AN ECONOMETRIC STUDY OF WORLD DEMAND FOR HIGH-PROTEIN MEAL

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Chung-liang Huang, Robert Jensen and David E. Kenyon

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VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
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INTRODUCTION

World production of oilcakes and meals (including fish meal) increased approximately 0.5 and 0.4 million tons annually in 1972 and 1973. This was an unusually small increase, for the average annual growth over the preceding decade had been about one million tons. Accompanying this small production increase in 1972 and 1973 was a worldwide expansion of exports of oilcakes and meals of 0.8 and 0.22 million tons. This expansion of exports in 1972 was greater than the average annual export increase of 0.65 millon tons during the sixties. In contrast, the uncharacteristically small increase in the 1973 export level could only be achieved by a reduction of exporters' stocks. Indeed, the reduction in U.S. and Canadian stocks alone (of soybean, rapeseed and linseed meals) was more than the increase in export levels of all oilcakes and meals between 1972 and 1973.[1]

As a result, the price of international protein feeds increased dramatically. The Food and Agriculture Organization (FAO) price index for all oilcakes and meals which had fallen to a level of 103 in 1971, started to rise

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[1] FAO Commodity Review and Outlook, 1973-1974, p. 101.

again in February 1972. The rapid rise in the price index continued to an average of 279 for 1973 in contrast to an average of 129 for 1972. Table 1 highlights recent production and export statistics by protein commodity group. Also shown in Table 1 are the FAO price indices for protein meals during recent years.

The difficult thing to explain about resulting prices is the intensity rather than the direction of the change. "Even with all the sophisticated models and analytical expertise within the profession,"[2] scarcely anyone correctly anticipated the magnitude of the price increases during late 1972 and early 1973.

The objectives of this study are to examine the degree of interdependency among countries in production, consumption, and trade of high-protein meals[3] and to explore the implications of this interdependency among international markets of high-protein meals. This study was undertaken to identify and measure empirically the underlying economic forces, interrelationships, and processes that determine and influence the price behavior of the world is high-protein meal market. More specifically, the objectives of this study were:

1. To develop an econometric model of world protein meal economy that isolates components of foreign and domestic demands.

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[2] J. S. Plaxico and D. E. Ray, "Implications for Agricultural Economists," American Journal of Agricultural Economics, Vol. 55, No. 3 (August 1973), p. 399.

[3] High-protein meals as defined for this study include oilseed meals such as soybean, cottonseed, peanut, sunflowerseed, rapeseed, linseed, copra, and palm kernel meals, and fish meal. Animal, grain, and synthetic proteins are excluded.

Table 1. Total World Production and Trade of Oilcakes.

	1966-70 Average	1970	1971	1972	1973[a]	1972/ 1971	1973/ 1972
	- - - -	- - - -	- - thousand tons	- - - -	- - - -	- -% Change	- -
Total Production	23,280	25,530	26,590	27,050	27,460	2	2
Soybean	11,480	12,900	13,470	14,430	15,710	7	9
Cottonseed	2,980	3,020	3,020	3,340	3,600	11	8
Groundnut	2,090	2,170	2,330	2,380	1,930	2	-19
Sunflowerseed	1,410	1,490	1,420	1,460	1,430	3	- 2
Rapeseed	970	1,060	1,360	1,390	1,320	2	- 5
Linseed	600	690	780	550	460	-29	-16
Copra	240	250	280	320	300	14	- 6
Palm Kernel	120	130	130	120	130	- 8	8
Fish Meal	3,130	3,540	3,480	2,770	2,310	-14	-17
Total Export[b]	10,210	12,020	12,280	13,120	13,340	7	2
Soybean	5,060	6,920	7,160	7,850	9,100	10	16
Cottonseed	520	570	490	550	560	12	2
Groundnut	1,110	980	890	920	860	3	- 7
Sunflowerseed	430	360	270	270	320	0	19
Rapeseed	250	300	470	470	490	0	4
Linseed	310	290	380	370	290	- 3	-22
Copra	200	190	210	240	220	14	- 8
Palm Kernel	80	90	100	110	90	10	-18
Fish Meal	1,970	1,990	1,970	1,950	1,010	- 1	-48
FAO Price Index (1964-66 = 100)							
All Cakes and Meals	99	107	103	129	279	25	116
Vegetable Oilcakes[c]	100	104	103	125	268	21	114
Fish Meal	95	117	104	141	315	36	123

[a]Preliminary.

[b]Including the meal equivalent of oilseed.

[c]Includes series for copra, cottonseed, groundnut, linseed and palm kernel cakes, as well as for soybean and sunflowerseed meals.

Source: FAO Commodity Review and Outlook 1973-1974, pp. 102-104.

2. To obtain parameter estimates of the economic model.
3. To examine the statistical results and determine if they are in agreement or disagreement with economic theory and statistical evidence available.
4. To analyze the economic implications of the estimated structural model and use it as a basis for evaluating policy considerations and/or short-term forecasting instruments for high-protein meal prices and utilization.

More accurate and adequate information of this nature would be useful to better assess the effects of foreign demand and supply changes on the U.S. domestic markets. Also, an improvement in the ability to predict future values of economic variables would allow the consequences of economic policies to be estimated. The results of the study, when appraised in the light of the information provided, should be helpful to many groups. Among whom are producers, producer organizations, business firms, and policy makers in government.

The procedure of this study generally follows the sequence of the objectives mentioned above. The assumptions and the development of the theoretical framework of the economic model to be used in the present study are discussed in the following section titled Economic Model. In the section Statistical Procedures and Results, the emphasis is focused on the statistical results obtained from the three-stage least squares estimator and comparisons of results reported by other researchers. The last section contains a summary of the major results obtained and the implications of the statistical results for policy considerations. Finally, Appendix A contains the data that were used in this study. Appendix B and C contains the statistical results obtained from ordinary least squares (OLS) for structural and reduced form equation estimates, respectively. The statistical results obtained from two-stage least squares (2SLS) procedure are reported in Appendix D.

ECONOMIC MODEL

This study was undertaken to examine and analyze the world economy of high-protein meals. Although protein meal and oil are joint products of the soybean crushing industry, each is part of a more or less distinct sub-sector of the economic structure because of the differences in their utilization. A certain degree of interrelatedness is expected to exist between these sub-sectors, but this relationship is probably much less complex and weaker than that within the sub-sectors. Studies on the oil sector, therefore, were not included in this study.

The economic model used to represent the world demand structure for high-protein meal is based on the following assumptions:

1. The interest of this study is concerned primarily with the behavior relationships of demand and prices for the United States and foreign economies. Factors that affect production will be ignored.
2. The United States is considered as a single buying market for high-protein meals. Other important buying markets are assumed to exist outside the United States, but these are aggregated into another market. In addition, it is assumed that domestic and foreign markets at wholesale level consist of a large number of utility and profit-maximizing buyers and sellers who possess no perceptible individual market power.
3. With respect to commodities, the demands for high-protein meals to be considered are divided into two categories:

soybean meal and other high protein meal, which includes cottonseed, peanut, sunflowerseed, linseed, copra, palm kernel, rapeseed, and fish meals.

4. The regional supply of protein meals may be regarded as exogenous or as endogenous variables which can be determined jointly within the model. More specifically, the consideration depends upon whether the region is a net exporting or importing region of a protein meal. The regional supply of a protein meal may be considered as predetermined if the region is a net exporter of that protein meal. On the other hand, it becomes endogenous if the region is a net importer of that protein meal. On an annual net trade basis, the United States is a net importing region of other high-protein meal and a net exporting region of soybean meal. The United States trade is characterized by more fish meal imports than exports of other oilseed meals, such as linseed meal and peanut meal. The rest of the world is a net importing region of soybean meal and a net exporting region of other meal.

5. While the annual variations in inventory may be considered as an important factor influencing the price and demand conditions in the producing and exporting countries, it seems reasonable to assume that production and imports are to be used immediately in the consuming countries. Consequently, it is assumed that the United States does not hold any stock of other meal, and the rest of the world does not hold

any stock of soybean meal. The relation for the foreign demand for inventory of other high-protein meal is omitted because data are not available on this variable.

The major economic relations of world demand and supply of high-protein meals are presented in Figure 1. For ease of recognition, circles are used in the figure to represent prices, while boxes are used to represent quantities. Solid lines indicate a causal relationships, while broken lines show quantity flows. Arrows give the directions of influence or flow.

Figure 1 is simplified in the sense that it describes only the nature of the interdependency between one exporting country (Country A) and one importing country (Country B) producing one oilseed converted into a vegetable oil product and an oilcake product. Diagrams of this kind can help to "think through" basic factors and relationships involved in the meal economic structure. For example, in response to adverse weather conditions (upper left corner), there is a decline in Country A's production of oilseed, and consequently its meal production. This decrease in production will have an effect on stock withdrawal, domestic consumption, and export which, in turn, causes the price to rise in Country A. Furthermore, a higher meal price in Country A also implies a higher import price of protein meal to Country B that imports and consumes Country A's meal exports. After some adjustment lags, trade and consumption of protein meal in both regions can be expected to be reduced toward a level more in accordance with the new price level. This process will continue, with the levels of inventory decreasing and prices rising until a point is reached where the rate of consumption declines below the production rate and the stocks begin to accumulate. At the same time, there will be effects on the substitute products

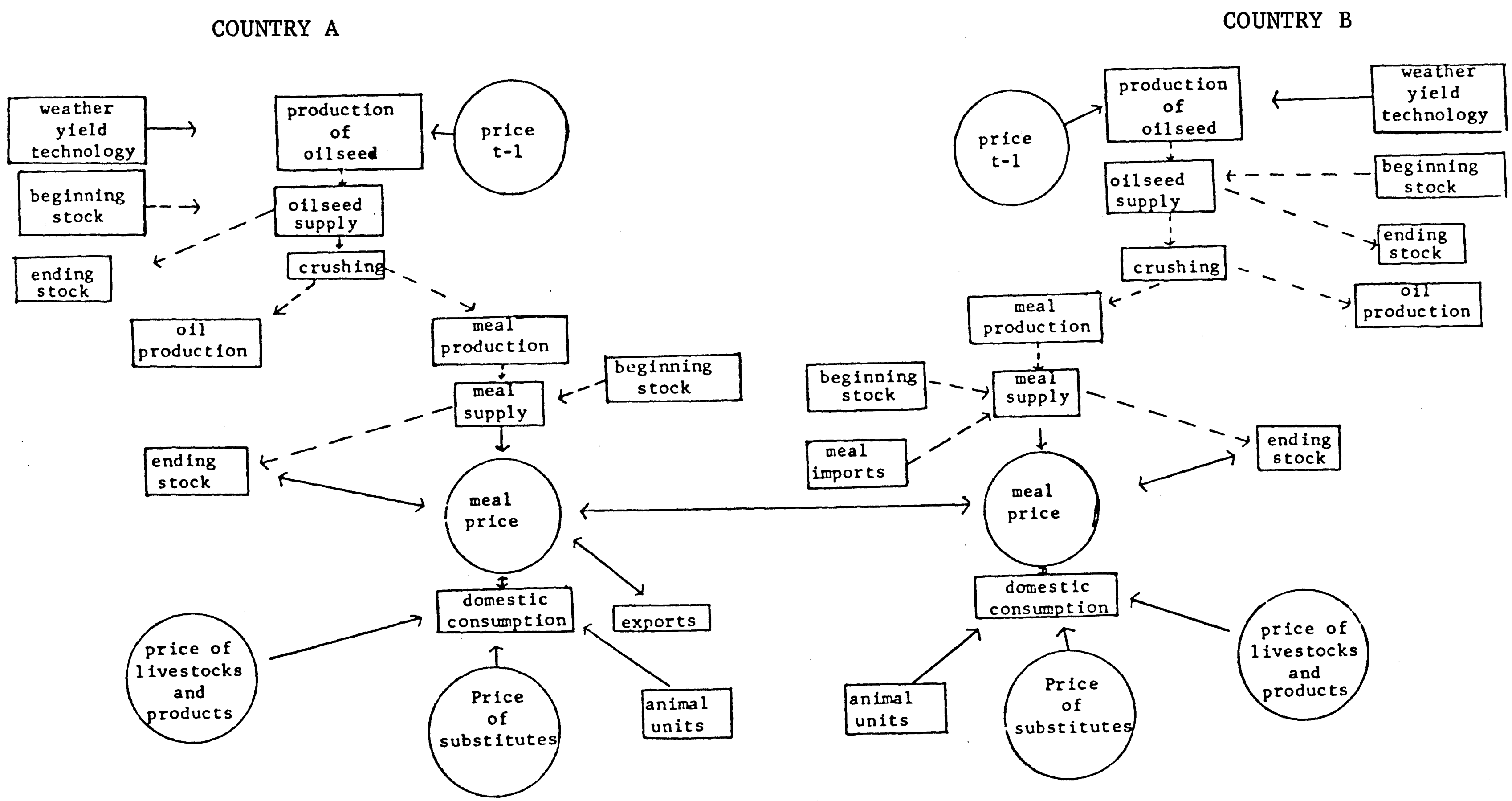

Figure 1. Flow Chart for World Demand and Supply of High Protein Meals.

which should not be overlooked. As consumption for one meal declines because of increases in prices, demand is shifted to other protein supplements. Nevertheless, if the quantity of other protein supplements supplied remains constant, the price of other protein meal will tend to increase. These changes, in turn, will cause readjustments in the consumption of various protein meals in both regions and in the quantity of protein meal traded between these two regions.

As shown in Figure 1, there are a number of economic variables that are components of the demand and price structure of high-protein meal markets, and they are affected and interrelated to each other. It is important to note that these interrelationships must be considered simultaneously. A system of equations that allows for the many aspects of simultaneity is needed to adequately describe the world economy of high-protein meals and to estimate the appropriate parameters in the structural demand equations. Moreover, all the above-mentioned adjustments among the economic variables will take place over a period of time. If the time elapsed between observations of these variables is long enough, then, the adjustment process might be expected to include all the variables and sectors considered in this price-demand mechanism. In this case, the value of all the endogenous variables included in the diagram will be simultaneously determined within the specified time period. Thus, a system of simultaneous equations appears to be an appropriate approach in the present study.

