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SUBSTITUTING SOY PROTEIN FOR OTHER PROTEINS IN FEED RATIONS: ECONOMIC ASPECTS

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By

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INTRODUCTION

The value of soy protein to an animal is dependent upon many complex and varying factors. In contrast to the papers presented here which concentrate attention on the nutritive value of soy protein, this paper focuses on capturing and evaluating these nutritional aspects in an economic framework.

The approach taken is a mathematical model (linear programming) of the U. S. feed-protein-livestock industry which can be used to quantitatively measure the impact of changes in underlying factors such as feed ingredient supply conditions, animal numbers, feed manufacturing costs, feeding programs, nutrient composition of feed ingredients, nutrient requirements of animals, and feeding rates by animal class. In addition, this conceptual framework can be beneficial in understanding and

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analyzing the demand for specific feed ingredients and/or nutrients, such as the economic effect of substituting soy protein for other proteins. An indepth analysis of the demand for soy protein requires simultaneous consideration of its multiple dimensions of space, time, commodities, quality, feeding programs, animals, and marketing levels. For brevity the approach here is to present the basic features of the model without the dimensions of space, time, and some marketing levels.

CONCEPTUAL FRAMEWORK

The major ideas underlying the conceptual framework are:

1. The formulation of specific feed rations.
2. The measurement of the aggregate quantity supplied and quantity demanded of specific nutrients across commodities.
3. The measurement of price relationships of feed ingredients and/or nutrients derived (imputed) from the physical nutritive analysis under alternative conditions assumed for ingredient and/or animal prices, available supplies, animal numbers fed, quality of ingredients, etc.

Feed Rations

The mechanism which determines the relative quantities of feed ingredients to be consumed is the animal or the feed ration. Feed rations are a means of measuring the value of any feed ingredient to the type of livestock raised based on the nutritional attributes of the ingredient and the nutritional requirements of the animal [3]. Therefore, feed rations are the mechanism from which feed price relationships are derived, depending on the relative quantities supplied and the relative quantities demanded. When a particular commodity is in short supply or perhaps unavailable (i.e., fishmeal in 1974), its price becomes more dear and will be allocated to its higher use value among animals. This implies a substitution effect on both the feed supply side and the animal demand side.

The feeding requirements of different classes of animals vary; however, the feed ration specifications are able to capture these multiple and complex relationships. Both the nutrient characteristics of a particular feed and the value of that feed to the animal are captured in a physical nutritive analysis. These physical or technical coefficients can be combined with feed costs and livestock prices in a linear programming model to facilitate analysis of optimal feed rations given availabilities of feedstuffs and demands of animals to be fed.

Measurement of Nutrients--Quantities Supplied and Demanded

The supply of a specific nutrient such as protein depends on the supply and composition of all feed ingredients. 2/

Further, the supply of protein can be broken into the specific essential amino acid structure of the ingredient and added to the specific amino acids of other ingredients. The demand for protein or a specific amino acid is determined by an aggregation of the requirements estimated for all animal classes under a given set of conditions. This procedure would enable the measurement of commodity(s) supply and demand situations in terms of specific nutrients. 3/ Rather than referring to a situation as a shortage of soybeans, the shortage would be measured in terms of specific nutrients that could best be alleviated by increasing the supplies of specific feedstuffs [1]. Table 1 illustrates the type of information which will be derived from the model.

Price Relationships--Nutrients and Feed Ingredients

The measurement of price relationships under alternative conditions is also dependent largely upon the nutrient composition of feeds and nutrient requirements of animals which was specified.

2/ (Note that implicit in the assumed composition of an ingredient is the quality factor, which will likely vary from year to year and conceivably from region to region). The quality factor of a feed ingredient implies that the weight per unit of measurement (say bushels) and/or the level or amount of a particular nutrient will vary. This relationship needs to be specified before the data are used in the model. Admittedly, there are limitations to the availability and quality of our data at this writing.

3/ Alternative sets of nutrients can be used for a given LP solution, depending upon the objectives.

