AN ECONOMETRIC ANALYSIS OF THE DEMAND FOR PECANS WITH SPECIAL REFERENCE TO THE DEMAND INTERRELATIONSHIPS AMONG DOMESTIC TREE NUTS

By

ELLIOTT B. LERNER

Bachelor of Science

University of California

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Thesis Approved:

Mark L. Fowler
Thesis Adviser

W B Back

Robert MacVicar
Dean of the Graduate School

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CHAPTER I

INTRODUCTION

The General Problem and Specific Objectives

The major objective of this thesis is to investigate the characteristics of demand for pecans at the farm level of the marketing process. However, there are two broad types of pecans produced in this country: improved pecans and seedling or native pecans.[1] Since these nuts are readily interchangeable in many uses, at least when shelled, it seems reasonable to assume that the two types are close substitutes in demand, although not necessarily perfect substitutes.

Moreover, pecans are only one of a group of four domestic edible tree nuts. The domestic tree nuts other than pecans are walnuts, almonds, and filberts. While the individual nuts may be best suited for specific uses, most of the nuts can be and are used for many of the same purposes. Consequently, it seems reasonable to postulate that the demands for domestic edible tree nuts are closely interrelated. Thus, the demand for pecans is jointly and simultaneously determined with the demands for other domestic tree nuts. Under such conditions, the obtaining of reliable estimates of the parameters of demand relations for pecans requires also an investigation of demand relationships between pecans and the other domestic tree nuts.

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[1] Improved pecans are from seedling pecan trees that have been budded, grafted or top-worked. They are usually characterized by thin shells and are larger in size than seedlings. Seedling pecans are from unimproved pecan trees, are usually thicker shelled and of smaller size than improved pecans.

Most of the earlier and contemporary empirical studies of demand for agricultural products deal primarily with a single commodity, although several studies of demand interrelationships between two or three commodities have been published.[2] In general, however, the method of estimation used in these studies has been that of the single equation least squares technique, which does not take into account explicitly the simultaneous nature of demand for closely related goods as assumed in the economic models.

Based on the above considerations, the specific objectives of this study are threefold:

1. To analyze the demand relationships between the two types of pecans without taking into explicit account the demands for other domestic tree nuts.
2. To analyze the demand interrelationships among all pecans and the other domestic tree nuts.
3. To compare the results from alternative methods of estimating the parameters connecting the variables in the related demand functions.

Usefulness of the Study

According to the theory of related demands, the price of a particular product is influenced not only by available supplies of that product but also by supplies of related products. If the demands for edible tree nuts are closely related, year-to-year changes in production (or supplies) of

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[2] Some of these studies will be mentioned later on in this chapter.

individual nuts would bring about changes in the price of that nut and the price of other tree nuts. Long-term trends in production of any individual nut, interacting with trends in imports, exports, national income and consumer tastes and preferences, would influence the long-term price level of all other tree nuts.

Many decisions at the various levels in the tree nut industry must be made which require a quantitative knowledge of demand interrelationships. Production plans of growers of individual tree nuts, as well as the plans of processors and handlers in providing marketing facilities, are dependent upon expectations of future events. Quantitative estimates of past and present demand interrelationships are basic in making conditional predictions of future demand conditions.

For example, if there is a significant substitutibility or complementarity in consumption (utilization) of tree nuts, the producer of any one of the individual nuts have a very real interest in governmental policies and programs, including tariff policies, relating to the production and marketing of the other tree nuts. The relative importance of this interest would depend upon the type and degree of demand interrelationships prevailing among the various tree nuts.

Consequently, quantitative knowledge of demand interrelationships have particular importance in the formulation and administration of marketing order and agreement programs which have been used in the marketing of almonds, filberts, walnuts and, to a lesser extent, pecans. For example, a knowledge of the type and degree of demand interrelationships in the tree nut industry would permit the policy planner to trace out the probable effects of a proposed program _a priori_. A control program formulated without reference to demand interrelationships may well result in the substitution of related products for the controlled products, thereby defeating the objectives of the program. The long-run effects of control programs are especially significant, since long-run interests may be jeopardized while attempting to increase short-run returns.

Moreover, it is believed that this study has considerable methodological interest. In only a limited number of empirical studies of related demands has the method of estimation been consistent with the assumptions of the economic model.

Previous Research in the General Problem Area

Only two empirical demand studies relating to tree nuts were noted in the literature. One was an unpublished study of walnut prices by Pennock[3] and the other a study of almond prices by Lee.[4] Lee reported the results of statistical analyses of the season's average returns to almond growers. He did not take into account explicitly the demand interrelations between almonds and related products. He did, however, include an index of the prices of competing domestic nuts (walnuts, filberts, and pecans) to indicate the influence of competing products on the price-quantity relationship for almonds.

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[3] Carolyn Pennock, "Statistical Analysis of Average Farm Price of English Walnuts", Program Policy Division, FDA, April 19, 1932, unpublished. (as cited by Geoffrey S. Shepherd, Agricultural Price Policy (Ames, 1947), p. 139).

[4] Ivan M. Lee, Statistical Analysis of Annual Average Returns to Growers of Almonds, 1924-25 to 1948-49, Giannini Foundation Mimeographed Report No. 103, (Berkeley, February, 1950).

Several studies concerned with demand relations between agricultural commodities have been published. These studies employed various measures to indicate the type and degree of the demand relations prevailing between the commodities. Meinken, Rojko and King[5] considered three approaches to the problem of measuring the substitutability of two commodities in demand and used an empirical example to illustrate the relation between the approaches. The three approaches compared are: the demand and cross elasticities, the relation of consumption ratios to price ratios (used as an approximation to the elasticity of substitution), and the estimated indifference surface.[6] The related products used in the empirical example were beef and pork consumption in Canada.

Rudd and Schufett[7] made a study of demand interrelationships among domestic cigarette tobaccos at the auction market level. Among the methods used for determining the degree and type of demand interrelationships were

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[5]K. W. Meinken, A. S. Rojko and G. A. King, "Measurement of Substitution in Demand from Time Series Data - A Synthesis of Three Approaches," Journal of Farm Economics, Vol. 38, (August, 1956), pp. 711-735.

[6]Morrisett derived the mathematical and statistical relationships of these three measures but he did not apply the derivations to an empirical problem. Irving Morrisett, "Some Resent Uses of Elasticity of Substitution - A Survey," Econometrica, Vol. 21, (January, 1953), pp. 41-62.

[7]Robert W. Rudd and D. Milton Shuffett, Demand Interrelationships Among Domestic Cigarette Tobaccos, Bulletin 633, (Lexington, June, 1955).

the so-called "rough test", the elasticity of substitution,[8] and the cross elasticities. In computing the cross elasticities of demand, they used single equation estimates stating that they felt the extra problems involved in using a simultaneous solution were not warranted in their problem.

Hoos[9] investigated the demand relations between pears and three other fresh fruits -- plums, peaches and oranges -- utilizing the "rough test", the "Hotelling conditions", and the "Slutsky condition" as measures of the types of related demands.[10] Schultz[11] develops the theoretical bases for these three tests and uses them in investigating the demand relations for beef, pork, and mutton in the United States; tea, coffee, and sugar in Canada; and barley, corn, hay and oats in the United States. The demand equations by both Hoos and Schultz are estimated using the single equation technique.

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[8]Meinken, Rojko and King, pp. 718-719, mention that this approach to the analysis of demand interrelationships for agricultural commodities has also been used recently by several other research workers. Among others they cite are: Kenneth W. Meinken, The Demand and Price Structure for Oats, Barley, and Sorghum Grains, United States Department of Agriculture Technical Bulletin 1080, September 1953; T. G. F. Woollam, "The Influence of Prices on the Relative Consumption of Beef and Pork," The Economic Annalist, Canadian Department of Agriculture, Vol. 23, (April, 1953), pp. 29-32; James N. Morgan, "Consumer Substitutes Between Butter and Margarine," Econometrica, Vol. 19,(January, 1951), pp. 18-39; and Marion Clawson, "Demand Interrelations for Selected Agricultural Products," Quarterly Journal of Economics, Vol. 57,(February, 1943), pp. 265-302.

[9]Sidney Hoos, "An Investigation of Complementarity Relations Between Fresh Fruits," Journal of Farm Economics, Vol. 23 (May, 1941), pp. 421-433.

[10]The validity and significance of these methods as used by Hoos are discussed by Adolph Kozlik, "An Investigation on Complementarity Relations Between Fresh Fruits; A Reply," Journal of Farm Economics, Vol. 23, (August, 1941), pp. 654-656; and by Sidney Hoos, "An Investigation on Complementarity Relations Between Fresh Fruits: A Rejoinder," Vol. 24, (May, 1942), pp. 528-529.

[11]Henry Schultz, The Theory and Measurement of Demand (Chicago, 1938). See Chapter 18, "The Special Theory of Related Demands," pp. 569-604 and Chapter 19, "The General Theory of Related Demands," pp. 607-654.

Method of Analysis and Procedure

In an attempt to achieve the stipulated objectives the study proceeds in the following manner. The conceptual framework is developed briefly. The basis for this framework lies in the theoretical tenets of demand theory, particularly those developed in the theory of related demands. A factual description of the economic sector is presented. Simplified economic models are postulated based upon the relevant economic theory and a factual understanding of the tree nut industry. Variables in the models are selected and classified as to type. The identification problem is resolved. Methods of estimation are then considered which are consistent with the economic and statistical assumptions underlying the models. A sample period is selected in connection with the data available chosen to reflect the variables included in the models.

The parameters connecting the variables in the various postulated models are estimated by different methods. Estimates of the parameters resulting from alternative models and methods of estimation are compared and subjected to various theoretical and statistical tests. Finally, the results are appraised and implications stated.

CHAPTER II

SOME DESCRIPTIVE ASPECTS OF THE TREE NUT ECONOMY

Although there are few well-specified procedures to follow in constructing economic models, the formulation of meaningful models would seem to require not only a knowledge of relevant economic theory but also descriptive or factual knowledge of the economic sector under study. On this point, Professor Judge has made the following comment: "...The construction of systems of autonomous relations is, therefore, a matter of intuition and factual knowledge; it is an art. Lack of knowledge is the prohibitive factor in the construction of economic models."[12]

The purpose of this chapter is to provide a descriptive background of the current situation and historical developments in the tree nut sector of our economy. The objective is to present an empirical description of the industry relating to the nature of the competitive relations existing among the individual nuts. The data presented will thus serve as one source for hypotheses regarding demand interrelationships and other cause-effect relations. In addition, the information presented in this chapter should provide a partial basis for appraising the models used in this study and some of the data is used to reflect the included variables in obtaining quantitative estimates of parameters in the postulated models.

[12] George G. Judge, "An Econometric Analysis of the Demand for Eggs," (unpublished Ph.D. dissertation, Iowa State College, 1952), p. 13.

Supply and Distribution

The total domestic supply of edible tree nuts for any given marketing year is composed of domestic production, imports of domestic-type and nondomestic-type tree nuts, and stocks of nuts carried over from previous seasons. Distribution of the total supply may be divided into domestic consumption, exports and carryover. Each classification may be further divided into its more important utilization components or by individual nuts.

The nuts which are produced domestically are walnuts, pecans, almonds and filberts. The nondomestic-type nuts included in import data are brazil nuts, cashews, chestnuts, pignolia, pistachio and miscellaneous tree nuts. These nuts are usually grouped together and called "other" nuts in the various statistical compilations. Imports of domestic-type and other nuts are important components of total supply. Usually, however, the volume of exports of domestic-type nuts is relatively unimportant. Data on carryover of nuts are fragmentary and of questionable validity.

Consumption

Before considering production and trade data for the individual nuts, apparent per capita consumption data[13] can be used to indicate the trend in total tree nut consumption in this country and the changing relative importance of the individual nuts in total consumption.

Per capita consumption of all tree nuts has been increasing since 1930, with most of the increase occurring in the post-World War II period

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[13]Apparent in the sense that the data reflect estimates of production, imports and exports but not estimates of carryover stocks. The data are on a shelled basis.

TABLE I

PER CAPITA CONSUMPTION OF TREE NUTS (SHELLED BASIS), UNITED STATES, CROP YEARS; 1920-55[a]

Crop Year	Almonds	Filberts	Pecans	Walnuts	Other[b]	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1920..................	0.20	0.07	0.04	0.31	0.36	1.0
1921..................	.31	.11	.16	.49	.36	1.4
1922..................	.29	.11	.05	.44	.34	1.2
1923..................	.30	.12	.19	.42	.39	1.4
1924..................	.26	.07	.13	.48	.35	1.3
1925..................	.23	.10	.17	.51	.29	1.3
1926..................	.26	.08	.30	.37	.35	1.4
1927..................	.24	.10	.11	.51	.14	1.1
1928..................	.26	.09	.21	.38	.30	1.2
1929..................	.20	.06	.16	.44	.23	1.1
1930..................	.21	.06	.17	.33	.29	1.1
1931..................	.17	.04	.26	.32	.33	1.1
1932..................	.14	.05	.20	.36	.27	1.0
1933..................	.12	.03	.23	.26	.25	.9
1934..................	.11	.03	.17	.33	.35	1.0
1935..................	.17	.04	.36	.34	.44	1.4
1936..................	.16	.05	.17	.28	.47	1.1
1937..................	.19	.03	.30	.38	.46	1.4
1938..................	.14	.03	.21	.32	.49	1.2
1939..................	.21	.05	.27	.38	.46	1.4
1940..................	.12	.03	.34	.32	.54	1.4
1941..................	.09	.04	.34	.44	.40	1.3
1942..................	.22	.03	.23	.35	.14	1.0
1943..................	.23	.05	.38	.37	.07	1.1
1944..................	.36	.10	.41	.41	.16	1.4
1945..................	.34	.10	.37	.38	.24	1.4
1946..................	.36	.13	.20	.38	.40	1.5
1947..................	.30	.08	.31	.33	.45	1.5
1948..................	.29	.09	.44	.38	.49	1.7
1949..................	.27	.10	.31	.41	.53	1.6
1950..................	.33	.06	.31	.36	.56	1.6
1951..................	.29	.08	.38	.42	.48	1.7
1952..................	.26	.09	.36	.42	.49	1.6
1953..................	.24	.06	.50	.32	.49	1.6
1954..................	.22	.08	.21	.38	.57	1.5
1955..................	.20	.07	.33	.42	.58	1.6

[a]Crop year beginning July of year indicated. Civilian per capita consumption beginning 1941.

[b]Includes the following nuts: brazil, pignolia, pistachio, chestnuts, cashews, and miscellaneous tree nuts.

Source: Supplement for 1956 to Consumption of Food in the United States, 1909-52, Agricultural Handbook No. 62, USDA, AMS, (Washington, D. C., September 1957), p. 30

(Table 1). In the six-year period 1930-35, average annual per capita consumption of all tree nuts was 1.1 pounds (Table II). Domestic-type nuts accounted for about 70 percent of total consumption. The seasonal average consumption of walnuts, pecans, almonds, and filberts in the period was .32, .23, .15 and .04 pounds per capita, respectively. The seasonal average consumption of other tree nuts was .32 pounds per capita.

TABLE II

EDIBLE TREE NUTS: PER CAPITA CONSUMPTION AND PERCENTAGE CHANGE BETWEEN THE PERIODS 1930-35 AND 1949-54, (SIX-YEAR AVERAGES)

Period	Almonds	Filberts	Pecans	Walnuts	Others	Total
1930-35						
Pounds per capita	.15	.04	.23	.32	.32	1.06
Percent of total	14.2	3.7	21.7	30.2	30.2	100.0
1949-54						
Pounds per capita	.27	.08	.35	.39	.52	1.61
Percent of total	16.8	4.9	21.6	24.2	32.5	100.0
Percentage increase	80.0	100.0	52.2	21.9	62.5	51.9

Source: Computed from Table I.

Average per capita consumption of all tree nuts increased to 1.6 pounds in the 1949-54 period. This represented an increase of 52 percent over the 1930-35 period. Although total consumption of domestic-type tree nuts increased in absolute terms, the percent this represented of all tree nut consumption decreased slightly to 68 percent in this period. Consumption of other tree nuts increased from .32 to .52 pounds per capita, or 63 percent.

In order of relative consumption in both periods, the domestic-type tree nuts were walnuts, pecans, almonds, and filberts. Per capita consumption of each nut increased between the periods 1930-35 and 1949-54, although the relative increase in the individual nuts varied considerably (Table II). Although the consumption of filberts shows the largest percentage increase, they represented only five percent of total tree nut consumption in the latter period. The consumption of walnuts accounted for 24 percent of the consumption of all tree nuts, and consumption of pecans and almonds accounted for 22 and 17 percent of the total, respectively.

Production and International Trade

In the 1930-35 period total imports of tree nuts were 88 percent of domestic production. In the 1949-54 period they were 85 percent of domestic production. Imports of domestic-type tree nuts, however, have declined substantially relative to domestic production and total imports. In the 1930-35 period, imports of domestic-type tree nuts were 33 percent of all tree nut imports, or about 29 percent of domestic production. By 1949-54, however, imports of domestic-type tree nuts had decreased to 15 percent of all tree nut imports. These imports of domestic-type tree nuts were about 13 percent of domestic production (Table III).

In terms of the volume of domestic production, the relative importance of the individual nuts stands in the same order as in consumption: walnuts, pecans, almonds and filberts. Walnut production, however, has been decreasing as a percentage of total domestic production. In the 1930-35 period, walnut production was 44 percent of total tree nut production. This percentage decreased to 38 percent in the 1949-54 period. Pecan

TABLE III

DOMESTIC TREE NUTS: PRODUCTION AND IMPORTS, 1930-35 (6-YEAR AVERAGE); PRODUCTION, IMPORTS AND EXPORTS, 1949-54 (6-YEAR AVERAGE)

	Unit	Almonds	Filberts	Pecans	Walnuts	Total
<u>1930-35 (6-Year Average)</u>						
<u>Production</u>						
Quantity	tons	13,137	788	39,442	42,017	95,564
Percentage of total production	percent	13.9	0.8	41.3	44.0	100.0
<u>Imports</u>						
Quantity	tons	12,129	5,227	286	10,488	28,130
As a percentage of production	percent	91.1	663.3	0.7	25.0	29.4
<u>1949-54 (6-Year Average)</u>						
<u>Production</u>						
Quantity	tons	40,317	7,945	72,272	74,583	195,117
Percentage of total production	percent	20.7	4.1	37.0	38.2	100.0
Percentage increase in production since 1930-35	percent	202.7	908.2	83.2	77.5	104.2
<u>Imports</u>						
Quantity	tons	9,064	6,714	478	9,321	25,577
As a percentage of production	percent	22.5	84.5	0.7	12.5	13.1
<u>Exports</u>						
Quantity	tons	3,202	437	1,260	2,322	7,221
As a percentage of production	percent	7.9	5.5	1.7	3.1	3.7

Source: Tables A-II and A-III, Appendix A.

production is close to walnuts as a percentage of domestic production. Pecans were 41 percent of domestic production in the 1930-35 period. In the 1949-54 period this percentage decreased to 37 percent. Almonds and filberts increased in their share of domestic tree nut production. In the 1930-35 period almond and filbert production was 14 percent and 1 percent, respectively, of domestic tree nut production. These figures increased to 21 percent and 4 percent in the 1949-54 period.

Almonds. The annual average production of almonds increased from 13,317 tons in 1930-35 to 40,317 tons in 1949-54 (Table III). This was an increase of 203 percent. In the earlier period imports of almonds were 91 percent of domestic production. However, this percentage had decreased to 23 percent in the 1949-54 period. Prior to 1952 almond exports never exceeded 2.1 percent of domestic production (Appendix Tables A-II and A-III). In 1952 almond exports reached 7 percent of domestic production and then increased substantially to 18 percent and 20 percent in 1953 and 1954 respectively.

Filberts. Filbert production has increased rapidly since the 1930-35 period. Annual average production increased from 788 tons in 1930-35 to 7,945 tons in 1949-54, an increase of over 900 percent. In the earlier period the bulk of domestic filbert supplies was imported. Imports were over six and one-half times as large as domestic filbert production. The importance of imports relative to total supply, however, has been decreasing. In 1949-54 imports of filberts averaged 85 percent of domestic production. Exports of filberts have never reached any substantial amount. In 1954 exports reached a peak of 11 percent of domestic production. In previous years exports never exceeded 6 percent of domestic production.

Pecans. Total pecan production has been gradually increasing in a highly irregular yearly pattern. Pecan production increased from an annual average of 39,442 tons in 1930-35 to 72,272 tons in 1949-54. The percentage increase between these two periods was 83 percent. Since 1927 imports of pecans have seldom exceeded one percent of domestic production. Imports of pecans averaged 286 tons in 1930-35. In the 1949-54 period imports of pecans had increased to an average of 478 tons. Because of increased domestic production, however, imports as a percent of production actually decreased. Exports of pecans have exceeded four percent of production in only one year. In 1938 pecan exports were 5.2 percent of production.

The total production of pecans is comprised of seedling pecans and improved pecans. Prior to 1936 most of the domestic production of pecans was of the seedling type (Table A-II, Appendix A). After this period, improved varieties began to make up an increasing share to total pecan supplies. However, in only five years has improved pecan production surpassed seedling production.

Walnuts. The production of walnuts increased from an annual average of 42,017 tons in 1930-35 to 74,583 tons in 1949-54. This was an increase of 78 percent. Imports of walnuts as a percentage of domestic production has been decreasing. In the earlier period imports were approximately 25 percent of domestic production. In the intervening seasons between 1930-35 and 1949-54, walnut imports seldom exceeded 9 percent of walnut production, but in 1949-54 imports averaged 13 percent of domestic production. Exports of walnuts reached a peak in 1936 of 6,160 tons (Table A-III, Appendix A). This was 13.4 percent of production. Since then, exports of walnuts as a percentage of domestic production has decreased. In the 1949-54 period imports of walnuts averaged only 3.1 percent of domestic production.

Other Tree Nuts. As pointed out previously, the other tree nuts imported into the United States are brazil nuts, cashews, chestnuts, pignolia and pistachio nuts. These nuts are not produced commercially in the United States. In recent years imports of cashews have accounted for more than one-half of total imports of all tree nuts, including imports of domestic-type tree nuts. In the 1930-35 period an average of 7,152 tons of shelled cashews were imported to the United States annually (Table IV). Imports of cashews increased to an average of 24,480 tons in the 1949-54 period, an increase of 242 percent. Unlike imports of all other tree nuts, imports of cashews have increased steadily through the years.

TABLE IV

IMPORTS OF BRAZIL NUTS, CASHEWS, CHESTNUTS, PIGNOLIA AND PISTACHIO NUTS

Year	Brazil		Cashew	Chestnuts	Pignolia		Pistachio	
Beginning October 1	In-shell	Shelled	Shelled	In-shell	In-shell	Shelled	In-shell	Shelled
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
1930-35 average	9,750	3,671	7,152	8,813	[a]	181	957	156
1949-54 average	7,832	2,966	24,480	8,566	11	151	3,394	190

[a] Prior to 1943 considered shelled.