The economic model consists of eight behavioral relations and four supply-utilization balancing equations. The model is presented in Table 2. Equation 1 represents the U.S. price of soybean. Equations 2 through 5 represent the consumption relationships for each region for soybean meal and

Table 2. The Economic Model.

Behavioral Relationships

1. U.S. Soybean Price Relation

   P^*_{sb}, P^*_{sm}, P^*_{smf}, Q^*_{sms}; P_{so}, some Z's

2. U.S. Demand for Soybean Meal

   Q^*_{smc}, P^*_{sm}, P^*_{om}, P^*_{smf}, P^*_{omf}; P_l, some Z's

3. U.S. Demand for Other High Protein Meal

   Q^*_{omc}, P^*_{om}, P^*_{sm}, P^*_{omf}, P^*_{smf}; some Z's

4. Foreign Demand for Soybean Meal

   Q^*_{smf}, P^*_{smf}, P^*_{omf}, P^*_{sm}, P^*_{om}; some Z's

5. Foreign Demand for Other High Protein Meal

   Q^*_{omf}, P^*_{omf}, P^*_{smf}, P^*_{om}, P^*_{sm}; some Z's

6. U.S. Exports of Soybean Meal

   Q^*_{smx}, P^*_{sb}, P^*_{om}, P^*_{smf}, P^*_{omf}; P_{so}, some Z's

7. U.S. Imports of other High Protein Meal

   Q^*_{omi}, P^*_{om}, P^*_{sm}, P^*_{omf}, P^*_{smf}; some Z's

8. U.S. Ending Stocks of Soybean Meal

   Q^*_{sms}, P^*_{sm}, Q^*_{smx}; P_{so}, some Z's

Supply-Utilization Identities in the United States

9. Soybean Meal: $Q_{smpu} + Q_{smsl} = Q^*_{smc} + Q^*_{smx} + Q^*_{sms}$

10. Other Meal: $Q_{ompu} + Q^*_{omi} = Q^*_{omc}$

Supply-Utilization Identities in the Rest of the World

11. Soybean Meal: $Q_{smpf} + Q^*_{smx} = Q^*_{smf}$

12. Other Meal: $Q_{ompf} = Q^*_{omf} + Q^*_{omi}$

Continued on next page.

Table 2. (Continued)

where:

Psb^* = Price of soybeans, Illinois country shipping point, dollar per metric ton. (Endogenous).

Psm^* = Price of soybean meal, 44% protein, Decatur, in dollar per metric ton. (Endogenous).

$Psmf^*$ = Price of soybean meal, Canadian 45% protein, c.i.f., European ports, dollar per metric ton. (Endogenous).

$Qsms^*$ = U.S. ending stocks of soybean meal, including meal equivalent of soybean stock, thousand metric tons. (Endogenous).

Pso = Price of soybean oil, Decatur, crude tank cars, dollar per metric ton. (Predetermined).

Z's = Unspecified predetermined variables.

$Qsmc^*$ = U.S. domestic consumption of soybean meal, thousand metric tons. (Endogenous).

Pom^* = Composite average annual price of other high protein meals in the United States, dollar per metric ton. (Endogenous).

$Pomf^*$ = Composite average annual price of other high protein meals, c.i.f., European ports, dollar per metric ton. (Endogenous).

Pl = Price level of livestock and livestock products in the United States. (Predetermined).

$Qomc^*$ = U.S. consumption of other high protein meals in terms of 44% protein soybean meal equivalent, thousand metric tons. (Endogenous).

$Qsmf^*$ = Foreign consumption of soybean meal, thousand metric tons. (Endogenous).

$Qomf^*$ = Foreign consumption of other high protein meals, in terms of 44% soybean meal equivalent, thousand metric tons. (Endogenous).

$Qsmx^*$ = U.S. net exports of soybean meal, including meal equivalent of soybean exports, thousand metric tons. (Endogenous).

$Qomi^*$ = U.S. net imports of other high protein meals, in terms of 44% soybean meal equivalent, thousand metric tons. (Endogenous).

Continued on next page.

Table 2. (Continued)

Qsmpu = U.S. annual production of soybean meal, thousand metric tons. (Predetermined).

Qsmsl = U.S. beginning stocks of soybean meal at January 1, including meal equivalent of soybeans in thousand metric tons. (Predetermined).

Qompu = U.S. annual production of other high protein meals, in terms of 44% soybean meal equivalent, thousand metric tons. (Predetermined).

Qsmpf = Foreign production of soybean meal, thousand metric tons. (Predetermined).

Qompf = Foreign production of other high protein meals, in terms of 44% soybean meal equivalent, thousand metric tons. (Predetermined).

P_c = Price of corn received by farmers, dollar per metric ton. (Predetermined).

other meals. Equations 6 and 7 are trade relations for soybean meal and other meals. Equation 8 represents the U.S. demand for ending stocks of soybean meal. Finally, equations 9 through 12 represent a set of identities indicating that the total use of high-protein meals must be equal to total availabilities in the United States and in the rest of the world, respectively. In what follows, the formulation and economic interpretation of the behavioral relationships presented in Table 2 are briefly discussed.

U.S. Soybean Price Relation. The price of U.S. soybeans can be expressed jointly in a function with prices of soybean meal in domestic and foreign markets, quantities of soybean meal stocked, and other predetermined variables. Soybean meal and oil are joint products of the crushing industry. To obtain one of the products, the other must be produced. The market price of beans may be affected directly by the price of meal and oil. In addition, one would also expect this price of soybeans to be influenced by the demand conditions in the foreign market, which will be reflected in their demand for the U.S. exports and the price of soybean meal in the foreign market. The U.S. inventory demand for soybeans and soybean meal is also expected to join the market demand forces to influence the price of soybeans, as shown in Equation 1, Table 2.

The first predetermined variable is the U.S. price of soybean oil which is, by assumption, an exogenous variable in the present study. Among those unspecified predetermined variables, the level of the U.S. beginning stocks of soybean meal is also expected to have an impact on the soybean price levels. On *a priori* expectation, the higher the opening stock level, the lower will be the price of soybeans. The price of corn is another logical determinant of U.S. soybean price. This variable may be regarded as representing the price of substitutes. Theoretically, one would expect the prices of competing products to move in the same direction.

U.S. Demand for Soybean Meal. The U.S. Domestic consumption of soybean meal is a derived demand for livestock and livestock products. The decision concerning the consumption of soybean meal is made by livestock producers. However, this decision is complicated, as there is close substituability between soybean meal, other protein meals, and the use of other feed stuffs in producing livestock. The decision to purchase feeds is closely related to the determination of the quantity of livestock to produce. The producer's input demand depends upon the input prices and the price of the product he produces.[4] Furthermore, since practically all high protein meals are traded on the international market, meal prices in foreign markets are also expected to have an impact on the domestic price levels.

To the extent that livestock producers may adjust the rate of feeding and the quantities of products marketed, depending on the current price of feeds, and thus influence the current price of livestock products, it is doubtful that the price of livestock and livestock products (P_1) may be regarded as entirely predetermined.[5] Nevertheless, the variable P_1 may be

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[4]For a mathematical derivation of the derived demand, see James M. Henderson and Richard E. Quandt, Microeconomic Theory: A Mathematical Approach (2nd ed.; New York: McGraw-Hill Book Company, 1971), p. 69. See also R. G. D. Allen, Mathematical Analysis for Economists (London: Macmillan & Co., Ltd., 1938), pp. 369-74.

[5]In the most recent years, it is evident that the livestock industry responded to the rather sharply rising feed prices by cutting back on feedstuff ingredients where possible, grazing more cattle on grass, and cutting back on livestock feeding and animal units, particularly in the case of poultry and hogs.

considered as given, largely because the sales of livestock products at times differ considerably from their production.[6] This is more the case for cattle and hogs, which require a longer production time to attain market weight, than for poultry, which has a relatively short production period. In fact, King argues that, historically, a large proportion of the livestock products sold during the first seven months of the marketing year are produced on feed from the previous year's crop, and would be sold during the period regardless of price.[7] Although prices of livestock and livestock products are, to some extent, determined simultaneously with the prices of feeds and quantity of feed fed; for this formulation prices of livestock and livestock products are assumed to be predetermined.

Among the unspecified factors, Z's, which are expected to have some influences on the U.S. demand for soybean meal, are the animal units of hogs, cattle and poultry, and consumption of feed grains in the United States. Animal units contribute to this demand relation in a manner similar to the population effect in a retail demand equation.[8] Animals are the consumers of protein meals. To the extent that there is no a priori knowledge about the relationship which may exist between the demand for soybean meal and feed grains, it is appropriate to assume that they can be either substitutes or

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[6] Richard J. Foote, "A Four-Equation Model of the Feed-Livestock Economy and Its Endogenous Mechanism," Journal of Farm Economics, Vol. XXXV, No. 1 (February 1953), p. 46.

[7] Gordon A. King, The Demand and Price Structure for Byproduct Feeds, USDA, Technical Bulletin No. 1183, August 1958, p. 82.

[8] It should be noted that the number of animal units have some of the limitations indicated for the variable P_1, in that prices of feedstuffs may influence, to some extent, the animal units fed during the current period.

complements. In fact, Moe and Mohtadi found that in the EEC, the relationships were competitive due to the high price of grains relative to that of meal; but in the United States, Japan, Canada and Western Europe, a complementary relationship existed.[9]

Based on the same theoretical and logical considerations, the demand relation for other high-protein meal in the United States, and the demand for soybean and other meals in the rest of the world are formulated in a similar manner as that of relation 2 and expressed in relations 3 through 5 in Table 2.

U.S. Exports of Soybean Meal. The demand by exporters for U.S. soybean meal is expressed as jointly determined along with the prices of soybeans and other high-protein meal in the United States and in the rest of the world (Equation 6, Table 2). It is noted that approximately 73 percent of the U.S. soybean meal exports are in the form of beans. Thus, it is likely that European and other foreign crushers will respond directly to the price of soybeans and import as much meal and oil as possible in the form of beans in any given year. Consequently, it may be expected that exports would be more responsive to the price of soybeans rather than to the price of soybean meal.

The U.S. exports of soybean meal were assumed to be negatively related to the price of soybean oil. It is argued that, historically, oil has been certainly more important than meal, and in any given year, low oil prices

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[9] L. E. Moe and Malek M. Mohtadi, World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, with Emphasis on Trade by the Less Developed Countries, USDA, Foreign Agricultural Economic Report No. 71 (March 1971), p. 85.

might encourage exports of soybeans for storage purposes.[10] In his 1967 studies, Vandenborre concluded that meal exports, in the past, have been influenced by price movements in the oil sector.[11] Therefore, the price of soybean oil was introduced into the U.S. soybean meal exports relation.

Among some of the Z's, the animal units, or per capita meat production, and the total availabilities of high-protein meals and feedgrains in the rest of the world may be specified. If real income continues to rise in the rest of the world, it seems quite certain that there will be substantial increases in both the consumption and the production of meat. This likelihood has important implications for the derived demand for protein feeds in the foreign countries. The demand for soybean meal should increase with the expansion of livestock production, and with more intensive feeding practices, therefore, foreign animal units were included in the export model. The export demand for soybean meal is somewhat different from the U.S. domestic demand in that soybean meal has to meet strong competition from other high-protein meals produced and consumed largely outside the United States, such as fish and rapeseed meals. In addition, there will also be competition from the foreign produced feedgrains. Consequently, the total availabilities of high-protein meals and feedgrains in the rest of the world are expected to be negatively related to the exports of U.S. soybean meal.

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[10] R. J. Vandenborre, "Demand Analysis of the Markets for Soybean Oil and Soybean Meal," Journal of Farm Economics, Vol. 48, No. 4, Part I (November 1966), p. 924.

[11] R. J. Vandenborre, An Econometric Analysis of the Markets for Soybean Oil and Soybean Meal, University of Illinois, Agricultural Experiment Station Bulletin 723, March 1967, p. 33.

An analogous formulation can be extended to the exports of other high-protein meal from the rest of the world. Relation 7, Table 2, is presented in terms of the United States import demand for other high protein meal rather than the export demand for other high protein meal in the rest of the world. In a two region economy, one region's exports are always equal to the other region's imports. The distinctions between exports and imports in the present model are trivial. Nevertheless, by specifying a U.S. importing function, the processes and work involved in the statistical fitting are substantially simplified.

U.S. Ending Stocks of Soybean Meal. In addition to the demand for current consumption and exports of soybean meal, the demand for inventory is another important element of total demand. While the demands for soybean meal consumption and exports are originated by livestock producers and exporters, respectively, the demand for soybean meal inventory is forthcoming from the processors and handlers who expect to profit from holding stocks from the current period for sale in the future. Furthermore, stocks are also carried over in a passive way during periods of seasonally high production.

As shown in relation 8, Table 2, the price of soybean oil was specified as one of the predetermined variables for similar reasons as discussed for the exports relation. It should be noted that meal stocks can be either meal or whole beans; however, there are fewer inventories of meal, because beans are cheaper and more convenient to stock than meal. More significantly, holding stocks in bean form provides more crusher flexibility to meet the changes in the demand for soybean products.

Since ending stocks may be influenced directly by the demand and supply conditions prevailing in the domestic and foreign markets, inventory can be considered as residual from the current consumption and export commitments. The behavioral relation for soybean meal stocks in this model is much less complex than it might be in a model focusing on inventory behavior in the soybean economy. Without a more sophisticated model for the inventory demand,[12] there is no *a priori* basis for specifying the exact behavioral relationships between the ending stocks and the price variables. In his 1967 study, Vandenborre reported that the price of soybean meal was of no importance in explaining meal stock, whereas the price of soybean oil was found to be negatively related to the amount of meal in stock. However, for the soybean oil stock relation, a positive relationship between oil stocks and price of oil was obtained. Vandenborre argues this is because that some stocks are held for speculative purposes.[13] If stocks are indeed held for price speculation, one would expect stocks to be accumulated at low rather than high price levels. Nevertheless, if the inventory demand is for "pipeline" stocks needed for current crushing requirements and export commitments, it seems reasonable to argue that stocks tend to be built up passively during the period when domestic and foreign demands are relatively weak.

The production of soybean meal is another predetermined variable that can be expected to affect the stock demand for soybean meal in the United

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[12] See, for example, George W. Ladd, *Distributed Lag Inventory Analyses*, Agricultural and Home Economics Experiment Station, Iowa State University of Science and Technology, Research Bulletin 515, April 1963.

