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An Economic Information Program for the U.S. Beef and Pork Sectors

N. A. Aulaqi

J. B. Hassler

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J. B. Hassler

The Agricultural Experiment Station
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H. W. Ottoson, Director

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SUMMARY AND CONCLUSIONS

The livestock industry is a major business enterprise in the U.S. agricultural economy. U.S. farmers receive more cash income annually from the sale of meat animals than from any other product.

Despite its major importance in the economy, the livestock industry has been plagued by seasonal and cyclical instabilities which result in large variations in prices and incomes received by producers. The wide fluctuations in prices cause windfall losses that are not, in many individual cases, offset by later windfall profits. Wide fluctuations in prices also cause over-expansion and under-utilization of capital investments, thereby increasing costs. Price fluctuations have occurred because production of beef and pork is influenced by biological, economic, and geographic factors.

Major objectives of the study were: first, to review present public data programs and to indicate areas of inefficient performance in the production and marketing of beef and pork that still exist under the present data system; second, to simulate an operational information service program for the beef and pork sectors based on programmed solutions for industry allocations and activities; and third, to outline possible implementation procedures for the information service programs and to indicate the role of each of the participants in making it successful.

In evaluating the performance problems of the U.S. beef and pork sectors under the current data programs, special emphasis was given to examining price relationships between forms with various time lags and basic production levels over time. Performance evaluations indicated that spatial decisions and value relationships between form alternatives (at a given point in time) have been made and maintained with reasonable efficiency under the existing structure of public data systems. However, the relationships between forms with various time lags and basic production levels over time have not been maintained efficiently by the beef and pork sectors.

This study utilized previously developed performance and efficiency models. However, the original models were structurally modified and updated. The models imply that the beef and pork sectors of the U.S. are purely competitive, with price patterns over time depending on the flow of meat supplies into the market against the demands. It is also assumed that for any given month, estimated demand functions for beef and pork are known as well as animal inventory numbers by categories for an initial date and subsequent time points.

The mathematical technique used is linear programming over the time dimension. Given the beginning inventories of cattle and hogs, estimated carrying and production costs, and projected demand function, the models for beef and pork are jointly, but separately, solved as a minimum-cost forward program that yields equilibrium allocations over time for beef and pork animals to reproduce, for feeding, and for final slaughter for consumption.

The size of the beef programming model is 824 rows by 2023 columns. The model corresponds to marketing and production activities for beef over a six-year period beginning with inventory conditions as of January 1, 1973. The longer period is necessary because of requirements in the future on present activities. The C_j values on the program activities are the total production costs of the animal to a given stage of growth. Costs incurred on initial inventory of beef animals were not considered.

The pork model has 265 rows and 514 activities. The model allocates competitively the production and marketing of pork over a three-year period beginning with inventory conditions as of January 1, 1973. The functions of the pork programming models were similar to the beef model.

Solutions of the models were reasonably logical and practical for actual usage in the data information system. The particular marketing or production activities selected by the models satisfy the dual criteria of least cost and equilibrium solution. Equilibrium production and marketing is continuously maintained by the models through short- and long-run adjustments. In the short-run, adjustments to move to or to maintain equilibrium are made in variation of slaughter weight levels. Long-run adjustments are made by increases or decreases in the aggregate size of hog and cattle inventories.

It was indicated that use of models for prediction purposes was limited. Rather, the estimated marketing and production recommendations should be used as performance criteria to be achieved by integrated and aggregate action of the beef and pork producers.

The programming solutions were computed sequentially over time to illustrate their operational usefulness. The temporal and form production and marketing allocations of cattle and hog inventories were simulated after a distorted allocation pattern of initial hog and cattle inventory class was assumed to have occurred during the first half of 1973. The new conditional solutions were used to modify the initial recommended allocations.

The use of the programming solutions as the structural basis of an information system for orderly production and marketing of cattle and hogs was evaluated. It was indicated that dynamic coordination of recommended solution allocations and actual allocations would be required, if the information system were to be effective and operational.

The statistical needs for the information system included accurate and comprehensive inventories of hogs and cattle subdivided by sex, weight and disposition, accurate and reliable demand estimates, and adequate data on cost conversion rates for beef and pork animals.

Operation of the information system could be handled by the Economic Research Service (ERS) of the U.S. Department of Agriculture. Responsibility for collecting the data could be given to the Statistical Reporting Service. However, cooperation between these two agencies would be required for effective operation of the data information system. For accurate and reliable data, cooperation and feedback by pork and beef producers would be needed.

An Economic Information Program for the U.S. Beef and Pork Sectors

Nasser A. Aulaqi and James B. Hassler[1]

INTRODUCTION

Livestock production and marketing constitutes a major proportion of the agricultural economy of the United States. In 1973, cash receipts from marketing of farm products were estimated at $83.4 billion. Meat animals were responsible for more than $29.9 billion, or nearly 35 percent of the total. Cattle and calves alone accounted for $22.1 billion. Sale of hogs was estimated at $7.4 billion.[2]

On January 1, 1974 approximately 127.5 million cattle and calves were reported on U.S. farm and ranches, up six million head from the inventory reported for January 1, 1973.[3] In the past five years, the number of cattle and calves on U.S. farms and ranches has increased by more than 17 million head.[4]

Most of the expansion in cattle numbers in the past several years has been in beef cows and calves. On January 1, 1974 beef cow numbers were up 5 percent from a year earlier to 42.9 million head, representing the largest increase during the past 10 years.[5]

Hog inventory numbers for December 1, 1973 were 61 million head, up 3 percent from a year earlier. However, the total pig crop for 1973 was 88.6 million head, down about 6 percent from 1972.[6]

The number of sheep and lambs was estimated at 16.5 million head on January 1, 1974. This was 7 percent less than a year earlier and the smallest inventory on record.[7]

Nature of the Problem

The livestock industry has been plagued by seasonal and cyclical instabilities which generate wide fluctuations in prices and incomes.

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[1] Nasser A. Aulaqi is a former research associate, Department of Agricultural Economics, University of Nebraska. James B. Hassler is Professor, Marketing and Price Analysis, Department of Agricultural Economics, University of Nebraska, Lincoln.

[2] "Farm Income Situation," Economic Research Service, United States Department of Agriculture, Washington, D.C., February, 1974.

[3] "Livestock and Meat Situation," Economic Research Service, United States Department of Agriculture, Washington, D.C., February, 1974.

[4] *Ibid.*, p. 5.

[5] *Ibid.*, p. 5.

[6] *Ibid.*, p. 10.

[7] *Ibid.*, p. 13.

From 1962 to 1973, the price of 900–1100 pound Choice slaughter steers at Omaha ranged from a low of $20.28 a hundredweight in May, 1964 to a high of $52.94 a hundredweight in August, 1973. The difference in average monthly prices between years reached a high of $17.24 a hundredweight between August, 1972 and August, 1973. The difference from one year to the next in monthly average prices for 600–700 pound Choice feeder steers at Kansas City reached a high of $15.37 a hundredweight between August, 1972 and August, 1973.

Seasonally, price variation was $12.29 a hundredweight for 900–1100 pound Choice slaughter steers at Omaha between January, 1973 and August, 1973. Seasonal variation in prices was also evident for hogs. On the average, a difference of about 25 percent in price level occurred between the low in November or December and the high in July or August. Between December, 1972 and August, 1973 the price difference for 220–240 pound No. 1 and 2 barrows and gilts at Omaha was $26.23 a hundredweight or more than 54 percent of the August, 1973 price level.[8]

A direct result of year-to-year and month-to-month price variations is substantial losses which producers suffer that are not, in many individual cases, offset by later profits.[9] Fluctuations in price also cause over-expansion and/or under-utilization of capital investments, thereby increasing costs.

Because of erratic variations in prices, cattle and hog producers are caught in cycles of over-production and under-production. Producers oscillate between viewpoints of optimism and pessimism. During optimistic periods, usually following favorable prices, producers increase production to a level which exceeds an equilibrium growth rate. Cattle and hog numbers are increased by additions to the basic breeding herds. Production is also increased by withholding animals to heavier weights during the subsequent, declining price period. During pessimistic periods, usually following low hog and cattle prices, producers reduce production below equilibrium growth levels.

Disequilibrium in production and marketing of cattle and hogs exists because beef and pork production is influenced by biological, geographic and economic factors. Not only is a long growing and feeding period required before cattle and hogs can be converted to consumable meat, but the gestation period is long. For instance, it requires about two years from the time a calf is born to the time it

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[8] "Livestock and Meat Statistics," Agricultural Marketing Service, Statistical Reporting Service, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., Statistical Bulletins No. 333 and 522 and Supplements.

[9] During the first six months of 1974, it is estimated that cattle and hog producers lost more than one billion dollars as a result of the depressed prices of hogs and beef cattle.

is ready for slaughter. The gestation period adds an additional nine months.

The large number of geographically dispersed beef and pork producers and the long period involved in production cause serious problems in coordinating supplies to demand at equilibrium prices.

Disequilibrium in production and marketing can also be traced to the relative inelasticity of demand for meat. Inelastic demand at the farm level contributes to instability in prices and incomes of cattle and hog producers in two different ways:

1. The inelastic demand for meat causes small changes in production or short-run supply to be magnified into large changes in prices and, therefore, in the incomes of livestock producers.

2. Conversely, because of the inelasticity of demand, a small shift in the demand function for meat will cause drastically different levels of prices and incomes to be associated with a given supply level.

Another important factor which contributes to disequilibrium production and marketing of hogs and cattle is the lack of a prescriptive outlook information service. Current data programs are inadequate bases for guiding producers toward continuous equilibrium in production and marketing of their products.

The combination of those factors leads to large fluctuations in output and prices in the beef and pork sectors.

