A RECURSIVE MODEL OF THE UNITED STATES DOMESTIC SOYBEAN MARKET

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ABSTRACT

A RECURSIVE MODEL OF THE UNITED STATES DOMESTIC SOYBEAN MARKET

by Leonardo A. Paulino

This study obtains parameter estimates relating to the demands for soybeans, soybean meal and soybean oil in the United States for the marketing years 1946-63. The investigation also examines the feasibility of the recursive method in analyzing the demand and price structure of the interrelated markets of these commodities.

A four-equation model of the United States soybean market is developed. The quantity of soybeans processed annually is first estimated using variables whose values are essentially known at the start of the marketing year. The generated estimates are then employed for the quantity-of-soybeans variable in each of the price-determining equations for soybean meal and soybean oil. The soybean price equation in the model is, in turn, dependent upon the calculated values of the quantity of soybeans processed and the prices of meal and oil from the first three relationships. For comparative purposes, two functional forms are used for each set of the four equations--one set in terms of the "natural" values of the observations and the other in terms of their logarithms.

The soybean quantity relationship serves its purpose well in the framework of the model; in both of the functional forms used, annual quantities of beans crushed are accurately estimated. Both of the estimated equations for soybean oil yield satisfactory coefficients of determination. The soybean meal equation expressed in terms of "natural" numbers fails to satisfactorily account for the variations in meal price during the sample period; a much better fit is shown by the logarithmic form of the relationship. Fair statistical fits to the observed data are obtained for the soybean price equations, apparently reflecting their dependence upon the performance of the other relations in the model. The estimated coefficients of the explanatory variables generally exhibit algebraic signs that are consistent with expected results.

Price flexibility estimates computed from this model are comparable to previous estimates obtained by ordinary least squares. They are also comparable to the results of an earlier investigation that employed a simultaneous-equations model estimated by two-stage least squares procedure. The non-logarithmic set of equations in the present study yields price flexibility estimates, at the point of means, of -0.74 and -0.77 for wholesale demands of soybean meal and soybean oil, respectively, and -1.21 for processing demand of soybeans at the farm level. Constant price flexibilities shown by the logarithmic equations are -1.30, -0.72 and -0.82, in the same order.

In accordance with the results of previous investigations, this study indicates that the demand for soybean meal in the United States is becoming less elastic over time. Differing from the findings in earlier studies, the results show that feed grains are complements with soybean meal. The tendency towards the increased use of prepared feeds in the United States livestock industry could result in complementarity between high-carbohydrate and high-protein feeds. As expected, the prices of soybean meal and soybean oil are shown to be more important determinants of the annual price of soybeans than the quantity of soybeans processed.

The study concludes by suggesting improvements for the recursive model and by suggesting some implications of the results with bearing on price analysis work on soybeans and other agricultural commodities.

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By

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To Emma

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CHAPTER I

INTRODUCTION

Soybeans, which now occupy a significant position among the agricultural commodities in the United States, are a unique crop. They are unique in the sense that, averaging over the past two or three decades, the value of soybeans is about equally provided by the joint products of meal and oil. The demand for soybeans is derived from the demands for soybean meal and soybean oil. These joint commodities flow into essentially independent markets; soybean meal enters the livestock industry while soybean oil joins the edible fats and oils complex of the food processing industry. An integrated analysis of the markets for soybeans and soybean products can yield additional information regarding the interrelated demands for these commodities.

The complexity of the structure of the markets for soybeans, soybean meal and soybean oil suggests the use of simultaneous relations for the above-mentioned analysis. Houck developed an analytical model in this framework and employed both the two-stage and ordinary least squares methods for estimating the different relationships in the model. In appraising the results of his

1963 study, Houck writes, "Most estimated equations displayed expected signs. The LS (least squares) and 2SLS (two-stage least squares) estimates of the structural coefficients are similar in most cases. Several least squares reduced form equations fitted actual data extremely well."[1] The ordinary least squares method was not appropriate for the model but nevertheless employed for comparative purposes. Based on these results of Houck's study, the use of ordinary least squares as a relatively simple procedure for an analysis of the complex soybean market invites further investigation. But, it would be well to first review the developments regarding the methods employed in price analysis work.

Statistical price analysis work entered a new dimension in the second half of the present century following the contributions made by Haavelmo, in 1943 and 1944, regarding the use of simultaneous equations systems and methods for the quantitative measurements of economic relationships.[2] Studies on price and demand relations before 1950 essentially revolved around the single-equation approach employing least squares

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[1] James P. Houck (1963) Demand and Price Analysis of the U. S. Soybean Market, University of Minnesota Agricultural Experiment Station Technical Bulletin 244.

[2] Trygve Haavelmo (1943) "The Statistical Implications of a System of Simultaneous Equations," Econometrica (11); and (1944) "The Probability Approach in Econometrics," Econometrica (12) Supplement.

techniques. The continued use of this method, despite the recognition that economic relationships exist as systems which are governed by simultaneity, invited doubts and began to be questioned. Haavelmo had argued that the separate determination of each equation contained in a group of simultaneous relationships is not a satisfactory procedure since due regard must be given to the several restrictions that might be imposed on a variable which appears in more than one equation. Simultaneous equations methods were then subsequently developed, with much of the initial work done by the Cowles Commission group.

These developments, however, have not prevented further applications of the traditional least squares technique; Fox argued that many of the market demand relationships for agricultural commodities are such that multiple correlation methods can be effectively employed.[3] With the development of high-speed computers which enabled small-sample evaluations of both techniques, results seem to indicate that least squares sometimes will not perform as well as simultaneous equations methods; however, the controversy remains unresolved. In a symposium on simultaneous equations in 1960, Christ pointed out, "it is not yet clear that the least squares method for structural

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[3]Karl A. Fox (1958) Econometric Analysis for Public Policy (Ames, Iowa: Iowa State College Press).

estimation is dead and should be discarded. . . . The most important task ahead is to learn more about how to decide which estimation method is likely to be best for any given actual econometric problem."[4]

Wold still believes in the soundness of the traditional regression methods and argues that "much of the confusion around the controversial issues can be removed by bringing out more explicitly logical principles behind regression analysis."[5] He evades the objections to the use of least squares by the selective application of the technique to sets of economic relations which can be formulated into "recursive" or "causal chain" systems. A distinct computational feature of such a system is that equations can be individually determined by using estimates of a variable which result from one relation for the values of the same variable in the other relations, rather than employing the observed values of the variable in all the equations where it is involved. The appeal of the recursive system lies mainly in the justified use of ordinary least squares; consequently, its advantages are those which accrue to the analytical method.

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[4]Carl F. Christ (1960) "Simultaneous Equations: Any Verdict Yet?" Econometrica (28).

[5]Herman Wold and Lars Jureen (1953) Demand Analysis (New York: John Wiley and Sons, Inc.)

Objectives of the Study

The objectives of the present study are essentially twofold. One is to analyze the demand and price structure of soybeans and soybean products in the United States. For this objective, the estimates of the economic parameters relating to the domestic demands for soybeans, soybean meal and soybean oil will be obtained. The other objective is to determine the feasibility of the recursive technique in analyzing the interrelated markets of soybeans and soybean products.

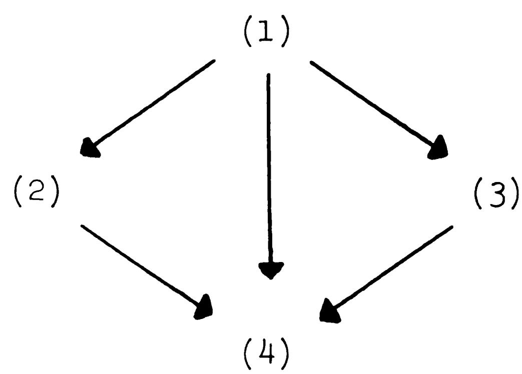
Procedure

A study of the United States soybean market at the national level is made by employing a model consisting of the following relationships: (1) an estimating function for the quantity of soybeans processed each year, (2) a wholesale-price-generating function for soybean meal, (3) a wholesale-price-generating function for soybean oil, and (4) a farm-level-price function for soybeans.

Each of the relationships in the above structure is formed by a combination of endogenous and predetermined variables.[6] Relation (1) contains an endogenous

[6]Richard J. Foote (1958) Analytical Tools for Studying Demand and Price Structures, U. S. Department of Agriculture Agricultural Handbook 146. A structure is a

variable and several predetermined variables; each of relations (2) and (3) has two endogenous variables, one of which appears in (1), besides the predetermined variables; and relation (4) contains four endogenous variables, one from each of the first three relations, and a single predetermined variable. The equations are formulated as a causal chain of market relations for each observation year, the functions being linked each year as shown:



Considering each numerical figure and arrowhead in the above diagram as representing an endogenous variable, one can easily note the number of endogenous variables in each of the relationships given earlier. Formulated as a causal chain, however, the arrowheads represent

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process by which a set of economic relations is believed to be generated. The variables whose values are explained by the structure are <u>endogenous</u> while those whose values are determined outside of the structure are <u>exogenous</u>; lagged values of endogenous variables together with exogenous variables are said to be predetermined. Statistically, the endogenous variables are assumed to be correlated with the unexplained residuals in the structural equations in which they belong.

estimates from previous relations. Thus, equation (1) is an independent function in itself, equations (2) and (3) both depend on the results from equation (1), and equation (4) depends on the results of the three previous relations. Computationally, therefore, each of the formulated relationships contains only one "real" endogenous variable since the calculated values of the other endogenous variables can be considered as predetermined.

The fully recursive systems formulated and described by Wold possess two properties, namely, (1) the system is recursive in a twofold sense; (a) if the development of the variables is known up to time t-1, the system gives the variables at time t, and (b) the variables at time t are obtained one by one; and (2) each equation in the system expresses a unilateral causal dependence.[7] The set of relationships forming a causal chain in this study thus differs from the fully recursive types in the extent of recursiveness. Recursiveness in the present model occurs only within periods; that in fully recursive models occurs within and between periods.

Foote lists the requisites of a recursive system as follows:[8]

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[7] Wold and Jureen (1953) op. cit.

[8] Foote (1958) op. cit.

1. At least one equation contains only a single endogenous variable. Consistent estimates[9] of the coefficients in such equations can be obtained by fitting them directly by least squares, provided the endogenous variable is treated as dependent.

2. At least one other equation must contain only one endogenous variable in addition to those contained in the first set. Consistent estimates of the coefficients in the equations can be obtained if they are fitted directly by least squares, provided calculated values of the endogenous variables included in the equations referred to in item (1) are substituted for actual values before making the computations and the single new endogenous variable is treated as dependent.

3. The recursive system as a whole must be of such a nature that by successive steps each of the equations can be transformed into one that contains only a single endogenous variable other than those which have been treated as dependent in prior analyses.

The use of calculated values in order to determine the equations where endogenous variables are made to occur as causal variables is reasoned out in the following way:

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[9]Alexander M. Mood (1950) An Introduction to Statistics (New York: McGraw-Hill Book Co., Inc.). A consistent estimate becomes near the true value of the parameter with probability approaching one as the sample size increases without limit.

> (1) The unexplained residuals in the several equations within an equation system are assumed to be correlated one with another and, by definition, an endogenous variable in a particular equation is assumed to be correlated with the unexplained residuals in that equation. (2) Calculated values for a given variable in a given equation are known to be uncorrelated with the unexplained residuals in that equation because the residuals are ignored in the computations. (3) Hence, calculated values for an endogenous variable obtained from one equation are uncorrelated with the unexplained residuals in another equation within the same system, and the calculated series becomes in effect a predetermined variable.[10]

The choice of the predetermined variables which enter in the functional relationships for soybeans and soybean products is based on *a priori* theory and on previous studies made on these commodities. Preliminary computations also led to the elimination of some initially-included variables which appeared to contribute little in explaining variations in the observed values of the dependent variables. Following the "traditional compromise" in the use of regression analysis for economic relationships, the study includes only those that are believed to be the main causal factors concerned with changes in the effect variables.

As already indicated, all of the formulated equations are estimated with least squares regression. Two different economic relationships among the variables are employed. Sub-model I expresses the relationships as linear in terms

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[10]Foote (1958) *op. cit.*

of "natural" numbers and thus assumes the relationships among the variables to be additive; on the other hand, sub-model II equations are linear in the logarithms of the observed values and therefore assume that the economic relationships are multiplicative. The estimated equations in both sub-models are examined as regards the goodness of fit to observed data and the algebraic signs of the estimated coefficients. Price flexibility estimates obtained from the model are compared with those found in earlier studies and from more complicated models.

Data for the study cover the 18 marketing years beginning October, 1946 and ending September, 1964. Price indexes for product groups and the deflators for actual price observations are on the 1947-49 base; they refer to the October-September year and are thus coincident with the observation periods. The sources of data are largely the publications of the United States Department of Agriculture (USDA), mainly from Agricultural Prices, Grain and Feed Statistics (an annual supplement of Statistical Bulletin 159), Fats and Oils Situation, and Feed Situation. Some data are also drawn from the Soybean Blue Book of the American Soybean Association and from publications of the Bureau of Labor Statistics on wholesale prices. The data used in this investigation are presented in Tables 6 to 11 of Appendix A.

CHAPTER II

THE UNITED STATES SOYBEAN INDUSTRY

Some background information about the United States soybean industry would be helpful in developing a model for an analysis of the domestic markets of soybeans and soybean products. Knowledge of the structure of the industry provides a useful guide in the selection of the relevant variables that enter the model. The present chapter is devoted to a discussion of the growth of the soybean industry in the United States since the mid-1930's, the domestic utilization of soybeans and soybean products, the processing of soybeans and the markets into which these products flow. The tables mentioned in this chapter are found in Appendix A.

Growth of the United States Soybean Industry

The development of the soybean industry in the United States underwent rapid strides during the past three decades. From an average annual soybean production of 56 million bushels in the 1935-39 period, at which time the country was ranked third among the world producers of the crop, output rose to 209 million bushels during the immediate post-World War II years and then climbed to almost 700 million bushels in 1963. These increased outputs represent 370 per cent and 1240 per cent, respectively, of the 1935-39 level. In a span of three decades, soybean output in the United States has grown more than a dozenfold. The national output started to outrank those of other countries in the early 1950's and by the 1962 season, the harvested soybean crop of the United States was about 65 per cent of world production. Corresponding acreage figures for the 1945-49 and 1963 periods are respectively 350 per cent and 940 per cent of the 1935-39 average annual harvested area. This is indicative of the relatively stable yields per acre during the first of the last three decades and a significant improvement in the past 20 years. But Kromer notes that the increasing yield per acre of soybeans in the country during the post-war years reached a "plateau" in 1957.[11] (Tables 11 and 12.)

The major impetus in the rapid growth of the United States soybean industry from the late 1930's was initially provided by the cutoff in the supply of foreign fats and oils in the Second World War; the consequent need to fill the domestic requirements in fats and oils stimulated an increased production of soybeans. Among other factors which brought about the rise in soybean output during the period, Goldberg includes the development of the

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[11] G. W. Kromer (1965) "Trends in U. S. Soybean Acreage and Production, 1947-65," Fats and Oils Situation, USDA, April issue.

mixed-feed industry, the high government support prices, and the government supply control operations on feed grains.[12] By the end of the war, the domestic market for soybeans was well established and instead of importing the crop upon return to world normalcy, the United States accelerated the development of the industry in order to meet the expanding local demand for soybean products. Further increases in soybean acreage and improved yields made the United States the major exporter of the crop by the 1950's.

The production location of the crop among regions in the country has undergone major shifts through the years.[13] In early 1920's the Atlantic States produced more than three-fourths of the national soybean output. The center of production moved to the Corn Belt States in the middle of the 1920's, where continued expansion during the following decade pushed the output of the region to over 90 per cent of the national production. Acreage increases during the World War II years boosted the Corn Belt output 2.5 times compared to prewar levels

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[12]Ray A. Goldberg (1952) The Soybean Industry (Minneapolis, Minnesota: University of Minnesota Press).

[13]The soybean producing regions given here are composed as follows: Atlantic States--North Carolina, South Carolina, Virginia, Maryland, and Delaware; Corn Belt States--Illinois, Iowa, Indiana, Ohio, and Missouri; Lake States--Minnesota, Wisconsin, and Michigan; Delta States--Arkansas, Mississippi, and Louisiana; Plains States--Kansas, Nebraska, North Dakota, and South Dakota.

but the largest relative rise in production among the regions was registered by the Plains States where production increased almost 40 times. Although the Corn Belt has maintained a large lead in absolute production, further expansions in other areas since World War II, especially in the Delta and Lake States, have diminished the relative share of the region in the total United States output to about 65 per cent in the 1960's. (Table 13.)

In point of value, soybeans were considered unimportant before the war; the estimated value in 1939 was only five per cent that of corn, the leading cash crop. This relative value increased to 10 per cent in 1946 and by 1963, the farm value of soybeans ranked fourth among the cash crops and amounted to $1.8 billion, or 41 per cent of the corn value for that year.

Domestic Utilization of Soybeans and Soybean Products

Although there are many uses of soybeans besides those of soybean meal and soybean oil (see Fig. 1), the bulk of the value of the beans comes from these two joint products. Over the years meal and oil have exchanged positions in their value contributions to soybeans. The share of oil in soybean value consistently exceeded that of meal up to 1947, then fell behind the latter in seven of the next ten years. Since 1957 the value of meal per

- Beans
  - Meal
    - Feed
      - Cats, dogs
      - Cattle
      - Fish
      - Fur animals
      - Pheasants, rabbits
      - Poultry
      - Sheep
      - Swine
    - Adhesive material
    - Core binder
    - Emulsifier
    - Fertilizer
    - Glue
    - Plastics
    - Food products
      - Beer brewing
      - Flakes
      - Flour
      - Grits
      - Milk
      - Sauce
      - Seasoning powder
      - Sugar
      - Wine
    - Industrial proteins
      - Artificial wool
      - Candy
      - Fire-fighting foam
      - Paper size
      - Textile dressing
      - Water paint
      - Waterproofing
      - Whipping powder
  - Oil
    - Candels
    - Caulking compounds
    - Celluloid
    - Core oil
    - Disinfectants
    - Elect. insulation
    - Enamels
    - Food products
      - Cooking oil
      - Dip coating
      - Margarine
      - Mayonnaise
      - Medicinal oil
      - Salad oil
      - Shortening
    - Fuel
    - Insecticides
    - Leather dressing
    - Lecithin
      - Candy
      - Cosmetics
      - Chocolate coating
      - Cocoa
      - Emulsifier
      - Gasoline stablizer
      - Leather tanning
      - Margarine
      - Medicines
      - Textile dyeing
      - Wood preservative
    - Lighting
    - Linoleum
    - Lubricant
    - Oilcloth
    - Paints
    - Printing inks
    - Rubber substitute
    - Synthetic resin
    - Varnish
    - Waterproofing cement
    - Waterproof goods
    - Soaps
      - Hard
      - Liquid
      - Soft
  - Immature beans
    - Canned
    - Dehydrated
    - Fresh
    - Quick frozen
    - Pickled
    - Succotash
  - Mature beans
    - Feed
      - Cattle
      - Pigeons
      - Poultry
      - Quail
      - Sheep
      - Swine
    - Flour
      - Baked products
      - Bee foods
      - Breakfast foods
      - Candy
      - Chocolate
      - Diabetic foods
      - Health foods
      - Ice cream cones
      - Ice cream powder
      - Infant foods
      - Insecticides
      - Macaroni extender
      - Milk
      - Noodle products
      - Spreads
    - Roasted
      - Beverages
      - Candied
      - Salted
    - Fermented beans
    - Sauce
    - Milk
      - Canned
      - Condensed
      - Curd
        - Canned
        - Fermented
        - Fresh
        - Smoked
      - Fermented
      - Fresh
      - Powder

Source: USDA Farmer's Bull. 2038.

FIGURE 1.--Utilization of soybeans in the United States.

bushel of soybeans has been larger than that of oil. In the 1963 marketing year, soybean meal constituted 65 per cent of the value of processed beans. (Table 7.)

Preliminary reports of the 1963 Census of Manufactures show that of the non-oil products of soybeans manufactured during that year, 97.6 per cent were of soybean cake and meal, 1.5 per cent of soy flour and grits, and the remaining 0.9 per cent of lecithin and other minor by-products.[14] Soybean meal is consumed by livestock and poultry as a high-protein supplement in feeds. The increased importance of soybean meal in the United States livestock industry is well indicated by the rise in its use from 12 per cent of all high-protein feeds fed to livestock during the 1935-39 period to more than 50 per cent in 1963. (Tables 14 and 15.) The non-oil products of soybeans for human consumption are principally soy flour and soy grits, which find their way into bakery and candy products. Lecithin, a by-product in the degumming process of soybean oil, has a number of uses, among them as baking ingredient, emulsifier and wood preservative. (Fig. 1.)

Soybean oil forms an important part of the domestic supply of edible fats and oils in the food processing

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[14] U. S. Bureau of Census, Census of Manufactures, 1963 (Preliminary reports).

industry. Before World War II it constituted only seven per cent of the edible fats and oils supply in the United States; in 1963, soybean oil represented 35 per cent. The major outlets of soybean oil for food uses are shortening, margarine and the salad and cooking oils, which absorbed more than nine-tenths of its domestic disappearance in 1963. During the 1935-39 period soybean oil was eight per cent of the total quantity of fats and oils used in the manufacture of shortening and ten per cent of that of margarine but by 1963, these percentages were 47 and 75, respectively. The non-food outlets of soybean oil include the drying oils industry, which absorbs about four per cent of the domestic disappearance, and other miscellaneous uses such as soaps, insecticides, adhesives and others. (Tables 16-19.)

A portion of the domestic disappearance of soybeans goes to seed use which accounts for some 5-6 per cent of output; a smaller fraction is fed on farms where soybeans are grown. Other miscellaneous food uses of soybeans, as beans, absorb small amounts and are part of the "residual" in official USDA data, a balancing item that also includes those amounts fed on farms other than where soybeans are produced. (Table 6.)

Processing of Soybeans

The major portion of United States soybean output is processed into meal and oil. Although the quantity of processed soybeans relative to total supply declined from 82 per cent to 62 per cent between 1946 and 1963, bean crushings actually increased 160 per cent above the initial level. During this 18-year period, a 60-pound bushel of soybeans yielded annual averages of 46 to 48 pounds of meal and 9 to 11 pounds of oil. (Tables 6 and 7.)

Until 1950 more than half of the total quantity of beans processed were reported crushed by the screw and hydraulic press methods. Processing is now largely done by the solvent extraction technique which has almost totally replaced the older methods. USDA statistics indicate that the solvent process was used for about 95 per cent of the beans crushed in 1958. With previous methods, the crude soybean oil was extracted from cooked soybeans by mechanical means; the solvent process separates the solid and liquid portions of conditioned beans by dissolving the oil component into a solvent and recovering it by vaporizing the solvent. The soybean flakes also undergo further treatment before these are processed into meal. The solvent method of processing soybeans is more effective in extracting the oil as it reduces the oil content in the meal from five per cent, the amount retained with older techniques, to only one per cent; on the other hand, the protein content of the meal is increased from 41 per cent to 44 per cent. King notes that although solvent-processed meal contains a higher percentage of protein than that yielded by mechanical process, it has less productive energy and a slightly higher fiber content.[15]

Markets for Soybeans and Soybean Products

Domestic

As mentioned earlier, the major portion of the annual soybean supply in the United States flows into the market for processed beans. Although soybean meal and soybean oil are linked by common origin and jointly supplied, these two commodities enter into essentially independent markets; the former flows into the livestock industry while the latter goes to the manufacturing industries using fats and oils.