[13] R. J. Vandenborre, *An Econometric Analysis of the Markets for Soybean Oil and Soybean Meal*, p. 35.

States. Based on *a priori* reasoning, the level of soybean meal stocks at the beginning of the time period is another logical determinant in the stock relation. The higher the level of opening stocks at the beginning of a given year, the smaller would be the expected increases in total inventory over the year. Ending stocks of soybean meal were hypothesized to be positively related to the production and beginning stocks of soybean meal and negatively related to the prices of soybean meal and oil.

STATISTICAL PROCEDURES AND RESULTS

The economic model was used as a basis for the statistical estimation of the parameters of the twelve-equation simultaneous model of the high protein feed market. Economic theory provides limited guidance regarding the functional form of the behavioral relationships to be estimated. In this analysis, the form of equations was presumed linear in actual numbers. Linearity in certain definitional identities required this restriction. The sample period included the 18-calendar-year observations, beginning with 1955 and ending with 1972. The structure of the market was assumed not to have changed during this period of time. The true relationships and parameters which underlie and fully determine the operation of this high-protein feeds sector are assumed unchanged during the 1955-72 time period. A further discussion of the actual data used and their sources is presented in Appendix A.

Method of Estimation

The conventional identification criteria indicates that all behavioral equations specified in the system are overidentified. Several estimation procedures are available for estimating structural parameters in this model. In general, they are either single-equation methods, which can be applied to each equation of the system one at a time, or complete system methods, which are applied to the system as a whole. The former approach is referred to as a limited-information method and the latter as a full-information method.

If these methods of estimation are not used, persistent bias in the estimation of the structural parameters of the equations can be introduced.[14]

While two-stage least squares (2SLS) is a limited-information method; three-stage least squares (3SLS) is a full-information method. Zellner and Theil have shown that 3SLS estimator may be more efficient than 2SLS.[15] That is, 2SLS estimator, although consistent, is in general not asymptotically efficient because it does not take into account the correlation of the structural disturbances across equations. When there is no such correlation, 3SLS estimates will be identical to 2SLS estimates. Thus, there is a gain in asymptotic efficiency of 3SLS over 2SLS only if the structural disturbances are contemporaneously correlated across equations.

Preliminary investigations indicated substantial correlation between the observed residuals of the fitted equations obtained by 2SLS. In addition, preliminary analyses also suggested that an estimator of reduced form coefficients derived from 3SLS lead to a smaller forecast error than an estimator derived from 2SLS. Accordingly, the structural coefficients in this study were obtained using 3SLS procedure.

Test of Statistical Significance and Inference

The conventional tests used in testing various regression related hypotheses are not valid for 2SLS and 3SLS estimates, because the properties of

[14] J. Johnston, Econometric Methods (2nd ed., New York: McGraw-Hill Book Company, 1972), pp. 342-44; and W. C. Hood and T. C. Koopmans, ed., Studies in Econometric Method, Cowles Commission Monograph No. 14 (New York: John Wiley & Sons, Inc., 1953), pp. 131-35.

[15] A. Zellner and H. Theil, "Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations," Econometrica, Vol. 30, No. 1 (January 1962), pp. 54-78.

these estimators are only asymptotic. The estimated variances and standard errors are estimates of asymptotic variances and standard errors, not estimates of variances and standard errors for finite sample sizes. Because no exact tests are available, the relative magnitude of the estimated coefficient over its estimated standard error is used in this study for testing the significance of the variable and for determining which variables should be retained in the regression equation. Thus, a regression coefficient will be retained if its absolute value is greater than its estimated standard error, provided its sign is theoretically correct.[16]

Although the presence of multicollinearity among the independent variables will not affect the overall goodness of fit,[17] it does hamper the efforts of obtaining precise and stable estimates of coefficients for correlated variables. According to Klein, multicollinearity among two independent variables is harmful if the correlation between them is greater than the overall degree of multiple correlation of the regression equation.[18] This simple criterion has been extended by Farrar and Glauber to consider the coefficient of multiple determination, R_i^2, between each independent variable and the remaining variables in the independent variable set. Specifically, "a variable x_i, then, would be said to be 'harmfully multicollinear' only if

[16]This criterion was used by Houthakker and Taylor in their study of consumer demand in the United States. See H. S. Houthakker and L. D. Taylor, Consumer Demand in the United States 1929-1970, (Massachusetts: Harvard University Press, 1966), p. 8.

[17]In fact, the estimate of the sampling variance of the entire equation is not affected or biased by multicollinearity unless the multicollinearity is perfect. See J. Johnston, op. cit., pp. 162-3.

[18]L. R. Klein, An Introduction to Econometrics (New Jersey: Prentice-Hall, Inc., 1962), p. 101.

its multiple correlation with other members of the independent variable set, R_{xi}, were greater than the dependent variable's multiple correlation with the entire set."[19] Farrar and Glauber also developed a series of tests based on the Chi Square, F, and t distributions to identify the presence, location, and patterns of the interdependence among the independent variables, respectively, These tests were used in this study for detecting the degree of multicollinearity among the independent variables in each fitted equation.

Results of the Statistical Estimation

The results of the 3SLS estimation process are presented in this section. The standard error of each coefficient appears in parentheses. The resulting estimates are examined to determine whether they are in agreement or disagreement with economic theory and other available evidence. Because much of the preliminary work in specification of the model was done with ordinary least squares (OLS) and, also, because the 3SLS estimation involved the 2SLS procedure as a middle step, the OLS structural estimates, the reduced form equations estimated at the first stage of 2SLS procedure, and the results of 2SLS estimation are presented for comparison in Appendices B, C and D, respectively.

U.S. Soybean Price Relationship

The price of U.S. soybeans was estimated as a function of U.S. prices of soybean meal and soybean oil, and the beginning stocks of soybean meal. Thus,

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[19] D. E. Farrar and R. R. Glauber, "Multicollinearity in Regression Analysis: The Problem Revisited," The Review of Economics and Statistics, Vol. 49, No. 1 (February 1967), p. 98.

$$3SLS\ P^{*}sb = -3.549 + .9508P^{*}sm + .1627Pso - .0007705Qsmsl$$
$$(.1073) \quad (.0254) \quad (.0003093)$$

All the coefficients displayed the expected sign and were relatively larger than their standard errors. The Farrar-Glauber test indicated a high correlation between the price of soybean meal and the stock variable. However, this was not considered to be a problem, because this correlation was significantly lower than the overall coefficient of correlation for the entire equation. The actual values and the computed values obtained from 3SLS are presented in Figure 2. While the fitted equation trades most of the important turning points in the price of soybeans, the equation wrongly predicted turning points for the price of soybeans in both 1957 and 1971.

Using the results obtained from 3SLS, one can infer from the coefficients that a 1% change in the price of soybean meal or oil was associated with a .75% or .39% change in the price of soybeans, respectively. A 1% change in the beginning stock of soybean meal affected the price of soybeans by 0.1% in opposite direction. The corresponding measures implied by Vandenborre (1970) for the period of marketing years 1948-1964 were .65% and .11% for soybean meal price and oil price, respectively.

U.S. Domestic Demand for Soybean Meal

The estimated U.S. domestic consumption of soybean meal equation does not incorporate all the variables included in its theoretical counterpart. Foreign prices of soybean meal and other high-protein meals were not included because the domestic and foreign prices are strongly correlated. Preliminary investigations also indicated that the price of livestock and livestock products and the price of corn were not significant in explaining the vari-

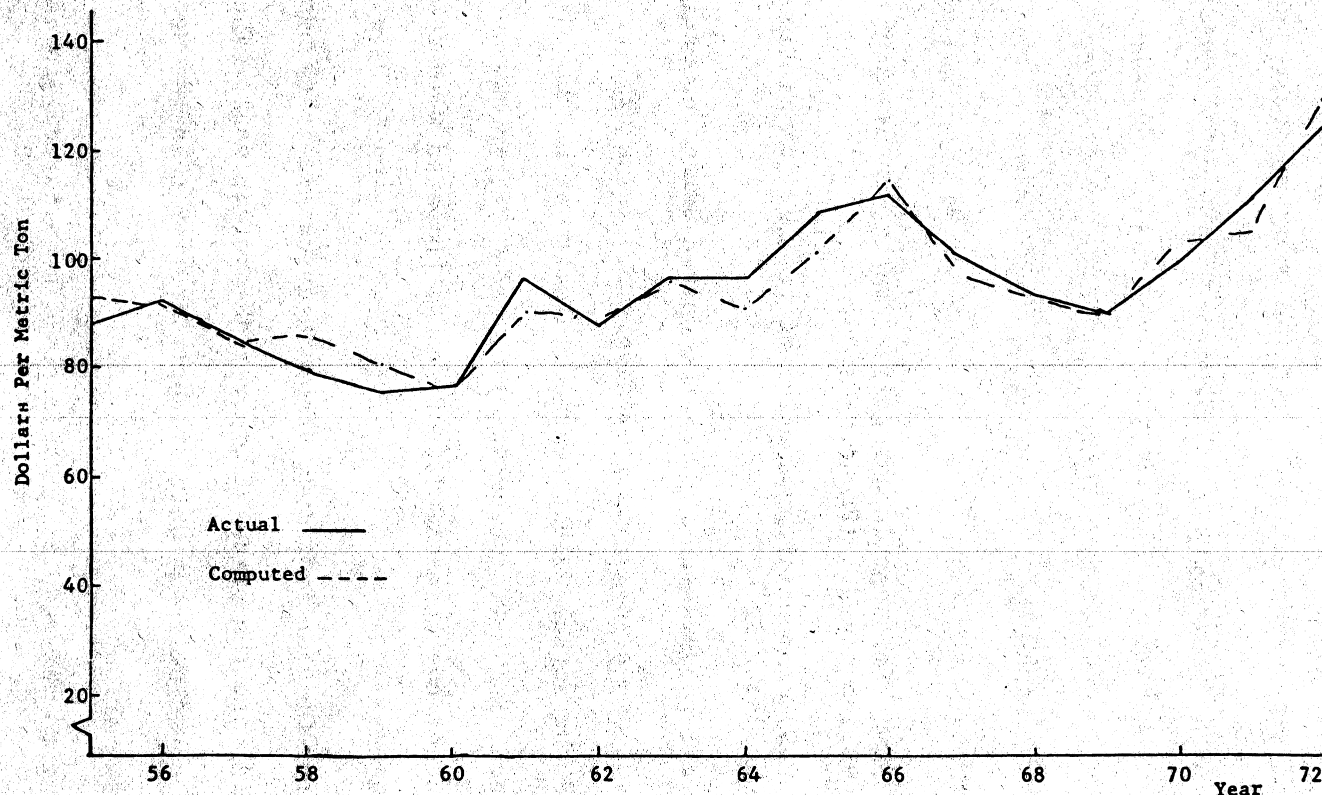

Figure 2. Average Wholesale Price of Soybeans, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

ation of the U.S. consumption of soybean meal during the period 1955-1972. However, the animal units of hogs and broilers were found to be highly related to the consumption of soybean meal in the United States during the same period of time. The fitted regression equation is presented as:

$$\text{3SLS } Q^*_{smc} = -3080. - \underset{(19.94)}{85.57} P^*_{sm} + \underset{(17.3)}{84.51} P^*_{om} + \underset{(.0109)}{.0534} Hog + \underset{(.283)}{3.499} Broil$$

where:

Hog = Number of hogs in the United States, thousand heads at January 1. (Predetermined)

Broil = U.S. commercial production of broilers in million heads. (Predetermined)

The overall goodness of fit for the United States domestic consumption of soybean meal can be observed from Figure 3. In general, the predicted values traced the actual values reasonably well during the period from 1955 to 1972. There were only two years, 1961 and 1971, in which the estimated equation produced the opposite directions as compared with the actual change of directions.

The Farrar-Glauber test indicates a high collinearity between the price of soybean meal and the price of other high-protein meal. The overall coefficient of correlation is only slightly greater than the correlation between these two prices.

According to the resulting estimates, the elasticities calculated at the means were -.73 for own price elasticity and .88 for cross elasticity with respect to the price of other meals. The price flexibility coeffi-

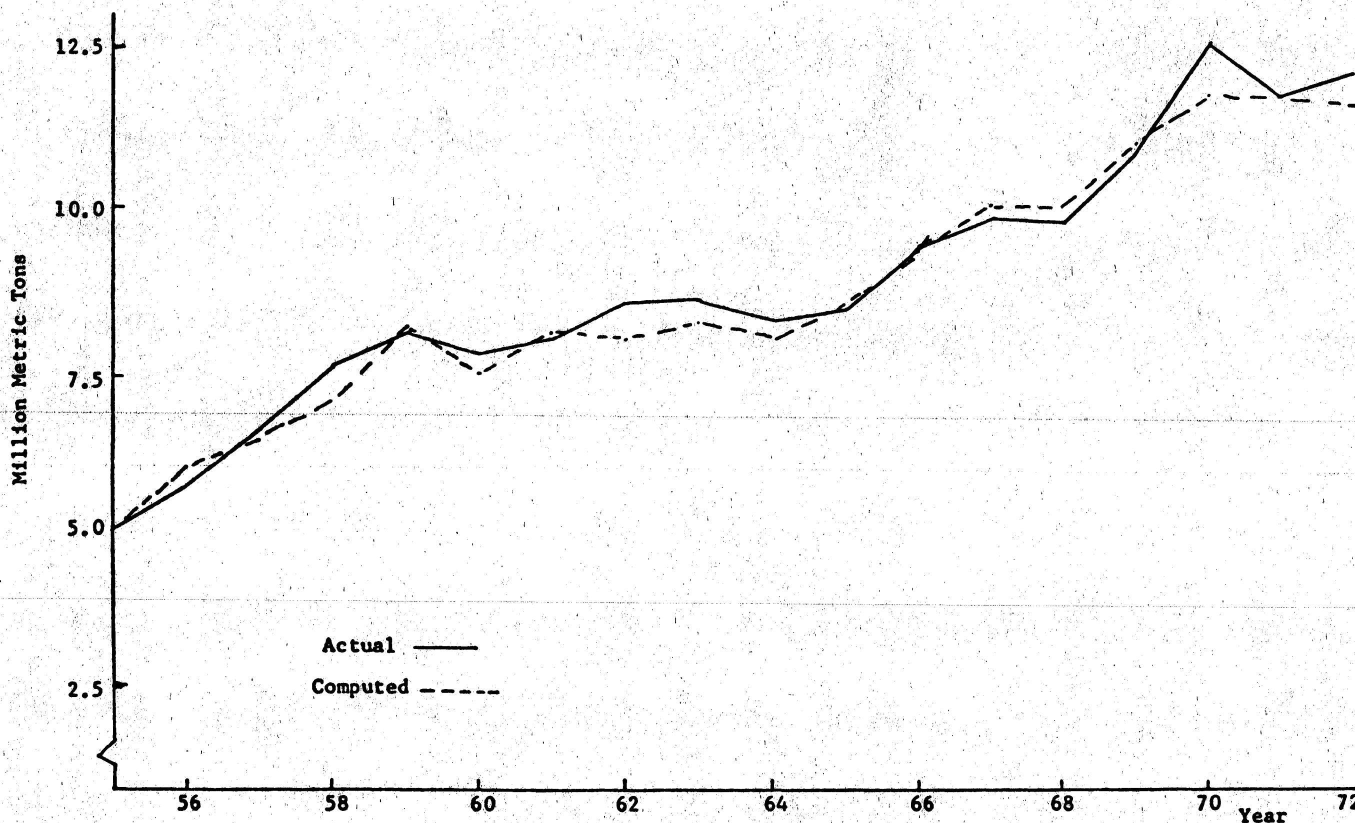

Figure 3. U.S. Consumption of Soybean Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

cients for soybean meal obtained by G. A. King[20] for the interwar and immediate postwar period were -.48 and -.58. These flexibilities implied price elasticities of -2.08 and -1.72, respectively. Houck (1963) in his study computed elasticities from price flexibility coefficients of -.89 to -.93 for the marketing years 1940-60. Another recent study by Houck (1968) indicated an elasticity of -.33 for the period 1946-64. Vandenborre (1967) obtained an elasticity of -.28 for the 1948-63 period and in his 1970 study -.44 for the 1948-64 period. The price elasticity implied in an article published in Feed Situation for the 1950-64 period was -.56.[21]