Possibilities of solving instabilities in the production and marketing of cattle and hogs have been discussed mainly in terms of measures which might influence producer behavior. These measures include supply controls, price guarantees and improved outlook information. Government programs have been applied directly to feed grains, but also have been planned and operated to influence the livestock sector as well. No direct supply control programs have been applied to livestock at least because, in part, of the historical opposition of livestock producers to any proposals that would directly interfere with production and marketing of their products.

This study assumes that a reasonable level of stability can be obtained through the interplay of the market forces of supply and demand without direct intervention. The price mechanism, however, can only be useful in directing resources to their best and most profitable use, if imperfections and distortions which arise as a result of unexpected cyclical and seasonal variations can be corrected.

Remedies analyzed and developed in this study were those that would come from a more active use of market information service programs. This would require "thermostatic" guidance of aggregate inventory management through an advisory information service to be dynamically adjusted over time.

Objectives

Specific objectives of this study were:

1. To indicate areas of inefficient performance in production and marketing of beef and pork.

2. To simulate a market information program for beef and pork producers based on linear programming models.

3. To outline implementation procedures for the information system and to evaluate probable industry response.

General Theoretical Framework

The competitive market concept in space, form, and time was used in this study. This concept is based on the viewpoint that many agricultural markets, including livestock markets, meet most conditions of the competitive model and that certain welfare gains accrue when economic performance is consistent with the perfectly competitive model.

The "efficiency"[10] model provides a standard, or norm, against which performance of beef and pork sectors of the economy can be compared and evaluated. It can be used in conducting meaningful appraisal of performance of the beef and pork sectors both in terms of the delineation of problem areas and of the indications of the magnitude and importance of distortions. Also, it provides a framework within which an action program can be developed to correct these problems.

EVALUATION OF DISORDERLY PRODUCTION AND MARKETING UNDER THE PRESENT DATA SYSTEM

An effective outlook information program is essential for orderly production and marketing of beef and pork. The central role of the USDA public data system should be to actively guide the marketing system of the beef and pork sectors to do its job consistently with minimum costs.

Using the competitive model as a standard of comparison, pricing efficiency studies attempt to appraise performance of the marketing system by contrasting actual prices with ones expected to be generated by the competitive (efficiency) model.

Spatial Evaluation

Many of the spatial studies conducted over the past two decades support the viewpoint that the livestock industry is rationally oriented spatially and performs the distribution function of marketing quite efficiently.[11]

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[10] In this study the "efficiency" model will be used interchangeably with the term "pure competitive model."

[11] J. B. Hassler, "An Appraisal of Spatial Studies Related to Agriculture," *Journal of Farm Economics*, December, 1964, Vol. 46, pp. 1380–1386.

Specialized areas of primary and secondary production of beef and pork have developed consistently with the economic criteria of comparative advantage and relative surplus-deficit conditions. Specialized processing and marketing plants are located strategically between principal points of production and consumption. Thus, the price pattern and distribution flows of beef and pork from the slaughter areas to retail outlets tend to reflect transportation costs and surplus-deficit conditions of supply relative to demand. It is realized that many minor, but not critical, problems must certainly have taken place. However, it can generally be assumed that prices at different production and marketing areas have been roughly uniform spatially plus or minus necessary transfer costs. The implication is that the price mechanism for beef and pork has performed reasonably well under the present data program with respect to the spatial dimension.

Form Evaluations

In a market characterized by pure competition, the price differentials among forms, grades, and classes of beef and pork should be equivalent to the corresponding differences in costs. The price of Choice steers, for instance, should exceed the price of Good steers by the difference in production costs and also be equivalent to the grade value difference reflected marginally on the demand side of the market.

Assuming a perfect market concept in form, Trierweiler and Hassler used relative price analysis to measure efficiency in the U.S. beef and pork sectors.[12] Linear regression analysis was employed as the mathematical form for measuring and evaluating price relationships. Price relationships between market levels were determined and the results indicated good performance between the slaughter, wholesale, and retail levels. Pricing performance at different market levels at a given point in time was found reasonably consistent with grade and yield aspects of form variations in quality and conversion rates.

A recent study which analyzed price relationships between different grades and weight classes of cattle arrived at essentially the same results as those discussed above.[13] Using monthly average prices at Omaha from 1962 through 1970, price relationships between Good and Choice feeder and slaughter cattle were evaluated. Results indicated a strong and competitive relationship in the cattle sector between different grades and forms of cattle at any given point in time.

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[12] J. E. Trierweiler and J. B. Hassler, "Measuring Efficiency in the Beef-Pork Sector by Price Analysis," Agricultural Economic Research, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., January, 1971, pp. 11–17.

[13] Franz Schwarz and J. B. Hassler, "Beef Cattle—At What Weight Should They Be Sold?", University of Nebraska Research Bulletin No. 254, July, 1973, pp. 26–28.

Temporal Evaluation

The purely competitive market concept is used to judge the economic performance of the price mechanism of beef and pork over the time dimension. Under an efficient pricing system, price differences through time should be equivalent to costs of storing products from one period of time to another. For example, costs incurred in carrying hogs or cattle to heavier weights should be equivalent to the extra returns from selling these animals at a later point in time. Comparisons based on added value for carrying hogs and cattle to heavier weight levels and associated carrying costs can be used to indicate the extent of disorderly production and marketing of beef and pork under the present form of public data programs.

Using monthly average prices for hogs No. 1, 2 and 3 at Omaha for 1962 through 1970, and costs and weight data, Hassler[14] estimated additional net returns or losses that would have resulted from marketing hogs at different weight levels. Study results suggested that there was disorderly marketing by weight classes over time. Within the study period, results indicated that there have been many times when it would have been profitable for hog producers to carry their hogs to heavier weights, and many times when the opposite situation occurred. In general, the study showed that during periods of rising hog prices, producers should carry their animals to heavier weights. Conversely, during periods of falling prices, producers should market their hogs at lighter weight levels.

Using procedures similar to those used by Hassler, Schwarz and Hassler evaluated marginal returns and marginal costs of carrying beef cattle between different weight levels.[15] To evaluate the pricing and allocation performance of beef cattle, the authors used actual and imputed prices as a decision criteria.[16] Disorderly performance was indicated when those prices differed excessively. Results disclosed industry-wide disorder in the production and marketing of beef cattle. Cattle prices were found to be inconsistent with production costs. They were either too high or too low most of the time.

Price analyses for feeder cattle versus slaughter cattle (during approximately constant feeding cost periods) indicate a performance failure in the beef sector. Prices between feeder and slaughter animals are not as closely correlated as they should be in a perfect pricing mechanism. Price differences among weights frequently do not

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[14] J. B. Hassler, "Hogs: At What Weights Should They Be Sold?", University of Nebraska Station Bulletin No. 492, Revised June, 1971, pp. 5–10.

[15] Schwarz and Hassler, *op. cit.*, pp. 4–24.

[16] Imputed price was defined as the value of an animal at a later point in time when it is sold minus production costs and divided by the initial weight to express it in dollars per hundredweight.

reflect cost or value differences.[17] For example, prices paid for feeder steers are not based on the future expected price of slaughter steers but rather on current slaughter prices.

Price analyses for hogs also indicate that disorderly temporal marketing is a common performance failure.[18] However, biological factors such as multiple births and shorter production cycles make adjustment easier.

Disorderly production and marketing over time causes disequilibrium price variations. The resulting economic consequences are either windfall gains or windfall losses by cattle and hog producers. Other economic consequences include exaggerated errors by cattle and hog feeders in prices paid for feeder cattle and pigs, and improper marketing rates by weight classes and grades to compensate for shortages or overabundance of cattle and hog numbers in aggregate.

Implications

Spatial decisions and value relationships between form alternatives (at a given point in time) have been made and maintained with reasonable efficiency under the existing form of public data system. On the other hand, relationships between forms with various time lags and basic production levels over time have not been maintained efficiently by the beef and pork sectors.

A relevant question might be why the present U.S. data information program has failed to remedy problems of disorderly production and marketing of beef and pork. The answer might be:

1. The current system of outlook information is not designed to inform producers with forward aggregate equilibrium advice. Projections given by the USDA are related to what will or might occur, and not what *should* occur. The USDA, in making these projections, relies on raw data and simple descriptive models.

2. There is no planned program of timely information about the present level and future consequences for the aggregate of individual decisions on such matters as:

   a. Reproduction base changes and cullings.
   b. Levels of aggregate breeding during critical build-up seasonal time periods.
   c. Levels of feedlot placements by age and weight group.
   d. Levels of marketings and further intended feeding for lighter weight slaughter cattle and hogs.
   e. Meat product inventory build-up evaluation for future supply and prices.

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[17] Trierweiler and Hassler, *op. cit.*, pp. 16–17.

[18] J. Y. Chen and J. B. Hassler, "Evaluating Economic Efficiency by Relative Price Analysis (Feed, Livestock and Product Sectors)," University of Nebraska Research Bulletin No. 239, April, 1970, pp. 17–18.

Only by knowing the current industry position on each of these activities and their estimated future consequences on supply, demand, and prices can adjustments be suggested in time to avoid periods of overproduction and underproduction in the beef and pork sectors.

3. Even if timely data were collected and disseminated to guide production and marketing, estimated forward projections should relate to some desirable criterion level and not just an arbitrary or neutral outlook projection. At present, the relevant data for future consequences are only available after the fact.

The conclusion that disorderly production and marketing are a serious performance failure by the beef and pork sectors under the present data outlook program suggests the establishment of a new positive data program to aid in the solution of the disorderly production and marketing problems.

MODEL FORMULATION, DATA REQUIREMENTS, SOLUTION PROCEDURES AND SPECIFICATIONS

The need for a structural model to provide standard performance measures for orderly production and marketing of beef and pork was stated previously. Standard performance levels are those which would be preferred under some acceptable optimizing principle.

Model Formulation and Assumptions

This study utilizes the performance and efficiency model developed by Trierweiler in 1969.[19] The original model was structurally modified and updated to make it feasible for use as a projective performance model for the U.S. beef and pork sectors.