Soybean meal forms with cottonseed, linseed, peanut and copra meals the oilseed-meal group used as feed of high protein content for livestock and poultry. Other high protein sources are grain by-products, especially wheat millfeeds, and those of animal and marine origin. The chief competitor of soybean meal in the oilseed group

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[15]Gordon A. King (1958) The Demand and Price Structure of Byproduct Feeds, USDA Technical Bulletin 1183.

is cottonseed meal. While soybeans are a direct source of soybean meal, cottonseed meal is only a by-product of the cotton industry, thereby limiting its competition to soybean meal. Rising competition has been noted from synthetic urea but its general acceptance as a substitute protein source for ruminant feeds still remains to be determined.[16]

The market demand for soybean meal as livestock feed was greatly enhanced by the development of the formula-feed industry. About 63 per cent of the total quantity of high-protein feeds consumed by livestock in the United States in 1949-50 were in the form of formula feeds; prepared feeds served as the outlet for 86 per cent of the total amount of soybean meal fed to livestock during that marketing year.[17] A recent development in the formula-feed industry that may further influence the soybean meal market in the United States is the increasing horizontal integration of the feed-mixing and bean-crushing operations.

Soybean oil, on the other hand, competes with other fats and oils mainly in the food fats and oils market. Direct competition is met with cottonseed oil for use in

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[16]USDA (1965) Feed Use of Urea in the United States (An Administrative Report).

[17]R. D. Jennings (1954) Feed Consumed by Livestock, Supply and Disposition of Feeds, 1949-50, by States, USDA Statistical Bulletin 145.

shortening and margarine; an indirect competition exists with butter and lard. Prior to the 1940's, cottonseed oil largely dominated the fats and oils needs in the manufacture of shortening and margarine but soybean oil surpassed it for shortening in 1944 and for margarine in 1951. Major use of soybean oil in margarine occurred much later than in shortening because of the tendency of the oil to flavor reversion. But developments in the further processing of soybean oil, especially in hydrogenation, were able to remedy this undesirable characteristic and made possible a wider use of soybean oil in the edible fats and oils market. Other vegetable oil competitors of soybean oil for food uses are the peanut, corn and coconut oils; however, their shares in the food fats supply are relatively small compared to that of soybean oil. (Tables 17 and 18.)

In the drying oils market, strong competition to soybean oil comes from linseed oil, the use of which has dominated in the industry. The quantity of linseed oil relative to the total quantity of fats and oils utilized for drying oil products has declined from about 71 per cent in 1946 to 45 per cent in 1963 while the relative share of soybean oil increased from seven per cent to 21 per cent during the same period. The slow-drying quality of soybean oil limits the competition it offers to linseed oil for use in the drying oils industry. (Table 19.)

Domestically, the price support operations of the government through the Commodity Credit Corporation (CCC) exert influence in the soybean market. Soybean price supports, which started in World War II, were continued after the war but since 1946 and except for the years 1957, 1958 and 1961, the season market prices of soybeans have stayed above the support level. The average percentage of the annual soybean crops under the price support program in 1946-63 was 9.7, with yearly percentages ranging from 1.9 in 1947 to 24.2 in 1958. The quantities of the crop in the program are mainly due to CCC price support loans to farmers but some arise from purchase agreements of farmers with the CCC. Many soybean producers avail themselves of the loans while awaiting favorable prices. After the loans mature, usually by the end of May each year, actual deliveries of the beans to the CCC are made. With the average annual market prices mostly above support prices, many of the soybeans placed under the loan for the period under study were redeemed before the maturity of the loan; thus actual holdings of the CCC have been generally small. The largest purchase and loan take-over by the Corporation was made in 1958, a year when the support price of soybeans exceeded the season average price. Actual deliveries to the CCC in 1958 amounted to about 83 million bushels, or 14 per cent of the soybean supply for the year. Of this holding, however, the Corporation was able to dispose 39 million bushels through normal trade channels before the end of the year.[18] (Table 10.)

Export

Output response in soybeans in the United States over the years has enabled the industry to meet not only the increasing domestic demand for crushings but also the much-enlarged demand for beans in the export market. Exports have so grown in importance as to substantially diminish the relative share of the supply which processors acquire annually. During the 1946-63 period, the average yearly exports of United States soybeans represented 19 per cent of total supply, sub-period averages being six per cent in 1946-52, 17 per cent in 1953-58 and 24 per cent in 1959-63. The major importers of United States soybeans are Japan, Canada and the Western European countries, notably West Germany, Netherlands and Italy. Soybeans from Mainland China offer competition to United States soybeans in the foreign markets, especially in Japan and Western Europe. Despite the lower prices of Chinese soybeans, however, the recurrent tight food situations reported in Mainland China and lower bean quality can set limits to the competition with the soybeans from the United States.

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[18]USDA (1960) Fats and Oils Situation, May issue.

Soybean meal exports for 1946-50 were largely military relief shipments of high-quality meal and low fat flour.[19] From small quantities averaging less than one per cent of supply in 1951-53, the commercial exportations of soybean meal started to increase in 1954 when five per cent of the supply were shipped abroad. In 1963, an estimated 1.5 million tons of soybean meal or 14 per cent of total supply were exported. (Table 14.) More than 70 per cent of the 1963 exports were sent to Western Europe where the leading importers were France, Spain, West Germany and Netherlands. The expanded livestock economy in Europe, especially the broiler production in the EEC countries, largely account for the recent increases in the export demand for meal.

The export market for soybean oil is relatively more important than that of meal since a large part of the oil leaves the country. Exports increased from about 112 million pounds, or six per cent of supply, in 1947 to a peak of 1.3 billion pounds, or 24 per cent of supply, in 1961. (Table 16.) In 1955, soybean oil joined the other domestically-produced fats and oils under the United States Public Law 480 (PL 480) program which started in 1954. Slightly more than half of the total quantity exported in 1961 were shipments through PL 480, mostly

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[19] King (1958) op. cit.

under Title I (sales for foreign currencies) of the Law. The major importing countries of United States soybean oil are led by Spain which acquired about a third of total exports in 1961; others are Pakistan, Yugoslavia and Turkey. The demand for soybean oil in foreign markets is greatly influenced by the supply of olive oil from the Mediterranean Basin and that of sunflower oil from Argentina.

The export markets of soybeans, soybean meal and soybean oil are closely tied since the meal and the oil can compete with soybeans in the world market. Importing countries with crushing facilities can import soybeans instead of oil or meal if demand and other conditions warrant. As an example, a study of the export trends of United States vegetable oils made by Thomason shows that the extent of the imports of United States soybeans by other countries during the second half of the marketing year is determined by both meal and oil requirements.[20] If the meal demand greatly exceeds oil demand after the first half of the year, soybean meal rather than bean imports are accelerated. Imports of oil, however, are determined at this part of the year by the foreign supply of oil as well as by the prospects for the succeeding crop of soybeans in the United States.

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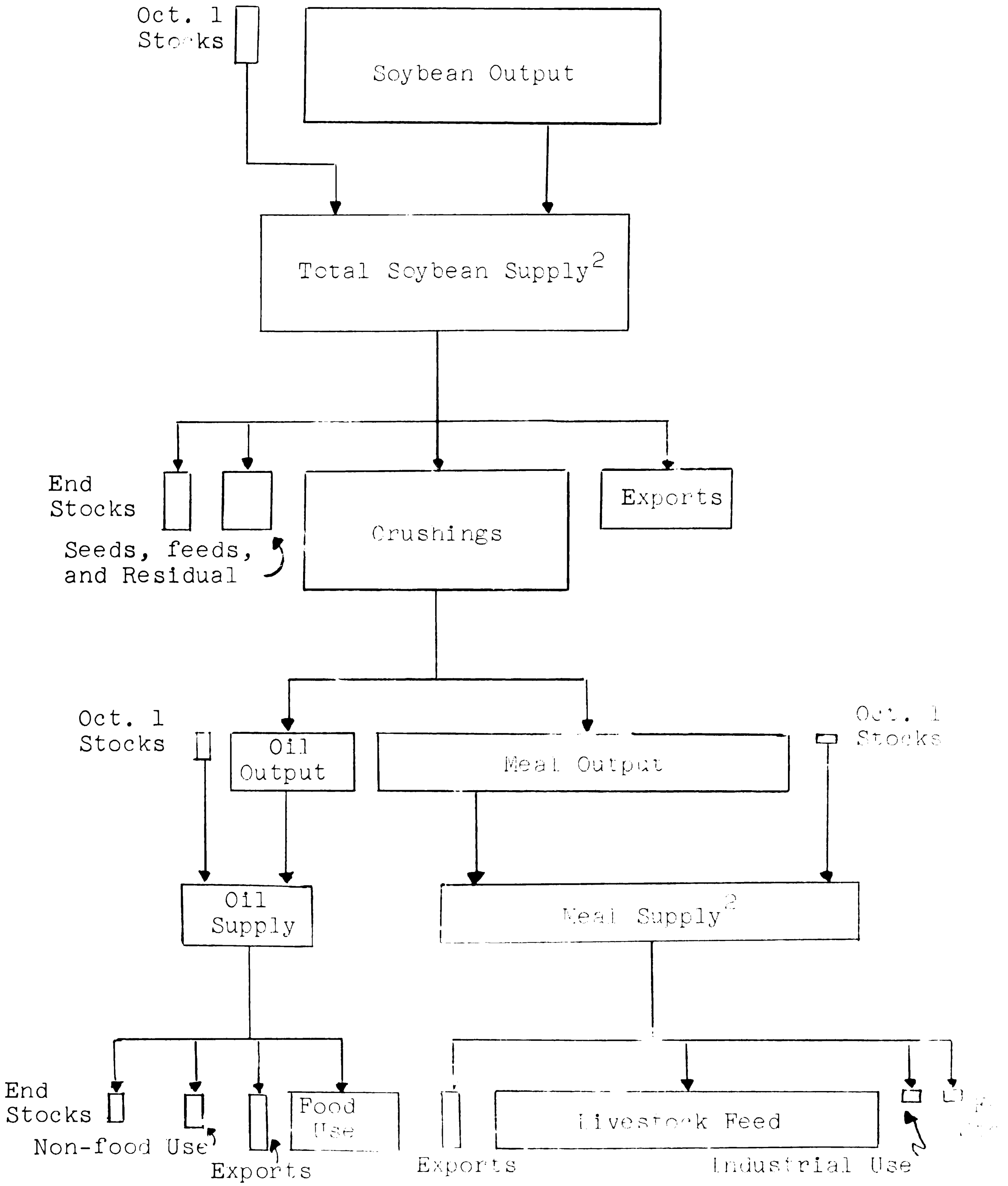
[20] Francis G. Thomason (1963) "The Changing Export Pattern for U. S. Edible Vegetable Oils," Fats and Oils Situation, USDA, May issue.

United States Soybean Supply and Disposition, 1946-63

Figure 2 shows the relative magnitudes of the different items of supply and disposition of soybeans and soybean products in the United States. The rectangles in the diagram represent the weighted averages of the reported quantities for the items during the 1946-63 period. These averages are computed from the data appearing in Tables 6, 14, and 16 of Appendix A. Since the computations are made on quantities, the portion of the diagram for soybean meal and soybean oil does not reflect the comparative values between the two commodities. For the 1946-63 period, meal and oil respectively accounted for 53 per cent and 47 per cent of the total value of soybean products. Within each major branch of the diagram, however, either weight or value comparisons can be made.

The average annual soybean supply in the United States of 12.7 million tons in 1946-63 was composed of about 0.4 million tons of October 1 stocks and 12.3 million tons of production. The different items of disposition for soybeans accounted for the following percentages: seeds, feeds and residual, seven per cent; exports, 18 per cent; quantity processed, 71 per cent and end stocks, four per cent.

October 1 stocks constitute a relatively minor portion of the total supply of soybean meal in the



[1]Based on 1946-63 averages; 1 square cm. = 1 million tons.
[2]Includes small quantities of imports in some years.

FIGURE 2.--United States supply and disposition of soybeans and soybean products, showing the relative magnitudes of the items.[1]

United States. In 1946-63, the average amount of stocks at the start of the marketing year was about 0.05 million tons; the average production each year was 7.07 million tons. Soybean meal imports during the 10 years from 1948 to 1958 averaged out to about 0.01 millionth of a ton for the 18-year period. The total annual meal supply was largely consumed by livestock, as shown by the following percentages of the different items of disposition: livestock feed, 92 per cent; exports, six per cent; industrial uses, one per cent and end stocks, one per cent.

In the case of soybean oil, significant quantities of the product are carried over from one marketing period to the next. Of the average annual supply of 1.74 million tons of soybean oil in the United States during the 1946-63 period, 0.14 million tons were stocks as of the start of the marketing year; production per year contributed 1.60 million tons. The relative quantities of the different items of disposition are as follows: food use, 65 per cent; non-food use, nine per cent; exports, 16 per cent and end stocks, 10 per cent. (The percentages for food and non-food uses are based on a relative breakdown of computed domestic disappearance. Starting in 1957, factory consumption reports have consistently exceeded the computed disappearance figures.)

CHAPTER III

REVIEW OF LITERATURE

Price analysis work on soybeans and soybean products has been largely approached with correlation and multiple regression techniques; a few investigations employing other methods have, however, appeared in recent years. The following reviews represent some of the statistical investigations made on these commodities, either singly or as a group, and are here presented in chronological order.

In a study made in 1949, Paarlberg found that the effect of the price level was the standout factor influencing the prices of soybeans, soybean meal and soybean oil during the 1931-41 period.[21] Among the factors used in the correlation analysis were the prices of other fats and oils, livestock products, corn and bran, the non-agricultural income, the supplies of soybeans and soybean products and the general price level. Specific results of the investigation indicated that the general price level and the annual prices of soybean meal and

[21]Don Paarlberg (1949) Prices of Soybeans and Soybean Products, Purdue University Agricultural Experiment Station Bulletin 538.

soybean oil, taken together, accounted for more than 80 per cent of the variations in soybean price. No close relation was found with the measures of production and supply. General price level, bran price and soybean meal production explained 86 per cent of the price variations of soybean meal. In the case of the price of soybean oil, the closest relationship was found with the general price level while considerable effects were also shown by soybean output and the price of cottonseed oil; these three factors in combination explained 90 per cent of the price variations of soybean oil.

Another empirical study on the factors affecting the prices of soybeans and soybean products was conducted by Jordan in 1951, with data covering the 1936-49 period with the exclusion of the World War II years.[22] The composite price of all protein supplements was related to factors influencing the price of soybean meal and the composite price of all edible fats and oils was related to factors affecting the price of soybean oil. The method was devised to avoid an otherwise complicated analysis arising from the existence of many substitutes for both of the commodities.

The annual composite price of protein supplements, weighted by protein content, was related with disposable

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[22] G. L. Jordan (1951) _What Determines Soybean Prices?_ University of Illinois Agricultural Experiment Station Bulletin 546.

income, corn production and supplement production. The estimated relationship accounted for more than 97 per cent of the variations in the logarithm of the composite price. Ninety-five per cent of the year-to-year fluctuations in the logarithm of the composite price of edible fats and oils were accounted for by disposable income and the supply of fats and oils. In order to relate soybean prices with the prices of soybean products, the prices of meal and oil were determined by considering their relative contributions to the respective group outputs. The marketing and processing margin function that was formulated contained the value of soybean products and trend as variables and yielded estimates that were in close agreement with the actual margins for the years studied. Jordan noted, however, that because of the dynamic nature of the development of the industry in the period covered by the analysis, a frequent review of the factors affecting margins would be necessary.

Empirical work on the demand and price structure for food fats and oils was done by Armore at the USDA in 1953.[23] The study placed major emphasis on cottonseed oil and treated soybean oil just as a competitor among others; although gaining importance then, soybean oil was yet considered a relative newcomer in the fats and oils

[23] Sidney Armore (1953) The Demand and Price Structure for Food Fats and Oils, USDA Technical Bulletin 1068.

industry. The period of analysis covered the years from 1922 to the early 1950's but the relationships involving soybean oil as an individual competitor used data starting with 1935. Relationships among the factors were investigated by the use of multiple correlation and regression, mostly in terms of the logarithms of the observed data. In an analysis of the factors affecting the prices of food fats and oils other than butter and lard, the per capita supply of fats and oils (other than butter and lard) used in food products, and personal disposable income, explained 92 per cent of the variations in price.

A study of the demand and price structure for by-product feeds conducted at the USDA by King in 1958 included an individual analysis for soybean meal.[24] Two sets of data were employed, one for the period 1921-41 and another for 1921-54 with the exclusion of the war years. Although the major part of the analysis was on the demand relationships between high-protein feeds, as a group, and feed grains, the coefficients for individual by-product feeds were also determined. A partially recursive approach was used. A separate estimating function for determining the annual quantity of feed grains placed under the government support program, a variable

[24]King (1958) op. cit.

considered as endogenous in the analysis, was included. Estimates from this relation were subsequently applied in the demand functions for high-protein feeds and feed grains; these functions were then changed to reduced forms and estimated by least squares procedures. The statistical analysis on individual by-product feeds involved a modification of the relations above by a breakdown of the demand function for high-protein feeds into two equations, one for the particular high-protein feed under consideration and another for other protein feeds taken collectively. Thus, the set of relationships in the analysis for an individual by-product feed contained one more equation than that for high-protein feeds as a whole but a common technique was employed for both analyses.

In general terms, the demand quantities for high-protein feeds and feed grains were each expressed as a function of the price of high-protein feeds, the price of feed grains, the price of livestock and livestock products and the number of animal units. In the individual by-product feeds portion of the study, the set of equations for soybean meal included prices and quantities of soybean meal and of other high-protein feeds, in line with the modification mentioned in the preceding paragraph. Among some of the results of the investigation were: (a) the difference between the elasticities of demand for high-protein feeds for the two periods studied was not significant, (b) high-protein feeds and feed grains appeared strongly competitive, on the average, and (c) a certain independence in demand for the different oilseed meals was indicated, reflecting differences in their physical characteristics and relative values in livestock rations.

Another USDA study in 1959 showed that for the period 1946-57, three factors which largely influenced soybean meal prices were the total supply of soybean meal, the prices farmers received for livestock and livestock products, and the production of formula feeds.[25] In combination, these factors explained 87 per cent of the price variations of soybean meal. Other factors which were tried in this multiple correlation study were the quantity of soybean meal fed to livestock, the supply of other high proteins, other high proteins fed to livestock and the number of high-protein-consuming animal units. But these factors were considered to have explained relatively smaller proportions of the variations in soybean meal price during the period of analysis.

Hieronymus made an analysis of soybean meal prices for forecasting purposes in 1961 with data for the period

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[25]USDA (1959) "Factors Influencing Soybean Meal Prices," Feed Situation, July issue.

1947-58.[26] Using logarithms, about 100 different combinations of some fifteen explanatory variables were tested for their ability to account for variations in the undeflated price of soybean meal. The two functional relations yielding the best results both include soybean meal supply, animal numbers and livestock prices. These equations differed only in the nature of the supply variable employed, with supply in one representing the total soybean meal production and that in the other excluding exports. The former accounted for 86 per cent of meal price variations for the years studied while the latter accounted for 84 per cent.

Two features of the animal number series are worth noting: (1) the series was constructed specific to the consumption of soybean meal alone and thus differs from the USDA series on high-protein consuming animal units which involves the eleven high-protein feeds, and (2) a trend value representing the difference between the uptrend in the consumption of soybean meal and the downtrend in meal price during the period was incorporated as an adjuster to the computed animal number series.

Perhaps the first attempt to interrelate the prices of soybeans and soybean products in an analysis employing

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[26]T. A. Hieronymus (1961) "Forecasting Soybean Meal Futures Prices," Commodity Yearbook, Commodity Research Bureau, Inc., New York.

simultaneous equations techniques was an investigation by Houck in 1963.[27] It will be recalled that an early effort to do the same with the use of "composite" prices was made by Jordan in 1951, a study reviewed earlier in this chapter. Viewing the pricing of soybeans and soybean products as an interrelated simultaneous process, Houck developed an eight-equation model in studying the demand and price relationships in the United States soybean market. The analysis employed data for the marketing period 1946-60 and took account of market outlets via exports and government storage programs. Five of the eight equations were stochastic. They pertained to (a) soybean meal demand, (b) soybean oil demand, (c) crushing and handling margin, (d) export demand for soybeans, and (e) storage demand for soybeans; the remaining equations were identities involving relations between the farm-level price of soybeans, the value of soybean products, meal and oil prices, and the soybean supply.

In arriving at parameter estimates from the model, two-stage least squares procedures were employed; the reduced-form equations were also estimated by ordinary least squares for comparative purposes. Satisfactory results in parameter estimation and good statistical

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[27]Houck (1963) op. cit.

fits were obtained with the procedures employed. Although the investigation attained relative success in the empirical estimation of parameters, Houck pointed out the lack of clear a priori grounds on which to base the theoretical and statistical analyses made. Headway was gained, however, in treating the pricing of soybeans and soybean products as an integrated process.

Using the same set of data and procedures, Houck later followed up his earlier investigation by reformulating the original model to six equations.[28] The commercial storage demand for soybeans was considered as completely inelastic with respect to the soybean price for the current year thus eliminating one stochastic equation; also, two of the identities in the previous model were combined into one. With the modified set of equations, the estimated coefficients obtained differed but slightly from the earlier results. Houck found that the estimated relationship for soybean oil was weakest in the model which he attributed to the strictly linear relation employed and to the complexity of the fats and oils pricing mechanism.

Nakamura et al. undertook a study in 1963 which analyzed the soybean sector of the United States economy

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[28]James P. Houck (1964) "A Statistical Model of Demand for Soybeans," Journal of Farm Economics, Vol. 46, No. 2.

within the framework of spatial equilibrium analysis.[29] Major concern in the investigation rested on the optimum geographical flows and equilibrium price differentials for soybeans and soybean products which are the main objectives of this type of analysis. The generation of an aggregate demand function that used oilseed meal consumption, soybean meal price, price of livestock and livestock products, and time as variables was merely incidental in the study, being used only as a means to estimate regional demands for soybean meal.

Many other phases of economic investigation of soybeans and soybean products have been made; these include, among others, the transportation economics of the industry, the structure of the industry as a whole, and the structure of the export market in particular.[30]

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[29]H. Nakamura, T. A. Hieronymus and G. C. Judge (1963) Interregional Analyses of the Soybean Sector, University of Illinois Department of Agricultural Economics, AERR-67.

[30]Earl C. Hedlund (1952) Transportation Economics of the Soybean Processing Industry (Urbana, Illinois: University of Illinois Press); Goldberg (1952) op. cit.; Eric Berg (1960) Structure of the Soybean Oil Export Market, University of Illinois Department of Agricultural Economics, AERR-30.