TABLE 1 -- U.S. selected nutritional supply and consumption data 1974/75 with comparison 1/

Item	Supply		Minimal requirements		Actual consumption	
	1973/74	1974/75	1973/74	1974/75	1973/74	1974/75
Protein (million tons)						
Fat (million tons)						
Calcium (million tons)	THIS TABLE IS FOR ILLUSTRATIVE PURPOSES ONLY.					
Phosphorus (million tons)						
TDN (million KCAL)						
Met. energy (million KCAL)						
Amino acids (million grams):						
Thiamine						
Riboflavin						
Niacin						
Pantothentic acid						
Choline						
Lysine						
Methionine						
Cystine						

1/ See Table 2 for list of commodities included, except Pasture.

TABLE 2 -- U.S. Imputed Prices, by Feed Ingredient in Dollars Per Ton 1973-74 Feed Year 1/

Feed Ingredient	Assumed 2/ Price	Imputed 3/ Price
	- - - - Dollars per ton - - - -	
Corn		
Soybean Meal	THIS TABLE IS FOR ILLUSTRATIVE PURPOSES ONLY.	
Cottonseed Meal		
⋮		
Pasture		

1/ Beginning October 1.
2/ The assumed price is from the objective function of the model.
3/ The imputed price is the marginal or shadow price derived from the structural values of the dual of the linear programing model.

If we assume, a priori, that corn is priced at $2.50 per hundredweight in Illinois during 1970, then the model will derive or impute a price to other feed ingredients based on the rate of technical substitution (RTS). This relationship is hypothesized from economic theory: The use of inputs (feed ingredients) to produce a given level of output (animal) should be such that the RTS is equal to the price ratio of the inputs (feed ingredients) [2]. The RTS's are obtained from a linear programming (LP) model. However, in contrast to the classical derivation, the LP estimate can exhibit many different RTS values for a given input (feed) combination. This is so because the marginal products are discontinuous, particularly between animal classes. Furthermore, the LP model outlined in this presentation recognizes that the RTS is a function of output levels as well as input levels, and will reflect changes in quality and quantity of feed ingredients as well as changes in animal requirements and numbers. Therefore, the RTS may vary for each quality and quantity level specified for each feed ingredient, animal class, their nutrient requirements, and the type of feeding program. This means the RTS obtained from an LP solution of this model will be a desirable measure of the relative feeding values needed to help determine the new price relationships due to changed conditions.

Several LP solutions derived from alternative supply and demand conditions for a specific feed ingredient such as soybean meal can then be used to "map" the quantities of soy protein demanded (by animal class) at various soybean meal prices, assuming prices and quantities of all other feed ingredients are held constant [4]. This procedure will also provide insights into the structure of the demand for other types of feed in relationship to soy protein. Furthermore, this mathematical framework can be used to measure quantitatively the economic effect of new feed products on the demand for soy protein. An example of the type of price information to be derived from the model is illustrated in Table 2.