The models for beef and pork are jointly, but separately, solved as a minimum-cost, forward program for national inventory management to meet projected meat demand functions for a period of time (six years for beef and three years for pork) to permit adjustment to an equilibrium path. Solution results of the models yield the optimal form and time allocation for cattle and hogs for a given set of biological, technical, and economic data.

General Assumptions

The models imply that beef and pork sectors of the U.S. are purely competitive, with price patterns over time dependent on the flow of meat supplies into the market against the demands. Also, for any given month, estimated demand functions for beef and pork are assumed to be known as well as animal inventory numbers by categories for an initial date and subsequent time points.

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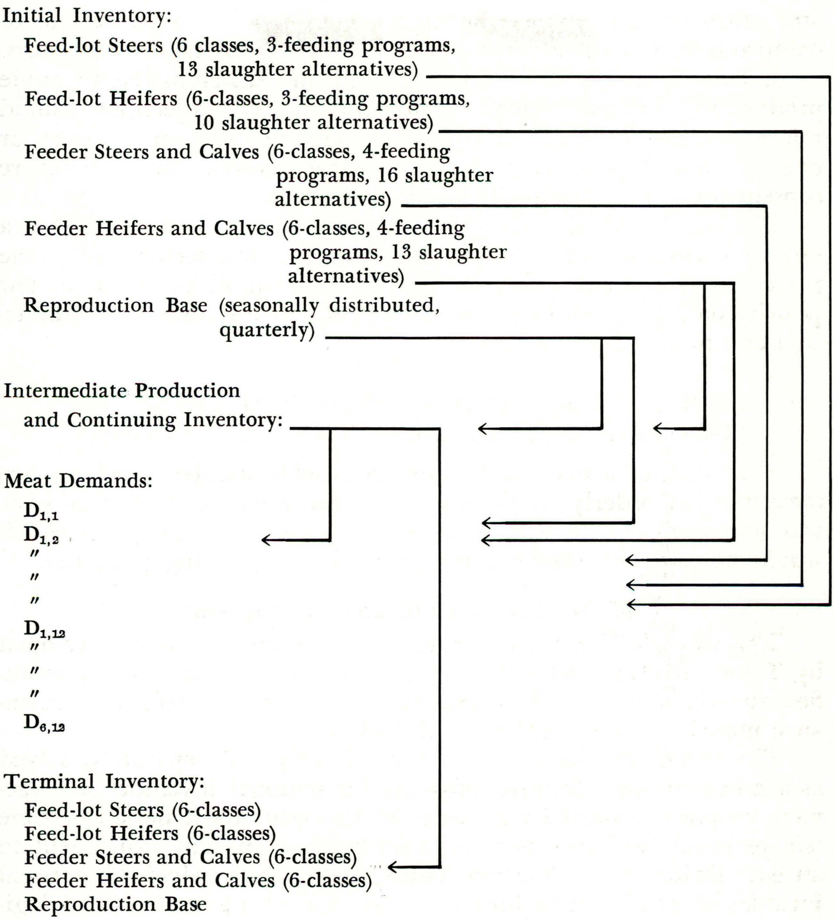
[19] Trierweiler, John E., "Data Needs and Use for Orderly Production and Marketing in the Beef-Pork Sector," unpublished Ph.D. thesis, University of Nebraska, Lincoln, Nebraska, 1969.

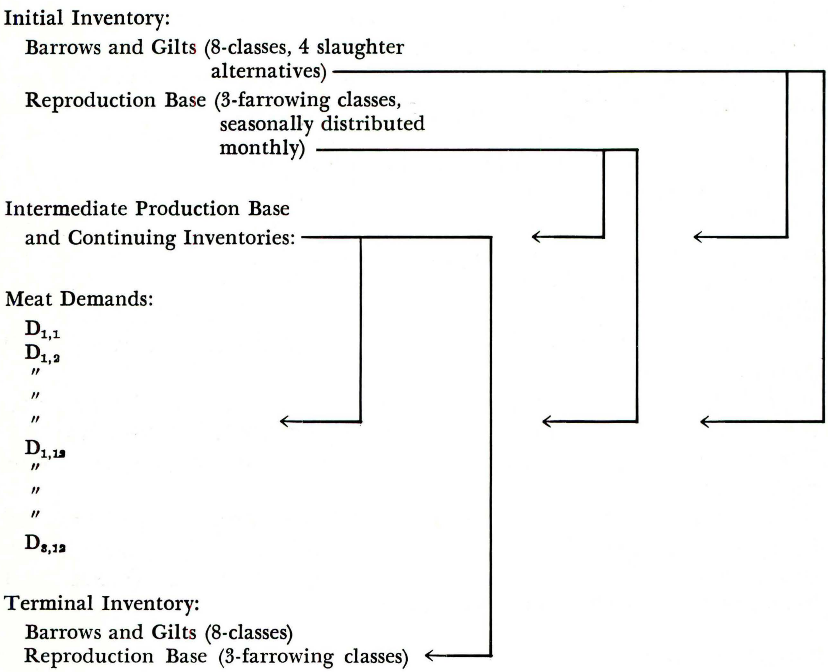
Figure 1. Schematic of beef programming model.



The mathematical technique used is linear programming over the time dimension. Given initial animal inventories, estimated carrying costs, and projected demand functions, the linear programming models for beef and pork determine the equilibrium minimum cost allocation over time for beef and pork animals to reproduce, for feeding programs, and for final slaughter for consumption.

Figures 1 and 2 schematically outline the programming models. The linking arrows indicate the different transfer activities feasible in the structure. The function of the intermediate production and inventory row restrictions is to provide specific time linkage for the beef and pork activities.

Figure 2. Schematic of pork programming model.



Practical Improvements

The original models discussed were practical and logical in structure. However, the solutions displayed "lumpiness" in selection of activity levels by the programs. To illustrate, the marketing allocations of steers and heifers to demand periods showed that during a number of months the entire quantity of beef demanded could be met from a single weight class of steers or heifers.

Practical use of the programming models required rounding and smoothing of the specific program-generated production and marketing allocations. These smoothing modifications were accomplished by placing reasonable upper and lower limits on the proportion of final demand requirements which could be met by single activities.

Models used in this study are, therefore, extensions of the earlier models but differ from them in the following ways:

1. The models include new row restrictions that restrict the amount of meat that can come from a given activity. By increasing the row restrictions, the programs selected more activities to meet given demand requirements.

2. Supply and transfer costs represent cost conditions for 1973, while original models used cost conditions for 1968.

3. Demand functions were estimated by data from 1962–1972. Original models used 1957–1966 data.

4. The base period for inventory numbers is January 1, 1973. Base period for the original models was January 1, 1968.

Data Requirements

The main data required for program solutions were:

1. Beef cattle and hog inventory numbers by weight, sex, and status (cow herd, feeding program position, etc.).

2. Costs per animal for alternative growth and feeding programs, with time requirements and weight gain rates on monthly bases.

3. Calving rates, pigs-saved rates per sow, slaughter and retail conversion rates.

4. Demand functions for beef and pork expressed as linear functions of a specific spot price (retail level or slaughter level equivalent). For solution purposes only single-valued estimates on these functions were used.

5. Many forms of basic raw data were required for the demand function and cost estimates, including population and income projections, feeding budgets, import-export balances in the future, and beef contribution by the dairy sector.

Initial Inventories

Initial inventory numbers used in the beef and pork model are presented in Tables 1 and 2.[20] The aggregate inventory numbers were compiled from published reports by the U.S. Department of Agriculture. The breakdown of inventory numbers into class and weight categories was made by considering seasonal reproduction and slaughter levels in previous years and normal growth rates.

Inventory numbers for hogs were reported for December. Therefore, they were adjusted to represent a January 1 inventory status. The composition of the reproduction herd in the initial inventory of hogs was assumed to be 40 percent gilts, 30 percent one-litter sows, and 30 percent two or more litter sows.[21]

Carrying and Production Costs

Costs per animal for alternative growth and feeding programs

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[20] Initial inventory numbers of beef cattle were compiled and furnished to the authors by Dr. John E. Trierweiler, Economic Research Service. Personal correspondence, October, 1973.

[21] The percentage breakdown of the pork reproduction herd was based on consultation with experts in Animal Science and Agricultural Extension at the University of Nebraska.

Table 1. Initial inventory of steers and heifers on feed, feeder steers and heifers, and the reproduction base, January 1, 1973.

Description	Number (1,000 head)
Feedlot steers	
1200 pounds	133
1100–1200 pounds	530
900–1100 pounds	2675
700– 899 pounds	3300
500– 699 pounds	2613
500 pounds	1120
Feedlot heifers	
1100 pounds	0
950–1100 pounds	261
800– 949 pounds	884
700– 799 pounds	1333
500– 699 pounds	711
500 pounds	925
Feeder steers and calves	
800 pounds	252
725 pounds	489
550 pounds	2846
425 pounds	6211
300 pounds	3478
125 pounds	3200
Feeder heifers and calves	
800 pounds	1925
700 pounds	2642
550 pounds	3697
425 pounds	5106
300 pounds	2869
125 pounds	2640
Reproduction base	
Cows to calf in winter quarter	12034
Cows to calf in spring quarter	15678
Cows to calf in summer quarter	7458
Cows to calf in fall quarter	7203
Culls from previous year cow base	4120

with time requirements and weight gain rates on a monthly basis were based on cost estimates by Trierweiler in 1968 for pork[22] and 1969 for beef.[23] These cost figures were adjusted upward to reflect 1973 cost conditions.

Production cost of an animal at any given marketing weight is the sum of the carrying costs of all the individual production activities necessary to carry the animal from birth. Prior production costs on initial inventory animals are not considered.

Adjustments were made in the beef model to account for changes in quality or grade during growth. No adjustment for grade or quality

[22] Trierweiler, *op. cit.*, p. 48.