CHAPTER IV

THE MODEL

The model of the United States domestic soybean market presented in this study is a simplified one, both from the economic and statistical viewpoints. Economic relations are formulated by using a generalized version of the market for soybeans and soybean products in the United States (see Fig. 2, p. 27) and a number of simplifying assumptions. These assumptions are necessary in order to reduce the complex and interrelated markets for soybeans, soybean meal and soybean oil into a relatively convenient analytical form. The choice of the variables which enter in the market relations is based on *a priori* considerations from economic theory and upon studies by previous investigators. Preliminary computer runs also enabled limiting the number of explanatory variables in each of the relationships. Statistically, the functional relations are interlinked into a simple causal chain for each marketing year and do not follow the fully recursive system where the functions also interlink from one observation period to the next.[31]

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[31]As an example, see R. J. Crom and W. R. Maki (1965) "A Dynamic Model of a Simulated Livestock-Meat Economy," *Agricultural Economics Research*, Economic Research Service, USDA, Vol. 17, No. 3.

In a strict sense, the functions of the model form a set of simultaneous relationships and would thus call for the use of simultaneous-equations techniques; however, they are formulated such that one equation generates estimates for an endogenous variable which appears as an explanatory variable in another equation. This permits a uni-equational approach to each relationship and makes the ordinary least squares procedure applicable to the whole model.

Following the identification of all the variables, the economic and statistical aspects of the model are presented. The distinction between these two aspects is not clearcut and certain areas of discussion may overlap; nevertheless, the separate treatments are made in the hope that a clearer presentation of the model can be achieved.

Variables Employed

The model makes use of four endogenous and 12 predetermined variables; these are identified below with the symbols that are used later. All of the variables refer to the marketing year beginning October 1 and ending September 30.

Endogenous Variables

The following are treated as endogenous variables in the four relationships of the model:

Q_{BC} = total quantity of soybeans processed in the United States for meal and oil, thousand tons.

P_M = average price of soybean meal, bulk Decatur, quoted at 41 per cent protein up to June 1950 and at 44 per cent protein thereafter, deflated by the U. S. Bureau of Labor Statistics Wholesale Price Index, dollars per ton.

P_O = average price of domestic crude soybean oil, tank cars, Midwestern Mills, deflated by the U. S. Bureau of Labor Statistics Wholesale Price Index, dollars per ton.

P_B = average price received by United States farmers for soybeans, deflated by the U. S. Bureau of Labor Statistics Wholesale Price Index, dollars per ton.

Predetermined Variables

The predetermined variables in the model consist of exogenous variables and of endogenous variables whose lagged values are used in the different relationships. These are:

S_B = total supply of soybeans in the United States, equal to the sum of production and October 1 stocks, thousand tons.

P_{VO} = index of wholesale prices for all vegetable oils of domestic origin, 1947-49 = 100.

Q_{FB} = foreign output of soybeans, thousand tons.

V_{SP} = average value of soybean products derived from a bushel of soybeans crushed, deflated by the U. S. Bureau of Labor Statistics Wholesale Price Index, dollars.

R_P = ratio of the government support rate for soybeans to the average price received by United States farmers for the crop in October.

P_L = index of prices received by United States farmers for livestock and livestock products, 1947-49 = 100.

Q_{FG} = domestic disappearance of the four major feed grains in the United States, in terms of corn equivalents, million tons.

Q_{FF} = production of formula feeds in the United States, million tons.

Q_{VO} = domestic disappearance of vegetable oils other than soybean oil in the United States, million pounds.

Q_{BT} = domestic disappearance of butter (actual weight) in the United States, million pounds.

Q_{LD} = domestic disappearance of lard in the United States, million pounds.

T = linear trend, 1946 = 1, ..., 1963 = 18.

Notes on Some of the Variables

The sources of data for the variables in the model were mentioned in the first chapter but a few brief explanations of some of them would be helpful.

1. All of the price indexes, including the index of wholesale prices for all commodities that serves as a deflator for the price and value observations, are on the January 1947 to December 1949 base. These indexes are averages for the twelve months starting in October of each year, in conformity with the observation period used in the study.

2. Based upon the preliminary computations for the different functions, the observed values of some of the variables are converted to units different from those published. This is done in order to have as many significant figures as possible for the resulting estimated coefficients. The results are reported in the units cited in the preceding page.

3. The quantities of feed grains are expressed in terms of corn equivalents, computed with the use of the following conversion factors:[32] corn, 1.00; oats, 0.90; barley, 0.90 and sorghum grain, 0.95.

4. Vegetable oils other than soybean oil include cottonseed, linseed, corn, coconut, peanut and olive oils.

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[32]From Ralph D. Jennings (1958) Consumption of Feed by Livestock, 1909-56, USDA Production Research Report No. 21.

5. Estimates of formula-feed production are approximations from a series of calendar year data of the Bureau of Census for 1962-64 and backward projections for 1946-61 based on percentage changes published by the American Feed Manufacturers Association.[33] Marketing year outputs are derived by adding 25 per cent of the production in one calendar year to 75 per cent of that of the succeeding calendar year.

The Economic Model

Functional Relationships

The four causal relationships constituting the model are presented below with the use of the symbols for the variables given earlier; secondary subscripts t and t-1 indicate values for the current and previous marketing years, respectively. Following the notation of Foote, a colon separates the endogenous variable(s) from the predetermined variables in each of the relations.[34]

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[33] U. S. Bureau of Census (1965) Poultry and Livestock Feed Production, M20E (1964); American Feed Manufacturers Association, AFMA Bulletin, November 24, 1965 and Feedstuffs, a weekly publication of the Miller Publishing Company, Minneapolis; February 1950.

[34] Foote (1958) op. cit.

1. Quantity of soybeans processed each year

Q_{BC_t} : S_{B_t} , $V_{SP_{t-1}}$, $P_{VO_{t-1}}$, $Q_{FB_{t-1}}$, R_{P_t}

2. Average price of soybean meal each year

P_{M_t}, Q_{BC_t} : $P_{L_{t-1}}$, Q_{FF_t}, Q_{FG_t}, $Q_{FB_{t-1}}$

3. Average price of soybean oil each year

P_{O_t}, Q_{BC_t} : Q_{VO_t}, Q_{BT_t}, Q_{LD_t}, $Q_{FB_{t-1}}$

4. Average farm-level price of soybeans each year

P_{B_t}, Q_{BC_t}, P_{M_t}, P_{O_t} : T_t

Assumptions

In the formulation of these relationships, some simplifying assumptions are made. These assumptions abstract from reality but are necessary if actually-observed economic data are to be employed for theoretical analysis.

1. Domestic soybeans and their joint products of soybean meal and soybean oil are assumed to be homogeneous commodities. This assumption is probably needed more for whole soybeans and soybean meal than for soybean oil. The American Soybean Association lists at least 28 leading commercial varieties of soybeans in the United States, yielding beans of different color classes which, together with other physical characteristics of the

product, set standard grades in trade.[35] Soybean meal is similarly governed by standard specifications. Rules governing the purchase and sale of soybean meal in the United States specify the protein, fat and fiber contents for the three classes of meal in the market. As previously mentioned, older methods of crushing soybeans yield meal of 41 per cent protein and modern techniques have reduced the oil content in the meal to result in 44 per cent protein; with a further reduction in the fiber content, meal of 50 per cent protein can now be obtained. In the case of crude soybean oil, the trade only requires the customary cleaning of the oil produced from any of the crushing methods employed.[36]

2. It is assumed that the private sector of the United States domestic soybean market is a single market composed of a large number of buyers and sellers who are adequately informed of prices and quantities, with no single buyer or seller large enough to affect prices. The assumption is not unrealistic considering the vast and efficient transportation network in the United States and an active futures market existing for soybeans and soybean products in the country. However, despite the characteristic of large numbers which appears to describe

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[35]American Soybean Association, Soybean Blue Book, an annual publication; Hudson, Iowa.

[36]Ibid.

the market, the conditional clause of the assumption may be violated. There are individuals in the United States soybean market who can be in positions to affect the prices of soybeans and soybean products because of their size; these are the large soybean processors, the major manufacturers of fats and oils products and the big formula-feed concerns. Trends in the soybean processing industry appear to indicate a decline in the number but increases in the size of crushing mills.[37] Furthermore, some of the large processors have started to integrate the processing of soybeans and the mixing of formula feeds. The significant sizes which some processors of soybeans and soybean products have reached can give them some market influence on these commodities.

3. It is also assumed that the seasonal pattern in the annual marketing of soybeans and soybean products occurs uniformly over the years and that transportation and other service costs of these products are constant over time. Since the analysis employs data which cover the whole marketing year and the whole country, some abstractions are made regarding time and space. Price changes resulting from differences in seasonal patterns through the years are ignored. Paarlberg found little

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[37]George W. Kromer (1964) "U. S. Soybean Processing Capacity Continues to Expand," Fats and Oils Situation, USDA, November issue.

seasonality in the prices of soybean products but a distinct seasonal concentration in the sales of soybeans.[38] As in many other United States crops, soybean prices move from a harvest low during the fall months to a pre-harvest high in the late spring and summer months. Price changes caused by changes in transportation and other service costs over the period of study are likewise ignored. Unchanged transportation and other service costs over time would mean that for each of these commodities, there exists a fixed price surface which rises and falls as a whole over the years.

4. The stocks of soybeans, soybean meal and soybean oil at the turn of the marketing year are assumed to be results of the normal end inventories in these products and not due to deliberate actions in anticipation of the sizes of succeeding crops or other bases of speculation. For the period covered by the study, the average quantities of end stocks of soybeans, soybean meal and soybean oil relative to their supplies are three per cent, one per cent and eight per cent, respectively (see also Fig. 2). Except for three years, the end stocks of soybeans in 1946-63 ranged from 0.5 per cent to 3.5 per cent of total supply; in 1957, 1958 and 1961, these percentages rose to 4.3, 10.3

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[38]Paarlberg (1949) op. cit.

and 8.4, in that order, with the bulk of the stocks in the hands of the CCC.

In the case of soybean meal, the assumption is not unrealistic since the quantities carried over from one marketing year to the next were very small and can be considered to have little effect in influencing prices; those for soybean oil, however, averaged about 9.5 per cent of the total supply in 1946-63. The wide difference between the relative amounts of carryover stocks of soybean meal and soybean oil may be traceable to the nature of the commodity in regard to storability, a factor which lends soybean oil to speculative purposes. This is borne out by the previously-cited study by Thomason (1963) on the pattern of United States soybean oil exports, showing that the quantities shipped abroad during the second half of the marketing year are influenced by the oncoming harvest crop of soybeans.

5. It is finally assumed that in the processing of soybeans, meal and oil are derived in relatively fixed proportions. The assumption of constant yields of soybean meal and soybean oil appears to be reasonable since the actual yields of these joint products have varied within narrow ranges over the years. As indicated by USDA data for 1946-1963, the reported average yields in soybean processing ranged from 46.2

to 48.1 pounds of soybean meal and from 9.0 to 11.1 pounds of soybean oil per bushel of soybeans.

Rationale of the Model

The framework of the economic model may be briefly stated as follows: If the amount of soybeans crushed in each marketing year can be estimated well enough without involving their price in the process, the subsequent estimates of the output quantities of their joint products, assuming constant yields, can lead to estimates of meal and oil prices. These prices, in addition to the quantity of soybeans processed, constitute the major determinants of the price of soybeans during the period.

Quantity of soybeans processed each year.--Like other basic commodities which give rise to joint products, soybeans for processing possess a derived demand. Such demand depends upon the demands for soybean meal and soybean oil, which in turn are dependent upon those of the end uses of these commodities in their separate markets. Soybean processors are interested in the margin they can realize from their operations as determined by the price of the basic commodity and the prices at which meal and oil would sell, taking into consideration the various service costs attendant to crushing activities. If processing were the only significant outlet for a given fixed supply of soybeans, and assuming that no institutional barriers exist, then processing demand would be the only active determinant of soybean prices. Consequently, only the supply of soybeans and the components of processing demand would be necessary in explaining the quantity of beans which are crushed each year. However, although the bulk of soybeans in the United States goes into processing, other bean outlets have been getting larger over time; the export market is rapidly expanding and, as a result of the price support activities of the government, the end stocks of soybeans have swelled to significant amounts in certain years. The annual amounts accounted for by seeds, whole-bean feeds and the residual are relatively constant so that their combined effect on soybean prices can be ignored. Considering that soybean supply for the year is a passive determinant, the price of soybeans is determined largely by the processing demand for beans and partly by the two outlets mentioned above.

The first relationship of the model fits in the overall framework primarily as a predictive function; it estimates the quantity of soybeans crushed during a given marketing year with the use of variables whose values are essentially known at the start of the year and, thus, are not in turn affected by the estimate itself. With the condition that soybean price is not used as an explanatory variable in the relationship, the quantity of soybeans processed during the year is taken to depend on the total supply of the beans, on factors which directly affect the processing demand and on indications of the influences of exports and end stocks. The value of soybean products obtained from a bushel of soybeans processed during the previous marketing year represents a measure of the combined demand for soybean meal and soybean oil. Because of the time lag between the decision to process a given quantity of soybeans and the sale of the joint products obtained therefrom, it is assumed that processors use a projection of the average prices of soybean products during the previous year rather than the immediate prices prevailing at the time the processing decisions are made. Soybean purchases by processors are largely concentrated during the early part of the marketing year.

In the hope that a variable representing the whole of one of the markets of the joint products will help attain estimates of the quantity of beans crushed each year which are close to the observed data, the price of all vegetable oils during the previous marketing year is also included in the relationship. The inclusion of both the prices of all vegetable oils and of all high-protein feeds, along with the value of soybean products, as explanatory variables may overly represent soybean meal prices in the relationship. As formulated, the effect of combined changes in the prices of soybean meal and soybean oil on the quantity of soybeans processed is obtained by allowing the value of soybean products to vary while the other variables are held constant. The result implicitly reflects the effect of changes in the price of all high-protein feeds since soybean meal prices dominate the high-protein feed price index. The same cannot be said for all vegetable oils since this group includes major non-food industrial uses where soybean oil is not dominant.

The influence of the export market for United States soybeans is considered by the inclusion of soybean output abroad during the previous year as an independent variable. While foreign output of soybeans for the current year would be the ideal indicator, it is not available at the beginning of the marketing year as a predictor variable thus preventing its use in the model. The relationship can only assume a lagged effect of foreign supply on soybean crushings every year. For an indication of the influence of the price-support operations of the government on soybeans, especially during the years when significant quantities held over to the succeeding period were government-owned, the relationship uses a ratio of the support rate to the average price received by United States farmers for soybeans during the initial month of the marketing year.

It is reasonable to expect that lower ratios (resulting from high market prices relative to the support rate) would tend to increase the direct flow of soybeans from producers to processors. Higher ratios are likely to be associated with significant quantities of end stocks owned by the CCC and thus, serve as indicators of increases in soybean demand for this outlet.

Average prices of soybean meal and soybean oil each year.--On the assumption that a constant technological relationship exists in the processing of beans for the production of meal and oil, estimates of the respective quantities produced of these joint products can be obtained from an estimate of the quantity of soybeans processed during the marketing year. Thus, the price-generating functions for soybean meal and soybean oil make use of the common estimate of the quantity of beans crushed during the year as a major determinant. Other explanatory variables for the two relations depend upon the separate markets of meal and oil. Also common to both relationships is the foreign output of soybeans in the previous year which, as in the quantity relationship, serves as an indication of the influence that the export markets of these commodities may exert on their prices.

The price-estimating function of soybean meal includes the prices of livestock and livestock products during the previous marketing year, the production of formula feeds and the domestic disappearance of feed grains as other explanatory variables. Hieronymus cites two reasons for the importance of livestock prices to soybean meal prices: firstly, livestock prices move in sympathy with the general price level, and secondly, producers of livestock change feeding practices according to changes in the prices of livestock.[39] His analysis, like those of King (1958) and Houck (1963 and 1964), treated current livestock prices as a predetermined variable. However, changes in feeding practices are likewise determined by feed prices, which can affect the supply of livestock products and, consequently, livestock prices. Because of the possible joint effects of feed and livestock prices, the model uses instead the prices of livestock and livestock products during the previous marketing year as an independent variable and assumes that livestock prices exert lagged effects on the price of soybean meal.

A high proportion of soybean meal production in the United States is consumed by livestock in the form of formula feed; as noted before, about 86 per cent of the soybean meal output in the country in the 1949-50 marketing year was absorbed by the mixed-feed industry.

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[39]Hieronymus (1961) op. cit.

As such, formula-feed manufacture is a direct demand for soybean meal. Employed by the USDA (1959) study and by Houck as an explanatory variable for soybean meal prices, formula-feed production supplants the use of the number of protein-consuming animal units included by King and, in a modified form, by Hieronymus (1961). Formula-feed production may be a better indicator of the trend in the demand of soybean meal by the livestock industry, as it reflects not only the changes in animal numbers but also that in the feeding rate per animal unit.

Also included as a price-affecting variable in the soybean meal relationship is the domestic disappearance of feed grains, a production input which constitutes the greater component of the total amount of concentrates consumed by livestock in the United States. Based on USDA data, about 152 million tons of corn equivalents consisting of the four major feed grains in the country, compared to about 16 million tons of soybean equivalents of high-protein feeds, were consumed by United States livestock in 1963. As a major determinant of the level of livestock production, the amount of feed grains fed to livestock exerts influence on soybean meal prices. The general price level, which was found to influence the price of soybean meal greatly in the analysis made by Paarlberg

(1949), is incorporated in the model through the use of deflated prices.

In the case of soybean oil, the independent variables which enter the price relationship include the quantities of the direct and indirect substitutes that are utilized during the year. The relationship is similar to that employed by Houck but with certain modifications. The effects of butter and lard are separated, the income variable is excluded and an indicator of the export market has been included in place of the export function in Houck's set of simultaneous relations. Besides the quantity of oils, income was also employed as a variable in the analyses of fats and oils made by Jordan (1951) and Armore (1953). Computations on intermediate forms of the relationship in this study included income as an explanatory variable but it was later omitted since its effects were negligible.

Vegetable oils other than soybean oil represent the directly-competitive products in the output of shortening, margarine, cooking oils, salad dressings and the drying oil products. Paarlberg included the effect of cottonseed oil, in particular, for his study but since the time his analysis was undertaken, cottonseed oil has relatively declined in importance as a distinctly significant substitute to soybean oil. Thus, as in Houck's model, cottonseed oil is included in the other-vegetable-oils group. Soybean oil is indirectly competitive to butter and lard through margarine and shortening, respectively. The effects of these indirect competitors on soybean oil prices are likely to depend upon the relative strengths of the direct competition offered by butter and lard to the margarine and shortening uses of soybean oil.

Average farm-level price of soybeans each year.--As major determinants of the price which United States farmers receive for soybeans during the marketing year, the last functional relationship of the model includes the quantity of soybeans processed during the period and the current prices of meal and oil. Estimates of these variables are provided by the three previous relationships.

The soybean-price function is patterned after that of Paarlberg's study, which used the general price level and the prices of meal and oil as explanatory variables, except that the quantity of soybeans and time have also been included. As in the case of the meal and oil relationships in the model, the general price level is taken into account by deflating the price variables by the wholesale price index for all commodities. Being the joint result of soybean supply and the processing demand for soybeans, the quantity of soybeans crushed each year bears a definite relation to soybean price. A linear trend variable has also been employed in the relationship as the best available measure for other sources of systematic variation which cannot be directly observed but which exert influence on soybean prices. Among others, these would include the possible effects of technology changes in the soybean industry, both in the processing and marketing of soybeans and soybean products; over time, crushing methods have relatively improved and the marketing margin[40] appears to have narrowed.

In relating the price of soybeans to those of meal and oil, Houck (1963) employed the price spread approximation as an identity, thus ignoring the time lags in processing activities. The annual price of soybeans and the quantity of soybeans crushed during the marketing year are not directly related in Houck's model, although such relationship is implied through a margin function. If the estimating equation for the price of soybeans were derived from this implied relationship, the resulting explanatory variables would be identical

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[40]Paarlberg (1949) op. cit. The marketing margin, usually expressed in dollars per bushel, represents the spread between the combined value of soybean products, with processing yields and current prices of meal and oil as bases, and the price which farmers receive for soybeans; it includes the costs of processing, freight, storage, risk, merchandizing and other services. The method of computation is only an approximation on account of the lag between the sale of the beans and the sale of the joint products obtained.

to those of the soybean price relation in the present model.[41] However, coefficients are imposed on the meal and oil price variables in their relationship with the price of soybeans (see equation 3, footnote 41).

It is probably more realistic to assume that the prices of soybean meal and soybean oil are functionally related to soybean price without specific coefficients. Therefore, no such restriction occurs in the soybean price relationship of this recursive model. Any coefficient restriction arising from the assumption of constant yields of the joint products can be imposed in

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[41] James P. Houck (1963) op. cit., p. 26. Expressing the concerned relationships of Houck's model in terms of the symbols for the variables that are employed in this study and writing the estimated form of his margin function, we have

(1) $P_B = 0.478P_M + 0.104P_O - M$ from 6.1 and 7.1

(2) $\hat{M} = \hat{b}_o + \hat{b}_1 Q_{BC} + \hat{b}_2 T$ " 3.1

An estimating function for soybean price can be derived from these equations by substituting the estimate in equation (2) for the margin, M, in equation (1). Thus,

$$(3)\ \hat{P}_B = 0.478P_M + 0.104P_O - \hat{M}$$

$$= 0.478P_M + 0.104P_O - \hat{b}_o - \hat{b}_1 Q_{BC} - \hat{b}_2 T$$

deriving the approximate margin function.[42] But to consider the soybean price equation as stochastic in Houck's model would complicate his set of simultaneous relationships. A strong reason for Houck's formulation of the marketing margin equation should be pointed out. By excluding the quantity of beans processed as an explanatory variable, the problem of multicollinearity is avoided. Multicollinearity arises when the explanatory variables are highly correlated with one another, as is the case when the quantity of soybeans and the prices of the joint products are used together. This is a possible weakness of the last relationship in this recursive model.

The Statistical Model

Equations

The economic relationships given in the previous section are shown below in specific functional forms including their statistical components. Statistically,

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[42] If the soybean price relationship were

$$\hat{P}_B = \hat{b}_o + \hat{b}_{21}Q_{BC} + \hat{b}_{22}P_M + \hat{b}_{23}P_O + \hat{b}_{24}T$$

a slight manipulation of the equation will give

$$\hat{P}_B = 0.478P_M + 0.104P_O + \hat{b}_o + \hat{b}_{21}Q_{BC} + (\hat{b}_{22} - 0.478)P_M + (\hat{b}_{23} - 0.104)P_O + \hat{b}_{24}T$$

A comparison of this last equation with equation (1) in footnote 41 will indicate an approximate margin function of

$$\hat{M} = -\left[\hat{b}_o + \hat{b}_{21}Q_{BC} + (\hat{b}_{22} - 0.478)P_M + (\hat{b}_{23} - 0.104)P_O + \hat{b}_{24}T\right]$$

the general model in this study breaks up into two sub-models, one for each of the assumed algebraic forms of the relationship between the variables. In the following equations, the same set of symbols for the variables are employed; the b's and d's are the structural coefficients of the variables, except b_{i0} and d_{i0} which are constants, and the u's and v's are disturbances.