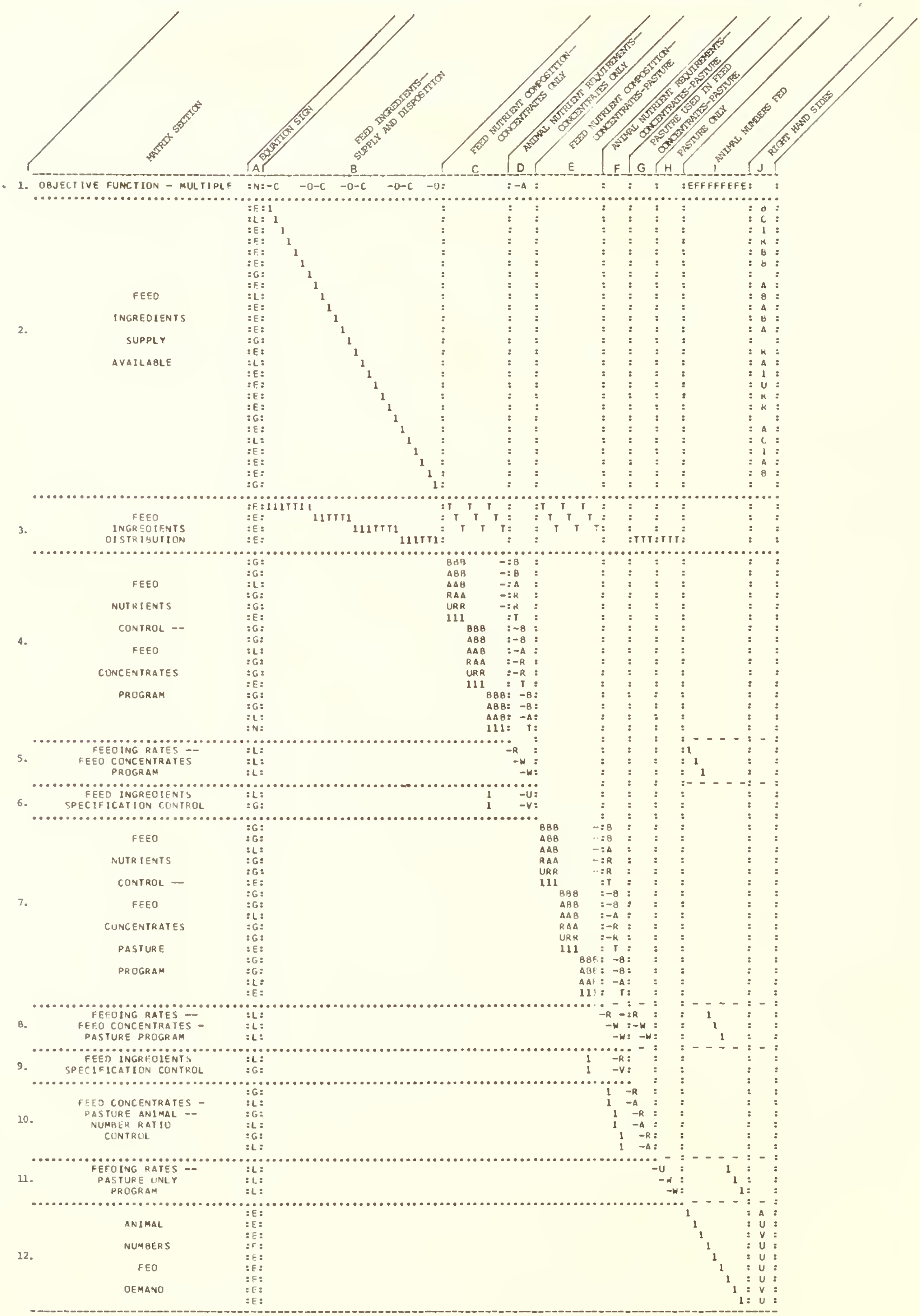
THE MODEL

The linear programming formulation of the feed-protein-livestock industry is represented in Figure 1. Illustrated is a simplified case involving three commodities plus pasture, three types of feeding programs and three animal classes. The additional dimensions of space and time periods are not represented.

The model is divided into several row and column sections for purposes of explanation:

1. The objective function (row section 1) shows the use of several types of feed costs and prices of animals, and represents total net revenue. It is maximized subject to

Figure 1. Linear Programming Format of Feed-Protein-Livestock Model



NOTE: ALL SYMBOLS "T" REPRESENT MINUS ONE (-1).

a set of linear equations (i.e., row sections 2-12) with the solution providing the largest difference between the total value of animal products and total feed ingredient plus processing costs that is consistent with the constraints. In the solution procedure, values are sought for the variables identified in the columns. Column section B represents the supplies and dispositions of the feed ingredients, and sections (C), (E), and (G) represent the quantities of feed ingredients consumed by the various animal classes by feeding method. The variables in column sections (D), (F), and (H) represent the total quantity of feed ingredients consumed by each class that are fed under the various feeding programs. Column section I variables are the number of animals in each class that are fed under the various feeding programs. Finally, column section (J), known as the right hand side, is used to specify limitations on the other activities.

2. The feed ingredient supply available for feeding animals is illustrated in row section (2). These equations input the supply of feeds into the model at costs per unit defined in the objective function. The quantity of feed available is specified in the right hand side of row section (2). The supply available for feeding is the sum of beginning stock (1), production (2), imports (3), and a

dummy supply (7), less nonfeed use (4), exports (5), and ending stocks (6).

