost-resisting trees began to produce positive results. 7

The Tung Growing Area

The area in which commercial cultivation of the

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Aleurites fordii tung trees are most successfully grown in the United States if restricted to a narrow strip of land including the southern portions of the States of Mississippi, Louisiana, Alabama, and Georgia; the northern half of Florida; and the eastern Gulf counties of Texas.

The best results are obtained in areas where the rainfall averages at least 40 inches each year. The western limit of successful cultivation is considered at about 98° longitude. Early experiments in California and other regions west of that line have indicated that the rainfall is insufficient or too irregular to furnish proper nourishment for tung trees.

The southern and northern limits are fixed by temperature considerations. The tree thrives best where there is sufficient cold weather during the year to allow for a dormant period and where early and late frosts will not injure the fruit buds. Very young trees may be killed by sudden drops in the temperature below 20° F. Only the mature trees can withstand temperatures below about 10° F. The climatic temperature found in the area described above is the most suitable for successful tung tree cultivation, because of the infrequent and mild frosts which occur there.8

8 Ibid., p. 23.
Soil and Drainage Requirements

It was observed from early experience with tung trees in this country that they would grow on practically any type of soil; however, experience through the years had demonstrated that much better results may be obtained through proper selection of the type of soil upon which tung orchards are to be established. Tung trees will live and grow in poor soils and they are hardy enough to withstand a certain degree of drought and frosts, but more favorable soil and climatic conditions will speed up growth, increase production per tree, and lengthen the productive life.

The Aleurites fordii species has very strong and distinct soil preferences which are based upon nutriment requirements of the tree. It is a heavy consumer of nitrogen and water. Abundant rainfall aids the tree in developing good feeding habits which permit it to take full advantage of the required plant foods present in the soil. 9

The basic soil requirements are good texture and liberal quantities of organic matter. The land should be well drained and situated on rolling terrain at elevations higher than surrounding land so that proper drainage and adequate aeration may be provided. 10


An acid soil is considered to be the most desirable. A soil with a pH value of from 5.5 to 6.5 should be selected. A soil reaction of below 5.5 indicates an excess of acid, and a soil with a reaction above 6.5 indicates a lack of acid and an excess of alkali. Lime present in the soil is a source of alkali and results in slow growth of the tree.

The soil should be loose in order to allow rapid passage of rainfall. Air penetration is desirable also.

Scientific and Technological Development of the Tung Oil Industry

Many very useful improvements have been made in the methods of processing tung fruit. This summary is not intended to be a detailed and technical description of the many processes of production found in the tung oil industry; instead, it is presented only as a general description of processing operations.

Experience has shown that excessive moisture in the tung fruit will slow up the processing operations and reduce the amount of oil which may be obtained by proper dehydration. Also experience has shown that artificial drying of the new fruit is very costly. Therefore, the general procedure among producers is to allow the nuts to dry on the

ground until the original moisture content of about 65 per cent is reduced to about 30 per cent, after which the fruit is collected and stored in barns for further drying. When the moisture content has been reduced to about 13 per cent, the nuts are carried to the processing mills. 12

At the mills, the nuts are subjected to further drying before they are crushed. The regular drying bins found at some mills are not very satisfactory because of the lack of uniformity and extended length of the drying process. The fatty acids which form in some of the nuts during the long drying period in the bins will reduce the quality of the entire output of oil from all the nuts.

The vertical driers found at some of the mills have been very satisfactory. In these driers, warm air is drawn through relatively thin layers of nuts. In this way, the drying time required to reduce the moisture content of the nuts from about 13 per cent to 3 per cent is reduced to a few hours. Also the drying process is more uniform than when regular bins are used.

The Hulling Process

Before the oil is expressed from the nuts, the hulls and part of the shell must be removed from the kernels. It

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appears that the most efficient way of doing this is by use of a ball-bearing disk hulling machine properly adjusted to do the work. It has been found that higher oil yields may be obtained if the fruit is hulled when it contains from 15 to 20 per cent moisture. Greater oil loss occurs when the fruit contains less than about 15 per cent moisture, because pieces of the oil-containing kernels tend to remain in the dry hulls.

It appears that the cost of extra handling could be reduced if not avoided entirely, if a process could be developed by which the nuts could be hulled immediately upon arrival from the drying barns of the producers when they contain about the proper amount of moisture for most efficient hulling. The hulled kernels could then be placed in the vertical dryers where moisture content could be reduced to the required minimum without the added cost of drying the hulls and shells which will be abandoned.

Expression of Oil From the Tung Nuts

After the kernels have been ground into a meal, the oil is separated from the meal by means of applied pressure of about 18,000 pounds per square inch. The best results are obtained by what is known as a continuous press, in preference to hydraulic expression or solvent extraction. There

13 Ibid., p. 2.
are several different types of continuous pressure presses, but in each of them the process is similar. The meal is preheated to about 180° F. and placed in a cylinder of steel bars. Pressure is applied by means of a jack-screw device which presses a shaft into the cylinder containing the meal. As pressure is applied, the oil flows out through openings between the bars. The crude oil containing much foreign matter then is forced through a filter press into storage tanks. Best results are obtained with meal containing 3.5 per cent moisture and about 30 per cent shell. The presence of pieces of shell in the meal aids the flow of oil when pressure is applied to the meal.

Through continuous operation of the filter press, the foreign material filtered from the oil accumulates on or near the filter screen. The formation of foreign material is known as filter cake and it contains a high percentage of oil. Extracting the oil from the filter cake constitutes a special problem to mill owners. The best that is done under present conditions is to mix the cake, containing about 50 per cent oil, with a sufficient amount of dry broken shells and send it through the screw press again. It does not appear to be a very satisfactory way of solving the problem.

It has been suggested that a method of extracting the oil from the filter cake by means of petroleum solvents may be the best way of solving the problem. It has been
shown by laboratory experiments that over 98 per cent of the oil may be extracted by the use of solvents.

Expression Efficiency

Commercial mills in the tung oil producing area reported the following yields from the tung fruit:

<table>
<thead>
<tr>
<th>Product</th>
<th>Yield Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hulls and shells</td>
<td>55 to 60 per cent of the fruit</td>
</tr>
<tr>
<td>Meal</td>
<td>40 to 45 per cent of the fruit</td>
</tr>
<tr>
<td>Oil</td>
<td>14.7 to 19.5 per cent of the fruit</td>
</tr>
<tr>
<td>Oil in cake</td>
<td>3.2 to 6.6 per cent of the cake</td>
</tr>
</tbody>
</table>

The efficiency of individual mills varies with the type and condition of the press and the condition of the fruit.

Filtration of Crude Oil

Because the crude oil contains a considerable amount of ground kernel, meal, and broken shells as it comes from the press, it is necessary to filter the oil to remove these impurities. Filtration is done by passing the oil through a steam-heated tank where it is heated to about 1800°F. While the oil is still hot it is forced through a filter press equipped with filter cloths. Sometimes a small amount of water is added to the oil in the steam-heated tank to increase the rate of filtration and to improve the transparent qualities of the oil.

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15 McKinney, op. cit., p. 5.
The filtration operation is continued until it is apparent from a reduced rate of flow of oil or from an increase in the amount of pressure required to maintain a normal rate of flow that the filter press is clogged with impurities. Before removing the cake, air is blown through the press to remove as much of the oil from the filter cake as possible.

**Solvent Extraction**

For a number of years it has been recognized by those in the industry that increased quantities of oil could be obtained if it could be extracted by the use of solvents. Through research, it was found that the oil could be extracted by the use of solvents and that solvent extraction secures a greater quantity of oil than the mechanical process, but the quality is somewhat inferior. It contains a fatty acid and tends to solidify.\(^\text{16}\)

Experimental studies conducted by the United States Tung Oil Laboratories at Gainsville, Florida, and Bogalusa, Louisiana, have demonstrated not only that greater quantities of oil may be obtained by solvent extraction, but that the solidifying tendency of the oil may be prevented by heat treatments. If the oil is heated to about 200\(^\circ\) C for

\(^{16}\) Raiford I. Holmes and Frank O. Pack, *The Applicability of Continuous Solvent Extraction to Tung Oil*, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture, Bogalusa, La., p. 6.
30 minutes, it becomes permanently liquid at normal temperature. Experimental studies have shown also that the efficiency of solvent extraction varies with the condition of ground kernels from which the oil is extracted. Solvent extraction of oil from press cake offers no particular problem. However, the efficiency of solvent extraction of oil from meal depends upon the method of grinding.

When the kernels are ground in attrition-type grinding mills, solvent extraction is not very satisfactory because of the compactness of the meal. After the oil is separated from the meal by the action of the solvent, a compact non-porous cake is formed which prevents the oil from flowing out of the cake freely. A very common way of aiding the flow of oil is to add alternate layers of porous material and ground kernels in the extraction chamber. In this way, about 98 per cent of the oil may be extracted. No such special preparation is necessary when the meal is ground with roller mills or in extracting oil from press cake. In a pilot test, about 99 per cent of the oil was extracted by the solvent method, using normal hexane as a solvent, from tung kernels ground in roller mills. Extraction efficiencies of 99 per cent or better were obtained with

17 McKinney, op. cit., p. 4.
18 Ibid., p. 4.
ground tung kernels, ground tung seeds, commercial press cake, and experimentally prepared tung press cake containing 20 per cent oil." 19 The meal ground in roller mills is porous and permits the oil to flow freely.

The Structure of the Industry 20

There are two groups of people responsible for the production of tung oil in the United States: the producers and the processors. In most instances, there is a clear distinction between the two groups. The producers are the people who own the tung orchards, and their chief function is to grow tung nuts. The processors are the people who own the crushing mills, and their primary function is to process the nuts and to distribute the oil and by-products. In some cases, the distinction between producer and processor is complicated by the ownership of orchards and processing plants by the same persons. Sometimes the functions of producers and processors appear to be over-lapping when the responsibility of distributing the oil is shared by each group.

19 Ibid., p. 4.

20 The information contained in the remainder of this chapter was obtained during an interview, July 8, 1950, with Mr. Tom Crawford, Managing Secretary of the Tung Council of America, 813 Caroline Avenue, Bogalusa, Louisiana,
The Producers

Tung producers may be regarded as those who own the orchards and direct the use of the necessary labor and capital in the production of tung nuts. It is estimated that there are 5,000 producers in the industry who own producing orchards. The majority of them own less than 500 acres. Probably, the most common type of producer is one who owns less than 40 acres which he operates in conjunction with some other employment.

Cultivating the Orchards

The cultivating season is from about April 1 to August 15. Cultivating equipment consists of a tractor, an off-set multiple disk, and a spring-tooth harrow. It is not necessary for producers to own the equipment, because cultivating service establishments are located in the producing areas. These establishments which own the necessary equipment, cultivate the orchards on a contract basis. A common practice is for cultivating pools to be formed prior to the growing season. Some producer, or other person, acts as manager of the pool. Those who desire employment during the season register with the manager and indicate the type and amount of equipment which they have. Likewise, the producers who desire to have their orchards cultivated on a contract basis register with the manager and indicate the type of work desired, amount of work, and the date. The manager of the pool arranges a
work-schedule for each worker registered with him. The workers usually work in groups of two or three.

Harvesting the Nuts

The harvest season is from about November 1 to January 1, during which time labor is employed to pick the nuts from the ground, place them in bags, and stack them along the edge of the orchards where they may be transported to the mills. Unskilled labor is employed for this purpose. The labor supply consists of local labor plus some workers who migrate from the cotton belt after the cotton-picking season is over. The tung producer obtains the workers through labor managers who form labor pools for that purpose. The producer requests the labor manager to bring the desired number of workers to his orchard on a certain date. The labor manager is paid on the basis of the number of workers per day, and the workers are paid on the basis of the number of pounds of nuts picked up and bagged.

Financing the Tung Crop

The procedure by which the growing of tung crops is financed varies with individual cases. Some of the producers rely upon their own resources, while others borrow funds. During the growing season, the producer may borrow funds from two sources, namely, the Production and Marketing Administration and the local banks. After about March 15, when there is not much danger of damage to the crop
from late frosts, a loan may be obtained by the producer from the Production and Marketing Administration on a pledge of the crop as security only after an investigation of the producer's orchard has been conducted. The maximum amount of a loan depends upon the size and estimated productivity of the orchards owned by the producer. The second source of funds available to the producer is to borrow from the Production and Marketing Administration or from a local bank on the security of oil produced during a previous year and placed in a bonded storage tank. The Production and Marketing Administration will make a loan of this type up to 90 per cent of the market price of the oil. The estimated cost of keeping oil in a bonded storage tank and obtaining a loan on the basis thereof from March through November is equal to about 1/2 cent per pound of tung oil.

Marketing the Tung Nuts, Oil, and By-products

The channels through which the products of the tung industry flow to the market include (1) the producer, (2) the processor, (3) the marketing-pool manager, (4) the broker, and (5) the consumer. The producer carries the nuts to the processing mill where they are processed on a fee or toll basis. The customary fee for the 1949 crop was about $12.50 per ton. If processing is done on a toll basis, the toll amounts to about 1/5 of the nuts. In either case, the hulls and press cake become the
property of the mill owner. The oil obtained from the nuts of of the producer remains the property of the producer and is placed in a bonded storage tank located at the mill and in trust of a marketing manager who has the authority to sell it at the best price he can obtain. The oil of producers and processors alike is placed in a common pool under the care of the marketing-pool manager. The amount of oil in each quantity of nuts brought to the mill is calculated on the basis of the oil content. A sample is taken of each truck load and sent to a chemical laboratory for analysis to determine the percentage of oil in the nuts. Each member of the marketing pool is issued a certificate indicating the quantity of oil in his account and assigned a serial number according to the time the oil is placed in the pool. Partial payment is made to the producers by serial numbers. Those who have the first numbers issued receive payment out of the first funds available from the sale of oil, and those who have higher serial numbers receive payment at a later time. Original payments are made on the basis of an estimated average price which is expected to be obtained from the sale of the entire pool. Adjustment payments are made after all the oil placed in the pool has been sold and the actual average price is calculated. Several marketing pools may be formed in each locality and use the same storage facilities. It is a common practice for some of the producers to act as marketing-pool managers.
The oil is distributed from the marketing pools to
the consumers through brokers who also handle other oils and
raw materials for manufacturers. Only small quantities of
tung oil are sold directly to manufacturers. It appears
that brokerage facilities have not been developed suffi-
ciently to provide the desired diversity of tung oil pur-
chasers to facilitate the most profitable flow of the pro-
duct to the market. A limited number of brokers handling
tung oil may be in a position to discourage manufacturers
from purchasing the oil directly from the marketing-pool
managers and thereby restrict the marketing channels. The
number of brokers buying tung oil may be too small to pro-
vide competition among them. The brokers may discourage
the placing of orders for tung oil produced in the United
States at a time when oil is not available from China and
other countries and encourage purchasing the oil only when
the price is depressed from imports. Adequate storage
facilities available to the marketing-pool managers, to-
gether with government support price for tung oil, should
enable the managers to correct whatever depressing effect
a limited number of marketing channels may have upon the
price. Storage facilities would permit the managers to
withhold oil from the market when imports are high and to
sell when quantities being imported are low. The govern-
ment support price (24.1 cents per pound for the 1949 crop)
gives protection to those producers who are forced to sell
when the market price is below the support price.

There are two by-products of the industry which have some economic value, namely, the hulls and meal. The hulls are sold to fertilizer-mixing establishments as an aid in mixing fertilizer. The meal is sold as a fertilizer for the citrus fruit groves in Florida. The average price obtained for the meal from the 1949 crop was about $12 per ton, f.o.b., Bogalusa area. Both of the by-products become the property of the processing-mill owners at the time the nuts are processed.

The Processors

There are thirteen processing mills in the tung producing area. Four of the mills are located in Louisiana: two in Bogalusa, one in Franklinton, and one in Covington. Two are located in Mississippi and the others in Alabama, Georgia, and Florida. One of the mills in Bogalusa is a proprietorship and the other is a corporation. The mill located in Franklinton, Louisiana, is a partnership, and the one in Covington is a cooperative.

The Ozone Tung Cooperative

The Ozone Tung Cooperative, Covington, Louisiana, was chartered in August, 1939. It started with only

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20 members who contributed about $5,000 to the original fund. A loan of $3,200 was obtained from the New Orleans Bank for Cooperatives. The loan plus the original contribution of members was used to purchase land, erect buildings, and purchase and install an expeller at a total cost of approximately $8,000. New and additional equipment has been purchased since 1938. The plant now has storage for 800 tons of nuts, 8 cars of oil, 8 cars of hulls, and six cars of meal. The total cost of the plant has been about $80,000, which is carried on the books at a depreciated value of $52,000. 22

In order to become a member of the cooperative, a tung grower must make a written application to the board of directors. Two members of the board are appointed to inspect the orchard of the prospective member and make a report. If the application is approved, the grower is required to sign a marketing agreement and buy preferred stock equal to $3 per acre of orchard up to $100. In the case of a large grower whose contribution exceeds $100, the amount is determined by the board of directors. Eighty-four producers were members of the organization in 1948. 23

The cooperative does not own any tung orchards. The nuts belong to the individual members "until they are

22 Ibid., p. 1.

23 Ibid., p. 1.
delivered to the mill and all costs of delivering nuts are paid by him." 24 Only a small payment is made at the time the nuts are delivered to the mill. Supplemental payments are made as the oil and by-products are sold. Final payment is made when all the products are sold and the pool is closed. Payment is made to members on the basis of oil content of nuts delivered. A 5 per cent dividend is paid on preferred stock and membership equity credits, after all operating expenses are paid. There is no common stock. Any balance of net proceeds is distributed on the following basis: (1) the board of directors determines the amount necessary to be retained for capital purposes, and (2) the balance is paid in cash on a patronage basis to the members. 25

The seasonal character of the tung producing business and lack of alternative uses of the mills when they are not being used to crush tung nuts appears to hinder the establishment of additional processing mills. The processing season is from about November 15 to May 31. The plants begin operation when sufficient quantities of nuts have accumulated in the storage bins and operate continuously to the end of the season, or as long as a supply of nuts is available. For the rest of the time, the plant is idle. During the

24 Ibid., p. 2.
25 Ibid., p. 2.
non-productive period, fixed costs continue. The cost of capital investment, insurance, and property taxes must be paid for the entire year. It is necessary for the plant to earn a rate of return during the period of operation equal to about twice as much as would be necessary on an annual basis. Milling fees are higher than would be necessary to earn a normal rate of return if the plant could be operated the entire year.
Tung oil was of considerable importance in the domestic commerce and industry of China even before the time of Marco Polo. It was used as a waterproofing material for hand-made articles, for caulking Chinese ships, and for illumination before it became an important article of international trade.

The oil first entered foreign commerce through the efforts of Portuguese traders who visited Canton in 1516 and received tung oil in exchange for European articles of commerce. In subsequent years, a very good foreign trade developed; and by the 20th century, China had come to depend upon tung oil as its most important item of export trade.

It was a natural thing for production of tung oil to decline during the Sino-Japanese War. Those trees which were growing in orchards were neglected badly. Many of them were cut down and used for fire wood. Still others were cut down and removed to make way for food crops to feed the dense population of China. Other factors which contributed to the neglect of the trees were low prices paid to the farmers or tung nut collectors and regulation of the industry by the
Chinese Government.  

The Producing Area

In many of the tung producing areas in China, especially in the interior, tung trees are grown in an unorganized fashion. On account of the high demand for the best grade of land for food production purposes, the growing of tung trees in many localities is confined to the fence rows, hillsides, and other areas which are considered to be unfit for general agricultural purposes.

Some systematic plantings have been made from time to time in the southern coast provinces of Kwangtung and Kwangsi and in the interior province of Szechwan. Even in these provinces, production of nuts has not been very high because of neglect and lack of proper methods of culture.

Roughly, the tung nut belt in China lies between 100° and 122° east longitude and between 22° and 24° north latitude, including a total area of about 900,000 square miles. 2 The Aleurites fordii species grows in the Yangtze Valley of the northeast; while the Aleurites montana grows in the southern part of China. 3

Harvesting Methods

Not all of the tung nuts which are produced in China

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2 Wood, op. cit., p. 46.
3 Ibid., p. 47.
are allowed to ripen and fall to the ground in an orderly way. Frequently, those which are found on trees growing wild outside the cultivated plantations are knocked from the trees with poles before they are fully ripe. It has been reported that this practice may be accounted for by the prevalence of the custom among the local tung-nut collectors of stealing the nuts before they have had sufficient time to ripen. The nuts which are harvested in a mere orderly fashion are allowed to ripen and fall to the ground and remain there exposed to the weather long enough for the hulls to crack open so that the seeds may be removed by hand. Sometimes the period required for the nuts to dry and pop open is reduced by one of three common methods. First, the nuts are collected into large piles and covered with a thick layer of straw. Water is poured on the bank of straw and tung nuts at frequent intervals. In this way, fermentation causes more rapid decay of the hulls. Second, the nuts are placed in large vats and covered with hot water. The hulls, softened by the hot water, burst open and permit the seeds to be removed easily by hand. Third, the nuts are placed in a large roasting pan to which heat is applied. The dry hulls crack open and the seeds are removed by constant stirring with a wooden stick. 

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4 Ibid., p. 47.
After the seeds are removed from the hulls, they are placed in baskets by the producer and transported to the local mill and sold to native mill owners.

**Drying and Pulverizing Methods**

When the seeds arrive at the mills, they contain a considerable quantity of broken hulls and other foreign matter which must be removed before they are pulverized. One method commonly employed is to pick the undesirable pieces of hulls and other material out by hand. Another method, known as "winding," is to pour the seeds from one container to another while the wind is blowing, permitting the lighter particles to be blown away while the heavier seeds and kernels fall into a basket.  

After the seeds have been cleaned, the moisture content is removed or reduced by roasting them in large iron-bottom pans. The roasting process not only removes the moisture, but it makes the seeds more brittle and suitable for pulverizing. The roasting method is known as the "hot-pressed process" and it produces a very dark grade of oil. The exposure to excessive heat causes an undesirable chemical reaction in some of the seeds. To avoid the dark color effect, some processors make use of a crude type of drying kiln. Others spread the seeds in the sunshine during the

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summer months in single layers where they are dried by the sun. The latter method produces the lightest colored oil, though the process is very slow. 6

After the seeds have been cleaned and dried sufficiently, the next step in the processing procedure is to pulverize or crush them into a meal-like substance. This crushing is done by placing the seeds in a large mortar and pounding them to pieces with an unusually large wooden hammer which fits into the opening in the mortar. The device is very primitive and is operated by manual labor.

Expressing Methods

After the kernels have been pulverized, the next step is to prepare the meal for expressing the oil by forming it into a cake of sufficient size to fit into the expressing device. The method most commonly used is to place the meal in the large vats which are used also for drying the nuts and mix enough water with it to form a mush-like substance. The substance then is heated until it is very soft and mushy. While the mush-like material is hot, enough straw is mixed with it to hold it together. Then the mixture is moulded into round cakes about four inches thick and fifteen inches in diameter.

6 Wood, op. cit., p. 48.
The cakes are placed in an expressing device consisting of a partly hollowed out log with a slit down the side, a wooden ram-rod which fits into the hollowed out opening in the log, and a set of wooden wedges. The cakes are stacked in the opening in the log while it is in a vertical position, and the wooden rod is pushed down on top of the stack of cakes. Constant pressure is applied by driving wooden wedges between the top of the wooden ram-rod and a stationary horizontal beam. The expressing process is slow and inefficient, yielding from 30 to 35 per cent of the weight of the kernels in oil.

The expressed oil is strained through coarse cloth a number of times to remove the impurities. The strained oil is placed in baskets carefully lined with varnish paper to be transported to the market.

**Chinese Transporting and Marketing Practices**

Transporting the processed oil from the interior regions of the Upper Yangtze and Han Rivers to the collecting centers is very difficult, slow, and expensive. The terrain is rough, the distance is great, and the methods employed are crude. The oil is transported overland by coolies and pack animals. Where waterways are accessible small junks are used.