Sub-model I

$$Q_{BC_t} = b_{10} + b_{11}S_{B_t} + b_{12}V_{SP_{t-1}} + b_{13}P_{VO_{t-1}} + b_{14}Q_{FB_{t-1}} + b_{15}R_{P_t} + u_{1_t}$$

$$P_{M_t} = b_{20} + b_{21}\hat{Q}_{BC_t} + b_{22}P_{L_{t-1}} + b_{23}Q_{FF_t} + b_{24}Q_{FG_t} + b_{25}Q_{FB_{t-1}} + u_{2_t}$$

$$P_{O_t} = b_{30} + b_{31}\hat{Q}_{BC_t} + b_{32}Q_{VO_t} + b_{33}Q_{BT_t} + b_{34}Q_{LD_t} + b_{35}Q_{FB_{t-1}} + u_{3_t}$$

$$P_{B_t} = b_{40} + b_{41}\hat{Q}_{BC_t} + b_{42}\hat{P}_{M_t} + b_{43}\hat{P}_{O_t} + b_{44}T_t + u_{4_t}$$

Sub-model II

$$\text{Log } Q_{BC_t} = d_{10} + d_{11}\log S_{B_t} + d_{12}\log V_{SP_{t-1}} + d_{13}\log P_{VO_{t-1}} + d_{14}\log Q_{FB_{t-1}} + d_{15}\log R_{P_t} + v_{1_t}$$

$$\text{Log } P_{M_t} = d_{20} + d_{21}\log \hat{Q}_{BC_t} + d_{22}\log P_{L_{t-1}} + d_{23}\log Q_{FF_t} + d_{24}\log Q_{FG_t} + d_{25}\log Q_{FB_{t-1}} + v_{2_t}$$

$$\text{Log } P_{O_t} = d_{30} + d_{31}\log \hat{Q}_{BC_t} + d_{32}\log Q_{VO_t} + d_{33}\log Q_{BT_t} + d_{34}\log Q_{LD_t} + d_{35}\log Q_{FB_{t-1}} + v_{3_t}$$

$$\text{Log } P_{B_t} = d_{40} + d_{41}\log \hat{Q}_{BC_t} + d_{42}\log \hat{P}_{M_t} + d_{43}\log \hat{P}_{O_t} + d_{44}\log T_t + v_{4_t}$$

Assumptions

In addition to the assumptions regarding the specified variables given under the economic model, the following are also made in connection with the statistical aspects of each functional relationship.

1. The economic relationships in sub-model I are assumed to be linear in "natural" numbers, or equivalently, the variables are presumed to be related in an additive way; those in sub-model II are assumed to be linear in the logarithms of the variables, or equivalently, the relationships between the variables are presumed to be multiplicative.[43]

Although previous studies on the analysis of the prices of soybeans and soybean products have employed either one of these assumptions, there appears no

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[43]Linearity in logarithms implies a multiplicative relationship between the variables. A non-linear function of the variables is transformed into a linear relationship with the use of logarithms. For example, the last function in sub-model II can be written as:

$$P_{B_t} = D_{40} \cdot \hat{Q}_{BC_t}^{d_{41}} \cdot \hat{P}_{M_t}^{d_{42}} \cdot \hat{P}_{O_t}^{d_{43}} \cdot T_t^{d_{44}} \cdot V_{4_t}$$

indication for the specific use of one over the other; accordingly, both types of relationships are considered here for the comparability of results.

2. All of the functions in the model are assumed to be continuous and differentiable at all points. This assumption is necessary in making estimates of the economic parameters relating to the demands for soybeans and soybean products.

3. The explanatory variables in the model, other than the calculated values of the endogenous variables, are assumed to be independent of the disturbance terms in the structural equations in which they belong. (It will be shown in the next section that, with this assumption, the calculated value of an endogenous variable which is used as an explanatory variable becomes independent of the disturbance term). The assumption is important because the nature of economic behavior and strict independence between economic variables are not consistent with each other. Within reasonable limits, however, the assumption is justified since the concerned variables in the model are either quantities or, with the exception of the price-ratio variable, one-year-lagged prices. The price-ratio variable is essentially predetermined as its components are a prescribed support rate and a price observation for the initial month of the marketing year.

Mathematically, the consequences of the assumption can be expressed in terms of expectations. Using the disturbance term of sub-model I and letting $\underline{x}$ be any explanatory variable in a relationship, we arrive at the following statements *if* x is independent of u:

a. $E(u_t|x) = E(u_t)$

b. $E(u_t^2|x) = E(u_t^2)$

c. $E(u_s u_t|x) = E(u_s u_t)$

These expressions respectively state that the mean, variance and covariance of the disturbances in the relationship are not conditional upon the given explanatory variable.

4. For each of the relationships in the model, the u's or v's, as the case applies, are assumed to be random disturbances with a population of zero mean and a homogeneous variance. It is further assumed that there is no serial correlation among the disturbances, i.e., the series of disturbances in the relation is not correlated with the same series lagged by one or more observation periods.[44] By following up the expressions in (3), we have in mathematical notation

a. $E(u_t) = 0$ for all t

b. $E(u_t^2) = \sigma^2$ " " "

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[44]Foote (1958) *op. cit.*

c. $E(u_s u_t) = 0$ for all $s \neq t$

which state the assumptions of zero mean, constant variance and absence of serial correlation in the population of disturbances belonging to each functional relationship.

Regarding these assumptions, Foote states, "When working with economic data, we usually assume that these specifications hold, but we may test at least the one regarding serial independence . . . after we have run the analysis."[45]

5. Since tests will be made on the estimates of the structural coefficients in the first relationship of each sub-model, the populations of u_1 and v_1 are each assumed to possess a normal distribution.

Rationale of Least Squares Application

When the least squares principle is applied to a single equation, the resulting estimators are best, linear and unbiased provided certain rigid assumptions, as specified by the Gauss-Markoff theorem, are satisfied.[46] These assumptions include the independence

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[45] _Ibid_.

[46] An _estimator_ refers to the statistic, or the method of computing such statistic, which yields the estimates of the parameters in the equation. Best, linear and unbiased estimators are those which respectively result in estimates of minimum variance, are functionally related in a linear fashion, and yield estimates whose mean over all possible samples of a given size is equal to the parameter being estimated; these properties of the estimators are commonly attached to the estimates obtained from their use.

Discussions on the Gauss-Markoff theorem can be between the explanatory variables and the disturbance terms in the relationship. However, this independence implies that the explanatory variables are fixed and, thus, enables setting one of them at different levels while holding the others constant. Since economic variables cannot be controlled like experimental variables, violations to the assumption become unavoidable and the above-mentioned properties of least squares estimators are not really attained when the technique is applied to economic relations. Johnston indicates two lines of approach in the use of the method for economic models.[47] One way would be to lean on the conditional probability statements regarding the estimates for the given levels of the independent variables in the equation; the alternative course is to assume that the independent variables are stochastic and to consider joint distributions.

A general justification for the use of the least squares approach in the recursive model of this study was made in chapter 1. The primary concern was focused on the endogenous variables which are used as explanatory variables in the different relationships and on reasons why the use of their calculated values can satisfy

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found in J. Johnston (1963) Econometric Methods (McGraw-Hill Book Co.: New York) and Arthur S. Goldberger (1964) Econometric Theory (John Wiley and Sons: New York).

[47]Ibid.

the requisites of the ordinary least squares method. Such concern is expected because the endogenous variables are, by definition, correlated with the disturbance terms and their use as independent variables in ordinary least squares analysis will lead to unsatisfactory results. But, as will be shown later, the independence between the calculated value of an endogenous variable and the disturbance term rests on the condition that the other explanatory variables in the relationship are independent of the disturbance term. Independence between these other explanatory variables and the disturbance term is one of the assumptions for the model and is implicit in the justification given in the first chapter.

An important implication of the assumption that the explanatory variable and the disturbance term are independent in each relationship is worth mentioning at this point. There is no problem when the assumption is made for a uniequational model since there will be only one set of explanatory variables and one population of disturbances to consider. However, when such an assumption is applied to a relationship that is part of a set composing a model, other relationships are automatically involved. For the particular set of relations in this study, the four populations of disturbances in each sub-model are correlated one with another. Thus, to assume that the explanatory variable is independent of the disturbance term in one relationship implies that it is likewise independent of the disturbances in the other relationships of the sub-model.

The reasoning behind the use of calculated values in applying the ordinary least squares method is similar to that for the two-stage least squares approach. The estimation procedures are similar except that in using ordinary least squares, regression is done on different sets of predetermined variables. The discussion that follows is an attempt to show that the calculated values of endogenous variables, which serve as explanatory variables, are free of stochastic components and are therefore essentially independent of the disturbance terms.

By omitting the primary subscript of the quantity variable and all secondary subscripts, and by grouping all the other explanatory variables in each equation as z, the relationships in sub-model I can be written as follows:[48]

$$Q = b_{10} + b_{11}z_1 + u_1 \qquad (1)$$

$$P_M = b_{20} + b_{21}Q + b_{22}z_2 + u_2 \qquad (2)$$

$$P_O = b_{30} + b_{31}Q + b_{32}z_3 + u_3 \qquad (3)$$

$$P_B = b_{40} + b_{41}Q + b_{42}P_M + b_{43}P_O + b_{44}z_4 + u_4 \qquad (4)$$

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[48]Except for some of the parameters in the first and last equations, the b's and u's in these relationships are not identical to those appearing in sub-model I.

With the exception of equation (1), the direct application of least squares to each of the above equations would result in unsatisfactory estimates of the structural coefficients. Working equation (1) by least squares, we get an estimate for Q which is

$$\hat{Q} = \hat{b}_{10} + \hat{b}_{11}z_1 \qquad (5)$$

The observed Q can now be expressed as

$$Q = \hat{Q} + \hat{u}_1 \qquad (6)$$

Substituting equation (6) in equation (2), we get

$$P_M = b_{20} + b_{21}\hat{Q} + b_{22}z_2 + (b_{21}\hat{u}_1 + u_2) \qquad (7)$$

It is the property of the least squares approach that the unexplained residual, $\hat{u}_1$, is independent of z_1. $\hat{Q}$ is independent of $\hat{u}_1$; it is also independent of u_2, the disturbance term in equation (2), because z_1 is predetermined in the model. Thus $\hat{Q}$ is independent of the composite disturbance $(b_{21}\hat{u}_1 + u_2)$ shown in equation (7). The same procedure can be applied to equation (3) to arrive at

$$P_O = b_{30} + b_{31}\hat{Q} + b_{32}z_3 + (b_{31}\hat{u}_1 + u_3) \qquad (8)$$

For the sake of brevity, we can let the composite disturbances in equations (7) and (8) be represented by u_2' and u_3', respectively. If we now apply least squares to these equations, we get estimates for P_M and P_O as shown:

$$\hat{P}_M = \hat{b}_{20} + \hat{b}_{21}\hat{Q} + \hat{b}_{22}z_2$$

$$\hat{P}_O = \hat{b}_{30} + \hat{b}_{31}\hat{Q} + \hat{b}_{32}z_3$$

And as in equation (6), we have

$$P_M = \hat{P}_M + \hat{u}_2' \qquad (9)$$

$$P_O = \hat{P}_O + \hat{u}_3' \qquad (10)$$

By substituting equations (6), (9) and (10) in equation (4) for P_B, the result will be

$$P_B = b_{40} + b_{41}\hat{Q} + b_{42}\hat{P}_M + b_{43}\hat{P}_O + b_{44}z_4$$

$$+ (b_{41}\hat{u}_1 + b_{42}\hat{u}_2' + b_{43}\hat{u}_3' + u_4) \qquad (11)$$

For the same reasons given before, the calculated values of Q, P_M and P_O are independent of the overall composite disturbance shown in equation (11). Thus, if the assumption regarding the independence between the other explanatory variables and the disturbance terms holds, the least squares technique can be justifiably employed in determining the equations in the model.

Although the use of the calculated values of the endogenous variables in the study paves the way for the application of the method of least squares, this step imposes statistical limitations for the model. Statistical inferences that are based on the estimates of the standard errors of the structural coefficients will have to be confined to the first relationship in each sub-model. As mentioned in the first chapter, recursive-model estimates are consistent. Since consistency is a large-sample property, the usual significance tests are not applicable to the estimates of the coefficients in the price relationships of the model. No small-sample tests have yet been formulated for recursive-model estimates. Christ mentions the same limitations for two-stage least squares estimates.[49] Nevertheless, the estimated standard errors of the coefficients in the three price equations can still be used to indicate the relative importance of the price determinants. For this purpose, the "level of significance" for each estimated coefficient, as shown by its estimated standard error, can be computed to serve as the standard measure for comparisons.

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[49]Christ (1960) op. cit.

CHAPTER V

RESULTS OF THE STUDY

The overall results of this investigation can be considered as satisfactory, despite some shortcomings in the performance of certain relationships in the model. The quantity relationships of the two sub-models show very good statistical fits to the observed data and both of the estimated equations for soybean oil give satisfactory coefficients of determination. One of the two soybean meal equations does not satisfactorily account for the variations in meal prices during the sample period but a better fit is obtained for the other. Fair statistical fits which are shown by the soybean price relations reflect the dependence of these equations on the nature of the results of the other relations in the model.

The estimated coefficients of the explanatory variables generally exhibit algebraic signs consistent with the expected results. As applied, the "levels of significance" of the estimated coefficients appear as good indicators of the important determinants of the dependent variables in the different relationships. The computed price flexibilities for soybean meal and soybean oil are of justifiably levels and are comparable with those found by other investigators. (Table 3.) Divergent results are obtained for the price flexibility of soybeans in the two sub-models and, consequently, only approximate relationships between the price flexibilities of soybeans and soybean products can be indicated. With the use of approximate tests, no evidence of serial correlation is shown for the different relationships. These results are discussed in detail in the chapter.

Estimated Relationships

The estimated equations for the different relationships in the model are presented below; corresponding equations of the two sub-models appear together under each general economic relation. All of the secondary subscripts of the variables have been omitted from the equations. The statistical measures obtained are indicated under each equation; these include the coefficient of determination--both uncorrected (R^2) and corrected ($\overline{R}^2$) for degrees of freedom, and the Durbin-Watson statistic for testing serial correlation among the disturbances. Instead of the usually-shown estimated standard errors of the estimated coefficients, the levels of significance for rejecting the hypothesis that the parameter coefficient is zero are given. Estimates of the structural parameters and their estimated standard errors are presented up to five decimal figures in Table 1. For the comparability of results between the two sub-models, "R^2," "$\overline{R}^2$" and "d" are indicated under the logarithmic equations; these measures are based on the actual observations and the antilogarithms of the estimates from the relationships. The corresponding measures calculated directly from the logarithms are shown in Table 2.

Quantity of Soybeans Processed

1. $$Q_{BC} = 7710 + \underset{(0.00)}{0.482_{SB}} - \underset{(0.00)}{1510V_{SP}} + \underset{(0.01)}{22.0P_{VO}} - \underset{(0.14)}{0.137Q_{FB}} - \underset{(0.31)}{913R_P}$$

$$R^2 = 0.995 \qquad \overline{R}^2 = 0.993 \qquad d = 2.48$$

2. $$\text{Log } Q_{BC} = 2.031 + \underset{(0.00)}{0.724\text{Log } S_B} - \underset{(0.00)}{0.411\text{Log } V_{SP}} + \underset{(0.01)}{0.183\text{Log } P_{VO}} - \underset{(0.01)}{0.297\text{Log } Q_{FB}} - \underset{(0.35)}{0.069\text{Log } R_P}$$

$$"R^2" = 0.997 \qquad "\overline{R}^2" = 0.995 \qquad "d" = 1.84$$

Average Price of Soybean Meal

1. $$P_M = 1.16 - \underset{(0.25)}{0.00484\hat{Q}_{BC}} + \underset{(0.23)}{0.302P_L} - \underset{(0.55)}{0.00184Q_{FB}} + \underset{(0.20)}{0.582Q_{FG}} + \underset{(0.77)}{0.341Q_{FF}}$$

$$R^2 = 0.565 \qquad \overline{R}^2 = 0.384 \qquad d = 1.32$$

2. $\text{Log } P_M = 1.5101 - 1.30\text{Log } \hat{Q}_{EC} + 0.371\text{Log } P_L$
$\qquad\qquad\qquad\qquad\qquad\qquad (0.01) \qquad\qquad (0.25)$

$- 0.243\text{Log } Q_{FB} + 1.78\text{Log } Q_{FG} + 1.11\text{Log } Q_{FF}$
$\quad (0.57) \qquad\qquad (0.02) \qquad\qquad (0.14)$

$"R^2" = 0.711 \qquad "\overline{R}^2" = 0.591 \qquad "d" = 1.28$

<u>Average Price of Soybean Oil</u>

1. $P_O = 1540 - 0.0202\hat{Q}_{EC} - 0.0131Q_{FB} - 0.254Q_{VO}$
$\qquad\qquad\qquad\qquad (0.01) \qquad\qquad (0.42) \qquad\qquad (0.01)$

$+ 0.181Q_{ET} - 0.402Q_{LD}$
$\quad (0.35) \qquad\qquad (0.01)$

$R^2 = 0.832 \qquad \overline{R}^2 = 0.762 \qquad d = 1.91$

2. $\text{Log } P_O = 11.7206 - 0.721\text{Log } \hat{Q}_{EC} - 0.369\text{Log } Q_{FB}$
$\qquad\qquad\qquad\qquad\qquad\qquad (0.00) \qquad\qquad (0.51)$

$- 1.10\text{Log } Q_{VO} + 0.984\text{Log } Q_{ET} - 1.39\text{Log } Q_{LD}$
$\quad (0.02) \qquad\qquad (0.26) \qquad\qquad (0.11)$

$"R^2" = 0.899 \qquad "\overline{R}^2" = 0.854 \qquad "d" = 2.14$

<u>Average Farm-level Price of Soybeans</u>

1. $P_B = 8.35 - 0.00384\hat{Q}_{EC} + 0.707\hat{P}_M + 0.119\hat{P}_O + 3.02T$
$\qquad\qquad\qquad\quad (0.21) \qquad\qquad (0.18) \qquad\quad (0.04) \qquad\quad (0.18)$

$R^2 = 0.689 \qquad \overline{R}^2 = 0.594 \qquad d = 2.42$

2. $\text{Log } P_B = 0.6364 - 0.080\text{Log } \hat{Q}_{EC} - 0.378\text{Log } \hat{P}_M$
$\qquad\qquad\qquad\qquad\qquad\qquad (0.77) \qquad\qquad (0.23)$

$+ 0.347\text{Log } \hat{P}_O + 0.058\text{Log } T$
$\quad (0.40) \qquad\qquad (0.68)$

$"R^2" = 0.682 \qquad "\overline{R}^2" = 0.584 \qquad "d" = 1.85$

TABLE 1.--Estimates of coefficients and standard errors, sub-models I and II.

Equation and Variable	Sub-Model I Estimated Coefficient	Sub-Model I Estimated S. E.	Sub-Model II Estimated Coefficient	Sub-Model II Estimated S. E.
(1) Q_{BC}:				
S_B	+ 0.48198	0.01999	+ 0.72404	0.03127
V_{SP}	-1507.10705	360.64714	- 0.41072	0.09675
P_{VO}	+ 22.02924	7.35814	+ 0.18338	0.05441
Q_{FB}	- 0.13673	0.08834	- 0.29750	0.09710
R_P	- 912.54180	867.90735	- 0.06914	0.07115
(2) P_M:				
$\hat{Q}_{BC}$	- 0.00484	0.00397	- 1.30467	0.43970
Q_{FB}	- 0.00184	0.00291	- 0.24290	0.41183
P_L	+ 0.30193	0.23958	+ 0.37069	0.30758
Q_{FG}	+ 0.58192	0.42713	+ 1.78436	0.67728
Q_{FF}	+ 0.34117	1.20385	+ 1.11297	0.71364
(3) P_O:				
$\hat{Q}_{BC}$	- 0.02021	0.00601	- 0.72121	0.15990
Q_{FB}	- 0.01315	0.01572	- 0.36908	0.53134
Q_{VO}	- 0.25374	0.07417	- 1.10499	0.41829
Q_{BT}	+ 0.18057	0.18641	+ 0.98395	0.84117
Q_{LD}	- 0.40214	0.13623	- 1.38984	0.81974
(4) P_B:				
$\hat{Q}_{BC}$	- 0.00384	0.00293	- 0.07969	0.27185
$\hat{P}_M$	+ 0.70732	0.50542	+ 0.37776	0.30104
$\hat{P}_O$	+ 0.11921	0.05164	+ 0.34668	0.39271
T	+ 3.02171	2.16171	+ 0.05772	0.13420

TABLE 2.--Values of R^2, $\overline{R}^2$ and d, sub-models I and II.

Equation	Sub-Model I			Sub-Model II					
				Based on Logarithms			Based on Antilogarithms		
	R^2	$\overline{R}^2$	d	R^2	$\overline{R}^2$	d	"R^2"	"$\overline{R}^2$"	"d"
Q_{BC}	0.9952	0.9933	2.48	0.9963	0.9948	1.89	0.9966	0.9951	1.84
P_M	0.5651	0.3839	1.32	0.7342	0.6235	1.18	0.7115	0.5913	1.28
P_O	0.8319	0.7619	1.91	0.8755	0.8236	2.09	0.8968	0.8538	2.14
P_B	0.6893	0.5937	2.42	0.7072	0.6171	1.53	0.6818	0.5838	1.85

General Results

The following discussions cover the results on the goodness of fit of the estimated equations and the algebraic signs and levels of significance obtained. Figures 3 to 10 provide rough visual aids for the measures of fit; further reference to these figures is made later in the chapter. It should be pointed out that because of the method of computations employed in determining the equations in the model, the statistical interpretation of the level of significance can be strictly applied only to the first relationship of each sub-model. "Level of significance" is used for the price relationships as an approximate measure of the importance of the explanatory variable associated with the estimated coefficient.

Comparisons are made between the coefficients of determination that are obtained for the price relationships in the model and those found for price formulations in other studies. Although the sample periods and the variables of the studies are not indicated, such differences are borne in mind when making the comparisons; the purpose is merely to appraise how well the formulated equations fit the observed data, regardless of the variables employed and the periods covered by the studies.

Quantity of Soybeans Processed

The estimated equations for the quantity of soybeans crushed during the marketing year both result in very satisfactory fits to the observed data. A comparison of the equations in the two sub-models shows that little advantage appears to be gained by the use of the logarithmic form. The coefficients of determination are practically the same and, except for those of the foreign-output variable, the corresponding estimated coefficients of the two equations exhibit about the same levels of significance. A considerable improvement in the level of significance is indicated for the coefficient of the foreign-output variable when the logarithmic relationship is employed.