Direct comparisons of the cross elasticity of soybean meal demand, with respect to the price of other high-protein meal, are not available. However, Houck in his 1963 study indicated that a 1% increase in the quantity of high-protein feed available for feeding (excluding soybean meal) decreases the price of soybean meal by .68 percent, or an elasticity of approximately -1.47. Vandenborre (1967) indicated that a 1% increase in other high-protein feed availabilities decreases soybean meal consumption by .38%. Vandenborre in his 1970 study indicated that the cross elasticity with respect to supply of other high-protein feed is -.88.

U.S. Demand for Other High-Protein Meals

The U.S. demand for other high-protein meals is an aggregated demand for all high-protein meals specified in this study, except soybean meal. The results of the 3SLS procedure in estimating the U.S. consumption of other high-protein meals are:

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[20] G. A. King, op. cit., p. 113.

[21] Malcolm Clough, "Major Factors Influencing High-Protein Feed Prices," Feed Situation, Fds-213, ERS, USDA, April 1966, p. 26.

$$3SLS\ Q^*_{omc} = 5283. + 54.8P^*_{sm} - 49.07P^*_{om} - .09538Q^*_{smc}$$

$$(9.45)\quad(11.44)\quad(.03283)$$

$$-28.07P_c$$

$$(8.32)$$

A high degree of multicollinearity was detected among the prices of soybean meal and other meal, and the quantity of soybean meal consumed. The interdependency among these three variables was found to be greater than the dependent variable's multiple correlation with the entire set. Thus, it is likely that the estimated coefficients for these variables are less reliable because of the high degree of multicollinearity. As shown in Figure 4, the estimated equation traced most of the turning points during the period 1961-1972. However, variations in the consumption of other high-protein meal prior to 1961 were not satisfactorily explained by the fitted equation. It is conceivable that a structural change might have occurred between these two periods that caused the performances of the fitted equation in the 1955-61 period to be so different from the period of 1961-1972. In addition, although demand for various kinds of protein feeds may have fluctuated substantially from year to year, it is likely that, on the average, variations associated with individual high-protein feeds were balanced out in the process of aggregation. Such a high degree of aggregation, however, tends to average out the demand structure of the individual feeds, and here it may have hampered the attainment of good statistical results.

The direct price elasticity was computed to be -1.6, and cross elasticity was 1.47 with respect to the price of soybean meal and -.45 with respect to the price of corn.

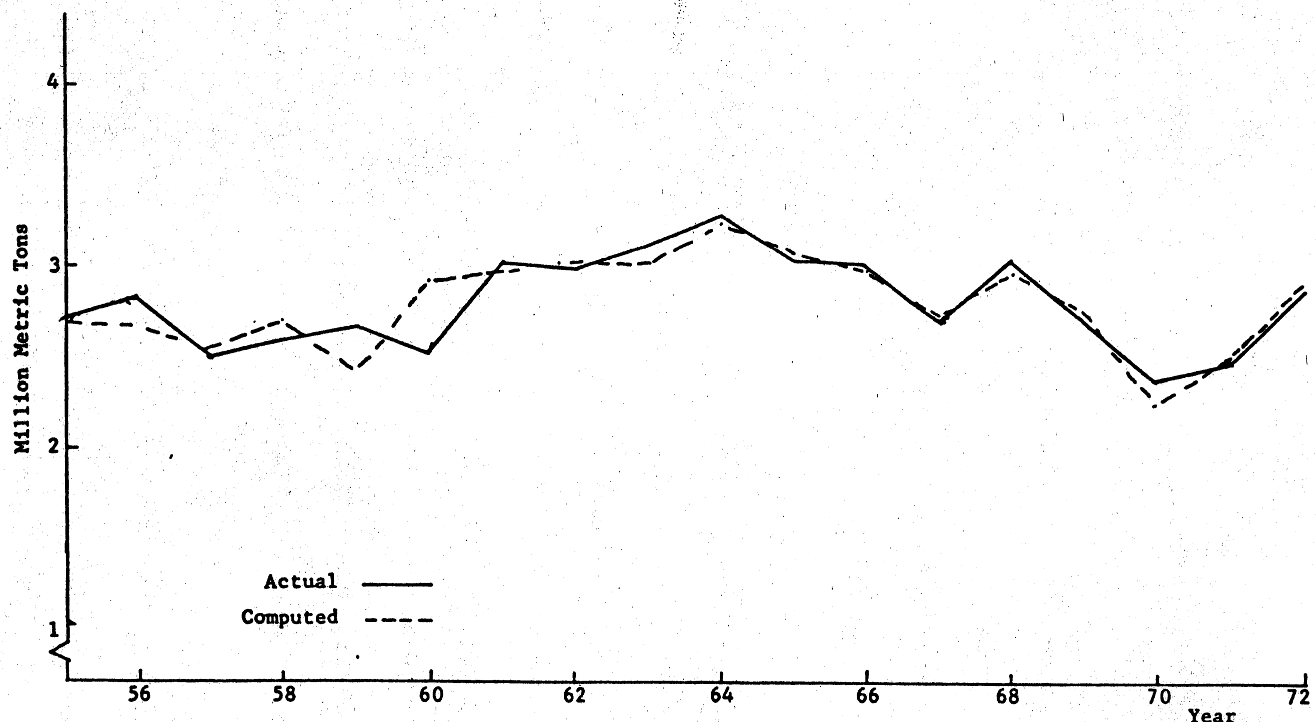

Figure 4. U.S. Consumption of Other High Protein Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

Direct comparisons of these elasticities are not available. In a study of the aggregated demand for all high-protein feeds, King estimated a direct price elasticity of -1.65, with cross elasticity of 0.68 for the price of feed grains.[22] For the limited information estimates of the Hildreth and Jarrett study, the elasticity of quantity of fed protein feeds is -1.84 with respect to the price of protein feeds and -.09 with respect to the price of feed grains.[23]

Results obtained from the present study and those of previous studies agree less as to the demand interrelationship between protein meals and non-protein feeds. To the extent that there is no _a priori_ expectation concerning the relationship between the demand for high-protein meals and feed grains, it is appropriate to assume that the relationships can be either competitive or complementary. This study indicates that other high-protein meals and corn tend to have a strong complementary relationship. This agrees with a recent study by Moe and Mohtadi.[24] They suggested that the complementary relationship exist in the U.S., Japan, Canada and other Western European countries. On the other hand, King suggests that feed grains in general are strongly competing with high-protein feeds.[25] In addition, Hildreth and Jarrett found that results obtained by limited information es-

[22] G. A. King, _op. cit._, p. 85.

[23] C. Hildreth and F. G. Jarrett, _A Statistical Study of Livestock Production and Marketing_, Cowles Commission Monograph 15, (New York: John Wiley & Sons, Inc., 1955), p. 72.

[24] L. E. Moe and Malek M. Mohtadi, _op. cit._, p. 85.

[25] G. A. King, _op. cit._, p. 93.

timation methods imply that feed grains and protein feeds are complements, whereas results obtained by least squares imply that they are substitutes. Hildreth and Jarrett, therefore, concluded that "our a priori knowledge in this case is probably insufficient for us to regard either outcome as implausible."[26] Moreover, the tendency toward the increased use of formula feeds in the United States livestock industry could also result in complementarity between high-carbohydrate and high-protein feeds.

Foreign Demand for Soybean Meal

The statistical relation for consumption of soybean meal in the rest of the world is:

$$\text{3SLS} \quad Q^{*}smf = -35870. -91.32P^{*}sb + 123.4P^{*}omf + 36.27Hpag$$
$$(32.96) \qquad (27.89) \qquad (2.42)$$

where:

Hpaf = High-protein consuming animal units in the rest of the world, million units. (Predetermined)

The Farrar-Glauber test indicates that the collinearity is present between the prices of soybeans and other high-protein meals, and to a lesser extent between the price of soybeans and high-protein consuming animal units. However, the multiple correlation coefficients for these variables are considerably less than the overall coefficient of correlation.

Preliminary investigations suggested that the U.S. price of soybeans was more significant than the foreign price of soybean meal in explaining the foreign consumption of soybean meal. This appears reasonable because the U.S. is the most important producer and exporter of soybeans in the

[26] C. Hildreth and F. G. Jarrett, op. cit., p. 74.

world, and to a considerable extent, most of the major consuming countries in the rest of the world are also the major importing countries of U.S. soybeans. The elasticities with respect to domestic price of soybean and European price of other meal were computed as -.76 and 1.13, respectively.

The foreign price of livestock and livestock products is not included in the statistical estimation of foreign demand for soybean meal, because data are not available on this variable. However, one would expect little to be gained by including this variable in the estimated equation since the three variables -- prices of soybeans and other high-protein meal, and high protein consuming animal units in the foreign countries -- accounted for almost all of the variations in the consumption of soybean meal during 1955-72. The presence of a linear time trend is apparent. Time is not incorporated because it is highly intercorrelated with high-protein consuming animal units. In fact, the influence of time may be reflected in the coefficient on the animal units variable that is found to be the most significant variable among the explanatory variables.

Annual estimates of the foreign consumption of soybean meal are compared with actual values in Figure 5. As shown in Figure 5, the general level and movement of soybean meal consumption were indicated by the estimated structure which failed, however, to predict the correct change of directions for foreign consumption of soybean meal in 1955, 1964, 1967 and 1970.

Foreign Demand for Other High-Protein Meals

The estimated statistical relationship is:

$$3SLS \quad \overset{*}{Q}omf = -19040. + 184.1\overset{*}{P}smf - 146.1\overset{*}{P}om + 24.71Hpaf$$
$$(38.03) \qquad (37.38) \qquad (2.95)$$

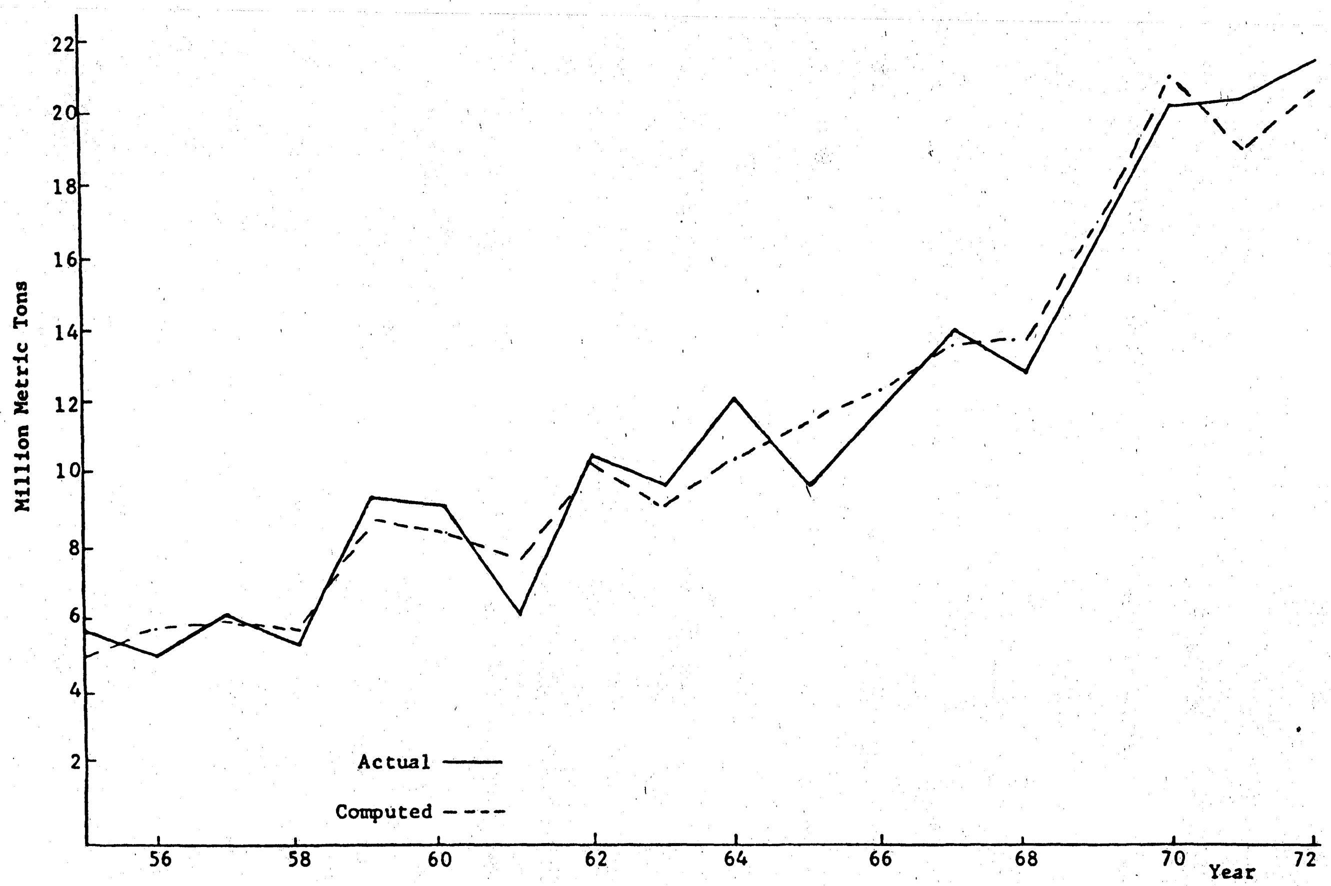

Figure 5. Foreign Consumption of Soybean Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

Although a certain degree of collinearity exists between the prices and the animal units, it does not appear to negatively affect the reliability of the estimates concerned. The number of high-protein consuming animal units again was found to be the most significant variable in explaining foreign consumption of protein feeds. Preliminary analyses suggested that foreign consumption of other high-protein meals was more responsive to the U.S. price of other protein meals than to the European price of other meals. Because international trade in these protein feeds is reasonably unrestricted, one would expect the two price series to be highly correlated. Therefore, it seems justifiable to use the U.S. price of other high-protein meal in substitution of the European price.