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The principal collecting centers are Lanchow, Ichang, Shasi, Changteh, Yochow, and Changsha in central China; Luchow, in western China; Nanning and Liuchow in southern China; and Hangchow and Wenchoow in eastern China. At each of these collecting centers the oil is transferred into larger and more durable containers for shipment to marketing centers.

The principal marketing centers are Wuchow, located on the Si River in southern China; Chungking and Mansien, located on the Upper Yangtze River in western and central China; and Shanghai, located on the coast at the mouth of the Yangtze in Eastern China. At each of these trading centers the oil is refined in order to remove as much of the impurities and moisture as possible. The refining process consists of placing oil in large tanks and heating it to about 80° C for about 10 hours and filtering it through a filter press. Sometimes the oil is not filtered through a press but is allowed to stand for several days in a storage tank. The impurities settle to the bottom and the better grade of oil at the top is drained off. The process may be repeated until a very clear oil is obtained.

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8 Ibid., p. 50.
9 Ibid., p. 50.
After the oil has been refined, it is shipped to the exporting centers where it is stored in tanks or pumped into tank ships engaged in export trade. The chief export centers today are Shanghai and Canton. Hankow is the principal interior market center for tung oil in China, and Shanghai is the central export city.

The Chinese tung growers or collectors sell the nuts to local expressing mill owners or, in cases where no mill is located, to tung nut peddlers who travel from one village to another during harvest season buying at a price below that paid by the mill owners. The peddlers, in turn, sell to the mill owners in the small towns. In some cases, the peddlers sell the nuts to oil dealers located in the collecting centers. Such cases, however, are rare on account of the difficulty and cost of transporting heavier nuts overland. If the oil is expressed locally, from 80 to 85 per cent of the weight is avoided.

The oil is shipped by the local mill owners and peddlers to dealers located in the collecting and marketing centers. The dealers have large storage facilities and credit resources for buying and holding considerable quantities of oil. Local banks extend short-term credit on the security of tung oil warehouse receipts. In addition, credit is extended to dealers by money shops on the basis of rather informal contracts and at an interest rate higher than that charged by the banks.
The dealers ship the oil to the marketing centers most accessible to them and sell to brokers representing Chinese exporting houses or directly to brokers representing foreign importers.

In normal times, the price which the exporters and foreign importers will pay for the oil depends upon the demand for tung oil abroad, principally in the United States and England.

**Production of Tung Oil**

It appears that no reliable figures on the production of tung oil in China have ever been available. However, one estimate places the average for 1935-37 at 100,000 tons annually; 1945, at 51,000 tons; and 1946, at 90,000 tons. Estimates for 1947 were stated at 105,000 tons and for 1948 at 115,000 tons. Neglect of the orchards during the war caused production to decrease. Some of the trees were removed from the land to make way for the production of food crops. Better care of the orchards after the war resulted in an increase in production.

**Quality of Chinese Tung Oil**

Generally, the Chinese tung oil is inferior to that produced in the United States because of the crude methods

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of handling the nuts and expressing the oil and because of
the practice of mixing the oil with other similar types of
vegetable oils to increase the quantity. When tung oil
prices are higher than the prices of other oils, the incenti-
tive is great for those who handle tung oil to adulterate
it by adding cheaper oils.

Considerable efforts were made by the Nationalist
Government to improve the quality of tung oil destined for
export. Testing stations were set up at the principal
market centers. A fair degree of standardization has been
accomplished. However, the oil which is cleared for ex-
port still is reported to be inferior to that produced in
the United States. "It is quite clear from the reports of
the results obtained that American oil is entirely satis-
factory and generally superior to imported oil." Domestic
oil sells on the American market at a premium of two
or three cents per pound.

Chinese Consumption

The amount of tung oil consumed domestically in
China seems to depend upon the relationship between the in-
ternal political and economic conditions and the export
market. During the period of the recent war and at the

11 Wood, op. cit., p. 53.

12 Gardner and Butler, op. cit., p. 91.
present time with civil war going on in China, tung oil is used as a substitute for fuel for heating, power, and lighting. Very little is consumed in manufacturing as a raw material.

When the foreign markets are good and prices are high, greater quantities of tung oil are channeled into the export trade. This situation accounts, in part at least, for the rapid recovery of the Chinese tung oil industry following World War II. During the war, with the Japanese blockade of the southern and eastern coast lines, exports dropped to a very low level. In fact, the oil which was exported had to be transported westward over the Burma Road to Rangoon. Domestic consumption increased during this period to a peak of about 60,000 tons annually.\(^\text{13}\)

With the removal of the blockade at the end of the war and the removal of all export duties on tung oil by the Nationalist Government, greater quantities of the Chinese output went into the export market. The export market also benefited from a reduction in the number of military craft on the navigable streams in China at the end of the war.

During the post-war period, special emphasis was placed on the export market by the Nationalist Government, because the receipts from tung oil exports constituted the

\(^{13}\text{Wood, op. cit., p. 52.}\)
primary source of foreign exchange so essential for financing vital imports.

Export Trade

After many years of experience with extraordinary burdens, such as internal taxation and export duties, the position of Chinese export trade in tung oil was improved to some extent with the removal of all export duties in September, 1946. During the war years, the export duty was 5 percent ad valorem. Prior to that time, various local and export taxes were levied on tung oil.

China has carried on a limited export trade in tung oil with some of the European countries for many centuries. About the middle of the 19th century, when industrial expansion was making considerable progress in Germany and England, the quantities exported to those countries began to increase. After World War I, an extensive tung oil trade developed between China and the United States.

Total exports of tung oil from China reached a peak of 226,553,580 pounds at the outbreak of the Sino-Japanese War in 1937, and declined to 2,271,500 pounds in 1942 and to even a lower figure during the next few years.14

Important quantity trends of tung oil exports from China since 1936 are indicated in the following table,

14 Wood, op. cit., p. 54.
which gives the total exports for the years indicated.

Table I. Chinese Tung Oil Exports, 1936-48

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity Exported (Pounds)</th>
<th>Value in U. S. Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1936</td>
<td>190,824,260</td>
<td>$21,802,266</td>
</tr>
<tr>
<td>1937</td>
<td>226,553,880</td>
<td>$26,329,342</td>
</tr>
<tr>
<td>1938</td>
<td>153,070,940</td>
<td>$11,771,111</td>
</tr>
<tr>
<td>1939</td>
<td>73,703,580</td>
<td>$10,084,438</td>
</tr>
<tr>
<td>1940</td>
<td>51,144,940</td>
<td>$15,907,353</td>
</tr>
<tr>
<td>1941</td>
<td>46,176,900</td>
<td>$29,803,123</td>
</tr>
<tr>
<td>1942</td>
<td>2,271,500</td>
<td>7,516,659</td>
</tr>
<tr>
<td>1946</td>
<td>77,470,360</td>
<td>$22,497,202</td>
</tr>
<tr>
<td>1947</td>
<td>177,182,080</td>
<td>$40,739,774</td>
</tr>
<tr>
<td>1948</td>
<td>167,293,720</td>
<td>$16,551,645</td>
</tr>
</tbody>
</table>


Export Distribution

Not only the importance of each country as a consumer of Chinese tung oil may be observed from a breakdown of export figures, but the changes in relative importance may be observed as well. A distribution of exports by countries is shown in Table II.
### Table II. Chinese Tung Oil Exports by Countries, Selected Years (1937-48)

<table>
<thead>
<tr>
<th>Country</th>
<th>1937</th>
<th>1938</th>
<th>1946</th>
<th>1947</th>
<th>1948</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>141,047,940</td>
<td>12,511,840</td>
<td>35,816,660</td>
<td>54,640,520</td>
<td>76,511,920</td>
</tr>
<tr>
<td>Germany</td>
<td>9,418,420</td>
<td>3,256,880</td>
<td></td>
<td>447,040</td>
<td>2,200</td>
</tr>
<tr>
<td>France</td>
<td>8,173,220</td>
<td>2,374,900</td>
<td>1,112,320</td>
<td>1,025,200</td>
<td>44,220</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>8,102,160</td>
<td>4,457,640</td>
<td>3,855,500</td>
<td>14,232,680</td>
<td>7,732,560</td>
</tr>
<tr>
<td>Macaco</td>
<td>2,377,540</td>
<td>4,393,620</td>
<td>447,920</td>
<td>53,900</td>
<td>3,244,120</td>
</tr>
<tr>
<td>Japan</td>
<td>1,642,740</td>
<td>122,760</td>
<td></td>
<td>1,776,720</td>
<td>1,937,000</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,320,000</td>
<td>771,980</td>
<td>490,600</td>
<td>1,943,040</td>
<td>1,985,940</td>
</tr>
<tr>
<td>Australia</td>
<td>1,202,520</td>
<td>127,600</td>
<td>4,400</td>
<td>390,940</td>
<td>11,000</td>
</tr>
<tr>
<td>Italy</td>
<td>1,145,760</td>
<td>249,260</td>
<td>670,340</td>
<td>1,203,840</td>
<td>335,280</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,095,600</td>
<td>376,420</td>
<td>561,880</td>
<td>105,160</td>
<td>335,280</td>
</tr>
<tr>
<td>Norway</td>
<td>1,069,640</td>
<td>65,780</td>
<td>542,960</td>
<td>1,133,000</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>1,041,260</td>
<td>319,220</td>
<td>1,519,100</td>
<td>2,038,080</td>
<td>111,320</td>
</tr>
<tr>
<td>Belgium</td>
<td>735,100</td>
<td>339,020</td>
<td>1,060,180</td>
<td>707,300</td>
<td>601,040</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>46,720,080</td>
<td>122,782,000</td>
<td>22,475,640</td>
<td>89,779,140</td>
<td>58,739,560</td>
</tr>
<tr>
<td>Others</td>
<td>1,458,600</td>
<td>922,020</td>
<td>9,022,860</td>
<td>7,705,500</td>
<td>5,912,280</td>
</tr>
</tbody>
</table>

**Total** 266,553,580 153,070,940 77,560,360 177,182,060 167,403,720

Today, tung oil is exported from China to many countries. Those countries in which the greatest amount of industrial activity is found require the greatest amount of tung oil. The chief consuming countries are the United States, United Kingdom, Netherlands, and Japan. In normal times, the United States consumes well over half the total output.

Export Duties on Tung Oil

The first export duty on tung oil from China became effective in 1858. At that time, the duty was established at .30 haikwan taels per picul of tung oil. The haikwan tael was the monetary customs unit used in China during this period. The picul was a unit of measurement equal to 133-1/3 pounds. No further change was made in the duty from 1858 to 1929, when the duty was increased by 50 per cent through the levying of a surtax of one-half of the export duty. At that time, the official exchange rate between the currency of China and the United States dollar was .64 to 1. By rough calculation, the export duty in terms of United States currency in 1929 was about $3.88 per ton of 2,000 pounds, plus a surtax of $1.44 per ton.15

The duty was increased June 1, 1931, when a new duty of 1.60 haikwan taels per picul was added. In terms of

15 Concannon, op. cit., p. 29.
United States currency, the total export duty was about $19.68 per ton after the new duty went into effect. 16

All export duties on tung oil were removed in September, 1946.

Prices of Chinese Tung Oil

The price of Chinese tung oil has fluctuated considerably in recent years. In terms of United States currency, the price was about 17 cents per pound at Hankow in 1927, 6 cents in 1931, and 12 cents in 1936.

The price showed a marked increase at the beginning of both the Sino-Japanese War in 1937 and World War II. It was 21 cents a pound in October, 1939, and 24 cents in July, 1940. The average price was 39 cents throughout 1946, 30.5 cents in 1947, and 24.5 cents in 1948. 17

There have been times during the postwar period when Chinese quotations of tung oil prices were higher than those in the United States, caused by changes in the exchange rate. As a result, foreign exporters were at a disadvantage and attempts were made to evade exchange controls. Exporters who were able to export from the British Colony of Hong Kong could avoid losses through exchange rate changes by keeping their receipts in foreign currency, rather than converting them into Chinese currency at an unfavorable rate. During

16 Ibid., p. 29.

17 Wood, op. cit., p. 52.
1946 and 1947, many exporters used this export channel to avoid some of the hardships caused by fluctuations in exchange rates between Chinese and United States currencies. However, in 1948 this situation was corrected by means of an agreement between China and Hong Kong providing that no tung oil could be exported from China through Hong Kong without a certificate indicating that the foreign exchange received for the shipment had been converted into Chinese currency.

In 1948, the Export-Import Bank established an export price of 19 cents per pound for tung oil f. o. b. Shanghai, in an effort to stabilize the price.18

18 Ibid., p. 53.
Efforts have been made at various times to introduce tung tree culture into countries other than the United States and China. The British probably were the first to undertake to develop tung trees in other countries. In the latter part of the 19th century, seeds of the *Aleurites fordii* species were planted in British Guiana, Jamaica, Ceylon, and Dominica in experimental gardens. About the same time, the French experimented with plantings in French Indo-China and other colonies. Several years thereafter, the Germans made some plantings in the German colonies in Africa.

From this beginning, other producing areas have developed to some extent in Latin America, Africa, and Asia.

Production in Latin America

Drawing from the experiences with tung tree culture in other countries, principally the United States and China, several of the Latin American countries have begun to experiment with the possibilities of growing tung trees in that region and to produce a sufficient amount of tung oil for commercial purposes in some areas. Experience has shown that the
trees may be grown very successfully in Argentina, Brazil, and Paraguay. These countries have been so successful with tung trees in recent years that cultivated orchards are well established in those countries and tung oil is being produced in quantities sufficient to supply the requirements within those countries.

**Argentina**

About the time tung oil was being produced commercially for the first time in the United States, experimental farms were being developed in the Territory of the Missions in Argentina from seeds obtained from the United States.¹

The first commercial planting in Argentina was made about 1939, when the Argentine Government placed restrictions on further development of yerba mate orchards. In that year, the first commercial grove was set out in the Province of Corrientes. Since that time, other producing areas have been developed in the Territory of the Missions and in other places in the Province of Corrientes, both situated in northeastern Argentina. The *Aleurites fordii* species grows best in that area.²

In 1947, there were 10,500,000 tung trees under cultivation in Argentina on an area of about 170,000 acres. In

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the following year, about 42,000 metric tons of nuts were harvested, from which approximately 6,000 metric tons of oil were produced. 3

At the present time, Argentina is able to produce annually more tung oil than is needed for domestic purposes. Its annual consumption is about 500 metric tons. Estimates place tung-oil exports for 1945 at 539 metric tons and 1,469 tons in 1946. It is believed that most of the exports go to Great Britain. 4

Brazil

The development of a tung oil industry in Brazil has been the result of a general process. The first experimental planting was made there during the 1920's. By 1930, there were about 100,000 tung trees of the Aleurites fordii species in the State of Sao Paulo. By 1935, commercial plantings had extended into the State of Parana. By 1945, the estimated number of trees in the entire country had reached an estimated 3,840,000. 5

The State of Parana, in which well over half the trees are located, is the chief producing center. Its soil and climate appear to be more suitable for growing tung

3 Wood, op. cit., p. 57.
4 Ibid., p. 58.
5 Ibid., p. 59.
trees than any other area in Brazil. The chief obstacle to further extension of the tung producing area is the lack of a dormant period during the year which is essential for healthy growth of tung trees and production of nuts. However, greater output can be expected as the groves develop into maturity. The majority of the trees still are too young for full production.

Total production of tung nuts amounted to 250 metric tons in 1942; 4,539 in 1946; 6,090 in 1947; and 7,000 in 1948. Oil production amounted to 19 metric tons in 1942; 291 in 1946; and 300 tons in 1948.7

Domestic consumption of tung oil amounts to approximately 100 metric tons annually, and the remainder of the output is either exported or stored.

Most of the oil produced in Brazil is extracted by mechanical expeller presses similar to those in the United States.

Paraguay

Experimental plantings of tung trees were made for the first time in Paraguay in 1929 from seeds imported from the United States and China. Throughout the 1930's, the producing area was extended into central and southeastern Paraguay. Most of the producing area is confined to the

6 Gardner and Butler, op. cit., p. 43.
7 Wood, op. cit., p. 52.
Parana River region of the southeast. The situation in Paraguay is similar to that in Brazil: the orchards are relatively young and oil output can be expected to increase very rapidly within the near future. This factor plus the fact that Paraguay exports its entire output indicates that oil from that country will be a reliable contender for a small portion of international trade in tung oil. Most of its oil currently is being sold in Europe. By 1947, there were about 2,000,000 tung trees of the *Aleurites fordii* species in Paraguay.\(^8\)

In 1946, Paraguay production of tung oil amounted to 208 metric tons, and 600 tons were produced in 1947. Annual production since 1940 is shown in the following table.\(^9\)

Table III. Paraguay Tung Oil Production and Exports, 1940-46 (Kilograms)

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>1,837</td>
</tr>
<tr>
<td>1941</td>
<td>2,912</td>
</tr>
<tr>
<td>1942</td>
<td>6,870</td>
</tr>
<tr>
<td>1943</td>
<td>14,571</td>
</tr>
<tr>
<td>1944</td>
<td>22,317</td>
</tr>
<tr>
<td>1945</td>
<td>62,292</td>
</tr>
<tr>
<td>1946</td>
<td>208,086</td>
</tr>
</tbody>
</table>


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\(^8\) Ibid., p. 59.

\(^9\) Ibid., p. 59.
It is expected that production will increase by about 30 per cent each year for the next few years as a result of the growth and development of the young orchards in Paraguay. The lack of a good road system in that country hinders the development of the industry. The cost of transporting nuts to the expressing mills is so high that the buyers are unable to pay the farmers a price sufficient to induce them to bring the entire crop to the mills and at the same time dispose of the oil in the world market in competition with other countries which can produce it at less cost.

PRODUCTION IN AFRICA

Moderate development of tung oil industries have been observed in recent years in certain regions in Africa. The principal producing areas are located in Madagascar, Belgian Congo, and the Union of South Africa. From the data available, it seems that tung nut production in Africa is of little importance.

Madagascar

Tung trees have been growing in Madagascar for a number of years, but widespread interest in developing the orchards into a profitable industry is of very recent origin. By 1947, there were 1,000,000 trees of the Aleurites
Montana species growing in orchards of various ages.\textsuperscript{10} About one-half of the trees were of producing age. The \textit{Aleurites fordii} type may be grown successfully in the high altitude regions.

Oil production was only 29 tons in 1945 and 60 tons in 1946. It is estimated that annual production will reach 300 tons by 1950.\textsuperscript{11} Total production is exported to France and the United States.

\textbf{Belgian Congo}

Experimental plantings of tung trees were made during the early 1930's. Some commercial plantations were established in the Belgian Congo in 1938.

During the short period of two years, in 1945 and 1946, the number of acres of orchards in the Belgian Congo increased from 1,500 to 3,000. Only 20 tons of nuts were produced in 1946, which indicates that the orchards are very young. It is estimated that annual production of nuts will reach 1,000 tons by 1950.\textsuperscript{12} Because of climatic and soil conditions, the producing area seems to be confined to low altitude regions away from the central equatorial belts. Even though only 6,700 pounds of tung oil were exported in 1947, it is estimated that exports will reach from 80 to 100

\begin{footnotesize}
\begin{enumerate}
\item \textsuperscript{10} Ibid., p. 61.
\item \textsuperscript{11} Ibid., p. 82.
\item \textsuperscript{12} Ibid., p. 62.
\end{enumerate}
\end{footnotesize}
tons by 1950. Lack of adequate mill facilities and high transportation costs constitute outstanding obstacles to further development at the present time.13

**Union of South Africa**

Initial plantings of tung trees were made in the Union of South Africa as early as 1923, when seeds were imported for experimentation. By 1941, there were approximately 60,000 trees planted in groves of about 2,000 trees each. It is estimated that there were about 500,000 trees in the Union of South Africa in 1947, most of which were of the *Aleurites montana* species.14 The total production, however, is not sufficient for domestic purposes. Instead, the Union imports around 50 tons annually.

**India**

Experimental plantings of tung trees were made in India in 1928 for the first time.15 Additional plantings of the *Aleurites montana* species were made in 1934 and 1940.

By 1945, the orchards had begun to produce nuts for commercial purposes. The oil output for that year was 76 long tons. Annual domestic consumption is estimated at approximately 250 tons. India imported about 220 long tons annually.

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13 Ibid., p. 62.
14 Ibid., p. 62.
15 Gardner and Butler, *op. cit.*, p. 34.
in 1947.

Japan

Japan is a consumer of tung oil as well as a producer. Even before World War II, tung oil was imported annually from China to meet domestic requirements. Imports from China dropped from 462 metric tons in 1940 to 60 tons in 1945. Domestic consumption was 260 metric tons in 1945. Production also declined during the war. Production was 259 metric tons in 1940; 294, in 1944; 200, in 1945; and 270, in 1946.

Two different species of tung trees are found in Japan. The *Aleurites cordata* is native to Japan and it has been growing there for a long time. The *Aleurites fordii* was imported from China about 1900. By 1945, there were 9,750 acres of the *cordata* species under cultivation; while 2,250 acres were planted in the *fordii* species.

Australia

Considerable quantities of tung oil are produced annually in Australia, but the domestic demand for the oil is greater than the quantities produced. 66,689 pounds of oil were produced in 1945; while the output dropped to 17,448 pounds in 1946, on account of war conditions. For 1947,

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16 Wood, op. cit., p. 64.
17 Ibid., p. 65.
18 Ibid., p. 65.
domestic consumption was approximately 1,300,000 pounds. 19
The domestic markets are able to consume considerably more than the local industry can produce. Imports come in annually from China.

Experimental plantings of the *fordii* species were made as early as 1910. From this beginning, commercial orchards have been developed in the coastal region from Sidney northward to Rockhampton. In a publication of the Technological Museum of Sidney, Australia, it was stated that "prior to 1926 experimental cultivation of tung oil trees in Australia had produced oil of at least equivalent quality to that imported from China, ... and that establishment of the industry in that country is thoroughly warranted." 20

By 1946, there were about 1,000 acres planted in Australia. 21 It is believed that the industry will continue to expand because of the favorable domestic demand.

**Russia**

Since 1922, when serious attention first was given to the development of a domestic tung oil industry under the first Five Year Plan in Russia, extensive plantings have been

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19 Ibid., p. 66.


made in the Black Sea Coastal area. By 1946, it is estimated that approximately 41,000 acres were planted in both the *fordii* and *cordata* species.

Production figures are unavailable, but it is believed that the total amount produced plus imports from China are consumed domestically.

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22 Ibid., p. 44.

CHAPTER V

CHARACTERISTICS AND USES OF TUNG OIL

Tung oil is only one of the many oils used by manufacturers in the preparation of compounds which require good drying qualities. The extent to which manufacturers demand tung oil as a raw material depends, to a great extent, upon the quality of its physical and chemical properties. The primary characteristics and principal uses of the oil are bound inseparably together, as one can hardly be considered without the other.

Physical Characteristics

In its natural state, tung oil is a colorless material neutral in reaction and low in acid content. The preservation of the oil's natural qualities requires care and caution in the handling of the nuts and in the processing and the storing of the oil. The oil has a high viscosity and will thicken upon exposure to light without good ventilation.

The most valuable features of tung oil are (1) the manner and rapidity in which it dries and (2) the durability of the film which it forms upon drying. Some of its

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1 McKinney, op. cit., p. 5.
characteristics are indicated in the quotation below.

"It dries even more quickly than linseed oil but, unless subjected to special treatment, is inferior to it for paint because of the opacity and inelasticity of the film. In the manufacture of varnishes and enamel paints, however, it is superior to linseed oil. When heated and treated with rosin it gives a varnish that is waterproof, wears longer than ordinary varnishes, and does not turn white." 2

USES OF TUNG OIL

Tung oil has gained a prominent place in industry as a raw material in the preparation of coating and finishing products such as varnishes, paints, and enamels. It is an important ingredient of such other products as printing inks, linoleum, paint driers, synthetic resins, and polishing and grinding compounds. It has contributed to the quality and efficiency of these products in their diversified uses. It has improved industrial finishes in electrical equipment, construction, automobiles, textile goods, and specialized inks.