Statistically, the estimated coefficients of S_B, V_{SP} and P_{VO} are all highly significant in both sub-models; that of Q_{FB} is insignificant in sub-model I but highly significant in sub-model II. The estimated coefficients for R_P in the two sub-models are both insignificant; the resulting levels of significance indicate that with repeated sampling, coefficients as large as the respective estimates can be obtained 31 per cent of the time with sub-model I and 35 per cent of the time with sub-model II, if the true parameters are zero.

The algebraic signs of the coefficients of the different economic variables are, in general, consistent with those expected; only the coefficient of the foreign-output variable appears to have a wrong sign. It is reasonable to assume that the lagged effect of foreign soybean production on the quantity of domestic crushings would be in the same direction, but of a lesser degree, as the effect of the current value of the variable. Such being the case, a large soybean output abroad in the preceding year would lead to a decrease in the current export demand for United States soybeans. The resulting decline in the total demand for beans is apt to decrease soybean prices and consequently increase the quantity demanded for domestic processing. Thus, it appears that the foreign-output variable in this study may not be a good indicator for the soybean export market. The other coefficients show acceptable signs, including the price-ratio variable.

The soybean quantity relationship serves its purpose well as an estimating function. Accurate estimates of the observed quantities are obtained with the use of variables whose values are essentially known at the start of the marketing year. With this performance, the relationship attains its objective in the overall framework of the model.

Average Price of Soybean Meal

The estimated equation for soybean meal in submodel I appears the weakest in this recursive system, with respect to both statistical fit and "levels of significance." The resulting R^2 of 0.57 is rather low, compared to the results obtained for meal-price equations in other studies that similarly assumed an additive relationship between variables. (Table 3.) Price formulations by Paarlberg (1949) and in the 1959 USDA study gave uncorrected coefficients of determination of 0.86 and 0.87, respectively. Houck (1963) obtained an $\overline{R}^2$ of 0.69 in applying ordinary least squares to the meal equation in his model. The corrected coefficient of determination for sub-model I in this study is only 0.38. It is seen that the lower the value of R^2, the greater is the difference between R^2 and $\overline{R}^2$.

In earlier studies which employed logarithmic relationships, the soybean meal equation used by King (1958) gave uncorrected coefficients of determination of 0.80 and 0.94 for two sample periods. The highest R^2 from the different combinations of variables tested by Hieronymus (1961) was 0.86. An R^2 of 0.73 is indicated for the soybean meal price equation in sub-model II of this study.

The results of this investigation show strong evidence that a multiplicative, rather than an additive, relationship exists between the economic variables in soybean meal pricing. In sub-model I, variations in the values of the explanatory variables account for

TABLE 3.--Results of some studies on soybean products, showing the coefficients of determination of the estimated equations and the reported or implied price flexibility estimates.[a]

Study	Method	Sample Period	Functional Form	Meal Equation R^2	Meal Equation f	Oil Equation R^2	Oil Equation f
Paarlberg(1949)	OLS	1931-41	Non-logarithmic	0.86	-0.20	0.80	-0.10
King(1958)	"	1930-41	Logarithmic[b]	0.87	-0.58	-	-
	"	1930-41,46-54	"[b]	0.83	-0.48	-	-
USDA(1959)	"	1946-57	Non-logarithmic	0.87	-0.76	-	-
	"	"	"	0.91	-0.77	-	-
Hieronymus(1961)	"	1947-58	Logarithmic	0.86	-1.38	-	-
	"	"	"	0.84	-1.45	-	-
Houck(1963):[c]							
Model I	OLS(RF)	1946-60	Non-logarithmic	0.69	-1.08	0.54	-0.39
	2SLS	"	"	-	-1.12	-	-0.43
Model II	OLS(RF)	"	"	0.64	-0.84	0.85	-
	2SLS	"	"	-	-1.32	-	-
Houck(1964)[c]	2SLS	1946-60	Non-logarithmic	-	-1.12	-	-0.52
Present study	OLS	1946-63	Non-logarithmic	0.57	-0.74	0.83	-0.77
	"	"	Logarithmic	0.73	-1.30	0.88	-0.72

[a]The earlier studies given in the table are: Don Paarlberg, Prices of Soybeans and Soybean Products, Purdue Univ. Agric. Expt. Sta. Bull. 538; Gordon A. King, The Demand and Price Structure for Byproduct Feeds, USDA Tech. Bull. 1183; USDA, "Factors Influencing Soybean Meal Prices," Feed Situation, July 1959; T. A. Hieronymus, "Forecasting Soybean Meal Futures Prices," 1961 Commodity Yearbook; and James P. Houck, Demand and Price Analysis of the U. S. Soybean Market, Univ. of Minnesota Agric. Expt. Sta. Tech. Bull. 244 and "A Statistical Model of Demand for Soybeans," Journal of Farm Economics, Vol. 46, No. 2.

[b]First difference of logarithms.

[c]In both of Houck's studies, the indicated coefficients of determination are $\bar{R}^2$.

0.57 of the variations in the price of soybean meal during the 1946-63 period. With a logarithmic relationship, 0.14 more of the variation in soybean meal price can be associated with variations in the values of the same set of cause variables for the same period (see "R^2" in Table 2). Based on the "levels of significance" of the corresponding estimated coefficients, three of the five explanatory variables show increased importance when the logarithmic equation is used; the remaining two appear unaffected by the change in the algebraic form of the relationship.

The quantity of soybeans processed determines the quantity of soybean meal that is produced. As an important determinant of meal prices, the quantity of soybeans appears better represented by the results in sub-model II than those in sub-model I. Similarly, the non-logarithmic equation does not appear to reflect the due importance of feed grain consumption and formula feed output, two variables which can be expected to significantly affect soybean meal prices. Livestock prices and foreign soybean output, the two lagged variables, maintain their relative importance in both sub-models.

The algebraic signs of the estimated relationships generally agree with expectations. The normal price-quantity relationship of the demand for a commodity is exhibited. Increases in the price of livestock and livestock products are expected to be associated with increases in soybean meal prices when the quantity of soybeans is held constant. Livestock prices in the formulation reflect lagged effects while formula feed output represents the current influence of the livestock complex. The algebraic sign for formula feed production is likewise reasonable since increases in the manufacture of formula feeds can be associated with increases in the price of meal when the other variables remain constant.

The positive coefficient for the quantity of feed grains suggests a complementary relationship between soybean meal and feed grains. This result differs from the findings of King in 1958 which showed that "high-protein feeds and feed grains are strongly competitive on the average."[50] However, it is also likely that the expanded production of mixed feeds can lead to a complementary relation between these two commodities; high-protein feeds and feed grains tend to be mixed in proportions which yield certain percentages of protein and carbohydrates per given weight of the prepared feeds.

A negative relationship with soybean meal prices is indicated for the foreign output variable. As noted earlier, soybean meal and soybeans are competitive to a certain degree in the foreign market; importing countries which have crushing facilities can import either meal or

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[50]King (1958) op. cit.

beans. But whichever the United States exports, changes in the foreign output of soybeans are likely to be counter to those in the price of soybean meal. For example, a decrease in the production of soybeans abroad will lead to an increase in the foreign demand for United States soybean meal and directly tend to increase meal prices. On the other hand, if importing countries prefer beans instead of meal, the likely increase in the price of soybeans can put pressure on the price of soybean meal. In the latter case, however, it is also possible that the marketing margin may absorb the price "squeeze" and keep the price of meal unchanged.

Average Price of Soybean Oil

Good statistical fits are shown by both of the estimated relationships for the average price of soybean oil during the marketing year. Comparison of the equations in the two sub-models shows that the logarithmic form "explained" 0.07 more of the price variations of soybean oil in 1946-63. Based on the actual price observations and the antilogarithms of estimates, the uncorrected coefficient of determination obtained for the logarithmic relationship is 0.90. The uncorrected coefficients of determination in both equations exceed the R^2 obtained by Paarlberg (1949) in his oil price equation. The soybean oil price function in Houck's (1963) model gave an $\overline{R}^2$ of 0.54; comparative measures in the present study are 0.76 in sub-model I and 0.85 in sub-model II. The results of this study indicate a tendency for the relationship of the variables in the soybean oil relation to be multiplicative, but the evidence is not as strong as that shown for soybean meal.

With the "levels of significance" of the estimated coefficients as indicators, the oil equations in the two sub-models show that the quantity of soybeans and the quantities of other vegetable oils and lard are important determinants of the price of soybean oil. However, the quantity of lard appears to be of lesser importance in sub-model II than in sub-model I. Both equations fail to reflect the expected significance of the soybean oil export market whose influence is represented in the study by the foreign soybean output during the preceding year. Because a large part of the United States soybean oil output is exported, it is reasonable to expect that the export market for soybean oil is of greater importance than what the results of the equations suggest. This may indicate need for a more appropriate signal of foreign demand in the oil relation of the model.

All but one of the estimated coefficients of the cause variables exhibit acceptable algebraic signs. The negative coefficients for the quantity of soybeans processed and the foreign output of soybeans are explained by the same reasons presented for the soybean meal equations. A negative sign for the quantity of other vegetable oils is consistent with the directly competitive relationship between this group and soybean oil. In the case of the indirect competitors of soybean oil, the negative coefficient of the quantity of lard agrees with the expected result but the positive coefficient of the quantity of butter appears unacceptable. The results suggests that soybean oil and butter are complements, which is contrary to the "known" relationship between the two commodities.

Average Farm-level Price of Soybeans

The estimated equations for the average price United States farmers received for soybeans during the 1946-63 period indicate fair statistical fits. The uncorrected coefficients of determination are about the same for the two sub-models but are lower than the 0.79 obtained by Paarlberg (1949) for his soybean price equation. Except for Paarlberg's investigation, the other studies reviewed earlier did not include specific price relationships for soybeans.

Based on the indicated "levels of significance" of the estimated coefficients, the results of the soybean price relation are not as consistent between the two functional forms as they are in the meal equations. Comparing the relative "levels of significance" of the estimated coefficients in the two sub-models, it appears that an additive relationship between the variables is a better assumption for the soybean price relation. However, if the "levels of significance" were used as an indicator of the relative importance of the explanatory variables within each equation, it would appear that the logarithmic relationship gives better results. Although both relationships indicate that the quantity variable is of lesser importance than meal and oil prices in determining the price of soybeans, sub-model I shows that the price of soybean oil is the major determinant while sub-model II indicates that soybean meal is more important. While a slightly larger portion of the value of soybeans for the early part of the sample period was contributed by soybean oil, the share of soybean meal was larger for a longer part of 1946-63. Furthermore, due to differences in physical storability, soybean meal is almost wholly consumed during the year it is produced while soybean oil can be stored for the succeeding marketing period. It is for these reasons that the result indicated by sub-model I appears less acceptable than that shown by sub-model II.

The algebraic signs of the coefficients of the quantity of soybeans and the prices of meal and oil are those expected. As in the meal and oil equations, the normal price-quantity relationship is indicated.

Increases in the prices of meal and oil are expected to be associated with increases in soybean price when the quantity of soybeans is unchanged. The estimated price equation for soybeans shows a positive trend over time. The positive sign of the trend variable in the estimated equations possibly reflects the results of the improved techniques in soybean processing and a thinning of the marketing margin over time. More efficient methods of bean crushing tend to increase the value of soybean products from a given quantity of soybeans processed. There may also be a tendency for lesser margins per unit with larger volumes of the commodity.

Although the results of the soybean price equation in sub-model I are fairly satisfactory, there are reasons to believe that an additive relationship between variables is the correct specification. As shown by the model in this study, the soybean price relation is dependent upon the results of the estimated equations for the quantity of soybeans processed and the average prices of meal and oil. The quantity relationships perform satisfactorily and the results of the soybean oil equations appear acceptable. The poor results come from the soybean meal equations; however, the meal equation in sub-model II gives relatively much better results than that in sub-model I.

It is reasonable to assume that a large part of the inconsistent results of the estimated equations for the price of soybeans is contributed by the meal equations. If the correct specification for the soybean price relation were sub-model I, the fair performance of the estimated equation is likely caused by the poor results of the meal equation in that sub-model. On the other hand, despite the relatively better results of the meal equation in sub-model II, the resulting soybean price equation of this sub-model still yields rather unsatisfactory "levels of significance." It is therefore doubtful that a multiplicative relationship would be appropriate for the soybean price equation. A further reason which suggests the use of sub-model I is that one would expect an additive relationship between the price of soybeans and the price of meal, price of oil, and marketing margin. This relationship includes two of the major explanatory variables of the soybean price relation in the model.

Derived Estimates of Economic Parameters

Estimates for other economic parameters related to soybeans and soybean products are derived from the statistical estimates of the structural coefficients in the different relationships of the model. The computational procedures used in arriving at the estimates shown by the study are given in Appendix B. Because of the direction of causation in the functional relations, estimates of the price flexibilities of demands for soybean meal, soybean oil and soybeans are obtained, rather than their price elasticities. The price elasticity of demand for a commodity can be defined as the percentage change in the quantity demanded of the commodity associated with a one per cent change in the price of the commodity, assuming that the prices of other commodities are constant. On the other hand, the price flexibility of demand for a commodity is the percentage change in the price of the commodity associated with a one per cent change in the quantity demanded of that commodity, assuming that the quantities demanded of other commodities are constant.

In the discussion of the results of this study, the suggested price elasticities will be indicated as reciprocals of the estimates of price flexibilities. Although this is done, it should be pointed out that, in general, one measure is not the reciprocal of the other; the definitions of price elasticity and price flexibility indicate that these two measures are obtained under different assumptions. Regarding the relationship between price elasticity and the reciprocal of price flexibility, Houck writes,

> . . . the departure of the true price elasticity from the flexibility reciprocal depends upon the cross effects of substitution and complementarity

> with other commodities. . . . The reciprocal of the direct price flexibility forms the lower limit, in absolute terms, of the direct price elasticity.[51]

The recursive model in the present study yields an estimate of the price flexibility of demand for soybean meal at wholesale, measured at the point of means, in sub-model I of -0.74; sub-model II, which assumes a constant price flexibility, gives an estimate of -1.30. A flexibility estimate of -0.2 is implied in the study made by Paarlberg (1949) with data for 1931-41 (see Table 3). From two sets of data covering 1930-54, the price flexibilities computed by King (1958) were -0.48 and -0.58. The 1959 USDA study indicated estimates of -0.76 and -0.77 for the years 1946-57.[52] Data for about the same sample period, 1947-58, were used by Hieronymus (1961) and the two most satisfactory combinations of variables in his analyses suggested price flexibilities of -1.38 and -1.45. With two-stage and ordinary least squares prodedures on the same sets of equations, Houck (1963) obtained estimates of -1.12 and -1.08 in one model and -1.32 and -0.84 in a second model. His follow-up study a year later used the same 1946-60 data and indicated a price flexibility of -1.12.

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[51]James P. Houck (1965) "The Relationship of Direct Price Flexibilities to Direct Price Elasticities," Journal of Farm Economics, Vol. 43, No. 3.

[52]Cited by Houck (1963) op. cit.

The estimate of the price flexibility of demand for soybean meal from sub-model I of this study appears to agree with those of the 1959 USDA study while the estimate from sub-model II compares with later studies, particularly the analysis by Hieronymus in 1961. Judging from the comparative results of the two sub-models as discussed in the previous section, it would be more reasonable to accept the price flexibility estimate from the logarithmic equation. The sub-model II estimate and the results shown by past investigations indicate that the price flexibility of demand for soybean meal has increased in absolute value since the 1930's. This implies that the demand for soybean meal in the United States is becoming less elastic over the years. The lower bounds of the price elasticity of demand for meal suggested by the price flexibility estimates of this study are -1.35 in sub-model I and -0.77 in sub-model II.

In the case of soybean oil, the corresponding equations of the two sub-models show consistent results. The estimate of the price flexibility of demand for soybean oil at wholesale, again computed at the point of means, in sub-model I is -0.77; that directly indicated in sub-model II is -0.72. Paarlberg's (1949) study suggested a price flexibility of -0.10. The direct wholesale price flexibility estimate for soybean oil obtained by Brandow in 1961 was -1.77.[53] Houck (1963) obtained price flexibility estimates of -0.43 with two-stage least squares and -0.39 with ordinary least squares; his reformulated model in 1964 gave an estimate of -0.52.

The lower bounds of the price elasticity of demand for soybean oil suggested by the results of this study are -1.3 for sub-model I and -1.4 for sub-model II. These suggested estimates of elasticity from the two sub-models may appear rather low. Because of the high degree of substitutability between soybean oil and the other food fats and oils in the edible fats and oils group, it is expected that the demand for soybean oil is highly elastic. However, it is for the same reason of high substitutability that a large deviation between the price elasticity of demand for a commodity and its price flexibility reciprocal (the suggested price elasticity) can be expected. The elasticity matrix in the study by Brandow gave an estimate of the direct price elasticity of demand for soybean oil at wholesale of -3.99; on inversion of his matrix the estimate of price flexibility was -1.77.[54] If the price flexibility estimate obtained by Brandow were used as an indicator of the price elasticity

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[53] G. E. Brandow (1961) Interrelations Among Demands for Farm Products and Implications for Control of Market Supply, Pennsylvania State Agricultural Experiment Station Bulletin 680.

[54] Ibid.

of demand for soybean oil, the suggested elasticity would be $-\frac{1}{1.77}$ or -0.56, a figure much lower than the suggested elasticities in this study. Following Brandow's reasoning, it would take a larger change in quantity of soybean oil to clear the market with a one per cent change in the price of soybean oil if the prices of other fats and oils were held unchanged than if the quantities of other fats and oils were unchanged.[55]

Apparently absorbing the divergent results of the meal price equations, the estimates of the price flexibility of processing demand for soybeans from the two sub-models are almost reciprocals of each other. The estimate in sub-model I, determined at the point of means, is -1.21; that computed from sub-model II is -0.82. The suggested lower bounds of the elasticities from these estimates are respectively -0.83 and -1.22. Approximate farm-level elasticities of processing demand for soybeans computed by Houck (1963) in one model were -1.48 and -0.82 from two-stage and ordinary least squares, respectively. Estimates for a second model which employed time as a variable, as in the formulation of the present study, were not computed in Houck's investigation.

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[55]Ibid., p. 61. In reasoning for the difference between the price flexibility and reciprocal of price elasticity, Brandow writes, "It is intuitively evident that a much larger price change would be required to clear the market of a 10 per cent increase in soybean oil production when production of other fats and oils was unchanged than when prices of other fats and oils were unchanged."

The linked relationships of the prices and quantities of soybeans, soybean meal and soybean oil in the model enable the determination of the approximate relationships between the wholesale price flexibilities of demands for meal and oil and the farm-level price flexibility of soybean demand for processing. Using f_B, f_M and f_O to denote the price flexibilities of processing demand for soybeans at the farm level and of wholesale demands for meal and oil, the resulting relationships are:

Sub-model I: $f_B = -0.479 + 0.576\ f_M + 0.388\ f_O$

Sub-model II: $f_B = -0.080 + 0.378\ f_M + 0.347\ f_O$

These linear relationships between the farm-level price flexibility of processing demand for soybeans and the price flexibilities of demands for meal and oil at whosesale are rough approximations. They, however, reflect the results of the corresponding equations in the two sub-models which yield close estimates of price flexibility for soybean oil but diverse results for both meal and soybeans. In sub-model I, the estimates of price flexibilities are -0.74, -0.77, and -1.21 for meal, oil and beans, respectively; those in sub-model II are -1.30, -0.72, and -0.82, in the same order.

Actual Observations and Estimates

The observed values and the estimates for the quantity of soybeans crushed, the average price United States farmers received for soybeans and the average wholesale prices of meal and oil for the marketing years 1946-63 are presented in Tables 4 and 5. Graphical comparisons between actual data and the estimates from each equation and for each sub-model appear in Figures 3 through 10.

Estimates of yearly soybean crushings during the sample period are close to the observed quantities in both sub-models. (Figures 3 and 4.) The largest difference between actual and computed values in sub-model I is an overestimate of about seven per cent of the quantity of beans processed in 1949; in sub-model II, the maximum deviation from actual data is an underestimate of around five per cent of the crushings in 1951.

The resulting coefficients of determination for the meal price equation are indicative of the major deviations between the estimates and the observed values of the average wholesale price of soybean meal in the sample period. Figure 5 shows that sub-model I appears to have merely indicated the general trend of soybean meal prices for 1946-63. Although both of the sub-models fail to account for the price changes from the immediate years after World War II up to the outbreak of the Korean War

TABLE 4.--Actual and estimated quantity of soybeans crushed and average farm-level price of soybeans in the United States, 1946-63.

Marketing Year	Quantity of Soybeans Crushed			Farm-Level Price of Soybeans[a]		
	Actual	Estimated		Actual	Estimated	
		I	II		I	II
	1000 tons	1000 tons	1000 tons	dollars per ton	dollars per ton	dollars per ton
1946	5,107	5,062	5,121	91	96	93
1947	4,842	4,975	4,942	108	86	85
1948	5,510	5,401	5,533	75	84	83
1949	5,858	6,279	6,043	72	73	80
1950	7,560	7,276	7,408	72	79	79
1951	7,331	7,204	6,978	81	74	78
1952	7,032	7,020	6,973	82	82	79
1953	6,395	6,699	6,549	82	81	79
1954	7,470	7,214	7,275	75	78	73
1955	8,494	8,436	8,365	65	70	69
1956	9,478	9,618	9,646	62	62	61
1957	10,614	10,443	10,549	58	66	64
1958	12,037	12,057	12,303	56	60	61
1959	11,803	11,907	11,946	55	60	61
1960	12,067	11,745	11,808	60	61	61
1961	13,165	13,017	13,096	64	60	61
1962	13,425	13,565	13,423	66	56	59
1963	13,228	13,497	13,486	70	67	61

[a]Deflated by the BLS Wholesale Price Index (1947-49=100).

[b]Average prices received by U. S. farmers.

[illegible] of data in "Actual" columns: *Fats and Oils Situation*, USDA and *Wholesale* [illegible]

TABLE 5.--Actual and estimated average wholesale prices of soybean meal and soybean oil in the United States, in dollars per ton, 1946-63.

Marketing Year	Price of Soybean Meal[a]			Price of Soybean Oil[a]		
	Actual[b]	Estimated		Actual[c]	Estimated	
		I	II		I	II
1946	76.91	68.99	72.72	487	462	458
1947	78.54	63.58	62.00	462	380	380
1948	65.45	69.98	68.39	259	317	308
1949	64.30	69.00	70.58	246	231	256
1950	56.54	67.89	62.96	312	297	286
1951	74.42	70.60	74.19	202	214	219
1952	61.41	66.20	64.83	220	273	256
1953	71.50	62.54	68.09	245	248	235
1954	55.18	57.13	55.84	216	250	235
1955	46.50	54.49	53.00	221	216	212
1956	40.56	46.46	42.88	217	202	192
1957	44.87	48.08	46.37	182	231	200
1958	46.89	50.32	46.44	160	196	179
1959	46.68	52.90	50.99	139	145	156
1960	50.92	54.29	54.42	190	116	144
1961	53.45	53.56	53.83	160	129	148
1962	59.87	48.04	50.83	150	124	142
1963	59.66	49.59	50.12	143	180	160

[a]Deflated by the BLS Wholesale Price Index (1947-49=100).
[b]From prices for bulk, Decatur, quoted at 41% protein up to June 1950 and at 44% protein, thereafter.
[c]From prices for domestic, crude, tank cars, Midwestern Mills.