Source: Jules V. Powell and Richard S. Berberich, Marketing Tree Nuts--Trends and Prospects, United States Department of Agriculture, AMS, Marketing Report No. 139, (Washington, D.C., October 1956); pp. 28-29.

The majority of the other imports, besides domestic-type imports consists of brazil nuts and chestnuts (Table IV). Brazils are imported in both shelled and in-shell form, although the majority are imported in-shell. Chestnuts are imported exclusively on an in-shell basis.

Carryover

An important component of the total domestic supply of tree nuts available each season, in addition to domestic production and imports, is the quantity of tree nuts carried over from previous seasons. In order to completely understand the supply side of the tree nut industry it would be desirable to have reliable estimates of the quantities of carry-in at the beginning of each marketing season for each year included in the analysis. Although these estimates are not available there are estimates of cold-storage and carry-in for certain years covered in the analysis. These estimates are presented in Table V to indicate the approximate magnitude of carry-in for those years for which data are available.

The accuracy of these figures in representing the entire amount of carry-in for each season is not known.[14]

Almonds, Filberts and Walnuts. Using estimates of carry-in furnished by the Department of Agriculture (Table V) the relative amounts of carry-in was computed for the 1950-54 period for almonds, filberts and walnuts.[15] Comparing almond carry-in of 17,000,000 pounds to 79,440,000 pounds of almonds produced in the 1950-54 period, the annual average of

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[14]The large California cooperatives have major cold storage for tree nuts and they are not included in the cold storage reports.

[15]All figures are computed on an in-shell basis.

TABLE V

ESTIMATES OF CARRY-IN STOCKS

A. Carry-in Stocks of Almonds, Filberts and Walnuts

Year[a]	Almonds	Filberts	Walnuts	
	1,000 pounds shelled	1,000 pounds in-shell	1,000 pounds in-shell	1,000 pounds kernels
1939	6,800	(b)	7,088	4,481
1940	7,400	(b)	4,154	8,467
1941	100	(b)	2,378	4,104
1942	400	(b)	5,151	9,396
1943	100	(b)	3,576	221
1944	200	(b)	2,176	314
1945	(c)	(b)	1,563	1,836
1946	3,700	(b)	3,025	399
1947	4,100	(b)	5,634	2,892
1948	3,000	(b)	2,611	2,727
1949	7,600	(b)	7,294	2,992
1950	6,600	2,080	17,394	6,260
1951	7,900	610	7,840	1,947
1952	11,500	794	12,927	2,798
1953	8,900	2,658	14,322	7,747
1954	9,300	1,096	10,656	4,164
1955	8,100	2,031	7,328	1,729

[a]For almonds year begins July 1. For filberts and walnuts year begins August 1.

[b]Not available.

[c]Less than 50,000 pounds.

B. Cold Storage of Edible Tree Nuts, July 1, By Kinds

Kind	1948	1949	1950	1951	1952
			(In thousands of pounds)		
			Shelled		
Almonds	6,269	6,917	7,603	10,387	12,595
Filberts	1,557	1,937	1,691	1,504	2,191
Walnuts	2,140	6,082	9,799	7,083	9,488
Pecans	7,331	9,167	5,683	9,764	6,880
Brazil nuts	1,515	1,380	1,351	441	899
Cashews	2,283	4,308	2,518	4,060	2,495
Other tree nuts	1,568	2,381	2,480	5,204	3,958
Unclassified	8,924	9,174	7,918	7,214	5,768
Total	31,587	41,346	39,043	45,657	44,274
			In-shell		
Almonds	415	910	920	1,249	1,076
Filberts	94	234	389	379	345
Walnuts	1,865	10,867	19,474	8,967	15,952
Pecans	20,708	29,013	7,422	12,356	21,371
Brazil nuts	195	502	460	44	187
Cashews	13	11	6	4	10
Other tree nuts	1,466	3,175	3,780	3,285	3,535
Unclassified	6,300	4,292	4,551	2,670	9,968
Total	31,056	49,004	37,002	28,954	52,444

Source: Jules V. Powell, Agricultural Economist, AMS, USDA, Washington, D. C., in a letter to the writer, August 14, 1958.

carry-in to production was 21 percent. For filberts carry-in was 10 percent of production, annual average, or 1,448,000 pounds of carry-in to 14,832,000 pounds produced. Walnut carry-in was 23,536,000 pounds. In comparison to 143,880,000 pounds of walnuts produced the annual average of carry-in to production was 16 percent.

Pecans. The only available data on pecan storage are from the cold storage reports of the Department of Agriculture. These reports are given for the years 1948-52 (Table V). For these years the average annual amount of pecans in cold storage on July 1 was 39,761,000 pounds. This compares with total production of 146,907,000 pounds, annual average, for the 1948-52 period. Using these figures the annual average amount of carry-in to production was 27 percent.

Marketing Tree Nuts

Methods and systems of marketing the individual domestic tree nuts vary from highly organized and integrated to unorganized. The California Almond Growers Exchange marketed approximately 70 percent of the California almond crop. The rest of the crop was marketed through independent packers and shellers.[16] The filbert crop is marketed through cooperative grower organizations, independent grower-packers and packers sometimes classified as independent or cash buyers. Over 80 percent of the filbert crop in recent years has been handled by three cooperatives and four large independent packers. The remainder of the marketing operations is divided among approximately fifteen firms, mostly small grower-packers.

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[16] The bulk of the information on marketing tree nuts is from Jules V. Powell and Richard S. Berberich, Marketing Tree Nuts--Trends and Prospects, Marketing Research Report No. 139, (Washington, D.C., October, 1956) pp. 12-14.

The major portion of the walnut crop is marketed by the California Walnut Growers Association. Through their extensive processing and marketing facilities they market 75 to 80 percent of the commercial crop. Independent growers, shellers, and packers handle the remainder of the California crop. In the Pacific Northwest, more than 50 percent of the walnut crop is marketed through the Northwest Nut Growers Association.

Methods used in the marketing of pecans are more varied than for any other domestic nut crop. They range from the grower bringing his own pecans to the sheller to highly integrated grower-marketing enterprises. As pecans are grown in widely scattered areas, especially the seedlings, grower cooperatives are found infrequently.

Utilization of Domestic Tree Nuts

Tree nuts are shelled or left in-shell and distributed to various outlets. Shelled tree nuts are used by salting trade, candy manufacturers, bakers, households (unsalted), ice cream manufacturers, and manufacturers of nut syrups and pastes. In-shell nuts are packed in straight packs or mixtures for direct consumption, primarily for the holiday seasons in November and December.

Almonds. Only 11 percent of the total supply of almonds in the 1950-52 period went to the in-shell market; the rest was shelled (Figure 1). In-shell almonds went to grocery stores in mixtures and straight pack. Most of the shelled almonds (64 percent, 1950-52 average) went to confectioners while the rest of the shelled crop was divided among salters, 13 percent; households (unsalted), 10 percent; bakers, 8 percent; ice cream manufacturers, 5 percent, and others less than 1 percent (Table VI).

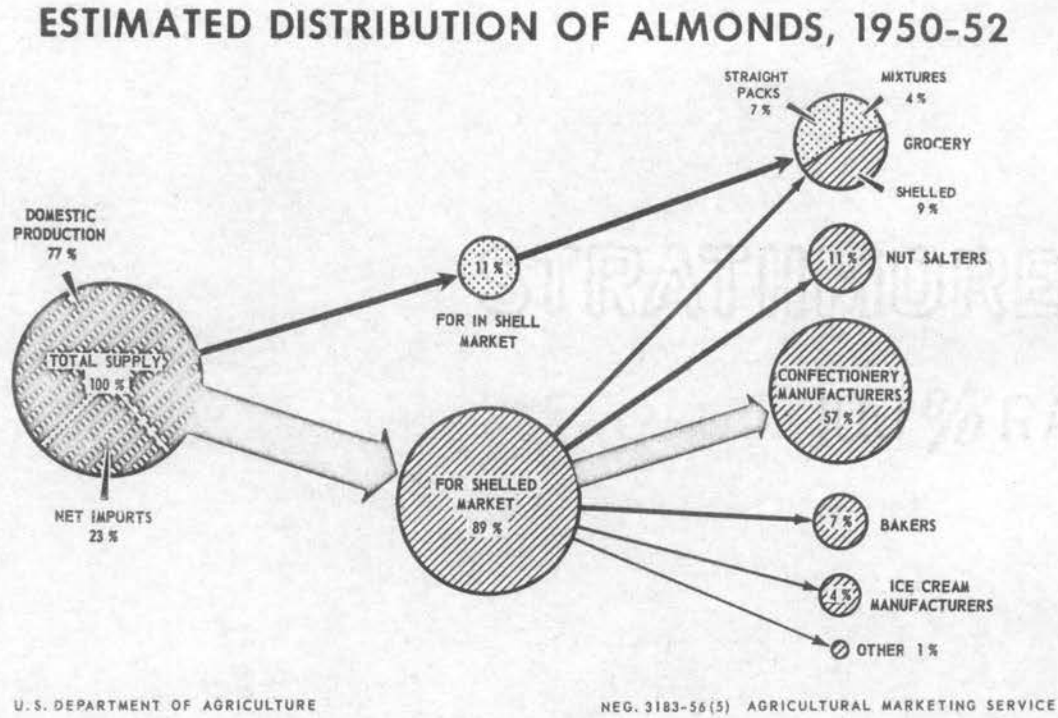

Figure 1.

Source: Powell and Berberich, p. 13.

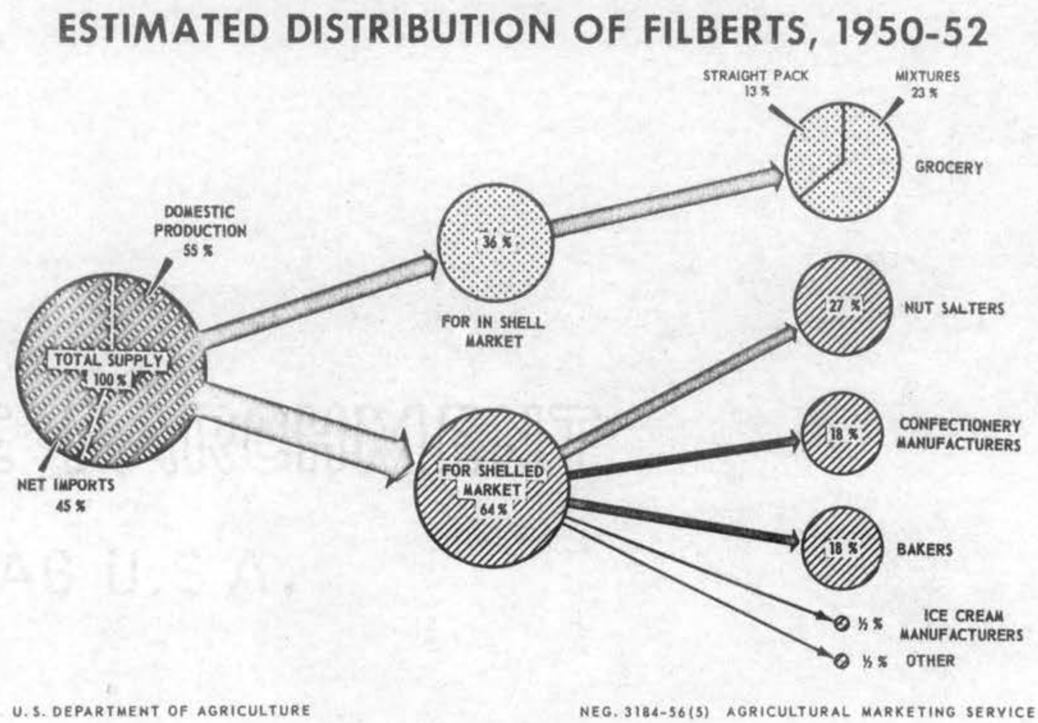

Figure 2.

Source: Powell and Berberich, p.13.

Filberts. In-shell filberts were distributed to grocery stores, 13 percent and 23 percent of the total supply going in straight pack and mixtures, respectively (Figure 2). The shell market used the greater percentage of the supply, 64 percent, with the salting trade using 43 percent of the shelled crop. The rest of the sales of shelled filberts was distributed to bakers, and confectioners, approximately 28 percent going to each, with the remaining 1 percent being distributed to households (unsalted), ice cream manufacturers and other uses.

Pecans. Pecans have shown a different trend, more pronounced than for any other domestic nut crop, in that the majority of nuts are marketed on a shelled basis. In the 1950-52 period, 75 percent of the pecan crop was distributed on a shelled basis while the rest of the pecan supply went to the in-shell market (Figure 3). In-shell pecans went for distribution in grocery stores; 16 percent of the total supply went into straight pack and 9 percent in mixed pack. Most of the shelled pecans, 44 percent of the total amount shelled, was purchased by bakers. Other purchasers, as of the total amount shelled, were: confectioners, 20 percent; household use and ice cream manufacturers, 12 percent each; the salting trade, 7 percent; and other uses, 5 percent.

Walnuts. In the 1950-52 period approximately 53 percent of the walnut supply was sold in-shell, 42 percent in straight pack and 11 percent in mixtures (Figure 4). Before this period the majority of the walnut crop was sold in-shell but the in-shell market appears on the decline as the shelled market gains in importance.[17] The majority of the shelled walnuts

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[17]United States Tariff Commission, Edible Tree Nuts (Washington, September 1954), p. 16.

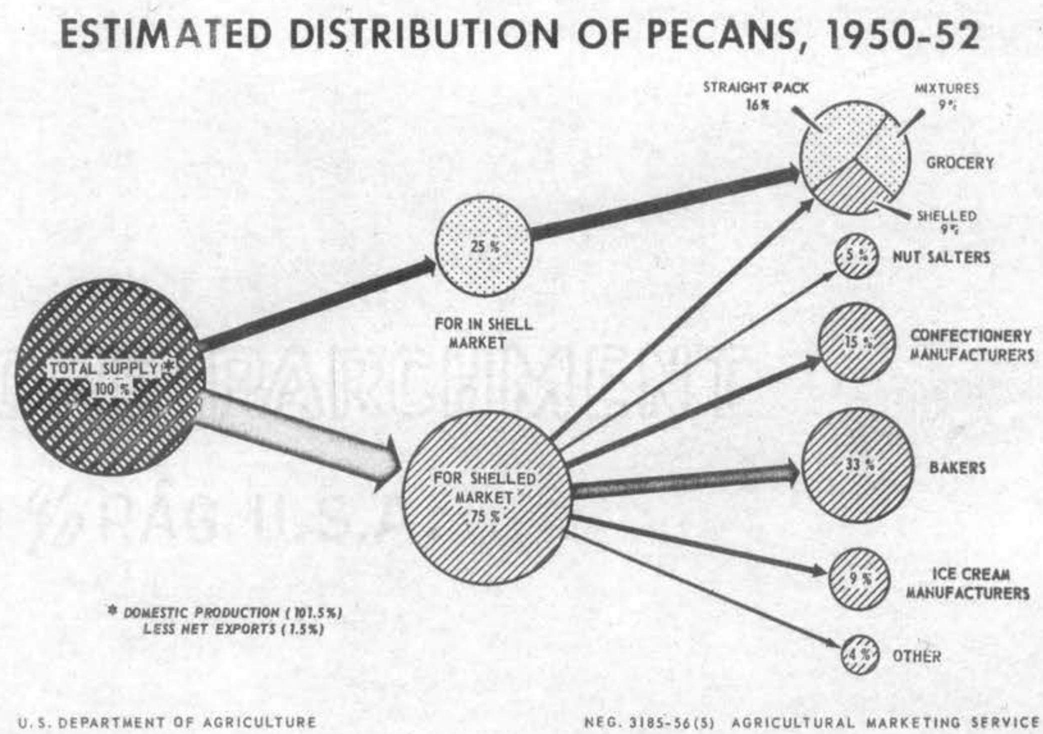

Figure 3.

Source: Powell and Berberich, p. 15.

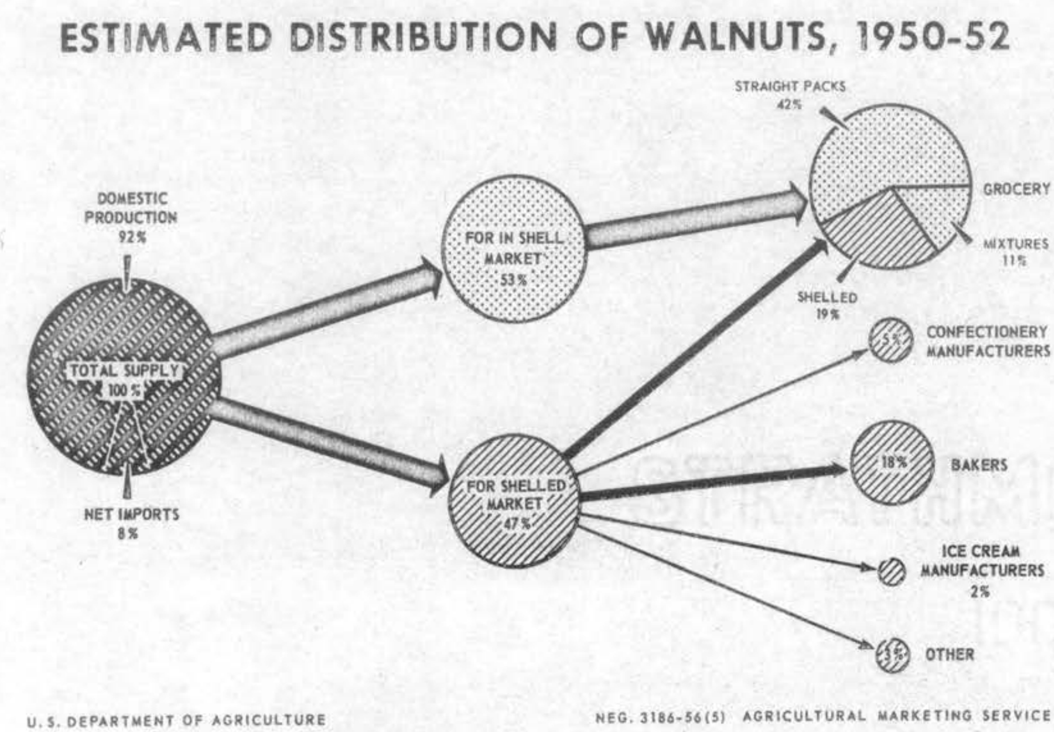

Figure 4.

Source: Powell and Berberich, p. 15.

went to the baking trade and to households (unsalted); each accounting for 39 percent of the shelled crop. Confectioners used 11 percent; ice cream manufacturers, 4 percent; and the remaining 7 percent of the shelled walnuts going to other uses.

Nature of Competition Among Tree Nuts

In-shell Mixtures. An area of direct competition among in-shell tree nuts is in in-shell mixtures. It would be expected that if there were a large supply of one tree nut relative to the other tree nuts, the nut in relatively large supply would comprise a larger percentage of the in-shell mixture. For example, mixtures usually contain 35 percent walnuts, but this proportion varies and depends largely on the relative prices of the component nuts.

Competition from in-shell imports is greatest from in-shell brazil nuts, since in-shell brazils along with walnuts are the chief constituents of in-shell mixtures. There is relatively little competition from imports of domestic-type in-shell tree nuts with in-shell nuts grown in the United States. This is due to the development of (a) improved varieties in the United States, (b) superior grading, and (c) existing tariff protection.

Shelled Nuts. Competing more directly than the other types of shelled tree nuts are shelled walnuts and shelled pecans. This is due to the possible interchangeability in many of their uses. These two nuts account for over 75 percent of the shelled tree nuts used (annual average 1950-52) in commercial baking, household cooking and in ice cream (Table VI). A change in the demand or supply conditions for one would be expected to have repercussions on the other.

TABLE VI

ESTIMATED SALES OF SHELLED TREE NUTS IN THE UNITED STATES, ANNUAL AVERAGE OF YEARS BEGINNING OCTOBER 1, 1950-52[a]

A. By Outlets

	Total	Confec-tionary	Salting	Baking	Households (Unsalted)	Ice Cream	Other
			(million pounds)				
Almonds	39	25	5	3	4	2	(b)
Filberts	7	2	3	2	(b)	(b)	(b)
Pecans	41	8	3	18	5	5	2
Walnuts	28	3	-	11	11	1	2
Cashews	48	3	43	2	-	-	(b)
Brazils	6	2	3	1	(b)	(b)	(b)
Total	169	43	57	37	20	8	4
			(percent)				
Almonds	23	58.14	8.77	8	20	25.0	(c)
Filberts	4	4.65	5.26	5	(c)	(c)	(c)
Pecans	24	18.60	5.26	49	25	62.5	50
Walnuts	17	6.98	-	30	55	12.5	50
Cashews	28	6.98	75.44	5	-	-	-
Brazils	4	4.65	5.26	3	(c)	-	-
Total	100	100.00	100.00	100	100	100.0	100

B. By Kinds

Outlet	Total	Almonds	Filberts	Pecans	Walnuts	Cashews	Brazils
			(percent)				
Confec-tionary	25	64	28.5	20	11	6	33
Salting	34	13	43.0	7	-	90	50
Baking	22	8	28.5	44	39	4	17
Households (unsalted)	12	10	(c)	12	39	-	(c)
Ice Cream	5	5	(c)	12	4	-	(c)
Other	2	(c)	(c)	5	7	(c)	(c)
Total	100	100	100.0	100	100	100	100

[a]Powell and Berberich, p. 33

[b]Probably less than one-half million pounds

[c]Less than 1 percent

Source: U. S. Tariff Commission

Although almonds and filberts are sold in some of the same outlets as pecans and walnuts, they do not compete to any great extent. Imports of both pecans and walnuts enter the United States. The amount of pecans entering is small and offers no competitive problem, although imports of other tree nuts might substitute for domestically grown shelled pecans. As the imports of walnuts are smaller and of generally poorer quality than domestic walnuts, they are diverted to the confectionery and baking industries where they are not in competition with the domestic crop.

The major portion of the shelled crop of almonds (64 percent, 1950-52 average) goes to the confectionery trade (Table VI). Shelled domestic almonds are to some extent subject to competition from cashews[18] and imported shelled filberts. Imported shelled filberts probably do not compete closely with domestic almonds, however, since almonds used in salting are the more expensive grades. Imports of shelled almonds compete with the domestic crop, but imports are restricted, according to domestic supply, by tariff duties.

The major outlet for shelled filberts is the salting trade where they are in direct competition with the usually large importations of shelled filberts. For this reason the tariff rate is an important factor in determining the price of shelled filberts. In fact, "...the landed duty paid cost of Mediterranean shelled filberts determines the maximum price which can be obtained for domestic shelled filberts."[19] About 43 percent of the shelled filberts are salted, consisting largely of imports.