The traditional use of tung oil in the United States has been as an ingredient in the manufacture of high-grade varnishes. Spar varnish, which is prepared from tung oil and phenolic resins, is reported to be superior to the older

type of varnish made from linseed oil and fossil gums. Spar varnish dries quickly into a durable and waterproof film.

The paint and varnish industry of the United States consumed 92,294,000 pounds of tung oil in 1948, out of a total of 120,872,000 pounds consumed during the same period. Thus, the one industry consumed about 76 percent of the total amount of tung oil consumed. Some of the other industrial consumers are linoleum and oilcloth, printing ink, textile, wallboard and paper products, and electrical equipment manufacturers.

Paint and Varnish

Tung oil first made its appearance in the varnish industry as a flux for some of the hard gums which were difficult to fuse without loss of color. It was found later that in combination with rosin a varnish having better resistant and waterproof properties than the older type made from linseed oil and fossil gums could be produced.

The growing demand for quick-drying finishes to speed up commercial operation and maintenance jobs likewise has strengthened the demand for tung oil. It is now recognized as an essential part of industrial varnishes.

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for both general and specialized uses, and it is gaining in importance for enamels and certain paints. The use of synthetic gums in varnish formation has contributed to the usefulness of the oil for that purpose.

The manufacture of specialized industrial varnishes constitutes a very important outlet for tung oil. Because of its superior quality as a coating material, it appears to be more desirable for this purpose than the other drying oils. Some of the uses of special-type varnish are lithographic printing on metal surfaces, coating the interior of metal containers, aviation finishes, and insulating electrical equipment.

Printing Ink

Tung oil is used as a drying agent in the preparation of printing ink and specialized drawing ink. In 1948, the printing ink industry consumed 1,426,000 pounds, representing less than 1 per cent of the total amount consumed. This particular market practically disappeared during the war years when tung oil was a scarce commodity and the limited quantity was applied to more profitable uses. This industry, in 1944, used only 27,000 pounds, which indicated that the printing ink business was approaching

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4 Ibid., p. 23.

5 Ibid., p. 23.
the position of a submarginal consumer.

Linoleum and Oilcloth

Manufacturers use drying oils as a raw material in linoleum, oilcloth, and various types of floor mats. It is used in conjunction with cork or powdered wood and a coloring pigment. Tung oil is useful in products of this type in which flexibility is not a desirable quality. These industries consumed 8,943,000 pounds of tung oil in 1948.6

Tinware and Lithographic Printing

The rather extensive use of tin containers for canned foodstuffs, cigarettes, spices, medicines, and beverages has brought about an expansion of lithographic printing. As a protective coating for the printed inscription or design, varnish is applied either directly to the metal base or as a finished coat over the printed inscription. High grade varnishes having a strong adhesion to metals and capable of producing a very durable film are required for this kind of work.

Aircraft Industry

Varnish made from tung oil has found a relatively new market outlet as a protective coating for the surfaces of planes exposed to the elements. Tung oil is particularly useful for this purpose because of its light weight

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6 Ibid., p. 23.
and ability to stick to metal surfaces. Paint has proved to be too heavy for practical use. During World War II, tung oil found wide application as an important constituent of products being used for coating metal aircrafts and parts.

**Insulating Varnish**

Tung oil is employed in the electrical industry as an ingredient in insulating varnishes. Tung-oil varnishes are particularly adapted to electrical uses, because they are more resistant to water and oil and produce a firmer and faster drying film than most other materials. The polymerization process by which the oil dries makes it highly desirable in the electrical manufacturing industry. It is not readily affected by high-tension electrical fields; whereas other materials which dry by oxidation tend to disintegrate slowly in the presence of high-tension fields and lose their insulating qualities.

Some of the specific applications of this type of varnish in the electrical industry include insulating metal surfaces, plates, and wire; coating cloth and tapes which go into the building of cables; insulating the metal parts of armatures for electric motors and generators, and insulating wires used in building actuating coils, transformers, electric generator and motor field coils.

**Paint Drier**

Tung oil is used in the formation of paint driers employed to speed up drying time of paints and varnishes.
The driers are usually metallic soaps with drying oil as an organic base. Cobalt is regarded as one of the most efficient and satisfactory metallic bases. Others are iron, manganese, copper, lead, and zinc.

**Enamel and Lacquer**

Very high-grade enamels may be prepared by combining a good type of pigment for coloring purposes with either rosin or a high quality synthetic resin and by using tung oil as a solvent.

Tung oil has not made the progress in the field of lacquers that its special characteristics would seem to indicate. The development of lacquers has tended to curtail the use of tung oil in certain fields. However, the oil has been able to make some progress along with other materials in the preparation of lacquers. In metal finishing, auto body work, and other uses, tung oil has been used as a plasticizer, and in priming coats on copper and aluminum.

Some of the special-purpose paints in which tung oil is used are aluminum, asphalt, ship, and traffic paints, as well as paints used for coating concrete, steel, and wood where good waterproof qualities are desired such as dams, piers, locks, and swimming pools.

**Wall Board and Paper Products**

In the preparation of coatings for paper bags and containers and in the preparation of material for the
impregnation of wall board, tung oil is used as an ingredient. Its ability to resist moisture and acids adds to the usefulness and value of those products.

**Textile Industry**

Tung oil is used in the preparation of protective coatings for textile goods where a durable and waterproof coating is desired. Considerable quantities are used in the manufacture of oilcloth, floor covering, and artificial leather. A good grade of linoleum may be made by combining tung oil with linseed oil. Solidified linseed oil provides body and flexibility; while tung oil imparts durable and waterproof qualities.

As a waterproofing agent for textiles, tung oil is used in bagging and packing cloth, tents, awnings, tarpaulins, raincoats, and automobile seat covers. It is used in combination with asbestos and cotton in the manufacture of automobile brake linings.

**Other Uses**

The use of tung oil by steel manufacturers constitutes an important market outlet which appears to be increasing in importance. Drying oils known as "core" oils are used by the steel industry to temper steel. During the first six months of 1949, the steel manufacturers, using 625,000 pounds of tung oil for this purpose, ranked third as a market outlet.  

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7 Ibid., p. 23.
Domestic Consumption of Tung Oil

Factory consumption of tung oil depends upon the relationship between the supply of oil available and its price and the business activity of the consuming industries. During the war period, factory and warehouse stocks were placed under government control and made available for war purposes only.

After the war, consumption increased to the pre-war level because of an increase in available supply and in business activity of the consuming industries.

The following table shows the factory consumption and warehouse stocks for the years indicated.

Table IV. Domestic Consumption and Stocks of Tung Oil, 1937-49
(In Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Factory Consumption</th>
<th>Factory and Warehouse Stocks, December 31.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1937</td>
<td>120,378,145</td>
<td>48,656,000</td>
</tr>
<tr>
<td>1938</td>
<td>87,415,084</td>
<td>61,189,000</td>
</tr>
<tr>
<td>1939</td>
<td>90,720,000</td>
<td>31,400,000</td>
</tr>
<tr>
<td>1940</td>
<td>59,057,000</td>
<td>57,093,000</td>
</tr>
<tr>
<td>1941</td>
<td>54,000,000</td>
<td>32,809,000</td>
</tr>
<tr>
<td>1942</td>
<td>11,850,000</td>
<td>31,631,000</td>
</tr>
<tr>
<td>1943</td>
<td>12,047,000</td>
<td>27,067,000</td>
</tr>
<tr>
<td>1944</td>
<td>10,109,000</td>
<td>20,203,000</td>
</tr>
<tr>
<td>1945</td>
<td>21,569,000</td>
<td>6,514,000</td>
</tr>
<tr>
<td>1946</td>
<td>28,062,000</td>
<td>16,847,000</td>
</tr>
<tr>
<td>1947</td>
<td>88,359,000</td>
<td>37,777,000</td>
</tr>
<tr>
<td>1948</td>
<td>120,276,000</td>
<td>47,145,000</td>
</tr>
<tr>
<td>1949</td>
<td>100,853,000</td>
<td>18,199,000</td>
</tr>
</tbody>
</table>

Source: Bureau of Census, Department of Commerce.
A distribution of consumption of tung oil by industries is shown in the table below:

Table V. Consumption of Tung Oil in the United States by Industries, 1937-49

(000 Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Consumption</th>
<th>Paint and Varnish</th>
<th>Linoleum and Oilcloth</th>
<th>Printing Inks</th>
<th>Miscellaneous Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1937</td>
<td>120,378</td>
<td>105,731</td>
<td>7,198</td>
<td>2,762</td>
<td>4,687</td>
</tr>
<tr>
<td>1938</td>
<td>67,415</td>
<td>78,310</td>
<td>4,151</td>
<td>2,084</td>
<td>2,990</td>
</tr>
<tr>
<td>1939</td>
<td>90,720</td>
<td>82,307</td>
<td>3,763</td>
<td>2,105</td>
<td>2,545</td>
</tr>
<tr>
<td>1940</td>
<td>59,057</td>
<td>54,611</td>
<td>2,044</td>
<td>1,728</td>
<td>654</td>
</tr>
<tr>
<td>1941</td>
<td>54,008</td>
<td>48,825</td>
<td>1,896</td>
<td>2,960</td>
<td>327</td>
</tr>
<tr>
<td>1942</td>
<td>11,530</td>
<td>10,896</td>
<td>82</td>
<td>255</td>
<td>597</td>
</tr>
<tr>
<td>1943</td>
<td>12,947</td>
<td>9,867</td>
<td>...</td>
<td>17</td>
<td>2,363</td>
</tr>
<tr>
<td>1944</td>
<td>10,109</td>
<td>8,084</td>
<td>...</td>
<td>27</td>
<td>1,998</td>
</tr>
<tr>
<td>1945</td>
<td>21,559</td>
<td>16,939</td>
<td>2,337</td>
<td>156</td>
<td>2,134</td>
</tr>
<tr>
<td>1946</td>
<td>28,968</td>
<td>25,458</td>
<td>104</td>
<td>521</td>
<td>2,876</td>
</tr>
<tr>
<td>1947</td>
<td>68,359</td>
<td>68,968</td>
<td>5,254</td>
<td>1,397</td>
<td>12,720</td>
</tr>
<tr>
<td>1948</td>
<td>120,872</td>
<td>92,294</td>
<td>8,943</td>
<td>1,426</td>
<td>18,194</td>
</tr>
<tr>
<td>1949</td>
<td>100,853</td>
<td>80,155</td>
<td>10,276</td>
<td>... 1</td>
<td>10,422</td>
</tr>
</tbody>
</table>

1. Not computed separately in Census Reports.

Source: Fats and Oils, Bureau of the Census, United States Department of Commerce.

Tung oil consumption prior to World War II was at the highest level in 1937, when 120,378,000 pounds were consumed. The paint and varnish industry consumed 87.9%; linoleum and oilcloth, 6%; printing inks, 2.3%; and miscellaneous products, 3.8%. By 1943, the distribution had changed to some extent. Only 12,047,000 pounds were consumed and, of this amount, the paint and varnish industry consumed 80.3%; linoleum and oilcloth, less than .5%; printing inks, less
than .5%; and miscellaneous products, 19.6%. It appears that the use of tung oil in the manufacture of unclassified products was making some progress by this time. Its use in the manufacture of linoleum and oilcloth and printing inks had been reduced to practically nothing, and its relative use in the paints and varnish industry was less than in previous years. The increase in the relative importance of tung oil in the manufacture of miscellaneous products probably is accounted for by greater quantities being consumed as a sealing compound by munitions industries and the manufacturers of textile goods for the armed forces.

Total consumption of tung oil in the United States in 1949 was less than in 1937. Only 100,853,000 pounds were consumed. Of this amount, the paint and varnish manufacturers consumed 79.5%; linoleum and oilcloth, 10.2%; and miscellaneous products, 10.3%. The amount used in printing inks is included in miscellaneous products.
CHAPTER VI

PRODUCTION AND CONSUMPTION OF DRYING OILS
IN THE UNITED STATES

The relative importance of tung oil as an article of commerce in the United States may be shown by a consideration of the availability and utilization of all the oils with which tung oil must compete. The raw materials from which some oils are obtained are produced and processed in the United States, some are produced and processed abroad while the oil is imported for consumption, and others are produced abroad and imported into the United States for processing and consumption. Availability of drying oils obtained from raw materials produced and processed in the United States is shown by production figures for each oil obtained from such raw materials. Availability of oils obtained from raw materials produced abroad and processed both in the United States and countries of origin is shown by production figures of the United States plus quantities imported. Net import figures alone serve to reveal the availability of oils produced and processed outside of the United States. Production and import figures are shown for those oils obtained from raw materials produced and processed in the United States and other countries.

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Other factors useful in showing the relative importance of tung oil are (1) comparative prices, (2) tariff status of competing oils, (3) government price support programs, and (4) consumption of the most important drying oils. The consumption figures shown in the following are estimated quantities consumed for drying-oil purposes alone.

The Availability of Drying Oils in the United States

The following treatment includes a statistical presentation of production and imports, if any, of drying oils used in the United States, plus a brief statement in regard to the properties, uses, and importance in domestic trade of each type of oil. This section includes tung oil, linseed oil, soybean oil, castor oil, oiticica oil, perilla oil, and fish oil.

Tung Oil

The availability of tung oil for consumption in the United States is shown in Table VI, which follows. Some of the oil is imported from foreign countries and some of it is produced in the United States; therefore, import and production figures are given.
Table VI. United States Imports and Production of Tung Oil, 1938-1949

(000 Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantities Imported</th>
<th>Quantities Produced in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>107,456</td>
<td></td>
</tr>
<tr>
<td>1939</td>
<td>78,718</td>
<td>3,000</td>
</tr>
<tr>
<td>1940</td>
<td>97,049</td>
<td>62</td>
</tr>
<tr>
<td>1941</td>
<td>83,800</td>
<td>3,533</td>
</tr>
<tr>
<td>1942</td>
<td>6,269</td>
<td>2,290</td>
</tr>
<tr>
<td>1943</td>
<td>68</td>
<td>5,310</td>
</tr>
<tr>
<td>1944</td>
<td>17,771</td>
<td>2,558</td>
</tr>
<tr>
<td>1945</td>
<td>339</td>
<td>10,353</td>
</tr>
<tr>
<td>1946</td>
<td>36,207</td>
<td>11,046</td>
</tr>
<tr>
<td>1947</td>
<td>181,964</td>
<td>12,680</td>
</tr>
<tr>
<td>1948</td>
<td>133,284 (1)</td>
<td>16,637 (2)</td>
</tr>
<tr>
<td>1949</td>
<td>74,968 (1)</td>
<td>20,020 (2)</td>
</tr>
</tbody>
</table>


It appears that the quantities of imported oil decreased considerably with the development of political and military disturbances in China. The decrease had become quite noticeable by 1941 and was reduced to only 68,000 pounds for 1943. By 1947, imports were back to the pre-war level, having increased very rapidly after the end of the
war in 1945. Political and military disturbances were the causes of the decrease in imports, as the price of tung oil in the United States was unusually high during the war. When quantities imported were decreasing, the price was rising or was at the government price ceiling of 39 cents per pound. When quantities imported were increasing after the end of World War II, the price of tung oil was decreasing.

There appears to have been no increase in the trend of production of tung oil in the United States until 1945; yet the price of tung oil was higher than it had been in previous years. Apparently, tung producers planted more trees when the price of tung oil was high in 1941 and 1942, and output did not increase until the end of the required gestation period of about three years for tung trees. Greater production of tung oil in the United States and an increase in imports, beginning about 1946, resulted in greater quantities of oil available in 1947 and 1948 than in 1938. Quantities available in 1941 and 1946 were about equal.

Some of the economic forces affecting the price of tung oil from about 1938 to 1949 are indicated in the following quotation.

"Reflecting curtailed imports of tung oil from China and increasing industrial activity in the United States, the price of tung oil rose rapidly from 1938 to early 1942, when the wartime price ceiling was reached. After the
Imports of tung oil recovered and the price declined. Declining industrial activity in 1949 and a substantial reduction in linseed oil prices in the latter part of the year will tend to depress the price of tung oil. But reduced imports of tung oil will tend to have an opposite effect."

Linseed Oil

The quantities of linseed oil produced in the United States and imported for consumption annually since 1938 are shown in the table below.

Table VII. Linseed Oil Produced in the United States and Imported, 1938-1949

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantities Imported</th>
<th>Quantities Produced in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>64</td>
<td>501,545</td>
</tr>
<tr>
<td>1939</td>
<td>18</td>
<td>579,056</td>
</tr>
<tr>
<td>1940</td>
<td>69</td>
<td>707,230</td>
</tr>
<tr>
<td>1941</td>
<td>56</td>
<td>988,267</td>
</tr>
<tr>
<td>1942</td>
<td>55,584</td>
<td>849,160</td>
</tr>
<tr>
<td>1943</td>
<td>84,580</td>
<td>1,046,972</td>
</tr>
<tr>
<td>1944</td>
<td>27,112</td>
<td>633,109</td>
</tr>
<tr>
<td>1945</td>
<td>105,452</td>
<td>588,520</td>
</tr>
<tr>
<td>1946</td>
<td>162,251</td>
<td>485,254</td>
</tr>
<tr>
<td>1947</td>
<td>13,796</td>
<td>593,137</td>
</tr>
<tr>
<td>1948</td>
<td>3,959 (1)</td>
<td>726,034 (1)</td>
</tr>
<tr>
<td>1949</td>
<td>1,298 (1)</td>
<td>744,502 (1)</td>
</tr>
</tbody>
</table>


Greater quantities of linseed oil were available for consumption in the United States during the war-period, from about 1941 to 1945, than during previous years. In contrast to the availability of tung oil, both production and imports of linseed oil were high during World War II. This increase in linseed oil imports was brought about on account of the stopping of the shipment of flaxseed from Argentina to the United States. The Argentine Government insisted upon processing its own flaxseed output in that country and shipping the oil in international trade. It appears that the price of linseed oil was responsible for the increase in production from 1940 to 1943. The average annual price was 9.7 cents in 1940 and 15.6 cents per pound in 1943 (see Table XV). It is probable that as tung oil became scarce and the price increased, consumers purchased less tung oil and greater quantities of linseed oil. An increase in the demand for linseed oil caused the price to increase, and a higher price brought forth greater production and imports. Foreign sources of linseed oil were not affected by the war as much as foreign sources of tung oil. Argentina and Canada are the principal sources of linseed oil imports, and the greatest portion of tung oil imports come from China. Transportation facilities between the United States and Argentina were not disrupted by the war as much as they were between the United States and China. Consequently, linseed oil imports increased, while
tung oil imports decreased. Quantities of linseed oil available in the United States began to decrease after 1943 and reached the lowest point in 1947, when the average annual price was 34.3 cents per pound. The total amount was low in 1947 and the price was higher than it had been in previous years, reflecting the effect of the government support program upon the price of linseed oil. The 1947 flax crop was supported at $6.00 per bushel.  

**Soybean Oil**

The table below shows the quantities of soybean oil produced in the United States and the quantities exported for the years indicated.

**Table VIII. United States Production and Exports of Soybean Oil, 1938-1949**

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (000 Pounds)</th>
<th>Exports (000 Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>416,111</td>
<td>7,142</td>
</tr>
<tr>
<td>1939</td>
<td>553,417</td>
<td>18,158</td>
</tr>
<tr>
<td>1940</td>
<td>564,417</td>
<td>14,424</td>
</tr>
<tr>
<td>1941</td>
<td>706,678</td>
<td>20,585</td>
</tr>
<tr>
<td>1942</td>
<td>1,206,186</td>
<td>44,101</td>
</tr>
<tr>
<td>1943</td>
<td>1,219,453</td>
<td>58,757</td>
</tr>
<tr>
<td>1944</td>
<td>1,346,704</td>
<td>67,154</td>
</tr>
<tr>
<td>1945</td>
<td>1,414,718</td>
<td>73,928</td>
</tr>
<tr>
<td>1946</td>
<td>1,531,096</td>
<td>91,455</td>
</tr>
<tr>
<td>1947</td>
<td>1,532,667</td>
<td>115,118</td>
</tr>
<tr>
<td>1948</td>
<td>1,604,324 (1)</td>
<td>83,035 (1)</td>
</tr>
<tr>
<td>1949</td>
<td>1,859,066 (1)</td>
<td>116,860 (1)</td>
</tr>
</tbody>
</table>


—

The production of soybean oil in the United States in recent years presents an interesting picture. First of all, it is the only one of the vegetable oils considered up to this point which has a volume of domestic production sufficient for export. Production has been increasing at a steady rate during the past few years. The very existence of such large quantities of the oil would offer serious competition to the other drying oils if it could be substituted readily for other drying oils in the manufacturing process. It can not be used for a drying oil in any satisfactory way without special preparations. It must be broken down into its constituent parts and rebuilt according to an established formula before it can be used as a good drying oil. This process is known as fractionation, and is the result of wartime research. However, in spite of the contributions of research, the oil appears to be most useful in the manufacture of goods which do not require drying reactions. Only 162,152,000 pounds were used for drying oil purposes in 1946 out of a total of 1,604,324,000 pounds available for consumption.

Castor Oil

The beans from which castor oil is extracted are obtained from the castor oil plant which grows in many of the tropical regions. The chief producing countries are Brazil and India. The beans are not grown commercially in the United States. Castor beans are imported into the United
States and the oil is extracted from the beans in this country. Also, castor oil is imported. The availability of castor oil for consumption in the United States is indicated by the quantities produced from imported beans and the quantities of oil imported. Production and import figures since 1948 are shown in the table below.

Table IX. United States Factory Production and Imports of Castor Oil, 1948-1949

<table>
<thead>
<tr>
<th>Year</th>
<th>Factory Production From Imported Beans</th>
<th>Imports (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942</td>
<td>147,142</td>
<td>7,027</td>
</tr>
<tr>
<td>1943</td>
<td>120,940</td>
<td>23,879</td>
</tr>
<tr>
<td>1944</td>
<td>165,617</td>
<td>7,449</td>
</tr>
<tr>
<td>1945</td>
<td>143,485</td>
<td>4,124</td>
</tr>
<tr>
<td>1946</td>
<td>91,198</td>
<td>9,476</td>
</tr>
<tr>
<td>1947</td>
<td>117,189</td>
<td>8,024 (2)</td>
</tr>
<tr>
<td>1948</td>
<td>136,036</td>
<td>2,441 (2)</td>
</tr>
<tr>
<td>1949</td>
<td>126,456</td>
<td>10,618 (2)</td>
</tr>
</tbody>
</table>


Oiticica Oil

Oiticica oil is not produced in the United States, It is expressed from the seeds of the licania regida tree
which grows in Brazil. Its availability for consumption in
the United States may be indicated by import figures which
are shown in the table below.

Table X. United States Imports of Oiticica Oil,
1938-1949
(000 Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>5,301</td>
</tr>
<tr>
<td>1939</td>
<td>18,876</td>
</tr>
<tr>
<td>1940</td>
<td>15,537</td>
</tr>
<tr>
<td>1941</td>
<td>36,578</td>
</tr>
<tr>
<td>1942</td>
<td>1,224</td>
</tr>
<tr>
<td>1943</td>
<td>1,642</td>
</tr>
<tr>
<td>1944</td>
<td>10,543</td>
</tr>
<tr>
<td>1945</td>
<td>21,614</td>
</tr>
<tr>
<td>1946</td>
<td>22,593</td>
</tr>
<tr>
<td>1947</td>
<td>8,471 (1)</td>
</tr>
<tr>
<td>1948</td>
<td>17,558 (1)</td>
</tr>
<tr>
<td>1949</td>
<td>8,940 (1)</td>
</tr>
</tbody>
</table>


Perilla Oil

Perilla oil is obtained from the seeds of a plant
which grows in China, Japan, and Manchuria. It is a good
drying oil and may be used as a substitute for tung oil
for some purposes. However, it is not as adaptable to gen-
eral usage as some of the other drying oils, because it
forms an unusually hard film and a great amount of surface tension when used in the raw state. Heat treatments tend to reduce the surface tension and to give the oil the quality of forming a very hard and glossy film. For the above reasons, perilla oil is most valuable as a raw material in the preparation of hard-surfaced enamels, though it is undesirable in the manufacture of paints and ordinary varnishes.