Sources of data in "actual" columns: *Fats and Oils Situation*, USDA and *Wholesale Price Index*, BLS.

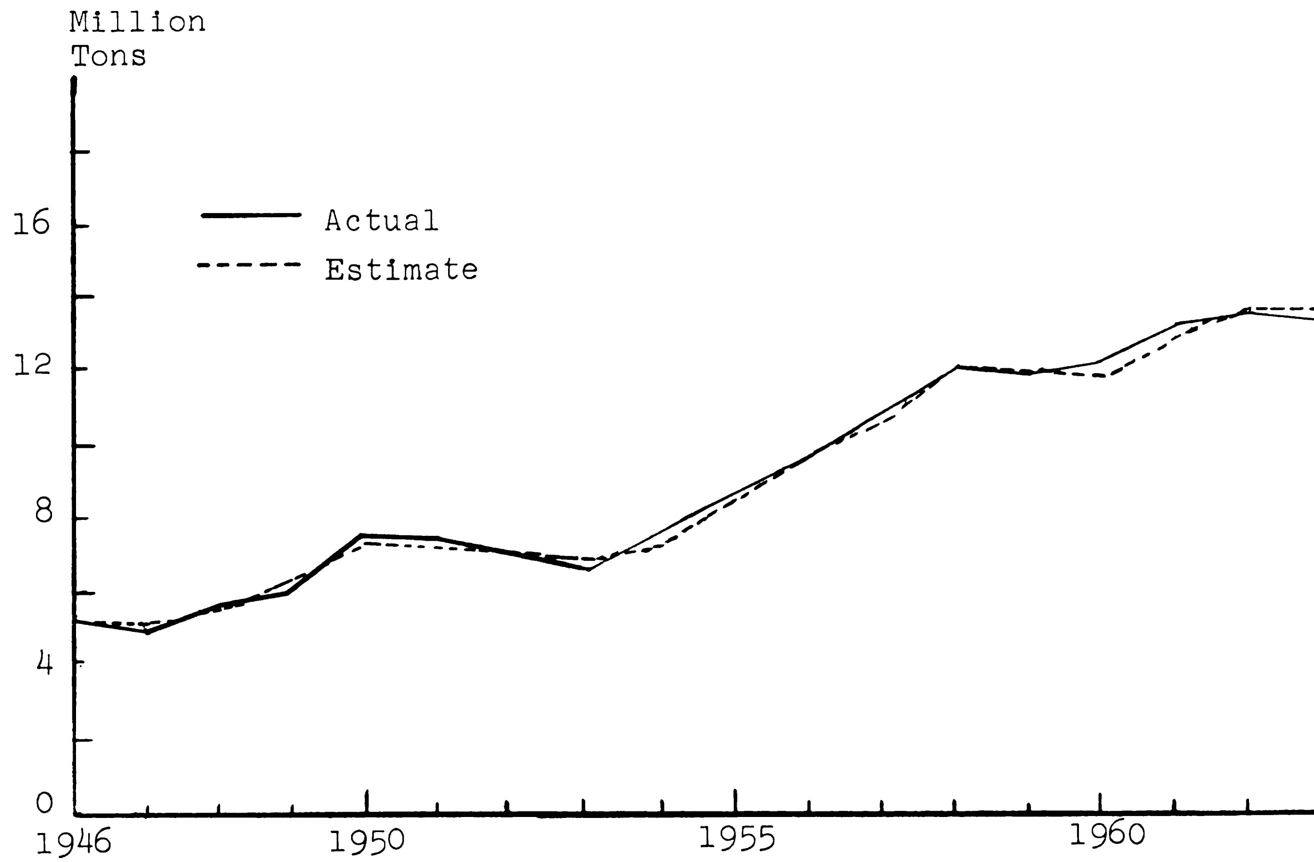

FIGURE 3.--Annual quantity of soybeans processed, actual and estimates obtained from sub-model I, 1946-63.

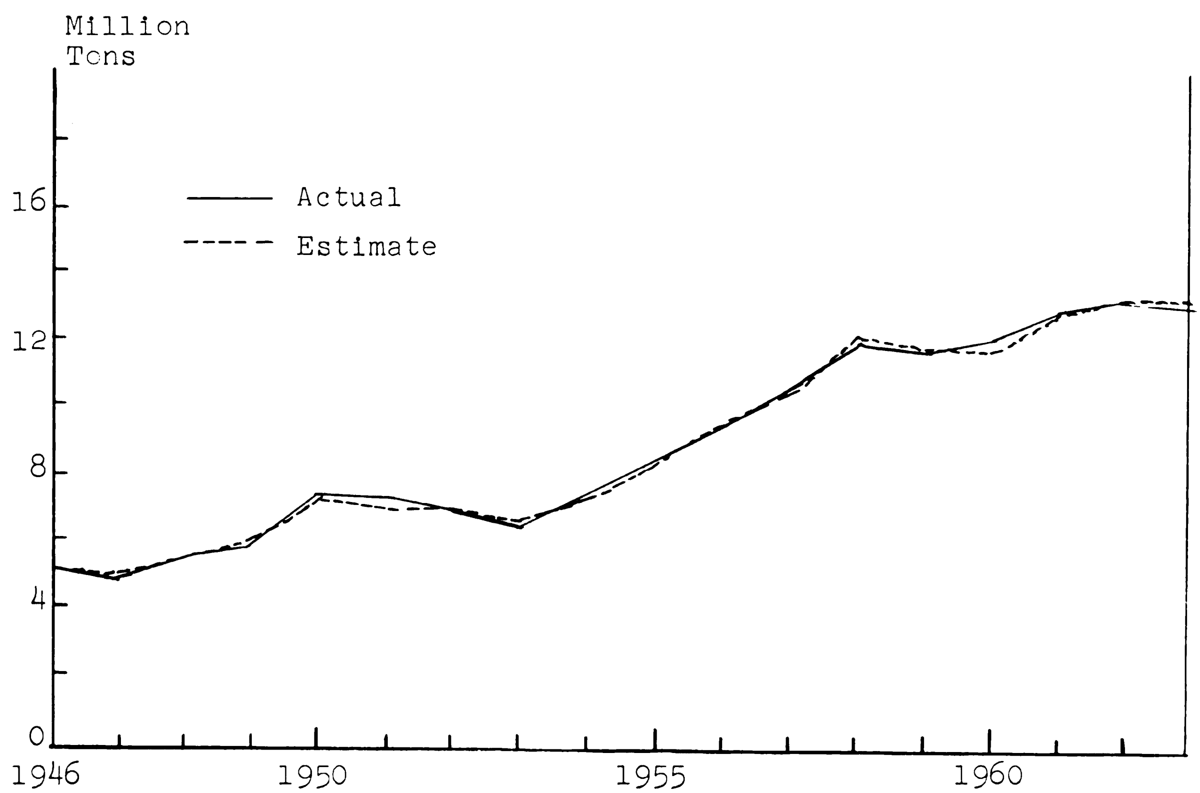

FIGURE 4.--Annual quantity of soybeans processed, actual and estimates obtained from sub-model II, 1946-63.

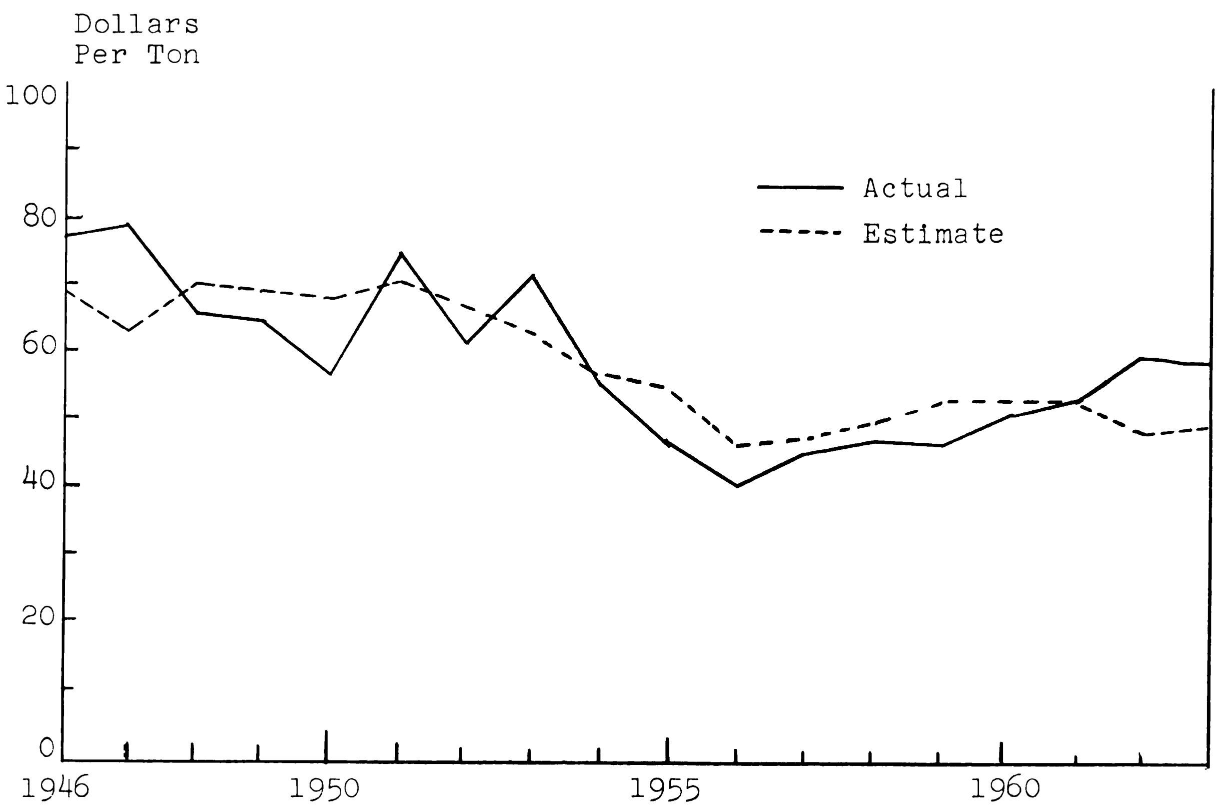

FIGURE 5.--Average wholesale price of soybean meal deflated by the wholesale price index, actual and estimates obtained from sub-model I, 1946-63.

in 1950, sub-model II gives relatively satisfactory estimates of meal prices for the following decade. (Figure 6.) Both sub-models overestimate the prices of soybean meal for the years from 1954 to 1960, with the exception of the 1958 marketing year in sub-model II. These overestimates are caused by the large increases in the feed grain consumption by livestock and the production of formula feeds, two variables which positively affect soybean meal prices. The two sub-models result in considerable underestimates for the 1962 marketing year. An increase in formula feed production from 1961 fails to offset the simultaneous negative effects of increases in the soybean output variables, both the domestic and the foreign, and the decrease in feed grain consumption.

The two fitted equations for the soybean oil relation fail to "explain" the price variations of soybean oil during the first three years of the period covered by the study. (Figures 7 and 8.) From 1948 forward, the logarithmic equation results in estimates which are relatively better than those of sub-model I. Outside of 1946-48, the largest deviations of the estimates from the observed oil prices are both indicated by the two sub-models for the 1960 marketing year. The computed values in 1960 underestimate the observed price of soybean oil by 39 per cent and

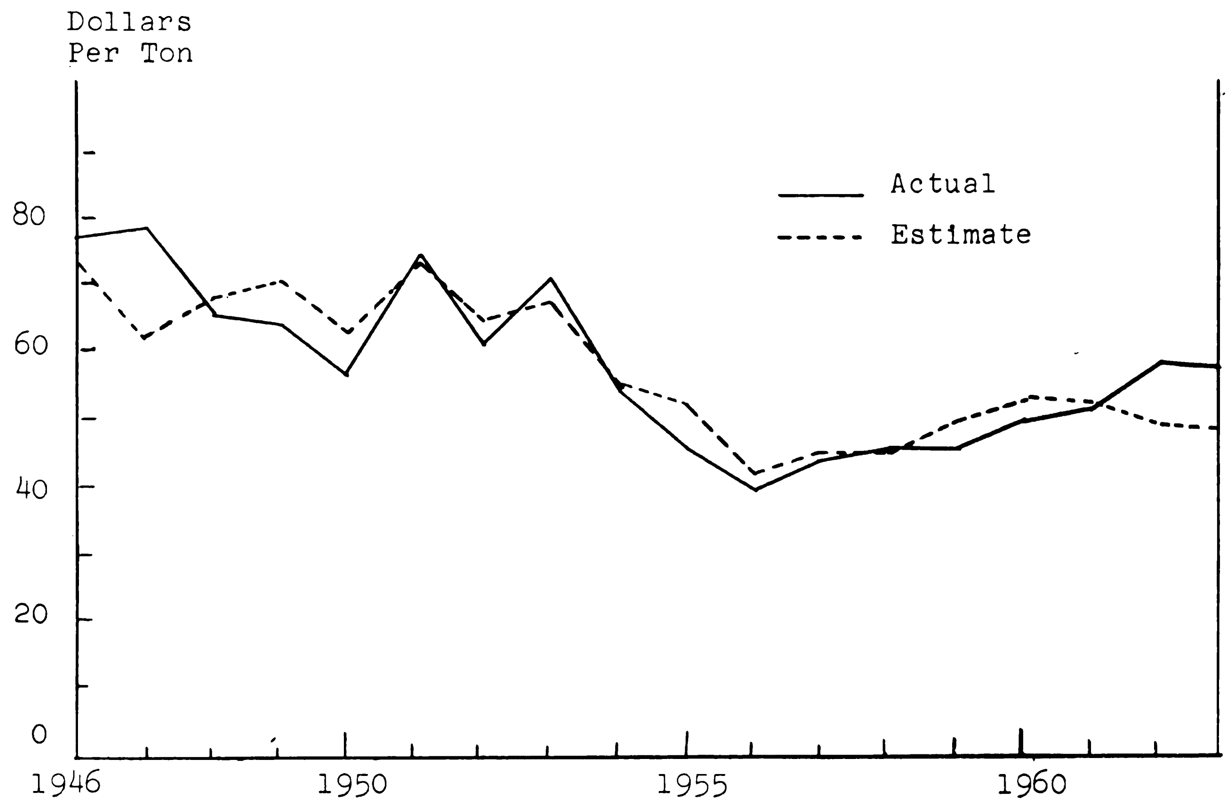

FIGURE 6.--Average wholesale price of soybean meal deflated by the wholesale price index, actual and estimates obtained from sub-model II, 1946-63.

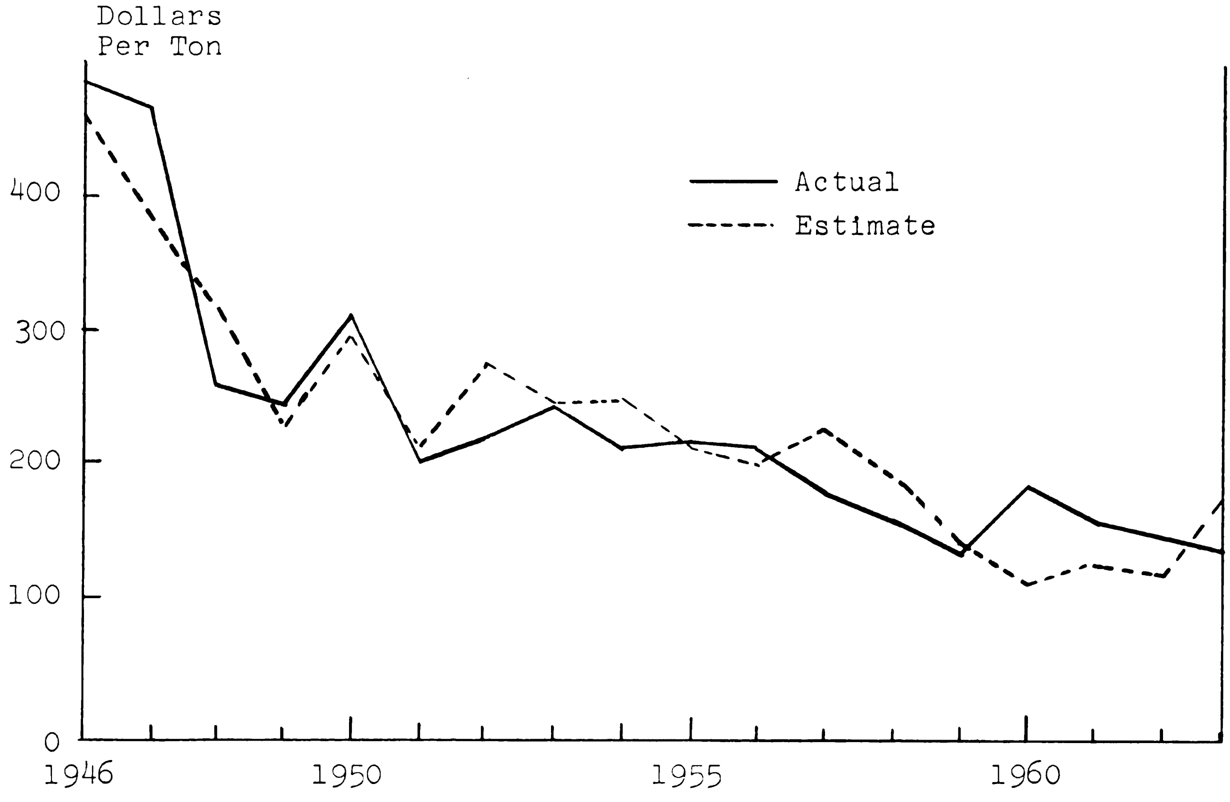

FIGURE 7.--Average wholesale price of soybean oil deflated by the wholesale price index, actual and estimates obtained from sub-model I, 1946-63.

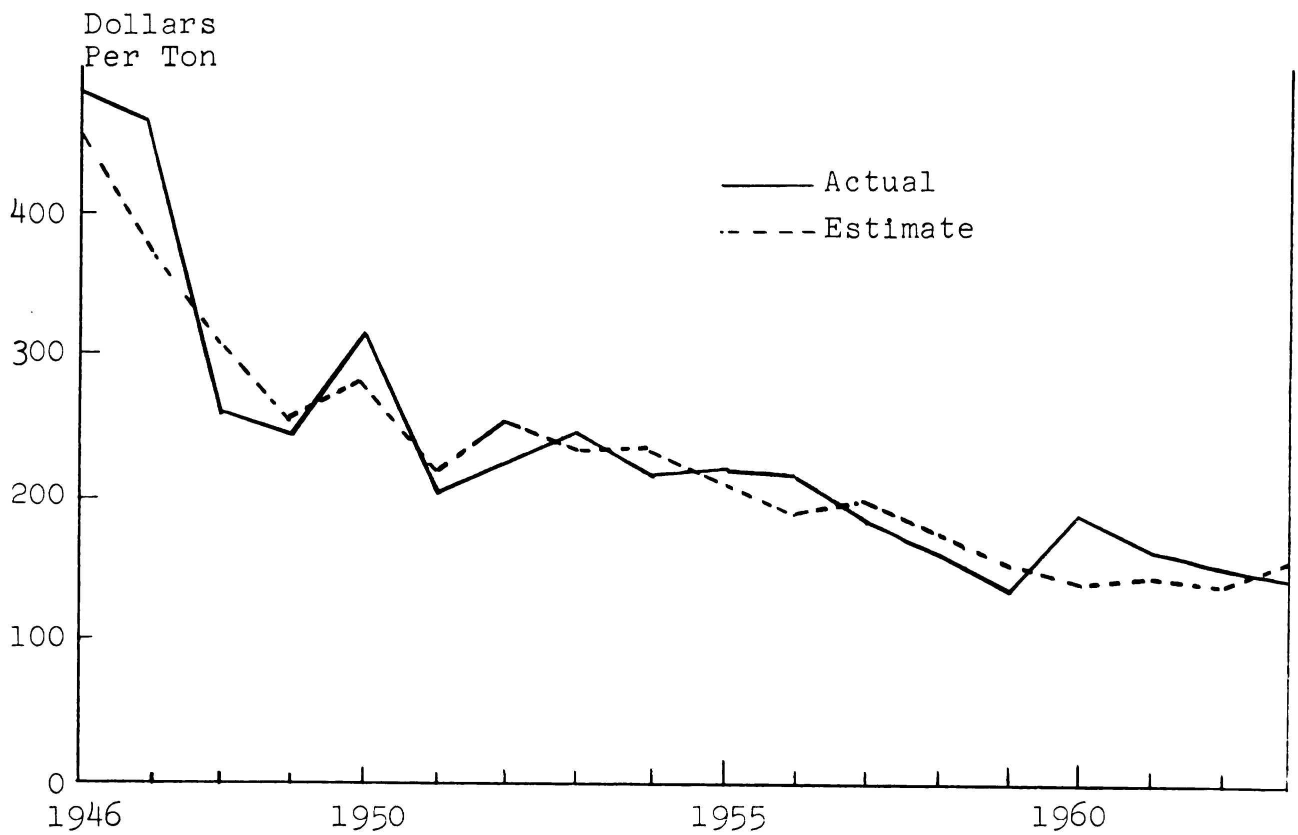

FIGURE 8.--Average wholesale price of soybean oil deflated by the wholesale price index, actual and estimates obtained from sub-model II, 1946-63.

24 per cent in sub-models I and II, respectively. This underestimate is due mostly to a 12 per cent increase in the quantity of other vegetable oils utilized between 1959 and 1960; other explanatory variables either stayed at the same levels or show changes which tend to increase soybean oil prices. Changes in the quantity of other vegetable oils appear to similarly cause the deviations between the estimates and the actual observations for the years 1952, 1954, 1957, and 1958. This time, however, decreases in the use of other vegetable oils cause noticeable overestimates by both models that are more marked in sub-model I than in sub-model II. A considerable decrease in the value of the foreign output variable and a decline in the use of lard in 1963 seem to account for the overestimates by both sub-models for that year.