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[18]The majority of the tree nuts used for salting were cashews (Table VI).

[19]United States Tariff Commission, Edible Tree Nuts, (Washington, D.C., September 1954), p. 12.

<u>Competition with Peanuts</u>. Powell and Berberich[20] discuss and compare the various uses and interrelated uses of peanuts and tree nuts. They believe the competition may be between tree nuts as a group and peanuts. In many instances there may be practically no competition between tree nuts and peanuts due to the large price differentials and differences in use.

Tree nut consumption on a shelled basis is far less than peanut consumption. For example, in the 1950-52 period, the salting and confectionery trade used 285 million pounds of peanuts annually in comparison to 100 million pounds of tree nuts used in this same period. In all uses peanuts (excluding peanut butter) were used to the extent of 290 million pounds compared to 169 million pounds of tree nuts.

The salting trade in the 1950-52 period used an estimated 212 million pounds of nuts of which 73 percent were peanuts while tree nuts comprised the rest of the shelled nut mixtures.

Confectioners use more peanuts than all other nuts combined. In the 1950-52 period, out of a purchase of 168 million pounds of shelled nuts annually about 75 percent were peanuts, 15 percent almonds, 5 percent pecans, with the remaining 5 percent consisting of equal quantities of filberts, walnuts, cashews and brazil nuts.[21]

To a limited extent peanuts compete with tree nuts in the baking trade. The baking trades use, as a percentage of the total, approximately 12 percent peanuts in comparison to 43 percent pecans and 26 percent walnuts.

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[20] Powell and Berberich, pp. 22-23. The figures in this section are taken from their report.

[21] <u>Ibid</u>, p. 22.

Peanuts do not compete with tree nuts in ice cream manufacturing or in household use (unsalted). In order of relative utilization, the predominating nuts in these uses are walnuts, pecans and almonds.

Governmental Marketing Programs

The marketing of the domestic supply of almonds, filberts and walnuts is regulated under Federal marketing agreements and order programs pursuant to the Agricultural Marketing Agreement Act of 1937, as amended.[22] In addition to quality controls for filberts and walnuts, the programs are used for controlling the quantity of the three tree nuts other than pecans going into the in-shell and the shelled market. These controls are designed to enable growers to realize higher returns than would otherwise be possible.

Supplementary to the marketing agreement and order program the Department of Agriculture, pursuant to Section 32 of Public Law 320, as amended[23] has the authority to support the domestic price of tree nuts by diversion payments, export payments or surplus removal programs. However, the Secretary of Agriculture and the Directors of the Commodity Credit Corporation must approve the use of these programs in a particular crop disposal situation prior to their use.

Imports of tree nuts are regulated by the U.S. Tariff Commission. In addition to regular import duties (Table VII), additional restrictions may be placed upon the quantity of imports when it is believed the imports

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[22] Agricultural Marketing Agreement Act of 1937, Public Law No. 137, U.S. Statutes at Large, 75th Congress, First Session, L (June 3, 1937), pp. 246-249.

[23] Section 32 of Public Law 320, U.S. Statutes at Large, 74th Congress First session, XLIX (August 24, 1935), pp. 774-775.

will interfere with domestic marketing programs or the amount of product processed from domestic tree nuts. The regular duties are higher on imports of domestic-type tree nuts than on the other imported tree nuts.

TABLE VII

UNITED STATES RATES OF DUTY UNDER THE TARIFF ACT OF 1930 FOR EDIBLE TREE NUTS, 1954[a]

Kind of Nuts	Duty in Cents Per Pound	
	Not Shelled	Shelled
Almonds	5.5	16.5[b]
Almonds, prepared or preserved		18.5[b]
Filberts	5.0	8.0[c]
Pecans	5.0	10.0
Walnuts	5.0	15.0
Brazil nuts	0.375	1.125
Cashews	1.5	1.5

[a]United States Tariff Commission, Almonds (Washington, September 1957), Table 1, Appendix, and Powell and Berberich, p. 9.

[b]Additional fees imposed pursuant to Section 22: October 1, 1954-September 30, 1955--10 cents per pound on imports in excess of 5 million pounds.

[c]Additional fees imposed pursuant to Section 22: October 1, 1954-September 30, 1955--10 cents per pound on imports in excess of 6 million pounds. In no case may an additional fee imposed pursuant to Section 22 exceed 50 percent ad valorem (exclusive of the regular duty).

Almonds. The marketing agreement and order program for almonds limits the domestic supply of almonds by declaring a percentage of the production as "surplus." The "surplus" almonds are sold in outlets which are noncompetitive with the remaining "salable" almonds. In practice, the "surplus" almonds have usually been exported at prices lower than that obtained for "salable" almonds in the domestic market.

The quantities of almonds diverted by marketing agreement and order programs were: 4.2 million pounds of the 1951 crop; 5.3 million pounds of the 1952 crop; 5.9 million pounds of the 1953 crop; and 6.6 million pounds of the 1954 crop. Most of these almonds were exported. However, 3.3 million pounds (shelled basis) of the 1951 "surplus" almonds were diverted to crushing with the use of government benefit payments of 30 cents per pound under "Section 32," and, in 1949, 2.4 million pounds of shelled almonds were crushed, with benefit payments of about 30 cents per pound.[24]

Filberts. The filbert marketing order and agreement program is designed to allocate the "merchantable"[25] in-shelled filberts between in-shell and shelled outlets. The percentage of the "merchantable" in-shelled filberts diverted from the domestic in-shelled market, called "surplus" filberts, may be exported in-shell, or shelled and sold in the domestic market.

The declared "surplus" percentages of the "merchantable" in-shell filberts were: 25 percent for the 1949 crop year; zero for the 1950 crop year; zero for the 1951 crop year; 34 percent for the 1952 crop year; and zero for the 1953 crop year. Under Section 32 programs, 4.2 million pounds of in-shell filberts were diverted to the shelled market aided by Government payment of about 6.5 cents per pound.[26]

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[24] United States Tariff Commission, Almonds, (Washington, D.C., September, 1957), Table 13, Appendix.

[25] Filberts meeting minimum quality and size standard.

[26] United States Tariff Commission, Edible Tree Nuts, (Washington, D.C., September, 1954), Table 25, Appendix.

Walnuts. The marketing of walnuts is controlled in a fashion similar to that for the other nuts. In addition, due to the increasingly important shelled walnut market, the Secretary of Agriculture in 1954 was given the authorization to declare an "over-all" surplus that cannot be marketed in the normal in-shell or shelled outlets.

The declared "surplus" percentages of "merchantable" in-shell walnuts was: 30 percent for the crop of 1949; 10 percent for the crop of 1950; 15 percent for the crop of 1951; 20 percent for the crop of 1952; and 15 percent for the crop of 1953. The "surplus" walnuts were shelled. Under Section 32 programs (1) 27.5 million pounds of in-shell "merchantable" walnuts and shelling stock of the 1949 crop year were crushed with the aid of government payments of about 10 cents per pound and (2) 3.25 million pounds, shelled equivalent, of "merchantable" walnuts and shelling stock of the 1952 crop year were crushed with the aid of Government payments of about 32 cents per pound.[27]

Pecans. The marketing of pecans was regulated from September 20, 1949, to October 1, 1957, only in the five states of South Carolina, Georgia, Florida, Alabama, and Mississippi. The marketing controls applied to grades and sizes and only to those pecans which were marketed in-shell outside of these five states.

Under Section 32 programs the Government purchased 3.3 million pounds of shelled pecans at about 72 cents per pound. In 1953 the Government purchased 0.6 million pounds of shelled pecans at about 66

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[27]Ibid.

cents per pound. The pecans that were purchased were distributed for school lunches and other eligible non-competitive outlets.[28]

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[28] *Ibid.*

CHAPTER III

THE THEORETICAL FRAMEWORK

The objective of this chapter is twofold: First, to present briefly some of the theoretical considerations underlying the economic models, and; second, to present some aspects of the statistical models, including methods of estimation consistent with the postulated economic models. Various theoretical and statistical tests based on the theory of related demands are discussed.

Economic Considerations

The Theory of Consumer Choice

It is assumed that the individual consumer possesses an utility function $U = U(X_1, X_2, \ldots X_n)$ and desires to maximize this utility function in buying commodities $(X_1, X_2, \ldots X_n)$ at the market place. He is faced with two restrictions. One is the price of the commodities $(P_1, P_2, \ldots P_n)$ which are determined on the market, and which the individual consumer takes as given. The second restriction is that the consumer is assumed to have a given money income (M), the entire amount of which is spent on the n commodities. This may be written as

$$M = \sum_i P_i X_i . \tag{3.1}$$

since in spending his entire income the consumer desires to maximize U or some F (U), the problem is one of determining his demands for the n commodities such as to maximize U under the given restraints.

By making use of the Lagrange multiplier λ, the restrained function which is to be maximized may be written as

$$\max. \left[U - \lambda \left(\sum_i P_i X_i - M \right) \right] . \qquad (3.2)$$

Setting the first order partial derivative equal to zero and solving, we find

$$U_i = \lambda P_i \qquad i = (1, 2, \ldots n), \qquad (3.3)$$

where $U_i = \partial U / \partial X_i$ = the marginal utility of X_i.[29] Equation (3.3) is the condition for consumer equilibrium; it is an equalization between the marginal utility of X_i and the price of X_i, multiplied by λ.[30] It expresses the consumer's demands for commodities under the monetary restraint of $M = \sum_i P_i X_i$ and the assumption that prices are given to the individual consumer. According to equation (3.3), in equilibrium λ can be put in the form

$$\lambda = \frac{U_1}{P_1} = \frac{U_2}{P_2} \cdots = \frac{U_n}{P_n} . \qquad (3.4)$$

Equation (3.4) states that the consumer is in equilibrium when the ratio of marginal utility to price for all goods is equal. Condition (3.4) can be expressed such that the marginal rate of substitution between any two commodities is equal to the corresponding price ratio (P_i/P_j) or

$$\frac{dX_j}{dX_i} = \frac{P_i}{P_j} . \qquad (3.5)$$

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[29] J. R. Hicks, Value and Capital, (Oxford, 1946) p. 305.

[30] Where λ corresponds to Marshall's marginal utility of money.

Equations (3.1) $\sum_i P_i X_i = M$ and (3.3) $U_i = \lambda P_i$ are the necessary conditions for the maximization of U. Sufficient conditions are

$$d^2U = \sum_{j=1}^{n} \sum_{j=1}^{m} U_{ij}\, dX_i\, dX_j < 0 \qquad (3.6)$$

subject to

$$dU = \sum_{j=1}^{n} U_i\, dX_i = 0.$$

These are the stability conditions as given by Hicks.[31] The condition $d^2U < 0$ indicates that the marginal rate of substitution must be diminishing for substitution between commodities in every direction or that the indifference curves are convex to the origin.

It is important to note that the results obtained in the maximizing procedure are invarient for the substitution of F(U) for U.[32] We can therefore go from a cardinal utility function to a scale of ordinal preferences. The consumer's behavior is now explained in terms of his preferences which are, in turn, generated by his behavioral responses to the surrounding environmental stimuli instead of the undefinable utility surface.

The theoretical effects brought about by a change in the consumer's income or a change in the prices confronting him have been presented in detail in many publications analyzing demand behavior.[33] Since the

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[31] Hicks, p. 306.

[32] R. G. D. Allen, Mathematical Economics, (New York, 1957), p. 660

[33] The reader is referred to Allen, Chapter 19; Hicks, Chapter II, III and pp. 307-311; and Henry Schultz, The Theory and Measurement of Demand, (Chicago, 1938), Chapter 1, pp. 569-582, pp. 607-628, and pp. 644-654.

primary concern of this study is to investigate demand interrelationships, we turn directly to a consideration of concepts dealing with related demand theory.

Demand Interrelationships

The market demand function for a particular good can be obtained by the summation over all demand functions of individual consumers. For commodity 1 the market demand function may be written in linear form as

$$P_{1t} = a_1 + b_{11}Q_{1t} + b_{12}Q_{2t} + b_{13}I_t \qquad (3.7)$$

where P_1 represents the price of commodity 1; Q_1 and Q_2 are the supplies of commodities 1 and 2; and I is aggregate consumers' income.

The coefficients of equation (3.7) define the nature of demand for commodity 1 and the nature of the demand interrelationships. The nature of demand for commodity 1 is indicated by the magnitude and the sign of b_{11}. In general the sign would be negative, indicating the expected inverse relationship between the quantity taken and the price paid for a commodity. The sign of b_{13} is usually positive since the price of a commodity and the income level are usually positively related. Infrequently there may be cases where b_{13} would be negative. Commodity 1 would then be referred to as an inferior good.

Demand interrelationships between commodity 1 and 2 are indicated by the sign and magnitude of b_{12}. The sign indicates the type of relation and the magnitude indicates the intensity of the relation. Commodities 1 and 2 are said to be competing in demand if $b_{12} < 0$, that is, an increase in the supply of commodity 2 would depress the price of commodity 1. They are said to be independent in demand if $b_{12} = 0$, that is, an increase in the supply of commodity 2 would have no effect on the price of commodity 1. A complementary relationship is indicated if $b_{12} > 0$, that is, an increase in the supply of commodity 2 would have the effect of increasing the price for commodity 1.

If the commodities were perfect substitutes for each other, on a unit for unit basis, b_{12} would not only be negative but it would also equal b_{11}. This would mean a change in the supply of commodity 2 would have the same effect on the price of commodity 1 as a change in the supply of commodity 1. The consumer would be indifferent to the commodities.

The "Hotelling Conditions". The market demand function for commodity 2 can be written in the same form as equation (3.7)

$$P_{2t} = a_2 + b_{21}Q_{1t} + b_{22}Q_{2t} + b_{23}I_t, \qquad (3.8)$$

where P_2 represents the price of commodity 2 and the other variables are as defined previously.

The "Hotelling conditions" as referred to by Schultz[34] is a condition of the rationality or consistency of consumer behavior for commodities related in demand. According to the "Hotelling conditions" if commodities 1 and 2 are related in demand, the change in the price of 1 brought about by a change in the quantity of 2 should equal the change in the price of 2 brought about by the change in the quantity of 1. This adds an additional restriction upon the parameters of equations (3.7) and (3.8). If, for example, commodities 1 and 2 are competing in demand, not only should b_{12}

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[34] Schultz, p. 581.

and b_{21} be negative, but according to the "Hotelling conditions" b_{12} should equal b_{21}.[35]

The "Rough Test". Schultz suggests the use of the "rough test"[36] for distinguishing between commodities that are completing (complementary) or competing in demand. The test is one of comparing the price ratios and consumption ratios of the two commodities. If the two commodities are completing it would be expected that the ratio of the consumption of one to that of the other would fluctuate less than their corresponding price ratios. When the goods are competing it would be expected that the price ratios would fluctuate less than their corresponding consumption ratios. However, several objections have been raised to the use of this test.[37]

Measurements of Competitive Relations. Three other methods used to measure the competitive relations between commodities in demand are (1) the demand and cross-elasticities, (2) the relation of consumption ratios to price ratios, and (3) the indifference function. Although the three measures are designed to measure the same thing (that is, the competitive relations between two commodities) and they involve the same variables, it

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[35] There are two limitations to the validity of the "Hotelling conditions" from theoretical considerations. One is that it is based on the assumption that utility is measurable; the other that the marginal degree of the utility of money is constant. Both these limitations are overcome by resorting to another test based on the theory presented by Slutsky. See Schultz, pp. 620-624.

[36] Schultz, pp. 571-572.

[37] See Charles C. Peters and Walter R. Van Voorhis, Statistical Procedures and Their Mathematical Bases, (New York, 1940), pp. 78-79; Kozlik, pp. 654-56; Sidney Hoos, "An Investigation of Complementary Relations Between Fresh Fruits: A Rejoiner," pp. 528-529.

has been shown that, while it is possible to go from the demand functions to the ratios or the indifference surface, it is impossible to go the other way.[38]

The relation of consumption ratios to price ratios is used as a short-cut method to estimate the elasticity of substitution (E_s). Empirically it can be defined as

$$E_s = \frac{d(X_1/X_2)}{d(P_1/P_2)} \quad \frac{P_1/P_2}{X_1/X_2} \tag{3.9}$$

for two commodities X_1 and X_2 and prices P_1 and P_2. This concept, defined as an estimated measure of the "ease of substitution" of one commodity for another along an indifference curve, is not a very useful concept in estimating demand interrelations. Morrissett, in reviewing the use of this concept in interrelated consumer demand studies, points out that in most of the previous research the original assumptions underlying this concept have not been adequately recognized. He concludes his article in agreeing with Pigou that "... there is no gain in working with E_s, which is a combination of price elasticities and cross-elasticities, rather than working with the latter elasticities directly."[39]

Economic Models and Methods of Estimation

The construction of an economic model is an attempt to explain or describe in simplified form the underlying relationships which generate

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[38] Meinken, Rojko and King, pp. 711-735.

[39] Irving Morrissett, "Some Recent Uses of Elasticity of Substitution--A Survey," Econometrica, Vol. 21, January 1953, p. 61.

the jointly dependent economic variables observed in the sector of the economy being analyzed. Using the economic model as a base, a method of estimating the structural parameters has to be determined. The estimating procedure should be consistent not only with the hypothesized economic model but the assumptions underlying the statistical technique as well. Once the estimating procedure is determined and the statistical assumptions supplied, the set of structures can be referred to as the statistical model.

The Single Equation Model

When it can be assumed that the path of a single variable, referred to as dependent, is "explained" or generated by a set of variables which are independent of the action of the dependent variable, the single equation model is appropriate.

The method of estimation usually used to obtain estimates of the structural parameters of the single equation model is the method of least squares. This method of estimation consists of minimizing the sums of the squares of the deviations of the observed values from the estimated values of the single dependent variable.

The single equation model can be written as

$$Y_t = A + \sum_{i=1}^{k} B_i Z_{it} + U_t \qquad (3.10)$$

where Y represents the estimated dependent variable; A the constant value; Z_{1t} the independent variables ($i = 1, 2, \ldots k$); U_t the random disturbances; and $t = 1, 2, \ldots T$ the number of observations. The Z_{it}'s are assumed to be fixed, independent of U_t and measured without error. Any errors of measurement are assumed to be associated with the one dependent variable and are reflected by the disturbance factor U_{tj}, which also reflects the effects of omitted independent variables. Estimates of the structural parameters, the B_i's, are obtained by minimizing the sums of squares of the errors about the dependent variable. That is, the sum of squares

$$\sum_{t=1}^{T} (Y_t - \hat{Y}_t)^2 \qquad (3.11)$$

is minimized by the well-known technique of least squares, where Y_t is the observed value and $\hat{Y}_t$ the estimated value of the dependent variable.

Historically, this method of estimating parameters has been of significant importance in the empirical work done in demand analysis. It uses a simple technique to estimate the parameters which is not computationally laborious. A researcher may gain in both time and financial resources in using this technique and in many cases more elaborate methods will not give more useful results.[40]

One of the main criticisms directed against the use of the least squares approach is that in theory, and quite likely in fact, the observed variables are generated through the interdependence of mutual economic

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[40]Karl A. Fox, "Structural Analysis and the Measurement of Demand for Farm Products," Review of Economics and Statistics, 1954, pp. 57-66, points out how in many instances the single equation approach can be used successfully in estimating the demand for farm products.

forces.[41] This seriously limits the use of the single equation technique since it fails to take into account the joint and simultaneous determination of the economic variables. When a jointly dependent relationship exists a method of estimation should be used that takes into consideration all the available information for a simultaneous solution.

The Simultaneous Equation Model

The simultaneous model is a model for which it is postulated that the economic variables are generated by a complete system of equations which have to be solved simultaneously. As in the single equation case, the statistical model is constructed so as to be consistent with the underlying economic model.

A complete general model of structural equations may be written as

$$BY_t' + AZ_t' = U_t' \qquad t = 1, 2 \ldots T \qquad (3.12)$$

where B is a G x G nonsingular matrix of the linear coefficients of G endogenous variables in transposed row Y_t'; A is the G x K coefficient matrix of the K exogenous or predetermined variables in Z_t'; and U_t' is the transposed row vector of G disturbances, one relating to each equation.

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[41] Trygve Haavelmo, "The Statistical Implications of a System of Simultaneous Equations," Econometrica, 1943, p. 7 says that when one has to deal with a system of joint relationships the "system should, for statistical purposes be considered as a system of transformations, by which to derive the joint probability distribution of the observable variables from the specified distribution of the error terms. And then to avoid inconsistencies, ... all formulae for estimating the parameters involved should be derived on the basis of this joint probability law of all the observable variables involved in the system."

In connection with such models, the following assumptions are usually made.[42] The elements of B and A are assumed linear and the following assumptions are made regarding the random elements U_{it}:

1. The U_{it} are independent of the z_{it}
2. The U_{it} are normally distributed with zero mean and finite variance σ^2.
3. The U_{it} are jointly dependent with covariance $E(U_{it}\ U_{jt}) = \sigma_{ij}$, $ij = 1, 2, \ldots G$, $i \neq j$, $t = 1, 2, \ldots T$.
4. The U_{it} are independent over time, $t = 1, 2, \ldots T$ $E(U_{it}\ U_{it-0}) = 0$. That is, there is no serial correlation in the residuals.

Four distinct types of structural equations may be contained in the model. They are: (1) behavioral, (2) identities, (3) technical, and (4) institutional equations. Only behavioral equations are dealt with in this study. "The behavior equations represent the joint response of groups of individuals or firms to common stimulus."[43] An example is the interrelated demand equations for two different types of tree nuts.

Variables in the behavioral equations are defined as to their influence in the statistical model. "The endogenous variables are those whose observed values, or probability distribution of the observed values, are determined by the structural relations."[44] They are jointly

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[42] George G. Judge, "An Econometric Analysis of the Demand for Eggs," (unpublished Ph.D. Dissertation, Iowa State College, 1952), pp. 22-23.

[43] George G. Judge, <u>Economic Analysis of the Demand and Supply Relationships for Eggs</u>, Storrs Agricultural Experiment Station Bulletin, No. 307, (January, 1954), p. 6.

[44] <u>Ibid</u>.

dependent. "The exogenous variables are those whose observed values, or probability distribution of the observed values, are determined independent of the structural relations."[45] While exogenous variables influence the generation of endogenous values, they in turn are not influenced by the endogenous variables.

Another type of variable is the predetermined variable. A predetermined variable is a variable whose observed value is determined independently of the current structural relations. An endogenous variable with a designated time lag would fit in this category.