Perilla oil is not likely to offer serious competition to other drying oils in the United States at the present time because of uncertainties and difficulties of production. Manchuria has been the principal source of the world's supply of the oil, but further production there has been disrupted in a serious way because of unsettled political conditions. Imports into the United States amounted to about 50,000,000 pounds annually from 1934 to 1938. Imports since that time are shown in the following table.

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4 Ibid., p. 40.
5 Ibid., p. 41.
Table XI. United States Imports of Perilla Oil, 1938-1949

(1,000 Pounds)

<table>
<thead>
<tr>
<th>Year</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>39,318</td>
</tr>
<tr>
<td>1939</td>
<td>34,236</td>
</tr>
<tr>
<td>1940</td>
<td>9,321</td>
</tr>
<tr>
<td>1941</td>
<td>3,416</td>
</tr>
<tr>
<td>1942</td>
<td>603</td>
</tr>
<tr>
<td>1943</td>
<td>0</td>
</tr>
<tr>
<td>1944</td>
<td>0</td>
</tr>
<tr>
<td>1945</td>
<td>14</td>
</tr>
<tr>
<td>1946</td>
<td>0</td>
</tr>
<tr>
<td>1947</td>
<td>0</td>
</tr>
<tr>
<td>1948</td>
<td>0</td>
</tr>
<tr>
<td>1949</td>
<td>0</td>
</tr>
</tbody>
</table>


Fish Oils

Of all the drying oils, fish oil is the only one which is not of a vegetable origin. It is obtained from several varieties of fish. Among the most important oils of this type are those obtained from the herring, sardine, and the menhaden. "The most important of domestic fish oils is menhaden oil. This oil is extracted from the menhaden or pogy, a fish found only in the waters off the Atlantic coast of the United States, and hence its manufacture is purely a domestic industry." 6 As a drying oil it

6 Wright, op. cit., p. 67-68.
occupies a position similar to that of soybean oil. In 1948, the soap industry consumed 35,476,000 pounds of fish oil, while the paint and varnish industry consumed only 27,216,000 pounds.7

Industrial research has contributed much to the improvement of fish oil in recent years. A new fractionation process used in processing soybean oil, may be used to improve the quality of fish oil. The oil is separated by this process into its fatty acid parts which are separated further into fractions by a process of distillation.8 When the fractions are treated with glycerol, a very rapidly drying material is produced.9 Fish oil makes a fairly good substitute for tung oil in the manufacture of some products, such as linoleum, oilcloth, and printing ink.

Production of fish oil in the United States since 1941 is shown in the table which follows:

---

7 Facts for Industry, Fats and Oils, Bureau of the Census, United States Department of Commerce.

8 Wood, op. cit., p. 39.

9 Ibid., p. 39.
Table XII. United States Production of Fish Oils, 1941-1947

<table>
<thead>
<tr>
<th>Year</th>
<th>Pilchard (1,000 Pounds)</th>
<th>Menhaden</th>
<th>Herring (1,000 Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1941</td>
<td>135,939</td>
<td>46,704</td>
<td>22,845</td>
</tr>
<tr>
<td>1942</td>
<td>93,817</td>
<td>39,697</td>
<td>7,428</td>
</tr>
<tr>
<td>1943</td>
<td>104,605</td>
<td>44,386</td>
<td>12,978</td>
</tr>
<tr>
<td>1944</td>
<td>155,742</td>
<td>46,959</td>
<td>17,942</td>
</tr>
<tr>
<td>1945</td>
<td>88,897</td>
<td>64,514</td>
<td>19,935</td>
</tr>
<tr>
<td>1946</td>
<td>33,234</td>
<td>76,025</td>
<td>28,255</td>
</tr>
<tr>
<td>1947</td>
<td>16,150</td>
<td>61,440</td>
<td>28,710</td>
</tr>
</tbody>
</table>


United States Government Price Support for Drying Oils

The availability of linseed, soybean, and tung oils in the United States has been affected to some extent by the price support program of the Federal Government. The procedure by which the government endeavors to support the price of a commodity is to enter into an option contract, through the Commodity Credit Corporation, with the producer whereby the producer may sell the commodity to the Commodity Credit Corporation at a price representing a specified percentage of the market price during a base period. The price is established by the Secretary of Agriculture after an investigation has been conducted by the Production Marketing Administration. The price established in this manner is known as the "support price" and it seeks to maintain a minimum price for individual commodities at a specified percentage of the general price level.
In some cases, the Commodity Credit Corporation agrees to purchase the agricultural product from which the oil is obtained from the producer at the support price. In other cases, it agrees to purchase the oil from the processor who purchases the oil-containing product from the producer at the established price.

**Tung Oil**

At the present time, the support price for tung oil is 24.1 cents per pound and for tung nuts, $60 per ton.

"Nearly 11.5 million pounds of tung oil from the 1949 crop of tung nuts were placed under purchase agreements with CCC. This accounts for a little more than half of the estimated total production of 21 million pounds of oil from the 1949 tung-nut crop. The support for the nuts is 60 dollars per ton and that for the oil is 24.1 cents per pound, f.o.b., shipping point. Prices of domestic tung oil, f.o.b., mill, from December through early April were quoted mostly between 25.5 and 26.5 cents per pound."  

The period during which producers could place tung nuts under purchase agreements with the Commodity Credit Corporation expired March 31, 1950. Producers are required to notify their Production Marketing Administration county committees of their intention to deliver tung oil

---


under purchase agreements to the Commodity Credit Corporation by September 30, 1950. 12

**Linseed Oil**

The current government support price for flaxseed from which linseed oil is obtained is about $4 per bushel.

"It was announced in late October that the price of flaxseed produced in 1948 would be supported at not less than 90 per cent of parity price on July 1, 1949. Ninety per cent of the parity price of flaxseed in mid-December 1948 was $3.75 per bushel. This is equivalent to about $4.00 per bushel, Minneapolis basis, compared with the present support of $6.00 per bushel, Minneapolis." 13

The support price of $6.00 per bushel for flaxseed in 1947 and 1948 was the equivalent of 26.7 cents per pound for linseed oil.14

The effect of the government's support program on the availability of flaxseed in the United States may be shown by a record of acres of flax harvested, production, and average annual price. Those items are shown in the following table for the years 1936 through 1947.

---

12 Ibid., p. 13


Table XIII. United States Production, Acreage, and 
Average Annual Price of Flaxseed, 1938-1947

<table>
<thead>
<tr>
<th>Year</th>
<th>Acreage harvested</th>
<th>Production</th>
<th>Average annual price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>905</td>
<td>6,032</td>
<td>1.59</td>
</tr>
<tr>
<td>1939</td>
<td>2,171</td>
<td>19,668</td>
<td>1.46</td>
</tr>
<tr>
<td>1940</td>
<td>3,182</td>
<td>30,924</td>
<td>1.42</td>
</tr>
<tr>
<td>1941</td>
<td>3,266</td>
<td>32,133</td>
<td>1.79</td>
</tr>
<tr>
<td>1942</td>
<td>4,408</td>
<td>40,976</td>
<td>2.36</td>
</tr>
<tr>
<td>1943</td>
<td>5,691</td>
<td>50,000</td>
<td>2.83</td>
</tr>
<tr>
<td>1944</td>
<td>2,610</td>
<td>21,665</td>
<td>2.91</td>
</tr>
<tr>
<td>1945</td>
<td>3,783</td>
<td>34,557</td>
<td>2.89</td>
</tr>
<tr>
<td>1946</td>
<td>2,452</td>
<td>22,585</td>
<td>4.04</td>
</tr>
<tr>
<td>1947</td>
<td>4,028</td>
<td>39,763</td>
<td>6.10</td>
</tr>
</tbody>
</table>


Import Duties on Drying Oils

The question of a tariff on tung oil imports has been of considerable importance to those associated with the industry since its beginning on a commercial basis in 1932. Interest in and agitation for a tariff was intensified when tung oil imports increased very rapidly in 1946 and 1947 and the price decreased from about 39 cents to as low as 17 cents per pound. In spite of the interest of tung growers in a tariff on the commodity which they produce, no such tariff has been enacted up to the present time. For completeness and thoroughness of analysis, therefore, it seems appropriate to give consideration to the probable effect of a tariff on the price of tung oil if such were enacted.
The tariff status of the principal drying oils is shown in the table below, which table shows the duties established by the Acts of 1930, 1945, and 1948. Some oil-bearing seeds which are imported are included in the list of commodities. In addition to the tariff, an excise tax is levied on some of the commodities to be collected at the time the seeds are sold to owners of crushing mills or, in the case of oils, at the time they are purchased by manufacturers for processing.

**Table XIV. Import Duties on Principal Drying Oils, 1930, 1945, and 1948**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tax</td>
<td>Tax</td>
<td>Tax</td>
</tr>
<tr>
<td>Menhaden Oil</td>
<td>5¢ gal or 0.67¢#</td>
<td>3¢#</td>
<td>3¢# 3¢# 3¢# 1½¢#</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>3½¢ #</td>
<td>None</td>
<td>3½¢# None 3½¢ or not less than 22½%</td>
</tr>
<tr>
<td>Linseed Oil</td>
<td>4½¢ #</td>
<td>None</td>
<td>4½¢# None</td>
</tr>
<tr>
<td>Flaxseed Oil</td>
<td>65¢ bu. None 32½¢ bu.</td>
<td>None</td>
<td>32½¢ bu. None</td>
</tr>
<tr>
<td>Tung Oil</td>
<td>Free</td>
<td>None</td>
<td>Free</td>
</tr>
<tr>
<td>Perilla Oil</td>
<td>Free</td>
<td>None</td>
<td>Free 4½¢# Free 4½¢#</td>
</tr>
<tr>
<td>Perilla Seed</td>
<td>Free</td>
<td>None</td>
<td>Free $1.38¢ Free $1.38</td>
</tr>
<tr>
<td>Oiticica Oil</td>
<td>Free</td>
<td>None</td>
<td>Free</td>
</tr>
<tr>
<td>Castor Oil</td>
<td>3¢ #</td>
<td>None</td>
<td>3¢# None 3¢# None</td>
</tr>
<tr>
<td>Castor Beans</td>
<td>Free</td>
<td>None</td>
<td>Free</td>
</tr>
</tbody>
</table>

Currently, there is a tariff on linseed, soybean, castor, and menhaden oils; and tung, perilla, and citicica oils are on the free list. It might appear at first that this situation gives the protected oils a competitive advantage over those on the free list, but judgment should be postponed until additional facts are presented.

There is an exportable surplus of soybean oil and the quantity of linseed oil being imported into the United States is negligible. Castor oil is not produced in the United States in commercial quantities, and menhaden oil is produced in the United States only. It is obvious that an import duty has no effect upon those oils which are not available for imports. Domestic production of soybean oil is sufficient for domestic needs plus some for export.

Domestic producers undoubtedly would like for a tariff on tung oil to be enacted sufficient to exclude the highest cost foreign producers and thereby reduce supply and increase the price. From the standpoint of public policy, the purpose of such a tariff would be to increase the price of tung oil (1) in order to stimulate further development of the industry in the United States and (2) to increase the income of tung oil producers through governmental policy.

What would be the probable effect of a tariff on the price of tung oil? The effect of a tariff upon the price of a product depends upon the extent to which the product is being imported and the extent to which other goods may be used as a
substitute for the product upon which a tariff is placed. A tariff has very little effect upon the price of a good for which there is an export balance at the time of the enactment of the tariff. A tariff has a great effect upon the price of a good for which there is an import balance at the time of enactment and substitutes are not available. When a tariff is placed upon a product which is being imported and produced in the United States, it increases the price of the product and encourages the development of the industry within the United States. A tariff on tung oil would be of the latter type. It would tend to increase the price of tung oil and encourage the development of the industry in the United States. The extent to which the price increases would depend upon the availability of substitutes for tung oil. The price at first would increase by about the amount of the tariff. The high price for tung oil would invite the use of substitutes. Duty-free oils and others whose prices had become adjusted in the market at a lower level could be substituted for the higher price tung oil. Substituting other oils by industrial consumers would cause the demand for tung oil to decrease and the demand for substitute oils to increase. As a result, the price of substitutes would increase and the price of tung oil would decrease toward the former level. These economic forces would not operate without some friction, because substitutions could not be made without some degree of inconvenience. Oiticica oil is about the only one of the commercial drying oils which could be used as a substitute for tung oil without extra cost. The use of castor oil for drying
purposes requires extra cost of dehydration. The net effect of a tariff on tung oil would be to (1) increase the price of tung oil by less than the full amount of the tariff, (2) reduce the quantity purchased, (3) increase the price of other oils which may be substituted most readily for tung oil by an amount less than the tariff, (4) increase the quantity of substitute oils purchased, and (5) increase domestic production of tung oil. The prices at which consumers could buy drying oils would be higher and the prices of products containing drying oils would be higher than before by an amount less than the full amount of the tariff.

Relative Prices of Drying Oils

The average annual prices of drying oils are shown in the following table for the years indicated.

Table XV. Average Annual Prices of Drying Oils, 1940-1949 (Cents per pound, N. Y.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Linseed</th>
<th>Tung</th>
<th>Soybean</th>
<th>Castor</th>
<th>Oiticica</th>
<th>Menhaden</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>9.7</td>
<td>26.3</td>
<td>4.8</td>
<td>15.6</td>
<td>18.9</td>
<td>7.1</td>
</tr>
<tr>
<td>1941</td>
<td>10.7</td>
<td>32.2</td>
<td>8.5</td>
<td>15.2</td>
<td>20.2</td>
<td>10.1</td>
</tr>
<tr>
<td>1942</td>
<td>13.3</td>
<td>39.6</td>
<td>11.6</td>
<td>18.3</td>
<td>25.6</td>
<td>11.6</td>
</tr>
<tr>
<td>1943</td>
<td>15.6</td>
<td>39.0</td>
<td>11.8</td>
<td>18.4</td>
<td>26.2</td>
<td>12.4</td>
</tr>
<tr>
<td>1944</td>
<td>15.6</td>
<td>39.0</td>
<td>11.8</td>
<td>17.9</td>
<td>21.9</td>
<td>12.6</td>
</tr>
<tr>
<td>1945</td>
<td>15.5</td>
<td>39.0</td>
<td>11.8</td>
<td>17.9</td>
<td>23.7</td>
<td>13.0</td>
</tr>
<tr>
<td>1946</td>
<td>19.9</td>
<td>39.1</td>
<td>14.6</td>
<td>23.5</td>
<td>26.8</td>
<td>15.9</td>
</tr>
<tr>
<td>1947</td>
<td>34.3</td>
<td>30.5</td>
<td>23.3</td>
<td>33.6</td>
<td>28.9</td>
<td>24.9</td>
</tr>
<tr>
<td>1948</td>
<td>29.7</td>
<td>24.6</td>
<td>22.3</td>
<td>26.6</td>
<td>21.5</td>
<td>21.8</td>
</tr>
<tr>
<td>1949 (1)</td>
<td>25.1</td>
<td>22.9</td>
<td>18.5</td>
<td>21.7</td>
<td>18.2</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Source: Edmund C. Wood., op cit., p. 33.

(1) Compiled from Fats and Oils Situation, Bureau of Agricultural Economics, United States Department of Agriculture, 1949.
**Total Consumption of Drying Oils**

The table below shows total quantities of six of the most important drying oils consumed in the United States for the years indicated.

Table XVI. Total Consumption of Drying Oils in the United States, 1938-1948

<table>
<thead>
<tr>
<th>Year</th>
<th>Linseed Oil</th>
<th>Tung Oil</th>
<th>Castor Oil</th>
<th>Soybean Oil</th>
<th>Oiticica Oil</th>
<th>Fish Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>486,828</td>
<td>90,295</td>
<td>6,043</td>
<td>21,784</td>
<td>5,301</td>
<td>30,663</td>
</tr>
<tr>
<td>1939</td>
<td>557,855</td>
<td>105,596</td>
<td>11,944</td>
<td>33,355</td>
<td>16,867</td>
<td>43,599</td>
</tr>
<tr>
<td>1940</td>
<td>566,586</td>
<td>66,937</td>
<td>14,687</td>
<td>46,680</td>
<td>15,537</td>
<td>46,894</td>
</tr>
<tr>
<td>1941</td>
<td>808,641</td>
<td>68,515</td>
<td>46,895</td>
<td>62,410</td>
<td>26,785</td>
<td>56,539</td>
</tr>
<tr>
<td>1942</td>
<td>820,283</td>
<td>11,825</td>
<td>62,756</td>
<td>33,422</td>
<td>9,196</td>
<td>31,779</td>
</tr>
<tr>
<td>1943</td>
<td>759,663</td>
<td>12,047</td>
<td>24,991</td>
<td>32,974</td>
<td>3,602</td>
<td>34,188</td>
</tr>
<tr>
<td>1944</td>
<td>680,373</td>
<td>10,109</td>
<td>90,037</td>
<td>36,648</td>
<td>10,741</td>
<td>47,178</td>
</tr>
<tr>
<td>1945</td>
<td>653,440</td>
<td>22,672</td>
<td>66,656</td>
<td>45,757</td>
<td>19,389</td>
<td>57,852</td>
</tr>
<tr>
<td>1947</td>
<td>587,536</td>
<td>106,077</td>
<td>43,501</td>
<td>158,607</td>
<td>12,707</td>
<td>44,946</td>
</tr>
<tr>
<td>19481</td>
<td>595,460</td>
<td>129,739</td>
<td>57,876</td>
<td>182,152</td>
<td>13,115</td>
<td>35,187</td>
</tr>
</tbody>
</table>


The oils in which there was a noticeable increase in consumption in the drying-oil industries of the United States, beginning about 1940, are linseed oil and castor oil. The trend in linseed oil consumption turned downward in 1943. The rate of consumption of castor oil also was reduced in 1943, but unusually great quantities were consumed in 1944 and 1945. The oils in which there was a noticeable decrease in consumption during 1942 and 1943 are tung oil and oiticica oil, both
of which were not available in usual quantities. A better picture of what drying oils have been used for may be presented by a statistical presentation of drying oil consumption by products.

Table XVII. Utilization of Oils and Fats in Drying-Oil Products, by Type of Product, 1938-1948

<table>
<thead>
<tr>
<th>Year</th>
<th>Paint and Varnish</th>
<th>Covering and Oilcloth</th>
<th>Printing Inks</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>564,773</td>
<td>84,100</td>
<td>21,884</td>
<td>14,121</td>
<td>732,878</td>
</tr>
<tr>
<td>1939</td>
<td>675,973</td>
<td>107,781</td>
<td>22,873</td>
<td>18,884</td>
<td>925,451</td>
</tr>
<tr>
<td>1940</td>
<td>654,175</td>
<td>111,813</td>
<td>21,178</td>
<td>22,229</td>
<td>809,395</td>
</tr>
<tr>
<td>1941</td>
<td>876,396</td>
<td>136,840</td>
<td>29,319</td>
<td>38,852</td>
<td>1,081,407</td>
</tr>
<tr>
<td>1942</td>
<td>774,465</td>
<td>116,235</td>
<td>17,337</td>
<td>65,865</td>
<td>973,824</td>
</tr>
<tr>
<td>1943</td>
<td>696,859</td>
<td>75,792</td>
<td>23,024</td>
<td>93,912</td>
<td>891,887</td>
</tr>
<tr>
<td>1944</td>
<td>668,134</td>
<td>85,444</td>
<td>30,611</td>
<td>114,460</td>
<td>915,649</td>
</tr>
<tr>
<td>1945</td>
<td>656,075</td>
<td>78,879</td>
<td>38,034</td>
<td>119,274</td>
<td>892,262</td>
</tr>
<tr>
<td>1946</td>
<td>681,792</td>
<td>88,306</td>
<td>33,593</td>
<td>136,407</td>
<td>940,278</td>
</tr>
<tr>
<td>1947</td>
<td>704,583</td>
<td>141,818</td>
<td>23,710</td>
<td>144,489</td>
<td>1,014,600</td>
</tr>
<tr>
<td>1948</td>
<td>764,054</td>
<td>166,280</td>
<td>22,167</td>
<td>129,538</td>
<td>1,082,339</td>
</tr>
</tbody>
</table>


For each year represented in the table above, greater quantities of drying oils were consumed in making paint and varnish than in any other product. The second most important drying-oil product was floor covering and oilcloth until 1943, when other products became the second most important consumer of drying oils. By 1948, floor covering and oilcloth had regained its former position. Printing ink
was the third most important drying-oil product until 1940, when it was exceeded by other products. The term "ether" products includes core oils, synthetic resins, insulation, linings and packings, coated fabrics other than oilcloth, caulking and other protective coatings.\textsuperscript{15}

**Paint and Varnishes**

The amount of each type of drying oil used in the manufacture of paint and varnishes is shown in the table below.

**Table XVIII. Consumption of Oils in Paints and Varnishes, 1937-1943**

<table>
<thead>
<tr>
<th>Type of Oil</th>
<th>Average (000 Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1937-1941</td>
</tr>
<tr>
<td>Linseed</td>
<td>495,618</td>
</tr>
<tr>
<td>Fish Oil</td>
<td>27,875</td>
</tr>
<tr>
<td>Tung Oil</td>
<td>97,541</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>24,894</td>
</tr>
<tr>
<td>Castor Oil Dehydrated</td>
<td>-----</td>
</tr>
<tr>
<td>Coticica Oil</td>
<td>13,399</td>
</tr>
<tr>
<td>Perilla Oil</td>
<td>24,504</td>
</tr>
</tbody>
</table>

Source: *Fats and Oils Situation, Bureau of Agricultural Economics, United States Department of Agriculture, May, 1949, p. 15.*

\textsuperscript{15} Ibid., May, 1949, p. 14.
On the basis of quantity used, linseed oil is the most important drying oil used in the manufacture of paints and varnishes. It amounts to approximately 70 per cent of the oils used for paints and varnishes. About equal quantities of tung oil and soybean oil were used in 1948. The importance of soybean oil appears to be increasing as a raw material for paints and varnishes. The greatest quantities of tung oil were consumed when it was available at a price not far out of line with other drying oils.

**Linoleum and Oilcloth**

The quantities of drying oils used in making linoleum and oilcloth are shown in the following table.

**Table XIX. Consumption of Oils in Linoleum and Oilcloth, 1937-1948**

<table>
<thead>
<tr>
<th>Type of Oil</th>
<th>Average (000 Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1937-1946</td>
</tr>
<tr>
<td>Linseed Oil</td>
<td>77,213</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>5,179</td>
</tr>
<tr>
<td>Fish Oil</td>
<td>15,536</td>
</tr>
<tr>
<td>Citricola</td>
<td>563</td>
</tr>
<tr>
<td>Caster Oil</td>
<td>----</td>
</tr>
<tr>
<td>Oil Dehydrated</td>
<td>3,810</td>
</tr>
<tr>
<td>Tung Oil</td>
<td>5,698</td>
</tr>
<tr>
<td>Perilla Oil</td>
<td>5,698</td>
</tr>
</tbody>
</table>

Source: *Fats and Oils Situation, Bureau of Agricultural Economics, United States Department of Agriculture, May, 1949, p. 15.*
As shown in the above table, more linseed oil is used in the manufacture of linoleum and oilcloth than any other oil. It constituted about 78 per cent of all oil used for this purpose in 1948. Increasing quantities of soybean oil are being used.

**Printing Inks**

The use of drying oils in making printing inks is shown in the following table.