Comparisons between the actual and the computed average prices United States farmers received for soybeans during the 1946-63 period are shown in Figures 9 and 10. The joint results of the meal and oil equations are reflected in the estimates of soybean prices. Like those for meal and oil prices, the estimated equations for the farm-level price of soybeans do not satisfactorily "explain" the price changes in the early part of the same period. After 1948, sub-model I yields estimates which fit the observed-price

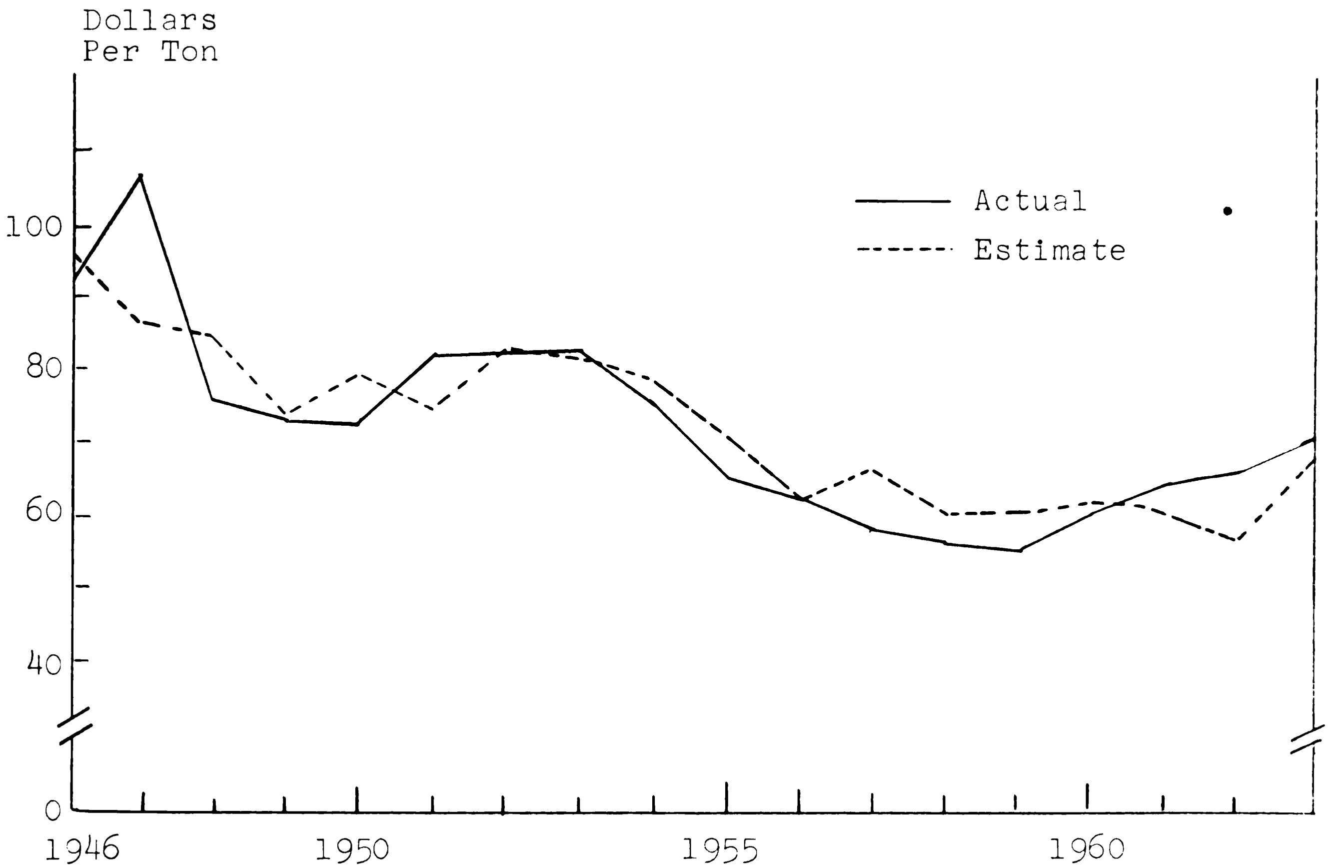

FIGURE 9.--Average price received by farmers for soybeans deflated by the wholesale price index, actual and estimates obtained from sub-model I, 1946-63.

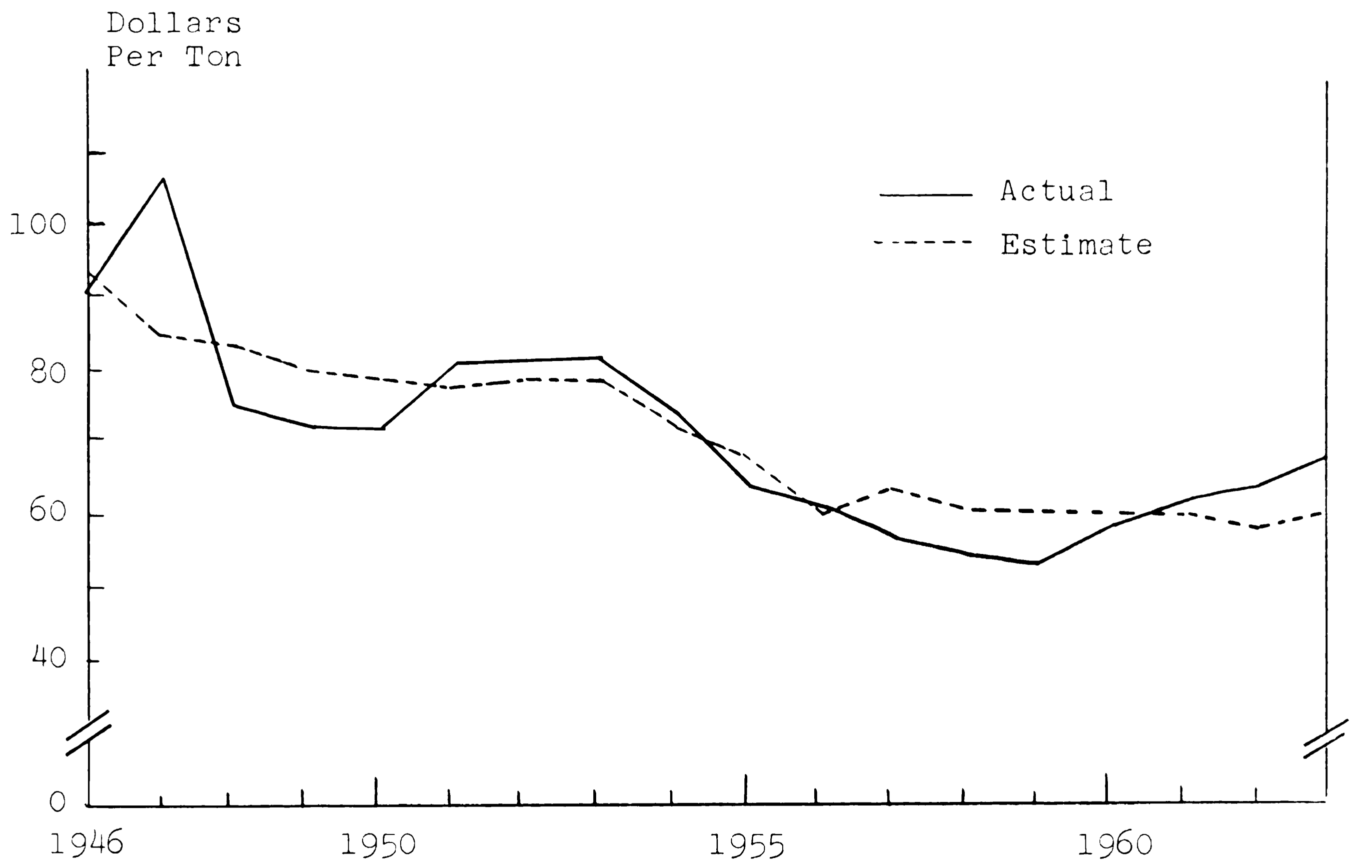

FIGURE 10.--Average price received by farmers for soybeans deflated by the wholesale price index, actual and estimates obtained from sub-model II, 1946-63.

line fairly well but sub-model II appears to poorly account for the year-to-year changes in soybean price.

Sub-model I significantly underestimates soybean prices for 1951 and 1962 and yields overestimates for the years 1954-60, except the 1956 marketing year. While the low estimate in 1951 appears to be caused by a decline in the price of oil alone, the significant underestimate for 1962 is caused by changes in the quantity and price variables of the soybean price relation, all tending to exert downward effects on the price estimate. Increases in the prices of meal and oil in 1957 and of meal alone in 1958-59 appear to have caused the noticeable overestimates for these years.

The pattern of estimates in sub-model II for 1955-62 generally follows that in sub-model I and the estimates for the period may be explained by the same reasons as for sub-model I. The apparent divergence of the results between the sub-models for the 1963 marketing year is largely due to the differences between the corresponding estimates of the quantity of soybeans crushed and the price of soybean meal in the two sub-models. In sub-model II, the calculated values for these variables indicate an increase in the quantity of soybeans crushed and a decrease in the price of meal; these changes are in contrast to those shown for the estimates of the same variables in sub-model I.

Tests for Serial Correlation

A test for serial correlation among the disturbances in each relationship of the model is made with the Durbin-Watson statistic, d, which is computed from the unexplained residuals of each equation. The values of d are given under each of the estimated relationships presented earlier and, as previously noted, those appearing for the logarithmic relations are based on the differences between actual observations and the antilogarithms of the estimates (see also Table 2). Applied to this model, the test for serial correlation is only approximate because the model involves calculated values of the endogenous variables which cannot be considered "fixed." The test is specially applicable "to regression models in which the independent variables can be regarded as fixed variables."[56]

Durbin and Watson give the lower and upper bounds of d for tests at specified levels of significance.[57] In a test for positive serial correlation, the hypothesis

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[56]J. Durbin and G. S. Watson (1951) "Testing for Serial Correlation in Least Squares Regression," Biometrika, Vol. 38.

[57]Ibid.

is made that no positive serial correlation exists. If the computed value of d is less than the lower bound, the test statistic is significant at the given level and the hypothesis is rejected. If the computed d exceeds the upper bound, the value is not significant and the hypothesis can be accepted. However, if the test statistic falls within the test bounds, the result of the test is inconclusive. A test for negative serial correlation is made by computing (4-d) and subjecting the result to the same test as for positive serial correlation, although this time the hypothesis is that there is no negative serial correlation.

The lower and upper bounds of d for a two-tailed test at the five per cent level of significance are given below; these values are for testing the relationships in this model, each of which has 18 observations and four or five independent variables.[58]

(a) For five independent variables:

$d_L = 0.62 \qquad d_U = 1.93$

(b) For four independent variables:

$d_L = 0.72 \qquad d_U = 1.74$

We apply (a) for approximate tests on the relationships for the quantity of soybeans processed and the average

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[58]The values shown are upper and lower bounds for a single-tailed test at 2.5 per cent level of significance. From table by Durbin and Watson (1951) op. cit., p. 174.

wholesale prices of meal and oil; (b) is applied for testing the soybean price relation.

The results of the tests show no significant serial correlation among the unexplained residuals at the five per cent level of significance (see table on page 115). Only the soybean price relationship in sub-model II shows an insignificant value of d for both positive and negative serial correlation. If the tests for sub-model II were applied to the actual d, as computed from the residuals in the logarithmic relationships, the results are similar to those shown in the table except that the test for positive correlation on the soybean price equation yields an inconclusive result.

Results of Tests for Serial Correlation

Relationship	Positive Serial Correlation		Negative Serial Correlation	
	Sub-model I	Sub-model II	Sub-model I	Sub-model II
Q_{BC}	Insignificant	Inconclusive	Inconclusive	Insignificant
P_M	Inconclusive	Inconclusive	Insignificant	Insignificant
P_O	Inconclusive	Insignificant	Insignificant	Inconclusive
P_B	Insignificant	Insignificant	Inconclusive	Insignificant

CHAPTER VI

CONCLUSION

I conclude that, despite some shortcomings of the study, the stated objectives were attained to a reasonable degree. The quality of the results is less than what was desired but much has been gained. This chapter gives a brief summary of the principal findings in this study and indicates measures for improving the model. Finally, some implications of the results are stated, with the hope that they will be of value in future price analysis work on soybeans and other agricultural commodities.

Major Findings of the Study

The ability of this recursive model to yield a meaningful analysis of the demand the price structure of the domestic soybean market depends, in a large measure, on the performance of the quantity-of-soybeans relation. Both estimates of this relationship appear to have achieved their purpose in the analytical framework of the model. Consequently, the findings of economic importance, as shown by the price equations for soybean meal, soybean oil and, to a certain extent, soybeans, are deemed useful. Among these findings are:

1. The results of this study, in accordance with those of other investigations, indicate that the demand for soybean meal in the United States is becoming less elastic over time.

2. Feed grains appear to be complements with soybean meal. This result differs from those of previous findings. However, changes in the feeding of livestock in the United States indicate a tendency towards the increased use of prepared feeds. This could result in complementarity between high-carbohydrate and high-protein feeds.

3. Of the two indirect competitors of soybean oil in the domestic market, lard appears to exert more influence on the price of soybean oil than butter does. Since soybean oil is a major component of shortening and margarine, this result suggests that the direct competition between shortening and lard is relatively stronger than that between margarine and butter.

4. The prices of soybean meal and soybean oil are more important determinants of the farm-level price of soybeans than the quantity of soybeans processed. This was expected because the demand for soybeans is derived from the demands for soybean products.

On the statistical aspects of the study, the following results are worthy of note:

1. With a recursive model of the type employed in this study, an analysis of the markets of soybeans and soybean products can be made with the legitimate use of ordinary least squares. The application of least squares procedures does not essentially violate the requisite that the explanatory variables should be independent of the disturbance term in a functional relationship.

2. Estimates of price flexibilities computed from this model are comparable to previous estimates obtained by ordinary least squares. The least squares estimates in a number of earlier investigations are considered reasonable but nevertheless deemed unsatisfactory because the procedure employed violated the assumption of independence between explanatory variables and disturbance terms. The price flexibility estimates from the model are also comparable to the results from a simultaneous-equations model of an earlier investigator who employed the two-stage least squares procedure.

3. The logarithmic form of the estimated equation for soybean meal yields much better results than the non-logarithmic form. This suggests that the soybean meal pricing relationship tends to be multiplicative rather than additive.

4. The estimated equations for soybean oil perform relatively better than those for soybean meal. The logarithmic relationship for soybean oil appears to give more satisfactory results than the equation of "natural" values; however, the evidence of a multiplicative relationship among variables is not as strong as that shown for meal.

5. The hypothesis that the structural coefficient is zero was tested for each parameter in the various relationships. In the quantity equations, the estimated coefficients of three explanatory variables in the non-logarithmic form and four of those in the logarithmic form were found significant at the one per cent level. As applied to the price equations of this study, the computed "levels of significance" of the estimated coefficients appear as reasonable indicators of the relative importance of the corresponding explanatory variables.

6. Price estimates for soybean meal, soybean oil and, consequently, soybeans obtained by this study indicate that the major determinants of the prices of these commodities in this model are clearly unable to account for the large price variations for the marketing years 1946-48. Evidently, exogenous factors during the immediate period after World War II were not reflected in this

model; these factors caused significant deviations between the estimates and the observed prices of meal, oil and beans.

Suggested Improvements in the Model

A better specification of the variables in the meal equation appears necessary. Despite the improvement associated with the use of the logarithmic form for the relation, the results obtained still fail to attain desirable levels. Prior to the final form of the meal relationship in the model, a number of other explanatory variables were tested for use. Among these were the quantity of other high-protein feeds consumed by livestock in the United States during each marketing year, the animal-number series of the USDA and a linear trend variable. The number of experiments was limited by the time available; it is possible that some untried combination between these variables and those appearing in the final form of the equation may yield better results. Other variables which may improve the meal relation are the animal-number series formulated by Hieronymus[59] and the price expectation series worked out by Lerohl.[60]

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[59]Hieronymus (1961) op. cit.

[60]Milburn L. Lerohl (1965) Expected Prices for U. S. Agricultural Commodities, 1917-62. Unpublished Ph.D. thesis, Michigan State University.

The increasing importance of the export markets of soybeans and soybean products suggests that the export sector might be explicitly represented in the relationships. The lagged foreign-soybean-output variable is apparently not a good indicator of changes in export demand; the price of United States soybeans in foreign ports during the previous year could be tried in its place. For the soybean oil price relationship, the foreign output of all edible vegetable oils or oilseeds during the past year could be an alternative variable to account for the influence of the export market. It is likely that United States exports of soybean oil are affected more by the foreign output of all edible vegetable oils or oilseeds than of soybeans alone.

An improved performance of the model as a whole might be obtained by using a combination of equations from the two sub-models in this study. Based on the performance results of the equations, one can choose the more satisfactory functional form to employ for each of the economic relationships of the modified model. Results indicate that a logarithmic equation is appropriate for the meal relation while a non-logarithmic form of relationship appears to perform better for soybean price. Either of the two functional forms can give satisfactory results for the quantity-of-soybeans relation. Although the logarithmic equation of soybean oil seems slightly better, both of the functional forms appear applicable. Four combinations of the different relationships are thus possible for a reconstructed model. In modifying the set of structural equations, however, one should not limit the changes to the functional forms alone. As pointed out earlier, there is likewise the need for trying to improve the specification of the variables.

Some Implications of the Results

The failure of the price equations in this model to "explain" satisfactorily the price variations of soybeans and soybean products in 1946-48 was mentioned earlier in this chapter. A possible cause of the poor estimates for these years is the relatively large increase in United States soybean exports from 3 million bushels in 1947 to 23 million bushels in 1948 (see table 6); as previously noted, the export market appears inadequately represented in the model. However, despite the inclusion of an export demand function in Houck's simultaneous set of relationships of the United States soybean market, his model also did not yield good estimates of prices for the above-mentioned years.[61] The results of Houck's investigation and those of this

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[61]Houck (1963) op. cit.

study suggest that it might be well to exclude the 1946-48 marketing years as part of the sample period in an analysis of the markets of soybeans and soybean products.

An important implication of the results found in this study is the possibility of a wider use of recursive models for price analysis work on agricultural commodities. In recent investigations, fully recursive models were applied by Harlow, in an analysis of hog supply,[62] and by Crom and Maki in their simulation study of the United States livestock-meat economy.[63] A model of the type employed in this study, where recursiveness occurs only within observation periods, may find use in demand studies on other agricultural commodities. For example, with the use of appropriate predetermined variables, relationships might be formulated to generate estimates of the marketed quantities of farm products. And, as in this study, ordinary least squares procedures can be legitimately applied to the subsequent relationships between the calculated quantities and the prices of these commodities.

Finally, the method employed in this investigation can be of value in countries where computer facilities are limited. While more complicated models of analysis involve computational procedures requiring the services

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[62]Arthur Harlow (1962) Factors Affecting the Price and Supply of Hogs, USDA Technical Bulletin 1274.

[63]Crom and Maki (1964) op. cit.

of modern computers, the recursive model in this study is relatively simpler and computations can be performed with ordinary calculators. In places where the quality of available agricultural economic data does not lend itself to elaborate analytical models, the output obtained from a complicated set of relations may not prove commensurate with the costs of computations required for the more "sophisticated" analytical procedures. The estimation of demand parameters by the method in this study can then be a practical approach.

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APPENDIX A

TABLES OF BASIC DATA

TABLE 6.--United States soybean supply and disposition, in thousand bushels, 1946-63.

Marketing Year	Supply			Disposition			
	Production	Oct. 1 Stocks	Total	Seeds	Feeds and Residual[a]	Exports	Quantity Crushed
1946	203,395	4,356	207,751	17,455	10,186	3,880	170,245
1947	186,451	5,393	191,844	16,066	8,821	2,972	161,397
1948	227,217	2,617	229,834	15,945	4,040	23,015	183,664
1949	234,194	3,181	237,375	18,893	7,177	13,142	195,265
1950	299,249	2,907	302,156	18,979	-800	27,833	251,990
1951	283,777	4,161	287,938	19,780	3,144	17,046	244,380
1952	298,839	3,589	302,428	20,689	5,295	31,908	234,404
1953	269,169	10,134	279,303	22,900	2,256	39,663	213,158
1954	341,075	1,345	342,420	23,446	-603	60,619	249,010
1955	373,682	9,949	383,631	25,768	3,527	67,483	283,126
1956	449,251	3,727	452,978	26,442	15,357	83,361	315,950
1957	483,425	9,889	493,314	29,531	3,391	85,507	353,805
1958	580,250	21,079	601,329	27,402	547	110,072	401,225
1959	532,899	62,084	594,983	29,296	7,671	141,382	393,417
1960	555,307	23,218	578,525	32,855	7,399	130,064	402,217
1961	679,566	5,994	685,560	33,478	2,525	153,154	438,838
1962	669,211	57,565	726,776	34,883	21,993	180,347	447,498
1963	699,363	15,096	714,459	36,501	13,938	191,159	440,917

[a]The residual item includes quantities fed to livestock on farms other than those where soybeans are produced and small quantities used directly for human food. Negative quantities in some years resulted from the use of the new crop in September of the previous marketing year.

Source of data: Fats and Oils Situation, USDA.

TABLE 7.--Value of products per bushel of soybeans crushed, average price received by farmers for soybeans and wholesale price index in the United States, 1946-63.

Marketing Year	Yield per Bushel of Soybeans Crushed		Price of Meal[a]	Price of Oil[b]	Value of Products per Bushel Crushed[c]	Average Price Received by Farmers	Wholesale Price Index (1947-49=100)
	Meal	Oil					
	lbs.	lbs.	cents/lb.	cents/lb.	dollars	dollars/bu.	-
1946	48.0	9.0	3.62	22.9	3.80	2.57	94
1947	47.5	9.5	4.04	23.8	4.12	3.33	103
1948	47.1	9.8	3.30	13.1	2.80	2.27	101
1949	47.0	9.9	3.22	12.3	2.73	2.16	100
1950	46.8	9.7	3.22	17.8	3.24	2.47	114
1951	46.7	10.0	4.17	11.3	3.08	2.73	112
1952	47.4	10.8	3.38	12.1	2.91	2.72	110
1953	47.4	11.0	3.93	13.5	3.34	2.72	110
1954	45.8	10.9	3.04	11.9	2.69	2.46	110
1955	46.2	11.1	2.63	12.5	2.60	2.22	113
1956	47.5	10.9	2.37	12.7	2.51	2.18	117
1957	46.8	10.7	2.67	10.8	2.41	2.07	119
1958	47.3	10.6	2.79	9.5	2.33	2.00	119
1959	46.5	11.0	2.78	8.3	2.20	1.96	119
1960	47.0	11.0	3.03	11.3	2.66	2.13	119
1961	47.1	10.9	3.18	9.5	2.54	2.28	119
1962	46.9	10.7	3.56	8.9	2.62	2.34	119
1963	48.1	10.9	3.55	8.5	2.64	2.51	119

[a]Bulk, Decatur, quoted at 41% protein up to June 1950 and 44% protein, thereafter.

[b]Domestic, crude, tank cars, Midwestern Mills.

[c]Product sum of yield by price for meal and oil.

Sources of data: Fats and Oils Situation, USDA; Soybean Blue Book, American Soybean Association; Wholesale Price Index, BLS.

TABLE 8.--Values of selected variables used in the analysis, 1945-1962.[a]

Marketing Year	Price Index (1947-49=100)		Value of Soybean Products[c]	Foreign Soybean Output
	Livestock & Livestock Products	Vegetable Oils[b]		
			dollars/bu.	1000 tons
1945	77	63	3.27	9,490
1946	97	118	4.04	10,419
1947	108	123	4.00	10,529
1948	97	73	2.77	10,079
1949	93	64	2.73	8,594
1950	112	90	2.84	11,125
1951	109	62	2.75	10,416
1952	94	66	2.65	11,284
1953	87	68	3.04	11,470
1954	81	62	2.45	11,719
1955	77	63	2.30	11,829
1956	81	64	2.15	11,980
1957	92	60	2.03	11,878
1958	90	53	1.96	12,788
1959	85	47	1.85	12,502
1960	87	59	2.24	11,542
1961	87	53	2.13	12,386
1962	86	48	2.20	10,866

[a]Entered as lagged data in the model.
[b]Domestic origin.
[c]Deflated by the BLS Wholesale Price Index (1947-49=100).