[23] Cost estimates for beef (1969) were furnished by Dr. John E. Trierweiler, Economic Research Service. Personal correspondence, October, 1973.

Table 2. Initial inventory of hogs, January 1, 1973.

Description	Number (1,000 head)
Barrows and gilts	
25 pounds	4049
25– 50 pounds	3655
51– 85 pounds	6536
86–130 pounds	10750
131–180 pounds	7955
181-230 pounds	5628
231–270 pounds	1385
271–300 pounds	390
Bred sows to farrow	
First litter in January	347
First litter in February	510
First litter in March	583
First litter in April	580
Second litter in January	261
Second litter in February	383
Second litter in March	438
Second litter in April	436
Third litter in January	261
Third litter in February	323
Third litter in March	438
Third litter in April	436
Lactating sows	
First litter, first month	228
First litter, second month	76
Second litter, first month	171
Second litter, second month	222
Third litter, first month	171
Third litter, second month	222
Non-bred sows (being conditioned for sale)	
One litter sows	95
Two litter sows	237
Three litter sows	142

was made in the pork model because it was assumed that quality of pork does not change significantly with added weight. Total production costs and carrying costs per animal are presented in Appendix A.

Estimated Demand Functions

One essential ingredient of programming models for beef and pork is estimation of demand functions. For program purposes, the retail demand functions must be transformed to the slaughter level.

Demand at Retail—Several factors influence the amount of beef and pork purchased by consumers. One important factor is the price level. Economically rational consumers will tend to buy more meat, when it is relatively cheap. Disposable income of consumers is another factor which influences the amount of meat consumed. Consumers with high incomes usually spend more on meat than those with lower incomes. A third factor is the price of competing items. For example, consumers will buy more of a particular type of meat at a given price, when prices of other meat and meat substitutes are relatively high. Changes in the quantity of pork consumption associated with changes in the price of beef are evidence of this relationship.

Data used in estimating the demand functions for beef and pork cover the period 1962 through 1972. Quarterly data were used in the analyses to evaluate the seasonal variation in demand.

The statistical analyses of demand were conducted by the use of the single-equation, least-squares technique. This technique assumes that the supply of beef and pork is essentially predetermined for each quarter. Consequently, the average prices for successive marketing seasons are considered to trace a demand curve. This approach is reasonably satisfactory for many commodities, especially livestock products.[24]

The numerical results of the demand for beef and pork are:

$$P_1 = 26.65165 - \underset{(1.03037)}{2.75729X_1} + \underset{(.00831)}{0.05734X_3} + \underset{(1.6744)}{1.83241S_1}$$

$$R^2 = .791$$

$$P_2 = 45.55785 - \underset{(.68384)}{0.80945X_1} - \underset{(.50184)}{2.85573X_2} + \underset{(.00563)}{0.03886X_3} - \underset{(1.26427)}{2.806077S_2}$$

$$R^2 = .849$$

where:

P_1 = Retail price of beef (cents per pound), U.S. average

P_2 = Retail price of pork (cents per pound), U.S. average

X_1 = Quarterly per capita consumption of beef (lb)

X_2 = Quarterly per capita consumption of pork (lb)

X_3 = Per capita disposable income at annual rates (dollars) deflated by the consumer price index (1957–1959 = 100).

S_1 = Dummy variable for seasonal variation in summer and fall quarters (July–December)

S_2 = Dummy variable for seasonal variation in spring and summer quarters (April–September).

Signs of all the coefficients agree with economic theory. Numbers in parentheses are the standard errors of the regression coefficients immediately above them. A t-test was conducted to measure the significance level of the regression coefficients. Results indicated that most of the coefficients were significant at the one percent level of probability. The R-squared values were also highly significant. The independent variables in the demand function for beef explained about 79 percent of the variation in beef prices, while the independent variables in the demand equation for pork accounted for about 85 percent of the variation in retail pork prices.

[24] Fox, K. A., "The Analysis of Demand for Farm Products," U.S. Department of Agriculture, Washington, D.C., Technical Bulletin No. 1081, September, 1953, p. 90.

The estimated equations for P_1 and P_2 were algebraically transposed to show quarterly per capita consumption as a function of price in order to derive demand elasticities and for later usage in the study. In their quantity dependent form, the beef and pork demand functions are:

$$X_1 = 9.665886 - .3626750P_1 + .020795X_3 + .664569S_1$$

$$X_2 = 13.213364 + .1027995P_1 - .350173P_2 - .188390S_1 - 1.00176S_2 + .007714X_3$$

Average values of variables were used in deriving the elasticities of demand for beef and pork. These values are: $X_1 = 26$, $X_2 = 16$, $X_3 = 2357$, $P_1 = 90$, and $P_2 = 68$. The computed price elasticities are –1.25 and –1.45 for beef and pork, respectively. Price elasticity results indicate that pork is slightly more elastic than beef.

Income elasticities of demand were computed for both beef and pork. The derived income elasticity for beef is 1.8, suggesting that a 1 percent rise in per capita-disposable income is associated, on the average, with a rise of about 1.8 percent in per capita consumption of beef. The income elasticity of demand for pork is 1.13. Even though the income elasticity for pork is positive, the results indicate that beef is more popular than pork in the diet of U.S. consumers.

Cross elasticities of demand for beef with respect to pork and pork with respect to beef were evaluated. The cross elasticity of beef with respect to pork was of the wrong sign and the price response coefficients were statistically insignificant. Consequently, it was dropped from the beef equation. Cross elasticity of pork with respect to beef price is .17. This elasticity suggests that a 1 percent change in beef price has been associated with a .17 percent change in pork consumption.

Seasonal differences in demand for beef and pork were also evaluated. As expected, the analysis showed that per capita consumption of beef was higher in the summer and fall than in winter and spring. The computed difference amounted to about .66 pounds per capita per quarter. The evaluation of seasonal differences in the pork equation indicates that per capita consumption of pork increased by slightly more than one pound in the fall and winter quarters in relation to spring and summer consumption.

Market Price Functions at Slaughter Level—Price functions relating live slaughter animals with the retail level were estimated by use of monthly time series data for the period 1962 to 1972. The estimated functions are:

$$P_s = -3.46594 + \underset{(.02783)}{0.4959P_1} - \underset{(.76035)}{4.5155W}$$

$$R^2 = 0.923$$

$$P_h = -7.52652 + \underset{(.02453)}{0.59495P_2} - \underset{(.50270)}{4.45983W}$$

$R^2 = .867$

where:

P_s = Price of Choice slaughter steers (900 to 1100 lb) at Omaha in dollars per hundredweight

P_1 = Retail price of beef (cents per pound), U.S. average

W = U.S. hourly wage rate of food and kindred product employees in dollars

P_h = Price of No. 1, 2 and 3 butcher hogs (220 to 240 lb) at Omaha in dollars per hundredweight

P_2 = Retail price of pork (cents per pound), U.S. average.

Signs of all the regression coefficients are as theoretically expected. Numbers in parentheses are the standard errors of the regression coefficients. Results of the t-test showed that all the regression coefficients in the beef and pork equations were significantly different from zero. The R-squared values were also highly significant, suggesting a high degree of association between the dependent and independent variables. In the beef equation the independent variables explained about 92 percent of the variation in slaughter steer prices, while the independent variables in the hog price equation accounted for more than 86 percent of the variation in butcher hog prices.

Regression coefficients of P_1 and P_2 should reflect carcass yield rates in a competitive market system. However, the estimated coefficients tend to be slightly different from their expected values. The constant terms in both functions include non-labor processing costs (after by-product allowances) from slaughter to retail level. These costs are about \$3.50 per hundredweight for beef and \$7.50 per hundredweight for pork. In general, the above analysis seems to confirm the evidence of relatively efficient marketing performance from the slaughter to the retail level for both beef and pork.

Derived Demand Functions—Basic to determination of optimum production and marketing of beef and pork is the estimation of derived demand functions at the slaughter level. This requires that the retail price of beef (P_1) and the retail price of pork (P_2) be converted to their functional equivalent in terms of the slaughter prices P_s and P_h for beef and pork, respectively.

The price function at the slaughter level when converted to retail price dependent form follows:

Beef

$$P_1 = 7.067722 + 2.039193P_s + 9.301883W$$

Pork

$$P_2 = 12.650677 + 1.68081P_h + 7.496143W$$

Previously, demand functions at retail for beef and pork were estimated by the use of time series quarterly data. However, in the linear programming analysis, monthly data are needed. Converting the quarterly retail demand functions to a monthly basis results in:

$$X_1 = 3.221962 - .12089P_1 + .22153S_1 + .00693X_3$$

$$X_2 = 4.404455 + .0342665P_1 - .116724P_2 - .062797S_1 - .333925S_2 + .002638X_3$$

Upon substitution of the converted market price functions into the retail demand functions, the slaughter derived demand functions are obtained for Choice steers and hogs. These relationships are on a per capita basis and are as follows:

$$X_1 = 2.36754 - .246518P_s - 1.124605W + .22153S_1 + .00693X_3$$

$$X_2 = 3.170004 + .069876P_s - .19619P_h - .556236W - .062797S_1 - .333925S_2 - .002638X_3$$

The demand functions used in the programming models contained a number of exogenous variables. Trend functions for these exogenous variables were estimated using simple least-squares analyses. In each analysis one exogenous variable was treated as a dependent variable and time as an independent variable. The following results were obtained:

$$N_i = 160.20545 + \underset{(.06206)}{2.59923}t_i$$

$$r^2 = .991$$

$$D_{ik} = 280.16606 - \underset{(.00544)}{9.50397}t_{ik}$$

$$r^2 = .965$$

$$W_{ij} = 1.61363 + .00788t_{ij}$$

$$r^2 = .928$$

$$C_{ij} = 87.37619 + .23185t_{ij}$$

$$r^2 = .895$$

where:

N_i = U.S. civilian population in ith year (millions)

D_{ik} = U.S. disposable income at annual rates (billions of dollars) in ith year and kth quarter.