**Table XX. Consumption of Oils in Printing Inks, 1937-1948**

(000 Pounds)

<table>
<thead>
<tr>
<th>Type of Oil</th>
<th>Average of 1937-1941</th>
<th>1942</th>
<th>1943</th>
<th>1944</th>
<th>1945</th>
<th>1946</th>
<th>1947</th>
<th>1948</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linseed Oil</td>
<td>19,065</td>
<td>21,362</td>
<td>27,477</td>
<td>34,042</td>
<td>30,409</td>
<td>19,336</td>
<td>18,407</td>
<td></td>
</tr>
<tr>
<td>Castor Oil dehydrated</td>
<td>----</td>
<td>29</td>
<td>220</td>
<td>323</td>
<td>138</td>
<td>100</td>
<td>259</td>
<td></td>
</tr>
<tr>
<td>Tung Oil</td>
<td>2,328</td>
<td>17</td>
<td>27</td>
<td>156</td>
<td>521</td>
<td>1,397</td>
<td>1,426</td>
<td></td>
</tr>
<tr>
<td>Oiticica Oil</td>
<td>62</td>
<td>11</td>
<td>219</td>
<td>444</td>
<td>500</td>
<td>143</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Fish Oil</td>
<td>223</td>
<td>118</td>
<td>109</td>
<td>282</td>
<td>359</td>
<td>209</td>
<td>392</td>
<td></td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>108</td>
<td>48</td>
<td>23</td>
<td>29</td>
<td>108</td>
<td>1,119</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Perilla Oil</td>
<td>1,474</td>
<td>162</td>
<td>76</td>
<td>23</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>


Greater quantities of linseed oil are consumed in printing inks than any other type of oil, but there is a noticeable difference in the proportion of tung oil consumed.
in printing inks than in linoleum and oilcloth. Printing inks use a greater proportion of tung oil than linoleum and oilcloth. Soybean oil is not nearly as important in printing inks as it is in linoleum and oilcloth and paints and varnishes.
CHAPTER VII
ECONOMIC ASPECTS OF PRODUCING DRYING OILS

The over-all objectives of this chapter are (1) to present a thorough description of the economic characteristics of the tung oil industry with chief emphasis upon the economic aspects of supply and cost of production, (2) to isolate those conditions which originate in and are closely associated with the process of production, and (3) to evaluate the elements of supply from the standpoint of their influence upon the market price of the chief product of the industry: tung oil. The industry appears to be subjected to a considerable degree of instability which cannot be wholly accounted for by a consideration of supply and cost of production alone. The problem is more involved than that. Yet, the various conditions under which a commodity is produced eventually will influence the market price of that commodity. As a general rule, those economic forces which originate out of supply do possess the quality of persisting upon certain modifications being made in the market place. "... as a general rule, the shorter the period which we are considering, the greater must be the share of our attention which is given to the influence
of demand on value; and the longer the period, the more important will be the influence of the cost of production on value." ¹ Marshall goes on to explain that the actual price of a commodity at a given time "is often more influenced by passing events and by causes whose action is fitful and short lived" ² than by the more persisting forces which stem from cost of production. But in the long-run, "persistent causes dominate value completely." ³

Cost of production is not the only force of supply-origin which tends to influence the price of tung oil and the stability of the industry in the United States. A more complete investigation will include such factors as annual quantities produced, rate of expansion of domestic orchards, existing quantities of tung oil in stock, the length of the productive period, imports from abroad, and the stability or instability of imports. Of course, the above factors alone do not make a complete list of the forces which determine the price of a commodity. It is the relationship between the composite of all supply factors on the one hand and the composite of all demand factors on the other hand which determines the market price of a commodity. An orderly

² Ibid., p. 349.
³ Ibid., p. 350.
sequence of thought requires that a treatment of a balance between these two sets of opposing forces be delayed until after each set of forces - demand and supply - has been considered individually.

PRODUCING TUNG NUTS IN THE UNITED STATES

The domestic production of tung oil is confined to a relatively small area in the United States. The producing area includes parts of only six states in the southeastern part of the United States. The average annual amount produced constitutes not more than 12 per cent of the average annual amount consumed by domestic consumers. The oil is the principal product of the industry.

Tung meal is a by-product of minor importance to the producer. It is sold by the mill owners as a fertilizer at about $12 per ton. From the standpoint of tung nut producers who are not members of an integrated system, the by-product is of little or no economic value. The nuts are sold to mill owners on an oil-content basis (or processed by mill owners on an oil-content basis) without calculating the value of the meal. Whatever sale price the mill owner can get for the meal accrues to him as additional compensation for processing tung nuts. Of course, the value of the meal may be passed on to the growers in the form of a reduced milling fee. Such a result is highly unlikely, however, on account
of the limited number of mills in the area and the high cost of transporting tung nuts to other than the nearest mill. Growers who are members of a cooperative system receive a direct benefit from the utilization of the meal either as a reduction in the purchase price of the product for fertilizer in their own orchards, or as a reduction in milling costs.

Practically all the tung trees in the United States are grown in cultivated orchards. Very few trees are grown in wild and uncultivated areas. It is true that some trees are grown carelessly in patches, gardens, cemeteries, fence-rows, and on rough hillsides. In such a case, very little attention is given the trees and production of nuts is small. By far the greatest portion of tung nuts produced in the United States comes from well-cultivated orchards. In fact, the whole process of producing tung oil requires technical knowledge.

Expansion of the Domestic Tung Oil Industry

The production of tung oil in the United States on a commercial basis began about 1932. Prior to that time and after the introduction of the tung tree into the United States, activity in the industry was on an experimental basis. According to the United States Census of Agriculture, there were only 350,793 tung trees of all ages in the United States
in 1930. From these trees, a total of 119,310 pounds of tung nuts were harvested and sold at a total market value of $5,969. The trees were grown on 144 different farms.

By 1935, the number of tung trees had increased to 3,632,361, representing a 935 per cent increase in the number of trees. During the five-year period from 1930 to 1935, 3,281,568 trees were added to the domestic orchards. The number of farms on which tung trees were grown had increased to 627.

By 1940, there were 2,304 tung orchards in the United States in which 12,671,344 trees were growing. Since 1935, 9,038,983 trees had been added. In 1940, 2,321,139 pounds of tung nuts were harvested and marketed at a value of $82,523.

The number of orchards had increased to 4,160 by 1945, and the number of trees of all ages had decreased to 9,583,087. At the same time, 62,693,347 pounds of tung nuts were harvested. The 1945 crop was sold for a total of $3,130,197.

The record of the expansion of the tung oil industry in the United States during the fifteen-year period from 1930 to 1945 is contained in Table XXI which follows:

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Table XXI. Tung Orchards, Trees, Production, and Value of Nuts in the United States, 1930-1945

<table>
<thead>
<tr>
<th>Year</th>
<th>Orchards</th>
<th>Trees of all Ages</th>
<th>Production (Pounds)</th>
<th>Yield per tree (Pounds)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930</td>
<td>144</td>
<td>350,793</td>
<td>119,310</td>
<td>13.3</td>
<td>$5,969</td>
</tr>
<tr>
<td>1933</td>
<td>627</td>
<td>3,632,361</td>
<td>9,553,067</td>
<td>119,310</td>
<td>$5,969</td>
</tr>
<tr>
<td>1940</td>
<td>2,304</td>
<td>12,671,344</td>
<td>2,321,139</td>
<td>0.6</td>
<td>52,523</td>
</tr>
<tr>
<td>1945</td>
<td>4,180</td>
<td>9,683,087</td>
<td>62,693,347</td>
<td>6.5</td>
<td>3,150,197</td>
</tr>
</tbody>
</table>

The above figures indicate that the period of greatest expansion on the basis of number of trees of all ages was during 1930-1940 period, and the greatest rate of expansion of production of tung nuts took place after 1940. It is apparent that a time-lag is involved between the time of actual planting of trees and the placing of tung nuts on the market. The length of the time-lag is determined by the length of the productive process -- that is, the time required for a plant to grow from a mere seedling to a full-grown tree capable of bearing a normal crop of nuts. It has been estimated that a tung tree will produce some tung nuts at about three years of age, but that it will not reach its full productive capacity until after the fifth year under normal conditions of care and growth. The yield per tree indicated that in 1930 the number of trees was high relative to the quantity of tung nuts produced. Presumably most of those trees were mere

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Ibid., p. 535
seedlings under three years of age. Considering the fact that the industry was in its infancy at that time, it is highly probable that many of those trees were still in the nurseries.

The production figure for 1935 does not appear in the foregoing table, neither does the yield per tree. However, the number of trees of all ages in 1935 shows that the average net increase in the number of trees had been about 656,314 per year during the previous five-year period. Assuming that the majority of the trees in the 1930 figure had survived and reached full production by 1935, it is very probable that there were about 1,007,107 (656,314 plus 350,793) trees five years of age or over in 1935. Also, there were approximately 2,625,254 (3,632,361 minus 1,007,107) trees below five years of age in 1935. Considering both the increase in the proportion of fruit-bearing trees and the increase in the age of many of them, it seems logical to assume that an increase in both total production, and yield per tree had taken place during the previous five year period.

The production time-lag is revealed still more clearly in the relationships between the figures for 1930 and 1940. In 1940, there were 12,671,344 trees of all ages, in contrast to 350,793 trees in 1930. There were thirty-five times as many tung trees in the United States in 1940 as there were in 1930. Nineteen times more tung nuts were produced in 1940 than in 1930. The product of the trees planted during the 1930-35 period was coming on the market about five years later: in 1940.

There is even stronger evidence of the existence of a production time-lag in the growing of tung nuts in the
relationship between the relevant figures for 1940 and 1945.
In the latter year, 1945, the number of tung trees had decreased from 12,671,344 in 1940 to 9,583,087, and production of tung nuts had increased to 62,698,347 pounds from 2,321,139 pounds in 1940. There were about three-fourths as many trees in 1945 as in 1940; yet about thirty times as many tung nuts were harvested. The decline in the number of trees was due primarily to two factors. First, the tung growers hesitated to enlarge their orchards because of a scarcity of labor during the war period and they anticipated a decline in the market price of tung oil at the end of war. Second, and of primary significance, is the misleading nature of the figures as an indication of the character of tung orchard expansion during the war period. Orchards were enlarged during this period, to be sure; but relative to the rate of expansion during previous periods, the rate of expansion during the latter period appears to be insignificant. Many of the trees planted in former periods were located in areas unsuited for growing tung trees successfully. In some cases, unsound promotional practices were conducted in the industry whereby land not suitable for growing tung trees was sold to prospective tung growers. After it had been demonstrated that trees planted on land purchased in this fashion would not be profitable, they were either destroyed or abandoned. The census reports taken during 1935 and 1940 were unusually high in respect to the number of tung trees and low in respect to production because they included a large number of trees growing in areas described above.

In addition to the influence of unsound and unwise
promotional practices during the 1930's, many sincere efforts were scientifically wrong. Tung growers desirous of enlarging their original orchards made mistakes in locating additional groves on improper soils. They had neither experience nor scientific guidance in an industry which required a great deal of both. Expansion of this type also proved to be unprofitable and in the wrong direction.

With the disappearance of early promotional practices and the development of greater maturity in tung tree culture aided by experience of individual tung growers and the assistance of the United States Department of Agriculture and State experimental stations, further expansion of the industry began to decrease quantitatively after 1940 and to improve qualitatively. Submarginal orchards were abandoned and improvements were made in soil selection and quality breeding to the effect that the total number of trees declined and total production increased.

In spite of the factors which have resulted in a lack of proportionality in the rate of expansion of tung groves and the increase in quantity of production, the existence of a production time-lag is in evidence. The quantity of tung nuts harvested in 1945 shows the influence of sound expansion of tung groves in prior years.

The significance of a production time-lag is based upon the effect which it has upon the prevailing market price of tung oil and the long run stability of the industry. To a large extent, additions are made to productive facilities in
any industry in accordance with present expectations of future returns from such additions. In an expanding and growing industry, such as the tung oil industry, present expectations of future returns become increasingly great. In periods of optimism and high prices, those expectations become even greater and provisions are made for greater production. As long as future prices are in line with present expectations, future returns will tend to be in line with present production. On the other hand, the use of substitutes for a commodity may reduce the price so that future returns will be less than expectations. A relatively long productive process increases the possibility of using substitutes and makes the process of calculating future returns more hazardous and difficult. In the tung oil industry, when more trees are planted and groves are improved in response to an increase in the market price of tung nuts, the arrival of additional quantities of tung nuts on the market is delayed for a period of time equal to the length of the production process, which is three to five years for tung trees. Such a delay causes the domestic supply of tung oil to be sluggish over short periods of time. The sluggish character of supply invites the development of substitutes for tung oil. It tends to encourage additional imports of tung oil. Industrial consumers are induced to use other drying oils as a substitute for tung oil in the manufacturing process.
After the passage of time sufficient to permit the productive process of tung growers to increase the supply of tung oil, the additional quantities may come on the market at an inopportune time. The development of substitutes and alternate sources of supply of tung oil tend to reduce the market price. Therefore, tung oil has to be marketed at prices below expectations of a previous period. The immediate connection between supply and price of tung oil is broken by the influence of short-term forces. The time required to make a fundamental change in the domestic supply of tung oil is in excess of the time required to make the necessary change in the supply of substitutes. The supply of tung oil substitutes appears to be more elastic than the supply of domestic tung oil.

The Elasticity of Supply of Tung Nuts

The responsiveness of the quantity of a commodity supplied or demanded to changes in the price may be stated in terms of elasticity of supply or of demand. It is customary to indicate the degree of elasticity as (1) equal to unity, (2) relatively elastic, or (3) relatively inelastic. Elasticity of supply or demand is equal to unity when "a given change in price produces an equal proportionate change in the quantity" 6 supplied or demanded. A relatively

elastic supply or demand "is one in which a given change in price will produce a finite but more than proportionate change in quantity." 7 Relatively inelastic supply or demand "is one in which a given change in price produces a less than proportionate change in quantity." 8 When the term "elasticity" is used in this study, it is used in the sense indicated above unless it is stated otherwise.

A more complete understanding of the elasticity of the supply of tung nuts may be had by observing the relationship between the actual market prices at which tung nuts were brought to market during a representative number of years and the quantities which were marketed at each of the various prices. The rate of change in the quantities of tung nuts which are placed on the market resulting from a similar change in the market price is an indication of the elasticity of supply. A comparison of this relationship of each of the principal substitutes for tung oil with that of other oils indicates the relative abilities of the interchangeable commodities to effect a change in supply. Other things being equal, the commodity which is most responsive to changes in the market price (highest degree of elasticity of supply) is in the most favorable competitive position. Because

7 Ibid., p. 131.
8 Ibid., p. 132.
changes in the quantity of a commodity produced under conditions of relatively elastic supply can be made most readily, an increase in price will permit a greater than proportionate increase in the quantity of the commodity to be marketed. Likewise, a decrease in price will bring about more than a proportionate decrease in the quantity of the commodity which will be brought to the market.

A record of domestic production of tung nuts since 1939 is shown in the table below, together with a record of the average price received by the growers and the total value per year of tung nuts marketed.

Table XXII. Production, Price, and Farm Value of Tung Nuts Produced in the United States, 1939-1949

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (Tons)</th>
<th>Price in Dollars Per Ton</th>
<th>Farm Value ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>1,160</td>
<td>$42.20</td>
<td>$49</td>
</tr>
<tr>
<td>1940</td>
<td>11,000</td>
<td>60.00</td>
<td>660</td>
</tr>
<tr>
<td>1941</td>
<td>8,750</td>
<td>83.30</td>
<td>773</td>
</tr>
<tr>
<td>1942</td>
<td>16,350</td>
<td>91.80</td>
<td>1,501</td>
</tr>
<tr>
<td>1943</td>
<td>6,200</td>
<td>99.00</td>
<td>614</td>
</tr>
<tr>
<td>1944</td>
<td>26,680</td>
<td>108.00</td>
<td>2,730</td>
</tr>
<tr>
<td>1945</td>
<td>37,080</td>
<td>98.90</td>
<td>3,667</td>
</tr>
<tr>
<td>1946</td>
<td>57,400</td>
<td>96.90</td>
<td>5,864</td>
</tr>
<tr>
<td>1947</td>
<td>53,200</td>
<td>73.60</td>
<td>4,909</td>
</tr>
<tr>
<td>1948 (1)</td>
<td>58,500</td>
<td>49.10</td>
<td>2,873</td>
</tr>
<tr>
<td>1949 (1)</td>
<td>66,100</td>
<td>62.10</td>
<td>4,105</td>
</tr>
</tbody>
</table>


It may be observed that the relationship between the degree of change in quantity and the degree of change in price is not a constant one. As an over-all proposition, the quantity of production increased by about 64 times during the entire period; whereas the maximum price received during the period from 1939 to 1949 was slightly less than two and one-half times the minimum price, and the maximum price did not coincide with the maximum quantity from the standpoint of time. For any given year, there seems to be very little connection between quantity and price. Consequently, the tung industry is characterized by a high degree of instability. This situation is doubtless the origin of many of the troubles of the industry.

The elasticity of supply of a commodity varies with the length of time required to effect a change in the quantity produced. There are three time-periods involved in the production of a commodity. The first is the "market time," which may be defined as "time long enough to permit increases or decreases in the rate of sale from a given stock of goods on hand which the seller does not have time to alter by purchase or production." 9 The quantity included in the stock is known as market supply. The second time-period is known

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as the short-run. It may be defined as a period "long enough to permit expansion of production by the use of additional variable factors but not long enough to permit an increase in fixed factors." 10 The quantity of a good produced within the short-run is known as short-run supply. The third time-period in the production of a good is the long-run. This period may be defined as "time long enough to increase the quantity of 'fixed factors' employed...." 11 The quantity of a good produced within the long-run is known as long-run supply.

Market Supply

When the supply of tung nuts is taken to include only those nuts which have already been produced and are in stock ready to be sold, price movements will have very little effect upon quantities offered for sale. The connection between price and cost appears to be broken, and the supply curve tends to be inelastic. The nuts can not be withheld from the market from one year to another, because they can not be stored successfully for that length of time. Consequently, the reservation price of the seller is very low, and a very low price is sufficient to attract the entire market supply, even though it is insufficient to cause an increase in the quantity produced over longer periods of time.

The market supply of tung nuts includes those quantities which are at the crushing mills and other collecting

10 Ibid., p. 196
11 Ibid., p. 203
centers at any given time. It also includes those quantities which will be transported to the mills and offered for sale by growers who have full knowledge of the condition of the market at any given time. From the standpoint of the individual producer, market supply includes those quantities which have already been picked-up, placed in bags, and are ready to be transported to the crushing mills, so long as the anticipated marginal cost of transporting them to the mill is less than the market price. The producer would profit more, or lose less, by transporting the nuts to the processing plant than he would by leaving them in the orchards. As long as the current practice prevails among tung-nut haulers of charging for their services on the basis of tonnage and distance from the mill, quantities of tung nuts included in the concept of market supply will tend to vary inversely with the distance of the tung grove from the nearest crushing mill.

Market supply appears to be a limited quantity which varies from locality to locality and from time to time in accordance with varying circumstances of production and marketing and the attitude of the individual seller. The length of the supply period varies from one day to several. The character of supply in each market is likely to be relatively inelastic, because the power of price changes to influence the quantity of nuts which will be brought to the market is relatively low.
Short-run Supply

Short-run supply of tung nuts includes the quantity which can be produced within a growing season from existing orchards. Not only must the price be high enough to cover the costs of cultivating the orchards in the usual manner, but it must be high enough to cover extraordinary variable costs as well as some of the fixed costs before there will be an increase in short-run supply. Within the short-run, the price of tung nuts must be high enough to cover average prime cost plus a portion of supplementary cost in order to bring forth the desired quantity. This price is known as the short-run supply price.

The minimum time required for changes in the market price of tung nuts to bring about a change in the quantity which will be placed on the market is less than one year. The harvest period begins soon after the first frost in the area and is completed within two and one-half or three months. During October, November, and December, the nuts fall to the ground and, after a reasonable drying period, they must be moved either to temporary drying barns or to the crushing mills and to the market. Tung nuts which have been stored properly in drying barns cannot remain there from one season to another without injury and loss in value through a chemical reaction of the acid within the kernels. "The crops maturing in the fall must be processed by the following May
or June to avoid deterioration." 12 The actual marketing period extends over six or seven months during the year.

No attempt is made in this study to determine the degree of elasticity of short-run supply. The price and quantity figures listed in the table on page 117 are not suitable for that purpose. They are stated in terms of annual average prices and annual quantities; whereas short-run supply of tung nuts is taken to mean only the quantity which is produced in less than a year. It is probable, however, that this concept of supply is relatively inelastic for the entire tung industry, as well as for individual producers. In the first place, the tung growers are inclined to bring the nuts to the crushing mills as soon as they have dried sufficiently, because storing them in temporary storage sheds tends to increase the cost of handling and to increase the hazards of deterioration. The growers tend to disregard prices to some extent in order to move the crop to the market as soon as it is harvested. This situation tends to render supply relatively inelastic.

Because of the perennial character of tung trees, the growers will bring the minimum normal short-run supply

12 Wilson Kilby and G. F. Potter, Tung Culture in Southern Mississippi, Revised, Agricultural Experimental Station, Mississippi State College, State College, Mississippi, (June, 1949), p. 34.
of nuts to the market only when the price is high enough to cover the essential average variable cost - that is, the cost of picking the nuts from the ground and bagging them. These cost items are considered to make up the very minimum variable costs, and as long as the price is high enough to pay these costs plus an amount to pay for at least a part of the fixed costs incident to operating a tung farm, an annual crop produced without the use of fertilizer, cultivation, or other extraordinary efforts on the part of the grower will move to the market.

Should the price rise above the level of average ordinary variable cost, the quantity of tung nuts produced and offered for sale will tend to be more responsive to price changes. With the price high enough to justify extraordinary cost and effort, the tung growers would be encouraged to intensify cultivation and harvesting practices. More intensive cultivation means that fertilizer will be used, the disk and spring-tooth harrow will be used to cultivate the orchard, cover crops will be planted, and the orchards will receive better care. More intensive harvesting practices means that efforts will be made to eliminate waste, fewer nuts will be left on the ground, and extra cost will be incurred to gather nuts from scattered or isolated trees.

It has been demonstrated that more intensive cultivation of tung trees will bring forth greater production
In other words, an increase in variable costs will bring about an increase in the quantity produced. An increase in total variable cost will be made only when the price of tung nuts increases sufficiently to justify the extra expenditure. Therefore, if an increase in price of tung nuts will bring about an increase in total variable costs, and if an increase in total variable costs will bring about an increase in the quantity of tung nuts produced, an increase in the price will increase the production of tung nuts.

A case may be cited in which additions were made to variable costs of producing tung nuts under experimental conditions. An experiment was begun at the Experimental Tung Field near Poplarville, Mississippi, in 1941, "to determine the most economical rate of fertilising tung." 13 Trees were planted on four different plots of land which were very similar in type. For a period of seven years (1942-1948) varying portions of fertilizer were applied to the trees. The results in terms of output and growth of the trees were noted and recorded. A summary of the yield in tung nuts is given in the table below. Efforts were made to keep all variable costs constant except fertilizer. It is an experimental case in which additional quantities of fertilizer were added to constant quantities of land, labor, management

and capital.

Table XXIII. Production of Tung Nuts on Experimental Tung Field, 1942-1948

(Yield in tons per acre)

<table>
<thead>
<tr>
<th>Year</th>
<th>Plot I (No fertilizer used)</th>
<th>Plot II (¼ pound per tree)</th>
<th>Plot III (½ pound per tree)</th>
<th>Plot IV (1 pound per tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942</td>
<td>.002</td>
<td>.012</td>
<td>.012</td>
<td>.011</td>
</tr>
<tr>
<td>1943</td>
<td>.400</td>
<td>.090</td>
<td>.087</td>
<td>.105</td>
</tr>
<tr>
<td>1944</td>
<td>.245</td>
<td>.338</td>
<td>.415</td>
<td>.468</td>
</tr>
<tr>
<td>1945</td>
<td>.496</td>
<td>.713</td>
<td>.868</td>
<td>1.073</td>
</tr>
<tr>
<td>1946</td>
<td>.670</td>
<td>.787</td>
<td>.972</td>
<td>1.376</td>
</tr>
<tr>
<td>1947</td>
<td>.279</td>
<td>.437</td>
<td>.586</td>
<td>.859</td>
</tr>
<tr>
<td>1948</td>
<td>1.097</td>
<td>1.223</td>
<td>1.550</td>
<td>1.913</td>
</tr>
</tbody>
</table>

Source: Mississippi Farm Research, Mississippi Agricultural Experimental Station, Dec., 1949, p. 7.