Identifiability. The identifiability of the structural equation has to be established before the estimation process is carried out. The necessary identifiability conditions on a single structural equation are summarized by Judge as:

$$K^{**} \geq G^{*} - 1$$

> . . . where G is the number of structural equations or endogenous variables appearing in the model; G* is the number of endogenous variables in the structural equation to be estimated; G** is the number of endogenous variables appearing in the model but not appearing in the structural equation to be estimated; K is the number of exogenous or predetermined variables in the model; K* is the number of exogenous or predetermined variables in the structural equation to be estimated; and K** is the number of exogenous or predetermined variables which appear in the model but not in the structural equation to be estimated. Thus:
>
> $$G^{*} + G^{**} = G$$
>
> $$K^{*} + K^{**} = K$$ [46]

If $K^{**} = G^{*} - 1$, the equation is said to be just-identified. If $K^{**} > G^{*} - 1$, the equation is over-identified and similarly if $K^{**} < G^{*} - 1$,

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[45] Ibid.

[46] Ibid.

the equation is under-identified and estimation of the parameters are not possible.

Methods of Estimation. Each of the endogenous variables can be expressed in terms of all the exogenous variables if the structural equation is just-identified. Equations of this sort are referred to as reduced form equations. Estimates of the coefficients of the reduced form equation can be obtained by the method of least squares in that the equation contains only one endogenous (or dependent) variable.

From the general model of structural equations (3.12), we can go to the reduced form in the following manner.

$$BY_t' + AZ_t' = U_t' \tag{3.13}$$

$$B^{-1}BY_t' = -B^{-1}AZ_t' + B^{-1}U_t \tag{3.14}$$

$$Y_t' = \pi Z_t' + V_t' \tag{3.15}$$

where $\pi = -B^{-1}A$ and $V_t' = B^{-1}U_t'$. Equations (3.14) and (3.15) imply B is non-singular.[47]

When the structural equations are all just-identified as they are in this study and normalization is to be made on predetermined variables, a method of going from the reduced form equations to the structural equations by an algebraic transformation of the reduced form coefficients is given by Foote.[48] This method is used in this study and is demonstrated below for a three equation model.

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[47] The "method of moments" may be used also to estimate the structural coefficients when the structural equation is just-identified. Judge presents the computations necessary, ibid., pp. 49-51.

[48] Richard J. Foote, Analytical Tools for Studying Demand and Price Structures, U. S. Department of Agriculture Handbook No. 146, (Washington, August 1958), pp. 90-92.

The reduced form equations may be written as:

$$p_1 = b_{11}q_1 + b_{12}q_2 + b_{13}q_3 + c_{11}y + c_{12t} \qquad (3.16)$$

$$p_2 = b_{21}q_1 + b_{22}q_2 + b_{23}q_3 + c_{21}y + c_{22t} \qquad (3.17)$$

$$p_3 = b_{31}q_1 + b_{32}q_2 + b_{33}q_3 + c_{31}y + c_{32}t \qquad (3.18)$$

where the endogenous variables are p_1, p_2, and p_3, the prices of the three commodities; the exogenous variables or predetermined variables are q_1, q_2, q_3, the quantities consumed, and y and t represent other exogenous variables, income and time.

Equations (3.16), (3.17), and (3.18) may be written in matrix notations as:

$$P_t' = BQ_t' + CZ_t' \qquad (3.19)$$

Multiplying (3.19) by B^{-1} and rearranging terms the structural equations are obtained and are written as

$$Q_t' = B^{-1}P_t' - B^{-1}CZ_t' \qquad (3.20)$$

where the elements of B^{-1} are the structural parameters relating to the endogenous variables and the elements of $B^{-1}C$ are the structural parameters relating to the exogenous variables.

CHAPTER IV

THE CHARACTERISTICS OF THE DEMAND FOR PECANS

In this chapter the demand relationships within the pecan industry, at the grower level, are investigated. Procedures followed in this investigation are (1) to construct alternative models explaining price formation in the pecan industry; (2) to select sample time periods and present the data which were chosen to reflect the included variables; (3) to postulate the algebraic form of the relationships hypothesized in the models, and (4) to estimate the parameters associated with the models by alternative methods.

Model I: Single Equation Model of the Demand for All Pecans

Discussion of the Model

Based on the tenets of economic theory and a consideration of the descriptive aspects of the pecan industry it is postulated that the demand for all pecans at the grower level is a function of the quantity of pecans sold, the level of consumer income and the influence of commodities that are related in demand with pecans.

Prices received by pecan growers are assumed to be determined by economic forces operating during the marketing season, while the other factors in the model are assumed not to be influenced by the price of pecans. Among these other factors are the quantities of pecans marketed and consumed each season. Quantities of pecans consumed are assumed to be the quantities produced within the season. Since production in the current season is not affected by current market price, the quantity variables are said to be predetermined. Two problems arise when the assumption is made that production is equal to consumption. First, the quantity of pecans actually harvested, as contrasted with production, may be determined to some extent by prices prevailing during the harvesting period. Therefore, the validity of assuming supply is predetermined might be questioned. The other problem is concerned with storage. If there are large amounts of pecans stored by growers or by marketing organizations the price of pecans will be affected not only by the current production but also by the quantities of carry-in and the quantities of production stored for future seasons.[49]

Consumer income is included in an attempt to reflect the influence of changes in consumers' purchasing power as a demand shifter. The income variable can be assumed to be independent of pecan sales since pecan purchases constitute only a small part of the consumer's budget. It would be expected, however, that changes in aggregate consumers' purchasing power to influence prices received by farmers for pecans, by shifting the level of the demand function.

To some extent prices of all other commodities influence purchases of pecans, but it would be impossible to estimate the relationships between pecans and all other commodities. Therefore, only those commodities which are believed to have the most influence on pecan prices are included in

[49] Since data are not available showing the amount of storage or of pecans not harvested there is no way to adjust the quantity variables for these discrepancies.

the models. These commodities, assumed to be independent of pecan sales, are domestic supplies of other domestic tree nuts and pecan imports.

Time is included as a trend variable. This variable reflects the effects of excluded factors upon demand that change over time.

When it is assumed there is only one dependent variable and all the other variables are independent of changes in the dependent variable, a single equation model is appropriate. In Model I, the demand for all pecans is postulated to be of the form:

$$B_{11}Y_{1t} + \alpha_{12}Z_{2t} + \alpha_{13}Z_{3t} + \alpha_{17}Z_{7t} + \alpha_{18}Z_{8t} + \alpha_{1,10}Z_{10t} + \alpha_{1,11}Z_{11t} = U_{1t} \qquad (4.1)$$

where Y_{1t} represents the season average price received by growers of all pecans; Z_{2t} and Z_{3t} are the quantities produced of seedling and improved pecans, respectively; Z_{7t} is the actual consumers' disposable income; Z_{8t} is the time variable with origin 1922; Z_{10t} is the production plus imports of walnuts, filberts and almonds; and Z_{11t} is the quantity of pecan imports.

The Y_{it}'s denote endogenous or dependent variables; the Z_{it}'s exogenous or predetermined variables; U_{it} represents the residual errors; and $t = 1, 2, \ldots, T$, the time period of the observations.

The Data

The data used to estimate the parameters in the postulated model are collected from secondary sources and are in the form of time series. It is believed the time series selected are generated by the economic forces represented in the models. If they are measured with sufficient accuracy, they should yield results acceptable for use.

The time period selected is from 1922 to 1955. Observations for the war years 1942-46, inclusively, were excluded from the analysis. This was done primarily because of price controls and other abnormal conditions influencing consumer and producer behaviour patterns which resulted in a period non-comparable with other periods used in the analysis.

Data on prices and income are deflated by the consumer price index.[50] It is realized that full allowance cannot be made for changes in the general price level except in the case where the relationship between the deflator and the original series are in a one-to-one ratio; moreover, only rarely would one expect a time series to meet this rigid specification.

To adjust for the influence of general growth factors, such as an increase in net population, the quantity and income series are put on a per capita basis. The estimate of total population as quoted by the Department of Agriculture from the Bureau of Census consists of the civilian population residing in the continental United States plus all Armed Forces of the United States, including those members overseas, as of July 1 of the year indicated.

The time series representing the price-quantity relations are aggregates measured at the grower level for the crop year. Each series is treated as if it consisted of homogenous items. Actually, however, this is far from the case since each series represents a composite of factors, such as different grades, sizes, location of purchase and periods of sale

[50]The consumer price index is based upon a price series prepared by the Bureau of Labor Statistics that measures the time-to-time changes in costs of fixed quantities of selected goods, rents, and services used by moderate income families in large cities.

within the season. All these different components, however, are included in one figure and aggregated over the entire marketing period.

The income variable is represented by actual disposable personal income for the calendar year as quoted by the Department of Agriculture. This series is defined as "... the actual current income receipts of persons from all sources, less personal tax and nontax payments to federal, state, and local governments. It is the closest overall statistical approximation to consumer purchasing power derived from current incomes."[51] As the majority of pecans are purchased in the last quarter of the year it could be argued that the income series should be income during the last quarter or last half of the year instead of the entire calendar year. This adjustment, however, was not attempted in this analysis.

The adjusted time series data are presented in Table VIII with a description of each of the series. The basic series from which these tables were computed are given in Appendix A.

The Algebraic Form of the Equation

Usually, equations in this type of analysis are assumed to be linear in natural units or in common logarithms. *A priori* there is little reason for choosing one functional form over the other, although the logarithmic form has an advantage in that the estimates of the coefficients can be directly interpreted as elasticities. From a statistical viewpoint, Foote makes the following comment:

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[51]United States Bureau of Agricultural Economics, *Consumption of Food in the United States, 1909-52*, Agriculture Handbook No. 62, (Washington, D.C., September 1953), p. 176.

TABLE VIII

TIME SERIES DATA FOR MODELS PRESENTED IN CHAPTER IV

Year	Y_1	Y_2	Y_3	Z_2	Z_3	Z_7	Z_8	Z_{10}	Z_{11}
1922	37.01	26.12	62.15	.0718	.0313	756	1	1.624	2.243
1923	26.47	19.34	58.30	.4242	.0939	845	2	1.602	.7000
1924	32.01	25.44	59.92	.2703	.0627	834	3	1.846	2.382
1925	29.47	23.07	50.13	.3467	.1063	848	4	1.912	.8748
1926	20.63	15.61	42.99	.6672	.1493	861	5	1.508	.9532
1927	27.76	20.75	47.71	.2266	.0802	869	6	1.745	.2185
1928	22.65	16.37	40.38	.4195	.1494	891	7	1.422	.4490
1929	20.05	15.55	43.25	.3654	.0725	930	8	1.864	.6002
1930	20.87	15.13	38.79	.3514	.1127	846	9	1.549	.4086
1931	12.00	8.92	21.38	.5360	.1774	792	10	1.366	.3718
1932	10.27	7.53	23.12	.4521	.0946	668	11	1.384	.0192
1933	14.47	10.85	23.51	.4448	.1847	658	12	1.018	.5661
1934	22.03	19.23	27.10	.2904	.1540	719	13	1.189	.8188
1935	11.58	8.52	21.12	.7470	.2316	782	14	1.547	.5495
1936	20.91	16.19	24.79	.2149	.2518	872	15	1.380	.0952
1937	12.54	9.45	17.75	.5214	.3108	897	16	1.593	.3610
1938	15.59	11.94	19.57	.3007	.2719	839	17	1.318	.2974
1939	16.33	13.13	20.54	.4287	.3128	906	18	1.624	.4301
1940	14.86	11.52	21.37	.6113	.3189	962	19	1.203	.2710
1941	16.38	13.51	20.35	.5272	.3857	1,108	20	1.422	.0030
1947	23.35	19.16	30.78	.5164	.3136	1,228	26	1.862	.9604
1948	11.87	9.73	14.78	.6720	.5288	1,245	27	1.939	.3254
1949	18.47	16.70	21.41	.5066	.3358	1,239	28	2.130	.1917
1950	28.02	25.00	30.93	.4077	.4139	1,322	29	1.869	.9209
1951	17.75	15.50	19.55	.4413	.5738	1,319	30	1.925	1.0078
1952	19.47	16.56	22.20	.4578	.5068	1,332	31	1.999	.6331
1953	14.25	12.85	15.56	.6764	.6655	1,371	32	1.616	.3853
1954	24.91	21.95	24.48	.3128	.2697	1,365	33	1.878	.5450
1955	28.65	25.85	35.72	.6319	.2565	1,428	34	1.759	1.2260

Y_1 is the season average price, on a cents per pound basis, received by growers of all pecans, deflated by the consumer price index.
Y_2 is the season average price, on a cents per pound basis, received by growers of seedling pecans, deflated by the consumer price index.
Y_3 is the season average price, on a cents per pound basis, received by growers of improved pecans, deflated by the consumer price index.
Z_2 is the seedling pecan production on a pounds per capita basis.
Z_3 is improved pecan production on a pounds per capita basis.
Z_7 is actual disposable personal income, dollars per capita, deflated by the consumer price index.
Z_8 is the time period, origin at 1922.
Z_{10} is the supply of competing nuts, on a pounds per capita basis. This series was computed by adding domestic production of almonds, filberts, walnuts to the imports of each of these nuts.
Z_{11} is the total imports of pecans (in-shell basis), pounds per 100 persons.

> ...logarithmic equations should be used when (1) the relationships between the variables are believed to be multiplicative rather than additive, (2) the relations are believed to be more stable in percentage rather than absolute terms, and (3) the unexplained residuals are believed to be more uniform over the range of independent variables when expressed in percentage rather than absolute terms.[52]

In this study both functional forms are used. Equations in natural units are presented in the text while the logarithmic forms are presented in the Appendix.[53]

Empirical Results

The empirical result of estimating the demand for all pecans, using the method of least squares is:

$$Y_1 = 9.4400 - \underset{(5.0143)}{17.6035}Z_2 - \underset{(3.4860)}{19.3067}Z_3 + \underset{(5.5631)}{0.0344}Z_7 - \underset{(3.1051)}{0.3984}Z_8 - \underset{(1.5580)}{4.2232}Z_{10} + \underset{(4.7673)}{4.6939}Z_{11} \qquad R^2 = .8982 \qquad (4.2)$$[54]

The "t-ratios" are shown in parentheses directly below each of the net regression coefficients. The t-ratios indicate that all coefficients are significantly different from zero at the 5 percent level, considering both tails of the t-distribution, except the coefficient of Z_{10}. The coefficient of Z_{10} is significantly different from zero at the 20 percent level. The coefficient of determination (R^2) indicates that 89.8 percent of the variation in the price of pecans was "accounted for" by the combined influence of the independent variables in the equation. The t-ratios and

[52] Foote, p. 37.

[53] A prime attached to a model number indicates that the equations in the model are postulated to be linear in the logarithms of the variables.

[54] The logarithmic forms of the equations are presented in Appendix B and can be used as a basis for comparison.

the coefficient of determination are presented for all the equations estimated by the method of least squares in the same format as above.

Conditional inferences may be made from the net regression coefficients to describe the average relationships, ceteris paribus, prevailing during the time period analyzed. Examples of these types of inferences are:

(1) A change of one pound per capita in seedling pecans produced (Z_2) was associated, on the average, with a change in the opposite direction of 17.60 cents per pound in the "real" price received by growers of all pecans;

(2) A change of one pound per capita in improved pecans produced (Z_3) was associated, on the average, with a change in the opposite direction of 19.31 cents per pound in the "real" price received by the growers of all pecans;

(3) A change in "real" per capita disposable income (Z_7) of one dollar was associated, on the average, with a change in the same direction of .03 cents in the "real" price received by growers of all pecans.

The signs of the net regression coefficients, except for Z_{11}, agree with a priori expectations. The negative sign of the coefficients on Z_2 and Z_3 are indicative of the inverse relationship between production and the price of pecans. A change in the quantity of improved pecans appears to have a greater influence on the price received for all pecans than a change in the quantity of seedlings. This could be accounted for by the usual higher shell-out for improved pecans than for seedlings. The coefficient of the time variable (Z_8) is negative and highly significant, according to the "t-test," indicating a factor or a combination of factors moving over time is inversely related to Y_1. The negative sign on the coefficient of Z_{10} (the supply of other domestic tree nuts besides pecans) exemplifies a competitive relationship between pecans and the other tree nuts.

The positive coefficient of Z_{11} (imports of pecans) is in disagreement with its theoretical counterpart. It would be expected for imports of pecans to be competitive with domestic pecans. However, it could be argued that the sign is positive because imports of pecans are not, in reality, independent of domestic price.[55] In fact, in years when there is a high domestic price more foreign supplies are sought. Actually the competition of pecan imports with domestic pecans is probably not too great an influence because of the small amount of pecans grown outside the United States.[56]

Two Equation Models: The Demand for Seedling and Improved Pecans

Model II

Discussion of the Model. The two equation models contain all the same variables as the single equation models except the variable representing price received for all pecans. The weighted average price variable

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[55] Note that the magnitude of this coefficient is higher than it would be if this time series were on the same population base as the other quantity time series in the equation. The other time series are on per capita basis, while imports are on the bases of pounds per 100 persons.

[56] Only 5 percent of the world's pecans are grown outside the United States. In the 1949-52 period pecan imports were only .6 percent of domestic production.

for all pecans is replaced by two variables representing the prices of seedling and improved pecans.

Seedling and improved pecans are readily substituted for each other. Since it is assumed that the quantities of each are predetermined, the postulated model should reflect the joint determination of their prices. Prior to the development of the simultaneous technique of estimating parameters, the single equation approach was usually used in studying demand relationships, and it was one of the methods used in this study. In using the single equation approach the price of each type of pecan is assumed dependent while the quantities sold and the other variables are assumed to be independent. Two single equations are estimated, first using one price, then the other, and then by comparing the coefficients of the two quantity variables, inferences are made regarding demand relationships.

In contrast, a simultaneous approach is used in which the joint determination of the prices of seedling and improved pecans can be taken into account explicitly in the estimating procedure. This is done by algebraically transforming the single equation estimates[57] into just-identified estimates. The price variables are thus hypothesized to be endogenous and simultaneously determined within the system. The just-identified structural equations in the two equation model are postulated to be of the form:

$$\beta_{22}Y_{2t} + \beta_{23}Y_{3t} + \alpha_{22}Z_{2t} + \alpha_{27}Z_{7t} + \alpha_{28}Z_{8t} + \alpha_{2,10}Z_{10,t} + \alpha_{2,11}Z_{11,t} = U_{2t} \qquad (4.3)$$

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[57]Referred to in Chapter III as the reduced form equation.

$$\beta_{32}Y_{2t} + \beta_{33}Y_{3t} + \alpha_{33}Z_{3t} + \alpha_{37}Z_{7t} + \alpha_{38}Z_{8t} + \alpha_{3,10}Z_{10,t} + \alpha_{3,11}Z_{11,t} = U_{3t} \qquad (4.4)$$

where Y_{2t} and Y_{3t} represent the season average price received by growers of seedling and improved pecans, respectively; the other variables are as defined before.

The data representing the "real" prices received by growers of seedling and improved pecans are included in Table VIII with the other time series. The time period and the form of the equations are the same as for the previous model.

Empirical Results.

(1) Single equation estimates. The empirical results of the single equation estimates are:

$$Y_2 = 5.1905 - \underset{(4.1476)}{13.4700}Z_2 - \underset{(3.5910)}{18.3984}Z_3 + \underset{(4.7617)}{0.0272}Z_7 - \underset{(1.3595)}{0.1613}\,Z_8 - \underset{(1.2662)}{3.1751}Z_{10} + \underset{(4.3827)}{3.9920}Z_{11} \qquad (4.5)$$

$$R^2 = .8675$$

$$Y_3 = 6.8566 - \underset{(1.8534)}{8.8602}Z_2 - \underset{(4.6971)}{35.4238}Z_3 + \underset{(7.5305)}{0.0634}Z_7 - \underset{(8.8960)}{1.5541}Z_8 - \underset{(0.7345)}{2.7113}Z_{10} + \underset{(5.1530)}{6.9088}Z_{11} \qquad (4.6)$$

$$R^2 = .9552$$

The value of the net regression coefficient of Z_8 (time) in equation (4.5) and of Z_{10} in both equations (4.5) and (4.6) are not statistically significant at the 5 percent level. The values of all the other net regression coefficients are significant at the 5 percent level except for Z_2 in equation (4.6). Its value is significant at the 10 percent level. Compared with equation (4.2) the value of R^2 for equation (4.5) decreased while R^2 increased for equation (4.6). The signs of the net regression coefficients are consistent with theoretical considerations except, as before, for the sign of the coefficient on Z_{11}.

Using these equations, inferences can be drawn regarding the demand interrelations between seedling and improved pecans. The sign and magnitude of the coefficient of the quantity of one type on the price of the other type exemplifies the demand interrelationships. The negative sign of the coefficient on Z_3 in equation (4.5) and on Z_2 in equation (4.6) indicates that the two types are competing in demand. Economic theory suggests that the price of a commodity would be influenced more by a change in its quantity than a change in the quantity of a related commodity. This, however, is not the case in equation (4.5) where the quantity of improved pecans influences the price of seedlings to a greater extent than does the quantity of seedlings. This is probably the result of the higher shell-out percentage for improved than for seedling pecans.

If seedling and improved pecans were perfect substitutes, on a pound for pound basis, the coefficients of Z_2 and Z_3 would be approximately equal. These coefficients, with their standard errors in parentheses, from equation (4.5) are:

$$\underset{(3.2476)}{-13.4700}Z_2 \text{ and } \underset{(5.1235)}{-18.3984}Z_3;$$

and from equation (4.6) they are:

$$\underset{(4.7805)}{-8.8602}Z_2 \text{ and } \underset{(7.5416)}{-35.4238}Z_3.$$

The coefficients are approximately equal, within one standard error in equation (4.5), but in equation (4.6) this is not so. The implication is that while improved pecans are a perfect substitute for seedlings, the converse is not true. Examinations of their uses would reveal why this is so; whereas improved pecans can readily substitute for seedling pecans in shelled form, seedling pecans cannot readily be substituted for improved pecans for in-shell use.[58]

(2) Just-identified estimates. The just-identified results with quantities expressed as a function of all other variables are:

$$Z_2 = -0.1128Y_2 + 0.0586Y_3 - 0.0006Z_7 + 0.0728Z_8 - 0.1992Z_{10} + 0.0455Z_{11} \quad (4.7)$$

$$Z_3 = +0.0282Y_2 - 0.0429Y_3 + 0.0019Z_7 - 0.0621Z_8 - 0.0267Z_{10} + 0.1836Z_{11} \quad (4.8)^{59}$$

Assuming that production is approximately equal to consumption each season,[60] the equations may be interpreted, ceteris paribus, as follows:

(1) A change in the "real" price of one cent per pound received by growers of seedling pecans was associated, on the average, with a change in the opposite direction of .11 pounds of seedling pecans demanded, per capita.

(2) A change in the "real" price of one cent per pound received by growers of improved pecans was associated, on the average, with a change in the same direction of .06 pounds of seedling pecans demanded, per capita.

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[58] Most of the seedling pecans are shelled and almost all of the in-shell pecans are of improved varieties.

[59] Standard errors were not computed for the simultaneous results.