W_{ij} = Hourly wage rate for food and kindred product employees (dollars) in ith year and jth month.

C_{ij} = Consumer price index in ith year and jth month (1957–59 = 100)

t = time (general symbol) with

i = years (1955 = 1 except in the case of disposable income where 1960 = 1)

j = months

k = quarters

The above relationships show that there is a high degree of correlation between time and each of the exogenous variables indicating good forecasting relationships. The population trend function was used to estimate total consumption of beef and pork by multiplying estimated per capita consumption by population.

The estimated demand function for beef includes cull cows and calves from the dairy herd, plus the import-export balance. The import-export balance in the pork function is considered insignificant.

Solution Procedures

This section summarizes solution procedures and specifications for beef and pork programming models. A detailed description of the models is presented in Appendix B.

The programming models are designed to determine optimum inventory flows for beef and pork to aid these livestock sectors in making economic adjustments toward orderly production and marketing. The models are capable of simultaneously allocating existing inventories of animals to future demands and also determining the proper consistent levels of replacement and culling of the reproduction base for future production. The specific activities selected by the programs are those which meet the dual criteria of minimum supply cost and an equilibrium solution.

The size of the beef programming model is 824 rows by 2023 columns. The model provides for marketing to meet future demands from the initial inventories, cow cull and heifer replacement, and the production and marketing of program generated supplies over a six-year time period. The C_j values on the program activities are the total production costs of producing the animal to a given stage of growth. Costs incurred on initial inventory of beef animals are not considered. These costs should not affect the decision making process into the future.

The programming model for beef provides for a number of production and marketing alternatives. The production alternatives allow for four types of feeding programs. These are high-energy feedlot finishing, medium energy feedlot finishing, low energy feedlot finishing and non-feedlot finishing programs. Cattle may be sold for slaughter at weights ranging from 800 pounds to more than 1,200 pounds for steers and from 800 pounds to 1,130 pounds for heifers. Thus, there is a wide range of marketing alternatives allowed by the beef model.

The programming model for pork has 265 rows and 514 activities. The model simulates production and marketing of pork over a three-year period. The functions of the pork programming model are very similar to those of the beef model.

Activities in the pork model provide for production and marketing of barrows and gilts and also for maintenance and adjustment necessary in the reproduction base. Only a single feeding program is considered on butcher hogs. However, there are four marketing alternatives. Barrows and gilts may be sold for slaughter over a four-month period at weights ranging from 180 to 300 pounds. In the pork programming model, multi-farrowing is limited to three litters per sow.

Solution Specifications for Use in Data Information Program

Programming models for beef and pork carry with them the assumption that the optimal production and marketing performance targets will be effective for the entire programmed period. In reality this may not be possible. Some deviation in actual performance from the target levels would likely occur. Optimal performance targets for a particular point in time inevitably require a series of revisions as time and the future course of events unfold and more information becomes available.

Once program solutions are worked out (called initial optimal solutions hereafter), they would be released at the beginning of the planning period (quarter) as performance targets for the beef and pork sectors. Dynamic coordination of target data distribution and actual data on achieved performance would be essential to gauge system effectiveness and to reformulate new targets consistent with continuous optimum adjustments.

On the basis of actual performance data collected during the first quarter, a new optimal program solution would be made. This new solution would be released at the beginning of the second quarter and used instead of the outdated solution. This process would be repeated each quarter, but only up to one year of forward solution activities would be reported although the complete models would cover six years and three years, respectively.

Initial Optimal Solutions

Estimates of demand and initial inventories, in conjunction with alternative production activities and their costs, provide materials needed to formulate the models to solve for orderly production and marketing processes for beef and pork over time. The initial base period for the program solutions for beef and pork began with inventory conditions on January 1, 1973.

Beef Model

Although the beef model solutions indicate equilibrium production and marketing over a six-year period, only about one year of forward solution activities would be reported each time the model is solved. The longer period is required because the solution process should include the effects of future demand-supply forces on present activities.

The solution results for the beef model are presented in Tables 3 through 7. The live animal allocations results are grouped in each table according to specific allocation categories. These categories

Table 3. Optimal allocations of initial inventory of feedlot steers to slaughter by months, weight, and grade, 1973.

Description	Initial inventory subdivided by weight groups[a] 1,000 head					
	133	530	2675	3300	2613	1120
Slaughter						
January	124[b] (1190, P)	530 (1060, C)				
February	9 (1240, P)		2036 (1060, C)	374 (920, G)		
March			515 (1130, C)	90 (990, G)		
April			124 (1190, P)	1337 (1060, C)		
May				1470 (1130, C)		
June				29 (1190, P)	1288 (990, G)	
July					853 (1060, C)	
August					472 (1130, C)	
September						472 (1060, C)
Continuing						648

[a] See Table 1 for definition of these weight groups.

[b] The numbers and letters in parentheses are individual liveweights at the time of slaughter and grade, respectively. The grades are P = Prime, C = Choice, and G = Good.

Table 4. Optimal allocations of initial inventory of feedlot heifers to slaughter by months, weight, and grade, 1973.

Description	Initial inventory subdivided by weight groups[a] 1,000 head				
	261	884	1333	711	925
Slaughter					
January	261 (1030, C)[b]	832 (910, G)			
February		52 (970, C)			
March					
April			144 (910, G)		
May			239 (970, C)		
June			798 (1030, C)		
July			152 (1080, P)		
August				711 (1030, C)	
September					
Continuing					925

[a] See Table 1 for definition of these weight groups.

[b] See Table 3 for clarification of weight-grade code in parentheses.

Table 5. Optimal allocations of initial inventory of feeder steers, steer calves, and steer calves to be born, to feedlot placements and slaughter by months, weight, and grade, 1973.

Description	Initial inventory subdivided by weight groups[a] 1,000 head						Steer calves born 1,000 head		
	252	489	2846	6211	3478	3200	Jan-Mar 5052	Apr-June 6831	July-Sep 3381
Feedlot Placements[b]									
January	252 (800)	489 (700)							
February				1554 (450)					
March									
April									
May			1511 (700)		268 (450)				
June									
July			1335 (800)	952 (700)					
August						1267 (450)			
September							750 (450)		
Slaughter									
January									
February									
March	252 (990, G)								
April		233 (920, G)							
May		256 (990, G)							
June									
July			1169 (920, G)						
August			342 (990, G)						
September			342 (990, G)						
Continuing									
Out of feedlot				3705	3210	1933	4302	6831	3381
In feedlot			993	2506	268	1267	750		

[a] See Table 1 for definition of these weight groups.

[b] Feeder steers are assumed to be placed on feed weighing about 600 pounds, 700 pounds, or 800 pounds, respectively.

include slaughter allocations (projected for nine months), production reserve allocations (projected for nine months), and reproduction base allocations (projected for one year).

Allocations of Feedlot Steers and Heifers—Tables 3 and 4 present optimal allocations of feedlot steers and heifers by weight and grade.[25] For a given inventory weight classification of either steers or heifers, the model determines the minimum-cost distribution of animals over the projection period to meet monthly demands for beef. In the programming model, beef demands are expressed in terms of millions of pounds of carcass beef. On the other hand, supply is expressed in terms of live animal units of one-thousand head.[26] Slaughter production on a liveweight basis is converted to the demand basis through dressing percentages. For approximate purposes, a 60 percent dressing yield rate can be used to compute the meat equivalent from the liveweight numbers of steers and heifers. Cull beef and dairy cows were assumed to be marketed at 1,000 pounds liveweight and yielding 54 and 36 percent carcass meat, respectively.

Allocations of Feeder Steers and Steer Calves—The optimal allocations of feeder steers, steer calves, and steer calves to be born in the immediate future, to feedlot placements and slaughter are presented in Table 5. These solutions represent the equilibrium allocations (over the projection period) of feeder steers and steer calves to specific feeding programs and eventually to slaughter by months and weights. Feeder steers are assumed to be marketed for slaughter at weights ranging from 800 pounds to 1,240 pounds.

Allocations of Feeder Heifers and Heifer Calves—Feeder heifers can either be fed and marketed for slaughter or used for beef cow replacements for future production. The particular alternative selected by the model depends on the opportunity value in immediate production versus the opportunity value in future production. Table 6 gives the optimal program allocations of the initial inventory of feeder heifers, heifer calves, and programmed heifer birth to feedlot placements, slaughter and beef cow replacements. Slaughter activities are given by months, grade, and weight. Beef heifer replacement activities are presented by quarters for a one-year projection period.

Reproduction and Culling Allocations—A 14 percent culling rate is assumed in the beef model. This rate represents an industry average of physical deterioration of the reproduction base. The beef model allocates competitively the number of heifers that can go to either immediate slaughter or replacement for future production. Table 7

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[25] In the model slaughter weight is used partially as an indicator of grade. It is assumed that grade improves as the weight of the animal increases.

[26] Supply of imported meat, which also satisfies demand, is expressed in terms of millions of pounds (carcass-weight basis). Net imports for 1973 were placed at 2,100 million pounds with a limit of 300 million pounds (approximately 15 percent of monthly U.S. civilian consumption of beef) that can enter in any given month.

Table 6. Optimal allocations of initial inventory of feeder heifers, heifer calves, and heifer calves to be born, to feedlot placements and slaughter by months, weight, and grade and to cow herd replacements by quarters, 1973.