The dummy supply (7) is included only for efficient analytical and feasibility purposes. This section can easily be reduced to represent any combination of the above variables for each ingredient. Column section (A) at the top of the matrix in Figure 1 shows the type of equation for each row:

E = an equality (i.e., the left hand side and the right hand side of the equation must be exactly equal).

L = less than or equal ($\leq$)

G = greater than or equal ($\geq$)

N = nonconstrained or free row (i.e., this equation does not restrict the value of the objective function).

3. The feed ingredients distribution section illustrates the transfer of feed supplies available to three types of feeding programs. Types of feeding programs are:

1 = feed concentrates only--column section (C)

2 = feed-pasture--column section (E)

3 = pasture only (with supplements)—column sections (G) and (H).

4. The feed nutrients control section for feed concentrates only feeding program illustrates the nutrient compositions of three feed ingredients where five types of nutrients are specified for the first two animal classes and three types of nutrients are specified for the third type of animal class. This section also controls the nutrient requirements of the three animal classes within the feed concentrates only feeding programs for the specified types of nutrients, column section (D).
5. Row section (5) of the model controls the feeding rates by animal class within the feed concentrates only feeding programs.
6. The ingredient specification controls the amount of a specific ingredient fed to a specified animal class within a range or specified exactly. Together row sections (4), (5), and (6) control the amount and kinds of feed ingredients and nutrients received by animal classes for the feed concentrates only feeding programs.

Similarly, row sections (7), (8), and (9) control the amount and kinds of feed ingredients and nutrients received by animal classes for the concentrate-pasture feeding programs, with the amount of forage (pasture) brought into the solution directly, without specific nutrient control. The amount of pasture allowed is controlled in row section (10) by the feed-forage animal number ratios for each animal class.

The forage or pasture only feeding programs are controlled in row section (11) and column section (H). The assumption implied is that all nutrients are met when the animal class is fed pasture, but may include a mineral and vitamin supplement to the animal's diet.

Demand for feed is established in row section (12) and column section (I). This block contains the number of animals fed by class in each type of feeding program as specified in the RHS. These numbers combined with their respective feeding rates determine the quantities of feed required.

EXTENSIONS OF MODEL

The development of this conceptual framework has already foreseen the need to build more dynamics into the models. Several additional variables will be incorporated into the model presented, one at a time. Some of these have already been developed.

In the future this framework will be extended to include additional features such as: Feed ingredient supply functions, animal numbers fed demand functions, stock of feed ingredients functions--based on nutrient supplies, additional time periods and regions, currency evaluation indices, variable feeding rates, and growth rates of animals.

Ultimately, this model(s) of the feed-livestock sector can be interfaced with a model of the human-food sector, where production of meat is only one of several types of foods available to satisfy alternative levels of human nutrition, income or costs.

SUMMARY

The present model represented by fixed supplies, animals, feeding rates, and animal requirements by class and/or age is a simplification of the U. S. feed-protein-livestock sector. The U. S. feed-protein-livestock sector is an extremely large and complex sector and the number of variables affecting it will need to be specified for more detailed study. The U. S. aggregate model presented here is designed as a first stage toward the development of the full system. Its major use will be the complete specification of feed ingredient supplies, their approximate nutrient composition, animal nutrient requirements, feeding rates and animal numbers being fed. The conceptual framework will bring a sense of objectivity to the analysis of the feed and livestock sectors. Additionally, this model provides insights into the impact of structural changes in the market system on a particular commodity's supply and demand situation.

Feed ingredient supplies are very close substitutes for one another, and no one commodity is able to satisfy the feed ration required for each animal class. The question addressed is how to satisfy the animal requirements in a physical nutritive and economic framework simultaneously. This required that the objective function interact with the constraints in a manner which allows both to vary simultaneously. Thus, the supplies of the various feedstuffs compete with each other for the variety of nutritive demands of the livestock sector. From this is measured the relative value of each ingredient, conditional on the supply (quantity and quality), demand, and cost-price conditions specified.

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