[60] As was previously discussed, this assumption may be invalid if pecan stocks are carried over for future seasons by farmer organizations.

(3) A change in "real" per capita disposable income of one dollar was associated, on the average, with a change in the opposite direction of .001 pounds of seedling pecans demanded, per capita.

In comparison with the single equation estimates two apparent differences are noted in the just-identified results. One is the unexpected negative income effect indicated by the negative sign of the coefficient on Z_7 in equation (4.7). This means that as income increases a smaller quantity of seedling pecans is demanded. One argument that could be advanced for this negative income effect is that as income rises people desire more pecans but bought fewer seedlings. If people preferred in-shell pecans and the type of kernel the improved pecan produced,[61] they might shift their purchases from seedlings to improved pecans as incomes increased. The other difference is the change in the relative magnitudes of the coefficients indicating the competitive relationship between seedling and improved pecans, as given in equation (4.7) in comparison to equation (4.5). Seedlings and improved pecans are still competitive, as revealed by the positive sign of the coefficient on Y_3, although now the intensity of this relationship is more in consistency with its theoretical counterpart. This can be noted by examining equation (4.7) in which the price of seedlings influences the quantity of seedling to a greater extent than does the price of improved pecans.

The relative intensity of competitiveness of other domestic tree nuts increased in the just-identified results. This is noted by comparing the

[61] Kernels of improved pecans are usually larger than those of seedlings.

relative magnitude of the coefficients of Z_{10} in equations (4.7) and (4.8) with the coefficients of other variables within these equations with the relative magnitude of Z_{10} with the coefficients of other variables in equations (4.5) and (4.6).

(3) Comparison of the "Hotelling condition". The empirical results of demand relationships can be examined and compared using the "Hotelling conditions" of related demands.

According to the "Hotelling conditions", if two goods, i and j, are related in consumption and the consumers act rationally, the change in quantity (price) of the i^{th} good brought about by the change in price (quantity) of the j^{th} good will equal the change in the quantity (price) of the j^{th} good brought about by a change in the price (quantity) of the i^{th} good. The "Hotelling conditions" which are used in examining the equations are:

$$\frac{\partial Q_i}{\partial P_j} = \frac{\partial Q_j}{\partial P_i} \quad (1); \text{ or } \quad \frac{\partial P_i}{\partial Q_j} = \frac{\partial P_j}{\partial Q_i} \quad (II)$$

Schultz points out that conditions (1) and (II) are conditions on the signs and the absolute magnitude of the coefficients. When both terms of conditions (I) are negative [positive for terms of condition (II)] and statistically significant, the commodities are said to be complementary in demand. When both terms are positive [negative for terms of condition (II)] the commodities are competing in demand. He adds that "When one of the signs is negative and the other positive, the condition is not satisfied, no matter how many times each coefficient exceeds its standard error."[62]

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[62]Schultz, p. 595.

Examination of Table IX indicates the competitive relationships based on the preceding equations. A question mark before the statement of the probable type of relationship in Table IX of the single equation estimates means one or both of the coefficients are not significant at the 5 percent level, or the terms are not equal within one standard error. Coefficients from the just-identified estimates are judged only according to sign as their standard errors are not computed.

TABLE IX

OBSERVABLE CONDITIONS OF RELATED DEMANDS FOR MODEL II

Commodities	Hotelling conditions	Probable Type of Relationship
Seedling and improved pecans		
Single equation estimates	-18.3984 = -8.8602 (5.1235) (4.7805)	?Competing
Just-identified estimates	+ 0.0586 = +0.0282	Competing

(4) <u>Comparison of the price elasticities</u>. For equations in natural units the coefficients of price elasticities are computed as the means. From the single equation estimates the coefficient of price flexibility is first computed at the mean and then its reciprocal is used as a measure of the price elasticity. The price elasticities from model II are:

	Seedling pecans	Improved pecans
(1) Single equation estimates...	-2.7293	-3.4423
(2) Just-identified estimates...	-4.1421	-5.2023

The average price elasticities for the years included in the analysis are elastic. The elasticity coefficient for improved pecans is higher than that for seedlings in each case, indicating that buyers are more responsive to changes in the price of improved pecans. The just-identified estimates of elasticities are greater than single-equation estimates for both seedling and improved pecans.[63]

(5) <u>Comparison of the cross-price flexibilities and the cross elasticities</u>. The cross-price flexibilities and cross elasticities are measures closely related to the "Hotelling conditions". If price is the dependent variable the "Hotelling condition" implies that

$$\frac{\partial P_i}{\partial Q_j} = \frac{\partial P_j}{\partial Q_i} .$$

The analogous pair of cross-price flexibilities are computed by multiplying each side of this equation by the appropriate ratio of quantity to price, that is,

$$\frac{\partial P_i}{\partial Q_j} \; \frac{\bar{Q}_j}{\bar{P}_i} \quad \text{and} \quad \frac{\partial P_j}{\partial Q_i} \; \frac{\bar{Q}_i}{\bar{P}_j} .$$ [64]

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[63] The reverse of these two observations is true in the logarithm form of the equations. When logarithm form is used the price elasticity is assumed to be constant throughout the years of the analysis. Elasticities from the logarithm equations are:

	Seedling pecans	Improved pecans
(1) Single equation estimates	-3.1928	-2.1413
(2) Just-identified estimates	-3.1300	-2.0989

[64] The $\bar{Q}$ and $\bar{P}$ indicates these are measured at their mean.

In a like fashion, the corresponding results could be shown for the cross-elasticities. When prices are the dependent variables the "Hotelling conditions" and the cross-price flexibilities will have the same sign. When quantities are dependent, the "Hotelling conditions" and the cross elasticities have the same sign. The equating of the "Hotelling conditions" does not apply, however, to the measures of flexibilities and elasticities; they are used to measure responsiveness in percentage terms of changes in the price (quantity) of one tree nut associated with changes in the quantity (price) of another tree nut.

The following values of the cross-price flexibilities were obtained from the single equation estimates. A change of one percent in the quantity of improved pecans was found to be associated with a change in the opposite direction of 0.2889 percent in the price of seedlings. A change of one percent in the quantity of seedling pecans was found to be associated with a change in the opposite direction of 0.1267 percent in the price of improved pecans. The cross elasticities obtained from just-identified estimates are: A change of one percent in the price of seedlings was associated with a change in the same direction of 1.7925 percent in the quantity of improved pecans. A change of one percent in the price of improved pecans was associated with a change in the same direction of 4.1052 percent in the quantity of seedlings.

All these measures indicate that seedlings and improved pecans are competitive in demand. The larger the measure the stronger is the relationship. Seedling pecan prices (quantities) are found to be more responsive to changes in the quantity (price) of improved pecans than vice versa. This is consistent with the empirical results, in absolute terms, of the single equation estimates.

(6) Comparison of income elasticities. Income elasticities were computed at the means for the equations in natural units. In order to make the income coefficients comparable the coefficient of income elasticity for the single equation estimates were computed by first transposing the relevant quantity variable to the dependent position in the appropriate equation. The income elasticities are:

	Seedling pecans	Improved pecans
Single equation estimates...	+4.4761	+6.9734
Just-identified estimates...	-1.3428	+7.3608

A priori, as previously discussed, the negative income effect was not expected for seedling pecans.[65] From these measures it can be said that quantities of improved pecans consumed have been more responsive to changes in income.

Model III

Discussion of the Model. Since imports of pecans (Z_{11}) account for only a small percentage of the domestic supply and the sign of this variable disagreed with a priori expectations, Z_{11} was eliminated from Model II. This was done to determine whether excluding this variable would change the resulting parameter estimates in any important respect.

[65] In the logarithm form the coefficient of income elasticity from this equation is positive. However, an indicated complementary relationship between seedling and improved pecans was obtained which is at variance with previous results as well as theoretical expectations (see equation (4.7'), Appendix B).

Except for the exclusion of this variable, Model III is the same as Model II.

Empirical Results.

(1) Single equations estimates. The single equation estimates are:

$$Y_2 = 4.2019 - \underset{(3.8035)}{16.2223}Z_2 - \underset{(3.1133)}{21.1858}Z_3 + \underset{(4.4696)}{0.0332}Z_7 - \underset{(1.8617)}{0.2870}Z_8 - \underset{(0.6452)}{2.1562}Z_{10} \quad (4.9)$$

$$R^2 = .7518$$

$$Y_3 = 5.1456 - \underset{(1.9992)}{13.6234}Z_2 - \underset{(3.7017)}{40.2479}Z_3 + \underset{(6.2107)}{0.0737}Z_7 - \underset{(7.1925)}{1.7716}Z_8 - \underset{(0.1775)}{0.9479}Z_{10} \quad (4.10)$$

$$R^2 = .9011$$

Except for the net regression coefficient of Z_{10}, the sign and the magnitudes of the coefficients did not change to any great extent. In comparison to equations (4.5) and (4.6) the coefficient of Z_{10} was reduced in magnitude and the level of significance decreased considerably.

(2) Just-identified estimates. The just-identified estimates are:

$$Z_2 = -0.1105Y_2 + 0.0582Y_3 - 0.0006Z_7 + 0.0713Z_8 - 0.1831Z_{10} \quad (4.11)$$

$$Z_3 = +0.0374Y_2 - 0.0445Y_3 + 0.0020Z_7 - 0.0682Z_8 + 0.0384Z_{10} \quad (4.12)$$

The elimination of Z_{11} resulted in the changing of the sign of the coefficient of Z_{10} (the supply of other domestic tree nuts besides pecans) from negative to positive in equation (4.12) in comparison with equation (4.8). This changed the relationship of these other nuts to complementary with, rather than competitive to, improved pecans. This result disagrees with *a priori* expectations and the previous empirical results.

(3) Comparison of the "Hotelling conditions". The preceding estimates are compared with the "Hotelling conditions" in Table X.

TABLE X

OBSERVABLE CONDITIONS OF RELATED DEMANDS FOR MODEL III

Commodities	Hotelling conditions	Probable Type of Relationship
Seedling and improved pecans		
Single equation estimates	-21.1858 = -13.6234 (6.8049) (6.8144)	?Competing
Just-identified estimates	+ 0.0582 = + 0.0374	Competing

Again the competitive relationships are indicated; however, the single equation estimates are now equal within one standard error. The estimate of the coefficient of Z_2 is still not significant at the 5 per-cent level, although it has increased in significance, according to its "t-ratio".

(4) Comparison of the price elasticities. The price elasticities from Model III are:

	Seedling pecans	Improved pecans
(1) Single equation estimates...	-2.2665	-3.0303
(2) Just-identified estimates...	-4.0577	-5.3964

and they are comparable with previous estimates.

(5) Comparison of the cross-price flexibilities and cross elasticities. From the single equation estimates the cross-price flexibility of the price of seedlings with respect to the quantity of improved pecans was -0.3326; the cross-price flexibility of improved with respect to seedlings was -0.1948. The estimates of cross elasticities from the just-identified equations are +2.3773 for the quantity of improved pecans with respect to the price of seedlings, and +4.0772 for the quantity of

seedlings with respect to the price of improved pecans. These results are comparable with the results from model II.

(6) Comparison of income elasticities. The computed income elasticities for Model III are:

	Seedling pecans	Improved pecans
Single equation estimates...	+4.4761	+6.9734
Just-identified estimates...	-1.3428	+7.7482

These income elasticities are the same as for model II except for the just-identified estimate of income elasticity for improved pecans, which is slightly higher in magnitude than in model II.

Model IV

Discussion of the Model. Model IV is the same as Model III except for the exclusion of Z_{10}. This variable, representing the supply of domestic tree nuts other than pecans, was omitted because it was not significant and its relationship with improved pecans was complementary--disagreeing with previous empirical results and *a priori* expectations. There are no noticeable changes in these estimates compared with those from model III.

Empirical Results.

(1) Single equation estimates.

$$Y_2 = 3.1812 - \underset{(3.7959)}{15.8186}Z_2 - \underset{(3.0988)}{20.7029}Z_3 + \underset{(5.8891)}{0.0297}Z_7 - \underset{(1.7720)}{0.2468}Z_8 \qquad (4.13)$$

$R^2 = .7473$

$$Y_3 = 4.6969 - \underset{(2.0362)}{13.4460}Z_2 - \underset{(3.7818)}{40.0356}Z_3 + \underset{(9.0257)}{0.0722}Z_7 - \underset{(7.9459)}{1.7539}Z_8 \qquad (4.14)$$

$R^2 = .9010$

(2) Just-identified estimates.

$$Z_2 = -0.1128Y_2 + 0.0583Y_3 - 0.0009Z_7 + 0.0745Z_8 \quad (4.15)$$

$$Z_3 = +0.0379Y_2 - 0.0446Y_3 + 0.0021Z_7 - 0.0688Z_8 \quad (4.16)$$

(3) A comparison of the "Hotelling conditions". The tests implied by the "Hotelling conditions" when applied to these equations are shown in Table XI.

TABLE XI

OBSERVABLE CONDITIONS OF RELATED DEMANDS FOR MODEL IV

Commodities	Hotelling conditions	Probable Type of Relationship
Seedling and improved pecans		
Single equation estimates...	-20.7029 = -13.4460 (6.6809) (6.6035)	?Competing
Just-identified estimates...	+ 0.0583 = + 0.0379	Competing

The coefficient of Z_2 is not significant at the 5 percent level.

(4) Comparison of the price elasticities. The price elasticities from Model IV are:

	Seedling pecans	Improved pecans
(1) Single equation estimates	-2.3240	-3.0460
(2) Just-identified estimates	-4.1421	-5.4085

(5) Comparison of the cross-price flexibilities and cross elasticities. The estimates of cross-price flexibilities from the single equation estimates are -0.3250 for the price of seedlings with respect to the quantity of improved pecans, and -0.1923 for the price of improved pecans with respect to the quantity of seedlings. The estimates of cross

elasticities from the just-identified equations are +2.4091 for the quantity of improved pecans with respect to the price of seedlings, and +4.0842 for the quantity of seedlings with respect to the price of improved pecans.

(6) A comparison of the income elasticities. The computed income elasticities for model IV are:

	Seedling pecans	Improved pecans
Single equation estimates	+4.2523	+6.9734
Just-identified estimates	-2.0142	+8.1357.

CHAPTER V

DEMAND INTERRELATIONSHIPS AMONG DOMESTIC EDIBLE TREE NUTS

The results of the statistical study of interrelationships among domestic edible tree nuts are presented in this chapter. The procedures followed and the various measures employed in examining the empirical results are the same as those used in the preceding chapter.

Four Equation Models

Model V

Discussion of the Model. The characteristics of demand facing the growers of walnuts, filberts, and almonds are similar to those facing pecan growers in that the prices received for each nut is determined primarily by the quantity of the tree nut placed on the market, the level of consumer income, and the influence of related products. Prices received for each tree nut are assumed to be determined within the marketing season, while the other variables are assumed to be predetermined or exogenous to the system.

Data on production, which is predetermined, are used to reflect the quantities of each tree nut on the market at the grower level. This infers that the quantity produced is equal to the quantity harvested and sold each season. The validity of using production to reflect marketings and consumption can be questioned because of storage of tree nuts and the disposition of tree nuts in non-competitive outlets under provisions of marketing agreements and orders. Both of these factors tend to bias upward the variables representing quantities of tree nuts on the market.

An attempt is made to account for the influence of domestic tree nut imports by including a separate variable to reflect the imports of all domestic-type tree nuts combined. This variable is postulated to be exogenous in that exports are largely controlled by policies of the United States Tariff Commission.

The parameters associated with the four-equation models were estimated in the same way as were those of the previous two-equation models. First, the single equation approach is used in which the price of each tree nut is assumed to be dependent upon the quantities of each nut produced and the other independent variables. Then the single equations are algebraically transposed to obtain just-identified estimates which reflect the joint and simultaneous determination of all four prices. The just-identified structural equations are postulated to be of the form:

$$\beta_{41}Y_{1t} + \beta_{44}Y_{4t} + \beta_{45}Y_{5t} + \beta_{46}Y_{6t} + \alpha_{41}Z_{1t} + \alpha_{47}Z_{7t} + \alpha_{49}Z_{9t} + \alpha_{4,12}Z_{12,t} = U_{4t} \tag{5.1}$$

$$\beta_{51}Y_{1t} + \beta_{54}Y_{4t} + \beta_{55}Y_{5t} + \beta_{56}Y_{6t} + \alpha_{54}Z_{4t} + \alpha_{57}Z_{7t} + \alpha_{59}Z_{9t} + \alpha_{5,12}Z_{12t} = U_{5t} \tag{5.2}$$

$$\beta_{61}Y_{1t} + \beta_{64}Y_{4t} + \beta_{65}Y_{5t} + \beta_{66}Y_{6t} + \alpha_{65}Z_{5t} + \alpha_{67}Z_{7t} + \alpha_{69}Z_{9t} + \alpha_{6,12}Z_{12t} = U_{6t} \tag{5.3}$$

$$\beta_{71}Y_{1t} + \beta_{74}Y_{4t} + \beta_{75}Y_{5t} + \beta_{76}Y_{6t} + \alpha_{76}Z_{6t} + \alpha_{77}Z_{7t} + \alpha_{79}Z_{9t} + \alpha_{7,12}Z_{12t} = U_{7t} \tag{5.4}$$

where Y_{1t}, Y_{4t}, Y_{5t}, Y_{6t} represent the seasonal average price received by growers of pecans, walnuts, filberts, and almonds respectively; Z_{1t}, Z_{4t}, Z_{5t}, Z_{6t} are the quantities produced of pecans, walnuts, filberts, and almonds; Z_{7t} represents actual consumers' income; Z_{9t} is time with origin at 1927; and Z_{12t} is the combined imports of pecans, walnuts, almonds and filberts.

The Data and Algebraic Form of the Equations. The price data used to reflect the theoretical variables in the four equation model were deflated by the consumer price index and the quantity data were put on a tons per million persons basis. The parameters of these models were estimated from annual data for the period 1927-55, excluding the war years 1942-46. The time series used in the analysis are presented in Table XII with a description of the series. The basic series from which these tables are computed are given in Appendix A.

The equations were fitted in two functional forms--linear in natural units and linear in common logarithms. Equations in natural units are presented in the text while the logarithmic forms are given in Appendix B.

Empirical Results.

(1) Single equation estimates. Empirical results of the single equation estimates are:

$$Y_1 = 205.7399 - \underset{(5.8760)}{0.8315}Z_1 - \underset{(0.8963)}{0.2017}Z_4 - \underset{(0.4663)}{0.6744}Z_5 - \underset{(0.2838)}{0.0906}Z_6 + \underset{(3.3505)}{0.7086}Z_7 - \underset{(0.8376)}{5.5245}Z_9 - \underset{(1.1655)}{0.2627}Z_{12} \qquad R^2 = .7856 \tag{5.5}$$

$$Y_4 = 289.5348 + \underset{(0.0320)}{0.0041}Z_1 - \underset{(2.5386)}{0.5154}Z_4 + \underset{(0.7107)}{0.9273}Z_5 - \underset{(0.5206)}{0.1500}Z_6 + \underset{(2.6276)}{0.5013}Z_7 - \underset{(2.1692)}{12.9069}Z_9 - \underset{(0.4650)}{0.0945}Z_{12} \qquad R^2 = .6288 \tag{5.6}$$

$$Y_5 = 528.6388 - \underset{(0.0260)}{0.0031}Z_1 - \underset{(1.9333)}{0.3704}Z_4 - \underset{(0.4870)}{0.5996}Z_5 - \underset{(2.5900)}{0.7042}Z_6 + \underset{(1.7712)}{0.3189}Z_7 - \underset{(1.4689)}{8.2472}Z_9 - \underset{(1.9679)}{0.3776}Z_{12} \qquad R^2 = .7531 \tag{5.7}$$

TABLE XII

TIME SERIES DATA FOR MODELS PRESENTED IN CHAPTER V

Year	Y_1	Y_4	Y_5	Y_6	Z_1	Z_4	Z_5	Z_6	Z_7	Z_9	Z_{12}
1927	555	446	431	431	153.4	437.8	0.5042	100.8	869	1	334.5
1928	453	574	518	464	284.4	227.4	1.660	116.2	891	2	365.2
1929	401	438	409	655	219.0	356.3	1.642	38.59	930	3	538.4
1930	417	574	476	280	232.1	246.1	2.437	109.7	846	4	418.3
1931	240	343	385	271	356.7	275.8	3.387	119.4	792	5	285.9
1932	205	307	346	283	273.4	393.4	3.926	112.2	668	6	182.7
1933	289	405	537	336	313.7	270.7	8.519	102.7	658	7	130.0
1934	441	334	353	315	222.2	372.6	9.573	94.94	719	8	121.3
1935	232	346	448	477	489.3	451.3	9.748	99.84	782	9	215.2
1936	418	366	455	678	233.4	357.5	16.39	83.53	872	10	233.1
1937	251	295	353	448	416.1	484.5	19.95	191.0	897	11	103.1
1938	312	367	373	428	286.3	426.0	18.80	141.8	839	12	73.67
1939	327	283	380	352	370.7	477.5	29.72	219.3	906	13	87.89
1940	297	384	417	541	465.1	384.6	24.30	113.6	962	14	80.30
1941	328	401	486	1,119	456.5	524.7	43.10	71.21	1,108	15	72.12
1947	467	400	264	584	415.0	447.6	61.07	247.7	1,228	21	179.2
1948	237	408	252	411	600.4	481.9	41.34	249.0	1,245	22	198.8
1949	369	345	215	324	421.2	588.5	70.98	290.2	1,239	23	116.0
1950	560	375	340	531	410.8	432.2	38.17	248.5	1,322	24	229.4
1951	355	386	316	425	507.6	501.3	41.77	276.6	1,319	25	147.9
1952	389	349	263	409	482.3	533.8	73.69	231.8	1,332	26	163.4
1953	285	360	301	416	671.0	370.9	30.08	241.9	1,371	27	167.2
1954	498	305	279	434	291.3	462.4	52.16	266.0	1,365	28	161.1
1955	573	482	367	752	444.2	468.2	46.64	231.7	1,428	29	139.2

Y_1 is the season average price, on a dollars per ton basis, received by pecan growers, deflated by the consumer price index.
Y_4 is the season average price, on a dollars per ton basis, received by walnut growers, deflated by the consumer price index.
Y_5 is the season average price, on a dollars per ton basis, received by filbert growers, deflated by the consumer price index.
Y_6 is the season average price, on a dollars per ton basis, received by almond growers, deflated by the consumer price index.
Z_1 is domestic production of pecans on a tons per million persons basis.
Z_4 is domestic production of walnuts on a tons per million persons basis.
Z_5 is domestic production of filberts on a tons per million persons basis.
Z_6 is domestic production of almonds on a tons per million persons basis.
Z_7 is actual disposable personal income, dollars per capita, deflated by consumer price index.
Z_9 is time, origin at 1927.
Z_{12} is the sum of the imports of pecans, walnuts, filberts and almonds on a tons per million persons basis.

$$Y_6 = -121.2030 - \underset{(0.1414)}{0.0344Z_1} + \underset{(0.8349)}{0.3232Z_4} + \underset{(0.2528)}{0.6288Z_5} - \underset{(6.0046)}{3.2981Z_6} + \underset{(3.7245)}{1.3547Z_7}$$

$$R^2 = .7822 \qquad - \underset{(1.3110)}{14.8709Z_9} - \underset{(2.1970)}{0.8516Z_{12}} \qquad (5.8)$$

These equations can be examined for consistency with theoretical considerations. Consistent with economic theory, the price of each nut is inversely related to its quantity. Except for the low t-ratio of the coefficient of Z_5 in equation (5.7) the coefficients of these quantity variables are significant at the 5 percent level. The income effect is positive in all cases, and the coefficients of the income variables are significant except in equation (5.7). Although time is significant at the 5 percent level in only equation (5.5), the t-ratio of this coefficient is greater than 1 in two of the other equations. The negative sign of Z_{12} in each equation is an indication of the competitiveness of domestic tree nuts and their imports.