The estimated relationship implies the elasticities of -.78 and 1.18 with respect to own price and price of soybean meal, respectively. It is noteworthy that the present study indicates that price response of demand for other high-protein meals in the United States is approximately twice as elastic as that in the rest of the world. In view of the easy availability of soybean meal in the United States, it appears reasonable to expect that for the same time dimension of observations, the demand elasticity would be higher in the U.S. than the rest of the world.

The overall goodness of fit for foreign consumption of other high-protein meals can be seen in Figure 6. In Figure 6, the estimated values approximate the actual data reasonably well. In terms of turning points, the fitted structural equation incorrectly predicted the change of directions only four times during the 18 year period -- in 1957, 1958, 1959, and 1968.

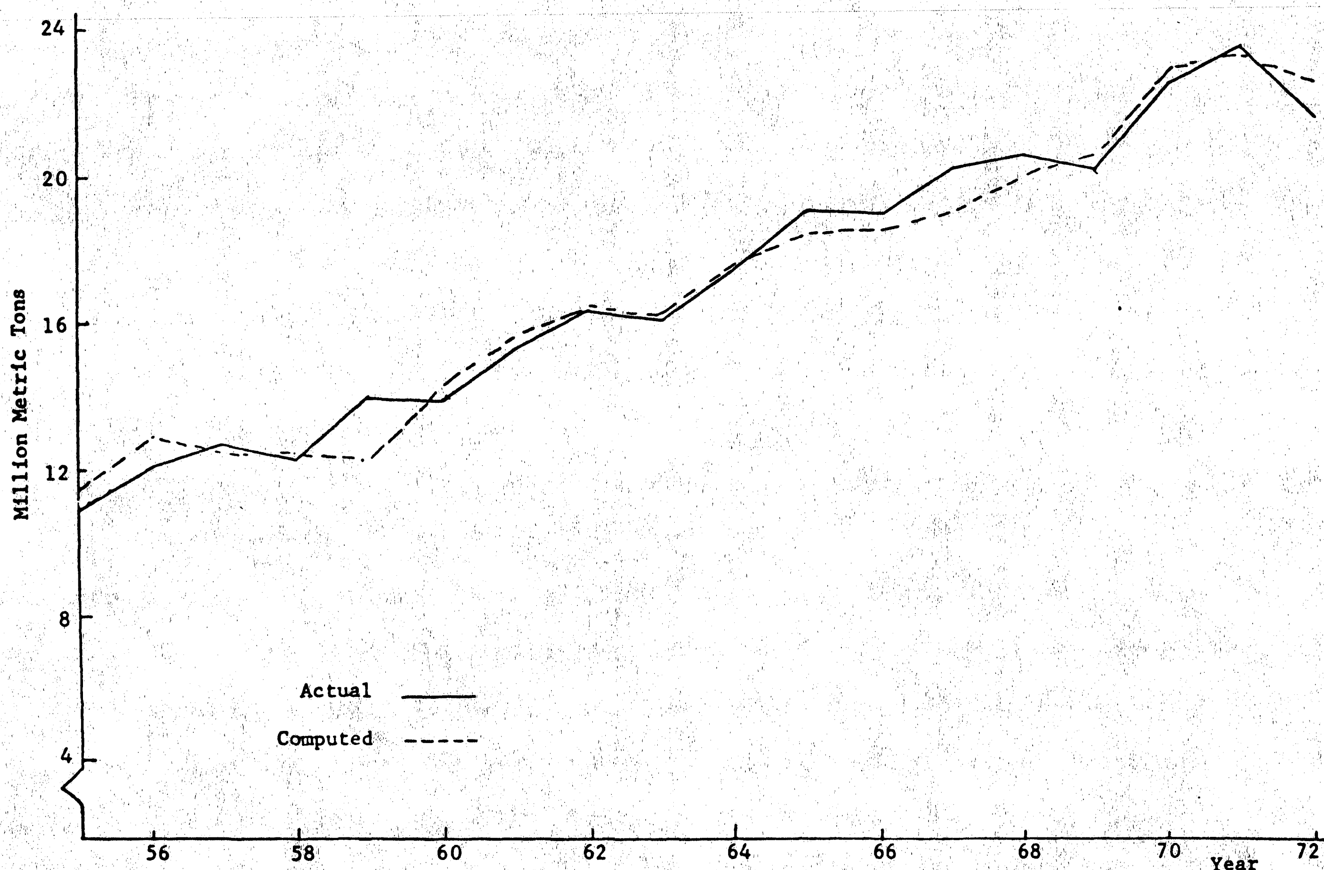

Figure 6. Foreign Consumption of Other High Protein Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

U.S. Exports of Soybean Meal

Prices of soybeans and soybean meal, and the number of high-protein consuming animal units in the rest of the world were significant factors in explaining variations in the U.S. exports of soybean meal. The statistically estimated export relation is presented below:

$$\text{3SLS } Qsmx = -28210. - 99.08Psb + 159.6Psmf + 22.39Hpaf$$
$$\qquad (49.61) \qquad (72.14) \qquad (5.16)$$

The test for multicollinearity suggests that some correlation exists between the prices of soybeans and soybean meal. However, according to the criterion employed in this study, it does not appear to impair the reliability of the estimates.

Estimates of U.S. export demand elasticities with respect to domestic soybean price and European price of soybean meal are -1.47 and 2.72, respectively. Houck (1963) implied elasticity of demand for soybean exports of -.89. In the 1968 study by Houck and Mann, elasticity estimates of -.60 to -1.13 were obtained for exports. In the same study, the price elasticities, with respect to the price of soybean meal, were .51 to 1.04. The elasticity of European demand for U.S. soybean meal with respect to the ratio of price of European and Canadian livestock to price of soybean meal reported by Vandenborre (1970) was 1.21. As noted earlier, approximately 73% of U.S. soybean meal exports were in the form of beans. Thus, it is likely that European and other foreign crushers would respond directly to the price of soybeans to import as much meal and oil as possible in the form of beans in any given year.[27] This equation also suggests that U.S. soybeans and soybean meal compete in foreign outlets as livestock feed sources.

The actual versus estimated values computed from 3SLS structural estimates are presented in Figure 7. The fitted regression seems to reasonably explain the general movement of the soybean meal exports during the time period of observations. The performance of the estimated relation is rather poor with regard to turning points.

U.S. Imports of Other High-Protein Meals

The U.S. import equation is estimated as:

$$\text{3SLS } \overset{*}{Q}omi = 845.9 + \underset{(7.04)}{40.11\overset{*}{P}smf} - \underset{(4.23)}{30.19\overset{*}{P}omf} + \underset{(.0172)}{.0215\overset{*}{Q}sms}$$

$$\underset{(.621)}{-1.648Hpaf}$$

In terms of turning points, it can be seen from Figure 8 that the estimated relation predicts most of the directions correctly, except for four years, i.e., 1955, 1959, 1963 and 1971, where the overestimate (underestimate) of actual value causes the predicted value of the following year to appear to move in the wrong direction. Furthermore, the Farrar-Glauber test

[27] An alternative formulation not presented in the analysis, however, was estimated with the price of U.S. soybean oil as an additional explanatory variable. Although the estimated coefficient on this price variable was relatively greater than its standard error, it suggested that price of soybean oil behaved as a supply factor in the U.S. demand for soybean meal exports. This implies that, as the price of soybean oil increases, more soybeans will be crushed for oil purposes, thereby increasing the supply of soybean meal, because oil and meal are joint products of the crushing industry. Moreover, preliminary analyses also indicated that the estimated structural relation when price of soybean oil was excluded, provided a more accurate prediction of the short-term variations of soybean meal exports than did when the price of soybean oil was incorporated.

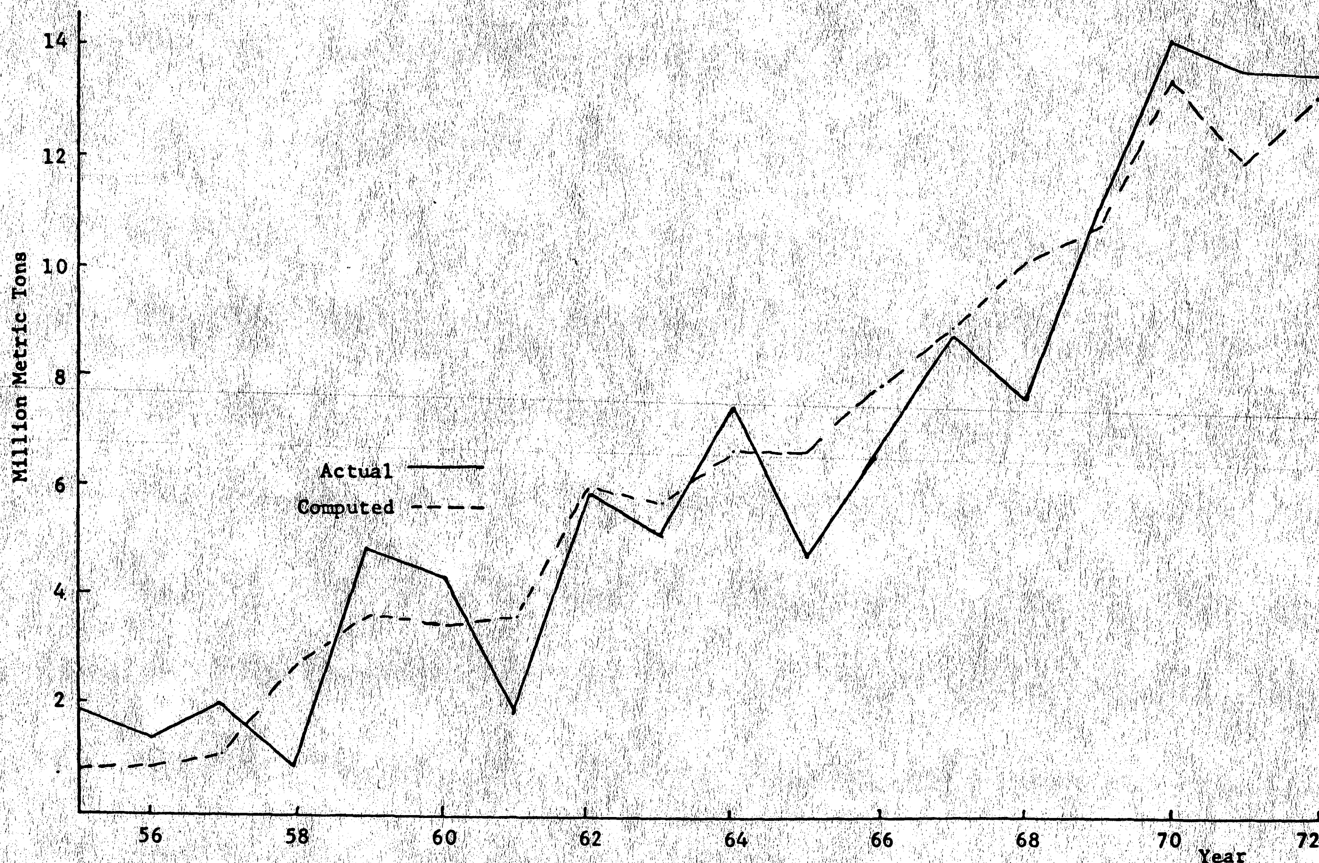

Figure 7. U.S. Exports of Soybean Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