	Initial inventory subdivided by weight groups[a] 1,000 head						Heifer calves born 1,000 head		
Description	1925	2642	3697	5106	2869	2640	Jan-Mar 4802	Apr-June 6585	July-Sep 3134
Feedlot Placements[b]									
January	1568 (800)								
February									
March									
April		48 (800)	3447 (700)						
May									
June									
July			250 (800)	1634 (700)					
August						95 (450)			
September									
Slaughter									
January	357 (815, G)								
February									
March	1291 (970, C)								
April	277 (1030, C)								
May									
June									
July		48 (1030, C)							
August			1320 (970, C)						
September			1975 (1030, C)						
Replacement									
Jan–Mar		2594							
Apr–June				3293					
July–Sept					2670				
Oct–Dec						1500			
Continuing									
Replacement		2594		3293	2670	1500			
Out of feedlots				179	199	1045	4802	6585	3134
In feedlots			302	1634		95			

[a] See Table 1 for definition of these weight groups.

[b] Heifer feeders are assumed to be placed on feed weighing about 600 pounds, 700 pounds, or 800 pounds, respectively.

Table 7. Cow cull and heifer replacements, by quarters, 1973.

Year	Description	Cow herd (by calving quarter)	Cow cull	Replacement	Net replacement
			1000 head		
1973	Total	42373	5932	10057	4125
	1st quarter	12034	1685	2594	909
	2nd quarter	15678	2195	3293	1098
	3rd quarter	7458	1044	2670	1626
	4th quarter	7203	1008	1500	492

presents the distribution of the initial reproduction herd, cow cullings, and heifer replacement by quarters. Net replacement in 1973 out of the initial inventory was approximately 4.1 million heifers or 9.7 percent. Table 7 indicates that proportionately greater replacements took place in the spring and summer quarters than in the winter and fall quarters. This may reflect cost differences between seasons.

Pork Model

Procedures and solution results of the pork model are in many ways similar to those of the beef model. The pork programming model results indicate the equilibrium production and marketing activities over a three-year period. However, for this study only six months of forward solution activities are reported.

The initial optimal solutions of the pork model are grouped according to specified termination categories. These categories cover the allocation of the initial inventory and the program generated supplies to slaughter, intermediate production, and the reproduction base.

Slaughter Allocation of Barrows and Gilts—The equilibrium slaughter allocation of barrows and gilts is presented in Table 8. Numbers in parenthesis under the monthly allocations indicate the slaughter liveweight at the time of marketing.[27] In the model, monthly demands for pork are expressed in terms of millions of pounds of carcass pork (excluding lard). Slaughter production, however, is expressed in terms of live animal units of one thousand each. Supply and demand are, therefore, equivalently converted by dressing percentages. A 56 percent yield rate can be used to compute the meat equivalent from liveweight numbers of barrows and gilts.

Reproduction Allocations of Gilts—Table 8 also presents the optimal program allocation of initial inventories to reproduction activities. Gilt replacement for future production is determined competitively by the pork programming model. Gilts can either be slaughtered for immediate meat demand, carried for additional periods for slaugh-

[27] No quality differences are used in the pork model.

Table 8. Optimal allocations of initial inventory of barrows and gilts to slaughter and reproduction activities, by months, 1973.

Description	Initial inventory subdivided by weight groups[a] 1,000 head							
	1 4049	2 3655	3 6536	4 10750	5 7955	6 5628	7 1385	8 360
Slaughter								
January						4923 (230)	1385 (270)	360 (300)
February					7167 (230)	705 (270)		
March				7002 (230)	214 (270)			
April			3189 (230)					
May		2568 (230)	2697 (270)					
June	2960 (230)	835 (270)						
Replacement[b]								
January					574			
February				823				
March			650					
April		252						
May	742							
June	347							

[a] See Table 2 for definition of these weight groups.

[b] Gilts for replacements are presented according to the month of intended breeding.

ter at heavier weights, or returned to the reproduction base as replacements. All these alternatives are determined by considering the opportunity value of gilts to meet current demand versus their value in future production.

Slaughter Allocations of Sows—Tables 9 and 10 present the optimal flow of bred and lactating sows to slaughter activities by weight and month of slaughter. In the pork model, bred sows are classified according to number of previous farrowings and the month of expected farrowing. After a lactation period of two months or less, sows can either be culled for slaughter to meet monthly demands or rebred for further reproduction. However, first-litter sows are culled arbitrarily by a rate of 25 percent to eliminate inefficient breeders. Cull sows are marketed at 310, 400, and 460 pounds, yielding 52, 50, and 48 percent carcass pork equivalent (excluding lard), respectively.

Reproduction Allocation of Sows—The model determines the equilibrium allocations of bred and lactating sows to slaughter versus continuation in the reproduction herd. Results are given in Tables 9 and 10. Allocations to reproduction are specified according to months of intended breeding.

In the pork model, it is assumed that the average number of pigs saved per litter is 6.5 pigs for first-litter sows and 8 pigs for second

Table 9. **Optimal allocations of initial inventory of bred sows to slaughter and reproduction activities by months, 1973.**

	Bred sows subdivided by months and number of farrowings 1,000 head											
	First-litter-sows				Second-litter-sows				Third-litter-sows			
Description	Jan 347	Febr 510	Mar 583	Apr 580	Jan 261	Febr 383	Mar 438	Apr 436	Jan 261	Febr 383	Mar 438	Apr 436
Slaughter												
January												
February												
March	87 (310)				122 (400)				261 (460)			
April		127 (310)								383 (460)		
May			146 (310)				438 (400)				438 (460)	
June				145 (310)								436 (460)
Reproduction[a]												
January												
February												
March	260				139							
April		383				383						
May			437									
June				436								
Continuing[b]								436				

[a] Reproduction allocations of sows are given according to the month of intended breeding.
[b] The sows in this category are still uncommitted to either reproduction or slaughter at the end of the six-month project period.

and third-litter sows. Table 11 shows composition of the reproduction herd and pigs saved by months. Sows are subdivided according to number of farrowings and month of expected farrowing.

Table 11 figures indicate unusually low and high levels of farrowing for the months of May and June, respectively. This is in contrast to actual practices where June farrowing is usually substantially lower than for May. Because of the short production period for hogs, the program solution found it more economical to adjust production levels in May and meet future demand by carrying a substantial part of April production of pigs saved to heavier marketing weights in November. This complex interdependent solution response was required to adjust to a distorted initial inventory of bred and lactating sows.

Usage Evaluation

Solution results in Tables 3 through 11 represent the optimal set of transfer activities which meet meat demands and carry-out inventory requirements at minimum costs. The particular marketing or production activities selected by the beef and pork models meet the

Table 10. Optimal allocation of initial inventory of lactating and non-bred sows to slaughter and reproduction activities, by months, 1973.

	Lactating sows subdivided by months and number of farrowings 100 head						Non-bred sows 1,000 head		
	First-litter		Second-litter		Third-litter				
Description	First mo. 228	Second mo. 76	First mo. 171	Second mo. 222	First mo. 171	Second mo. 222	One-litter sows 95	Two-litter sows 237	Three-litter sows 142
Slaughter									
January		19 (310)		222 (400)		222 (400)		237 (400)	142 (460)
February	57 (310)				171 (460)				
March									
April									
May									
June									
Reproduction[a]									
January		57					95		
February	171		171						
March									
April									
May									
June									

[a] Reproduction allocations are presented according to the month of breeding.

dual criteria of least cost and equilibrium solution. Specifically, the primal solution gives the activity levels of production and marketing. The dual solution (for demand restrictions) gives the marginal values of production which under perfect competition are equal to equilibrium prices of the product in demand. Equilibrium is continuously maintained by the models through short- and long-run adjustments. In the short-run, adjustments are made in slaughter weights. In the long-run, adjustments are made by increases or decreases in the aggregate size of the inventory.

Actual data on slaughter, feedlot placement, and beef heifer and gilt replacement activities are not directly comparable to data generated for these activities by the models. The level and time pattern

Table 11. Allocation of sows farrowed by litter number, and pigs saved by months, 1973.

Month	First-litter sows	Second-litter sows	Third-litter sows	Pigs saved
		1000 head		
January	347	261	261	6401
February	510	383	383	9348
March	583	438	438	10997
April	580	436	436	10746
May	574	152	......	4947
June	823	171	171	8085

of the model solutions do not correspond very closely to the actual results during 1973. The solution results provided by the efficiency models describe the optimal structure of production and marketing under the assumption of a perfect market in form, space, and time. The actual results are the product of an industry characterized by disequilibrium production and marketing over time. It is obvious that the use of the beef and pork efficiency models for predictive purposes, particularly in the short-run, is limited. Rather, the estimated projections of the models should be used as performance targets to be achieved by the industry if actual performance is to be in accord with the performance of the efficiency models.

OPERATIONAL AND IMPLEMENTATION PROCEDURES FOR THE MODELS

The programming model solutions can be determined sequentially over time and thereby provide a continuing series of projective performance measures for a data information system. A non-optimal actual usage of initial cattle and hog inventories will be assumed to have occurred and the models will then be resolved for new solutions. The solution results will then be used to alter the initial optimal allocations for current and future time periods. Finally, an outline of implementation procedures for the use of the programming models for more orderly production and marketing of cattle and hogs will be suggested.

Assumed Performance Deviations

To illustrate operational usefulness, the programming models will be used to simulate subsequent adjustments of production and marketing for cattle and hog inventories stemming from assumed distortions in actual usage of beginning inventories during the first quarter of 1973. The main cause of the distortions in the pattern of production and marketing was assumed to be the lack of adequate and prescriptive information.[28] The magnitudes of the distortions were arbitrary. Nevertheless, they were generally similar to what actually occurred in 1973. Non-optimum performance deviations assumed for the first two quarters of 1973 were:

Beef Sector

1. A 10 percent increase above optimum levels in marketings of lightweight steers and heifers.[29]

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[28] It is recognized, however, that outside forces may have initiated the distorted pattern of production and marketing, but due to the lack of a diagnostic and periodic monitoring, adjustments by producers to correct these distortions were delayed and in many cases were either excessive or short of requirements for orderly production and marketing.

[29] Lightweight marketings are defined as those below 920 pounds (liveweight basis).