Demand interrelations can be explored by the examination of the sign of the quantity variable (Z_1, Z_4, Z_5 or Z_6) of one tree nut in the equation where the price of another tree is dependent. A negative sign indicates a competitive relationship, and a positive sign indicates the tree nuts are complementary in demand. In these single equation estimates competitive relationships are evident in equations (5.5) and (5.7) where the sign of the coefficients of Z_1, Z_4, Z_5 and Z_6 are negative. Complementary relationships are indicated by the positive sign of the coefficients of Z_1 and Z_5 in equation (5.6) and of Z_4 and Z_5 in equation (5.8). The consistency of these signs are examined in greater detail in the comparison of the Hotelling conditions.

(2) Just-identified estimates. The results obtained by the algebraic transformation of the single equation estimates into just-identified

equations are:[66]

$$Z_1 = -1.2013Y_1 - 0.2289Y_4 + 0.8519Y_5 - 0.1385Y_6 + 0.8819Z_7 - 4.6242Z_9 - 0.1335Z_{12} \quad (5.9)$$

$$Z_4 = -0.0122Y_1 - 0.9385Y_4 - 1.1378Y_5 + 0.2860Y_6 + 0.4545Z_7 - 17.3123Z_9 - 0.2780Z_{12} \quad (5.10)$$

$$Z_5 = +0.0004Y_1 + 0.5606Y_4 - 0.6765Y_5 + 0.1189Y_6 - 0.2267Z_7 + 3.4272Z_9 - 0.1010Z_{12} \quad (5.11)$$

$$Z_6 = +0.0114Y_1 + 0.0173Y_4 - 0.2493Y_5 - 0.2511Y_6 + 0.4029Z_7 - 5.5035Z_9 - 0.3033Z_{12} \quad (5.12)$$

When it is assumed that all that is produced is sold each season, it can be said the tree nut price structure is generated by the actions of buyers in purchasing tree nuts. Given this assumption, conditional economic inferences may be made from these just-identified estimates which describe the average relationships, ceteris paribus, that prevailed during the time period analyzed. To illustrate the interpretations that may be made, equation (5.9) is interpreted as follows:

(1) A change of one dollar per ton in the "real" price of pecans was associated, on the average, with a change in the opposite direction of 1.20 tons of pecans purchased per million people.

(2) A change of one dollar per ton in the "real" price of walnuts was associated, on the average, with a change in the opposite direction of .23 tons of pecans purchased per million persons.

(3) A change of one dollar per ton in the "real" price of filberts was associated, on the average, with a change in the same direction of .85 tons of pecans purchased per million persons.

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[66]The computations necessary for this transformation are presented in Appendix C.

(4) A change of one dollar per ton in the "real" price of almonds was associated, on the average, with a change in the opposite direction of .14 tons of pecans purchased per million persons.

(5) A change in the "real" per capita disposable income of one dollar, on the average, was associated with a change in the same direction of .88 tons of pecans purchased per million persons.

(6) A change of one year in the time period analyzed was associated, on the average, with a change in the opposite direction of 4.62 tons of pecans purchased per million persons.

(7) A change in the sum of the imports of pecans, walnuts, filberts, and almonds of one ton per million persons was associated, on the average, with a change in the opposite direction of .13 tons of pecans purchased per million persons.

Similar statements could be made for the other equations.

Corresponding with the single equation estimates and *a priori* expectations, the price of each tree nut is inversely related to its quantity. Also in agreement is the negative sign of the coefficient of Z_{12} in the just-identified estimates, indicating that imports of domestic-type tree nuts are competitive with domestic tree nuts. One change, however, is noted in the coefficients on income compared with the single equations. In equation (5.11) the coefficient of Z_7 is negative. *A priori*, one would not expect to find a negative income effect for tree nuts. An explanation may be found in the single equation estimates where only in equation (5.7) is the influence of income on filberts not significant.

(3) Comparison of the Hotelling conditions. The tests appropriate to these two sets of equations for demand interrelationships within the tree nut industry are given in Table XIII in which the single equation estimates and the just-identified estimates are compared using the Hotelling conditions. A negative sign for the terms of the single equation estimates indicates the commodities are competitive in demand, a positive sign indicates that they are complementary. The sign criteria of competitive and complementary commodities for the just-identified estimates are the reverse of the single equation estimates. A question mark before the statement of the probable type of relationship of the single equation estimate means one or both of the terms are not significant at the 5 percent level, or the two terms are not equal within one standard error. Coefficients from the just-identified estimates can only be judged according to sign because their standard errors were not computed.

From the single equation estimates, competitive relationships are indicated between pecans and filberts and between pecans and almonds. These relationships, however, are questionable since the appropriate coefficients in the single equation estimates are not significant. From the just-identified estimates, the indicated relationships are (1) complementary between pecans and walnuts, (2) competitive between pecans and filberts, and (3) competitive between walnuts and almonds.

The inconsistencies in the estimated demand interrelations, as well as other disagreements with theory and *a priori* expectations, could exist because the time series chosen to represent the "true" quantity variables (reflecting quantities of tree nuts on the market) are incomplete and thus

TABLE XIII

OBSERVABLE CONDITIONS OF RELATED DEMANDS FOR MODEL V

(Standard errors in parenthesis for single equation estimates)

Commodities	Hotelling conditions	Probable Type of Relationship
Pecans and Walnuts		
Single equation estimates	-0.2017 = + 0.0041 (0.2250) (0.1281)	?
Just-identified estimates	-0.2289 = - 0.0122	Complementary
Pecans and Filberts		
Single equation estimates	-0.6744 = - 0.0031 (1.4463) (0.1192)	? Competing
Just-identified estimates	+0.8519 = + 0.0004	Competing
Pecans and Almonds		
Single equation estimates	-0.0906 = - 0.0344 (0.3192) (0.2433)	? Competing
Just-identified estimates	-0.1385 = + 0.0114	?
Walnuts and Filberts		
Single equation estimates	+0.9273 = - 0.3704 (1.3048) (0.1916)	?
Just-identified estimates	-1.1378 = + 0.5606	?
Walnuts and Almonds		
Single equation estimates	-0.1500 = + 0.3232 (0.2881) (0.3871)	?
Just-identified estimates	+0.2860 = + 0.0173	Competing
Filberts and Almonds		
Single equation estimates	-0.7042 = + 0.6288 (0.2719) (2.4873)	?
Just-identified estimates	+0.1189 = - 0.2493	?

not representative of the actual supply of tree nuts on the market each year. The time series reflecting quantity should be representative of the actual supply sold in the domestic market each year. This time series would be composed of domestic production plus imports and carry-in minus exports and carryover.[67] In an attempt to approach more closely this "true" quantity variable, imports of domestic-type tree nuts were added to the amount of production for each season.[68] The results of this analysis are presented in Appendix D and will be referred to as model VI. Although the empirical results of using these other time series differ somewhat from those just given, the changes did not increase the acceptability of these results over the empirical results just presented to any great extent. In model VI the Hotelling conditions that were partially met and the probable type of relationship are:

(1) Single equation estimates: a competitive relationship for pecans and almonds, although neither sign was significant.

(2) Just-identified estimates:

  (a) A competitive relationship for pecans and walnuts. In the previous just-identified estimates the probable type of relationship between pecans and walnuts was complementary.

  (b) A competitive relationship for pecans and filberts which is consistent with the just-identified estimates of model V.

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[67] In using this quantity series the demand relationships would be measured at a marketing level above the grower level.

[68] The other series were not available or complete for the years included in the analysis.

(c) A complementary relationship for pecans and almonds.

(d) A competitive relationship for filberts and almonds.

The only demand relationships that are the same in both models are the competitive relationship between pecans and filberts indicated in the just-identified estimates.

(4) Comparison of the price elasticities. The price elasticities for each of the tree nuts computed at the means are:[69]

	Pecans	Walnuts	Filberts	Almonds
(1) Single equation estimates	-1.1875	-1.8025	-23.0415	-0.8626
(2) Just-identified estimates	-1.1863	-0.8719	- 9.3483	-0.7144

The average price elasticity for pecans, from both the single equation estimate and the just-identified estimates, is -1.19, indicating an elastic demand curve. When the equations are expressed in natural units the demand elasticity varies at each point on the demand curve. To illustrate this variability the demand elasticity for pecans was computed for each year in the analysis, using the just-identified estimate of the slope of the demand curve. These estimates are given in Table XIV. The coefficient of elasticity is elastic in years of relatively low production and high prices and inelastic in years of relatively high production and low prices.

The coefficient of price elasticity for walnuts is -1.80 based on the single equation estimate, and -0.87 using the just-identified estimate. By one estimation procedure the elasticity of walnuts is elastic, by the other it is inelastic. As the just-identified equations reflect the joint

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[69] The elasticity coefficient from the single equation estimates is the reciprocal of the computed price flexibility coefficient.

determination of all the prices it could be argued that the estimate of -0.87 is unbiased and the average demand elasticity for walnuts is, considering only this condition, inelastic.

TABLE XIV

POINT ELASTICITY FOR PECANS

1927	: -4.3463	1935	: -0.5696	1948	: -0.4742
1928	: -1.9135	1936	: -2.1514	1949	: -1.0524
1929	: -2.1996	1937	: -0.7246	1950	: -1.6376
1930	: -2.1583	1938	: -1.3091	1951	: -0.8401
1931	: -0.8083	1939	: -1.0597	1952	: -0.9689
1932	: -0.9008	1940	: -0.7671	1953	: -0.5102
1933	: -1.1067	1941	: -0.8631	1954	: -2.0537
1934	: -2.3842	1942	: -1.3518	1955	: -1.5499

The coefficients of price elasticity for filberts indicate the average elasticity is highly elastic. Due to the large amount of filbert imports one would be hesitant in accepting these high measures of price elasticity for filberts. Price elasticities were also computed from model VI, in which imports were included with production. The single equation estimate of price elasticity for filberts was lower than the previous single equation estimate, but the just-identified estimate was greater than the previous just-identified estimate.[70]

The coefficients of price elasticity for almonds, computed from estimates from Model V, indicate the average price elasticity of almonds is inelastic. In comparison, the estimates of elasticity from Model VI indicate the price elasticity for almonds is highly elastic. The difference in the estimates of elasticity are probably because almond imports constitute a considerable amount of the domestic supply.[71]

(5) Comparison of the cross-price flexibilities and cross elasticities. Inconsistencies in the demand relationships were previously discussed in the comparison of the Hotelling conditions. These inconsistencies are also clearly evident in the examination of cross-price flexibilities and cross elasticities (Table XV).

None of the demand relationships are consistent for both the cross-price flexibilities and the cross elasticities, except that between pecans and filberts. The negative signs of the price-flexibilities and the positive sign of the cross elasticities for pecans and filberts indicates that they are competitive in demand.

(6) Comparison of income elasticities. The computed income elasticities are:

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[70]The price elasticities, computed from empirical results of Model VI are:

	Pecans	Walnuts	Filberts	Almonds
(1) Single equation estimates	-1.2728	-1.4470	-5.8824	-3.2072
(2) Just-identified estimates	-1.2869	+4.9022	-10.8382	-7.7673

These estimates of price elasticities differ considerably from the previous estimates. Note especially the positive price elasticity for walnuts from the just-identified estimates. This is in disagreement with previous results and its theoretical counterpart.

[71]According to the U.S. Tariff Commission net imports were 23 percent of the domestic supply of almonds in the 1950-52 period.

TABLE XV

THE CROSS-PRICE FLEXIBILITIES AND CROSS ELASTICITIES OF DEMAND AMONG ALL DOMESTIC TREE NUTS

The Cross-Price Flexibilities

Percentage Change in the Price of:	Percentage Change in the Quantity of: Pecans	Walnuts	Filberts	Almonds
Pecans	---	-0.2259[a]	-0.0492	-0.0407
Walnuts	+0.0040	---	+0.0650	-0.0647
Filberts	-0.0031	-0.4115	---	-0.3137
Almonds	-0.0273	+0.2833	+0.0359	---

The Cross Elasticities

Percentage Change in the Quantity of:	Percentage Change in the Price of: Pecans	Walnuts	Filberts	Almonds
Pecans	---	-0.2352	+0.8481	-0.1747
Walnuts	-0.0109	---	-1.0242	+0.3263
Filberts	+0.0055	+7.9953	---	+2.0824
Almonds	+0.0254	+0.0401	-0.5599	---

[a]An example of how this table should read is: The percentage change in the price of pecans associated with the percentage change in quantity sold of walnuts is -0.2259 percent.

	Pecans	Walnuts	Filberts	Almonds
Single equation estimates	+2.3228	+2.3970	+20.1245	+2.5250
Just-identified estimates	+2.4037	+1.1201	- 8.5772	+2.4764

According to these income elasticities, except for filberts, a change of one percent in the income level was associated with a change in the quantities consumed of each tree nut of from one to about two and one-half percent. The just-identified estimate of the income elasticity of filberts was negative and in disagreement with *a priori* expectations. In the logarithmic form of the just-identified equations, the income elasticity for filberts was positive; however, the rest of the income elasticities were negative in sign. The income elasticities were also computed from model VI.[72] The just-identified estimates of income elasticities from model VI for both walnuts and filberts were negative. As before this was in disagreement with a priori expectations.

[72]The income elasticities computed from the empirical results of model VI are:

	Pecans	Walnuts	Filberts	Almonds
Single equation estimates	+2.1435	+1.9947	+6.9018	+9.0378
Just-identified estimates	+2.1459	-8.8317	-15.6518	+27.4861

CHAPTER VI

SUMMARY AND CONCLUSIONS

The major objective of this thesis was to investigate the demand relationships for pecans at the grower level. Specifically, the first objective was to analyze the demand relationships within the pecan industry between seedling and improved pecans. The study was then expanded to analyze the demand relationships among pecans, almonds, filberts and walnuts. The third objective was to compare the parameter estimates from alternative methods of estimation.

To achieve the first two objectives several economic models of the demand relationships were postulated. These models were based upon a factual study of the tree nut industry in conjunction with an examination of the relevant economic and statistical theory. Observations from time series data were then chosen to reflect the variables included in the models. The parameters of the models were then estimated using alternative techniques. First, the parameters were estimated by the single equation least squares method. The single equation estimates were then algebraically transformed into just-identified equations. These just-identified equations explicitly allowed for the simultaneous determination of the jointly dependent variables (endogenous variables) within the system. The empirical results of this analysis are presented in the following section.

Summary and Comparison of Empirical Results

The Characteristics of Demand of the Pecan Industry

Four different models were used to study the demand relationships between seedling and improved pecans at the grower level. The first was a single equation model in which the price of all pecans was the dependent variable. The independent variables were the quantities produced of seedling and improved pecans, income, time and the domestic supply of all other domestically produced tree nuts. The other three models of the pecan industry were two equation models in which the prices of seedling and improved pecans replaced the price of all pecans. The two-equation models differ by the number of exogenous variables included.

A competitive relationship between seedling and improved pecans was evident in the single equation model. In this model the supply of domestic tree nuts other than pecans was found to be competing with pecan supplies. In the single equation model, as well as the two equation models, imports of pecans were indicated to be complementary in demand for domestic pecan supplies. This result disagreed with *a priori* expectations.

The demand relationships of the two equation models are summarized in terms of elasticities and flexibilities for comparison between the different models.

The price elasticities for seedling and improved pecans are given in Table XVI. All these measures indicate that the price elasticity of demand for the two types of pecans was elastic over the years included in the analysis. The elasticity coefficients for improved pecans, estimated from equations expressed in natural units are of higher magnitude than the corresponding estimates for seedlings. This would indicate that buyers were more responsive to changes in the price of improved pecans than to changes in the price of seedlings. However, the reverse situation was true when the equations were expressed in logarithmic form. When the data were in natural units, the price elasticity estimates from the just-identified equations were larger than corresponding measures from single equation estimates. In the logarithmic equations, the corresponding price elasticities from single equation estimates and just-identified estimates are quite similar in magnitude.

TABLE XVI

PRICE ELASTICITY FOR PECANS

	Model II	Model III	Model IV
Natural Units			
Seedling Pecans			
Single equation estimates	-2.7293	-2.2665	-2.3240
Just-identified estimates	-4.1421	-4.0577	-4.1421
Improved Pecans			
Single equation estimates	-3.4423	-3.0303	-3.0460
Just-identified estimates	-5.2023	-5.3964	-5.4085
	Model II'	Model III'	Model IV'
Logarithm			
Seedling Pecans			
Single equation estimates	-3.1928	-3.1046	-3.0817
Just-identified estimates	-3.1300	-3.0758	-3.0647
Improved Pecans			
Single equation estimates	-2.1413	-1.9904	-2.1249
Just-identified estimates	-2.0989	-1.9715	-2.1131

The demand interrelationships between seedling and improved pecans were investigated by use of the measures of cross-price flexibility and cross-elasticity (Table XVII). If the coefficient of cross-price flexibility is negative the commodities are said to be competing in demand. If the sign is positive the commodities are said to be complementary in demand. The sign criteria of competing and complementary commodities for the coefficients of cross elasticity are the reverse of the coefficients of cross-price flexibility. The intensity or degree of the demand relationship, as indicated by either measure, varies directly with the magnitude of the coefficient.

The signs of the cross-price flexibilities and cross elasticities of the equations in natural units indicate there was a competitive relationship between seedling and improved pecans. The magnitudes of these measures indicated that seedling prices (quantities) were more responsive to changes in the quantity (price) of improved pecans than vice versa. In logarithmic form the signs of these measures were inconsistent, since in one instance the commodities were apparently competing in demand, while in another instance they were apparently complementary.

The income elasticities for seedling and improved pecans are given in Table XVIII. The just-identified estimates of the income elasticities for seedling pecans are negative for all three models when the data were expressed in natural units. This is inconsistent with the single equation estimates of income elasticities and a priori expectations. The single equation estimates indicate improved pecans were more responsive to changes in the income level than were seedlings when the equations were linear in the original variables. Just-identified estimates in logarithms also indicate the greater responsiveness of improved pecans to changes in income. However, the reverse is true for the single equation

TABLE XVII

THE CROSS-PRICE FLEXIBILITIES AND CROSS ELASTICITIES OF DEMAND BETWEEN SEEDLING AND IMPROVED PECANS[a]

The Cross-Price Flexibilities

Percentage Change in the Price of:	Percentage Change in the Quantity of:		
		Improved Pecans	
	Model II	Model III	Model IV
Seedling Pecans			
Natural Units	-0.2889[b]	-0.3326	-0.3250
Logarithm	-0.2263	-0.2692	-0.2295
		Seedling Pecans	
Improved Pecans			
Natural Units	-0.1267	-0.1948	-0.1923
Logarithm	+0.0131	+0.0057	+0.0038

The Cross Elasticities

Percentage Change in the Quantity of:	Percentage Change in the Price of:		
		Seedling Pecans	
	Model II	Model III	Model IV
Improved Pecans			
Natural Units	+1.7925	+2.3773	+2.4091
Logarithm	-0.0875	-0.0349	-0.0247
		Improved Pecans	
Seedling Pecans			
Natural Units	+4.1052	+4.0772	+4.0842
Logarithm	+1.5168	+1.6480	+1.4948

[a]Cross-price flexibilities computed from single equation estimates and cross elasticities computed from just-identified estimates.

[b]An example of how this table should read is: In model II the percentage change in the price of seedling pecans associated with the percentage change in the quantity sold of improved pecans is -0.2889 percent.

estimates in logarithmic form. These latter estimates indicate that seedlings were more responsive to changes in income.

TABLE XVIII

INCOME ELASTICITIES FOR PECANS

	Model II	Model III	Model IV
Natural Units			
Seedling Pecans			
Single equation estimates	+4.4761	+4.4761	+4.2523
Just-identified	-1.3428	-1.3428	-2.0142
Improved Pecans			
Single equation estimates	+6.9734	+6.9734	+6.9734
Just-identified estimates	+7.3608	+7.7482	+8.1357
	Model II'	Model III'	Model IV'
Logarithm			
Seedling Pecans			
Single equation estimates	+6.0536	+5.9944	+4.8250
Just-identified estimates	+3.2943	+3.0229	+2.5922
Improved Pecans			
Single equation estimates	+3.7270	+3.5217	+3.1362
Just-identified estimates	+3.8191	+3.5556	+3.1574

The Demand Relationships Among Domestic Tree Nuts

The demand relations among domestic tree nuts were investigated using models consisting of four equations. Two models were postulated, the main difference between the models was in the construction of the time series reflecting quantities of each tree nut on the market. In model V production of each tree nut was assumed to reflect the quantity sold. In that model one variable represented imports of all domestic-type tree nuts.[73]

[73]The empirical results, in natural units, indicated a competitive relationship between each domestic tree nut and the sum of all domestic-type imports. This was true for both the single equations and just-identified equations.

In model VI production plus imports of each domestic tree nut were used to reflect the quantities of each domestic tree nut sold. A variable represented by a time series of all tree nut imports except domestic-type tree nut imports was used to reflect the influence of other tree nuts on domestic sales.[74]

Estimates of price elasticities were computed using the empirical results from models V and VI. They are presented in Table XIX. The coefficient of the price elasticity of demand for pecans ranged from -1.16 to -1.37, indicating that demand for pecans was elastic over the period analyzed. The range of the estimates of the price elasticity of demand for pecans was less than for the corresponding estimates of the price elasticities of the other tree nuts. The closeness of the corresponding elasticity estimates for pecans between models V and VI could be explained by examining the quantity of pecan imports. The ratio of imports to production is smaller for pecans than is the ratio of imports to production for any of the other domestic tree nuts.

A positive price elasticity for walnuts is indicated by the just-identified estimates of model VI. This is in disagreement with its theoretical counterpart and the other estimates of the price elasticity of demand for walnuts. The other estimates indicate price elasticity for walnuts was elastic, except for the just-identified estimate of model V in which the equations were linear in natural units.