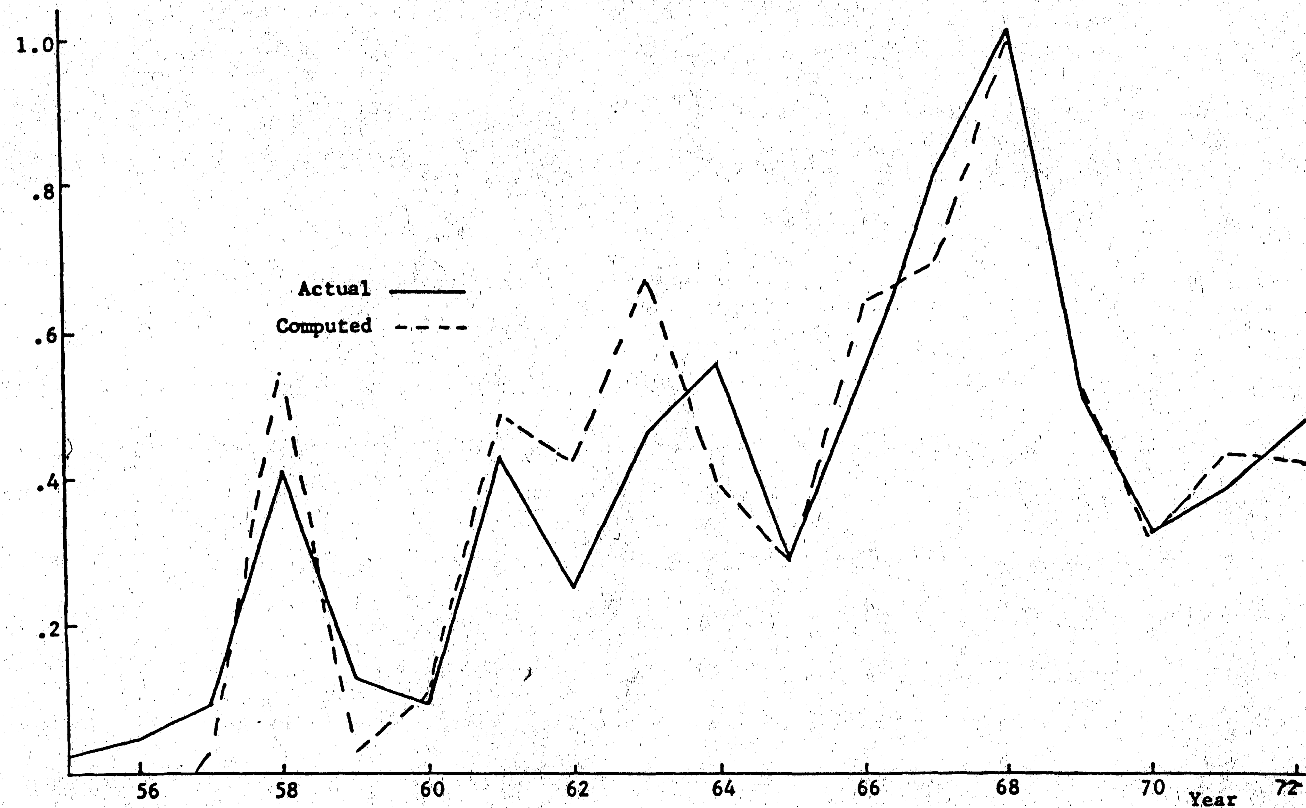

Figure 8. U.S. Imports of Other High Protein Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

also suggests that the presence of multicollinearity may impair the reliability of the estimated structural parameters.

The U.S. import elasticity with respect to the European price of other high-protein meals was computed to be -8.2 and with respect to the European price of soybean meal was 11.29. These elasticity measures suggest that the U.S. demand for imports of other high-protein meals is highly price-elastic. The U.S. is primarily an exporter of protein meals. Most U.S. imports of meal are fish meal. Inasmuch as the U.S. is the world's largest producer of soybean meal, a priori expectation would suggest that U.S. imports of other protein meal would be highly price-elastic, because of the relatively easy availability of soybean meal. A recent study of the fish meal industry also suggest that U.S. demand for imports is highly responsive to price changes. The elasticity of U.S. import demand for Peruvian fish meal with respect to fish meal price is reported to be -3.25 from estimates of indirect least squares and -1.29 from 2SLS estimates.[28]

The number of animal units in the United States seem to play a negligible role in determining U.S. imports of other high-protein meals. However, the variable of high-protein consuming animal units in the rest of the world was found to be one of the significant variables explaining the variation in U.S. imports of other high-protein meals. To the extent that U.S. imports are exports from the rest of the world and without inventory adjustments in the rest of the world, one would expect exports to be decreased as protein consuming animal units and consumption of protein meals

[28] E. L. Segura, An Econometric Study of the Fish Meal Industry, FAO Fisheries Technical Paper No. 119 (Rome: Food and Agriculture Organization of the United Nations, 1973), pp. 155-6.

to be increased in the rest of the world. In addition, for any given year, stocks of soybean meal may be accumulated because of seasonally high production of soybean meal. If such is the case, imports of other protein meals may be expected to be reduced. On the other hand, imports of other protein meal may be expected to be positively related to the stocks of soybean meal if increased quantity of other protein meals are used to substitute for soybean meal in feeding livestocks. The estimated structure of U.S. demand for imports of other high-protein meals seems to suggest that other imported protein meals strongly competed with soybean meal as a source of livestock feed in the U.S.

U.S. Ending Stocks of Soybean Meal

The results of the statistical estimates for the stock relation are presented. Thus,

$$\text{3SLS } \overset{*}{Q}sms = -6351. + \underset{(20.12)}{86.4\overset{*}{P}sm} - \underset{(.144)}{1.103\overset{*}{Q}smx} + \underset{(.117)}{1.594Qsms1}$$

The Farrar-Glauber test indicates a high degree of collinearity between the price of soybean meal and the beginning stocks of soybean meal. The multicollinearity, although present, is not considered to be a problem according to the criterion used in this study. As shown in Figure 9, the fitted regression explains the variations in U.S. ending stocks of soybean meal during the 1955-72 period, except for the years of 1961, 1969, and 1971, when the estimated equation gave predicted values that moved in the wrong direction.

In his 1963 and 1968 studies, Houck indicated that coefficients on the price of soybeans were positive in the soybean storage equation but were not

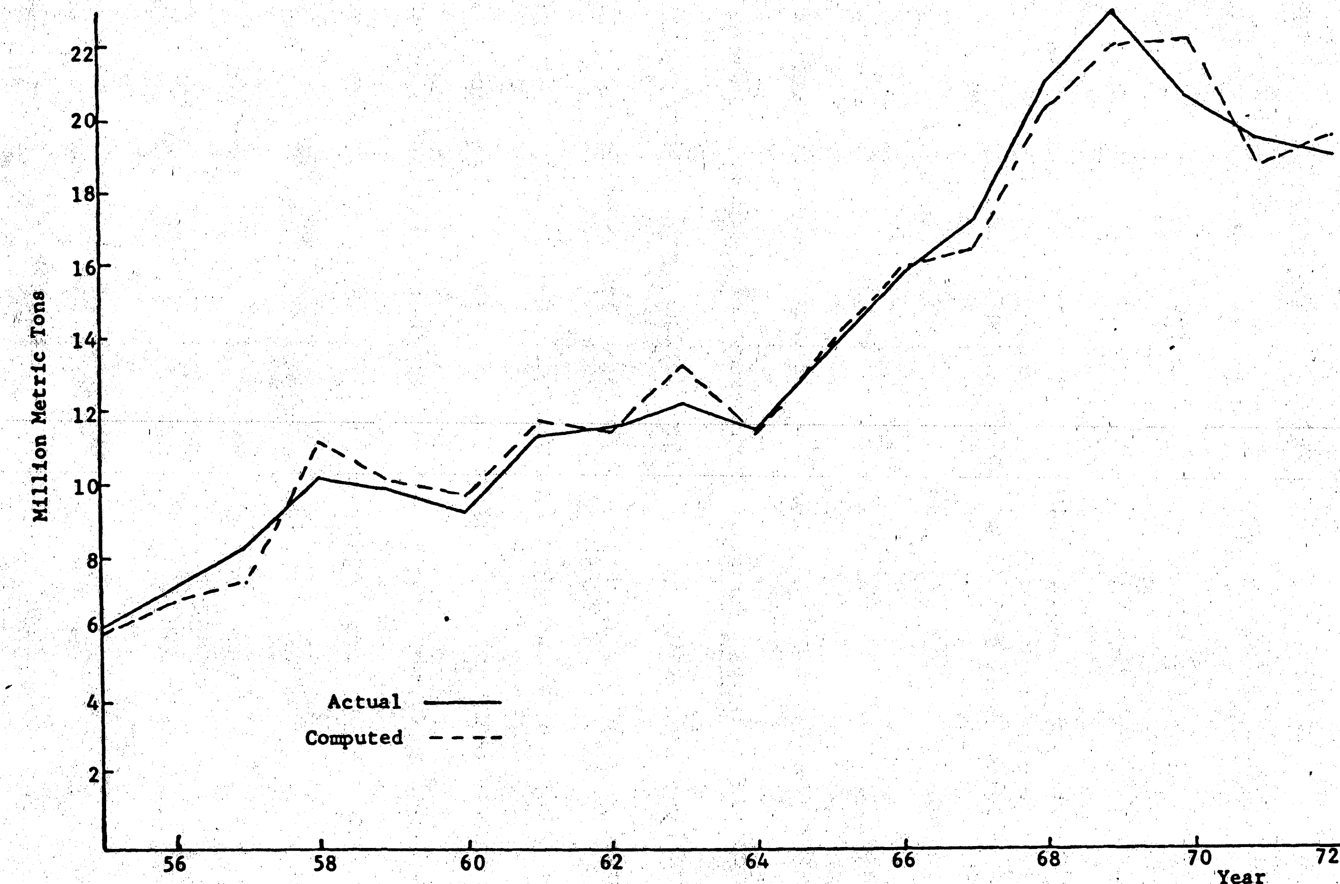

Figure 9. U.S. Ending Stocks of Soybean Meal, Actual and Computed from 3SLS Structural Estimates, 1955-1972.

large in relation to their standard errors. This study also shows that there is a positive relationship between ending stocks and the price of soybean meal. This may have reflected the influence of factors such as price anticipations and, to some extent, trend.

Price elasticity of ending stocks was calculated to be .48 with respect to soybean meal price during the observation period. In his 1970 study, Vandenborre reported that demand elasticity of soybean meal stocks with respect to price of soybean meal was .70. Conclusions of the present study and those of Vandenborre tend to indicate that ending stock of soybean meal was price inelastic.

As in the export equation, the U.S. demand for ending stocks of soybean meal includes meal as well as meal equivalent of soybeans. That is, soybeans may be held for price speculation reasons, on the expectation that the price of soybean meal and/or price of soybean oil is going to increase. Attempts to establish an acceptable empirical relationship between the ending stocks of soybean meal and the price of soybean oil as specified in the theoretical model were unsuccessful. Accordingly, the price of soybean oil dropped from this structural equation.

SUMMARY AND IMPLICATIONS

This study was concerned with identifying the underlying economic forces, interrelationships, and processes which determine and influence the price behavior of the world high-protein meal market. The objectives of the present study were to develop and estimate a complete econometric model of world protein meal economy which isolates components of foreign and domestic demands.

Using a set of simplifying assumptions, the world economy of high-protein meal was expressed and formulated in a theoretical framework. The analysis utilized a twelve-equation model of the high-protein meal sector that focuses on the price-making forces in the United States and the rest of the world for soybean meal and other high-protein meals. Demand relationships were formulated for each region and for soybean and other high-protein meals.

The model included eight linear stochastic behavioral equations and four linear identities in actual numbers. The behavioral relations represented the wholesale price relationship for U.S. soybeans, the U.S. and foreign demands for soybean meal and other high-protein meals, the U.S. net exports and imports of soybean meal and other high-protein meals, respectively, and the U.S. ending stocks of soybean meal. The four identities defined the utilization and supply relationship for soybean meal and other high-protein meals, both in the United States and the rest of the world.

The same period included the eighteen annual observations for each variable specified in the model during the period from 1955 to 1972. Crop year data were adjusted to calendar year basis so that production, trade and consumption throughout the world could be measured in the same time dimension.

The unknown parameters of the statistical model were estimated by 3SLS (three-stage least squares) procedure. Statistical fits on most of the structural equations were satisfactory. Most estimated structural coefficients were large, relative to their standard errors, and were of the expected sign.

Elasticity measures obtained for the structural relations are summarized in Table 3. The major contributions of this study relate to the quantification of demand interrelationships between soybean meal and other high-protein feeds and to demand relationships between the United States and foreign markets. The empirical analyses suggest that domestic as well as foreign demand for soybean meal during the 1955-72 period was price inelastic. Such a result is consistent with that of previous work.

During the period of analysis, the demand for high-protein meals in both domestic and foreign markets increased. The implication of such shifts in demand is that for a given level of supply, demand for high-protein meals will become more price elastic. In fact, elasticity measures obtained in this study suggest that demand for high-protein meals have become more elastic in the recent years as compared with those reported in previous studies. In view of the recent developments of substitutes--such as modified-protein corn and cereal crops, and synthetic amino acids and urea supplements--it is evident that the market for high-protein meals is likely to become more competitive. In addition, this study indicates that demand for

Table 3. Summary of Demand Elasticities.

Elasticities of / with respect to	Qsm	Qom	Qsmf	Qomf	Qsmx	Qoml	Qsms
Psb					-1.47		
Psm	-.73	1.47					.48
Pom	.88	-1.60		-.78			
Pc		-.45					
Psmf			-.76	1.18		11.29	
Pomf			1.13			-8.2	

high-protein meals in the U.S. is approximately twice as elastic as that in the rest of the world.

Judging from the cross price elasticities, soybean meal and other high-protein meals appeared to be very close substitutes and strongly competed as livestock feeds during the period 1955-72. Furthermore, this study suggests that a complementary relationship exists between corn and other high-protein meals in the United States. The increasing tendency towards the production and utilization of prepared feeds in the United States livestock industry could be the major factor accounting for this complementarity between corn and other high-protein meals.

For the trade relations, the results obtained by this study, which confirm a priori expectations, suggest that both export and import demands for protein meals were price elastic--particularly, the U.S. demand for imports of other protein meals which was estimated to be highly price elastic. Observations of the historical movements of the U.S. imports and the easy availability of soybean meal in the U.S. seem to support this finding. The rapid growth in the Brazilian soybean production in the past few years has been most remarkable and significant. In 1970, the U.S. accounted for 92% of all soybean and soybean meal exports. However, in 1974, Brazilian exports of soybeans accounted for 20% of the world total. Increases in imports from Brazil have reduced the U.S. exports share of the market to slightly below 80% of the world total, as reported by Walter. This also suggests that the international soybean market is extremely price sensitive in determining where they obtain high-protein meals.

Recently, Schuh argued that the exchange rate has been an important variable omitted in our past interpretation of U.S. agricultural trade and development problems. He argued that over-valuation of the dollar in the post World War II period and the devaluations during 1971-73 have been important factors in causing the "farm problem" in the past and the rise of agricultural prices in the recent years. In the present analysis, the U.S. devaluations are the cause of imports of other high-protein meals being relatively more expensive domestically, with exports of soybean meal relatively less expensive in foreign markets. The increased price for imports of other high-protein meals may induce more resources into these sectors, simultaneously inducing a shift in demand toward substitutes (soybean meal) while this demand is already rising in response to increased foreign demand for U.S. exports. The combined effect has produced a considerable upward pressure on the prices of high-protein meals. The greater the foreign demand elasticity, the stronger the tendency is for domestic prices to rise. Events in 1973 seem, for the most part, confirmable by evidences suggested in the present analysis.