In the first place, the table shows that the use of fertilizer does increase the yield of tung nuts per tree and that the amount of the increase in yield varies with the age of the tree. In 1942, when the trees were only one year old, the highest yield was obtained from Plots II and III with the use of ¼ pound and ½ pound of fertilizer used on the respective plots. For each year after 1943, the highest yield was obtained from Plot IV with the use of 1 pound of fertilizer. However, the rate of increase in production as a result of the use of fertilizer appears to decrease as the trees grow older. In 1948, when the trees were nine years of age, the yield was 1.097 tons per acre without the use of fertilizer. Only 1.913 tons per acre were produced with the use of...
1 pound of fertilizer per tree.

Some observations may be made from the above study which will be useful in determining the elasticity of short-run supply of tung nuts. First, the record of the experiment shows that the amount of fertilizer used in Plot III was twice the amount used each year in Plot II, and the amount used in Plot IV was twice the amount used in Plot III. In other words, the amount of fertilizer was doubled in each case. On the other hand, the yield was less than doubled in each case. The responsiveness of supply to changes in only one item of variable cost was less than unity (relatively inelastic). Further experimental research of this nature is needed to determine the most productive use of cultivation practices on tung trees of varying ages. If the older trees do not respond to cultural practices any better than they do to the use of fertilizer, some of the costs of cultivating trees in the higher age brackets may be discontinued with profit.

Tung growers will refrain from increasing variable costs until the price rises high enough in their estimation to justify it. If fertilizer is representative of other variable cost items, additional applications of capital and labor to the existing orchards will bring forth greater production of tung nuts within the limit of profitable employment of such additional capital and labor. From the point of view of the individual tung grower, the point of most
profitable employment is determined by the relationship between marginal cost per ton of tung nuts produced and marginal income per ton. Marginal income is equal to the price per ton. Therefore, the producer may employ additional quantities of capital and labor so long as the additional cost per ton does not exceed additional income per ton.

Short-run supply of tung nuts appears to be relatively inelastic, but more elastic than that of market supply.

Long-Run Supply

The long-run supply of a commodity consists of the quantity which is produced as a result of the fixed factors employed in the production of that good. Changes in the quantity of a good produced as a result of changes in the fixed factors employed are regarded as changes in the long-run supply and are of considerable importance in determining the elasticity of this concept of supply. Changes in long-run supply may result from either a net increase or a net decrease in fixed factors. The time required for a change in long-run supply to take place after a change has been made in the fixed factors depends primarily upon the peculiar characteristics of the product and the method or process by which it is produced. As a general rule, manufacturing establishments which make use of existing raw material in producing other goods can bring about a change in the quantity of goods offered in the market by changing the physical plant. The time required to effect a change
in the long-run supply of the product being produced varies with the time required to effect a change in the fixed factors employed. Producers who are engaged in the production of goods which are obtained from agricultural and forestry commodities can not bring about a change in long-run supply without allowing sufficient time for the crops to grow to maturity and produce the desired commodities. The time required for growers of agricultural commodities to effect a change in long-run supply is determined primarily by the length of time required for their particular crops to grow to maturity and produce a crop sufficient for commercial distribution. Variations in the pre-productive growing period of the various agricultural plants is fixed rather definitely by nature. Of course, plants may grow to maturity quicker by proper care and attention than they would without such care, but such accomplishments are limited. The growing period of crops which are produced annually may be reduced by a few days, or perhaps weeks, by favorable climatic conditions and the exercise of proper care. Perennial plants which do not grow to maturity and produce commodities within a year may be made to yield a greater quantity by proper care and favorable growing conditions. On the other hand, the pre-productive growing period of perennial plants may not be made to conform to the pre-productive growing period of annual plants. Therefore, the time required to effect a change in
the long-run supply of commodities produced from annual plants is shorter than the time required to effect a change in the supply of commodities produced from perennial plants. The time-elasticity of long-run supply of commodities obtained from annual plants is less than that of commodities obtained from perennial plants.

In the case of tung nuts, long-run supply consists of the quantity which may be produced within a given long-run period by changes in the number of producing trees. Changes in this concept of supply may take place as a result of either an increase or decrease in the number of producing trees. Producers increase or decrease the number of producing trees as a result of similar changes in the current and anticipated market price of tung nuts. The time required for the quantity of tung nuts produced by the entire industry to increase as a result of an increase in price is equal to the time required for young seedlings to be grown in the nurseries, transplanted to the orchards, and to grow to maturity capable of producing a normal crop of tung nuts. It appears that, under favorable conditions of growth, tung trees will reach maturity at about three years of age and, under less favorable conditions, they reach maturity at about five years of age. The elasticity of supply is concerned with the relationship between changes in the quantity produced as a result of similar changes in the market price. When supply is considered in the long-run sense, elasticity
is indicated by the ratio of the change in quantity to the change in price within a particular long-run period. The responsiveness of supply to changes in price usually is less sluggish over long periods of time than it is within the short-run. The price of tung nuts must rise high enough, in the long-run, to cover both fixed and variable costs (average total cost) of the highest cost grower whose supply is necessary to satisfy the demand for tung nuts in order to maintain constant and stable production. The price must rise above the lowest average total cost of the marginal producer in order to bring forth a greater supply. The average total cost curve is the supply curve in the long-run and under conditions of pure competition. The average total cost curve does not rise as fast as either the variable cost curve or the marginal cost curve. The extent to which the quantity of tung nuts offered in the market increases in response to an increase in the price depends upon the conditions of cost of marginal producers. Conditions of increasing cost tend to reduce the elasticity of supply as less efficient factors are appropriated to tung production. There is evidence that, from the point of view of the industry as a whole, tung nuts currently are being produced under conditions of increasing costs. To be sure, some of the individual tung growers may be operating temporarily under conditions of decreasing cost. Individual growers may be utilizing an uneconomical combination of factors. The
many small producers in the industry who have only a few acres in tung orchards probably operate under conditions of decreasing cost year after year. Unit cost of capital investment tends to be high when the quantity of output is limited because of limited acreage. Under such conditions, utilization of more land with the same investment in operating equipment would tend to reduce unit cost by spreading fixed cost over greater output. In addition, it is probable that some of the medium size producing units could reduce total cost by enlarging their orchards. On the other hand, the greatest portion of the domestic supply of tung nuts comes from the large orchards; and, by their very size, the large orchards are the producing units which influence supply most. Also, the large producing units influence elasticity of supply through the effect which they have upon the total cost curve for the industry. The most profitable orchards are those which are being operated at that level of output which is produced at the least total average cost. Such producers enjoy maximum utilization of all factors of production. An increase in the use of any factor, especially land, would disturb the least cost combination and increase total unit cost of production. The most profitable combination of factors at a greater level of output would be at a higher cost per unit than at a previous combination, because of increasing opportunity cost of additional factors.
When the large tung growers attempt to expand their orchards and increase production primarily by utilizing greater quantities of land, the cost of obtaining the land for tung growing purposes must be at least as high as the price which could be obtained by the landowner either through sale, use or rent of the land for its next most profitable alternative use. For example, land located in the tung belt which may be used profitably for growing tung nuts and as pasture land for livestock may not be obtained by tung growers for less than what the livestock growers would be willing to pay for it. The two groups - tung and livestock growers - would be competing in the market for the use of the land. Even if the profitability, and therefore the value, of land in the tung belt for non-tung growing purposes is assumed to be constant, the natural geographic and climatic limitations on the use of land for growing tung trees will tend to broaden the spread between the profitability, and therefore the value of land for tung growing purposes and its next most profitable alternative value, as additional quantities are used for growing tung trees. Further land utilization for tung orchards will result in opportunity cost (alternative value) exceeding its value for tung purposes and will tend to fix a limit on the expansion of the tung industry landwise until the price of tung nuts rises further. A rise in price encourages further expansion and utilization of more land. Further utilization of land
encounters still more valuable alternative uses and greater opportunity costs. To the extent that opportunity cost per unit of output rises higher than the increase in market price during a long-run period, elasticity of supply tends to be reduced.

Not only must the market price of tung nuts rise to or above the opportunity cost of land before greater quantities of nuts will be produced, but it must rise to or above the total average opportunity cost of all factors of production, including labor, management, and capital. However, the cost of other factors will not rise as rapidly as the cost of land as expansion of the tung oil industry takes place and greater quantities of all factors are used in the production of tung nuts. The limitations on the supply of other factors do not appear to be as definite and rigid as limitations on the supply of land suitable for growing tung trees. Limitations on the availability of tung-producing land are fairly definitely established by soil and climatic requirements; while other factors, especially capital, may be employed in the industry without the necessity of overcoming such qualifying limitations. When it becomes profitable to employ additional capital in the industry, there are no restrictions on the availability of the supply of capital because of industrial requirements peculiar to the industry. The availability of labor is not limited by qualification requirements peculiar to the
industry. The lack of special restrictions on the supply of factors of production, other than land, renders them available for tung growing purposes.

As the tung industry expands and employs greater quantities of all factors, the opportunity cost of labor, capital, and management tends to rise somewhat less than the opportunity cost of land. Since land is the principal cost item in the fixed-plant expenditures of a tung grower, it appears logical to conclude that those growers who attempt to increase the production of tung nuts by enlarging existing orchards or by adding new ones will be able to do so only by encountering conditions of increasing costs. A definite calculation of how much costs will increase with a given increase in output can not be made with this method of reasoning. No such definite calculation is attempted. Knowledge of the fact that the tung industry has expanded to or beyond the most optimum level of output and that additional orchards may be established only by increasing unit cost gives very strong support to the conclusion that the elasticity of long-run supply of tung nuts is less than infinite and that supply tends to become inelastic as output increases.

Summary Statement of Supply Periods

In the preceding pages an attempt has been made to analyze the most important economic aspects of growing tung nuts. It is hoped that this analysis will serve at least as a partial explanation of the competitive position of tung oil
in respect to other commercial drying oils. A thorough under­
derstanding of the underlying forces determining the supply­
elasticity of each of the competing drying oils may be of
considerable value in establishing a basis of comparison.
It appears that the supply price-elasticity of tung oil does
not differ radically from the supply price-elasticity pat­
tern of the majority of agricultural products. The degree
of elasticity varies with the period of time under consider­
ation. Within the very short-run period - market supply -
there is a tendency for supply to be relatively inelastic.
The difficulty and hazards of storing tung nuts until a bet­
ter market situation exists appears too great to permit
growers to withhold nuts from the market for a very long
period of time. Consequently, tung nuts are placed on the
market as they are harvested for whatever price they will
bring. So long as the prevailing price, which is determined
by the relationship between total supply and total demand,
is high enough to cover actual out-of-pocket costs, the en­
tire crop of nuts will be brought to market. A change in
price will have very little effect upon the quantity offered
for sale. Such a situation is characteristic of a commodity
of relatively inelastic supply.

Within the short-run period, which is about one year
in this particular case, the supply-elasticity of tung nuts
tends to be greater than in the shorter period. To the
extent that producers have knowledge of their cost curves
and that they employ variable cost factors in such a way as to maximize profits, the marginal cost curve becomes the supply curve. There is a strong tendency that the marginal cost curve does become the variable cost factor supply curve, because individual growers endeavor to familiarize themselves with cost conditions as a result of experience and maturity. Graphically, the marginal cost curve rises faster than the average total cost curve; therefore, short-run supply-elasticity, which is determined by the relationship between price and marginal cost, is less elastic than long-run supply.

By a similar method of reasoning, it may be established that the supply-elasticity of the long-run period is greater than the supply-elasticity of shorter periods. In the long-run, price must be high enough to cover all costs; therefore, price is determined by supply, average total cost, and demand. Average total cost does not rise as fast as marginal cost under conditions of increasing cost. Long-run supply-elasticity tends to be somewhat greater than either market or short-run supply-elasticity.

**IMPORTING TUNG OIL**

Approximately 90% of the total amount of tung oil consumed in the United States annually is imported from foreign countries, principally China, Argentina, and
Paraguay. From the standpoint of quantity, this situation imposes a serious problem for the domestic tung oil industry and injects instability into the price structure of far-reaching consequences. With stable consumption in the United States, even a slight percentage increase in imports of tung oil from abroad will produce a relatively great effect upon the domestic market. With other factors remaining unchanged, a given percentage increase in imports tends to reduce the quantity of domestic tung oil purchased by a much higher percentage. Likewise, a given decrease in quantities imported tends to increase the quantity of domestic tung oil purchased by a higher percentage. Thus, tung oil imports tend to produce an inverse leverage effect upon the domestic market.

Other factors do not remain unchanged, however, and the problem is more involved than the above statement suggests. What is the price-elasticity of imports from China? Does the time-elasticity of tung oil imported from China differ from that of tung oil produced in the United States? These questions suggest some of the most important economic problems of tung oil imports into the United States. It may be observed that they are related to the method in this chapter of comparing the competitive positions of drying oils.
Price-elasticity of Imports from China

Certain descriptive features of the Chinese tung oil industry were pointed out in a previous chapter dealing with that particular source of drying oils. Some of those features become increasingly important for the purpose of this study. The fact that the Chinese industry is an old one is of particular significance. The maturity of the tung trees provides an ever-ready source of nuts to be processed and placed on the market when it becomes profitable to do so. Out-of-pocket cost of harvesting and marketing tends to determine the nature of the supply curve. Costs, and therefore minimum price determinants, begin at the time of harvest. Under conditions of rising prices, additional quantities of nuts will come forth when the price rises high enough to cover the additional out-of-pocket cost of harvesting and marketing. There is a tendency for both opportunity cost of land and the principle of diminishing returns to have a minimum effect upon the cost curve and, therefore, the elasticity of supply. The abundance of land suitable for growing tung trees in the interior of China plus the lack of alternative industrial uses of land exercise a negative influence upon opportunity costs. Variable out-of-pocket cost of harvesting and marketing tung nuts from mature trees excludes cost of intensive land cultivation in which the principle of diminishing returns plays an important part. The exclusion of land utilization cost reduces the disadvantage of an increasing cost industry and produces a more
elastic supply curve.

The second distinguishing feature of Chinese-produced tung oil is the fact that it is grown in uncultivated groves. There are some well-cultivated tung orchards in China, especially in the southwestern region of the interior, but the greatest portion of the exported oil comes from undomesticated trees growing in uncultivated groves. This situation enables Chinese tung nut collectors to avoid not only the variable cost of cultivation but the fixed cost of capital investment in land and machinery as well. In contrast to the producing practices in the United States, Chinese producers are able to sell tung nuts at a very low price. Their "reservation price" is below that of American producers, on account of the absence of these important cost factors. It would be necessary for prices to go very low before the supply would disappear. At a lower price range, these considerations tend to produce a relatively elastic supply.

A third factor influencing supply-elasticity of Chinese tung oil is the condition of industrial development under which it is produced. It was shown in Chapter 3 that both Chinese harvesting and producing methods are very crude. The use of capital investment in machinery is noticeably lacking and the use of hand labor plays a very important role throughout the industry. It is a well-known economic principle that an industry which makes use of a relatively great amount of hand labor, especially unskilled and semi-skilled labor, and minimizes the use of labor saving
machinery tends to be a constant cost industry. It appears that this fact alone presents a strong case for an elastic supply curve for the Chinese tung oil industry as a whole. There are other factors which tend to nullify the effect of hand labor and make supply less elastic, nevertheless, the influence of this factor is significant. Final judgment must be deferred until other similar factors have been developed.

Still other factors influencing cost and supply-elasticity are location of tung producing area, transportation facilities, distance to market, and political and military situation. The principal producing area is situated in the interior along the Upper Yangtze River a great distance from an export center. Nuts are brought from the groves to the local mills by crude transportation methods and the oil is transported to larger collecting centers by Chinese coolies and pack animals. Navigable streams serve as the principal means of transporting to export centers. These factors make those producers located in the remote interior high cost producers. There appears to be a direct relationship between distance from the better navigable streams and cost of production. This situation reduces the responsiveness of supply to changes in price and, therefore, reduces the elasticity of supply.

At the present time, the United States is the principal consumer of Chinese tung oil. It is a product which
finds its best market outlets in countries with high industrial activity. Other countries using considerable quantities are Great Britain and Canada. Prior to the recent war, Germany and Japan were important consumers. Thus, the primary tung oil markets are great distances from China. The transportation expense of getting the oil to market increases the cost which must be covered by market price before the desired quantity will be produced. However, ocean transportation has the earmarks of a decreasing cost industry, especially when the commodity being hauled is of a specialized nature. The special equipment required to transport tung oil constitutes a fixed cost which decreases per unit in proportion to the volume of business handled. Conditions of decreasing cost do not reduce price-elasticity of supply.

Political and military conditions in China and other countries of the Far East have a direct effect upon quantities of goods exported. Chinese exports of tung oil to the United States dropped to a very low level during World War II, thus causing the market price in the United States to be at an all-time high. Exports increased during the post-war period in the face of declining prices. It is clear that political disturbances do have some effect upon the flow of export goods from China. The extent of the effect is difficult to determine because of the frequency of occurrence in the past and the apparent uncertainty of the future. It does seem logical, however, to conclude that great effort
will be made to export as much tung oil from China as possible in the future regardless of what party or group is in power. This commodity is China's most important item of export and its primary means of obtaining currency balances abroad. For this reason, it would not be sound policy for the tung oil industry in the United States to depend upon the persistence of political disturbances in China to maintain a low rate of tung oil imports into this country.

Summary and Conclusions of Elasticity Factors

In the preceding section the underlying forces determining supply-elasticity of Chinese tung oil were considered. No attempt has been made to include all possible factors which have some bearing upon elasticity. Instead, only those factors having the greatest effect upon supply-elasticity of this particular commodity are included. Some of the factors listed above have a positive effect; while others have a negative effect. Those having a positive effect tend to increase supply-elasticity, and those having a negative effect tend to make the supply curve more inelastic. These factors may be classified and evaluated collectively to ascertain an estimate of the nature of the supply curve for the entire industry.

Positive Factors:

I. A relatively large portion of the producing tung trees in China has reached a mature age.

I. The effect of opportunity factor cost and the principle of diminishing returns upon
cost curves is negligible
2. Out-of-pocket cost is the primary determinant of the individual cost curve
3. Factors 1 and 2 produce conditions of constant cost and inject a high degree of elasticity into cost curves

B. Chinese tung oil is obtained from uncultivated trees
1. Variable cost of cultivation is unnecessary
2. Fixed cost of investment in machinery and equipment for the individual producer is negligible
3. Out-of-pocket cost of harvesting determines reservation price of tung nuts at a constant or uniform level
4. A series of constant cost curves produces an elastic cost curve for the industry

C. Chinese tung oil is produced by crude methods
1. A great amount of unskilled labor is used in harvesting and processing operations
2. An abundance of unskilled labor and use of small amount of machinery produces constant cost curve and relatively elastic supply

II. Negative Factors

A. Chinese tung producing area is located in the interior
1. Variation in location of individual producers causes individual cost curves to vary in amplitude
2. Costs tend to vary directly with distance of producer from market outlet
3. A series of individual cost curves conditioned by location factors produces a condition of increasing cost for the industry
4. An increasing industrial cost curve renders supply to be inelastic

B. Transportation requirements constitute a major problem for the Chinese tung oil industry
1. Transportation cost varies directly with transportation needs - variable cost.
2. High and low variable cost producers in the same industry produce an increasing cost curve for the industry
3. An increasing cost curve for the industry tends to make supply inelastic
Chinese tung oil is produced primarily for foreign markets
1. The oil is transported in specially equipped steamers
2. Cost of special equipment is a fixed cost for steamship companies
3. High fixed cost tends to produce an elastic supply when prices are rising and an inelastic supply when prices are falling

If each of the foregoing factors affected supplyelasticity to the same extent and all other possible factors could be excluded from having any bearing upon supply, the positive and negative factors would nullify each other. There would be no net change in the elasticity of supply as a result of the underlying factors. That, however, is not the case. It may be recognised readily that no pair of positive and negative factors necessarily have the same effect upon supply elasticity. On the other hand, the apparent superiority of the positive factors constitutes very strong evidence that the collective strength of these factors is greater than the collective strength of negative factors. Deductively, therefore, the most logical conclusion is that the supply of tung oil imported from China is relatively elastic. No quantitative value may be obtained by this method of analysis, nor is it necessary for this study. More exact values may be assigned to the concept of time-elasticity in the following section.

**Time-elasticity of Imports from China**

While the concept of price-elasticity of supply refers to the quantitative responsiveness of supply to changes in
price, the concept of time-elasticity refers to the period of time required for adjustments to be made in supply as a result of a change in price. Time-elasticity of supply is very important in situations wherein two or more goods may be used interchangeably in the manufacture of a primary product. It is especially important in the field of commercial drying oils. As a general rule, the product which has the shortest time-elasticity is in the most favorable competitive position. When prices are rising, the commodity with short time-elasticity can expand output and take advantage of a preferred market; and when prices are falling, that same commodity can make the necessary adjustments in supply and maintain a higher and more stable price than the substitutes which have a longer time-elasticity.

The time-elasticity of tung oil produced in China is shorter than that of tung oil produced in the United States. This salient fact arises out of differences in production methods employed in the two countries. The longest supply period associated with the Chinese method of production is comparable to the short-run period in the United States, which is one year or less. It is similar, in some respects, to the market-supply period in the United States. It may be recalled that the long-run supply of tung nuts includes quantities produced by additions to orchards and increasing the number of producing trees. The time required to effect an increase in supply is at least three
years, and the average total cost curve becomes the supply
curve in the long-run. In China, where tung trees grow
wild, no change in the number of producing trees takes place
through the efforts of individual producers. Long-run sup­
ply is a static concept, remaining constant as prices go
up and down. When market prices fall below out-of-pocket
cost of harvesting and marketing, the nuts become submargi­
nal and go unharvested to waste away in the groves. The
most significant change in supply is of a short-run charac­
ter. When prices rise above out-of-pocket cost, the con­
nection between price and cost is broken. The time required
to effect a fundamental change in supply is limited to the
time required for existing trees to yield a new crop plus
the time required for the crop to be harvested and placed
on the market. When prices are high, extra effort is made
to gather more nuts. When prices are low, submarginal
nuts remain ungathered. Under conditions of pure competi­
tion, the supply of goods produced in this fashion becomes
infinitely elastic and the time required for elasticity to
develop is limited to a maximum of one year when prices rise
and to a few weeks when prices fall.

The time-elasticity of Chinese-produced tung oil is
in contrast to that of domestic oil. The Chinese oil has
a time-competitive advantage of at least 2 to 1 in a rising
market. When additional quantities of oil are demanded in
the United States and prices rise accordingly, the additional
quantity required to satisfy the demand may be obtained from Chinese sources before American producers can increase output through orchard expansion. The long-run supply of the American producer must compete with the short-run supply of the Chinese producer.

The above conclusion can be strengthened very forcefully by use of data. There are two quantity series in the table below. The first column contains quantities of tung oil imported from China annually during the post-war period and the second column contains quantities produced annually in the United States during the same period.

Table XXIV. Imports from China and Domestic Factory Production of Tung Oil, 1944-1949

<table>
<thead>
<tr>
<th>Year</th>
<th>Imports from China (Pounds)</th>
<th>United States Factory Production (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>31,536</td>
<td>2,558,000</td>
</tr>
<tr>
<td>1945</td>
<td>10,353,000</td>
<td>10,353,000</td>
</tr>
<tr>
<td>1946</td>
<td>34,378,362</td>
<td>11,046,000</td>
</tr>
<tr>
<td>1947</td>
<td>121,105,173</td>
<td>12,680,000</td>
</tr>
<tr>
<td>1948</td>
<td>129,578,355</td>
<td>16,837,000</td>
</tr>
<tr>
<td>1949</td>
<td>52,392,000</td>
<td>19,465,000</td>
</tr>
</tbody>
</table>

Source: Compiled from Census Reports, Bureau of Census, United States Department of Commerce.