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[74] In natural units the single equation results indicated that imports of other tree nuts besides domestic-type were complementary in demand with domestic consumption of almonds, filberts, pecans and walnuts. The just-identified results, in natural units, indicated other imports besides domestic-type were complementary with pecans and almonds; competitive with walnuts and filberts.

TABLE XIX

PRICE ELASTICITY FOR PECANS, WALNUTS, FILBERTS AND ALMONDS

	Pecans	Walnuts	Filberts	Almonds
Natural Units				
Single equation estimates				
Model V	-1.1875	-1.8025	-23.0415	-0.8626
Model VI	-1.2728	-1.4470	- 5.8824	-3.2072
Just identified estimates				
Model V	-1.1863	-0.8719	- 9.3483	-0.7144
Model VI	-1.2869	+4.9022	-10.8382	-7.7673
Logarithm				
Single equation estimates				
Model V'	-1.1598	-2.2432	-20.3666	-1.6090
Model VI'	-1.1790	-1.4712	- 5.5127	-3.6206
Just identified estimates				
Model V'	-1.3671	-5.3853	-29.2622	-0.4409
Model VI'	-1.1560	+3.7192	- 8.6724	-8.1295

The estimates indicate a highly elastic demand for filberts, especially the results from model V. Since a large amount of the domestic filbert supply is comprised of imports, the inclusion of imports in the quantity variable would be expected to lower the price elasticity. Except for the just-identified estimate from model VI in natural units, this held true.

The estimates of price elasticity from model V in natural units indicate the demand for almonds was inelastic. Except for the just-identified estimate of model V′ in logarithms the other estimates indicate the demand for almonds was elastic.

The cross-price flexibilities and cross elasticities of demand among all domestic tree nuts are shown in Table XX. These two measures of demand relationships are constructed by using the cross-demand parameters from the single equations and the just-identified equations. However, in

TABLE XX

THE CROSS-PRICE FLEXIBILITIES AND CROSS ELASTICITIES OF DEMAND AMONG ALL DOMESTIC TREE NUTS

The Cross-Price Flexibilities

Percentage change in the price of:	Percentage change in the quantity of: Pecans		Walnuts		Filberts		Almonds	
	Model V	Model VI	Model V	Model VI	Model V	Model VI	Model V	Model VI
Pecans								
Natural units	-	-	-0.2259	-0.3534	-0.0492	+0.0591	-0.0407	-0.0799
Logarithm	-	-	-0.3467	-0.4283	+0.0560	+0.0336	+0.0038	-0.0865
Walnuts								
Natural units	+0.0040	+0.0197	-	-	+0.0650	+0.2000	-0.0647	-0.1599
Logarithm	-0.0033	+0.0275	-	-	-0.0330	+0.1644	-0.0632	-0.1923
Filberts								
Natural units	-0.0031	-0.0253	-0.4115	-0.4793	-	-	-0.3137	-0.2917
Logarithm	+0.0528	-0.0305	-0.4623	-0.4754	-	-	-0.2313	-0.2261
Almonds								
Natural units	-0.0273	-0.0128	+0.2833	+0.5010	+0.0359	-0.6524	-	-
Logarithm	-0.0049	-0.1293	+0.0585	+0.1083	+0.1007	-0.6263	-	-

The Cross Elasticities

Percentage change in the quantity of:	Percentage change in the price of: Pecans		Walnuts		Filberts		Almonds	
	Model V	Model VI	Model V	Model VI	Model V	Model VI	Model V	Model VI
Pecans								
Natural units	-	-	-0.2352	+0.0350	+0.8481	+0.6192	-0.1747	-0.2673
Logarithm	-	-	+4.3193	-0.3073	-3.0528	+1.3588	+0.6883	-0.5361
Walnuts								
Natural units	-0.0109	+0.2686	-	-	-1.0242	-6.0940	+0.3263	+3.1149
Logarithm	+0.1959	-0.0823	-	-	+2.8196	-6.6852	-0.5003	+2.9097
Filberts								
Natural units	+0.0055	+0.5397	+7.9953	+10.5626	-	-	+2.0824	+4.5781
Logarithm	-1.9593	+0.1227	+32.8600	+6.4023	-	-	+7.5362	+2.6019
Almonds								
Natural units	+0.0254	-0.6446	+0.0401	-14.2192	-0.5599	+12.8544	-	-
Logarithm	-0.2880	+0.2305	+4.7810	-12.9151	-4.4497	+16.4076	-	-

only a few instances were the cross-demand parameters of the single equation estimates significant at the 5 percent level, according to the t-test. This raises the question of the validity of the cross-price flexibilities as measures of competitive relationships. In turn, since the cross-demand measures of the just-identified equations are based upon estimates from the single equations, the question is raised as to the validity of the measures of cross elasticity. However, these measures are examined for the indicated demand relationship and for consistency of sign.[75]

From model V, the coefficients that were consistent according to sign and also consistent between the two measures according to the type of demand relationship are as follows:

(1) In natural units: Pecans and filberts - competitive

(2) In logarithmic form

  (a) Pecans and walnuts - competitive

  (b) Pecans and filberts - complementary

  (c) Filberts and walnuts - competitive

The only demand relationship that was consistent in both natural units and in logarithms was between pecans and filberts. The indicated type of demand relationship, however, was reversed in the two functional forms of the equations.

In model VI the only demand relationship that was consistent in terms of the cross-price flexibility and cross elasticity was the indicated competitive relationship between almonds and filberts.

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[75]The Hotelling conditions were used to test the cross-demand parameters. The results of this test of consumer rationality was, in most cases, not conclusive. However, the Hotelling conditions are conditions for consumer behavior and therefore may not be reflected at the primary level of the marketing process.

The income elasticities for the domestic tree nuts are presented in Table XXI. In general, the single equation estimates are more acceptable on an a priori basis than the just-identified estimates in regard to both magnitude and sign. The positive income elasticities for all the tree nuts are greater than 1.0, indicating that a change in consumer income was associated with a greater percentage change in the same direction in tree nut consumption.

TABLE XXI

INCOME ELASTICITIES FOR PECANS, WALNUTS, FILBERTS AND ALMONDS

	Pecans	Walnuts	Filberts	Almonds
Natural Units				
Single equation estimates				
Model V	+2.3228	+2.3970	+20.1245	+2.5250
Model VI	+2.1435	+1.9947	+ 6.9018	+9.0378
Just-identified estimates				
Model V	+2.4037	+1.1201	- 8.5772	+2.4762
Model VI	+2.1459	-8.8317	-15.6518	-27.4861
Logarithms				
Single equation estimates				
Model V'	+1.5698	+2.0433	+ 5.6802	+ 2.7817
Model VI'	+1.7109	+1.6972	+ 5.0121	+ 9.6477
Just-identified estimates				
Model V'	-2.4229	+4.7191	-32.1487	- 1.9621
Model VI'	+2.2252	-5.8418	- 6.6125	+21.3098

The coefficients of income elasticity for pecans estimated from alternative models and by different techniques are more consistent in magnitude than are the coefficients for the other nuts. Except for the negative income coefficient for seedling pecans in model V, the estimates of income elasticities for pecans range from +1.57 to +2.40. The negative sign of the just-identified estimate of model V, of course, is in disagreement with the other coefficients and its theoretical counterpart.

The coefficients of income elasticity for walnuts from model V are positive. Negative income elasticities are indicated in the just-identified estimates of model VI. All the negative estimates for each tree nut occur in the just-identified estimates.

The various estimates of the income elasticity for filberts are quite contradictory in regard to both sign and magnitude. Unlike the other coefficients, all of the just-identified estimates of income elasticity are negative.

In general, the estimated parameters for pecans were more acceptable based on a priori expectations, logical consistencies, and statistical tests than were the estimated parameters for the other domestic tree nuts. There are several possible explanations for the more "acceptable" results in the case of pecans:

(1) Foreign trade in pecans is relatively unimportant,

(2) There are no quantity controls in pecan marketing such as those imposed in the marketings of the other domestic tree nuts, and

(3) The amount of storage at the grower level[76] is probably smaller in pecans than the other nuts.

The marketing of pecans is also the least organized of all the domestic tree nuts; hence, it would be expected that the supply and demand forces

[76]Above the grower level of the marketing process, pecan storage is probably quite considerable.

in operation at other levels of the marketing system would be more readily and accurately reflected back to the grower level for pecans than in the case of other tree nuts.

A Comparison Between the Estimates for All Pecans and the Estimates for Seedling and Improved Pecans

Economic theory suggests that commodities which have good substitutes tend to have higher price elasticities. Seedling and improved pecans can substitute for each other at least to a greater degree than other commodities can substitute for all pecans as a group. It would therefore be expected for seedling and improved pecans to have higher coefficients of price elasticity than all pecans. This expectation is realized since the estimated price elasticities for seedling and improved pecans are of larger magnitude than the estimated price elasticities for all pecans (See Tables XVI and XIX).

The income elasticities computed from the two equation models for seedling and improved pecans are consistent with the income elasticities for all pecans computed from the four equation models. The positive income elasticities for seedling and improved pecans (Table XVIII) are greater in magnitude than the positive income elasticities for all pecans (Table XXI). This is logically consistent since, for a given income elasticity for all pecans, the quantity of either seedling or improved pecans would have to increase percentage wise to a greater extent in response to a given percentage increase in income than would the quantity of all pecans. Only in this way would the absolute increase in quantities of seedling and improved pecans be equal to the absolute increase in the quantity of all pecans.

Implications from This Study and Suggestions for Future Research

The inconclusiveness of the empirical results of the demand interrelationships among domestic tree nuts, as well as the other relationships that were not adequately described, could be a result of the choice of models, the time series used to reflect the included variables, or a combination of both factors. However, the implications that arise from the consideration of these results should be useful in future research of the demand relationships among domestic tree nuts and in studies of other agricultural crops which have economic characteristics similar to the domestic tree nut industry.

The empirical results of this study might be improved if additional or more adequate time series data were available. This would include data on storage of tree nuts, tree nuts not harvested, or tree nuts diverted to non-commercial outlets by marketing order and agreement programs. To further understand the demand relationships an attempt might be made to analyze the demand relationships between each tree nut and the quantity of its imports and imports of other tree nuts.

The point in time or the time period in terms of which individual observations of the data were defined should also be considered. The use of aggregate data for the entire crop season may mask demand relationships taking place during the season. If, in fact, the demand interrelationships are of a short-term, intraseasonal nature, they might be more definitely exposed by the use of time series on a monthly or quarterly basis. Another possible hypothesis is that the demand interrelationships are a result of changes from year-to-year in the price-quantity variables, as contrasted to changes from the mean of a long-term series. If this were true, the empirical results may be more consistent if first differences of series were used instead of actual data.

Another possibility for the inadequacies in the results is that tree nuts may be related in demand at wholesale level rather than at the grower level. For example, large purchasers of tree nuts, such as, confectioners, bakers and nut salters may be highly influential in determing the demand structure for tree nuts. The results of their actions or the actions of consumers may not be adequately reflected back to the grower level because of market imperfections. These hypotheses could be tested by an analysis of the demand relationships at marketing levels above the grower level.[77] Studies at other levels of the marketing system would also contribute to an understanding of the economics of the tree nut industry, especially when used and compared with a demand study at the grower level.

[77]In studies above the grower level, the demand relationships among tree nuts in-shell and shelled form should be considered.

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APPENDIX A

APPENDIX TABLE A-I

SEASON AVERAGE PRICE RECEIVED BY GROWERS, PER CAPITA DISPOSABLE PERSONAL INCOME, AND THE CONSUMER PRICE INDEX, UNITED STATES, 1920-55

Year	All Pecans[b]	Seedling Pecans[b]	Improved Pecans[b]	Almonds[c]	Filberts[e]	Walnuts[e]	Per Capita Disposable Personal Income	Consumer Price Index
	1	2	3	4	5	6	7	8
	cents per pound			dollars per ton			dollars	(1947-49 = 100)
1920	25.7	a	a	360	d	400	654	85.7
1920	17.6			320		400	508	76.4
1922	26.5	18.7	44.5	290		360	541	71.6
1923	19.3	14.1	42.5	260		400	616	72.9
1924	23.4	18.6	43.8	300		460	610	73.1
1925	22.1	17.3	37.6	400		441	636	75.0
1926	15.6	11.8	32.5	300		481	651	76.6
1927	20.6	15.4	35.4	320	320	331	645	74.2
1928	16.6	12.0	29.6	340	380	421	653	73.3
1929	14.7	11.4	31.7	480	300	321	682	73.3
1930	14.9	10.8	27.7	200	340	410	604	71.4
1931	7.8	5.8	13.9	176	250	223	515	65.0
1932	6.0	4.4	13.5	165	202	179	390	58.4
1933	8.0	6.0	13.0	186	297	224	364	55.3
1934	12.6	11.0	15.5	180	202	191	411	57.2
1935	6.8	5.0	12.4	280	263	203	459	58.7
1936	12.4	9.6	14.7	402	270	217	517	59.3
1937	7.7	5.8	10.9	275	217	181	551	61.4
1938	9.4	7.2	11.8	258	225	221	506	60.3
1939	9.7	7.8	12.2	209	226	168	538	59.4
1940	8.9	6.9	12.8	324	250	230	576	59.9
1941	10.3	8.5	12.8	704	306	252	697	62.9
1942	17.1	14.6	18.9	442	352	307	871	69.7
1943	23.0	19.0	28.5	732	499	478	977	74.0
1944	21.5	16.9	27.7	744	540	446	1,060	75.2
1945	23.8	20.0	29.2	720	551	509	1,075	76.9
1946	33.7	28.8	40.2	486	384	555	1,126	83.4
1947	22.3	18.3	29.4	558	252	382	1,173	95.5
1948	12.2	10.0	15.2	422	259	419	1,280	102.8
1949	18.8	17.0	21.8	330	219	351	1,261	101.8
1950	28.8	25.7	31.8	546	350	385	1,359	102.8
1951	19.7	17.2	21.7	472	351	429	1,464	111.0
1952	22.1	18.8	25.2	464	298	396	1,512	113.5
1953	16.3	14.7	17.8	476	344	412	1,568	114.4
1954	28.6	25.2	32.7	498	320	350	1,567	114.8
1955	32.8	29.6	40.9	861	420	552	1,635	114.5

[a] Data prior to 1922 not available.

[b] December 1 price 1920-1936. For all methods of sale. United States prices computed by weighting State prices by quantities sold.

[c] For all methods of sale.

[d] Data prior to 1927 not available.

[e] Equivalent returns for bulk nuts at first delivery point. United States price computed by weighting State prices by quantities sold.

Sources of Data:

Col. 1: 1920-33, p. 12 Col. 2: 1922-43, p. 25 Col. 3: 1922-43, p. 25 Col. 4: 1920-33, p. 11 Col. 5: 1927-33, p. 10 Col. 6: 1920-33, p. 7	United States Department of Agriculture, Bureau of Agricultural Economics, Tree Nuts, Acreage, Production, Farm Disposition, Value, and Utilization of Sales, 1909-45, (Washington, D.C., October, 1947).
Col. 1: 1934-55, p. 12 Col. 2: 1944-55, p. 13 Col. 3: 1944-55, p. 12 Col. 4: 1934-55, p. 2 Col. 5: 1934-55, p. 5 Col. 6: 1934-55, p. 3	United States Department of Agriculture, Agricultural Marketing Service, Tree Nuts by States, 1949-55, Revised Estimates, Statistical Bulletin No. 195, (Washington, D.C., October, 1956).
Col. 7: 1920-55, p. 55 Col. 8: 1920-55, p. 55	United States Department of Agriculture, Agricultural Marketing Service, Supplement for 1956 to Consumption of Food in the United States, 1909-52, Agricultural Handbook No. 62, (Washington, D.C., September, 1957).

APPENDIX TABLE A-II

DOMESTIC PRODUCTION OF TREE NUTS AND UNITED STATES POPULATION
1920-55

Year	All Pecans	Seedling Pecans	Improved Pecans	Almonds	Filberts[a]	Walnuts	Total Population as of July 1
	1	2	3	4	5	6	7
	1,000 Pounds			Tons[b]			Million
1920	10,375	8,077	2,298	6,000		22,950	106.5
1921	48,155	40,391	7,764	6,200		23,350	108.5
1922	11,355	7,907	3,448	9,000		29,400	110.1
1923	58,030	47,516	10,514	11,000		26,950	112.0
1924	37,998	30,848	7,150	8,000		24,650	114.1
1925	52,463	40,147	12,316	7,500		36,550	115.8
1926	95,861	78,326	17,535	16,000		16,200	117.4
1927	36,504	26,964	9,540	12,000	60	52,100	119.0
1928	68,550	50,545	18,005	14,000	200	27,400	120.5
1929	53,340	44,501	8,839	4,700	200	43,400	121.8
1930	57,135	43,260	13,875	13,500	300	30,300	123.1
1931	88,463	66,461	22,002	14,800	420	34,200	124.0
1932	68,234	56,421	11,813	14,000	490	49,100	124.8
1933	78,812	55,871	22,941	12,900	1,070	34,000	125.6
1934	56,172	36,704	19,468	12,000	1,210	47,100	126.4
1935	124,485	95,021	29,464	12,700	1,240	57,400	127.2
1936	59,787	27,530	32,257	10,700	2,100	45,800	128.1
1937	107,190	67,164	40.026	24,600	2,570	62,400	128.8
1938	74,323	39,032	35,291	18,400	2,440	55,300	129.8
1939	97,060	56,116	40,944	28,700	3,890	62,500	130.9
1940	122,884	80,758	42,126	15,000	3,210	50,800	132.1
1941	121,781	70,329	51,452	9,500	5,750	70,000	133.4
1942	77,374	31,991	45,383	31,500	4,170	58,250	134.9
1943	133,042	75,869	57,173	20,500	6,930	63,600	136.7
1944	142,104	80,916	61,188	31,700	6,420	71,500	138.4
1945	138,854	79,618	59,236	32,000	5,320	70,700	139.9
1946	76,225	42,733	33,492	47,200	8,450	71,900	141.4
1947	119,602	74,409	45,193	35,700	8,800	64,500	144.1
1948	176,043	98,511	77,532	36,500	6,060	70,650	146.6
1949	125,690	75,585	50,105	43,300	10,590	87,800	149.2
1950	124,630	61,842	62,788	37,700	5,790	64,200	151.7
1951	156,735	68,135	88,600	42,700	6,450	77,400	154.4
1952	151,436	71,866	79,570	36,400	11,570	83,800	157.0
1953	214,170	107,955	106,215	38,600	4,800	59,200	159.6
1954	94,600	50,800	43,800	43,200	8,470	75,100	162.4
1955	146,860	104,460	42,400	38,300	7,710	77,400	165.3

[a]Data prior to 1927 not available.

[b]Includes only quantities harvested.

Sources of Data:

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Col. 2: 1920-33, p. 12
Col. 3: 1920-33, p. 12
Col. 4: 1920-33, p. 11
Col. 5: 1927-33, p. 10
Col. 6: 1920-33, p. 7

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Col. 1: 1934-55, p. 12
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Col. 5: 1934-55, p. 5
Col. 6: 1934-55, p. 3

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APPENDIX TABLE A-III

FOREIGN TRADE--TREE NUTS, IN-SHELL BASIS, 1920-55[a]

Year	Pecans[b] Imports	Pecans[b] Exports[c]	Almonds[d] Imports	Almonds[d] Exports[c]	Filberts[f] Imports	Filberts[f] Exports[c]	Walnuts[g] Imports	Walnuts[g] Exports[c]	Imports of: Domestic-type Tree Nuts	All Tree Nut Imports	Column 10 Minus Column 9
	1	2	3	4	5	6	7	8	9	10	11
	Tons		Tons		Tons		Tons		Tons	Tons	Tons
1920	1,098		13,898		12,672		18,926		46,594	85,000	38,406
1921	541		8,177		11,745		41,865		62,328	133,000	70,672
1922	1,234		5,686		14,383		30,908		52,211	119,000	66,789
1923	392		4,978		15,356		31,453		52,179	124,500	72,321
1924	1,359		17,927		11,136		43,588		74,010	123,500	49,490
1925	506		19,069		9,847		37,725		67,147	111,500	44,353
1926	560		5,122		13,358		37,818		56,858	110,500	53,642
1927	130		2,510		12,948		24,215		39,803	83,000	43,197
1928	270		2,292		12,290		29,158		44,010	104,000	59,990
1929	366		33,258		7,877		24,073		65,574	91,500	25,926
1930	252		22,108		7,931		21,204		51,495	93,000	41,505
1931	230		13,898		5,797		15,521		35,446	91,000	55,554
1932	12		8,177		6,570		8,044		22,803	63,000	40,197
1933	356		5,686		3,525		6,762		16,329	71,000	54,671
1934	518		4,978		3,544		6,288		15,328	82,000	66,672
1935	350	182	17,927		3,993		5,108	6,049	27,378	107,000	79,622
1936	61	903	19,069		4,798		5,926	6,160	29,854	118,500	88,646
1937	232	1,307	5,122		2,278		5,643	5,192	13,275	98,500	85,225
1938	193	1,927	2,510		2,221		4,638	6,353	9,562	105,500	95,938
1939	282	1,244	2,292		3,493		5,438	4,347	11,505	99,500	87,995
1940	179	506	3,309		1,672		5,447	1,948	10,607	123,000	112,393
1941	2	282	6,205		92		3,322	2,006	9,621	103,000	93,379
1942	4	38	1,686		66		302	1,360	2,058	32,000	29,942
1943	419	603	18,878	82	1,173	215	2	1,174	20,472	38,500	18,028
1944	216	1,977	37,580	148	8,072	249	26	1,990	45,894	91,500	45,606
1945	425	2,104	30,468	160	11,089	158	455	3,502	42,437	119,500	77,063
1946	330	1,501	15,082	552	13,451	232	997	2,826	29,860	125,500	95,640
1947	692	300	19,742	378	4,672	522	715	2,707	25,821	122,500	96,679
1948	238	826	17,176	103	8,641	195	3,088	1,378	29,143	147,000	117,857
1949	143	1,704	2,431	210	7,226	235	7,514	2,064	17,314	142,500	125,186
1950	698	881	20,874	110	5,501	339	7,730	1,911	34,803	186,500	151,697
1951	778	909	6,060	876	7,837	359	8,168	1,499	22,843	147,000	124,157
1952	497	1,149	11,272	2,594	5,862	487	8,030	1,628	25,661	156,000	130,339
1953	308	1,487	11,540	6,799	6,147	250	8,683	1,680	26,678	163,500	136,822
1954	442	1,430	2,206	8,624[e]	7,711	950[e]	15,803	5,147	26,162	195,500	169,338
1955	1,014	915	726		6,699		14,569	1,800	23,008	189,000	165,992

Appendix Table A-III (Continued)

[a]Year beginning July 1 of year indicated, except for imports of filberts which are on a calendar year basis for the years 1920-26.