In general, the fact that demands for high-protein meals are becoming more elastic implies that a given change in supply will result in greater price stability now than in past years. In particular, the extremely high price elasticity of U.S. demand for imports of other high-protein meals suggests the consequence of market pressures transmitted from abroad--such as the temporary decline in the Peruvian fish meal industry--will be considerably more rapid and stronger than otherwise expected. Furthermore, as the elasticity of foreign demand for U.S. soybeans increases, gross income as well as exchange earnings from the foreign market to the U.S. soybean industry may be reduced, and the sector may become more dependent on the domestic market. This is particularly true if there is an increase in the export price of soybeans or an appreciation in the U.S. dollar.

One of the limitations to the study was obviously that imposed by data unavailability, especially from foreign countries. Unfortunately, this limitation involved both the limited sources of data as well as, generally, a two-year lag in data reporting. In addition, some simplifying assumptions in the theoretical framework were obviously abstractions and thus only approached reality. The effort was designed to study the world demand for high-protein meal in a simultaneous system; however, the system was simultaneous only to the extent that demands for soybean and other high-protein meals are interrelated in the livestock feed economy. Omitting the simultaneous adjustment processes of the livestock and non-protein feed sectors, particularly the fat and oil sector, appeared to undermine the model's usefulness in providing a basis for policy considerations and economic forecasting. To the extent that meal and oil are joint products of the crushing industry, allowing only one product in the adjustment process is obviously unrealistic and may have obscured the attainment of more reliable and useful information. Moreover, aggregations of various kinds of high-protein meals into two main categories and aggregations of different consuming regions into two markets may have caused difficulties in obtaining good statistical estimations. Furthermore, such aggregations may present additional barriers to the attainment of successful predictions and identification of the relevant economic forces that underlie the behavior of individual commodity markets and demand structures. Thus, other formulations which may quantify the interdependent and simultaneous relationships among protein meals, fat and oil, livestock and livestock product sectors are suggested for further studies. In addition, research based on regional and commodity disaggregations would also seem to be necessary and appropriate for future studies.

It is believed that the relative success of the empirical estimation suggests that this particular framework is a useful approach for increasing our understanding of the basic structure and general nature of the operation of the high-protein meal economy. The value of this study appears to be its ability to provide useful information on the structure of the high-protein meal economy, its possible application in other areas, and its contributions in isolating the need for and the problems of additional studies of this kind.

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APPENDIX A

THE DATA

The purpose of this appendix is to describe and discuss the measurements and indicate the sources of the data used in this study. Some of the variables do not correspond very closely to any regularly compiled data. It is necessary, therefore, to construct from that available data measurements that will correspond as closely as possible to the concepts employed in the model. The observations actually in estimation are tabulated at the end of this section in Tables A-5 and A-6. The symbols used to represent the variables are defined in the text (pp. 11-13) and not reported here.

Calendar year production of oilseed crops is officially reported in the FAO Production Yearbook for each country. These data were used in this study as an estimate of oilseed meal production.[1] For all countries, production was allocated to the calendar year during which the crop's processing chiefly occurred. The schedule which assigns the year of oilseed crops to be processed for each country is presented in Table A-1. There is no easy division of production into one year or the next, inasmuch as oilseeds are growth throughout the world and harvest months vary from country to country. Assigning production to calendar years allows the measurement of annual production trade and consumption in the same time period.

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[1]Except for the U.S., where soybean production was obtained from Soybean Bluebook and production of other meal was obtained from Feed Situation.

Table A-1. Year of Oilseed Crops to be Processed Oil and Meal Production.

Type of Oilseed	Country	Production Year of Harvest	Assigned to Year Following Harvest
Copra	All countries	x	
Cottonseed	All countries		x
Flaxseed	India, Pakistan New Zealand	x	
	Others		x
Palm Kernel	All countries	x	
Peanut	Argentina, Bolivia, Brazil Ecuador, Paraguay, Peru, Uruguay, Indonesia, South Africa, Rhodesia, Zambia, Tanzania, Congo, Angola, Malawi, Gabon, Mozambique, Libera, Australia	x	
	Others		x
Rapeseed	Canada		x
	Others	x	
Soybean	Argentina, Brazil, Paraguay, Peru, Uganda, Thailand	x	
	Others		x
Sunflowerseed	Argentina, Brazil, Chile, Uruguay, South Africa, Australia	x	
	Others		x

Oilseed meal production was estimated on the basis of (1) annual calendar year production,[2] (2) assumed average crushing levels and (3) assumed average meal extraction percentages. This approach was used in an attempt to avoid understating the total potential meal production during periods when stocks of oilseeds are being accumulated in the indigenous producing countries. Furthermore, actual production data for many countries is not available. Also, actual production data from different origins using different methods of processing and in some cases the practice of adding back hulls to the meal from hulled seed, would make such data incomparable. The assumed crushing and extraction levels used varied between crops and between countries. They are presented in Table A-2 and Table A-3, respectively. Finally, the data for the various meals were adjusted for the average differences in crude protein content and protein digestibility to obtain a common base, expressed in terms of soybean meal equivalent. These adjustment factors are provided in Table A-4.

Estimates of high-protein meal consumption were developed using several assumptions which may not necessarily be true in any given year but which appear to balance out over a series of years. During the period under review, total production of protein meals was approximately equal to consumption. There was no long term build-up of stocks. Regional estimates of consumption were calculated as the sum of a region's production and net trade of meal plus meal equivalent of net trade in oilseed. Changes in stocks, which are not known for most commodities and countries, were assumed negligible and therefore were omitted from the calculation, except for the U.S., where changes in soybean mealstocks were taken into consideration.

[2]The actual calendar year production of fish meal for each country is reported in the FAO Yearbook of Fishery Statistics and is used in this study.

Table A-2. Percentage of Oilseed Crops Assumed Crushed for Oil and Meal by Countries.

Type of Oilseed	Country	% of the Crop Assumed Crushed
Copra	All countries	100
Cottonseed	EEC, Argentina	90
	Brazil	65
	China	25
	India	35
	Pakistan	60
	U.S.S.R.	85
	Others	75
Flaxseed	EEC	85
	Argentina, Mexico, Uruguay	92
	Others	90
Palm Kernel	All countries	100
Peanut (in shell)	Argentina, Brazil, Nigeria	80
	Senegal	77
	South Africa, India	75
	China	50
	Others	15
Rapeseed	All countries	90
Soybean	Japan	35
	Brazil	90
	Canada	92
	China	45
	Others	50
Sunflowerseed	U.S.S.R.	95
	Others	92

Table A-3. Conversion Rates for Oilseeds to Meal Equivalent, by Countries.

Country	Copra	Cottonseed	Linseed	Palm Kernel	Peanut (in shell)	Rapeseed	Soybean	Sunflower-seed
				Yield Percentage				
EEC	35.0	42.5	62.0	51.0	38.5	60.0	80.5	45.0
Canada	35.0	46.5	62.0	51.0	38.5	60.0	80.5	45.0
Japan	35.0	46.5	63.0	51.0	38.5	60.0	82.5	45.0
Argentina	35.0	38.5	63.0	51.0	42.5	60.0	80.5	45.0
Brazil	35.0	42.5	63.0	51.9	42.5	60.0	80.5	45.0
Mexico	35.0	46.5	65.0	51.0	38.5	60.0	80.5	45.0
China	35.0	45.5	63.0	51.0	39.5	60.0	80.5	45.0
U.S.S.R.	35.0	45.5	63.0	51.0	38.5	60.0	80.5	40.0
Others	35.0	46.5	63.0	51.0	38.5	60.0	80.5	45.0

Table A-4. Conversion Rates for Protein Meals Soybean Meal Equivalent.

Type of Meal	% of Crude Protein Content	% of Digestable Protein	Adjustment Factor
Soybean	44	92	1.0000
Fish	65	90	1.4402
Cottonseed	41	80	0.8103
Peanut	50	91	1.1240
Sunflowerseed	42	91	0.9442
Rapeseed	35	80	0.6917
Linseed	35	88	0.7609
Copra	21	85	0.4515
Palm Kernel	18	80	0.3557

The soybean meal stock variable has two components. The actual annual stocks of soybean meal were obtained by aggregating monthly data from various issues of The Soybean Blue Book published by American Soybean Association. The second component is the meal equivalent of soybean stocks which were converted from the stocks of soybean to meal equivalent. Data on the annual observations of soybean stocks were obtained from U.S. Department of Agriculture, Agriculture Statistics and included stocks on farms and off farms.

Animal units (cattle, hogs and chickens) in foreign countries were compiled from various issues of Agriculture Statistics. Because the different classes of livestocks are not of equal importance in consumption of protein meals, the following weights were assigned, 1.0 for cattle, 0.4 for hogs, and 0.025 for chickens. These weights were based on the feeding ratios in Western Europe. Different ratios for different countries were not used because information on the feeding practices in other nations was not available. Because Western Europe is the most important market in the world economy of high-protein feeds, these ratios were considered as appropriate and reasonable proxies for all foreign countries.

Actual number of annual observations was used for animal units (hogs and broilers) in the United States. The number of hogs in January 1 was obtained from Agriculture Statistics. Data on commercial broiler production from 1955-59 and 1960-72 were obtained from the U.S. Department of Agriculture, Selected Statistical Series for Poultry and Eggs through 1965, ERS 232, Revised May 1966, and Poultry and Egg Statistics through 1972, USDA, Statistical Bulletin No. 525, respectively.

Price series for soybean, soybean oil and corn were all taken from Feed Situation. Annual observations were obtained by taking a simple average of the monthly prices. As the metric system is seldom used for the quotations of these prices in the U.S. official sources, the price series was converted to a metric-ton basis because the relevant quantity variables were expressed in these units in the study.

U.S. price of soybean meal were obtained from The Soybean Blue Book. The annual observations were compiled from monthly prices of soybean meal weighted by monthly production of soybean meal. Soybean meal prices, c.i.f. European ports, were taken from various issues of Oilseeds and Products.

The composite prices of other protein supplements were weighted price series. The weights used were the production of each protein meal adjusted to 44% protein, soybean meal equivalent basis. This was done to standardize the relative fluctuations in costs per unit of protein among other supplements. Although such an adjustment cannot, of course, explain all of the differences in nutritional value, it does provide a common base for comparing the differences in costs of protein supplements. Furthermore, this is also in accordance with the relevant quantity variables which are all expressed in terms of 44% protein, soybean meal equivalent. The general formula used to construct the composite prices of other protein meals can be written as:

$$P = \frac{\Sigma p_i q_i}{\Sigma Q_i}$$

where:

P = the composite average price of other protein meals,

p_i = the actual prices of the ith protein meal,

q_i = the actual production figures of the ith protein meal, and

Q_i = the adjusted production of the ith meal, in terms of 44% soybean meal equivalent.

Thus, the above formula gave a weighted value per unit of other meals on 44% protein content basis.

For the United States, the composite price includes the price of cottonseed meal, 41% Memphis, peanut meal, 50% f.o.b. southeastern mills, linseed meal, 34% Minneapolis, and fish meal, 65% New York. All these price series were taken from Feed Situation. The procedure employed was to obtain the total annual values of production by multiplying monthly prices by the monthly production of each protein meal summed over 12 months and over each different kinds of protein meal. The total annual values of production was then divided by the total production of other meal on the 44% meal equivalent basis. The total production on the meal equivalent basis was obtained by converting monthly actual production figures into soybean meal equivalent then summed over 12 months and over various meals included.

Foreign price of other meal is constructed in the similar manner, except the annual observations on the price and quantities were used instead of monthly figures. The composite average price for other meal in the foreign market includes soybean meal, Canadian 45%, cottonseed meal, Argentine 44/45%, peanut meal, Nigerian 54%, linseed meal, Argentine 37/38%, copra, Indian, 30%, and fish meal, Peruvian 65%. Data on these price series are all prices c.i.f. European ports and were obtained from Foreign Agriculture Circular, Oilseeds and Products. It should be noted that price series on cottonseed meal is not available for the year 1955. The price of copra meal is not available for 1963 and for the period 1968-72. For fish meal price, there are no available data prior to 1960. The production figures that were used as the weights were, therefore, adjusted for those years accordingly.

Table A-5. Endogenous Variables: Data Used in the Simultaneous Equations Model, 1955-1972.

Year	P^{*}_{sb}	P^{*}_{sm}	P^{*}_{om}	P^{*}_{smf}	P^{*}_{omf}	Q^{*}_{smc}
			Dollars per metric ton			1000 metric tons
1955	89.29	62.32	82.62	102.28	115.61	5082.90
1956	93.33	56.30	75.65	98.50	110.65	5742.90
1957	84.14	51.78	74.06	89.86	95.55	6536.80
1958	79.37	61.73	82.50	93.78	83.58	7558.90
1959	77.90	62.38	88.08	94.56	100.80	8109.20
1960	76.79	58.41	72.87	90.58	91.21	7873.00
1961	96.27	63.37	80.16	99.65	90.13	8022.20
1962	88.92	73.14	86.94	105.75	98.89	8570.80
1963	95.53	79.92	92.62	112.82	102.02	8587.80
1964	95.53	76.07	84.67	112.31	109.76	8362.90
1965	109.50	78.65	88.93	115.55	116.65	8451.30
1966	112.07	91.85	105.31	123.81	115.65	9413.10
1967	101.05	84.15	102.09	119.01	106.23	9870.90
1968	94.43	85.08	99.57	120.41	97.51	9816.60
1969	92.59	82.32	97.93	116.30	109.09	10769.50
1970	99.21	87.17	107.16	125.11	121.43	12529.10
1971	112.07	85.91	100.39	123.83	115.05	11839.60
1972	126.40	116.65	128.58	137.01	131.22	12174.30

Table A-5. Continued.