Sources of data: Agricultural Prices, Fats and Oils Situation and Agricultural Statistics, USDA; Wholesale Price Index, BLS.

TABLE 9.--Formula-feed production and domestic disappearances of feed grains, other vegetable oils, butter and lard in the United States, 1946-63.

Marketing Year	Formula-Feed Production[a]	Domestic Disappearance			
		Feed Grains[b]	Other Vegetable Oils	Butter	Lard
	millon tons	million tons	million lbs.	million lbs.	million lbs.
1946	33.0	129.29	1,526	1,598[c]	1,881[c]
1947	32.6	112.06	1,633	1,522	1,956
1948	35.4	119.60	1,964	1,596	1,912
1949	36.9	128.61	2,091	1,609	2,022
1950	40.6	130.20	1,526	1,544	2,184
1951	43.3	130.82	1,785	1,375	2,071
1952	43.1	121.17	1,527	1,352	2,111
1953	44.2	122.09	2,200	1,438	1,773
1954	43.2	121.88	1,922	1,543	1,959
1955	44.8	130.45	1,767	1,526	2,065
1956	45.8	128.31	1,715	1,458	2,039
1957	50.4	133.66	1,606	1,467	1,994
1958	51.0	144.54	1,561	1,449	2,024
1959	50.7	151.81	1,702	1,373	2,005
1960	53.0	153.20	1,905	1,379	1,968
1961	55.6	156.92	1,792	1,400	1,985
1962	57.0	153.82	1,798	1,331	1,908
1963	56.2	152.12	1,895	1,399	1,789

[a]Derived from calendar year data of the Bureau of Census for 1962-64 and of backward projections for 1946-61 based on published reports of the American Feed Manufacturers Association.

[b]In terms of corn equivalents.

[c]Derived from calendar year data.

Sources of data: Feedstuffs, Miller Pub. Co.; AFMA Bulletin, American Feed Manufacturers Association; Grain and Feed Statistics and Fats and Oils Situation, USDA.

TABLE 10.--United States price-support operations on soybeans and ratio of support price to average price received by farmers in October, 1946-63.

Marketing Year	Under Price Support			Percentage Of Crop Under Program	Deliveries To CCC	Support Price	Support Price / October Price
	Loan	Purchase Agreement	Total				
	1000 bu.	1000 bu.	1000 bu.	per cent	1000 bu.	dollars/bu.	-
1946	6,456	-	6,456	3.2	-	2.04	0.895
1947	3,536	-	3,536	1.9	-	2.04	0.656
1948	6,928	4,065	10,933	4.8	10,652	2.18	0.960
1949	11,222	4,839	16,061	6.9	41	2.11	1.010
1950	14,716	238	14,954	5.0	29	2.06	1.015
1951	10,759	374	11,133	3.9	57	2.45	0.935
1952	11,671	2,427	14,098	4.7	3,858	2.56	0.945
1953	30,348	1,442	31,790	11.8	7	2.56	1.062
1954	37,943	3,470	41,413	12.1	15,550	2.22	0.874
1955	27,490	2,643	30,133	8.1	2	2.04	0.981
1956	59,769	5,943	65,712	14.6	27,286	2.15	1.039
1957	71,628	18,924	90,552	18.7	44,500	2.09	1.024
1958	126,800	13,400	140,200	24.2	83,000	2.09	1.083
1959	45,300	7,100	52,400	9.8	3,900	1.85	0.958
1960	25,400	200	25,600	4.6	0	1.85	0.954
1961	114,700	17,800	132,500	19.5	57,200	2.30	1.045
1962	66,600	2,200	68,800	10.2	1,200	2.25	1.009
1963	69,600	3,200	72,800	10.4	12,200	2.25	0.879

Sources of data: Fats and Oils Situation, USDA; Soybean Blue Book, American Soybean Association.

TABLE 11.--World soybean production, in million bushels, 1935-39 average and 1945-62.

Year	U. S. Output	Foreign Output: Mainland China[a]	Foreign Output: Others	Foreign Output: Total	Estimated World Output	U. S. Output Relative to World Output
						per cent
1935-39 average	56	359	49	408	464	12
1945	193	291	26	317	510	38
1946	203	319	29	348	551	37
1947	186	319	32	351	537	35
1948	227	307[b]	29[c]	336	563	40
1949	234	245	42	287	521	45
1950	299	330[b]	41[c]	371	670	45
1951	288	304	43	347	635	45
1952	299	325	51	376	675	44
1953	269	332	51	383	652	41
1954	341	334	57	391	732	47
1955	374	335	59	394	768	49
1956	449	340	60	400	849	53
1957	483	335	61	396	879	55
1958	580	360	66	426	1,006	58
1959	533	350	67	417	950	56
1960	555	315	70	385	940	59
1961	680	290	122	412	1,092	62
1962	669	283	79	362	1,031	65

[a] Reported separately for China and Manchuria prior to 1954.

[b] Where applicable, the 1945-49 and 1950-54 averages are used for unavailable data.

[c] Residual values.

Sources of data: Agricultural Statistics and Fats and Oils Situation, USDA.

TABLE 12.--United States soybean acreage, production, average yield per acre and farm value of production, 1920-21 and 1925-63.

Year	Area Harvested for Beans	Production	Yield per Acre	Farm Value of Production
	1000 acres	1000 bu.	bushels	1000 dollars
Averages:				
1920-21	171	2,546	14.8	6,503
1925-29	547	6,874	12.6	13,421
1930-34	1,163	16,603	14.3	14,314
1935-39	3,042	56,167	18.5	46,441
1940-44	8,246	151,004	18.1	255,266
1945-49	10,649	208,885	19.7	513,673
1950-54	14,747	298,422	20.3	779,316
1955-59	21,344	483,901	22.6	1,004,086
1960	23,655	555,307	23.5	1,185,352
1961	27,008	679,566	25.2	1,546,263
1962	27,604	669,211	24.2	1,564,470
1963	28,580	699,363	24.5	1,845,339

Sources of data: Yearbook of Agriculture and Agricultural Statistics, USDA.

TABLE 13.--United States soybean production by region, in thousand bushels, 1920-21 and 1925-63.[a]

Year	Corn Belt	Lake States	Plains States	Delta States	Atlantic States	Others	Output of Corn Belt / U.S. Output
							per cent
Averages:							
1920-21	208	106	-	34	1,964	234	8
1925-29	4,474	46	39	360	1,640	315	63
1930-34	13,672	102	74	422	1,833	409	83
1935-39	51,141	669	57	1,031	2,620	650	91
1940-44	132,872	4,916	2,208	4,020	4,376	2,612	88
1945-49	171,731	14,170	3,515	7,195	6,669	5,605	82
1950-54	221,333	28,664	9,287	18,308	11,647	9,184	74
1955-59	316,962	56,024	13,991	55,065	25,938	15,921	66
1960	347,899	46,711	21,179	75,925	39,578	24,015	63
1961	440,094	63,269	27,400	76,744	44,523	27,536	65
1962	434,595	52,636	27,749	84,067	43,389	26,775	65
1963	453,554	67,074	28,655	82,687	39,481	27,912	65

[a]The soybean producing regions are composed as follows: Corn Belt: Illinois, Iowa, Indiana, Ohio and Missouri; Lake States: Minnesota, Wisconsin and Michigan; Plains States: Kansas, Nebraska, North Dakota and South Dakota; Delta States: Arkansas, Mississippi and Louisiana; and Atlantic States: North Carolina, South Carolina, Virginia, Maryland and Delaware.

Sources of data: Yearbook of Agriculture and Fats and Oils Situation, USDA.

TABLE 14.--United States soybean meal supply and disposition, in thousand tons, 1946-63.

Marketing Year	Production	Oct. 1 Stocks	Total Supply[a]	Exports[b]	Domestic Disappearance
1946	4,086	-	4,086	142	3,944
1947	3,833	-	3,833	96	3,737
1948	4,330	-	4,334	151	4,170
1949	4,586	13	4,625	47	4,543
1950	5,897	35	5,965	181	5,748
1951	5,704	36	5,763	42	5,669
1952	5,551	52	5,644	47	5,540
1953	5,051	57	5,123	66	4,995
1954	5,705	62	5,767	272	5,458
1955	6,546	37	6,583	400	6,072
1956	7,510	111	7,621	443	7,123
1957	8,284	55	8,340	300	7,992
1958	9,490	48	9,538	512	8,967
1959	9,152	59	9,211	649	8,479
1960	9,452	83	9,535	590	8,867
1961	10,342	78	10,420	1,064	9,262
1962	11,127	94	11,221	1,476	9,586
1963	10,609	159	10,768	1,478	9,168

[a]Includes imports in years when larger than production plus stocks.

[b]Include military relief shipments from 1946-50.

Sources of data: Feed Situation and Grain and Feed Statistics, USDA; Soybean Blue Book, American Soybean Association.

TABLE 15.--Estimated use of by-product feeds in the United States, in thousand tons, 1935-39 average and 1946-63.

Marketing Year	High-Protein Feeds					Other By-product Feeds	Total By-product Feeds
	Soybean Meal	Cottonseed Meal	Other Oilseed Meals[a]	Animal and Grain Protein	Total		
1935-39 average	832	1,985	456	3,732	7,005	7,420	14,425
1946	3,745	1,434	658	4,284	10,121	9,589	19,710
1947	3,383	1,953	905	4,000	10,241	8,954	19,195
1948	4,158	2,271	887	4,090	11,406	8,861	20,267
1949	4,517	2,382	968	4,177	12,044	8,964	21,008
1950	5,718	1,853	1,088	4,618	13,277	9,066	22,340
1951	5,640	2,650	839	4,232	13,361	9,541	22,902
1952	5,510	2,671	735	4,162	13,078	9,761	22,839
1953	4,965	2,926	785	4,629	13,305	10,249	23,554
1954	5,428	2,405	688	4,522	13,043	10,595	23,638
1955	6,042	2,511	626	4,838	14,017	10,079	24,096
1956	7,093	2,220	711	4,540	14,564	9,947	24,511
1957	7,962	2,097	707	4,358	15,124	10,767	25,891
1958	8,938	2,198	638	4,584	16,358	10,830	27,188
1959	8,450	2,330	497	5,742	17,019	11,422	27,441
1960	8,837	2,498	615	4,832	16,782	11,205	27,987
1961	9,232	2,622	522	5,109	17,485	11,444	28,929
1962	9,556	2,585	498	5,219	17,858	11,931	29,789
1963[b]	9,132	2,696	500	5,465	17,793	12,362	30,155

[a]Include cottonseed meal, linseed meal, peanut meal and copra meal.
[b]Preliminary data.

Sources of data: _Feed Situation_ and _Grain and Feed Statistics_, USDA.

TABLE 16.--United States soybean oil supply and disposition, in million pounds, 1946-63.

Marketing Year	Production	Oct. 1 Stocks	Total Supply	Exports	Domestic Disappearance
1946	1,531	200[a]	1,731	98	1,429
1947	1,534	204	1,738	112	1,532
1948	1,807	96	1,903	300	1,488
1949	1,937	113	2,050	291	1,646
1950	2,454	113	2,567	490	1,906
1951	2,444	171	2,615	271	2,150
1952	2,536	194	2,730	93	2,462
1953	2,350	174	2,525	71	2,326
1954	2,711	127	2,838	50	2,609
1955	3,143	179	3,322	556	2,539
1956	3,431	227	3,658	807	2,565
1957	3,800	286	4,085	804	3,051
1958	4,251	281	4,532	930	3,320[b]
1959	4,338	298	4,636	953	3,551[b]
1960	4,420	308	4,728	721	3,515[b]
1961	4,790	677	5,467	1,308	4,135[b]
1962	5,091	618	5,709	1,165	4,029[b]
1963	4,822	920	5,742	1,106	4,403[b]

[a]Average of the reported stocks for August 31 and October 31 of the calendar year.

[b]Reported factory consumption (in years exceeding computed disappearance).

Sources of data: Fats and Oils Situation, USDA; Soybean Blue Book, American Soybean Association.

TABLE 17.--Fats and oils used in the manufacture of shortening in the United States, in million pounds, 1935-39 average and 1946-63.

Calendar Year	Soybean Oil	Cottonseed Oil	Peanut Oil	Corn Oil	Coconut Oil	Others[a]	Total
1935-39 average	119	1,014	68	1	28	316	1,546
1946	744	502	42	3	18	157	1,466
1947	705	300	65	3	87	236	1,396
1948	708	321	56	4	48	266	1,403
1949	713	532	12	1	20	216	1,494
1950	841	549	12	1	0	324	1,727
1951	731	335	21	1	20	297	1,405
1952	851	388	6	1	33	334	1,613
1953	903	376	4	1	2	395	1,681
1954	918	640	5	1	15	390	1,969
1955	930	439	6	3	4	606	1,988
1956	782	323	6	2	6	736	1,855
1957	796	272	6	4	8	738	1,824
1958	1,055	239	5	3	12	697	2,011
1959	1,143	320	1	5	20	755	2,244
1960	1,169	365	2	4	10	752	2,302
1961	1,160	356	3	14	26	900	2,459
1962	1,362	367	1	7	27	932	2,696
1963	1,228	330	3	3	19	981	2,564

[a]Include animal fats and secondary oils.

Source of data: Fats and Oils Situation, USDA.

TABLE 18.--Fats and oils used in the manufacture of margarine in the United States, in million pounds, 1935-39 average and 1946-63.

Calendar Year	Soybean Oil	Cottonseed Oil	Peanut Oil	Corn Oil	Coconut Oil	Others[a]	Total
1935-39 average	32	125	3	1	105	37	303
1946	201	223	12	7	15	7	465
1947	228	323	17	7	21	11	607
1948	255	453	11	1	5	11	736
1949	257	431	b	1	b	11	701
1950	312	418	7	1	0	26	764
1951	473	334	16	4	1	23	851
1952	652	354	3	b	0	37	1,046
1953	726	275	2	1	7	38	1,049
1954	665	397	2	b	5	37	1,106
1955	746	278	2	b	6	43	1,075
1956	752	283	3	1	8	64	1,111
1957	874	237	3	b	5	63	1,182
1958	1,070	145	4	1	4	45	1,269
1959	1,094	124	3	20	4	46	1,291
1960	1,105	136	4	55	4	63	1,367
1961	1,062	139	3	89	3	90	1,386
1962	1,058	106	4	99	5	122	1,394
1963	1,075	104	4	136	4	154	1,477

[a]Include animal fats and secondary oils.
[b]Less than 500,000 pounds.

Source of data: _Fats and Oils Situation_, USDA.

TABLE 19.--United States soybean oil utilization by product class, in million pounds 1935-39 average and 1946-63.

Marketing Year	Food Products				Non-Food Products				Domestic Disappearance
	Shortening	Margarine	Others[a]	Total	Drying Oils	Other Inedible	Foots & Loss	Total	
1935-39 average[b]	119	32	59	210	22	10	11	43	253
1946[b]	744	201	294	1,238	67	28	77	172	1,410
1947	764	263	233	1,260	99	103	70	272	1,532
1948	694	244	241	1,180	111	120	78	308	1,488
1949	776	265	288	1,329	112	127	78	317	1,646
1950	795	459	344	1,599	102	119	87	308	1,906
1951	800	583	404	1,786	120	147	97	364	2,150
1952	879	735	462	2,077	164	115	106	386	2,462
1953	905	661	437	2,002	145	95	84	324	2,326
1954	979	741	545	2,264	149	88	107	344	2,609
1955	803	725	668	2,196	124	113	107	344	2,539
1956	764	836	627	2,227	126	104	107	337	2,565
1957	993	1,041	692	2,726	112	82	132	325	3,051
1958	1,136	1,082	758	2,976	108	103	133	343	3,320
1959	1,183	1,114	878	3,175	105	122	147	375	3,551
1960	1,097	1,073	1,005	3,175	100	101	139	340	3,515
1961	1,353	1,036	1,386	3,775	92	117	151	359	4,135
1962	1,222	1,069	1,353	3,645	97	125	162	384	4,029
1963[c]	1,355	1,136	1,531	4,021	103	134	146	383	4,403

[a]Include cooking and salad oils and other edible oil uses.
[b]Calendar years.
[c]Preliminary data.

Source of data: Fats and Oils Situation, USDA.

APPENDIX B

COMPUTATIONAL PROCEDURES

The following computational procedures are employed in arriving at the derived estimates of and the relationships between the price flexibilities of demands for soybeans, soybean meal and soybean oil. Computations are indicated for obtaining the price flexibilities for soybean meal and soybean oil with the use of the estimate of the quantity of soybeans processed instead of meal and oil quantities. In deriving the estimate of the price flexibility of processing demand for soybeans at the farm level, the estimated functions of the prices of meal and oil are first substituted in the soybean price equation. This step is necessary since meal and oil prices are both dependent on the quantity of soybeans processed. The same results would be obtained if the total derivative of the price of soybeans with respect to the quantity of soybeans processed were determined instead of making the substitutions indicated here.

1. Price flexibilities of demands for meal and oil. On the assumption that constant proportions of meal and oil are obtained in the processing of soybeans,

the corresponding quantities of meal and oil can be expressed as

$$Q_M = k_M Q_{BC} \quad \text{and} \quad Q_O = k \; Q_{BC}$$

where k_M and k_O are the constants of proportionality. With the use of these relationships, the price flexibilities of demands for soybean meal and soybean oil are computed as shown below. Let the symbols f_M and f_O represent the price flexibilities for the two products.

<u>Sub-model I</u>: The price flexibility of demand for soybean meal, at the point of means, is given by

$$f_M = \frac{\partial P_M}{\partial \hat{Q}_M} \cdot \frac{\overline{Q}_M}{\overline{P}_M}$$

Substituting the quantity relationship between meal and soybeans in the equation and then simplifying, we have

$$f_M = \frac{\partial P_M}{\partial (k_M \hat{Q}_{BC})} \cdot \frac{(\overline{k_M Q_{BC}})}{\overline{P}_M}$$

$$= \frac{\partial P_M}{k_M \; \partial \hat{Q}_{BC}} \cdot \frac{k_M \overline{Q}_{BC}}{\overline{P}_M}$$

$$= \frac{\partial P_M}{\partial \hat{Q}_{BC}} \cdot \frac{\overline{Q}_{BC}}{\overline{P}_M}$$

$$= b_{21} \; \frac{\overline{Q}_{BC}}{\overline{P}_M}$$

Similarly, the price flexibility for oil, at the point of means will be

$$f = \frac{\partial P_O}{\partial \hat{Q}_{BC}} \cdot \frac{\bar{Q}_{BC}}{\bar{P}_O} = b_{31} \frac{\bar{Q}_{BC}}{\bar{P}_O}$$

<u>Sub model II</u>: This sub-model assumes a constant price flexibility of demand. Using the results given in sub-model I, the price flexibility of demand for soybean meal is

$$f_M = \frac{\partial P_M}{\partial \hat{Q}_{BC}} \cdot \frac{\hat{Q}_{BC}}{P_M}$$

Manipulating the above equation gives

$$f_M = \frac{\partial P_M/P_M}{\partial \hat{Q}_{BC}/\hat{Q}_{BC}}$$

$$= \frac{\partial \log P_M}{\partial \log \hat{Q}_{BC}} = d_{21}$$

In the same way, the constant price flexibility of demand for soybean oil will be

$$f_O = \frac{\partial \log P_O}{\partial \log \hat{Q}_{BC}} = d_{31}$$

2. <u>Farm-level price flexibility of processing demand for soybeans</u>. P_M and P_O are eliminated from the fourth relationship by substituting their respective estimated functions in the soybean price equation. Since the interest is the relation between P_B and Q_{BC}, only the relevant parts of the substituted functions are indicated.

<u>Sub-model I</u>: The price equations may be expressed as follows:

$$P_M = b_{21}\hat{Q}_{BC} + \dots$$

$$P_O = b_{31}\hat{Q}_{BC} + \dots$$

$$P_B = b_{41}\hat{Q}_{BC} + b_{42}\hat{P}_M + b_{43}\hat{P}_O + \dots$$

Making the necessary substitutions,

$$\begin{aligned} P_B &= b_{41}\hat{Q}_{BC} + b_{42}(b_{21}\hat{Q}_{BC} + \dots) + b_{43}(b_{31}\hat{Q}_{BC} + \dots) \\ &\quad + \dots \\ &= b_{41}\hat{Q}_{BC} + b_{42}b_{21}\hat{Q}_{BC} + b_{43}b_{31}\hat{Q}_{BC} + \dots \\ &= (b_{41} + b_{42}b_{21} + b_{43}b_{31})\,\hat{Q}_{BC} + \dots \end{aligned}$$

And the price flexibility for processing demand for soybeans, f_B, at the point of means, will be

$$f_B = \frac{\partial P_B}{\partial \hat{Q}_{BC}} \cdot \frac{\overline{Q}_{BC}}{\overline{P}_B} = (b_{41} + b_{42}b_{21} + b_{43}b_{31})\,\frac{\overline{Q}_{BC}}{\overline{P}_B}$$

Sub-model II: Using the same procedure of substitution shown for sub-model I, the soybean price equation is expressed as

$$\text{Log } P_B = (d_{41} + d_{42}d_{21} + d_{43}d_{31}) \log \hat{Q}_{BC} + \ldots$$

which results in the constant price flexibility of

$$f_B = d_{41} + d_{42}d_{21} + d_{43}d_{31}$$

3. Relating the three price flexibility measures. The relationships between the farm-level price flexibility of processing demand for soybeans and the wholesale price flexibilities of demands for meal and oil can be obtained as follows:

Sub-model I: Rewriting the flexibility equation for f_B in (2), gives

$$f_B = b_{41} \frac{\overline{Q}_{BC}}{\overline{P}_B} + b_{42}b_{21} \frac{\overline{Q}_{BC}}{\overline{P}_B} + b_{43}b_{31} \frac{\overline{Q}_{BC}}{\overline{P}_B}$$

Introducing the mean prices of meal and oil in the equation,

$$f_B = b_{41} \frac{\overline{Q}_{BC}}{\overline{P}_B} + b_{42}(b_{21} \frac{\overline{Q}_{BC}}{\overline{P}_M}) \frac{\overline{P}_M}{\overline{P}_B} + b_{43}(b_{31} \frac{\overline{Q}_{BC}}{\overline{P}_O}) \frac{\overline{P}_O}{\overline{P}_B}$$

which can be written as

$$f_B = b_{41} \frac{\overline{Q}_{BC}}{\overline{P}_B} + b_{42} \frac{\overline{P}_M}{\overline{P}_B} f_M + b_{43} \frac{\overline{P}_O}{\overline{P}_B} f_O$$

Sub-model II: The relationship between the three price flexibilities are directly indicated by the equation for the price flexibility of processing demand for soybeans, that is

$$f_B = d_{41} + d_{42} + d_{42}d_{21} + d_{43}d_{31}$$

and thus,

$$f_B = d_{41} + d_{42}f_M + d_{43}f_O$$