2. Feedlot placements of feeder steers and calves and feeder heifers and calves were reduced by 10 percent from optimum placement levels.

3. Replacement beef heifers were assumed to have increased by 10 percent above the optimum replacement levels.

Pork Sector

The assumed non-optimum changes in the pork sector involved an increase of 10 percent in the slaughter of lightweight butcher hogs.[30] The reproduction base was decreased by 5 percent below the optimum level. This distorted pattern was only simulated for the first quarter of 1973.

Operational Procedures

The linear programming models for beef and pork were adapted to the distorted activities in each quarter by the following procedures:

1. All assumed marketing activities during the first quarter were fixed at optimum or non-optimum levels by bound restrictions. To secure feasibility and consistency for the solutions, the monthly demand constraints were adjusted by the same magnitude as those on the supply side.

2. Reproduction activities were fixed within each quarter by bound restrictions.

3. Feedlot placements of cattle were fixed by bound and row restrictions. Those feedlot placements allocated to slaughter within the quarter were fixed by bound restrictions. However, feedlot placements (such as lightweight feeders) which were terminated across more than one quarter were fixed by inserting new row restrictions in the model equivalent to the aggregate number carried forward.

As a result of the imposition of the row and bound restraints on the production, marketing, and feeding activities, the linear programming computational process simply forced readjustments of the solutions until the bound and row constraints were met. Thus, the new solutions obtained are conditional, since they are conditioned by the fixed activities imposed on the solutions of the models.

Conditional Optimal Solutions

Initial optimal solutions for the beef and pork models were presented in Tables 3 through 11. Results obtained from the conditional solutions were compared with those obtained from the initial solutions. Detailed tabulation of the results are not given here.[31]

[30] Lightweight butcher hogs are defined as those weighing 180 pounds (liveweight basis).

[31] Complete tabulation of the conditional optimal solutions is given in Aulaqi, N. A., "A Projective Programming Information Model for the U.S. Beef and Pork Sectors," Unpublished Ph.D. thesis, University of Nebraska, Lincoln, October, 1974.

Attention will be given to tracing corrective adjustments required to counteract distortions assumed to have occurred in the temporal production, feeding, and marketing allocations of the initial inventories of cattle and hogs.

Beef Model

The beef model was solved sequentially. After an initial optimal solution was obtained (Tables 3 through 7) the model was recomputed after all activities in the first quarter were fixed at optimum or non-optimum levels. The same procedure was repeated for the solution computed at the end of the second quarter. Solutions were compared and evaluated with respect to differences in the temporal and form patterns of production and marketing allocations generated by the assumed non-optimum usage of the initial inventories. Comparisons were grouped into three categories: a) slaughter allocations, b) feeding allocations, and c) reproduction (replacement) allocations.

Slaughter Allocations—The pattern of allocations was generally different for the initial and the conditional solutions. As a result of the distorted pattern of allocating the initial inventories in the first two quarters, the adjustment by the beef model to counteract those distortions was to carry some inventory groups of steers and heifers to heavier weights. The adjustment also involved changed patterns of feeding and reproduction levels.

In the very short-run, the model was able to correct, the problem of marketing excessive lightweight steers and heifers by carrying some of the remaining feedlot inventory groups of steers and heifers to heavier weights. To illustrate, the initial optimal allocations for the month of June (Tables 3 and 4) were 2.115 million head of steers and heifers. When a distorted allocation pattern was imposed on the program solution for the first quarter, the demand for June was satisfied by 2.08 million head. Thus, the model stablized beef supplies with demands by carrying some slaughter steers and heifers to heavier weights.

Over a period of more than a quarter, the adjustment to disorderly marketing pattern became more flexible. In response to the distorted allocation pattern of the initial inventory, the program placed more cattle on feed to meet future demands rather than feeding the existing feedlot steers and heifers to heavier weights. For example, the number of slaughter steers and heifers allocated to July meat demand was 2.223 million head under the initial optimal solution. When a non-optimal use of the initial inventory in the first two quarters of 1973 was assumed, the new allocation was 2.321 million head or 98,000 head greater than the original allocation level.

Feeding Allocations—A 10 percent reduction in the optimal placement level was assumed for the first and second quarters of 1973.

To offset the reduction in feedlot placements in the first quarter, the model readjusted the optimal placements upward for the subsequent quarters. For instance, the optimal placement level of steers and heifers for the second quarter was raised from 5.274 million head (see Tables 5 and 6) to 5.788 million head—about 10 percent. These dynamic adjustments were made by the model to maintain stability of supply to satisfy the projected demand levels consistent with minimum carrying and production costs.

Reproduction Allocations—A 10 percent increase above optimal levels was assumed for beef heifer replacements. This increase is very close to what actually happened in 1973. Encouraged by high cattle prices in recent years, stockmen reacted by expanding their herds to levels which proved excessive to support reasonable prices.

The discussion of slaughter and feeding allocations focused mainly on the model short-run adjustments required to maintain or move toward temporal and form equilibrium conditions in the beef sector. The main adjustment mechanism was by controlling the numbers and weight levels of slaughter steers and heifers marketed. When a distorted pattern occurred in the reproduction herd, orderly and efficient supply levels were achieved by proper adjustments in the replacement level of heifers. In this study cow cullings and calving rates were assumed to be constant over the projection period. Therefore, efficient supply levels for the beef sector could be maintained in the long-run by proper control of beef heifer replacements.

Pork Model

To demonstrate the operational use of the pork programming model, the actual performance of the pork sector was assumed to have deviated from the optimal performance levels for the first quarter of 1973. Incorporating these changes into the model, a new solution was obtained. The solution activities were grouped into slaughter and reproduction activities.

Slaughter Allocations—It was indicated that a 10 percent increase in rate of marketing lightweight barrows and gilts was assumed for the first quarter of 1973. The effect of this change can be evaluated by comparing the marketing allocations for both the initial solution and conditional solution over the second quarter.

Marketing allocations for the second quarter indicated the evidence of overlap between optimal marketing levels under the initial solution and those obtained by the conditional solution. The marketing allocations of the conditional solution contained more heavyweight barrows and gilts than previously recommended by the initial solution. These adjustments were necessary to correct distortions that occurred in the first quarter. Thus, equilibrium was maintained in the short-run by adjusting the marketing weight levels.

Reproduction Allocations—In contrast to the beef model, the breeding herd in the pork sector was reduced below optimum allocations. A five percent reduction in the rate of gilt replacement and sow supply below optimum levels was assumed for the first quarter of 1973. Results indicated that adjustments in the pork model were more rapid and could be made with relative ease. To illustrate, the low rate of withholding gilts and sows for reproduction assumed for the first quarter was corrected very shortly by increasing the rate of withholding gilts in the second quarter. Through these timely and appropriate adjustments, the pork programming model maintained continuous equilibrium production and marketing over time at minimum carrying and production costs.

IMPLEMENTATION PROCEDURES FOR THE INFORMATION SYSTEM

This part of the study will consider procedures for using solutions in a data information system for achieving orderly production and marketing in the beef and pork sectors.

Information Program

The heart of the information program would be the programming solutions for the beef and pork models. Complete and accurate data on cattle and hog inventories subdivided by sex, weight, and status would be required so that appropriate forward projections could be determined.

Program solutions would be made each quarter for release at the beginning of each quarter. Results would be released as performance recommendations on production, feeding, and marketing activities to be achieved by the beef and pork sectors. Only up to one year of forward solution activities would be reported although the complete programming models for beef and pork would cover six years and three years, respectively.

Dynamic coordination of recommended and actual allocation patterns would be necessary to gauge the information system effectiveness and to reformulate new adjustment recommendations consistent with continuous optimum adjustments. This type of coordination could be achieved by having a secondary short-period data advisory system. This advisory monitoring system could operate continuously or at least on a weekly basis. The function of this advisory system would be to monitor actual activities in the beef and pork sectors as they unfold. Significant or serious deviations from performance recommendations would be the major items stressed in these short-term releases. The releases would attempt to point out ahead of time the consequences of these deviations on future allocations. The advisories would state estimated supply and price consequences of the deviations in terms of current and future effects. A case in point was the summer of 1973. Expecting cattle prices to go up following the lifting of the price freeze, many producers decided to withhold their cattle from the market. When the price freeze was lifted, cattle producers sold their cattle at unusually heavy weight levels. The result was a drastic drop in slaughter cattle prices. If there had been an advisory monitoring system, the excessive withholding of slaughter cattle might have been avoided.

On the basis of actual performance data collected during the first quarter, a new optional program solution would be determined. Results of this new solution would be released at the beginning of the second quarter and recommended instead of the outdated part of the initial optimal solution. The entire sequence would be repeated at the beginning of each quarter.

The new information program would be used in conjunction with many of the current outlook releases. However, much of the current data could be dropped because the data would be incorporated in the new program. This would include most inventory, marketing, and production reports currently in use.

No determination of costs involved in operating the information program has been attempted in this study. However, it is expected that the increase in operational costs would be modest because the amount of money spent on the dropped activities could be diverted to the new program.

Statistical Needs

The Statistical Reporting Service (SRS) of the U.S. Department of Agriculture could play a major role in implementing the information program. Two major areas of statistical work would be needed:

1. Statistical needs for the beef and pork programming models.
2. Statistical data required for the short-term advisory system.

The statistical needs for the programming models were specified previously. They include:

1. Accurate and comprehensive inventories of hogs and cattle at each quarter of the year.

2. Adequate data on consumption, imports, exports, prices, incomes, and population to support effective and accurate demand function estimation. The demand functions should be re-estimated at least every two years. However, abrupt changes in demand should be incorporated into the model when they occur in order to improve the recommendations.

3. Adequate and representative data should be collected to estimate time and form cost transformations for alternative feeding and growth programs.

The statistical data required by the short-term monitoring system would include:

1. Careful checking of marketings of cattle and hogs in the light and heavy weight groups to detect any major deviations from recommended performance levels.