Year	Q^*_{omc}	Q^*_{smf}	Q^*_{omf}	Q^*_{smx}	Q^*_{omi}	Q^*_{sms}
	1000 metric tons					
1955	2727.9	5845.89	10892.7	1944.89	16.30	6005.21
1956	2825.4	5196.50	12076.5	1205.51	44.50	7141.95
1957	2515.7	6368.30	12697.9	1991.30	91.10	8334.31
1958	2580.3	5420.86	12276.3	989.87	411.70	10245.40
1959	2665.6	9423.34	13976.9	4846.34	129.10	9844.45
1960	2588.3	9273.56	13939.7	4289.56	90.30	9211.77
1961	3030.7	6374.34	15390.0	1862.34	438.00	11342.10
1962	2991.9	10680.80	16395.2	5937.80	253.80	11537.00
1963	3125.2	9903.04	16156.1	5201.04	463.90	12227.50
1964	3264.5	12220.10	17440.4	7515.13	559.60	11481.50
1965	3049.5	9835.72	19095.9	4718.72	291.10	13764.90
1966	3016.4	11804.40	19071.6	6627.39	548.40	15732.50
1967	2642.3	14161.20	20274.4	8812.25	822.60	17139.00
1968	3029.3	12869.60	20699.3	7480.61	1178.70	20960.20
1969	2678.9	16717.40	20361.0	11102.40	517.00	22956.60
1970	2361.0	20229.90	22651.2	14233.90	325.80	20563.50
1971	2504.7	20522.40	23877.6	13745.40	384.40	19365.10
1972	2888.8	21585.10	21989.4	13679.10	473.60	18956.50

Table A-6. Predetermined Variables: Data Used in the Simultaneous Equations Model, 1955-72

Year	Hog 1000 units	Broil Million units	Pc Dollars per metric ton	Hpaf Million units	Qsmsl 1000 metric tons
1955	50474.0	1092.0	51.31	959.5	5653.01
1956	55173.0	1344.0	51.18	1008.7	6005.21
1957	51703.0	1448.0	45.66	1044.7	7141.95
1958	50980.0	1660.0	42.13	1065.4	8334.31
1959	58045.0	1737.0	42.28	1085.8	10245.40
1960	59026.0	1795.0	43.80	1107.3	9844.45
1961	55506.0	1991.0	39.84	1139.8	9211.77
1962	57000.0	2023.0	40.24	1165.9	11342.10
1963	58883.0	2102.0	44.19	1140.0	11537.00
1964	58119.0	2161.0	44.65	1149.1	12227.50
1965	50792.0	2334.0	46.52	1188.1	11481.50
1966	47414.0	2571.0	45.17	1223.6	13476.90
1967	53249.0	2592.0	46.18	1260.7	15732.50
1968	58777.0	2620.0	40.90	1278.8	17139.00
1969	60632.0	2789.0	44.42	1321.0	20960.20
1970	57046.0	2987.0	48.59	1407.1	22956.60
1971	67433.0	2945.0	49.91	1406.0	20563.50
1972	62507.0	3075.0	45.96	1432.5	19365.10

Table A-6. <u>Continued</u>.

Year	Pso Dollars per metric ton	Qsmpu	Qompu	Qsmpf	Qompf
			1000 metric tons		
1955	255.74	7379.98	2711.6	3901.0	10909.0
1956	291.01	8085.14	2780.9	3991.0	12121.0
1957	268.96	9720.46	2424.6	4377.0	12789.0
1958	231.49	10459.80	2168.6	4431.0	12688.0
1959	198.42	12554.60	2536.5	4577.0	14106.0
1960	194.01	11529.90	2498.0	4984.0	14030.0
1961	253.53	12014.80	2592.7	4512.0	15828.0
1962	198.42	14703.50	2738.1	4743.0	16649.0
1963	196.21	14479.30	2661.3	4702.0	16620.0
1964	202.83	15132.00	2704.0	4705.0	18000.0
1965	246.92	15165.40	2758.4	5117.0	19387.0
1966	257.94	18296.10	2468.0	5177.0	19620.0
1967	211.64	20089.60	1819.7	5349.0	21097.0
1968	180.78	21118.40	1850.6	5389.0	21878.0
1969	200.62	23868.30	2161.9	5615.0	20878.0
1970	264.55	24369.90	2035.2	5996.0	22977.0
1971	277.78	24386.60	2120.3	6777.0	24262.0
1972	233.69	25444.80	2415.2	7906.0	22463.0

APPENDIX B

OLS STRUCTURAL ESTIMATES

The following are the parameter estimates of the statistical model using OLS (ordinary least squares) procedure. The standard error of each coefficient appears beneath in parentheses. The Durbin-Watson statistic for measuring serial correlation in disturbances is denoted as DW. If the symbol (a) follows the statistic, the DW test indicates absence of serial correlation for the 0.05 significance level using a two-tailed test; the symbol (i) indicates the test was inconclusive. The coefficient of multiple determination is shown as R^2. The fitted regression equations are:

$$\text{OLS } \overset{*}{P}sb = -312 + .894Psm + .16\overset{*}{P}so - .0006409Qsms1$$

$$(.101) \qquad (.03) \qquad (.0003049)$$

$$DW = 2.09 \text{ (a)} \qquad R^2 = .92$$

$$\text{OLS } \overset{*}{Q}smc = -3357.4 - 76.33\overset{*}{P}sm + 81.06\overset{*}{P}om + .0588Hog + 3.31Broil$$

$$(22.62) \qquad (23.23) \qquad (.0205 \qquad (.33)$$

$$DW = 1.96 \text{ (a)} \qquad R^2 = 98$$

$$\text{OLS } \overset{*}{Q}omc = 4777.1 + 43.51\overset{*}{P}sm - 32.54\overset{*}{P}om - .115\overset{*}{Q}smc - 27.73Pc$$

$$(7.25) \qquad (8.56) \qquad (.028) \qquad (9.1)$$

$$DW = 2.89 \text{ (i)} \qquad R^2 = .81$$

$$\text{OLS } \overset{*}{Q}smf = -36967.2 - 124.5\overset{*}{P}sb + 157.59\overset{*}{P}omf + 36.82Hpaf$$

$$(35.17) \qquad (32.03) \qquad (2.44)$$

$$DW = 2.18 \text{ (a)} \qquad R^2 = .97$$

$$\text{OLS } \overset{*}{Q}omf = -18519.1 + 157.54\overset{*}{P}smf - 119.37\overset{*}{P}om + 24.67Hpaf$$

$$(34.92) \qquad (32.93) \qquad (2.52)$$

$$DW = 1.64 \text{ (a)} \qquad R^2 = .97$$

$$\text{OLS } Q^*_{smx} = -28115.1 - 95.03P^*_{sb} + 127.01P^*_{smf} + 24.996H_{paf}$$

$$(56.7) \qquad (76.39) \qquad (5.034)$$

$$DW = 2.06\ (a) \qquad R^2 = .91$$

$$\text{OLS } Q^*_{omi} = 991.64 + 33.79P^*_{smf} - 23.74P^*_{omf} + .0366Q^*_{sms} - 1.936H_{paf}$$

$$(5.79) \qquad (4.06) \qquad (.0158) \qquad (.602)$$

$$DW = 2.28\ (i) \qquad R^2 = .89$$

$$\text{OLS } Q^*_{sms} = -5774.1 + 73.15P^*_{sm} - 1.103Q^*_{smx} + 1.627Q_{sms1}$$

$$(20.84) \qquad (.166) \qquad (.128)$$

$$DW = 2.17\ (a) \qquad R^2 = .98$$

APPENDIX C

REDUCED FORM ESTIMATES

The following are first stage reduced form equations of the statistical model. The reduced form equations are useful as the instruments for short-term economic forecasting. They were estimated by ordinary least squares procedure and denoted as LNSR (least squares no restrictions). In general, fairly good statistical fits were obtained and the coefficient of multiple determination (R^2) ranged from .84 to .99, with only two equations having R^2 below .90. The reduced form equations are:

$$LSNR\ P^*sb = -68.5 - .000149Hog + .01306Broil + 1.108Pc + .0449Hpaf - .006001Qsmsl + .05986Pso + .004617Qsmpu + .01051Qompu - .000634Qsmpf + .0004871Qompf$$

$$R^2 = .96$$

$$LSNR\ P^*sm = -54.72 - .000695Hog + .009152Broil + 1.282Pc + .08723Hpaf - .00508Qsmsl - .132Pso + .005733Qsmpu + .01038Qompu + .0003055Qsmpf - .001961Qompf$$

$$R^2 = .94$$

$$LSNR\ P^*om = 6.194 - .0008013Hog - .003862Broil + .8846Pc + .09055Hpaf - .004238Qsmsl - .07217Pso + .006453Qsmpu + .003888Qompu + .0002716Qsmpf - .002916Qompf$$

$$R^2 = .91$$

$$LSNR\ P^*smf = -31.73 - .0005098Hog - .002136Broil + 1.445Pc + .08248Hpaf - .003902Qsmsl - .07717Pso + .004602Qsmpu + .009071Qompu - .00431Qsmpf + .0003798Qompf$$

$$R^2 = .94$$

$LSNR\ P^*omf = -8.314 - .00103Hog - .02257Broil + 1.849Pc - .01238Hpaf$

$+ .00007259Qsmsl - .03303Pso + .003298Qsmpu + .0254Qompu$

$+ .004843Qsmpf + .001167Qompf$

$R^2 = .96$

$LSNR\ Q^*smc = -3687. + .003412Hog + 2.028Broil - 22.58Pc + 10.03Hpaf$

$+ .2145Qsmsl - 1.01Pso - .203Qsmpu - .1205Qompu + .1578Qsmpf$

$- .1585Qompf$

$R^2 = .99$

$LSNR\ Q^*omc = 2956. + .009569Hog + .4291Broil - 8.265Pc - 2.033Hpaf$

$- .1105Qsmsl - 1.061Pso + .09836Qsmpu + .4891Qompu - .147Qsmpf$

$+ .04754Qompf$

$R^2 = .84$

$LSNR\ Q^*smf = -30540. - .0148Hog - 4.562Broil + 231.4Pc + 19.56Hpaf$

$+ .4849Qsmsl - 18.98Pso + .1916Qsmpu + 2.089Qompu$

$+ 1.401Qsmpf + .1146Qompf$

$R^2 = .98$

$LSNR\ Q^*omf = -2956. - .009569Hog - .4291Broil + 8.265Pc + 2.033Hpaf$

$+ .1105Qsmsl + 1.061Pso - .09836Qsmpu + .5109Qompu$

$+ .147Qsmpf + .9525Qompf$

$R^2 = .99$

$LSNR\ Q^*smx = -30540. - .0148Hog - 4.562Broil + 231.4Pc + 19.56Hpaf$

$+ .4849Qsmsl - 18.98Pso + .1916Qsmpu + 2.089Qompu$

$+ .4015Qsmpf + .1146Qompf$

$R^2 = .98$

$LSNR\ Q^*omi = 2956. + .009569Hog + .4291Broil - 8.265Pc - 2.033Hpaf$

$- .1105Qsmsl - 1.061Pso + .09836Qsmpu - .5109Qompu$

$$-.147Qsmpf + .04754Qompf$$

$$R^2 = .88$$

$$LSNR\ Qsms^* = 34220. + .01139Hog + 2.534Broil - 208.9Pc - 29.6Hpaf$$

$$+ .3006Qsms1 + 19.99Pso + 1.011Qsmpu - 1.969Qompu$$

$$-.5593Qsmpf + .04396Qompf$$

$$R^2 = .97$$

APPENDIX D

2SLS STRUCTURAL ESTIMATES

The results of the estimation process using 2SLS (two-stage least squares) procedure are presented below. The standard error of each coefficient appears beneath in parentheses. The Durbin-Watson statistic is denoted as DW. If the symbol (a) follows the statistic, the DW test indicates absence of serial correlation for the 0.05 significant level of a two-tailed test; the symbol (n) indicates a negative serial correlation; and the symbol (i) indicates the test was inconclusive. The estimated structural relations of the statistical model are:

$$\text{2SLS } \overset{*}{Psb} = -3.281 + \underset{(.1114)}{.9577}\overset{*}{Psm} + \underset{(.03)}{.1605}Pso - \underset{(.0003254)}{.0007912}Qsmsl$$

$$DW = -2.28 \text{ (a)}$$

$$\text{2SLS } \overset{*}{Qsmc} = -3377.4 - \underset{(26.92)}{83.52}\overset{*}{Psm} + \underset{(29.19)}{85.74}\overset{*}{Pom} + \underset{(.0208)}{.0582}Hog + \underset{(.374)}{3.388}Broil$$

$$DW = 1.99 \text{ (a)}$$

$$\text{2SLS } \overset{*}{Qomc} = 5073.1 + \underset{(10.08)}{53.82}\overset{*}{Psm} - \underset{(12.4)}{48.67}\overset{*}{Pom} - \underset{(.03466)}{.09116}\overset{*}{Qsmc} - \underset{(10.54)}{23.42}Pc$$

$$DW = 3.28 \text{ (n)}$$

$$\text{2SLS} = \overset{*}{Qsmf} = -37172.6 - \underset{(37.1)}{124.12}\overset{*}{Psb} + \underset{(33.67)}{161.48}\overset{*}{Pomf} + \underset{(2.48)}{36.61}Hpaf$$

$$DW = 2.2 \text{ (a)}$$

$$\text{2SLS } \overset{*}{Qomf} = -19265.6 + \underset{(40.63)}{200.76}\overset{*}{Psmf} - \underset{(40.55)}{152.05}\overset{*}{Pom} + \underset{(3.04)}{23.81}Hpaf$$

$$DW = 1.67 \text{ (a)}$$

$$\text{2SLS } \overset{*}{Q}\text{smx} = -28294.6 - 108.01\overset{*}{P}\text{sb} + 172.83\overset{*}{P}\text{smf} + 21.95\text{Hpaf}$$

(61.19) (91.25) (5.87)

DW = 2.09 (a)

$$\text{2SLS } \overset{*}{Q}\text{omi} = 1088.1 + 38.89\overset{*}{P}\text{smf} - 27.55\overset{*}{P}\text{omf} + .0348\overset{*}{Q}\text{sms} - 2.129\text{Hpaf}$$

(7.86) (5.0) (.0194) (.70)

DW = 2.33 (i)

$$\text{2SLS } \overset{*}{Q}\text{sms} = -6514. + 88.52\overset{*}{P}\text{sm} - 1.117\overset{*}{Q}\text{smx} + 1.60\text{Qsms1}$$

(24.43) (.217) (.157)

DW = 2.34 (a)