[b]Exports of shelled nuts converted to in-the-shell basis at ratio of 1 to 2.5. Imports of shelled nuts prior to January 1949 were converted at ratio of 1 to 2.63, thereafter 1 to 2.78.

[c]Not separately classified prior to date given.

[d]Shelled converted to in-the-shell basis at ratio of 1 to 3.33.

[e]Preliminary

[f]Shelled converted to in-the-shell basis at ratio of 1 to 2.22.

[g]Shelled converted to in-the-shell basis at ratio of 1 to 2.38.

[h]Includes almonds, filberts, pecans, walnuts, brazil nuts, pignolia, pistachio, chestnuts, cashews, and miscellaneous; excludes cocoanuts.

Sources of Data:

Col. 1: 1920-38, p. 329	United States Department of Agriculture, <u>Agricultural Statistics, 1952</u>, (Washington, 1952).
Col. 2: 1935-38, p. 329	
Col. 3: 1920-38, p. 327	
Col. 5: 1927-38, p. 328	
Col. 7: 1920-38, p. 331	
Col. 8: 1935-38, p. 331	
Col. 1: 1939-55, p. 257	United States Department of Agriculture, <u>Agricultural Statistics, 1956</u>, (Washington, 1957).
Col. 2: 1939-55, p. 257	
Col. 3: 1939-55, p. 255	
Col. 5: 1939-55, p. 255	
Col. 7: 1939-55, p. 257	
Col. 8: 1939-55, p. 257	
Col. 10: 1939-55, p. 254	
Col. 10: 1920-38, p. 234	United States Department of Agriculture, FAS, <u>United States Farm Products in Foreign Trade</u>, Statistical Bulletin No. 112, (Washington, 1953).
Col. 4: 1943-54, p. 130	United States Department of Agriculture, FAS, <u>Foreign Agricultural Trade</u>, Statistical Handbook No. 179,
Col. 6: 1943-54, p. 133	
Col. 5: 1920 p. 545	United States Department of Commerce, Bureau of Foreign and Domestic Commerce, <u>Foreign Commerce and Navigation of the United States for the Calendar Year 1920</u>, (Washington, 1921).
Col. 5: 1921-26, p. 487	United States Department of Commerce, Bureau of Foreign and Domestic Commerce, <u>Foreign Commerce and Navigation of the United States for the Calendar Year 1926</u>, Vol. II, (Washington, 1928).

APPENDIX B

THE LOGARITHM FORM OF THE EQUATIONS IN CHAPTER IV*

Model I'

$$Y_1 = -4.1566 - \underset{(3.2325)}{0.3082Z_2} - \underset{(1.9442)}{0.2154Z_3} + \underset{(4.4565)}{1.8234Z_7} - \underset{(2.0954)}{0.0083Z_8} - \underset{(1.6310)}{0.5170Z_{10}} + \underset{(2.4563)}{0.0663Z_{11}} \qquad (4.2')$$

$$R^2 = .7914$$

Model II'

$$Y_2 = -4.5228 - \underset{(2.8437)}{0.3132Z_2} - \underset{(1.7688)}{0.2263Z_3} + \underset{(4.0119)}{1.8960Z_7} - \underset{(1.2905)}{0.0059Z_8} - \underset{(1.3803)}{0.5053Z_{10}} + \underset{(2.2536)}{0.0702Z_{11}} \qquad (4.5')$$

$$R^2 = .7475$$

$$Y_3 = -3.7448 + \underset{(0.1592)}{0.0131Z_2} - \underset{(4.8988)}{0.4670Z_3} + \underset{(4.9431)}{1.7405Z_7} - \underset{(3.6915)}{0.0126Z_8} - \underset{(1.4991)}{0.4089Z_{10}} + \underset{(2.4998)}{0.0581Z_{11}} \qquad (4.6')$$

$$R^2 = .8995$$

$$Z_2 = -3.1300Y_2 + 1.5168Y_3 + 3.2943Z_7 + 0.0006Z_8 - 0.9614Z_{10} + 0.1318Z_{11} \qquad (4.7')$$

$$Z_3 = -0.0875Y_2 - 2.0989Y_3 + 3.8191Z_7 - 0.0269Z_8 - 0.9025Z_{10} + 0.1280Z_{11} \qquad (4.8')$$

Model III'

$$Y_2 = -4.7179 - \underset{(2.6971)}{0.3221Z_2} - \underset{(1.9611)}{0.2692Z_3} + \underset{(3.7674)}{1.9308Z_7} - \underset{(1.1297)}{0.0056Z_8} - \underset{(0.9692)}{0.3806Z_{10}} \qquad (4.9')$$

$$R^2 = .6892$$

$$Y_3 = -3.9061 + \underset{(0.0628)}{0.0057Z_2} - \underset{(4.8095)}{0.5024Z_3} + \underset{(4.5365)}{1.7693Z_7} - \underset{(3.2670)}{0.0123Z_8} - \underset{(1.0234)}{0.3058Z_{10}} \qquad (4.10')$$

$$R^2 = .8709$$

$$Z_2 = -3.0758Y_2 + 1.6480Y_3 + 3.0229Z_7 + 0.0031Z_8 - 0.6666Z_{10} \qquad (4.11')$$

$$Z_3 = -0.0349Y_2 - 1.9715Y_3 + 3.5556Z_7 + 0.0245Z_8 - 0.6162Z_{10} \qquad (4.12')$$

Model IV'

$$Y_2 = -3.6971 - \underset{(2.7210)}{0.3245Z_2} - \underset{(1.7539)}{0.2295Z_3} + \underset{(4.5112)}{1.5657Z_7} - \underset{(0.9408)}{0.0045Z_8} \qquad (4.13')$$

$$R^2 = .6765$$

$$Y_3 = -3.0858 + \underset{(0.0416)}{0.0038Z_2} - \underset{(4.7145)}{0.4706Z_3} + \underset{(5.5754)}{1.4759Z_7} - \underset{(3.1152)}{0.0115Z_8} \qquad (4.14')$$

$$R_2 = .8650$$

$$Z_2 = -3.0647Y_2 + 1.4948Y_3 + 2.5922Z_7 + 0.0032Z_8 \qquad (4.15')$$

$$Z_3 = -0.0247Y_2 - 2.1131Y_3 + 3.1574Z_7 - 0.0244Z_8 \qquad (4.16')$$

*The prime to the right of the equation number indicates the variables (except for the variable time) are expressed in the form of logarithms. The numbers of these equations correspond to the numbers in the text.

Appendix B (Continued)

THE LOGARITHM FORM OF THE EQUATIONS IN CHAPTER V

<u>Model V'</u>

$$Y_1 = +1.6903 - 0.8622Z_1 - 0.3467Z_4 + 0.0560Z_5 + 0.0038Z_6 + 1.3535Z_7 - 0.0022Z_9 - 0.0617Z_{12} \qquad (5.5')$$

(5.8223) (1.6600) (0.6869) (0.0343) (3.3341) (0.3110) (0.5295)

$$R^2 = .7800$$

$$Y_4 = +1.3813 - 0.0033Z_1 - 0.4458Z_4 - 0.0330Z_5 - 0.0632Z_6 + 0.9109Z_7 - 0.0054Z_9 - 0.0485Z_{12} \qquad (5.6')$$

(0.0272) (2.6481) (0.5025) (0.7003) (2.7834) (0.9382) (0.5158)

$$R^2 = .6087$$

$$Y_5 = +3.8335 + 0.0528Z_1 - 0.4623Z_4 - 0.0491Z_5 - 0.2313Z_6 + 0.2789Z_7 - 0.0028Z_9 - 0.1970Z_{12} \qquad (5.7')$$

(0.3979) (2.4703) (0.6719) (2.3042) (0.7665) (0.4315) (1.8859)

$$R^2 = .7270$$

$$Y_6 = -0.9403 - 0.0049Z_1 + 0.0585Z_4 + 0.1007Z_5 - 0.6215Z_6 + 1.7288Z_7 - 0.0096Z_9 - 0.1635Z_{12} \qquad (5.8')$$

(0.0263) (0.2205) (0.9731) (4.3692) (3.3536) (1.0483) (1.1051)

$$R^2 = .7208$$

$$Z_1 = -1.3671Y_1 + 4.3193Y_4 - 3.0528Y_5 + 0.6883Y_6 - 2.4229Z_7 + 0.0185Z_9 - 0.3638Z_{12} \qquad (5.9')$$

$$Z_4 = +0.1959Y_1 - 5.3853Y_4 + 2.8196Y_5 - 0.5003Y_6 + 4.7191Z_7 - 0.0258Z_9 + 0.2247Z_{12} \qquad (5.10')$$

$$Z_5 = -1.9593Y_1 + 32.8600Y_4 - 29.2622Y_5 + 7.5362Y_6 - 32.1487Z_7 + 0.1650Z_9 - 3.0597Z_{12} \qquad (5.11')$$

$$Z_6 = -0.2880Y_1 + 4.7810Y_4 - 4.4497Y_5 - 0.4409Y_6 - 1.9621Z_7 + 0.0088Z_9 - 0.7346Z_{12} \qquad (5.12')$$

APPENDIX C

COMPUTATION OF JUST-IDENTIFIED ESTIMATES FROM THE REDUCED FORM ESTIMATES

1. The equations, (5.5) to (5.8), in matrix form are:

$$P' = BQ' + CZ' \tag{C.1}$$

where

$$P' = \begin{bmatrix} Y_1 \\ Y_4 \\ Y_5 \\ Y_6 \end{bmatrix} \quad BQ' = \begin{bmatrix} -0.83146525 & -0.20170602 & -0.67438776 & -0.09064799 \\ +0.00408363 & -0.51537685 & +0.92731509 & -0.14998073 \\ -0.00313089 & -0.37039213 & -0.59963784 & -0.70418067 \\ -0.03441761 & +0.32315735 & +0.62880599 & -3.2981334 \end{bmatrix} \begin{bmatrix} Z_1 \\ Z_4 \\ Z_5 \\ Z_6 \end{bmatrix},$$

$$\text{and } CZ' = \begin{bmatrix} +0.70855449 & -5.5245054 & -0.26266907 \\ +0.50129845 & -12.906931 & -0.9454829 \\ +0.31886506 & -8.2472187 & -0.37755317 \\ +1.3546724 & -14.870861 & -0.85156374 \end{bmatrix} \begin{bmatrix} Z_7 \\ Z_9 \\ Z_{12} \end{bmatrix}.$$

2. Step 1. Compute the inverse of B.

3. Step 2. Premultiply each term of the single equations by B^{-1}. Equations (C.1) are written as:

$$B^{-1}P' = B^{-1}BQ' + B^{-1}CZ' \tag{C.2}$$

or

$$B^{-1}P' = Q' + B^{-1}CZ'. \tag{C.3}$$

4. Step 3. Equations (C.3) are the just-identified equations, (5.9) to (5.12), and by rearranging terms can be written as:

$$Q' = B^{-1}P' - B^{-1}CZ'$$

where

$$Q' = \begin{bmatrix} Z_1 \\ Z_4 \\ Z_5 \\ Z_6 \end{bmatrix} \quad B^{-1}P' = \begin{bmatrix} -1.20129669 & -0.22889219 & +0.85188262 & -0.13845855 \\ -0.01216155 & -0.93851986 & -1.13784257 & +0.28595237 \\ +0.00037757 & +0.56058544 & -0.67646263 & +0.11892808 \\ +0.01141648 & +0.01730914 & -0.24934883 & -0.25106452 \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_4 \\ Y_5 \\ Y_6 \end{bmatrix},$$

$$\text{and } B^{-1}CZ' = \begin{bmatrix} +0.88185783 & -4.62420133 & -0.13346015 \\ +0.45454213 & -17.31227620 & -0.27801931 \\ -0.22669643 & +3.42715118 & -0.10102419 \\ +0.40285256 & -5.50350163 & -0.30330458 \end{bmatrix} \begin{bmatrix} Z_7 \\ Z_9 \\ Z_{12} \end{bmatrix}.$$

APPENDIX D

MODEL IV--A VARIATION OF MODEL III

Single Equation Estimates in Natural Units*

$$Y_1 = +9.2184 - \underset{(6.0116)}{0.1970Z_1'} - \underset{(1.2984)}{0.0677Z_4'} + \underset{(0.5084)}{0.0811Z_5'} - \underset{(0.6169)}{0.0310Z_6'} + \underset{(4.2555)}{0.03067Z_7} - \underset{(1.6418)}{0.4039Z_9} + \underset{(1.7210)}{0.0428Z_{13}} \quad (D.1)$$

$$R^2 = .8071$$

$$Y_4 = +14.6131 + \underset{(0.1706)}{0.0051Z_1'} - \underset{(2.8620)}{0.1369Z_4'} + \underset{(1.9379)}{0.2837Z_5'} - \underset{(1.3934)}{0.0642Z_6'} + \underset{(3.9320)}{0.0259Z_7} - \underset{(3.1803)}{0.7176Z_9} + \underset{(0.2067)}{0.0047Z_{13}} \quad (D.2)$$

$$R^2 = .6522$$

$$Y_5 = +23.4797 - \underset{(0.2211)}{0.0064Z_1'} - \underset{(2.0142)}{0.0926Z_4'} - \underset{(1.6714)}{0.2352Z_5'} - \underset{(2.5764)}{0.1142Z_6'} + \underset{(3.3952)}{0.0215Z_7} - \underset{(3.0598)}{0.6637Z_9} + \underset{(0.3818)}{0.0084Z_{13}} \quad (D.3)$$

$$R^2 = .7720$$

$$Y_6 = -21.5011 - \underset{(0.0478)}{0.0041Z_1'} + \underset{(0.8971)}{0.1226Z_4'} - \underset{(2.7329)}{1.1432Z_5'} - \underset{(1.1739)}{0.1546Z_6'} + \underset{(3.4658)}{0.0654Z_7} - \underset{(2.1053)}{1.3575Z_9} + \underset{(1.0621)}{0.0692Z_{13}} \quad (D.4)$$

$$R^2 = .5365$$

Just-identified Estimates in Natural Units

$$Z_1' = -5.1334Y_1 + 0.1350Y_4 + 2.4483Y_5 - 0.8345Y_6 + 0.1555Z_7 - 1.4843Z_9 + 0.2564Z_{13} \quad (D.5)$$

$$Z_4' = +1.4018Y_1 + 24.7462Y_4 - 31.5424Y_5 + 12.7295Y_6 - 0.8376Z_7 + 14.6681Z_9 - 0.7939Z_{13} \quad (D.6)$$

$$Z_5' = +0.3934Y_1 + 7.4458Y_4 - 7.8339Y_5 + 2.6125Y_6 - 0.2073Z_7 + 3.8487Z_9 - 0.1672Z_{13} \quad (D.7)$$

$$Z_6' = -1.6604Y_1 - 35.4241Y_4 + 32.8338Y_5 - 15.6631Y_6 + 1.2865Z_7 - 25.5597Z_9 + 1.0477Z_{13} \quad (D.8)$$

MODEL VI'

Single Equation Estimates in Logarithms (except for Z_9, time)**

$$Y_1 = -0.9506 - \underset{(5.7122)}{0.8482Z_1'} - \underset{(1.5133)}{0.4283Z_4'} + \underset{(0.2368)}{0.0336Z_5'} - \underset{(0.6530)}{0.0865Z_6'} + \underset{(3.3510)}{1.4512Z_7} - \underset{(0.7018)}{0.0037Z_9} + \underset{(1.1153)}{0.2067Z_{13}} \quad (D.1')$$

$$R^2 = .7948$$

$$Y_4 = -0.3488 + \underset{(0.2260)}{0.0275Z_1} - \underset{(2.9333)}{0.6797Z_4'} + \underset{(1.4170)}{0.1644Z_5'} - \underset{(1.7729)}{0.1923Z_6'} + \underset{(3.2534)}{1.1536Z_7} - \underset{(2.3027)}{0.0101Z_9} - \underset{(0.7880)}{0.1196Z_{13}} \quad (D.2')$$

$$R^2 = .6251$$

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*Including the year 1942 for equations (D.1) through (D.8).

**Excluding the years 1942 for equations (D.1') through D.8').

Appendix D (Continued)

$$Y_5 = +0.2435 - 0.0305Z_1' - 0.4754Z_4' - 0.1814Z_5' - 0.2261Z_6' + 0.9092Z_7 - 0.0126Z_9 + 0.0230Z_{13} \qquad \text{(D.3')}$$
$$\qquad (0.2238) \quad (1.8303) \quad (1.3948) \quad (1.8594) \quad (2.2876) \quad (2.5641) \quad (0.1353)$$
$$R^2 = .7337$$

$$Y_6 = -5.1437 - 0.1293Z_1' + 0.1083Z_4' - 0.6263Z_5' - 0.2762Z_6' + 2.6647Z_7 - 0.0135Z_9 - 0.0595Z_{13} \qquad \text{(D.4')}$$
$$\qquad (0.5320) \quad (0.2338) \quad (2.7012) \quad (1.2741) \quad (3.7604) \quad (1.5517) \quad (0.1961)$$
$$R^2 = .5681$$

__Just-identified Estimates in Logarithms (except for Z_9, time)__

$$Z_1' = -1.1560Y_1 - 0.3073Y_4 + 1.3588Y_5 - 0.5361Y_6 + 2.2252Z_7 + 0.0024Z_9 + 0.1391Z_{13} \qquad \text{(D.5')}$$

$$Z_4' = -0.0823Y_1 + 3.7192Y_4 - 6.6852Y_5 + 2.9079Y_6 - 5.8418Z_7 - 0.0074Z_9 + 0.7887Z_{13} \qquad \text{(D.6')}$$

$$Z_5' = +0.1227Y_1 + 6.4023Y_4 - 8.6724Y_5 + 2.6019Y_6 - 6.6125Z_7 - 0.0088Z_9 + 1.0948Z_{13} \qquad \text{(D.7')}$$

$$Z_6' = +0.2305Y_1 - 12.9151Y_4 + 16.4076Y_5 - 8.1295Y_6 + 21.3098Z_7 - 0.0332Z_9 - 2.4536Z_{13} \qquad \text{(D.8')}$$

APPENDIX TABLE D-1

ACTUAL SERIES USED IN MODEL IV

Year	Y_1	Y_4	Y_5	Y_6	Z'_1	Z'_4	Z'_5	Z'_6	Z_7	Z_9	Z_{13}
1927	27.76	22.30	21.56	21.56	30.89	128.30	21.86	24.39	869	1	72.61
1928	22.65	28.72	25.92	23.19	57.58	94.26	20.82	27.15	891	2	99.59
1929	20.05	21.90	20.46	32.74	44.39	110.8	13.26	62.33	930	3	42.61
1930	20.87	28.71	23.81	14.00	46.82	83.68	13.37	57.85	846	4	67.42
1931	12.00	17.15	19.23	13.54	71.71	80.20	10.03	46.29	792	5	89.60
1932	10.27	15.32	17.29	14.13	54.69	91.58	11.31	35.54	668	6	64.42
1933	14.47	20.25	26.85	16.82	63.31	64.91	7.317	29.60	658	7	87.02
1934	22.03	16.70	17.66	15.73	45.26	84.47	7.522	26.86	719	8	105.5
1935	11.58	17.29	22.40	23.85	98.42	98.28	8.228	48.16	782	9	125.2
1936	20.91	18.30	22.76	33.90	46.77	80.76	10.77	46.48	872	10	138.4
1937	12.54	14.74	17.67	22.39	83.58	105.7	7.528	46.15	897	11	132.3
1938	15.59	18.32	18.66	21.39	57.56	92.35	7.182	32.22	839	12	147.8
1939	16.33	14.14	19.02	17.59	74.58	103.8	11.28	47.35	906	13	134.5
1940	14.86	19.20	20.87	27.04	93.29	85.16	7.391	27.72	962	14	170.2
1941	16.38	20.03	24.32	55.96	91.29	109.9	8.759	23.55	1,111	15	140.0
1942	24.53	22.02	25.25	31.71	57.36	86.81	6.280	49.20	1,250	16	44.4
1947	23.35	20.00	13.19	29.21	83.96	90.51	18.70	76.95	1,228	21	134.2
1948	11.87	20.38	12.60	20.52	120.4	100.6	20.06	73.23	1,245	22	160.8
1949	18.47	17.24	10.76	16.21	84.43	127.8	23.88	61.30	1,239	23	167.8
1950	28.02	18.72	17.02	26.56	83.08	94.83	14.89	77.22	1,322	24	200.0
1951	17.75	19.32	15.81	21.26	102.5	110.8	18.51	63.16	1,319	25	160.8
1952	19.47	17.44	13.13	20.44	97.09	117.0	22.21	60.73	1,332	26	166.1
1953	14.25	18.01	15.03	20.80	134.6	85.07	13.72	62.83	1,371	27	171.4
1954	24.91	15.24	13.94	21.69	58.80	111.9	19.93	55.92	1,365	28	208.6
1955	28.65	24.10	18.34	37.60	90.07	111.3	17.43	47.22	1,428	29	200.8

Y_1 is the season average price, in cents per pound, received by pecan growers, deflated by CPI.

Y_4 is the season average price, in cents per pounds, received by walnut growers, deflated by CPI.

Y_5 is the season average price, in cents per pound, received by filbert growers, deflated by CPI.

Y_6 is the season average price, in cents per pound, received by almond growers, deflated by CPI.

Z'_1 is domestic production plus imports of pecans on a pounds per 100 persons basis.

Z'_4 is domestic production plus imports of walnuts on a pounds per 100 persons basis.

Z'_5 is domestic production plus imports of filberts on a pounds per 100 persons basis.

Z'_6 is domestic production plus imports of almonds on a pounds per 100 persons basis.

Z_7 is per capita disposable personal income, deflated by CPI.

Z_9 is time, origin at 1927.

Z_{13} is the sum of all tree nut imports minus the sum of the imports of pecans, walnuts, filberts, and almonds, on a pounds per 100 persons basis.

VITA

Elliott B. Lerner

Candidate for the Degree of

Master of Science

Thesis: AN ECONOMETRIC ANALYSIS OF THE DEMAND FOR PECANS WITH SPECIAL REFERENCE TO THE DEMAND INTERRELATIONSHIPS AMONG DOMESTIC TREE NUTS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in New York, New York, May 13, 1935, the son of Harry N. and Dorothy Lerner.

Education: Attended grade school in New York, New York; attended high school in New York, New York and Los Angeles, California; graduated from Los Angeles High School in 1953; attended Pierce Junior College, Woodland Hills, California, in Spring, 1953; attended California State Polytechnic College, Pomona, California, the year of 1954; received the Bachelor of Science degree from the University of California, Berkeley, California, with a major in Agricultural Economics, in June, 1957; completed requirements for the Master of Science degree in August, 1959.

Professional Experience: Employed by the United States Department of Agriculture during summer of 1957. Research Assistant, Oklahoma State University from September, 1957, to February, 1959.