2. Monitoring rates and weight levels for feedlot placements. In case of distortions in actual placements, producers should be cautioned about the consequences of these distortions so that they can make timely corrective adjustments. The disposition rates of sows and the replacement level of gilts should also be monitored.

3. Other data on consumption, prices and net imports would have to be collected to make demand adjustments. Data on supply activities would be needed in case the effective inventory available is altered by bad weather, disease, or death losses.

Data needs for the information program have been outlined, but little has been said about how SRS should gather these data. Full coverage and sampling could be used. Data on slaughter cattle and hogs could be most efficiently collected from slaughtering plants. Sampling or a constant seasonal allowance could be used for on-farm slaughtering.

Placement data could be gathered from producers feeding cattle and hogs under intensive programs. Full coverage might be highly desirable but unbiased sampling and/or stratification would be satisfactory. A representative sample of producers could be designated to provide required data on production and feeding programs. Emphasis should be given to gathering data on such items as gains, time, and costs.

Non-feedlot and pre-feedlot activities pose the most difficult area of data collection. This is because of the large number of producers plus their wide geographic dispersion. It would be costly and impractical to cover all firms involved in these activities. Some listing coverage for part of the volume should be possible. Area cluster sampling might be used for the rest of the firms.

To secure complete and reliable data, cooperation by all industry participants would be an essential requirement. Producers who provide data on frequent or continuous basis could be paid a fee for their effort in collecting and reporting data.

Program Administration and Operation

The main function of the information program would be to guide beef and pork producers toward orderly production and marketing. In this study it was assumed that orderly production and marketing could be accomplished without direct restrictions on the decisions of individual livestock producers. This assumption, however, was based on the viewpoint that producers would respond positively (in the aggregate) to the information program recommendations.

Assuming producer support, the information program would attempt to guide the management of the livestock inventory over time to be consistent with estimated efficiency performance targets. This guide would involve indirect processes, namely, relevant forward targets for performance and timely evaluations during interim periods on how closely actual performance was moving toward these targets.

It is recognized that some deviation in actual performance from the recommended target levels would occur. This, however, is expected because of the statistical nature of the projection estimates and also the difficulty of securing indirect guidance for the entire industry from the decisions of numerous individual firms.

Administration and operation of the information program could be handled by a guidance agency which might be established under a marketing order. The guidance agency would include representatives from the livestock industry and the U.S.D.A. To have legal authority, the agency could operate under a marketing order. The U.S.D.A. personnel in the agency could be authorized to operate the information program and collect the necessary data for the programming models and the short-term advisory service. Livestock representatives in the agency could be given the role of administering the information program and setting policies of the program as provided by the marketing order.

The guidance agency could establish certain forms of economic incentives to encourage producer decisions to be in line with the forward performance solutions of the programming models. For instance, the agency could establish various forms of premiums and discounts for grades and weight classes that would tend to modify individual production and marketing plans.

If individual producers respond favorably to the data released by the information system, fewer controls would be required. In light of recent appeals by the livestock industry for more orderly production and marketing, it is expected that producers will accept some regulation of production and marketing in return for the prospect of more stable prices and incomes. Direct controls would be required, however, only if the economic incentives discussed above should fail to influence individual decisions toward more orderly production and marketing.

Before an actual operation of the information program is attempted, an intensive public relations activity should be conducted to explain the advantages of the program and to secure maximum level of industry support. In addition, before the data systems can be put into action, an analysis should be made to determine the costs of such a system.

APPENDIX A. PRODUCTION AND CARRYING COST DATA

Table A-1. Estimated carrying costs and total production costs for various weights of steers, unadjusted for seasonal variation or grade.

Decription	Carrying cost per animal	Total production cost per animal
Non-feedlot finished		
800– 820 pounds	$ 8.35	$378.22
820– 860 pounds	19.20	397.42
860– 890 pounds	20.17	417.59
Low energy feedlot finished		
800– 920 pounds	33.41	403.87
920– 990 pounds	24.25	428.12
990–1060 pounds	29.15	457.27
1060–1130 pounds	36.32	493.59
Medium energy feedlot finished		
800– 920 pounds	35.64	394.08
920– 990 pounds	24.04	418.12
990–1060 pounds	28.87	446.99
1060–1130 pounds	34.22	481.21
1130–1190 pounds	34.27	515.48
High energy feedlot finished		
800–1060 pounds	90.90	429.89
1060–1130 pounds	31.81	461.70
1130–1190 pounds	31.04	492.74
1190–1240 pounds	30.07	522.81

Source: The figures in this table are based on estimates developed by John E. Tr'erweiler (Economic Research Service). The original estimates (1969) have been modified to approximate 1973 cost conditions.

Table A-2. Estimated carrying costs and total production costs for various weights of heifers, unadjusted for seasonal variation or grade.

Decription	Transfer cost per animal	Total supply cost
Non-feedlot finished		
800– 815 pounds	$ 6.67	$388.68
815– 845 pounds	15.17	403.85
845– 870 pounds	20.29	424.14
Low energy feedlot finished		
800– 910 pounds	32.66	414.64
910– 970 pounds	21.20	435.84
970–1030 pounds	27.09	462.93
Medium energy feedlot finished		
800– 910 pounds	34.64	403.92
910– 970 pounds	21.50	425.42
970–1030 pounds	21.97	447.39
1030–1080 pounds	27.07	474.46
High energy feedlot finished		
800–1030 pounds	85.56	435.72
1030–1080 pounds	23.93	459.65
1080–1130 pounds	31.66	491.31

Source: The figures in this table are based on estimates developed by John E. Tr'erweiler (Economic Research Service). The original estimates (1969) have been modified to approximate 1973 cost conditions.

Table A-3. Estimated carrying costs and total costs for various weights of barrows and gilts, unadjusted for seasonal variation.

Description	Carrying cost per animal	Total cost per animal
Barrows and gilts		
50–180 pounds	$29.73	$46.23
180–230 pounds	11.60	57.83
230–270 pounds	12.26	70.09
270–300 pounds	12.56	82.65

Source: Figures in the table are based on cost estimates by Trierweiler, John E. "Data and Use for Orderly Production and Marketing in the Beef-Pork Sector." Unpublished Ph.D. Dissertation, University of Nebraska, Lincoln, 1969, p. 48.

APPENDIX B. ORGANIZATIONAL STRUCTURE OF THE BEEF AND PORK PROGRAMMING MODELS

Beef Model

The basic programming model for beef has 824 rows and 2023 columns. The model corresponds to marketing and production activities for beef over a six-year period. The longer period is necessary because the solution process should include the effects of requirements in the future on present activities.

Row Restrictions

The first 29 row restrictions in the beef model are initial inventories of beef as of January 1, 1973. These initial inventories are categorized according to weight, sex, and status (cow herd, feeding program position, etc.).

The initial inventory restrictions in the model are followed by 188 continuing inventory restrictions which provide for reproduction, culling, and heifer replacement for the programmed period. The main function of these restrictions is to generate calf production and the maintenance of the cow herd. A 14 percent cull rate is assumed in the model and the death loss is assumed to be two percent.

Following the continuing inventory restrictions are 432 restrictions which represent monthly quantities of beef demanded during the six-year period. Each monthly demand has a subset of six restrictions. The first restriction in the subset fixes the total quantity of meat demanded in a given month. The next five restrictions limit the quantities of meat coming from different grades of beef such as Prime, Choice, and Good, sex of animals, and also put a minimum percentage of non-fed beef going into each of the demand months.[1]

Subsequent to the demand restrictions are 29 final inventory classes. The function of the final inventory is to terminate the model and, thus, make it solvable, as well as providing for future continuity.

[1] The restriction on the amount of non-fed beef entering into various demand months was later dropped from the model. Enough non-fed beef from cull beef and dairy cows was going into the demand months to make this restriction unnecessary.

Following the final inventory restrictions are 120 restrictions which limit the quantity of beef animals that can be produced on a specific feeding program. Certain biological and capacity realities are behind these restrictions.

The last 24 row restrictions in the beef model allow meat and meat animals produced exogeneous to the United States beef sector to enter demand. These include culled dairy cows, imported meat, live animal imports, and dairy calves.

Column Activities

The 2023 column activities in the beef model provide for marketing of beef heifers and steers from the initial animal inventory to the monthly demands. The column activities also provide for cow culling and heifer replacement, the production and marketing of program-generated supplies, and the termination of the program into a final animal inventory. Associated with each activity is the estimated supply cost of producing the animal to a given stage of growth.

Pork Model

The basic programming model for the pork sector has 265 rows by 514 column activities. The model corresponds to the marketing and production activities for pork over a three-year period.

Row Restrictions

The first 29 row restrictions represent initial inventories of barrows, gilts and sows as of January 1, 1973. There are eight classes of barrows and gilts subdivided according to weight. Following these classes are 12 row restrictions which represent bred sows subdivided according to the number of previous farrowings and the expected month of next farrowing. The last nine restrictions represent nonbred and lactating sows in the breeding herd.

The next 108 row restrictions provide for reproduction, culling, and gilt replacements. It is assumed that 25 percent of the gilts are culled after their first farrowing because of their expected poor performance in future breeding.

The following 36 row restrictions pool the number of pigs saved by months during the three-year program period.

Monthly pork demands over the three-year period are represented by 72 row restrictions. These include 36 restrictions which represent monthly quantities of pork demanded, and 36 restrictions which put a limit on meat coming from lightweight barrows and gilts (180 pounds) during any month to less than 50 percent of the month's total pork demand.

The last 20 row restrictions are used to terminate the model into final inventory classes. The purpose of the final pork inventory is the same as that for the beef model.

Column Activities

The 514 column activities in the pork model allow for marketing and production of barrows and gilts, plus maintenance and adjustments necessary in the reproduction base. The carrying costs (C_j values) corresponding to these activities represent costs necessary for producing the animals to any given stage of growth.

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