Chinese exports of tung oil declined to a very low level during the war and ceased completely during 1945. During the first post-war year, 1946, exports immediately increased to the level of the early war years. At the same time, United States production was very high as a result of
orchard expansion of prior years. During the second post-war year, 1947, imports from China increased by approximately 350%; whereas, the domestic supply increased by less than 15%. In other words, Chinese producers were able to restore production to a normal level within a period of less than two years and reap the benefit of a favorable market; while American supply was less responsive to that same market. Because of the short time-elasticity of the Chinese supply, that oil can glut the market before the United States supply can reach the market with its longer time-elasticity.

**Imports from Latin America**

Even though very small quantities of tung oil have ever been imported into the United States from sources in Latin America, the possibility of oil from that region becoming a serious competitor of domestic oil merits inclusion of it in a long-run economic analysis of the tung oil industry in this country. Brazil, Paraguay, and Argentina are the principal producing countries and, in many respects, the situation in those countries parallels that in the United States. First of all, both Latin America and the United States are high-cost tung producing areas. Soil and climatic conditions prevent tung trees from growing as freely and as abundantly in Latin America as they do in China, the most natural source of tung oil in the world. The area of successful production is confined to the southern part of Brazil, Paraguay, and northeastern Argentina which corresponds
to the latitudinal position of the producing area in the United States. The lack of a natural habitation makes it necessary for tung trees to be grown in well-cultivated orchards. This requirement results in a cost structure similar to that of nuts grown in the United States. The price-elasticity of supply, therefore, is not greatly different from domestically produced tung oil.

The second point of similarity between the tung growing practices of Latin-American countries and the United States is that the orchards in each area are relatively young and are expanding. Demand for tung oil in excess of normal short-run supply is satisfied only by expanding orchards and increasing long-run supply. The expanding process is similar in both areas. The time required to effect a change in supply is about the same. Time-elasticity of Latin-American tung oil is very similar to that of domestically produced tung oil.

PRODUCING LINSEED OIL

Outside of the field of specialized uses, linseed oil probably is the most serious competitor of tung oil. It possesses qualities which make it useful for a wide variety of purposes, and it is one of the most firmly established drying oils on the market. As a competitor of tung oil, therefore, its ability to maintain a price advantage is of major importance. In keeping with the method
of approach employed in other chapters, the problem of relative price determination of linseed oil may be approached from the standpoint of supply-elasticity.

Price-elasticity of Supply

Linseed oil is obtained from the seed of the common flax plant which is grown commercially for the seed and for fiber. There are two different types of the common variety of the plant. One has been developed for high seed yield; whereas the other yields a high quality of fiber. The plant may be grown under different climatic conditions, but it is grown successfully in the temperate regions. It is grown chiefly for seed in Argentina, India, United States, and Canada. Argentina is the principal exporting country. It is grown extensively in Russia for both the seed and fiber.

The principal flax-producing centers in the United States are situated in Minnesota, North and South Dakota, and California. In Minnesota and the Dakotas, the producing units are small and high in number; and the flax farms appear to be larger in California. The great number of producing units and homogeneous quality of flax seeds results in a market situation for the producers resembling pure competition. Ordinarily, the industry cost curve for

14 Encyclopaedia Britannica, IX, (1946), p. 364
agricultural commodities is U-shaped and, under conditions of pure competition, price and output are determined by the equating of supply and demand. However, the high degree of mechanization of growing and harvesting flax seeds stimulates mass production and decreasing cost at high levels of output. The attainment of mass production modifies the conventional cost curve and makes supply more elastic as price rises and output is increased. Under the present conditions of technology, this factor constitutes strong evidence that price-elasticity of flax seed is greater than that of tung nuts. Harvesting of tung nuts is less mechanized than the harvesting of flax seed.

**Time-elasticity of Supply**

Flax is an annual crop which means that the time required to produce a crop is limited to one year or less and that only one crop may be obtained from each planting. The maximum time required for the plant to grow to maturity ready for harvest is four to five months, depending upon the area in which it is planted. "In Argentina, India, and California, flax is sown in the fall and matures about five months later. In Canada and the North-Central states, it is sown in the spring and ripens in about 100 to 120 days." 15

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15 *Encyclopaedia Britannica, op. cit.*, p. 364
The long-run supply of flax seed, therefore, may be changed within a period of five or six months. This conclusion is valid even when supply is limited to domestic production. When price is expected to rise or remain at a high level, producers in California may increase acreage in the fall which would increase the quantity coming to market in the spring, and producers in North-Central states may increase acreage in the spring and effect an increase in long-run supply in the fall. Unlike tung growers, flax growers can decrease acreage and make the necessary changes in supply within a very short period when the market is unfavorable and the price is expected to fall. The time-elasticity of linseed oil is less than the time-elasticity of tung oil by a ratio of at least two to three. The time advantage of linseed oil gives it a competitive advantage from the standpoint of production of great importance. Under conditions of shifting demand and increasing prices for drying oils, production of linseed oil may be increased quickly; and the market is glutted by the time long-run supply of tung oil is increased. The process is reversed when drying oil prices are falling.

Time-elasticity is related so closely to what is known as shifts in supply that the two concepts may be confused easily. Careful distinction between the two is important at this point. Changes in supply which take place from one production period to another are referred to as
supply shifts. It is a change in the schedule sense. Greater quantities will be offered at the same price or the same quantity will be offered at a lower price. On the other hand, time-elasticity refers to the time required for the shift to take place.

The effect of a short time-elasticity may be illustrated by the following price-production series for linseed oil.

Table XXV. Domestic Production and Price of Linseed Oil, 1940-1949

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (000 #)</th>
<th>Average Annual Price (cents per pound)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>606,246</td>
<td>9.7</td>
</tr>
<tr>
<td>1941</td>
<td>868,116</td>
<td>10.7</td>
</tr>
<tr>
<td>1942</td>
<td>960,248</td>
<td>13.3</td>
</tr>
<tr>
<td>1943</td>
<td>917,447</td>
<td>15.6</td>
</tr>
<tr>
<td>1944</td>
<td>936,560</td>
<td>15.6</td>
</tr>
<tr>
<td>1945</td>
<td>526,002</td>
<td>15.5</td>
</tr>
<tr>
<td>1946</td>
<td>579,899</td>
<td>19.9</td>
</tr>
<tr>
<td>1947</td>
<td>456,153</td>
<td>34.3</td>
</tr>
<tr>
<td>1948</td>
<td>726,033</td>
<td>29.7</td>
</tr>
<tr>
<td>1949</td>
<td>744,502</td>
<td>27.8</td>
</tr>
</tbody>
</table>

Source: Compiled from Bureau of Census, United States Department of Commerce.

The most significant development occurred in 1945. Linseed oil producers were able to avoid an anticipated decline in market price by registering an immediate decrease in production. In addition, output decreased in the face of an increase in price. The short producing period assisted
producers in reducing war-time excess capacity to the pre-war level. The situation was reversed in the case of tung oil. Tung growers were not able to adjust output below war-time requirements.

Other Drying Oils

Other drying oils of vegetable origin offer a similar type of competition to tung oil, differing only in extent or degree. Oiticica oil is reported to be the most perfect substitute for tung oil, but it does not have a competitive advantage from the standpoint of production. It is obtained from nuts grown on a perennial plant in Brazil. The time-elasticity of supply is very similar to that of tung oil. An outstanding disadvantage of oiticica oil is its limited supply. It is produced in Brazil only.

Soybean oil is obtained from annual crops having production features similar to linseed oil.

Summary and Conclusions of Supply

From the standpoint of production, tung oil occupies a disadvantageous position in respect to most of the other commercial drying oils. There is strong evidence that, in the long-run, the quantities of tung oil being offered for sale in the market are less responsive to changes in price, both as to quantity and time, than the other principal drying oils. With an increase in the price of drying oils, there is a tendency for the subsequent increase in quantities of other drying oils to be in excess of the increase in tung
oil. Tung oil is less responsive to changes in price, in the long-run. Its supply is less elastic.

It has been shown that tung oil has the longest productive period of any of the competing oils, with the exception of oiticica oil. The time required to bring about a change in supply is in excess of that of competing oils. Its time-elasticity is greater than that of other oils.

Therefore, when prices are high and the market is good, tung producers bring their product to the market too late and in quantities which are too small relative to competing producers. Chinese tung producers and domestic producers of other drying oils are able to bring greater quantities to the market at an earlier date. They glut the market by the time tung production is increased.

When prices are decreasing and the future market is expected to be unfavorable, tung producers are unable to contract production. Instead, they maintain the former high level of production and accept a decrease in price. On the other hand, producers of substitutes are able to reduce output within a maximum period of one year and, thereby, avoid a price reduction to some extent.

The effect of supply-elasticity upon commodity price movements may be illustrated graphically by a cobweb theorem arrangement. The price-quantity movements create a chronological curve which spirals inward or outward. The curve is constructed against a background of special supply and
demand curves. The demand curves are purely hypothetical and for that reason they are drawn in the shape of a straight line and with the same degree of elasticity for each demand curve. The supply curves are not intended to be accurate, but they do represent the condition of supply of the various commodities in a relative sense. The demand curves represent the relationship between the quantities purchased in any one period and the price at which that quantity is purchased. The supply curves represent the relationship between the price in any one period and the quantities which will be produced at that price in the following period. Supply elasticity of perennial crops is not reversible and, for that reason, the vertical lines dropped from the supply curve fix a limit to output reduction and cause the price to continue downward to equilibrium.

The uses of tung oil were presented in Chapter V, in which it was shown that the oil is used by industrial consumers as a raw material in the preparation of a variety of coating materials and related products. The principal consuming industries were shown to be (1) the paint and varnish industry, (2) the oilcloth and linoleum industry, and (3) the printing ink industry. Other minor uses of the oil have been developed; and research facilities of the industry, governmental and private, constantly are directing their efforts toward expanding market outlets. Up to the present time, the collective influence of the minor uses has not been substantial. It now becomes necessary to consider demand further and to determine what effect it has on price. What is the market situation in which tung nuts are sold? What is the market situation in which tung oil is sold? What is the nature of the demand for drying oils? These questions indicate some of the points of inquiry which need clarification in an analysis of the demand for tung oil. However, a brief presentation of some of the common market situations is made as a prelude to the presentation of demand for drying oils.
**Pure Competition**

A business unit which is only one of a great number producing homogeneous products and offering them for sale in the market is said to be operating under conditions of pure competition. Pure competition may be identified by the existence of two conditions, namely, (1) competition is on a price basis and (2) the individual seller is incapable of affecting price by changing output. The first condition arises out of the uniformity of the products being sold and "it is assumed that the only element which will cause a buyer to prefer one seller to another is the lower price."¹ The second condition specifies the relative abilities of the sellers and required "that the amount of the product offered for sale by the individual seller constitutes such a small proportion of the total supply that any change in the amount which he sells will not affect the price."²

**Monopolistic Competition**

Monopolistic competition is a type of market situation which includes many conditions in which competition is less than pure and greater than it would be under pure monopoly. It "lies somewhere between pure competition, on


² Ibid., p. 374.
the one hand, and pure monopoly, on the other." Lack of homogeneity of products being offered in the market gives rise to a condition of monopolistic competition. Methods of differentiating products by sellers are many and, because it is difficult sometimes to distinguish monopolistic from pure competition, two features may be used as a rough guide in making the distinction. First, advertising by the seller of the product in question is a good indication that he is attempting to differentiate his product from other similar ones. Under pure competition, there is little need for advertising because the products are homogeneous. Second, price quotations may be indicative of the type of market. Under pure competition, the price tends to move slightly, indicating that price is the object of competition. Under monopolistic competition, from time to time the price quotations tend to vary to a greater extent, indicating that the quality of the product is being emphasized. Two results of monopolistic competition are considered to be of considerable value in an economic analysis of tung oil. First, the demand is less elastic than under pure competition and the demand curve, instead of being horizontal, slopes downward and to the right. Second, "the price is inevitably higher and the scale of production inevitably

3 Ibid., p. 381
smaller under monopolistic competition than under pure competition." 4

The Market Situation in Which Tung Nuts are Sold

Tung nuts are marketed through two different channels. First, those tung growers who elect to dispose of their nuts at the time they are brought to the mills sell directly to the mill owners. The growers are paid the current price for tung oil on the basis of the percentage of oil contained in the nuts which they offer for sale. Second, those tung growers who desire to place their oil in a marketing pool do not sell the nuts to the mill owners. Instead, they have the nuts processed on a fee basis and place the oil obtained from the nuts in a marketing pool under the care of a manager who has the authority to dispose of the oil at a later date.

The conditions under which tung nuts are sold through the first channel suggest the existence of pure competition. The practice of mill owners of buying tung nuts on the basis of oil content reduces the product being sold to a uniform quality and places competition on a price basis. There were 4,160 tung growers in the United States in 1945. 5 With only about one-half of the growers electing to sell


tung nuts directly to the mill owners, it seems reasonable to conclude that individual sellers are unable to influence the price of tung nuts by changing the quantity which they offer for sale. Competition on a price basis and lack of ability of individual sellers to influence price by changing output suggests a condition of pure competition. An oligopsony situation exists in some areas of the tung belt.  

There are only thirteen operating mills in the domestic tung oil industry. The mill owners are buyers of tung nuts, and such a small number of buyers suggests an oligopsony situation. The oligopsony element is intensified by geographical considerations. Some of the buyers are located a great distance from other buyers. Within isolated areas, the sellers have very little alternative but to sell to the local buyer. Thus, an oligopsony condition may exist within limited areas of the tung belt.

**The Market Situation in Which Tung Oil is Sold**

Tung oil, which is owned by tung growers and mill owners, is placed on the market through marketing-pool managers. It is probable that an average of two marketing pools are located at each of the processing mills, making a total

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6 Oligopsony has been referred to as "the presence of a small number of buyers." and "... the basic feature characteristic of all forms is the fact that the buyers are aware that the volume of their purchases will affect the market price." (See John F. Due, *Intermediate Economic Analysis* (Chicago: Richard D. Irwin, Inc., 1950), pp. 75-76).
of about twenty-six tung oil sellers in the entire industry in the United States. Tung oil brokers are the buyers of tung oil, and it appears that the number of brokers engaged in buying tung oil is limited to five or six. Such a small number of buyers and sellers tends to reduce competition and to create a condition of oligopsony. The existence of an oligopsony element in the market in which tung oil is sold tends to reduce the price below what it would be under conditions of greater competition.

The Nature of the Demand for Drying Oils

By developing the analysis further and moving nearer the point of ultimate consumption, the nature and significance of the demand for competing drying oils becomes clearer. The greatest portion of commercial drying oils is consumed by manufacturers in the preparation of coating materials. Small quantities of some oils are used by individuals in mixing paints for immediate use. However, such consumption by individuals is negligible and has very little effect upon total demand. Consequently, this analysis is limited to industrial consumption.

The character of demand for a commodity is very useful in determining the effect of price changes on the quantity which may be sold. The "first law of price" may be stated as follows: "In general, the quantity of any good which people are ready to buy varies inversely with the price of
that good." 7 This economic principle refers to elasticity of demand and may be interpreted to mean that as the price of a good decreases the quantity which people are ready and willing to purchase increases. Sometimes it is referred to as the Law of Demand when demand is considered in the market sense, rather than as a schedule of prices and quantities. Elasticity of demand, therefore, is of considerable importance in studying the competitive position of a commodity for which substitutes exist.

The total demand for drying oils is contingent upon the demand for oil-containing products. In general, the demand for such products depends upon the rate of construction and the level of industrial activity. The first significant fact, therefore, affecting the demand for drying oils is that it is a derived demand. 8 People who buy drying oils do not do so for their own sake. Oils are bought since they are useful in producing other goods for which there is a demand. Derived demand has certain important features. In the first place, the intensity of demand depends upon the expected demand for the products of consuming industries


8 Boulding, op cit., p. 220.
An expected rise in the demand for oil-containing products will cause a rise in the demand for drying oils. A rise in the demand for drying oils, according to the Law of Supply and Demand, causes a rise in the price of drying oils. A rise in prices causes an increase in production of oils in proportion to the relative elasticity of their respective supplies. In this way, the prices of drying oils are related very closely to the business cycle and the general level of industrial activity.

The second significant feature of derived demand is that the more elastic the demand for the finished products of the oil-consuming industries, the more elastic is the demand for drying oils likely to be. On the other hand, the more inelastic the demand for paints and other products containing drying oils, the more inelastic is the demand for drying oils likely to be. This statement is derived from the assumption that if the price of the product from which demand is derived is reduced, greater quantities will be demanded and also greater portions of drying oils will be demanded by consuming manufacturers.

The third distinguishing feature of derived demand is based upon the relative contribution to the finished product of the constituent raw materials. The greater the contribution of the raw material to the finished product, the more

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9 Ibid., p. 222.
elastic is the demand for the raw material likely to be. Drying oil constitutes only about 20% to 25% of the material used in preparing paint. Drying oil contributes a relatively small amount to the final product and paint, in turn, contributes a small amount to the total of buildings and constructions to which it is applied as a coating material. A fall in the price of drying oils causes little change in the price and output of the paint and varnish industry and a fall in the price of paint and varnish has less effect upon the level of industrial activity. This factor alone tends to make the demand for drying oils inelastic.

The conclusion from the above discussion of the nature of derived demand is that the total demand for drying oils tends to be inelastic. This is evidenced very strongly by the last feature discussed. There also is evidence that the demand shifts directly with the level of national income and industrial activity.

The demand for individual drying oils is likely to be quite different from the demand for drying oils in general. They may be less elastic, more elastic, or similar in elasticity. For some general uses, drying oils constitute rival supplies for the general purpose products. "When two or more producers' goods compete among themselves to supply the same consumer's goods, ... they are said to constitute rival
supplies..."  

Goods which are produced under conditions of rival supplies give rise to the effect of substitutions upon demand and prices. "The better, and the cheaper, the substitutes for a factor of production, the more likely is it to have an elastic demand." The existence of substitutes for a good in the form of rival supplies causes its demand curve to be more horizontal than it would be otherwise; and when the demand for the good in question increases, its price may not rise as high as it would have had the substitute not been available. In the field of drying oils, substitutes are usually available and are effective in maintaining a relationship between prices. When the demand for tung oil increases, the existence of oiticica and castor oil prevents its price from rising as high as it would go if those substitutes had not been available. However, there are some instances in which tung oil is used for drying purposes almost exclusively because of special requirements and lack of availability of other oils which do meet those requirements. Special purpose varnishes which are designed to meet technical requirements of industry may require tung oil only because of its superior qualities for that particular


purpose. The electrical industry uses varnishes and other coating material because of its peculiar dielectric properties. Other industries may prefer tung oil-containing coatings because of high waterproof requirements. Some users of coatings prefer tung oil because of the durability of the film. Whatever the basis of the preference may be, the economic significance is that it produces a less elastic demand curve for the type of consumer in question, reduces purchases below what they would be for the same price with a more elastic demand, and increases the price of tung oil paid by the consumer to the coating manufacturer. It is of interest to note at this point that tung oil is bought under conditions approaching pure competition and sold under conditions of monopolistic competition based on differentiated products. The fact that tung oil is used not only for special purposes requiring qualities of technical superiority but for general purposes where ordinary drying qualities are required suggests conditions of rival demands. "When two or more different finished goods require the same factors of production, the demands of consumers for these finished goods are said to be rival demands for the agents used in producing them." 12 This combination of market situations presents a complex problem of analysis. The problem of rival demands is considered first.

12 Garver and Hansen, op. cit., p. 170.
Tung oil may be used for several different purposes, but its use for some purposes is more important than for others. The least important use for which it may be employed profitably is called its marginal use. In the preparation of underwater paint and varnishes for the electrical industry, a small amount of tung oil is very useful and valuable because of its good waterproof and dielectric qualities. The employment of the oil for these purposes probably constitutes its most valuable use. The use of tung oil in conjunction with other drying oils in manufacturing linoleum or general purpose paint probably constitutes its least important use. The use of the oil in manufacturing these products may be dispensed with and other oils used instead. The least important use of tung oil constitutes its marginal use which may be defined as that employment of tung oil which would be discontinued first if its price should rise. The price of any good for which there are rival demands tends to agree with its value in its marginal use. ... its marginal use sets the price for the entire market." 13 The market price of tung oil, therefore, tends to be determined at any time by the value of its marginal use. The value of its marginal use, in turn, is determined by the quantity being offered in the market and the amount taken by all consumers.

When products containing tung oil are sold under conditions of monopolistic competition, the demand for those products is less elastic than under more competitive conditions. The extent of elasticity depends, to some extent, upon the peculiar qualities of tung oil and the desires of those who purchase the oil. Manufacturers of tung-oil-containing products are in a position to create a separate demand for their products when suitable substitutes are not available to consumers. In markets where finished products are purchased for ordinary coating purposes and substitutes are not readily available, manufacturers are compelled to accept the market price fixed by the supply of and demand for all drying-oil products suitable for ordinary coating purposes. If the manufacturers attempt to sell at a price higher than the market price, they will make very few sales; and at a lower price, sales would be great. Elasticity of demand is very great. "By creating a separate demand for his product, he is enabled to charge a price higher than the market price..." 14 By creating a smaller but separate demand based upon quality of the product, the seller finds demand to be more intense and less elastic than in the more competitive market. Tung oil probably is more suitable for creating a separate demand than other oils. For some

purposes there is no substitute for tung oil. Chemical re-
search has not been able to produce a substitute. "No one
has yet made a synthetic tung oil, and if they do, what of
it?" This does not mean that none of the other oils
possess qualities capable of commanding a separate market.
Linseed oil is reported to be more suitable than tung oil
for making the most common types of linoleum because it
forms a more flexible film. It is possible for a separate
demand to be established for each of the drying oils. The
important thing is that these separate demands are likely
to be limited and that substitutes may be used interchange-
ablely by changing the formulas by which the coating materials
are prepared.

Summary and Conclusion

The various market situations found in all phases of
the distribution of tung oil and tung-oil-containing products
were presented in the previous section. Tung oil, which is
sold by the producers to mill owners, is sold under conditions
approaching pure competition. The processed tung oil pro-
duced in the United States, which is distributed by mill
owners through dealers, is marketed under conditions approach-
ing oligopsony, with sellers of domestic oil competing with

15 Frances Scofield, "The Competition of Synthetic
Oils with American Tung Oil", Proceedings, Thirteenth Annual
Convention of American Tung Oil Association, Pensacola,
Florida, (May 1, 1947), p. 89.
a limited number of dealers in tung oil from foreign countries. The demand for domestic oil appears to be slightly less elastic than it would be under more perfectly competitive conditions.

The marketing of finished products made from drying oils gives rise to a composite of complex market situations. In general, the many products containing drying oils are marketed under some type of monopolistic competition. The quality of the product and the purpose for which it is desired determine the shape of the demand curve for each type of product. Because of the peculiar qualities of tung oil, the demand for products containing this oil differs from that of products containing other oils. In general, the demand for products made from tung oil appears to be less elastic than that of products made from other drying oils when prices of drying oils are high. When drying oil prices are low, it is probable that the degree of elasticity of competing oils is about the same.

A significant thing about the demand for all drying oils is that it is an indirect or derived demand. It is derived from the demand for finished products in which it is used as a raw material. The demand for drying oils is derived from the demand for producers' goods which is derived from the demand for a variety of consumers' goods. Several peculiar features of the arrangement indicate that the composite demand for drying oils is relatively inelastic.
By isolating the various aspects of demand further, it was pointed out that the demand for each type of drying oil considered separately is not only a derived demand but constitutes rival demand as well. The existence of rival demands reduces the elasticity of the demand curve for each product as a result of substitutes. The peculiar qualities of tung oil give it a competitive advantage when prices are high and output is limited. The competitive advantage tends to disappear with greater output and lower prices.

Changes in the Demand for Tung Oil

The types of demand for competing products and a comparison of the degree of elasticity found in the demand for each product do not offer a complete explanation of the importance of demand in determining the price movements of a commodity. Changes in demand are of particular importance. At this point in the analysis of tung oil, therefore, a distinction must be made between the elasticity of demand and a change or shift in demand. The effect of a change in demand upon the price of tung oil is presented following the distinction between the two concepts.

Elasticity versus Change in Demand

Elasticity of demand may be defined as "the extent to which a change in price will affect the quantity of a good that will be purchased." 16 The Law of Demand states that

"In general, the quantity of any good which people are ready and willing to buy varies inversely with the price of that good." Both statements refer to the concept of elasticity and may be summarized as follows: Elasticity of demand is the extent to which a change in the price of a good causes an inverse change in the quantity which people are ready and willing to buy. Theoretically, the concept refers to an instant of time when only one price and one quantity are known. At the same time, there is a series of other simultaneous possibilities of different quantities being purchased at different prices. The total of all possible pairs of prices and quantities is known as a demand schedule. The concept of elasticity of demand refers to the extent of change in the quantity of a good purchased by consumers as a result of an inverse change in the price of that good.

On the other hand, by a change in demand is meant a shift in the entire demand schedule. A change takes place when people are ready and willing to purchase a different quantity of a good at the same price as formerly or to pay a different price for the same quantity. An increase in demand is said to take place when buyers decide to increase the quantity taken at a given price and to decrease when they decide to take a less quantity at the same price.18

17 Fairchild, Furniss, and Buck, op. cit., p. 164
The distinction between elasticity and changes in demand may be illustrated by the use of schedules and graphs. The following table represents a series of actual and assumed possible prices and quantities of tung oil purchased at a certain time in 1944, as well as a series of actual and assumed quantities for 1946 representing a new demand schedule.

Table XXVI. Demand Schedule for Tung Oil, 1944 and 1946

<table>
<thead>
<tr>
<th>Price</th>
<th>Former Demand (Pounds)</th>
<th>New Demand (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.36 cents</td>
<td>13,000,000</td>
<td>31,000,000</td>
</tr>
<tr>
<td>.37</td>
<td>12,000,000</td>
<td>30,000,000</td>
</tr>
<tr>
<td>.38</td>
<td>11,000,000</td>
<td>29,000,000</td>
</tr>
<tr>
<td>.39</td>
<td>10,102,000 (1)</td>
<td>28,962,000 (1)</td>
</tr>
<tr>
<td>.40</td>
<td>9,000,000</td>
<td>26,000,000</td>
</tr>
<tr>
<td>.41</td>
<td>8,000,000</td>
<td>23,000,000</td>
</tr>
<tr>
<td>.42</td>
<td>7,000,000</td>
<td>20,000,000</td>
</tr>
</tbody>
</table>

1 Fats and Oils, Bureau of Census, United States Department of Commerce.

Elasticity refers to the change which takes place in each quantity schedule as a result of a change in price. As the price increases the quantity demanded decreases, and as price decreases the quantity increases. The relationship is inverse. Price is the cause and quantity is the effect. The demand curve, line \( PD \), representing prices and quantities of the original demand schedule is plotted on Chart 3.

Assuming that no change takes place in price or supply, a change in demand is represented by a shift in the schedule of
quantities purchased. Greater quantities are purchased at each price. The new demand curve, showing the change in demand, is indicated by line dd in Chart 3.

The effect of a change in demand is that the price varies directly with changes in demand and that a change in demand causes a change in price. An increase in demand causes an increase in price and a decrease in demand causes a decrease in price.

What has been said about demand holds true for supply with the exception of one modification. In the case of supply-elasticity, the relationship is direct. An increase in the price of a commodity, other things remaining unchanged, causes an increase in the quantity offered in the market. As to changes in supply, the relationship between supply and price is inverse. A change in supply causes an inverse change in price.

**Elasticity versus Changes in Supply**

As this analysis progresses, the question of supply appears to be an economic factor of increasing importance in influencing the price of tung oil. The importance of supply is of even greater significance when it is considered in a relative sense. The relative inelasticity of supply, both as to price and time, was shown to be a contributing factor to the downward spiral of the price of tung oil in 1946. Also, it has been shown that changes in supply contributed to subsequent price declines of that commodity. It is important, therefore, that a distinction be made between these
two concepts and that the effect which they have upon price be shown.

Elasticity of supply has been defined as "the ratio of the relative change in the quantity supplied to the corresponding relative change in price, when the relative changes are infinitesimal." The relationship is direct and gives rise to the Law of Supply which holds that under pure competition, price varies directly with the quantity supplied. It is based on the assumption that as the price of a good rises, or is expected to rise, producers bring greater quantities of that good to the market. Elasticity is a useful analytical device in investigating price variations from normal, the effect of which was presented in Chapter VII. When the elasticity of supply of a commodity is less than that of demand, the price fluctuates severely at first and tends to return to normal with the passage of time. When elasticity of supply is greater than that of demand, price variations from normal tend to increase as time passes. These conditions are only some of the effects of elasticity of supply on price only when market conditions do not change. The presence of other factors may have the opposite effect upon price.

"A true change in supply takes place only when the producers decide to change the number of units offered for sale.

at a given price." A change in supply, therefore, is represented by a complete shift in the entire schedule of quantities which are offered for sale at different prices.

A change in the supply of tung oil may be illustrated by the use of a schedule of actual and assumed quantities offered for sale at three different times. Supply schedules for 1946, 1947, and 1948 are shown in the table below.

Table XLI. Supply of Tung Oil, 1946, 1947, and 1948

<table>
<thead>
<tr>
<th>Price (pounds)</th>
<th>1946</th>
<th>1947</th>
<th>1948</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>27</td>
<td>133</td>
<td>146</td>
</tr>
<tr>
<td>21</td>
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<td>133</td>
<td>147</td>
</tr>
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<td>32</td>
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</tr>
<tr>
<td>23</td>
<td>30</td>
<td>125</td>
<td>149</td>
</tr>
<tr>
<td>24.6</td>
<td>31</td>
<td>126</td>
<td>150,119,000</td>
</tr>
<tr>
<td>25</td>
<td>14</td>
<td>127</td>
<td>151</td>
</tr>
<tr>
<td>26</td>
<td>36</td>
<td>128</td>
<td>152</td>
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<tr>
<td>27</td>
<td>34</td>
<td>129</td>
<td>153</td>
</tr>
<tr>
<td>28</td>
<td>36</td>
<td>130</td>
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<tr>
<td>29</td>
<td>36</td>
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<tr>
<td>30</td>
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<td>156</td>
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<td>33</td>
<td>135</td>
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</tr>
<tr>
<td>33</td>
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<td>159</td>
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20 From n, op.cit., p. 286
The schedules of prices and quantities are plotted on Chart 4. Line S5 represents the supply curve for 1946; S'S', for 1947; and S''S'', for 1948. Of course, only one pair of actual prices and quantities may be shown for each period. The others are assumed values.

Assuming that no change takes place in price or demand, a change in supply is represented by a shift in the schedule of quantities assumed to be offered for sale at the same price.

The effect of a change in supply is that it causes an inverse change in price, other things being equal. An increase in supply causes a decrease in price and a decrease in supply causes an increase in price.

Changes in the Demand for and Supply of Tung Oil

The concept of changes in demand and supply is of particular importance when the two are considered together. An increase in demand and an increase in supply have opposite effects upon the price of a commodity and, if the increase is proportionate for both demand and supply, no change in price takes place. Various combinations of demand and supply changes are possible. It may be said that, other things being equal, an increase in the supply of a commodity causes a decrease in the price of that commodity; and a decrease in the supply causes an increase in price. Likewise, an increase in demand causes an increase in price, and a decrease in demand causes a decrease in price. The extent to which changes in demand and supply result in price
fluctuations depends upon the extent of the changes and the slope of the demand and supply curves when plotted graphically. These statements include some of the effects of elasticity of and changes in demand and supply only so long as other factors remain unchanged. They may be useful in determining the cause of changes in the price of a commodity when conditions of elasticity of demand and supply of that commodity either are known or assumed. The exact quantitative conditions of elasticity of demand for drying oils is not known and such a computation is beyond the scope of this work. However, there are certain qualitative factors which tend to strengthen otherwise arbitrary assumptions about the demand for tung oil. First, the availability of tung oil as a substitute for other drying oils produces an elastic demand for this oil when the quantity consumed is high and the price is relatively low. The interchangeability of drying oils for the purpose of preparing ordinary coating materials produces an elastic demand for each of the oils when the prices are about equal and quantities available are sufficient to supply the needs of commercial consumers. Further decreases in the price of any one of the commercial drying oils permits manufacturers of general purpose paints and varnishes to reduce cost of raw material by modifying their formulas and utilizing greater quantities of the cheaper oil. When the price of any one oil is increasing, higher manufacturing costs may be avoided by making the required formula
modifications and consuming smaller quantities of the high price oil. Therefore, when production and consumption of all drying oils are uniformly high, the slope of their demand curves tend to be similar. If the conditions which foster similarity of demand curves persist unchanged for a considerable length of time, the position of demand curves for competing oils will approach uniformity. Similarity of both slope and position of demand for different commodities produces close similarity of elasticity of demand for those commodities.

The second factor which influences the demand for tung oil is based upon its inherent qualities. It has come to be recognized as an essential ingredient in the preparation of spar varnish because of its quality of forming a durable, hard, and waterproof film when exposed to air for a very short time. There are other uses for which tung oil is regarded as the most desirable drying oil. It is essential for many special purposes and its marginal utility is high for purposes in which it is regarded as essential. Other oils cannot be substituted for tung oil very successfully for these special purposes, because they do not possess the necessary properties. From an economic point of view, tung oil is a differentiated product differing from other drying oils for a limited number of uses. To the extent that it is a differentiated product within a limited area of application, its demand becomes less elastic.
In consideration of the above factors, it seems logical to assume that the demand for tung oil is inelastic when the oil is scarce and the price is high and that it becomes progressively elastic as greater quantities are exchanged and the price declines.

By assuming the demand for tung oil to be of the nature described above, some important effects of changes in demand and supply may be observed. For the best sequence of deductive logic, the principles set forth at the beginning of this section should be recalled. It may be stated as a classical principle of economics that a given increase in supply causes the smallest decrease in the price of that commodity with the most elastic demand. Likewise, a given supply change produces the greatest effect upon the price of that commodity with the most inelastic demand. The direction of thought may be reversed without disturbing the value of the principle. Then, if the assumption in respect to the demand for tung oil is correct, it follows that a decrease in the supply causes the price to increase at a progressively increasing rate. The effect is accelerated directly with the degree of inelasticity of supply. On the other hand, any increase in supply causes a decrease in the price of tung oil at a progressively decreasing rate.

*Causes of Changes in the Price of Tung Oil From 1942 to 1946*

The material which has been presented in Part II includes the following topics: (1) the characteristics and uses of tung oil, (2) production and consumption of drying
oils in the United States, (3) economic aspects of producing drying oils, and (4) economic aspects of the demand for tung oil. It now becomes necessary to relate the material presented in Part II to the problem which was stated in the introductory chapter and to show how they have influenced the price of tung oil.

Tung oil is only one of several drying oils used in the manufacture of such products as paint, varnish, linoleum, oilcloth, and printing ink. Drying oils are partly interchangeable, making it possible for substitutes to be used in the manufacture of drying-oil products. The quantity of tung oil available in the United States decreased during the war, because the Japanese blockade of the Chinese coast reduced tung-oil exports to the United States. On the other hand, the quantities of other drying oils available for consumption increased during the war. It is probable that the demand for drying oils was increasing at the time tung-oil imports were decreasing. Producers of tung oil in the United States were unable to increase production, because tung trees are perennial plants which require a pre-production growing period of about four years before they can produce a crop of nuts. The decrease in the quantity of tung oil available for consumption in the United States during the early part of the war and the lack of ability of domestic producers to increase output caused the price of tung oil to increase. The increase in the price of tung oil caused consumers to increase consumption of
other oils which could be obtained at a lower price. Greater demand for other drying oils caused prices to rise. Higher prices for other drying oils brought forth greater production, especially linseed and soybean oils. Shorter time-elasticity of supply of oils obtained from annual crops permitted producers to increase production in less time than that required to increase production of tung oil. As long as the availability of tung oil in the United States was low, the price remained high.

In 1946, the price of tung oil began to decrease very rapidly. By 1948, it had decreased to about the pre-war level. An examination of the record of tung oil imports and the production of tung oil in the United States shows that the quantity of tung oil available for consumption in the United States was increasing at the same time the price was decreasing. The removal of the Japanese blockade of the Chinese coast at the end of the war permitted greater quantities of tung oil to be exported from China. Tung oil imports into the United States increased very rapidly. Production in the United States had begun to increase. Tung trees which were planted when the price of tung oil was high had begun to yield large crops. Greater quantities of tung oil available for consumption caused the price to decrease. By 1948, the quantity of tung oil available for consumption in the United States was about equal to that which
was available before the war and the price of tung oil was about equal to that of the prewar level. Lower tung oil prices encouraged consumers to purchase greater quantities of tung oil. Greater purchases of tung oil checked the decrease in price.

It appears that as long as tung oil is in competition with other drying oils which are obtained from annual crops, price variations less severe than those which occurred from about 1842 to 1943 can be expected. Basic differences in the responsiveness of annual and perennial crops to changes in price seem to subject tung oil prices to a considerable degree of instability. Conditions which affect the prices of other drying oils also have an effect upon the price of tung oil. However, such price changes are not likely to be extreme, because the operation of the principle of cross-elasticity of demand tends to keep the prices of drying oils close together under normal conditions.
CHAPTER IX

SUMMARY AND CONCLUSIONS

The purpose of this chapter is to present a summary of the material which has been developed in the previous chapters and, in order to facilitate greater clarity, to point out the relationship between the material presented and the problem which was stated in the introductory chapter.

The material has been presented in two parts, including eight chapters. The significance of the tung oil industry, a statement of the problem, and the method of approach were presented in Chapter I.

Industrial development, practices, and techniques were presented in Part I under the following chapter headings: (1) the domestic tung oil industry, (2) the Chinese tung oil industry, and (3) the development of tung oil in countries other than China and the United States.

The development of the tung oil industry in the United States was presented in Chapter II. The material was presented under the following topics: (1) origin of the domestic industry, (2) experimental development, (3) the domestic tung growing area, (4) soil and drainage requirements, (5) scientific and technological
development of the domestic industry, and (6) the structure of the industry.

A description of the Chinese tung oil industry is found in Chapter III. The phases of the industry described are (1) the producing area, (2) harvesting methods, (3) drying and pulverizing methods, (4) expressing methods, (5) Chinese transporting and marketing practices, (6) tung oil production, (7) quality of Chinese tung oil, (8) Chinese consumption, and (9) export trade.

The development of tung oil in countries other than China and the United States is presented in Chapter IV. Areas in which tung oil is being produced include (1) Latin America, (2) Africa, (3) India, (4) Japan, (5) Australia, and (6) Russia. The principal Latin American countries in which tung oil is being produced are Argentina, Brazil, and Paraguay. Production in Africa seems to be of little importance.

The industry was found to be new and relatively small in the United States; whereas it is ancient and of primary importance in China. The oil is produced in the United States for domestic consumption; whereas it is produced in China and the Latin American countries for export trade. Tung oil produced in the United States is processed by the use of modern machinery; while Chinese oil continues to be processed by crude methods. Tung nuts in the United States and Latin America are grown in well cultivated
orchards, and those in China are grown in cultivated orchards and in undomesticated groves.

The material included in Part II was presented under the following chapter headings: (1) characteristics and uses of tung oil, (2) production and consumption of drying oils in the United States, (3) economic aspects of producing drying oils, and (4) economic aspects of the demand for tung oil.

The uses of tung oil are found in Chapter V. It is used as a raw material in the manufacture of a variety of products, the most important of which are (1) paint and varnish, (2) linoleum and oilcloth, and (3) printing ink.

A statistical presentation of the availability and utilization of drying oils in the United States is found in Chapter VI. Other factors treated in the chapter which influence the price of drying oils are (1) the tariff on drying oils and (2) the government price support program for drying oils.

The similarity of properties of drying oils has far-reaching consequences. First, it means that all of the commercial oils are produced under conditions of rival supply. They are competing for similar market outlets. This type of a situation invites competition on a price basis and depresses the price below what it would be under different circumstances. Availability of substitutes plays an important part in this type of competition. For that reason,
the conditions of supply of the competing drying oils have been brought into the analysis in Chapter VII. The most significant economic aspects of producing drying oils have been presented. Of great importance is the fact that tung trees are perennial plants and that the vegetable oils which compete with tung oil in the market place are obtained from annual crops. A basic difference between perennial and annual crops arises out of the variations in time-periods of production. It requires a longer period to increase the supply of goods produced from perennials than it does from those produced from annuals. Once perennials are in production, supply continues to come forth each year during the life of the tree. The producer of perennials has less control over supply than the producer of annuals. The flax farmer has greater control over his annual supply of flax seed than the tung grower has over his annual supply of tung nuts. Inability of tung growers to make the necessary adjustments in the quantity of nuts produced annually produces instability in the tung oil industry so long as tung oil is used interchangeably with linseed oil and other drying oils obtained from annuals.

Economic aspects of the demand for tung oil were presented in Chapter VIII under the following topics: (1) the market situation in which tung nuts are sold, (2) the market situation in which tung oil is sold, (3) the nature of the demand for drying oils, (4) changes in the demand
for tung oil, (5) changes in the demand for and supply of tung oil, and (6) causes of changes in the price of tung oil from 1942 to 1948. Conditions surrounding the sale of tung nuts suggest the existence of a condition of pure competition, with the possibility of an oligopsony element in limited geographical areas. The demand for drying oils is of a derived nature. The interchangeable use of drying oils creates a rival demand in which the oils compete for similar market outlets.

In interpreting the material which has been presented, the following factors seem to be most important in explaining the changes which occurred in the price of tung oil during the war and postwar periods: (1) characteristics and uses of tung oil, (2) the availability of drying oils in the United States, (3) consumption of drying oils in the United States, (4) economic aspects of producing drying oils, and (5) the nature of the demand for drying oils. The rapid increase in the price of tung oil in 1940 and 1941 was due in part to the disappearance of imports from China and the inability of domestic producers to increase production in the United States. To be sure, more tung trees were planted during this period of rising prices, but the length of the pre-production growing period for tung trees made it impossible for the necessary increase in production to be made until the trees had begun to yield a crop. Throughout the war-period from 1942 to the latter part of 1945, the price of tung oil remained at or near the official price ceiling of 39 cents per pound, because
the quantity supplied at anything less than that price was insufficient to meet the needs of all consumers who were willing to pay that price. Domestic producers were encouraged to cultivate existing orchards more extensively and to expand and make preparations for greater output.

In the case of other drying oils, chiefly linseed and soybean oils, the price trend was upward but the extent of the increase was less than that of tung oil during the same period. In a general way, the factors responsible for the increase in the price of tung oil influenced the price of other drying oils but not in the same direction and to the same extent. The conditions which caused the demand for tung oil to increase also caused an increase in the demand for drying oils in general, but the factors which brought about a decrease in the supply of tung oil did not affect the supply of linseed and soybean oils. Instead, both domestic production and imports of linseed oil increased from 1940 through 1944. Soybean production and exports increased throughout the period under consideration. The ability of producers to make the necessary adjustments in the supply of these two oils obtained from annuals prevented the prices from rising as high as the price of tung oil.

An almost complete reversal of economic circumstances, beginning in 1946, brought about a decrease in the price of tung oil and an increase in the price of all the other commercial drying oils. Probably the most important cause of
the decrease in the price of tung oil was an increase in supply. At the same time, evidence of a decrease in demand is not lacking, but the greatest change in factors which influence price occurred in supply. Two factors account for the increase in supply during this particular period. First, with the end of the blockade of the Chinese coast in 1945, imports from that country increased very rapidly. Imports increased from less than one-half million pounds in 1945 to about 133 million pounds in 1948. An increase in supply of such great proportion, together with a demand which becomes progressively elastic as greater quantities are purchased, accounts for the major decrease in the price of tung oil from 1945 through 1948.

The second factor accounting for the increase in supply during this period was domestic production. During the war-period, when the price of tung oil was high, tung growers enlarged and improved their orchards in anticipation of continuing high prices. Those trees began to bear fruit on a commercial basis in 1945. Consequently, domestic production of tung oil increased from about two and one-half million pounds in 1944 to over ten million pounds in 1945. Since 1945, production has increased annually in excess of a million pounds. An increased supply from both of the above sources, together with a decrease in demand, brought about a decrease in the price of tung oil during the postwar period.
During the period, 1946 and 1947, the prices of all other commercial drying oils increased. Evidently, a set of circumstances differing materially from those influencing the price of tung oil were responsible for those upward price movements. At first it may seem logical to assume that the demand for all drying oils declined along with the decrease in the demand for tung oil. Upon further consideration, however, it appears that the demand for oils most suitable for general application in the drying oil field increased as a result of postwar construction.

From the supply side of the price determining mechanism, conditions were favorable for an increase in price. Beginning in 1945, domestic production of linseed oil decreased annually until 1947, when it reached the lowest point since 1938. Reference to Chart I, Chapter I, shows that the period of decreasing production coincided with the period of increasing price. This is in contrast with the increase in the supply of tung oil and reveals the ability of annuals to make desired adjustments in supply. Both imports and domestic production of castor oil decreased during the corresponding period. The price of oiticica oil increased very little during the period under consideration and decreased rapidly after 1947. Even this slight increase cannot be accounted for from the supply side. It is not produced domestically and any change in supply is revealed by changes in import figures. Evidently, the oil found an
improved demand in the postwar market.

The remaining oils, menhaden and soybean, do not follow the same pattern of analysis as the other oils. They are not used as extensively for drying purposes as some of the other oils. Menhaden oil is used most exclusively in the manufacture of soap, while soybean oil is most useful as an ingredient of food and soap. Consequently, the competitive position of these oils is not determined by the drying oil market alone. Instead, their prices are influenced by competition from other drying oils and from other products used in manufacturing food and soap.

In contrast to the previous two-year period, beginning in 1947, the prices of all drying oils turned downward. The downward trend has continued throughout the remainder of the postwar period into 1950. There was a noticeable check in the price decline of tung oil in 1948. The present price of 26$\frac{1}{2}$ cents f.o.b., southern mills, is above the lowest average price for 1948 and 1949.

Two factors are responsible for this last major change in prices of drying oils, namely, a decrease in demand and an increase in supply. It is doubtful if there has been a decrease in the demand for drying oils in general, but there are indications that the demand for particular oils has decreased. When the price of tung oil dropped below the price of linseed oil and dehydrated
castor oil in 1947, industrial consumers were afforded an opportunity to reduce cost of raw materials by using more tung oil and reducing their purchases of linseed and dehydrated castor oils. This market phenomenon is known as cross-elasticity of substitutes produced and sold under rival conditions. It had the effect of decreasing the prices of linseed and castor oils and checking the downward trend of tung oil. Because of the close similarity between tung oil and oiticica oil, the decrease in price of the former sent the price of the latter on a downward spiral. The inter-competition of drying oils has brought their average prices more closely together. Their price differentials are less than they were in 1940.

Another important factor partly responsible for the price decline was an increase in production. Beginning in 1947, there was an increase in production of linseed, soybean, and castor oils. Linseed and soybean oils are obtained from annuals capable of making adjustments in supply within short periods.

It appears that tung oil was not able to maintain a price-position comparable to that of other drying oils during the postwar period because of (1) the great increase in tung oil imports into the United States from 1946 through 1948, (2) the increase in production of tung oil in the United States which began in 1946, and (3) the increase in consumption of other oils, chiefly soybean oil
in the manufacture of drying-oil products. This list of factors contributing to the decrease in the price of tung oil is not considered as including all possible factors, because many things may influence the price of a commodity. However, they do appear to have been significant in this case.

The major economic forces which have been operating to undermine the position of tung oil in the domestic market include the following: (1) the time-elasticity of supply of tung oil imports is less than that of tung oil which is produced in the United States, (2) the short time-elasticity of oils obtained from annual plants permitted producers of other drying oils to increase production more quickly than producers of tung oil in the United States, and (3) the partial interchangeability of drying oils permitted substitute oils to be used when the price of tung oil was high.

The principal factors responsible for the high price of tung oil during the war appear to have been (1) the great decrease in tung oil imports, (2) lack of ability of tung growers in the United States to increase production of tung oil which is obtained from perennials.
Pp. xiii / 809.

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Major Field: Economics

Title of Thesis: Tung Oil: An Economic Analysis

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